ENTRO

EASTERN NILE TECHNICAL REGIONAL OFFICE

BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY PROJECT

Strategic Social and Environmental Assessment

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BRL Ingénierie

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LIST OF DELIVERABLES

The Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project has generated a set of deliverables which are summarised in the table below. This deliverable is highlighted in grey below.

THE BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY PROJECT	
A. The Integrated Water Resources Development and Management Plan	
A.1	Inception report
A.2	Consultation and Communication Plan
A.3	Scoping report
A.4	Baseline, Development Potentials, Key issues and Objectives report
A.5	**Strategic Social and Environmental Assessment**
A.6	Integrated Water Resources Development and Management Plan
B. Medium and Long Term Projects: Terms of references for feasibility studies	
B.1	The Integrated BAS Hydropower, Irrigation and Multipurpose Development Programme - Phase 1. Baro-Sobat component
B.2	The Akobo-Pibor Transboundary Multipurpose Development Project
B.3	Livelihood-based Watershed Management - Taking to Scale for a Basin Wide Impact
C. Short Term Project: Feasibility studies	
C.1	Feasibility Study for the Kinyeti River Multipurpose Development Project
C.2	Feasibility Study for the Majang Multipurpose Project
C.3	Design Details for the Akobo-Gambella floodplains Transboundary Development Programme
D. Project brochure	
D.1	The Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project: General overview
D.2	The Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project: Medium and Long Term Projects

	BRL ingénierie 1105 Av Pierre Mendès-France BP 94001 30001 NIMES CEDEX 5 FRANCE
	AURECON Ebène House – 3rd Floor – 33 Cybercity EBENE - MAURITIUS

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Contact	**Sébastien Chazot:** Sébastien.Chazot@brl.fr **Jean-Michel Citeau:** Jean-Michel.Citeau@brl.fr **Steve Crerar:** stevecrerar@live.com

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BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY

Strategic Social and Environmental Assessment

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ACRONYMS AND ABREVIATIONS

AfDB	African Development Bank
BAS	Baro Akobo Sobat
BAU	Business As Usual
BG	Benishangul Gumuz
BRL	Bas-Rhône Languedoc
CDIAC	Carbon Dioxide Information Analysis Center
CO_2eq	CO_2 equivalent
CRGE	Climate-Resilient Green Economy
CSBI	Cross-Sector Biodiversity Initiative
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
ENCOM	Eastern Nile Committee Of Ministers
ENPT	Eastern Nile Power Trade
ENSAP	Eastern Nile Subsidiary Action Plan
ENTRO	Eastern Nile Technical Regional Office (NBI)
ESIA	Environmental and Social Impact Assessment
ESMF	Environmental and Social Management Framework
ESMP	Environmental and Social Management Plan
EPA	Environmental Protection Authority
ERSS	Ethiopia Rural Socioeconomic Survey
ETP	Evapotranspiration Potential
EVDSA	Ethiopian Valley Development Study Authority
FAO	Food and Agriculture Organization
GDEM	Global Digital Elevation Model
GDP	Gross Domestic Product
GHG	Green House Gas
GTP	Growth and Transformation Plan
GWh/y	GigaWatt hour/year
Ha	hectare
HEP	Hydroelectric Power
IDEN	Integrated Development of Eastern Nile
IISD	International Institute for Sustainable Development
ILWRM	Integrated Land and Water Resources Management
IMR	Infant Mortality Rate
IPCC	Intergovernmental Panel on Climate Change
INDC	Intended Nationally Determined Contribution
INPE	National Institute for Space Research
IUCN	International Union for Conservation of Nature and Natural Resources
IWMI	International Water Management Institute
IWRDMP	Integrated Water Resources Development and Management Plan
IWRM	Integrated Water Resource Management

JMP	Joint Multipurpose Project
Kc	Crop coefficient
LSMS-ISA	Living Standard Measurement Study – Integrated Surveys on Agriculture
MASL	Meters Above Sea Level
MCA	Multi Criteria Analysis
MDG	Millennium Development Goals
MEDIWR	Ministry of Electricity, Dams, Irrigation and Water Resources
Mm^3	Million Cubic meter
MSIOA	Multi Sector Investment Opportunity Analysis
MT	Mega Tone (10^6 Tones)
MW	Mega Watt
NB-DSS	Nile Basin Decision Support System
NBI	Nile Basin Initiative
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NFE	Non-Farm Enterprise
NGO	Non-Governmental Organization
NOx	Nitrogen Oxide
PRSP	Poverty Reduction Strategy Program
RSS	Republic of South Sudan
SAP	Subsidiary Action Program
SD	South Sudan Pound
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessments
SSEA	Strategic Social and Environmental Assessment
SLMP	Sustainable Land Management Program
SNNPR	Southern Nations, Nationalities and Peoples' Region
SSCCSE	Southern Sudan Centre for Census, Statistics and Evaluation
SSEA	Strategic Social and Environmental Assessment
SWOT	Strength Weakness Opportunity Threat
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USGS	United States Geological Survey
WB	World Bank
WCYA	Women, Children and Youth Affairs
WEES	Water for Eastern Equatoria
WFP	World Food Program
WHO	World Health Organisation
WMO	World Meteorological Organization
WSS	Water Supply and Sanitation
WUA	Water Users Association

EXECUTIVE SUMMARY

ENTRO is the institution in charge of the implementation of the Eastern Nile Subsidiary Action Program (ENSAP) of the Nile Basin Initiative (NBI), a programme that 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. As part of this responsibility, ENTRO formulated a suite of integrated development projects including hydropower, irrigation and drainage, flood control, watershed management, and water resources management, as part of the Integrated Development of the Eastern Nile (IDEN) initiative. The Baro-Akobo-Sobat (BAS) Multipurpose Water Resources Development Study Project is one of the seven (7) projects identified in the IDEN. In this respect, the main purpose of this study is to develop an Integrated Water Resources Management and Development Plan (IWRDMPlan) for the Baro Akobo Sobat (BAS) sub-basin.

The Strategic Social and Environmental Assessment (SSEA) aims at integrating strategic environmental and social considerations into the preparation of the IWRDMPlan and has therefore been run in parallel with the development of the IWRDMPlan. It can be seen as a tool to guide decision-making, while providing stakeholders and decision-makers with a preferred water resources development and management scenario/pathway for developing the IWRDMPlan and related recommendations.

Since the IWRDM Plan is essentially a water resources driven and mediated project, it is worth highlighting here

- (i) the complexity of the hydrology of the BAS and the related data paucity and knowledge gaps,
- (ii) the relatively pristine nature of large tracts of the basin and the associated outstanding nature of the flora, fauna, ecosystems[1] and wildlife phenomena[2] and its dependency on water resources,
- (iii) the current low level of water development in the basin,
- (iv) the vulnerability of the population with respect to flood and droughts,
- (v) the persistently high degree of poverty,
- (vi) the importance of the status of natural resources bearing in mind the water-dependent nature of the livelihoods of the BAS,
- (vii) the overall context of insecurity and the existing natural resources based conflicts.

Based on the above considerations and bearing in mind the issues to be tackled as well as the vision and objectives[3] of the IWRDMPlan, an analytical tool, called the *SSEA analytical framework*, has been developed to guide the recommendation of a preferred water resources development and management pathway on which the IWRDM Plan should be based. This tool is multidimensional and captures the integrative and cumulative character of the potential benefits and risks related to the major water developments foreseen in the IWRMDPlan. Its role is to investigate the overall sustainability of the proposed development programme from a social and environmental perspective, while looking at the dimensions and their related indicators / criteria described in **Box 1** next page.

[1] The BAS hosts the main remaining forest ecosystem of the Region.

[2] The BAS is home of outstanding mammalian migration as large as the Serengeti.

[3] Which are themselves consistent with the Sustainable Development Goals

BOX 1: List of criteria used to conduct the assessment

Dimension	Sub-dimension	Indicator
Socio-economic development	Food security	• Level of food self-sufficiency
	Employment	• Number of jobs created by irrigation schemes and dams
	Energy security	• Population of the basin connected to national grid
	Access to water	• Population of the basin with access to improved water sources
	Health	• qualitative
	Flood reduction	• Qualitative at this stage
Change in riverine ecosystem services	Changes to hydrological regimes affecting aquatic extensions / wetlands	• Average annual maximum surface area; • Average annual minimum surface area; • Average annual surface area amplitude
	Changes to hydrological regime affecting instream flow / the river system itself	• Number of navigable months for an average year • Number of months under the 1/10 daily ranked flow (=duration of the severe low flows period) • Average mean monthly flow from December to May • Mean annual daily flow of the White Nile at Malakal • Mean amplitude between the wettest month and the driest month of a year
	Geomorphological changes	• Controlled watershed surface area by the combination of dams compared to the overall watershed surface area
Loss of natural/ existing ecosystem through land use conversion of project (infrastructure) footprints	Loss of settlements	• Population affected by the project combination (population to be resettled) • Existing agricultural and grazing land converted
	Loss of natural ecosystems	• Surface area of protected areas within projects footprint • Surface area of forests and upstream wetlands within projects footprint • Surface area of wildlife migration corridors within projects footprint
Contribution to transboundary cooperation	Contribution to regional and national economic growth	• Change in revenue generated from hydropower • Change in revenue generated from large-scale irrigation
	Level of transboundary cooperation and management required	• Degree of cross-border cooperation required in system operation
	Impact on flows downstream of Sobat/White Nile confluence	• Change in MAR entering White Nile • Change in average minimum flow in White Nile d/s of Sobat confluence
Change in water quality		• [N] loads in rivers, reservoirs and wetlands • [P] loads in rivers, reservoirs and wetlands
Change in GHG emissions		• Co2 eq emitted due to water developments

The analytical framework was first used to understand the respective impacts of hydropower, irrigation and both sectors together[4] and the main enhancement, avoidance and minimization opportunities to maximise benefits and to reduce potential negative impacts. More than enabling a

[4] Five levels of intensity have been investigated at that stage, mainly full irrigation development without upstream storage, full irrigation development with upstream storage, full irrigation and hydropower development, full hydropower development only.

first understanding on how the BAS system reacts to different natures and intensities of development, development of the analytical framework made it possible to define thresholds which reflect, for each of the dimensions, the estimated limits beyond which the sustainability is threatened and therefore delimit the sustainable development space. In addition, it has permitted the assessment of the level of uncertainty of the overall assessment and calibrate the *SSEA analytical framework*[5] consequently.

In a second phase, this tool was used to assess and compare six scenarios (see **Box 2**) consisting of various combinations of water-development projects[6] and their associated multi-purpose development opportunities (such as livestock development, fisheries, aquaculture, navigation, water supply, etc.). Their design made it possible to test the enhancement and mitigation opportunities identified previously, mainly i) avoidance of sensitive areas[7] in irrigation scheme command areas and ii) incorporation of dam/reservoir management rules aiming either at conserving natural flow patterns[8], maximising hydropower or maximising support to irrigation.

As such, the design and assessment of the scenarios are based on the **mitigation hierarchy**. This principle considers that enhancement and preventive measures such as avoidance and minimisation are the most effective way of maximising benefits and reducing negative effects. This in turn increases the suitability of scenarios in achieving the vision and strategic objectives developed for the BAS.

BOX 2: Overview of Scenarios analysed

All scenarios investigated include irrigation, livestock, fisheries, water supply and hydropower development as well as flood reduction. They have been designed keeping in mind the enhancement, avoidance and minimization opportunities identified as part of the SSEA process. They allow the assessment of the benefits and constraints associated with these enhancement and mitigation (avoidance and minimization) opportunities in order to identify a “preferred” option or development pathway for the development of the water resources of the sub-basin. They can be summarised as follows:

- **Scenario 0 or Baseline scenario**: it is the status quo, which provides a benchmark for the SSEA.
- **Scenario 1: This is a Precautionary Principle** case, using reduced irrigation areas with no encroachment into environmentally sensitive areas. All potential hydropower dams were included with the exceptions of Tams Dam and Birbir Dam (excluded in order to limit the potential downstream effects of “over-regulation”).
- **Scenario 2: This is an extension of the Precautionary Principle** case, similar to Scenario 1, except that Tams Dam and Birbir Dam are included.
- **Scenario 4a: This is a “full-development”** case, with all irrigation and hydropower included and Tams Dam operated to ***maximise hydropower*** production..
- **Scenario 4b: This is a “full-development case**, with all irrigation and hydropower included and Tams Dam operated to **optimise irrigation and flood control**.
- **Scenario 3a: This is an Intermediate or “trade-off” case**, similar to Scenario 2, but with environmental water releases imposed on all dams in order to conserve natural flow patterns.
- **Scenario 3b: This is another Intermediate of “trade-off” case**, similar to Scenario 4a, but with environmental water releases imposed on all dams in order to conserve natural flow patterns

5 The identified uncertainties are reflected into the calibrated SSEA analytical framework through the integration of specific margins of error either in quantifying the indicator the impact magnitude or in assessing the threshold.

6 These projects have been identified as part of the baseline phase via i) the review the existing sectoral Master Plans and strategies; ii) stakeholder interviews aiming, among others, at assessing further potential development projects and areas.

7 The first analysis has indeed shown that a large proportion of potential encroachment into the main sensitive areas (Biosphere reserves, national parks, mountain wetlands, forests, Kob migration area) was due to irrigation schemes and could therefore be avoided through adequate reshaping of the irrigation command areas.

8 The Machar marshes and Gambella plains wetlands/floodplains rely on spills mainly from the Baro and the Gilo (only for Gambella plains) rivers, which occur during high flows. Upstream water storage leads to a reduction of the amount of water reaching the wetlands due to a reduction of the duration and volume of the spills. The main opportunity to mitigate this effect relies in the dam management rules, which should allow significant releases during the wet season while still maximizing hydropower generation and storage for downstream irrigation.

Bearing in mind the caveat that this is based on best estimates, the following development potential and risks have been identified as part of this analysis.

This analysis has reaffirmed that the BAS sub-basin is endowed with a powerful hydrological system[9], confirming the anticipated major and currently untapped potential for water development:

- The hydropower potential is mainly located in the Ethiopian and South Sudan highlands. The combination of all hydropower projects could produce from around 10 000 to 12 000 GWh/year. In addition, the Kinyeti (South Sudan) multipurpose dam could produce up to 5.8 GWh/year. The potential of an additional hydropower dam on the upper Akobo in South Sudan should be assessed as part of the investigations planned in the IWRDMPlan but could contribute up to a further 500 GWh/year. The full hydropower development would guarantee access for 100% for the BAS population even if it is assumed that 80% of the hydropower generated is exported outside the BAS.
- According to irrigation Master plans, around 650 000 ha[10] could be irrigated in the BAS in addition to the existing diffuse irrigation and Abobo irrigation scheme in Ethiopia (10 400 ha). From a water resources point of view, the irrigation water demand can be satisfied at an assurance varying from around 50% to 95% according to the development priorities[11].
- Whatever these priorities, this accounts for a potential of additional food production of 40 000 to 60 000[12] tonnes/year. The associated benefits towards the food security of the BAS depend on the proportion of which is sold on local markets versus that which is exported. The financial and economic analysis has shown that it is very profitable to grow and irrigate a significant proportion of food crops.
- Even if not at the heart of the IWRDMPlan, potential has been identified to improve yields of rainfed agriculture. This can be achieved through the implementation of better agricultural practices which will aslo conyribute to efforts to reduce the pressure over soils and forest ecosystems. This will have benefits downstream through the restoration of baseflows and reduced extreme flood events etc.
- Livestock is of critical importance in most of the livelihoods areas in the BAS sub-basin, especially for pastoralists. This resource is currently mainly seen as a symbol of wealth and its related traditional management leads to low levels of productivity. There is a large margin for improvement with respect to the exploitation of this resource. Securing water resources through storage and adequate management together with the development of other services (veterinary and general extension services, control of pests, diseases …) should contribute to improving the meat and milk production by an order of magnitude[13]. In addition, the development of urban centres associated with irrigation development and the increased availability of electricity will create a new and rapidly increasing demand for both meat and dairy products which will support and indeed drive this improvement
- Development of capture fisheries in reservoirs and the development of fish farming associated with irrigation schemes and a more reliable supply of water, could generate production of additional 1.2 to 2.2[14] million tonnes of fish / year.
- Securing water resources through storage and adequate management should also lead to the subsequent assured availability of healthy water for potable water supply especially around reservoirs.

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9 The MAR of the Baro at Gambella is around 12.65 BCM; the MAR of the Sobat at Malakal is around 12.30 BCM.

10 This includes around 120 000 ha in South Sudan (incl. the potential in the Akobo/Pibor area) and around 550 000 ha in Ethiopia (mainly located in the lowlands).

11 Maximization of hydropower, versus irrigation, versus other downstream uses and environmental conservation.

12 Cropping patterns used in this study are based on master plans and meetings with relevant. It should be noted that the resulting cropping patterns are different from the plans indicated in the agricultural leases in the Gambella region, which are mainly cash crops.

13 Significant improvement in productivity in the livestock sector could lead to additional production of 700 000 to 1 000 000 tons of meat /year and 12 500 to 16 000 tons of milk / year.

14 This yield depends heavily on the intensity of fish farming that is implemented. The figure can be increased significantly when modern methods are employed

- The possibility of regulating river flows and therefore increasing the number of navigable days could act as a catalyst for measures to improve the navigability in the lower Baro and Sobat since the incentive would be access to markets for the large level of agricultural production that could be generated within the basin.
- Despite a considerable potential for livelihood and water-based/eco-tourism development, the existing initiatives remain sparse and this sector is given less political interest and priority compared to other water sectors.

The above water developments are deemed to subsequently improve the living conditions for the population of the BAS and beyond, especially via the improvement of access to electricity and through the other opportunities arising from a more efficient management of the water resources.

However, the analysis has also shown that this potential is not unlimited and that these developments are associated with a number of potential environmental and social risks.

A major level of water development might indeed lead to competition among water uses and the various activities they support:

- Even if irrigation development can benefit from hydropower development (especially on the Baro river), there is an upper limit above which it is not possible to both maximise hydropower production and the satisfaction of irrigation water demand.
- Development of irrigation in the Ethiopian part of the basin requiring more than 6.5 BCM per year could reduce the potential for irrigation development on the lower Pibor and Sobat in South Sudan. Below this limit, the development of irrigation is more constrained by the imposition of environmental flow requirements (including trying to mimic dry season low flows) than by upstream water developments.
- The implementation of all dams combined with an irrigation development above 2 BCM on the Ethiopian part of the BAS will lead to downstream river flows and spills to wetlands lower than the baseline dry values[15]. In other words, it means that the dry situation will become the average situation in the future. While the order of magnitude has been assessed, the data paucity does not allow to ascertain the significance of the related impacts, even if it is fair to acknowledge that there will be significant risks with respect to:
  - The aquatic fauna, the water-dependant ecosystems and the biodiversity features they support, eg :
    - through pressure on wetlands, bird and mammal population migrations are at stake, threatening at the same time the related water/eco-tourism potential of the BAS ;
    - Through pressure on wetlands and their connections to the main river system, fish population are at stake, which might have negative consequences on the nutritional status of local population who traditionally depends on fish resources;
  - The traditional direct and indirect water uses, which might in turn affect the living conditions of especially vulnerable populations, exacerbate the existing pressure on natural resources and the risks of ethnic tensions and conflicts over resources. The planned developments might indeed threaten:
    - The access to water for traditional users (including drinking water);
    - The access to quality grazing areas, which can have in turn negative consequences on livestock and pastoralism (which surface area might be significantly reduced due the reduction of flooding araising from river regulation);
    - The acess to crucial sources of food (arising from recession agriculture). .
  - The contribution of the Sobat to flows in the White Nile and its associated water uses in Sudan and in Egypt. In the case where all the identified irrigation schemes and dams projects are implemented without any avoidance or reduction measures, the **MAR entering the White Nile is deemed to reduce from 12.30 BCM to up to 7.54 BCM**. However, the avoidance of sensitive areas[16] combined with dams management rules allowing the **conservation of natural flow patterns leads to a MAR around 10.58 instead of 7.54**

15 Which corresponds to the water flows statistically experienced 1 year out of 5 under the current conditions.

16 Sensitive areas refer to biosphere reserves, national parks, mountain wetlands, forests and Kob migration areas.

BCM, which is close to the baseline dry value. The importance of the careful design of avoidance and reduction measures and the implementataion is therefore clearly evident.

- The implementation of numerous dams and their associated reservoirs, especially in the larger sub-catchments, will significantly affect the sediment transport and might lead to significant geomorphological changes (river incision, river bank destruction…). This in turn may lead to negative environmental and social implications in the BAS and further downstream.
- Both irrigation and hydropower development could affect the water quality of river and reservoirs because of increasing agricultural inputs and concentration of pollution into reservoirs.
- While an increased storage capacity and associated possibilities to irrigate may be seen as a mitigation opportunity in terms of resilience to climate change, inappropriate water uses or dam operating rules may worsen the impact of climate change on downstream river reaches and wetlands.

Because it is located in densely populated areas (e.g. hydropower dams in the highlands) or because it involves considerable surface areas (e.g. large-scale irrigation schemes in the lowlands), the development of water resources is associated with further environmental and social risks. These include the following:

- Displacement of up to around 200 000 people[17]. Since the area already experiences significant population movements, especially due to insecurity issues, such displacement magnitude has the potential to increase the risk of conflict with the host population.
- Dispossession of people used to cultivate land and to feed livestock. Up to around 60 000 ha of pasture land and land used for subsistence farming will be impounded or irrigated. In addition, other types of ecosystems (such as savannahs, forests, wetlands), which people used to live from, will be converted and previous access to water sources put into question. This will lead to significant losses of traditional sources of livelihood for various social groups. In addition to the related negative implications for food security and overall poverty, this has the potential for increasing the risks of conflicts over water and other natural resources.
- The magnitude of project footprints and their spatial aggregation, especially large-scale irrigation schemes, form a massive continuum of land which may no longer be accessible and which may impede the existing movement and migration patterns (especially pastoralist migration, normal population movements and wildlife migration).
- In the case where all identified projects are implemented without any mitigation measures, the encroachment into sensitive areas is very high and includes encroachment into: Gambella National Park, Sheka Biosphere Reserve, (and potentially into Boma National Park depending on the delineation of the Akobo - Lower Pibor irrigation scheme command area), Abobo-God, Godere, Sele Anreacha, Shako, Yaku, Yeki, Sibu-Tole-Kobo, Sigmo-Geba National forest priority areas and around 197 000 ha of the White-eared Kob migration area, leading to the conversion of around 86 000 ha of forest and around 257 000 ha of wetlands and floodplains. While sensitive areas can be avoided in most cases (by adapting irrigation schemes command areas), this is *a priori* not possible or limited when it comes to dams and reservoirs. Reservoirs' footprints do not encroach into National parks and Biosphere reserves but do encroach into forest ecosystems (10 000 ha[18]), into some of the Forest National Priority Areas (8 000 ha [19]) and into mountain wetlands (300 ha) which are of primary importance for the conservation of biodiversity features of the BAS and of the ecosystem services they provide to the population and to water resources (quality and quantity).

The cumulative and transboundary nature of the above-mentioned impacts can be highlighted through the main following examples:

17 Corresponds to the total estimated number of people living within the combined footprint of all identified projects.

18 It approximately corresponds to a third of the current annual deforestation and to 1% of the total surface area of forests within the BAS.

19 Which are already included into the 10 000 ha of forests.

- The total population indirectly impacted is estimated to be around 2.7 million[20] people if the cumulative impacts of projects footprints and changes to water availability are taken into consideration.
- Between 300 000 to 730 000 ha of wetlands could be impacted (conversion into irrigated/cultivated area and transformation into dry areas) over the entire BAS sub-basin (although largely concentrated in Machar Marshes in South Sudan and Gambella plains in Ethiopia). At the scale of the Gambella National Park for instance, this amounts to between 15% and 70% of the wetlands habitat of the area. At the scale of the overall white-eared kob migration area, this amounts for between 10 and 65% of their wetland habitats.
- Even if the development of Sobat irrigation could encroach into the Machar marshes, the main risks over this ecosystem arise from upstream water resources development (hydropower and irrigation) located in Ethiopia.
- The MAR discharge into the White Nile can be reduced to 40% of the current MAR discharge in the case all planned projects being implemented **without** mitigation measures.
- Unless the above quoted cumulative and transboundary impacts are correctly and effectively mitigated, the downstream parts of the sub-basin could be exposed to social and environmental effects out of proportion to the opportunities and benefits associated with the proposed largely upstream development projects.

The results of the economic analysis are consistent with the findings of the SSEA, mainly showing that the maximum profitability from the societal point of view is reached through compromise approaches, which propose a significant development of the water resources of the BAS sub-basin, while mitigating the main negative impacts via useful enhancement and mitigation measures. On the contrary, this analysis has shown that maximising water resources development without optimisation (through enhancement and mitigation measures) leads to significant loss of profitability from a societal point of view.

The **Box 3** below gives a clear and consice summary of the key findings, in terms of risks and opportunities, of the SSEA associated with each scenario.

[20] This is based on the assumption that social impacts could be felt up to 25 km away from project footprints and that all riverine and wetlands population located downstream projects might be impacted as well. This is a very rough estimates which will have to be fine-tuned as part of each ESIA projects.

BOX 3 : Summary of the risks and opportunities associated with each scenario and the potential trade-offs

	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a	Scenario 4b
Main characteristics	• Represents the "Precautionary Principle" option • Involves reduced but significant irrigation areas (small-scale and large-scale) with no encroachment into environmentally sensitive areas. =>Total irrigation demand: 550 000 ha • All potential hydropower dams were included, except Tams Dam and Birbir Dam.	• Extension of the "Precautionary Principle" option, except that Tams Dam and Birbir Dam are included	• Same as Scenario 2, but with environmental water releases imposed on all dams in order to conserve natural flow patterns	• Same as Scenario 4a (full development option), but with environmental water releases imposed on all dams in order to conserve natural flow patterns =>Total irrigation demand: 755 000 ha	• Is the full-development option, with Tams Dam operated to maximise hydropower production. • All future small-scale and potential large-scale irrigation schemes are included. =>Total irrigation demand: 755 000 ha • All identified potential hydropower schemes are also included.	• Represents the full-development option as per Scenario 4a, with Tams Dam operated to optimise irrigation and flood control.
Main opportunities	• Significant additional hydropower (3,950 GWh/year) and agricultural & fish production (2.3 million tons/year) • Rather low satisfaction of the water demand for irrigation: 69% • Significant reduction of the flood risk: 11% (relative to baseline at Gambella for a 50-year flood) • Significant storage capacity: 8.2 BCM	• Very high additional hydropower (12,300 GWh/year) and agricultural & fish production (2.5 million tons/year) • High satisfaction of the water demand for irrigation: 98% • Significant reduction of the flood risk: 57% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 11,300 GWh/year • Significant additional agricultural & fish production: 2.0 million tons/year • Rather low satisfaction of the water demand for irrigation: 43% • Significant reduction of the flood risk: 15% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 11,300 GWh/year • Significant additional agricultural & fish production: 2.6 million tons/year • Rather low satisfaction of the water demand for irrigation: 47% • Significant reduction of the flood risk: 15% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 12,300 GWh/year • Very high additional agricultural & fish production: 3.3 million tons/year • High satisfaction of the water demand for irrigation: 85% • Significant reduction of the flood risk: 57% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 11,400 GWh/year • Very high additional agricultural & fish production: 3.5 million tons/year • High satisfaction of the water demand for irrigation: 95% • Significant reduction of the flood risk: 57% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM
Main risks and cumulative impacts	• Limited risks on sediment transport and aquatic movements compared to the other 5 scenarios • Major displacement of people (124,000) and limited encroachment into natural and protected areas compared to scenarios 3b, 4a and 4b • Significant modification of the hydrological regime and the wetlands surface areas but stay within the thresholds of sustainability • Major cumulative impacts on wetlands: - 275,000 ha • Major reduction of the MAR entering the White Nile: -22% • Lowest risks of conflicts	• Major risks on sediment transport and aquatic movements • Major displacement of people displacement (126,000) and limited encroachment into natural and protected areas compared to scenarios 3b, 4a and 4b • Important modification of the hydrological regime and the wetlands surface areas but overpass the thresholds of sustainability for Machar marshes • Significant cumulative impacts on wetlands: - 488,000 ha • Important reduction of the MAR entering the White Nile: 27% • Important risks of conflicts	• Important risks on sediment transport and aquatic movements • Major displacement of people(126,000) and limited encroachment into natural and protected areas compared to scenarios 3b, 4a and 4b • Significant modification of the hydrological regime and the wetlands surface areas but stay within the thresholds of sustainability • Moderate cumulative impacts on wetlands: - 226,000 ha • Limited reduction of the MAR entering the White Nile: 14% • Limited risks of conflicts	• Major risks on sediment transport and aquatic movements • Very major displacement of people(178,000) and encroachment into natural and protected areas • Major modification of the hydrological regime and the wetlands surface areas • Significant cumulative impacts on wetlands: - 433,000 ha • Major reduction of the MAR entering the White Nile: 20% • Major risks of conflicts	• Major risks on sediment transport and aquatic movements • Very major displacement of people(178,000) and encroachment into natural and protected areas • Very high modification of the hydrological regime and the wetlands surface areas • Very high cumulative impacts on wetlands: - 722,000 ha • Very major reduction of the MAR entering the White Nile: 32% • Highest risks of conflicts	• Major risks on sediment transport and aquatic movements • Very major displacement of people(178,000) and encroachment into natural and protected areas • Very high modification of the hydrological regime and the wetlands surface areas • Very high cumulative impacts on wetlands: - 725,000 ha • Very major reduction of the MAR entering the White Nile: 39% • Highest risks of conflicts
Residual impact after implementation of the main potential trade-offs	• Moderate: the mitigation hierarchy has been implemented in the design of the scenario. As such, major avoidance and reduction measures are efficient.	• High: only part of major potential trade-offs are implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as the one included in the design of scenario 3a.	• Moderate: the mitigation hierarchy has been implemented in the design of the scenario. As such, major avoidance and reduction measures are efficient.	• High: only part of major potential trade-offs are implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as the avoidance and reduction measures included in the design of scenario 3a.	• Very high: trade-offs are not implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as avoidance and reduction measures included in the design of scenario 3a.	• Very high: trade-offs are not implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as avoidance and reduction measures included in the design of scenario 3a.
Level of economic return	• Low	• High	• Very high	• Fair	• Low	• Low
Level of financial return	• **Low**	• Very high	• High	• High	• Very High	• High
Contribution towards achieving the vision and strategic objectives for the sub-basin	• Moderate: socio-economic needs can only be partly met while ensuring a relative sustainable management and limited risks of conflicts.	• Moderate : socio-economic needs can be met for a significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts	• High : socio-economic needs can be met while ensuring a relative sustainable management and limited risks of conflicts.	• Moderate + : socio-economic needs can be met for significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts	• Moderate - : socio-economic needs can be met for a significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts	• Moderate - : socio-economic needs can be met for a significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts

The findings of both the application of the analytical framework and the economic analyses were presented to stakeholders with aim of reaching consensus on a “preferred development option” that will shape the core of the IWRDMPlan. Given both the magnitude of the anticipated impacts and the level of uncertainty on which they are based[21], consensus was reached that a phased and stepwise approach for implementation of the IWRDMPlan should be adopted rather than adopting a specific development option based on a single scenario. It was agreed that the implementation of a development pathway was more appropriate. First steps along this pathway would effectively correspond to the low-regret development options included in Intermediate Scenario 3a, while the steps further along the parhway could incorporate the developments included in the full development scenarios 4a and 4b, but only after the system is better understood and trade-off mechanisms are defined.

The say of the countries together with the SSEA and Financial & Economic analysis have indeed helped to highlight:

- Irrigation schemes which do not encroach into sensitive areas;
- Dams and reservoirs which show high multipurpose and transboundary potential benefits, and which potential negative impacts could be significantly reduced through adequate dams management rules;
- Enhancement and mitigation measures which can be applied on most projects, in order to improve their potential benefits and reduce their potential negative impacts.

As overall outcome, the following recommendations[22] are made to be taken on in development and finalisation of the IWRDMPlan:

- Inclusion into the IWRDM Plan, as a top priority action, of the detailed design and implementation of a basin wide environmental monitoring programme aimed at a major improvement in the understanding of the environmental (and socio-economic) functioning of the BAS sub-basin.
- Adoption of a precautionary approach reflecting the mitigation hierarchy. With respect to large-scale hydropower and irrigation, this principle and approach mean:
  - To further identify project characteristics, design and implementation modalities that maximize multipurpose and transboundary benefits and minimize social and environmental negative impacts according to the findings of the basin wide environmental monitoring programme. This means that fine-tuned enhancement and mitigation measures will be considered as leading principles in the detailed design of projects.
  - The implementation of the IWRDM Plan should start with the projects and actions of limited negative impact. As such, with respect to irrigation, the priority is given to projects which do not encroach into sensitive areas (“no-regret” projects). This would include implementation of large-scale hydropower development on the Baro River (managed on the principles of transboundary cooperation) and irrigation in both Ethiopia and South Sudan supported by the resulting flow regulation. Associated dam operation rules should be designed to reduce the impacts on riverine ecosystem services and thus respect the thresholds[23] that delimit the sustainable development envelop.
- While the SSEA has indicated reasoned reservations over many of the proposed identified development projects, it does not recommend that any of them are excluded from the IWRDMPlan. All projects identified in the various scenarios, or simply potential not yet identified in the form of projects such as on the Baro, Akobo or Pibor Rivers can still be considered and further investigated. It is recommended that projects or combinations of

[21] Which makes difficult the assessment of the impact significance.

[22] Given the above quoted reasons, one of the main outcome of this workshop is that the SSEA should not recommend a specific scenario among the 6 analysed scenarios but highlight its findings through recommandations towards the IWRMDPlan. These essentially consist of a phased and precautionary approach, based on the mititation hierarchy principle).

[23] These thresholds might be adjusted according to the findings of the basin wide environmental monitoring programme.

projects which have been shown to result in more negative impacts, will be included in the IWRDM Plan (without timeline) and indicated as “deferred” until the system is better understood in terms of their environmental and socio-economic impacts (+ve and -ve) and possible mitigation and conservation measures fine-tuned. As a result, the IWRDM Plan should be developed in detail (in terms of proposed sequencing and scheduling) only for the projects and actions of limited negative impact.

- The IWRDM Plan should be developed as a “living Plan”, with explicit provision for adaptation in response to results as indicated by strong monitoring and evaluation and adaptive management systems.
- In addition to the above-mentioned mitigation measures, the IWRDM Plan should include enhancement measures which are agreed to be requirements for project approval at the planning through to design and implementation phases, including:
  - Contribution to rural electrification an electrification of new existing and new urban centres;
  - Achievement of a balance between cash / food crops that supports local food security;
  - Training and hiring of local staff;
  - Upstream – Downstream benefit sharing (among sub-catchments of the same country);
  - Upstream – Downstream and transboundary benefit sharing (among the various countries: Ethiopia, South Sudan, and Sudan).
- Above all, given the magnitude of the potential impacts and their cumulative and transboundary nature, for the IWRMDPlan to be profitable at the scale of the BAS (for the various social groups of the BAS), at national (Ethiopia and South Sudan) and the greater regional levels; it requires a high level of internal and external cooperation among stakeholders. Strengthening the capacity of the various relevant institutions to adequately manage the water resources and their ability to work together is of critical importance. As a result, the IWRMDPlan should include strong institutional coordination and strengthening activities.

Despite these precautions, the residual effects and risks are likely to be significant. A tailored Environmental and Social Management Plan (ESMP) has therefore been designed to support the implementation of the IWRDM Plan and minimize and offset the residual effects and risks. It includes environmental and social management measures but also strong efforts towards data acquisition and monitoring activities to tackle the data paucity issue of the BAS. An institutional capacities and strengthening plan has been also designed to ensure that the relevant institutions will be able to implement, monitor and incrementally adjust the ESMP. The ESMP and the institutional capacities and strengthening plan of the SSEA are included in the IWRDMPlan.

1. INTRODUCTION

1.1 BACKGROUND TO THE STUDY

THE BARO AKOBO SOBAT SUB-BASIN

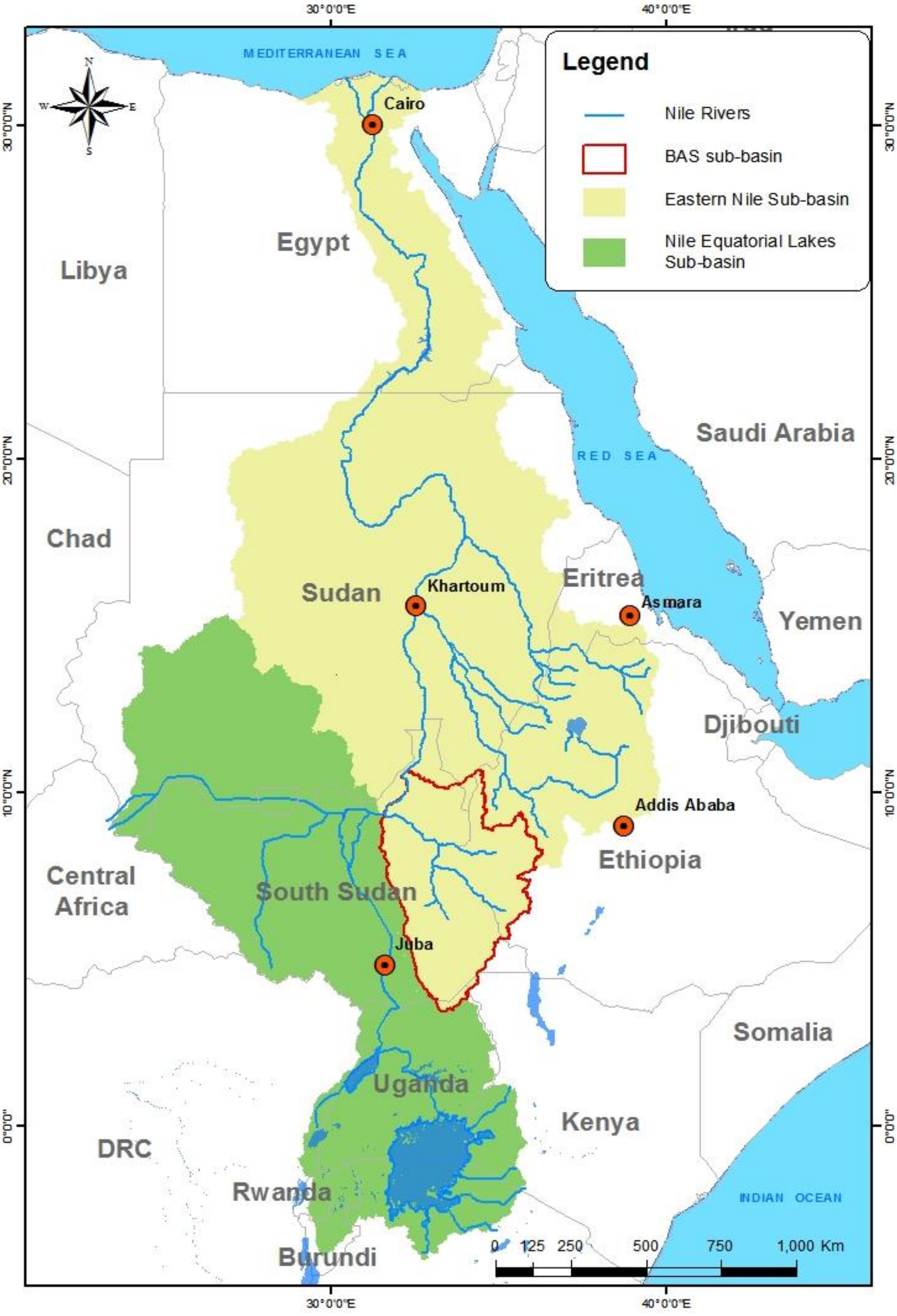


Figure 1-1: Location of the Baro-Akobo-Sobat sub-basin within the Nile Basin

As shown in the previous figure, the Baro-Akobo-Sobat (BAS) sub-basin, with its catchment area of more than 250,000 km^2, consists of the Baro, Akobo and Pibor Rivers; in addition to its main terminus stem of Sobat and the outflow through Machar marshes. The Baro River originates in the highlands of Ethiopia (2,000 – 3,500 masl); from the eastern parts of the BAS sub-basin, draining westwards through the Gambella plains (450 masl) into the Republic of South Sudan. The Pibor River with its tributaries, originates from the Imatong Mountains in in the south-eastern mountains of the Republic of South Sudan, draining northwest through grassy flat plains. The Pibor River is joined on its way by the Akobo, Gilo and Alwero Rivers originating from the Ethiopian highlands; and it continued its northwest flow direction; up to the confluence with Baro, where River Sobat is formed. In South Sudan, until its confluence with the White Nile 15 km south of Malakal city, the Sobat River forms a defined channel flowing north-westwards through grassy flat plains, giving formation of numerous backwater swamps and lagoons, whose prominence is the *Machar Marshes* wetlands. The topographic conditions here offer steady flow through the White Nile, until it joins the Blue Nile at Khartoum, Sudan.

ORIGIN OF THE BAS MWRD STUDY PROJECT

The **Nile Basin Initiative (NBI)** is a partnership between the riparian states of the Nile River: Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda. The NBI seeks to **develop the river in a cooperative manner, share substantial socio-economic benefits, and promote regional peace and security.**

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) and implemented by the Eastern Nile Technical Regional Office (ENTRO) in Addis Ababa, Ethiopia.

In pursuit of this objective, ENTRO formulated the **Integrated Development of the Eastern Nile (IDEN)** as a suite of integrated development projects including hydropower, irrigation and drainage, flood control, watershed management, and water resources management. Because of its regional water and land resources potentials and the role it can play in regional peace, stability and security, the Baro-Akobo-Sobat Multipurpose Water Resources Development Study Project became one of the seven (7) projects identified in the IDEN.

OBJECTIVES AND STEPS OF THE STUDY

The objective of the consultancy services is to assist ENTRO in preparing an Integrated Water Resources Development and Management Plan (IWRDMP) based on a Strategic Social and Environmental Assessment (SSEA), and further develop investment packages for cooperative development in the Baro-Akobo-Sobat sub-basin. The Consultant has taken note of the following specific objectives:

- Preparation of a participatory strategic social and environmental assessment (SSEA) of the sub-basin to facilitate identification of investment options that take into account social, environmental, economic and institutional considerations.
- Formulation of an Integrated Water Resources Development and Management Plan (IWRDMP) informed by the SSEA to identify sustainable investments and provide a sound framework for long term development and management of water resources.
- Identification and preparation of a feasibility study, in a participatory and consultative manner with relevant basin stakeholders, short-term investment ready projects.
- Identification with participation and engagement of relevant stakeholders in the sub-basin, medium and long-term projects and initiate project preparation activities.
- Provision of an objective and effective framework for stakeholder consultation and engagement in cooperative development and management of water resources of the Baro-Akobo-Sobat sub-basin, and support to ENTRO in mobilizing funds for the implementation of the prepared projects.

The figure below highlights the key steps of the study.

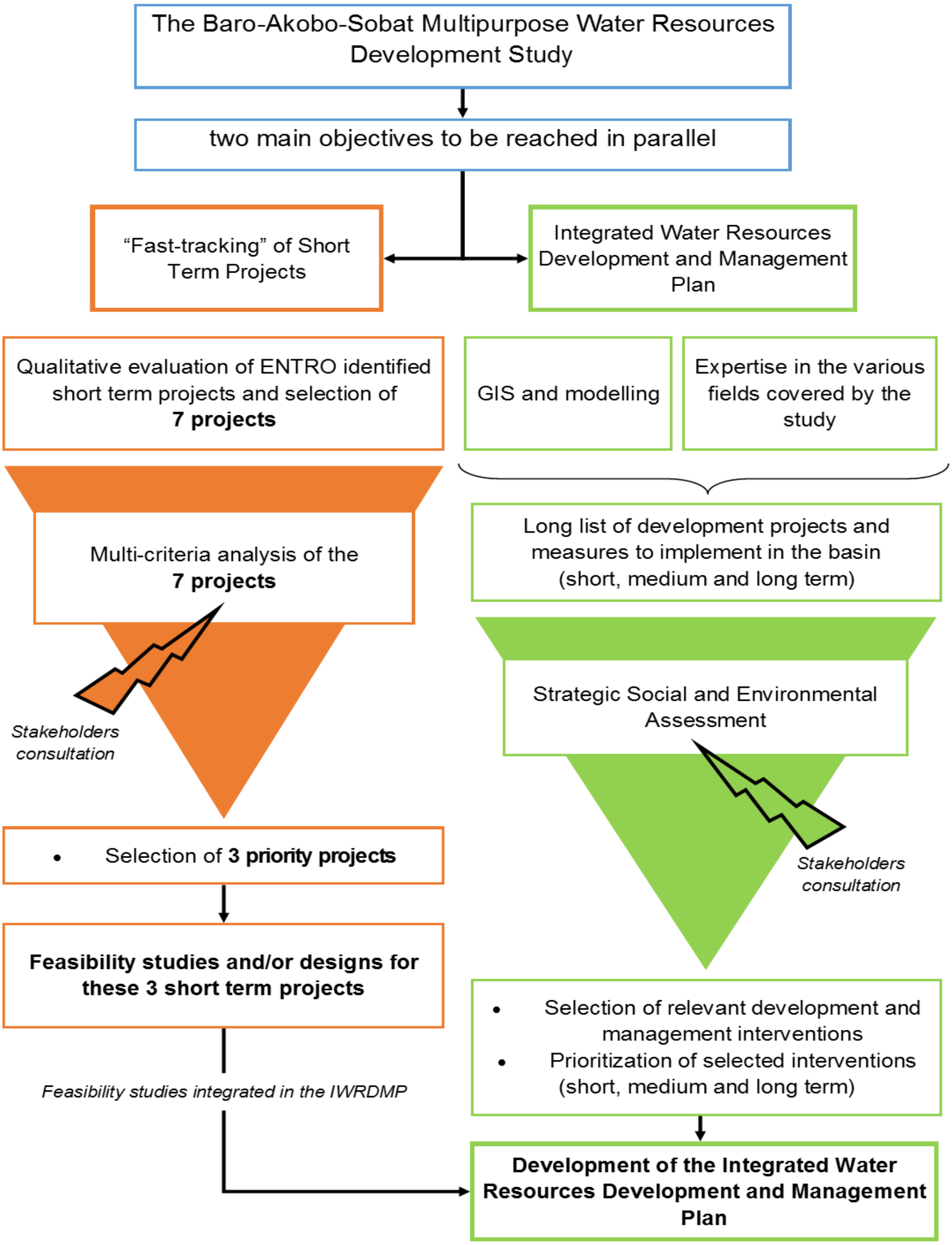


Figure 1-2: Flow chart showing key steps of the study

1.2 Purpose of the SSEA

As explained above, the present BAS study includes, amongst others, the following objectives:

- Preparation of a participatory strategic social and environmental assessment (SSEA) of the sub-basin to facilitate identification of investment options that take into account social, environmental, economic and institutional considerations.
- Formulation of an Integrated Water Resources Development and Management Plan (IWRDMP) informed by the SSEA to identify sustainable investments and provide a sound framework for long term development and management of water resources.

Because the aim of the SSEA is "to integrate strategic environmental and social considerations into the preparation" (AfDB, 2015) of the IWRDP, carrying out the SSEA runs in parallel with the elaboration of the IWRDP, even if finalisation of the IWRDMPlan follows after finalisation of the SSEA. This is a critical and welcome departure from the approach used in the past. This new approach indeed guarantees that, within the process of building the IWRDP, the main water related environmental and social priorities are addressed and potential negative risks are avoided or mitigated. This is a much more integrated and long-term sustainable approach than the one consisting in assessing the environmental and social implications of the IWRDMPlan once it is already established and validated.

The SSEA acts therefore as a tool to guide decision making in the selection of a development option that best matches with the vision and strategic objectives and that ensures sustainability of the planned development.

The SSEA allows early/upstream incorporation of environmental and social considerations in the IWRDMPlan development process. It is ultimately focused on the definition of "an institutional solution to managing potential downstream environmental and social risks" (AfDB, 2014).

1.3 Overview of the proposed IWRDMPlan

Objectives of the Plan

The objectives of the plan are not explicitly stated in the terms of reference for this study. Indeed, it is really only possible to identify these through a collaborative visioning or similar process. The terms of reference state that the IWRDMPlan is aimed at

- establishing a shared vision of the future development of the sub-basin;
- identifying principles of water resource management as well as water-linked ecosystem management and,
- reviewing, evaluating and recommending the institutional framework required for the implementation of the plan (roadmap).

Establishing the first two of these at a relatively early stage is important in order to provide a framework for the SSEA, recognizing at the same time that the baseline and preparatory work for the SSEA have contributed towards the fashioning of this framework and necessary principles of water resource management as well as water-linked ecosystem management.

However, it is important to recognise that the IWRDMPlan needs to go beyond the establishment of a strategic framework and principles. The terms of reference require that the IWRDMPlan "identifies sustainable investments and provide a sound framework for long term cooperative development and management of water resources". The terms of reference also indicate that the IWRDMPlan should optimise the various types of investments (including management and protection of the natural resources) and should also "develop a priority sequence of the multipurpose water resources development projects.

Thus while the plan is strategic in nature and rests squarely on the finding of the SSEA and options analysis, it also has to be concrete in terms of its presentation so that it can lead rapidly to implementation.

DESCRIPTION OF THE PLAN

The Plan aims to set out the actions that are required to move towards an agreed vision of the basin. However, it is important to note that the plan has a timeframe of 25 years but that the **Vision represents something a bit further into the future**, perhaps 40 or 50 years. Indeed, the economic analysis of the different options has been based on a 40 year timeline. The Plan includes the following key elements:

- A Vision and associated strategic objectives. The vision represents the desired future state for the basin to be achieved (at least in a large part) by implementation of the Plan
- Strategic actions. These are the strategic level actions that will have to be carried out to realize each strategic objective. They may be direct, infrastructure-orientated actions or actions that are aimed at supporting or providing an enabling environment.
- Specific actions. As their name suggests, these actions are specific in nature. Direct infrastructure type specific actions will include the implementation of specific infrastructure projects such as large dams and associated multipurpose projects (hydropower, irrigation, water supply etc.). Clearly the choice of which projects and when (prioritizing) depends to a large extent on the SSEA and options analysis.

  However, specific actions also include the specific actions that are required to support the implementation of direct actions. These could include, for example, actions relating to capacity and institutional aspects.
- Implementation strategy and plan. The Plan includes both a strategy for implementation and a plan with a timeline. Much of the strategy relates to the findings of the SSEA.
- Institutional framework. The Plan requires a suitable institutional framework at all levels. For this Plan, which has a high level, transboundary focus, the high level institutional framework is of particular interest.
- Monitoring and evaluation and adaptive management. A key component of the Plan is its monitoring and evaluation framework. The main purpose of this framework is to ensure that implementation of the Plan is leading to the desired outcome and ultimately the future vision of the basin.

The aim of the plan is to sustainably develop the water resources in the basin in order to satisfy the needs and address the key issues identified.

The IWRDMPlan is described into more details in chapter 2.

1.4 CONTENT OF THIS REPORT

The overall structure of this report strictly follows the report content recommended in the most recent AfDB guidelines (see AfDB, 2015).

The main chapters of this reports are as follows:

- Introduction to the study and to the SSEA;
- Key information from the baseline phase (more detailed baseline information is presented in Annex 3 and in the Baseline report);
- Summary of public consultations and the opinions expressed: description of the methodology adopted to consult stakeholders and to what extent the opinions expressed have been incorporated into the IWRDMPlan design.
- Description and justification of the key elements of the IWRDMPlan;
- Presentation of the SSEA analytical framework which is the tool for the multi-dimensional assessment;
- Presentation of the alternatives/options considered for the assessment (what are the main characteristics of the alternatives, how have they been chosen, …) ;
- Assessment of the environmental and social implications of each alternatives (nature, significance and magnitude of the impact). This chapter also discusses whether the identified impacts are mitigable and identifies the main mitigation options.
- Results of the comparison of alternatives (synthetic presentation of the previous chapter), leading to the recommendation of an optimal alternative;
- Assessment of the residual effects of the recommended way forward, taking into account the proposed avoidance and minimization measures.
- Environmental and Social Management Plan for the IWRDMPlan. It proposes the mitigation measures needed to address the residual effects of the selected development pathway and to address the uncertainties identified during the process.
- Institutional capacities and strengthening plan. The aim of this section is to assess whether the institutions designated to implement the ESMP have the required capacities and to proposed strengthening measures to address the potential needs/gaps identified
- Conclusion, concluding on the environmental and social acceptability of the IWRDMPlan, taking into account the impacts and mitigation/enhancement measures identified during the assessment process

1.5 METHODS ADOPTED TO CONDUCT THE SSEA

1.5.1 Consistency with the AfDB guidelines

The adopted approach follows the recommendations of the two most recent guidelines of the funding partner (African Development Bank):

- AfDB. (2014). Integrated Safeguards System Guidance Materials - Volume 1: General Guidance on Implementation of OS 1. Tunis: AfDB.
- AfDB. (2015). Environmental and social Assessment Procedures (ESAP). Abidjan: AfDB.

As stated in these guidelines, “SSEA should be undertaken in a more flexible and adaptive manner than traditional project ESIAs, depending on the nature of the Program-Based Operations (PBO), and especially the likely relationship between the PBOs and downstream decisions, activities and investments “.

1.5.2 The SSEA: an iterative process

MAIN STEPS OF THE SSEA

NB: The usual steps of the SSEA and their chronology are designed for SSEA starting during the finalization of the PBO[24]. This SSEA has started at the same time than IWRDMPlan and both have been conducted in parallel since the very beginning of the study. As a consequence, the steps have been adapted to match with this specific timeframe.

At the core of the SSEA is the assessment of the potential environmental and social implications of the existing development options and the selection of the preferred development option or development pathway Since, there is a wide range and even a continuum of development possibilities, the main purpose of the SSEA is to inform the IWRMP about the sustainable envelope within which development options can be defined. This requires understanding how the system reacts to various development intensities and defining environmental and social thresholds which reflect the limits of sustainability. As the SSEA is developed in synergy with the design of the IWRDMP, a stepwise and iterative process is followed. The baseline report defined the current situation in the basin, the various development potentials and the existing and potential environmental, social and institutional issues. This provides the starting point for the SSEA.

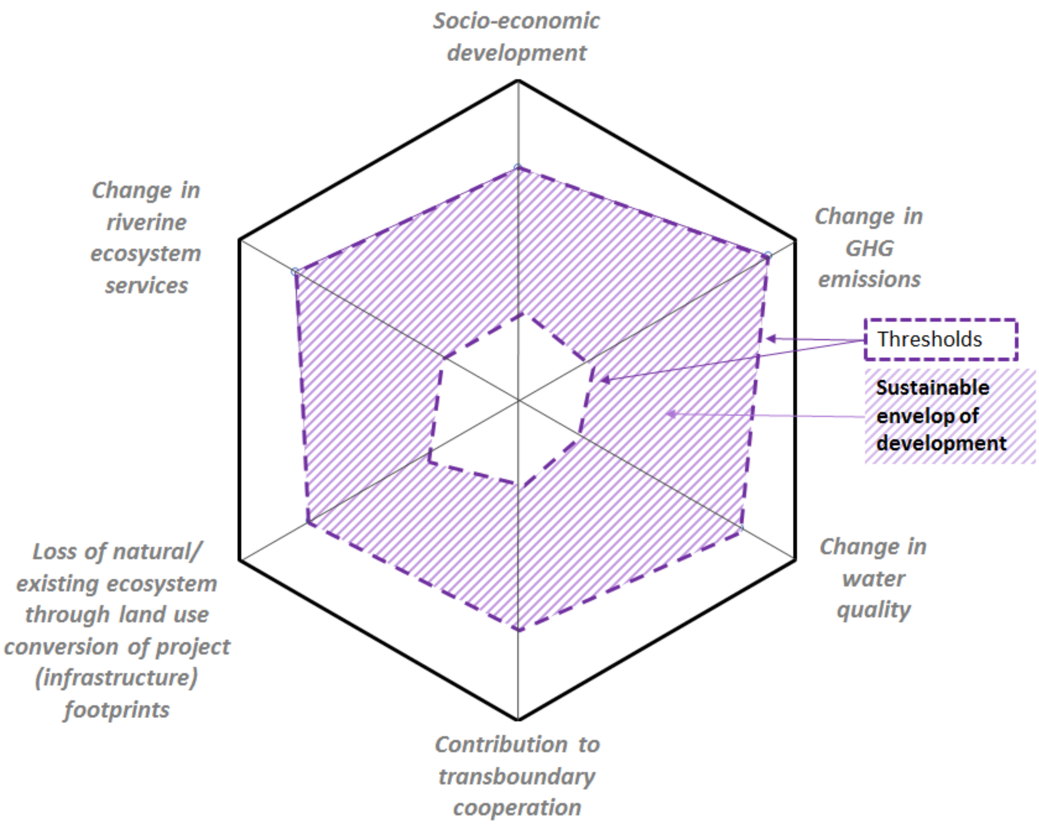
- In Step 1 the Vision and associated strategic objectives for the IWRDM Plan are decided. These are highly strategic in nature but are aimed at providing a consensual framework for the SSEA;
- In Step 2 the aim is to define the water resources related “development space” of the BAS, through the investigation of effects associated with different levels of hypothetical and highly contrasting water resources development intensities. This approach is used to investigate and understand the environmental and social implications and associated opportunities/possibilities of different water resources development and management options. It is important to stress three key aspects of this step:
  - The different options have been particularly designed to understand the respective effects of irrigation development, irrigation storage, hydropower and irrigation and hydropower combined together. An important part of the effects investigated relates to the positive and negative impacts on economic activities dependent on the ecological services provided by potentially impacted natural resources. This is a central part of the analysis.

[24] Programme-based operations. In this case, the “programme” is designated as the IWRMD Plan.

- The different levels of development intensity are represented by levels of water resources development, in particular the development of large irrigation and hydropower schemes. The design of each level of development intensity to be investigated has been done with the aim of understanding the different environmental and social impacts at the basin wide level through the use of water resources modelling and application of other tools. The investigation of different development intensities should not be confused with the assessment of water resources management and levels of development intensity which will come at a later stage and which will compare realistic and specific development options.
- The so-called development space is multidimensional in nature. There is not a single "hinge point" beyond which resources development becomes unsustainable. The approach adopted considers a number of key environmental and social dimensions each with their own thresholds. Figure 1 below illustrates the idea of the multi-dimensional analysis.

The tool used to carry out this multidimensional analysis is referred to as the *SSEA Analytical Framework.* At the core of this framework is the water resources model. Water resources modelling is critical in the investigation of these levels of development intensity since it makes it possible to look in detail at a wide range of water resources related effects for a large number of areas all around the basin.

Figure 1-3: The multi-dimensional concept



- In Step 3, the aim is to propose and investigate development options that fit within the development space. These options (scenarios) look at different realistic combinations of specific projects and/or management approaches as defined in a number of scenarios to be investigated in detail. The principal objective is that the water resources development and management scenarios fall within the multi-dimensional envelope of development space, that is to say, are within the social and environmental thresholds, guaranteeing the sustainability of the proposed development. However, there will most probably be a number of different options which fall within the development space. For this reason, <u>the comparison of the</u>

scenarios will include a Cost Benefit Analysis (CBA) carried out as part of the overall Economic and Financial Analysis, which converts social and environemental risks and benefits as identified in the SSEA and takes also into account project economic aspects not considered in the second step (*These results are summarized in Chapter 8 and presented into details in the Annex entitled: "Economic and Financial Assessment of options; Cost-benefit Analysis").*

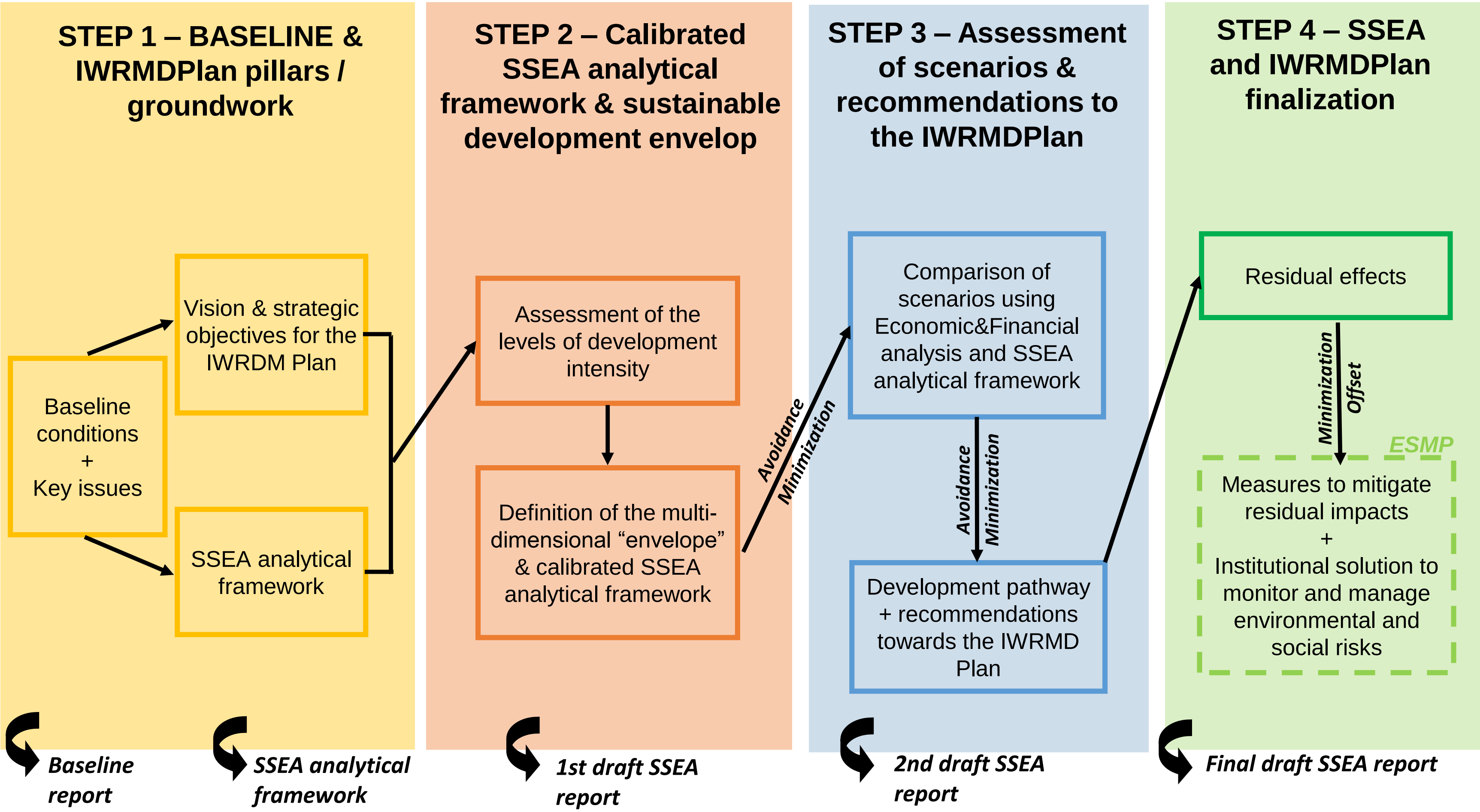
The result of Step 3 should be a preferred water resources development and management scenario or clear pathway which:

- is environmentally and socially sustainable (SSEA);
- is cost-effective (CBA), taking into account preliminary estimates of cost of mitigation measures recommended by the SSEA;
- Will lead to satisfaction of the agreed strategic objectives and therefore ultimately the vision for the basin (IWRDMPlan).

- Step 4. Once the preferred option is chosen, the residual effects of the IWRDMPlan are assessed and the Environmental and Social Management Plan (ESMP) designed. Although this is indicated as Step 4, work on this already started as part of the design of the analytical framework since defining the different environmental, social and institutional targets will require an understanding of what can be achieved through enhancement and mitigation measures.

The figure below summarizes the stepwise approach of the SSEA..

Figure 1-4: Main steps of the SSEA as presented and validated during the baseline workshop



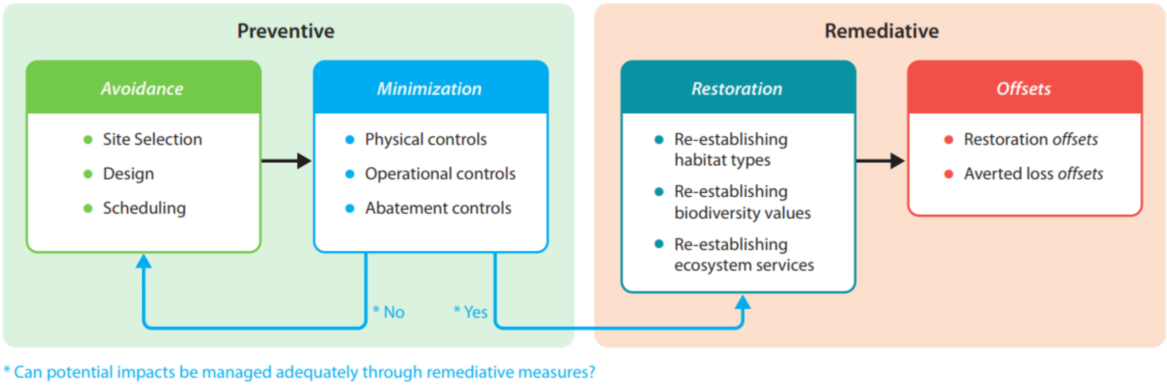
Source: this study, adapted from (AfDB, 2015)

THE MITIGATION HIERARCHY

Presentation of the mitigation hierarchy

The mitigation hierarchy defines: 'the sequence of actions to anticipate and avoid impacts on biodiversity and ecosystem services; and where avoidance is not possible, minimize; and, when impacts occur, rehabilitate or restore; and where significant residual impacts remain, offset. " (The Biodiversity Consultancy, 2015).

Figure 1-5: Schematic diagram showing the implementation of the mitigation hierarchy

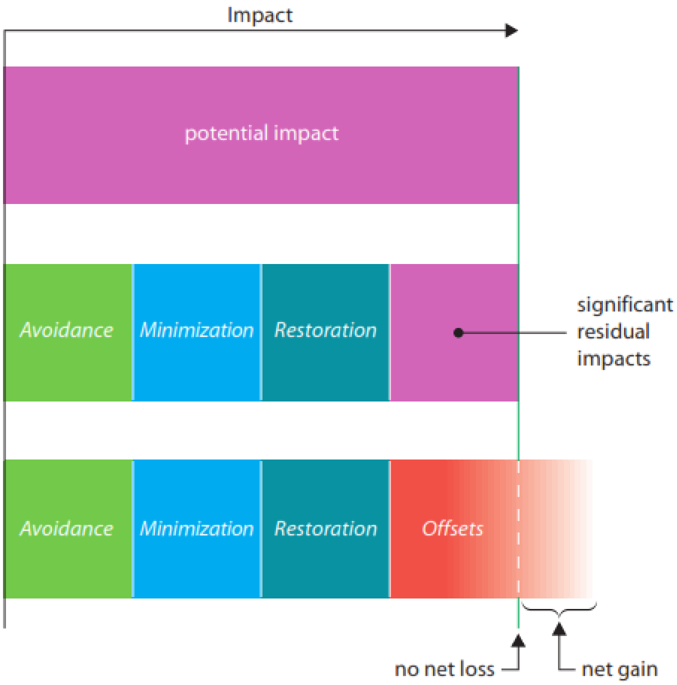


Source: (The Biodiversity Consultancy, 2015)

The biodiversity Conservancy (2011) further describes the sequence as follows:

- **"Avoidance** is often the most effective way of reducing potential negative impacts. Its proper implementation requires biodiversity and ecosystem services to be considered in the pre-planning stages of a project. When avoidance is considered too late, after key project planning decisions have been taken, cost-effective options can easily be missed.
- **Minimization**, is defined by the Cross-Sector Biodiversity Initiative (CSBI) as 'Measures taken to reduce the duration, intensity, significance and/or extent of impacts (including direct, indirect and cumulative impacts, as appropriate) that cannot be completely avoided, as far as is practically feasible' Well-planned minimization can be effective in reducing impacts to below significance thresholds.
- **Restoration** is used to repair biodiversity and ecosystem services features of concern that have been degraded by project activity. It involves measures taken to repair degradation or damage to specific biodiversity and ecosystem services features of concern following project impacts that cannot be completely avoided and/or minimized. Restoration is usually carried out on-site and to repair impacts caused (directly or indirectly) by the project. Implementation of offsets (see below) may also involve restoration activities carried out off-site to repair impacts not caused by the project.
- **Offsets** are defined by the CSBI as 'Measurable conservation outcomes, resulting from actions applied to areas not impacted by the project, that compensate for significant, adverse project impacts that cannot be avoided, minimized and/or rehabilitated/restored'. Offsets should have a specific and preferably quantitative goal that relates directly to residual project impacts. Often (but not necessarily) this is to achieve no net loss or a net gain of biodiversity. Offsetting is a measure of last resort after all other components of the mitigation hierarchy have been applied. Offsets can be complex, expensive and uncertain in outcome. The need for offsets should therefore be reduced as far as possible through considered attention to earlier components in the mitigation hierarchy" (The Biodiversity Consultancy, 2015).

Figure 1-6: Application of the mitigation hierarchy components



Source: (The Biodiversity Consultancy, 2015)

Application of the mitigation hierarchy to the SSEA

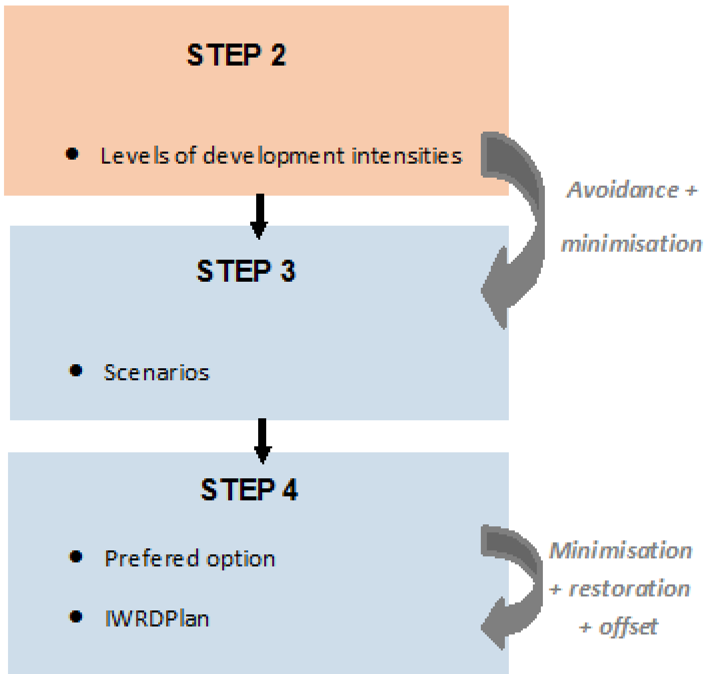
As already stated above, remedial measures are highly uncertain in outcome, complex and expensive. As such, they are measures of last resort to be applied after all preventive components of the mitigation hierarchy have already been applied. Considering that enhancement and preventive measures such as avoidance and minimization **are the most effective way** of maximizing benefits and reducing negative effects below the thresholds, such measures have been included in the IWRDMPlan development process.

Figure 1-7: Steps of the SSEA and the mitigation hierarchy

At the end of step 2, avoidance and minimisation measures are identified in order to develop scenarios that will fit into the sustainable development envelop.

As part as step 3, Scenarios 1, 2, 3a and 3b include avoidance and minimization measures.

Once the preferred option for the IWRDMPlan is chosen / designed by the stakeholders, residual effects are assessed and further minimization, restoration and offset measures defined as part of the ESMP.



2. KEY INFORMATION FROM THE BASELINE PHASE

2.1 KEY HYDROLOGICAL FEATURES OF THE BAS

The main rivers of the BAS take their source in the Ethiopian and South Sudan Highlands and join the Sobat in the plain. The Sobat is a major tributary of the White Nile: the mean annual outflow of the Baro-Akobo-Sobat Basin into the White Nile of about 12.4 billion m^3/a contributes about half of the flow of the White Nile at Malakal and about a sixth of the flow of the Main Nile at Aswan.

The hydrological system of the BAS is reputed to be complex and not very well known due to the lack of data and the remoteness of the area. At the heart of the system complexity lies the flatness of the plains, leading to meandering and moving river beds, as well as several hydrological links between the various streams. Another important characteristic of the hydrological system of the BAS is that most of the main rivers exhibit a high degree of overbank flowing, mainly during the wet season, and thus contribute to form important floodplains and wetlands. The wetlands hydrology is also poorly known and has been mostly deduced from information about the evolution of their size and the global water balance of the BAS. The main wetlands and floodplains complexes which are potentially impacted by the identified water development projects are the Machar Marshes, the Gambella plains and the Sobat wetlands.

The main rivers, wetlands, spills and links are located and characterized in the figures below. It is important to note that the numbers indicated in this schematic are average annual volumes of water as derived from a long series of daily hydrological data at each point. There is, therefore, a lot of hidden detail which is not shown in such a simplified schematic. The variability of flows through a typical year and the difference between wet and dry years are important considerations, and which are taken into account in the water resources modelling based, as it is, on a daily time step.

The current water use in the basin is very limited and includes diffuse domestic, livestock and small-scale irrigation throughout the basin as well as one large-scale irrigation scheme in the Alwero catchment (Abobo Dam). Furhthermore, there is a small hydropower installation on the Sor River – an upper tributary of the Baro River.

Figure 2-2 presents the current water balance in te basin and indicates the connectivity and mean annual flow in the main river network, including inter-catchment spills, the locations of wetlands and major dams including mean annual precipitation and evaporation associated with these storage areas, and large scale irrigation abstractions. It shows the extent of floodplains and wetlands along the lower Alwero, Gilo, Pibor and Baro rivers, along the Sobat River and the location of the Machar marshes along the right bank of the lower Baro River. It also indicates the extensive spills and interconnectivity in the Gambela floodplain with spills/links from the Lower Akobo to the Gilo River, from the Gilo to the Lower Alwero, from the lower Pibor to the Twalor and from the lower Baro to the Alwero and the Machar Marshes. Furhermore, depending on certain thresholds, significant spills also occur from the Upper Akobo into the Agwei River and wetlands.

Figure 2-1: Location of main rivers, spills and links and wetlands

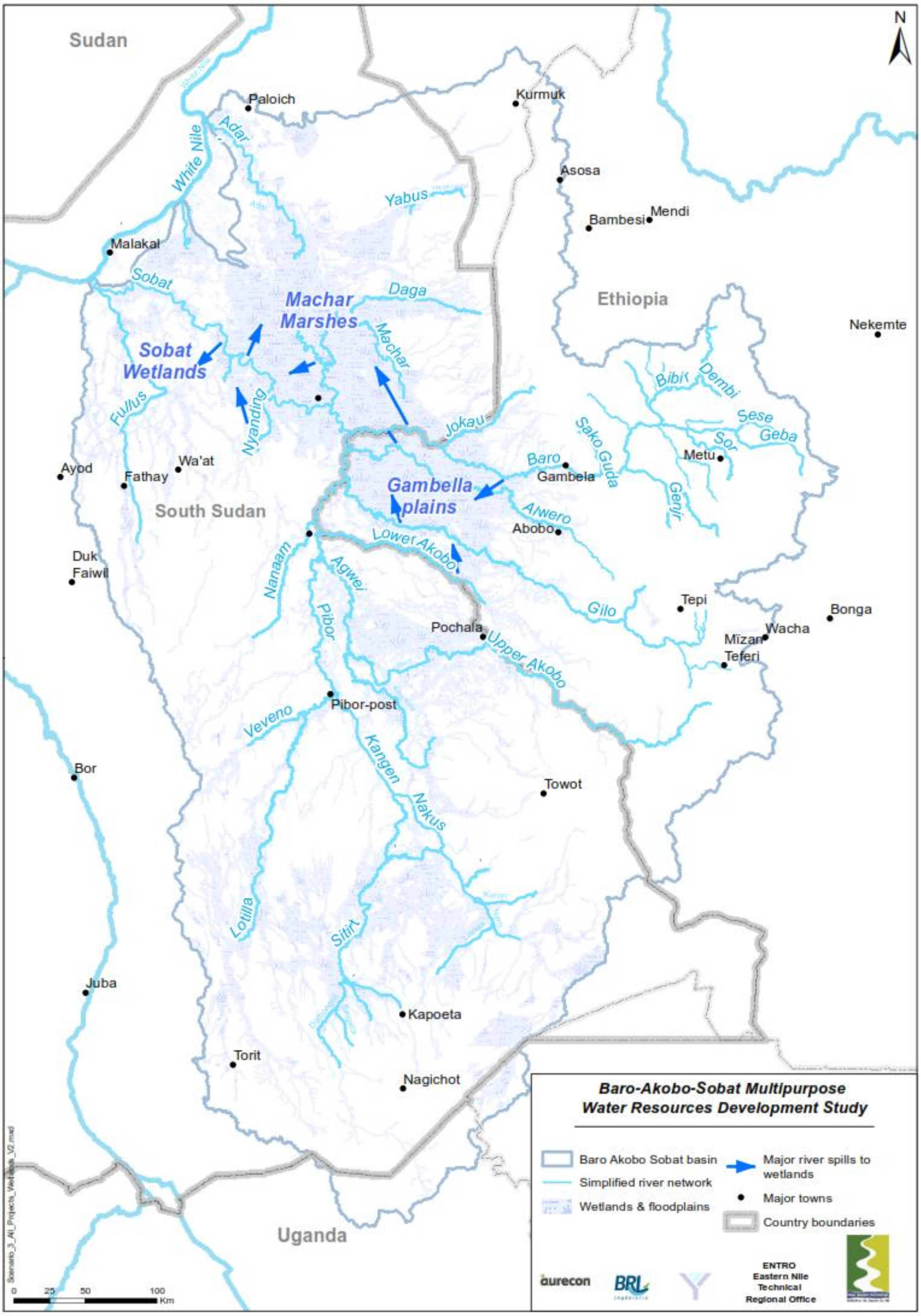
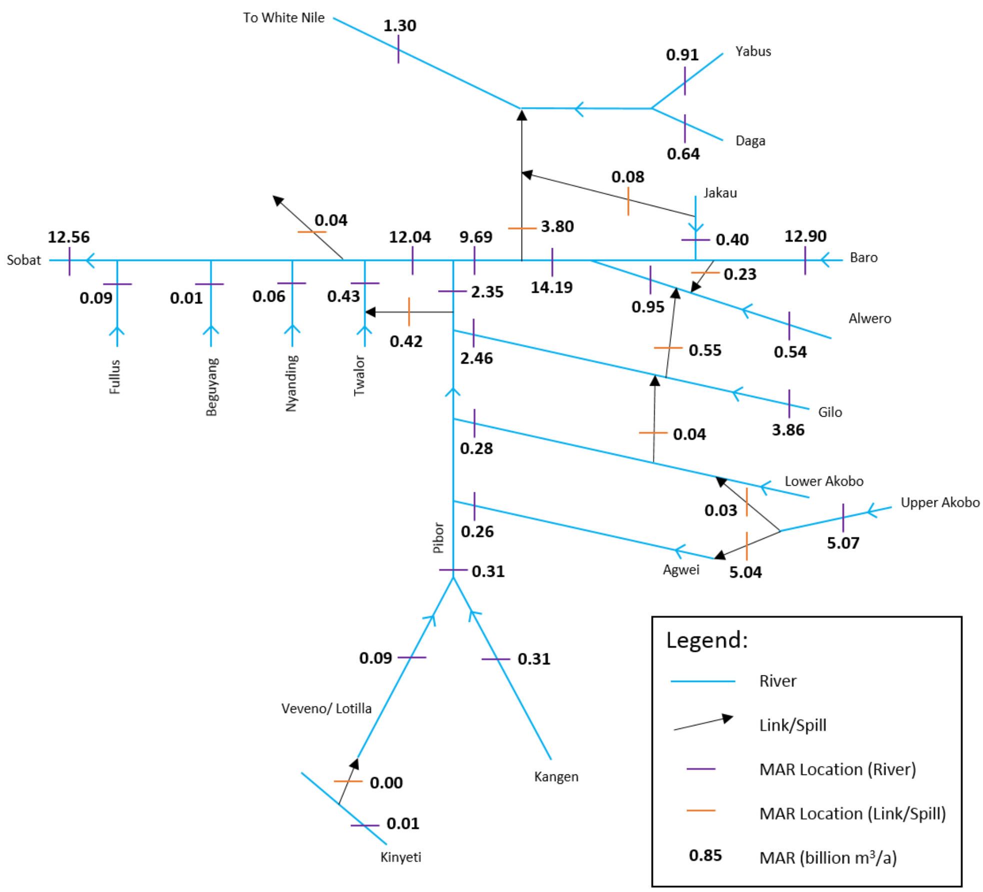


Figure 2-2: Water balance schematic under baseline conditions



The main spills rules, which are based on the mean daily flows, are as follows:

- Baro spill to Machar: the flow threshold assumed for the Lower Baro after which spill to Adura Junction occurs is 510 m3/s; 78% of the flow above this threshold at the Adura Junction spills to Machar.
- Baro spill to Alwero: the Baro does not spill up to 940 m³/s, after which it breaks its banks and spills up to a maximum 60 m³/s to the Alwero.
- Gilo spill to Alwero: The Gilo River has a capacity of 250 m³/s, after which it spills all surplus flow to the Alwero.
- Pibor spill to Twalor: The Lower Pibor has a capacity of 250 m³/s, after which it spills all surplus flow to the Twalor.
- Upper Akobo to Agwei: The Upper Akobo spills a maximum of 200 m³/s into the Lower Akobo, and the surplus spills into the Agwei.
- Akobo spill to Gilo: The Lower Akobo River has a capacity of 25 m³/s, after which it spills all surplus flow to the Gilo.
- Sobat spill to Wal: The Sobat River has a capacity of 1 400 m³/s, after which it spills all surplus flow to the Wal.

2.2 Key facts about each bio-physical area

2.2.1 Spatial and Temporal Limits

Spatial boundaries

The study area is the Baro-Akobo-Sobat Basin as defined by its hydrologic boundaries. The existing boundaries were reviewed during the baseline and some modifications made. Although minor, they did result in the Kinyeti River, which takes its source in the Imatong Mountains now being included in the basin.

Temporal limits

The planning horizon for the IWRDMPlan has been taken as 25 years. Within this time frame "short-term" is taken as up to 5 years, "medium term" as 5 to 15 years and "long-term" as 15-25 and beyond.

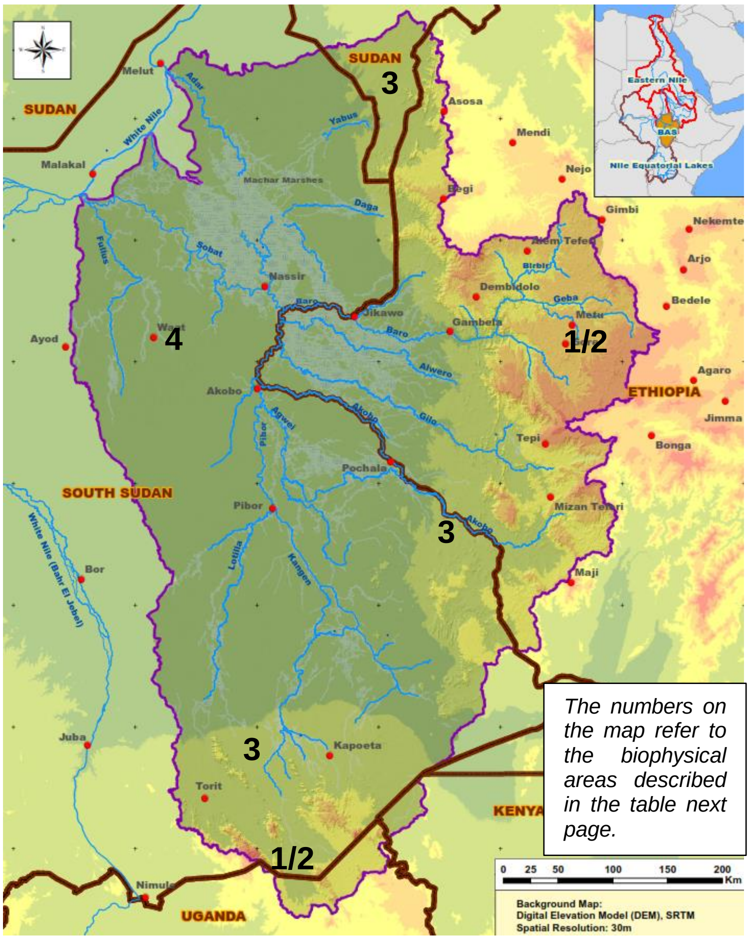
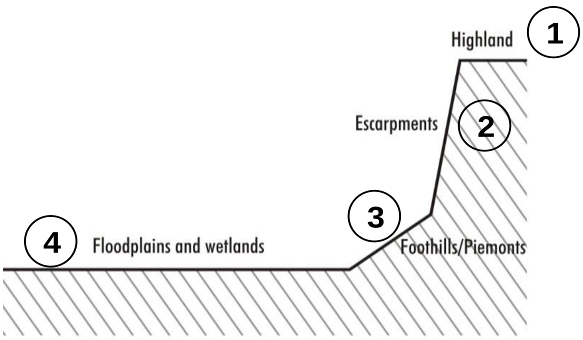


Figure 2-3: Drainage and Relief of the Baro-Akobo-Sobat Basin, showing basin limits

The baseline information on the environmental characteristics of the BAS is organised into four biophysical areas, namely: highlands, escarpments, foothills and floodplains. This approach enables the SSEA to gain a better understanding of the BAS study area and the linkages between the environmental and socio-economic systems.



Biophysical area of the BAS	Surface area (km²)	% of the BAS
Escapments	57439	22%
Highlands	13956	5%
Piedmont / FootHills	65563	25%
Flood plain and plain	125668	48%
Total basin	262626	100%

Figure 2-4: Proposed biophysical area in the BAS

2.2.2 Key facts about biophysical, biological, socio-economic environment and status of water development per biophysical areas

HIGHLANDS AND ESCARPMENTS (1/2)

Highlands are mainly situated in the eastern part and to a lesser extent in the southern part of the basin at an elevation varying from around 1,800 masl to 3,000 masl (Mont Kinyeti in the Imatong mountains reaches up to 3,187 masl). It is characterized by an undulating to rolling plateau, steeply incised by the major rivers with isolated high mountains such as Mount Tulu Welwel and Seccia (ENTRO, 2007a).

Escarpments are generally situated between 1,100 and 1,800 masl. These areas are characterized by very steep slopes (much more important than in the highlands and foothills). Some parts are also flatter like the Boma Plateau, situated between 1,100 and 1,300 masl.

These mountains areas are characterized by very high rainfall (from 2000 to 2500 mm per year) and moderate evapotranspiration compared to floodplains. The rainy season lasts from May to October.

Highlands and escarpments are the source areas for significant rivers such as the Baro, Alwero, Gilo, Akobo and Kinyeti and the population density is very high (refer to section 4.4).

Key social features

The highlands and escarpments in the Ethiopian part of the basin have the highest population and population densities ranging from 50 to 500 inhabitants/km^2 and out-migration in the basin.

The main ethnic groups occupying the highland and escarpment zone of the basin include the Oromo, Amhara, Kafficho, Shabo, Majang, Bench, Kafa, Me'en and Suri. These ethnic groups engage in a variety of livelihoods, including rainfed and shifting cultivation, herding, hunting, gathering bush and forest products, small businesses and petty trade. The largest ethnic group is the Oromo whose livelihoods include subsistence agriculture, trading in local markets, animal husbandry (mainly keeping draught oxen), and the harvest of wild coffee from the forest.

The Majang live in southeastern Gambella State bordering SNNPR. Their livelihood activities include slash and burn cultivation of maize, sorghum, godere (cassava), taro, yams, hunting, and they are especially known for beekeeping. The Berta are mostly Muslims and practice slash-and-burn cultivation of sorghum and other crops. The Bench people are agriculturalists cultivating sorghum, maize, wheat, and barley using a terracing system with the hoe as their principal tool. Sheep, cows and fowls are plentiful among the Bench people. Their food consists of meat of cattle and goats or sheep, milk, maize, and cassava.

Farmer ploughing, western highlands, Oromo, Ethiopia

Bench village scene in the highlands of SNNPR, western Ethiopia

Key environmental features

Common to all groups is a strong ethnic identity and attachment to their ancestral homelands and traditions. Recently political conflicts between the federal government and indigenous groups in Oromia have recently intensified in west-central Oromia in the easternmost part of the BAS basin.

The original vegetation of the BAS highlands was probably a mixture of closed forest (Friis, 1992 in Burgess et al., 2004). Currently, the highland areas are still largely covered with forest, even if forests have been severely encroached by agriculture. Highlands and escarpments host the last important remnant forest of the Ethiopian Upper Montane Forests, Woodlands, Bushlands and Grasslands ecoregion and the last important forest area in Ethiopia They are endowed with a high level of endemism. Forests are mainly threatened by expansion of coffee plantation, settlements and agricultural expansion (in highly populated areas, even steep slopes and mountain tops are being farmed) and logging.

Ethiopian highlands

South Sudan highlands

Afromontane natural forests also provide a variety of food products such as honey, spices, palm, wild fruits (Asseffa, 2007). The sale of wild coffee, growing under Afromontane highland and lowland Ethiopian forests is also an important source of subsistence for the local communities (NABU, 2015). Afromontane highlands and lowlands forests offer large old high quality wood from *Daniellia oliveri* and *Khaya senegalensis* trees for instance. Asseffa (2007) has estimated that households from Sheka forests generate about 44% of their income from forest and forest products.

Headwater catchments, wetlands and forests play an important role in flood regulation, micro-climate regulation and erosion control. Given potential water resources developments downstream, the natural regulation and reduced sediment load provided by these services can play a major role in reducing the costs of infrastructure. At the basin-scale, highlands and escarpment forests also play a critical role in carbon sequestration.

In highlands and escarpments, main sources of livelihoods are coffee, cereals, chat, maize, sorghum, spices, cereals in Ethiopia and maize, cassava and highland forest products in South Sudan. Agriculture is mainly subsistence and rarely irrigated, which makes it vulnerable to droughts.

Relief makes the access to water difficult, especially in the escarpments, where search for water implies reaching gorges, which are deep and far from villages, fields or cattle herds.

Ethiopian highland wetland

Source: (Hailu A, 2006; fework, 2001)

In western Ethiopia, the production from wetlands has been estimated to contribute up to 50 – 60% of the household's food security. Harvesting can be after the end of the dry season. Sedges (carex) found in the BAS wetlands are widely used for thatching. For example, in Western Oromia sedges prime importance is for thatching local houses (*tukuls*), among a variety of uses for the local communities, especially where other suitable materials are not available or are too expensive. In Illubabor Zone it is estimated that an estimated 85% of the local households use sedges or *cheffe* for roofing their houses or *Tukuls* (Hailu A, 2006; fework, 2001).

Highlands and escarpments are endowed with a large potential for hydropower, which could significantly improve the energy security in the basin (the population currently mainly depends on charcoal and fuelwood) and thus decrease pressure on natural resources. According to the Ethiopian map of potential for solar energy, the BAS area appears to be not suitable for the development of solar energy.

Potential for groundwater is high in some areas of Ethiopian highlands and escarpments. Small scale irrigation projects were identified in lower altitude and more flat areas.

Foothills/Piedmonts (3)

Foothills or Piedmonts are situated between 700 and 1,100 masl. They form a transition area between escarpments, characterized by very steep slopes and flood plains which are extremely flat. The rainy season lasts from April to September. They are mainly covered by shrubs, dry savannas and Woodlands.

Key social features

The foothills and piedmont zone has moderate population and population densities and are experiencing significant in-migration of both refugees from South Sudan and settlers from the Ethiopian highlands. On average, population density is estimated to 10 people per km² in Gambella to 70 people per km² in the parts of Oromia region.

This zone is inhabited by a large diversity of ethnic groups and livelihoods. Land tenure and use is based on customary practices, but is also subject to government policies and decisions regarding resettlement schemes, particularly in Gambella State, long-term agricultural leases to domestic and foreign investors, and political conflicts, mainly, between the Dinka and Nuer in South Sudan. There are a number of large refugee camps in this zone, particularly in Gambella and Benishangul-Gumuz Regional States in Ethiopia.

Among the main ethnic groups in the foothills and piedmont zone of the basin are the Anuak, Murle, Majang, Berta, Komo and Toposa. These ethnic groups practise a wide variety of livelihoods, including rainfed and shifting cultivation of sorghum, teff, enset, pastoral herding, harvesting forest products, beekeeping and coffee cultivation. The Anuak are primarily herdsmen and farmers. There are serious tensions between the Anuak in Gambella State and the Government of Ethiopia over complaints of discrimination, encroachment by recent settlers from the highlands and other parts of Ethiopia and leasing of large tracts of land to outside investors.

The Murle inhabit Pibor County and the Boma area in Jonglei State in South Sudan, as well as parts of southwestern Ethiopia. The Murle are pastoralists in an area where frequent and unpredictable shortages occur in rain, drinking water, bush fruits and grazing for cattle. This necessitates a semi-nomadic lifestyle that covers large areas. In times of shortages the Merle frequently come into conflict with larger groups, including the Dinka and Nuer.

The Berta inhabit the border area between the Upper Nile State in South Sudan and Benishangul-Gumuz State in Ethiopia. The Berta practise slash-and-burn agriculture, with their main crop and staple food being sorghum. The Toposa people live in the Kapoeta area in Eastern Equatoria. The Toposa raise cattle, sheep and goats, from which they obtain milk, blood, meat and leather. The women also engage in limited agriculture in the river valleys where the main crop is sorghum.

Itang Refugee Camp near Gambella, Ethiopia

Anuak people on the banks of the Baro River in Gambella Region

A Toposa village in the foothills of the Imatong Mountains near Kapoeta in Eastern Equatoria

Toposa woman threshing sorghum

Key environmental features

Lowland forests provide important sources of livelihoods, like forest products, wild coffee which grows naturally at these altitude and honey.

Wooded savannahs are used for fuel wood and charcoal and also serve as important ppasture lands.

In Ethiopia subsistence farming consist of cattle, maize, cereals whereas sorghum is more cultivated in South Sudan. Mechanized agriculture is raising and the area has been identified as suitable for large scale irrigation schemes.

Groundwater varies form 25-50 $10^3 m^3/Km^2/yr$.

Typical vegetation in the South Sudan Piedmont

Charcoal bags sold along the roads

The Boma plateau

Source: (IGAD, 2016)

Foothills and piedmonts are endowed with endemic plants and threatened mammal species include elephants (*Loxodonta Africana*), wild dog (*Lycaon pictus*), cheetah (*Acinonyc jubatus*), and lion (*Panthera leo*). The roan antelope's (*Hippotradus equinus*) can also be found.

PLAINS (4)

This biophysical area covers more than the half of the BAS. The Floodplains and wetlands biophysical area is situated between 370 and 700 masl. It consists of very flat clay plains that stretch from northwards South Sudan foothills and westwards from Ethiopia foothills to the Sobat river. These plains have very gentle slopes between 0,01 and 0,012% (ENTRO, 2007a).

The rainfall reaches between 600 and 800 mm/year, falling between April and September during the hot season when temperatures average 30-33°C, dropping to an average of 18°C in the cooler season (Burgess et al., 2004). Mean annual evaporation is from 1600 to 1900 mm/year (ENTRO, 2007a).

Key Social features

Plains are characterized by very low population density, except in urban areas, such as Gambella town. In the South Sudan part of the basin the highest densities of population are found along rivers, in particular the area along the Sobat River immediately north of the Gambella salient.

Malaria is reported in these areas and is a leading cause of death of children under age five, especially in South Sudan. Lowlands have the highest poverty rates of the BAS.

These areas of the BAS are the most affected by displacement due to political and ethnic conflicts are Jonglei and Upper Nile States in South Sudan and Gambella and parts of Benishangul-Gumuz regions in Ethiopia. Conflicts are reported both in the South Sudan and Ethiopia parts of the basin and mainly consist of historical pastoralist conflicts: cattle raids, communal clashes, revenge attacks and selective violence in the Jonglei and Upper Nile areas in South Sudan and in the Akobo area bordering Gambella in Ethiopia. Resource-based conflicts in South Sudan can also be a consequence of oil exploration and extraction activities and their related potential impacts on water quality, management, allocation and control over land and water resources.

Flooded refugee camp

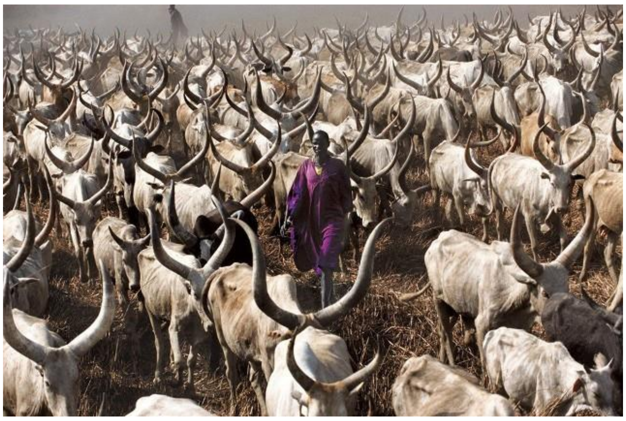
Source: (Columbia Journalism review, 2016)

Among the main ethnic groups in the plains zone are the Nuer, Dinka, Berta, Anywa, Komo, Murle, and Kwama. The plains encompass a variety of livelihood zones, including mixed maize and sorghum cultivation, livestock, agropastoral and pastoral livelihoods The Dinka form the largest ethnic group in South Sudan, accounting for 35.8% of the population. They are predominately pastoral people, but also practice shifting cultivation, growing millet, maize and occasionally cotton.

The Nuer people inhabit both the plains and piedmont zones in Ethiopia and South Sudan, and are pastoralists or, more accurately, agro-pastoralists. Nuers are predominantly cattle-breeders, but they also cultivate flood recession maize and sorghum to supplement their normal diet of milk and blood. Cattle are jointly owned by extended families. In South Sudan, the Nuer live in the basin states of Upper Nile and Jonglei. They are the second largest group in South Sudan, making up 15.6% of the population.

Aerial view of a Nuer village in the plains zone

A Dinka herd of white Acholi cattle east of Bor, Jonglei State, South Sudan



The seasonally river-flooded grasslands form the '*Toich*', which yields dry season grazing areas important to both the Nuer and Dinka agro-pastoralists. The Anywa, Opo and Komo grow maize and sorghum using the banks and levées of the main rivers. They also harvest wild Taro (Opelli) from river banks as the flood waters recede." (IGAD, 2015). Other ethnic groups in the plains practice rainfed sedentary and shifting cultivation, herding, hunting and gathering, fishing, beekeeping and petty trade as livelihoods.

A temporary village of the semi-nomadic pastoral Murle in Boma National Park - The circular, bordered area in the left center of the photo is a zariba where cattle are kept at night.

Historically the youth of the Dinka, Nuer and Murle have raided each other's cattle to obtain cows for the payment of dowries. However, in recent years the raiders are armed and the raids have become increasingly violent and destructive, resulting in abductions, stealing food, burning homes and even death. The part of this zone in South Sudan is experiencing both historical and more recent political conflicts, primarily between the Dinka and Nuer mainly in Jonglei and Upper Nile states, resulting in continuous instability and displacement of the population.

Key environmental features

In lowlands, mixed agriculture and agropastoral systems are the main sources of livelihoods in Ethiopia and consist of diverse systems in the various parts of South Sudan such as pastoralism, sorghum & cattle, maize & cattle and sorghum & livestock. Some large scale agricultural schemes are reported. Major suitable areas of large scale irrigation schemes have been identified around the Sobat rivers which consist of an important opportunity to improve food security since food aid requirements are still very high.

Gambella plains and the South Sudan parts of the plains are prone to flooding. In addition to losses of life, severe floods impede development by hindering access, transport and exchanges (half of the roads are not practicable during the wet season) and by damaging houses and crops.

Aerial view of the Gambella plain wetlands

Source: (IGAD, 2016)

The famous mamal migration of the BAS

Source: (The daily galaxy, 2011)

Life is also difficult during the dry season: perennial rivers, wells and hand-dug storage for livestock dry up, leading communities to be in a continuous search for water.

Floodplains and wetlands are key resources for livestock in the dry season since they provide high quality grass and water for cattle grazing and watering. The main valuable plants for grazing are flooded grasslands such as:

- Oryza providing high quality grazing for much of the year and which has a much higher yield (7x) where flooded for long periods and can also be used as a crop at the end of the dry season when other sources of food become rare.
- Echinochloa pyramidalis which also grows even during the dry season providing year-round pasture

According to (Hailu A, 2006), it “would be no exaggeration to claim that the survival of the country’s livestock is directly linked to the abundance of wetlands”.

Waterbodies and other wetlands provide important fish resources. Fish is the main source of protein for Anuak communities, who live along the banks of the Baro and Gilo Rivers. “The Gilo River is one of the many arteries that pump life into the Gambella Landscape. Communities depend heavily on its ample resources. Growing of crops along the fertile banks as the floodwaters recede (recession agriculture) and fishing are mainstays of local food supply throughout the calendar.” (IGAD, 2015)

Water hyacinth is found up to Baro at Gambella and impede navigation on the Sobat.

River siltation occurred in less than 10 years on the Machar mouth, along the Khor Machar, on the Zure River / Adura river, and on the Baro river and its major spills and bifurcations, having already important socio-economics and environmental impacts. Erosion of the upper parts of the catchment seems to be the cause of the observed downstream siltation.

The BAS lowlands host one of the most important mammal migration of the world (USAID, 2010b) The main migratory species is the White-eared Kob (Kobus kob leucotis), estimated to up to 1.2 million by USAID (2010). White-eared Kobs are endemic to the BAS since migration routes are nearly confined within the sub-basin limits. White-eared Kobs are listed as “least concerned” but faces increasing threats leading to population decline. Migration routes are strongly correlated with hydrological patterns (HoA-REC, 2011). Apart from the White-eared Kob, the migration consists of Tiang, Mongalla gazelle and East African eland all followed by Lion, Jackal and Hyena. At the southern end of the migration they are joined by Zebra, Bright’s Gazelle, Giraffe and Beeisa Oryx. There are also roan Antelope and Buffalo near the Ethiopian foothills (Frost, 2014).

Together with the Sudd wetlands, the BAS wetlands host the largest population of shoebill (*Balaeniceps rex*) in the world, estimated to be around 6,400 individuals (Robertson, 2001 in Burgess & al, 2004). The area is also a stronghold for the great white pelican (*Pelecanus onocrotalus*), ferruginous duck (*Aythya nyroca*) (Robertson, 2001 in Burgess & al, 2004), and black-cowed crane (*Balearica pavonina*) (Newton, 1996 in Burgess & al, 2004).

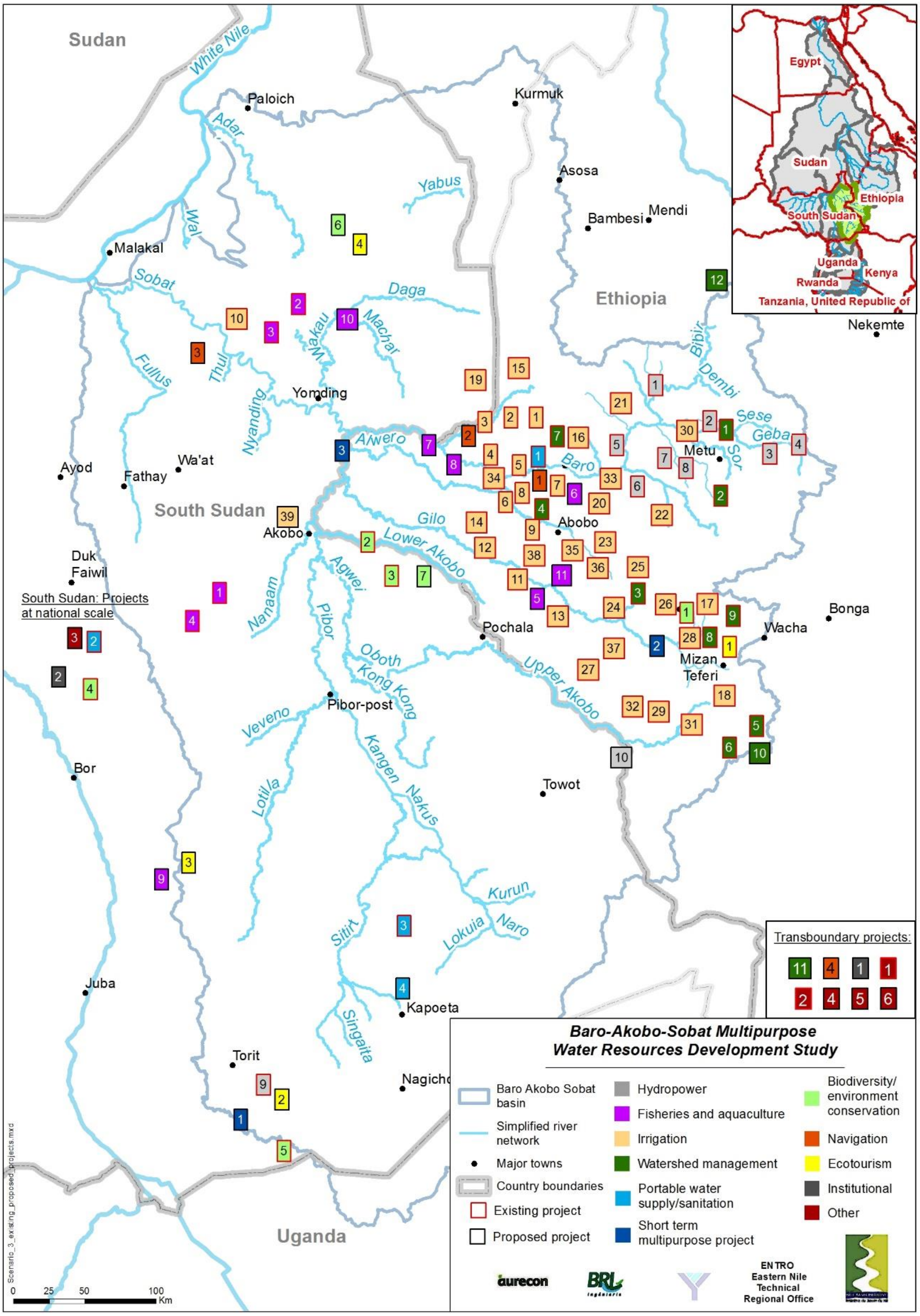
It also host the endangered and endemic Nile Lechwe which heavily rely on local patterns of flooding (Kingdon et al., 2013).

These natural assets bring a huge potential for ecotourism in the area as wwildlife experts consider that the mammal migration of the BAS is equal to that of the Massai Mara – Serengeti, which gathers around 400,000 visitors annually.

2.3 WATER DEVELOPMENT OPPORTUNITIES

Water development opportunities identified per sector are synthetized in the figure next page.

Figure 2-5: Water development opportunities



Existing development projects

Hydropower

1. BirBir (capacity 467 MW)
2. Sor 2 (capacity 5 MW)
3. Geba 2 (capacity 157 MW)
4. Geba 1 (capacity 215 MW)
5. TAMS (capacity 1700 MW)
6. Genji (capacity 216 MW)
7. Baro 2 (capacity 479 MW)
8. Baro 1 (capacity 166 MW)
9. Kinyeti (capacity 1 MW)

Fisheries and aquaculture

1. Microcredit for fisheries projects in Joglei States
2. Microcredit for fisheries projects in Upper Nile
3. Promotion of large scale aquaculture in Upper Nile
4. Promotion of large scale aquaculture in Jonglei State

Irrigation

1. Baro Right Bank (Gambela Dam / River Pumping) (potential area : 68000 ha)
2. Baro Right Bank (Itang Reservoir Pumping) (potential area : 58 000 ha)
3. Sako Guda
4. Baro Left Bank (Itang Dam) (potential area : 62 000 ha)
5. Baro Left Bank (Itang Reservoir Pumping) (potential area : 16 000 ha)
6. Baro Left Bank (Gambela Dam / River Pumping) (potential area : 57 000 ha)
7. Upstream Alwero Project (Abobo Area) (Chiru / Dum) (potential area : 42 000 ha)
8. Alwero Left Bank (Abobo dam) (potential area : 9000 ha)
9. Gilo Right Bank (Gilo 1 dam) (potential area : 81 000 ha)
10. Northern area (Sobat irrigation-South Sudan) (potential area : 816 000 ha)
11. Gilo Left Bank (Gilo 1 dam) (potential area : 72 000 ha)
12. Gilo Left Bank (Gilo 2 dam) (potential area : 34 000 ha)
13. Gilo Left Bank (Gilo 1 dam) (potential area : 9 000 ha)
14. Gilo Right Bank (Gilo 2 Dam) (Ubela-Pashala area)
15. Koji small scale irrigation project (potential area : 6 000 ha)
16. Sako Guda small scale irrigation project (potential area : 4 600 ha)
17. Bako small scale irrigation project (potential area : 6 000 ha)
18. Kilu small scale irrigation project (potential area : 5 600 ha)
19. Lafo Kotu small scale irrigation project (potential area : 9 000 ha)
20. Baro small scale irrigation project (potential area : 2 000 ha)
21. Birbir small scale irrigation project (potential area : 8 000 ha)
22. Fani small scale irrigation project (potential area : 1 200 ha)
23. Alwero small scale irrigation project (potential area : 5 500 ha)
24. Guy small scale irrigation project (potential area : 1 800 ha)
25. Godare small scale irrigation project (potential area : 3 300 ha)
26. Achani small scale irrigation project (potential area : 4 300 ha)
27. Awaya small scale irrigation project (potential area : 5 000 ha)
28. Babaka small scale irrigation project (potential area : 6 000 ha)
29. Guracha small scale irrigation project (potential area : 2 000 ha)
30. Gumero small scale irrigation project (potential area : 4 000 ha)
31. Akobo I small scale irrigation project (potential area :5 000 ha)
32. Akobo II small scale irrigation project (potential area : 30 000 ha)
33. Gambella dam
34. Itang dam
35. Chiru dam
36. Dumgong dam
37. Gilo 1 dam
38. Gilo 2 dam

Watershed management

1. Metu: Sustainable Land Management Programme (SLMP) 1
2. Masha: SLMP 2
3. Godere: SLMP 1
4. Abobo: SLMP 1
5. Bench Maji Zone: SLMP 2 for two woredas (Semien Bench and Meinit Goldiya)
6. Watershed Management Programme implemented by Farm Africa/SOS Sahel in the forest areas of Gesha, Chena, Gewata and Yeki woredas
7. Gambella Town: SLMP 1
8. Sustainable development of forest products operated by MELCA and NABU in Sheka and Kafa zones
9. Micro watershed management by Ethiowetlands of Ethiopia in Sheka,

Potable water supply/sanitation

1. Gambella Town and woreda: water supply and sanitation programmes
2. National investment plan for the WASH sector in South Sudan
3. Water for Eastern Equatoria State to improve understanding

Biodiversity/environment conservation

1. Majang forest: application to the biosphere reserve classification
2. Boma-Jonglei landscape project: promotion of trans-boundary and sub-regional interventions to address the environmental challenges of the area
3. IGAD Biodiversity Management Programme (BMP) to put in place the necessary policies and practices to sustainably manage natural resources, conserve biodiversity, and secure the livelihoods of local people of the BomaJonglei Landscape
4. UNDP launching protected area network management and building capacity in post-conflict South Sudan
5. Sustainable water management in the Imatong mountains by AWF

Ecotourism

1. Ecotourism development in Kafa, Majang and Sheka biosphere reserves

Other

1. 230 kV transmission line from Gambella to Malakal
2. 500 kV transmission line from Dedesa to Tepi then Juba

Proposed development projects

Hydropower

10. Upper Akobo

Fisheries and aquaculture

5. Fisheries development in the Gilo river
6. Fisheries development in Alwero reservoir
7. Fisheries development in the Alwero river
8. Fisheries development in the Baro river
9. Fisheries development in the Badingilo floodplains
10. Fisheries development in the Mashar Marshes
11. Opportunity to develop aquaculture in the rice fields in Gambella region

Irrigation

39. Akobo (South-Sudan)

Watershed management

10. Watershed management potential in Meinit Goldiya and Meinit Shasha woredas
11. Livelihood-based watershed management - taking to scale for a basin wide impact
12. Potential watershed management projects in the woredas of Yubdo, Ayra, Guliso, Haru and Genji

Potable water supply/sanitation

4. Combined water supply and cattle watering for Kapoeta counties

Short term multipurpose project

1. Kinyeti river multipurpose project - multipurpose reservoir for hydropower, irrigation, potable water supply, fisheries, aquaculture
2. Majang multipurpose project - developement of hydropower, irrigation, aquaculture, watershed management
3. Akobo-Gambella flood plain transboundary project - solar pumping for potable water supply, vegetable gardening, aquculture development

Biodiversity/environment conservation

6. Machar marshes integrated water resources management plan
7. Boma Gambella transboundary national park - biodiversity conservation and ecotourism development

Navigation

1. Rehabilitation of the port infrastructure in Gambella along the Baro River to develop the traffic
2. Baro river: improvement of water regulation and dredging, to make river navigation in dry season possible
3. Sobat river: improvement of water regulation and dredging, to make river navigation in dry season possible
4. Regional transport and navigation development project

Ecotourism

2. Hiking in the Imatong mountains
3. Badingilo national park: bird watching, recreational fishing
4. Mashar marshes: bird watching, recreational fishing

Institutional

1. Establishment of the BAS basin authority
2. Water tariff structure: setting of tariffs and charges for use by Local Government Authorities and Service Providers, in accordance with South-Sudanese policies

Other

3. Borehole Supplies - South Sudan national programme to improve collection and monitoring of data on yields and water quality
4. Transboundary hydro-meteorological and environmental monitoroing system and environmental flows assessment
5. Integrated BAS Hydropower, irrigation and multipurpose development programme - phase 1: Baro/Sobat component
6. Flood-risk mapping and early-warning system

2.4 KEY ISSUES AND CHALLENGES

Understanding the status of the basin from a number of perspectives leads also to appreciate the relayed issues and challenges. The issues presented below are grouped into environmental, socio-economic and institutional issues. The issues of availability of water is also relevant but this can be considered as something that cuts across environmental, social and institutional areas. Similarly, "technical issues" can be seen as cross-cutting in nature and therefore not enumerated in the table below.

Table 2-1: Key issues and challenges identified

Bio-physical environment: Key issues identified	Socio-economic environment: key issues identified
• Stress on Wetlands • Loss of biodiversity • Unsustainable hunting of wildlife • Loss of natural forest • Soil erosion • Scattered settlements • Poor agriculture extension and poor credit facilities • Flood and drought • Lack of peace and security • Poor physical and social infrastructure • Climate change • Lack of knowledge	• Poverty and Food Insecurity • Low level of well-being • Lack of peace and security • Low level of provision of social services • Vulnerable groups • Gender inequality • Scattered settlements • Poor agriculture extension and poor credit facilities • Recurrence of various forms, intensity, duration and impacts of conflicts • Potential for influx of people • Risks • Flood and drought • Land security/land tenure issues • Basin population dynamics place heavy pressure on natural resources • Climate change
Institutional Aspects: key issues identified	
• Lack of inter-sector coordination and cooperation • Planning based on limited consultation • Inadequate water resources data/monitoring • Land security/land tenure issues	• Weak institutions, poor coordination and cooperation among existing institutions • Transboundary Cooperative framework • Security and instability • Lack of capacity/ experience in (MPP) project implementation • Capacity of local government institutions and Water Users

3. SUMMARY OF PUBLIC CONSULTATIONS AND THE OPINIONS EXPRESSED

3.1 INTRODUCTION

Stakeholder consultation and engagement plays a critical role in the SSEA process. It is therefore important to identify and engaged stakeholders with knowledge of the various water resources sectors but also of the overall environmental and social conditions and the potentially affected communities. As per AfDB guidelines, these stakeholders can be involved in various manner such as identification of options, baseline analysis and in selecting management options" (AfDB, 2014).

The following sections only present a summary of the process and methodology adopted to consult key stakeholders. The ideas, contributions or opinions expressed by the stakeholders will also be presented in this section as well as the extent to which they are incorporated into the SSEA and the design of the IWRDMPlan.

For more details such as number and identity of participants and minutes of meetings, please refer to the Communication and consultation plan of the study and to the Annexes of the scoping and baseline reports.

3.2 DESCRIPTION OF THE CONSULTATION PROCESS

TYPE OF CONSULTATIONS

Three main types of consultation have been conducted as part of this study:

- Stakeholder interview and meeting with a wider range as possible of stakeholders, from those to be only consulted to the highest degree of involvement (empower);
- Stakeholder engagement through working sessions at the all workshops of the study. For this category, only stakeholders identified with important degree of involvement have participated.
- Communication with stakeholders on key outputs of the study.

The categories of stakeholders identified, their proposed degree of involvement as planned in the Consultation plan and their effective participation to the two types of consultations is presented in the table below. The detailed list of stakeholders met during interview is presented in Annex of the Consultation and communication plan (standalone report).

Key study outputs (deliverables) circulated by the Client to various stakeholders are presented in the table below.

Table 3-1: Proposed degree of involvement for the different categories stakeholders

Stakeholders identified	Proposed degree of involvement	Stakeholders met during interviews	Stakeholders invited to workshops	Concerned by key outputs communication
Eastern Nile Technical Regional Office	Empower	X	X	X
Nile Basin Initiative	Empower	X	X	X
Nile Basin Discourse	Empower			
African Development Bank	Empower	X	X	X
Ministries directly linked to water (water, irrigation, fisheries, energy, etc.)	Collaborate	X	X	X
Private sector directly linked to water	Collaborate	X		
Intergovernmental Authority on Development (IGAD) in Eastern Africa	Engage	X		
NGO involved in the BAS	Engage	X		
Ministries not directly linked to water (environment, wildlife, tourism, forest, transport, health…)	Engage	X		
National agencies/bureaus/authorities/institutions directly linked to water	Engage	X		
National agencies/bureaus/authorities/institutions not directly linked to water	Engage	X		
Administrative level 1 (regions/states) bureaus/authorities/institutions directly linked to water	Engage	X		
Administrative level 1 (regions/states) bureaus/authorities/institutions not directly linked to water	Engage	X		
Administrative level 2 (woreda/district) bureaus/authorities/institutions directly linked to water	Engage	X		
Administrative level 2 (woreda/district) bureaus/authorities/institutions not directly linked to water	Engage	X		
Protected areas management units	Engage	X		
Programs management units	Engage	X		
Water direct users representatives	Consult (through representatives)	X		
Water indirect users representatives	Consult (through representatives)	X		

NB: Stakeholder identification and degree of involvement have been defined as part of the Stakeholders consultation and communication plan. However, while the latter plan has recommended to invite to workshops stakeholders involved with environmental and social aspects, this recommendation has not been taken into account so far.

Table 3-2: Key study outputs and communication with stakeholders

Deliverable / Main Activity		Timeline	
ID	**Deliverable / Main Activity /**	**Date of issue**	**Date of workshop**
D1	Inception report	July 2015 (draft)	***WS #1*** Workshop completed 10-12 August 2016
		February 2016 (final)	
D2a	Preliminary Consultation and Communication Plan (Draft report)	January 2016	***WS #3*** Workshop completed 16 – 18 April 2016
D2b	Final Draft Consultation and Communication Plan	January 2016	
D3	Scoping Report	January 2016 (final)	***WS #2*** Workshop completed 24-25 November 2016
D4a & 4b	Baseline, Key Issues and Objectives Report- Draft	25 March 2016 (draft)	***WS #3*** Workshop completed 16 – 18 April 2016
		October 2016 (final)	
D4c	Development Potentials Report - Draft	25 March 2016 (draft)	***WS #3*** Workshop completed 16 – 18 April 2016
D5	SSEA Analytical framework	22 March 2016 (draft)	***WS #3*** Workshop completed 16 – 18 April 2016
		22 Jun 2016 (final)	
	SSEA – First draft Report	3 August 2016 (draft)	***WS #4*** Workshop completed 22 – 23 August 2016
		October 2016 (final)	
	SSEA- Second Draft Report (complete)	November 2016 (draft)	***WS #5*** Workshop completed 12- 13 January 2017
	SSEA – Final Draft Report	April 2017	**WS #6** Workshop completed 30 April to 2 May 2017

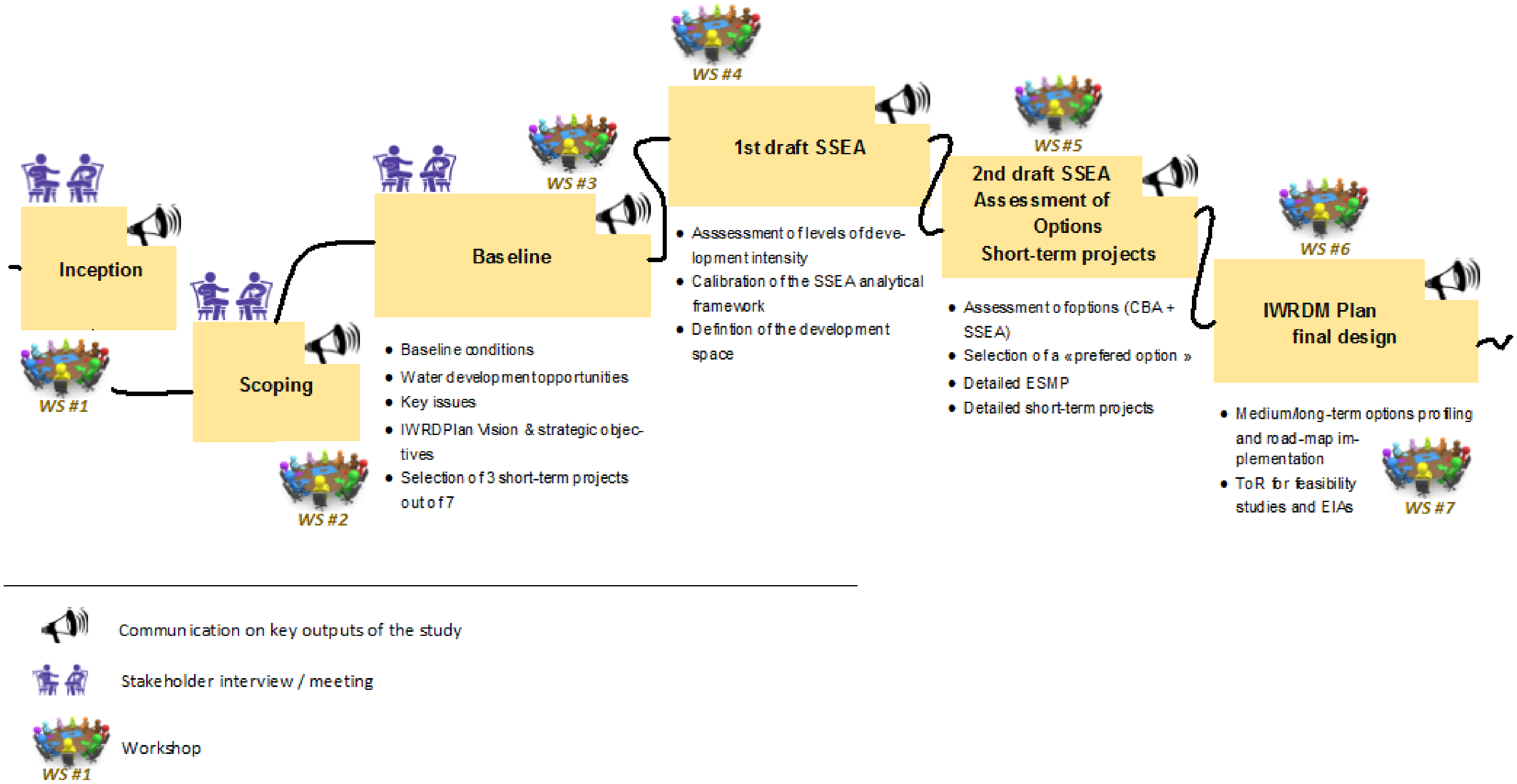
Deliverable / Main Activity		Timeline	
ID	**Deliverable / Main Activity /**	**Date of issue**	**Date of workshop**
D7	Assessment of Options – (Development Space) Modelling Annex to 1st draft SSEA	3 August 2016 (draft)	***WS #4*** Workshop completed 22 – 23 August 2016
		October 2016 (final)	
	Assessment of Options (part of second draft SSEA	November 2016 (draft)	***WS #5*** Workshop completed 12- 13 January 2017
D6	Short-term option – Concept Note	22 March (draft)	***WS #4*** Workshop completed 22 – 23 August 2016
		3 August 2016 (final)	
	Project Presentation	November 2016 (draft)	***WS #5*** Workshop completed 22 – 23 August 2016
	Final Output	April 2017	***WS #6*** Workshop completed 30 April to 2 May 2017
D8	IWRDMPlan – Draft Report; (incl. Institutional framework and M a	November 2016	***WS #5*** Workshop completed 22 – 23 August 2016
	IWRDMPlan – Final Draft	April 2017	***WS #6*** Workshop completed 30 April to 2 May 2017
D9	Medium/long-term options, Identification and profiling	April 2017	***WS #6*** Workshop completed 30 April to 2 May 2017
	Medium/long-term options, Implementation Road map; ToR for feasibility studies and EIAs	May 2017	***WS #7*** Workshop completed 22-23 May 2017 **Round table with Donors** completed 25 May 2017
	Medium/long-term options, Formalisation of outputs		
D10	Draft Final Report for study as a whole	May 2017	***WS #7*** Workshop completed 22-23 May 2017 **Round table with Donors** completed 25 May 2017
D11	Final Study Reports	May 2017	

ARTICULATION OF THE STAKEHOLDERS CONSULTATION PROCESS AND THE STEPS OF THE STUDY

Stakeholders have been consulted and involved at each of the key steps of the study.

The method of consultation used at each step of the study is presented in the figure below.

Figure 3-1: Stakeholder consultation at key steps of the study



3.3 CONSULTATIONS CONTRIBUTIONS TO THE SSEA / IWRDMPLAN

The following table presents stakeholders contributions to the SSEA / IWRDMPlan at each key step of the consultation process. At this stage, workshops 5, 6 and 7 have not taken place. This table will therefore be further completed as part of the final draft SSEA report. For further details, please refer to the minutes of meetings and to the outputs of group working sessions presented in the Consultation and communication plan (standalone report).

Table 3-3: Consultations contributions to the SSEA / IWRDMPlan

Consultation process	Opinions expressed / Contribution to the SSEA / IWRDMPlan
Inception stakeholders interviews	Identification of baseline conditions, existing projects / initiatives, water development opportunities, key issues and challenges
Scoping stakeholders interviews	
Baseline stakeholders interviews	
Workshop 1: Inception	Group sessions to identify issues, challenges and development opportunities. Discussion about overall methodology of the study.
Workshop 2: Scoping	Contributions to consultation and communication plan, thematic areas to be covered in the baseline, methods to collect data.
Workshop 3: Baseline / short-term project concept note	Group sessions to identify the BAS vision and strategic objectives. Contributions to the SSEA analytical framework.
Workshop 4: Calibrating SSEA analytical framework / delimitation of the development space / details on short-term projects	Group sessions to improve and enrich the SSEA analytical framework and to work on the main conclusions provided by the investigations of the levels of development intensities.
Workshop 5: Assessment of options	Group sessions to enrich the presentation of the comparison of alternatives and to discuss and reach consensus on a preferred option for the IWRMDPlan.
Workshop 6: Final report workshop including Final SSEA, short, medium and long-term projects	Workshop has not been hold yet.
Workshop 7: /Donor Round Table	Workshop has not been hold yet.

4. DESCRIPTION AND JUSTIFICATION OF THE PROPOSED IWRDMPLAN

4.1 INTRODUCTION

This chapter briefly describes the strategic framework of the IWRDMPlan and its justification in terms of the issues to be addressed. It aims only at providing an overview of the plan since a specific report is entirely dedicated to the IWRDMPlan.

4.2 FORMULATING THE IWRDMPLAN

4.2.1.1 The general process

The point of departure for formulation of the Plan is understanding the issues and water-related challenges of the sub-basin. The vision of how the sub-basin should look in the future is based on resolving these issues and facing the challenges. It also takes into account how the potentials of the sub-basin provides opportunities for resolving these issues. Achieving the vision rests on a number of strategic objectives. These are the objectives which have to be realised in order for the vision to become reality. Agreement on the vision and strategic objectives is an important milestone for the SSEA which depends heavily on stakeholder’s expectations for the sub-basin.

The Vision and strategic objectives define what is desired in the future but do not indicate how this future is going to be achieved. Clearly, making progress towards this future requires action. The plan has to provide the details of this actions. This is done through the formulation of strategic level actions and then specific actions with associated timelines. Detailing of the specific actions depends on the findings of the SSEA since the IWRDMPlan is going to be built around a “preferred” water resources development and management option or pathway and this is an output of the SSEA process.

4.2.1.2 The IWRDMPlan Strategic Framework and the SSEA

The vision and strategic objectives provide a framework for development of the SSEA and in particular the SSEA analytical framework as it is applied in the examination of water resources development and management scenarios.

The dimensions of the SSEA analytical framework relate strongly to:

- Key issues and opportunities;
- the proposed vision and strategic objectives and the Sustainable Development Goals);
- the type of effects which are expected with the implementation of the IWRDMPlan and the main elements of the physical, biological, cultural or human environment which are likely to be affected by the IWRDMPlan.

CONTRIBUTION OF THE VISION TO THE SSEA ANALYTICAL FRAMEWORK

One of the main idea of the proposed vision concerns **sustainability**.

The concept of sustainability is also at the heart of the SSEA since it addresses the 3 pillars of the sustainable development concept: "The selected alternative shall be the optimal alternative in terms of environmentally and socially sustainability, taking into account the technical and economic feasibility of the proposed programme, policy or plan" (AfDB, 2015).

The most commonly used definition[25] of sustainable development is the following:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
>
> - The concept of **needs**, in particular the essential needs of the world's poor, to which overriding priority should be given; and
> - The idea of **limitations** imposed by the state of technology and social organization on the environment's ability to meet present and future needs." (IISD, 2016)

The various needs that should be satisfied (at least partly) through the development of water resources in the BAS through the IWRDP, have been assessed during the baseline phase of the study.

Ultimately, the purpose of the SSEA is therefore to recommend a development option or pathway that addresses the needs identified while ensuring that the "developed environment" is still able to meet these needs, where:

- Meeting these needs implies the **development of technologies and infrastructure enabling people to better benefit from natural resources**, especially water resources (such as multipurpose projects enabling energy generation, water storage for irrigation and drinking water supply, flood reduction, …). This is mainly captured by the SSEA analytical framework within the **dimension "socio-economic development"**, which helps analysing how far the option meets the needs in terms of :
  - Food security,
  - Employment,
  - Energy security,
  - Health,
  - Access to water, and
  - Flood reduction.
- Meeting these needs also implies ensuring that the environment, the **"developed' natural resources will still be able to support the needs**, in other words, that the **ecosystem services will still be functional** and not negatively affected by the water development which originally aimed at optimizing them. This is why the SSEA analytical framework investigates the **main changes that development projects, due to their characteristics, can have (positively and/or negatively) on the environment**. These changes are categorized as follows and form the following dimensions:
  - Changes to riverine ecosystem services. Since the way of life of people in the BAS Sub-basin (especially the downstream part and downstream of the BAS) is strongly supported by these services (fisheries, water supply, recession agriculture, cattle watering and feeding, construction materials), their conservation contributes to meeting these needs. Geomorphological changes can also impact on riverine ecosystem services. Free aquatic life and sediment circulation in the river systems enables effective riverine ecosystem services benefiting the BAS inhabitants and downstream

[25] This definition was developed by the Brundtland Commission in the document "Our Common Future", which explicitly popularized and contextualized the concept of Sustainable Development.

- Loss of natural / existing ecosystem through land use conversion of project (infrastructure) footprint. For instance, the BAS inhabitants benefit (or have the potential to do so) from eco-tourism opportunities and natural resources sustainably managed by protected areas, or from flow regulation, erosion control, woody and non woody products provided by upstream forests. Ensuring that development projects do not harm these ecosystems is a way of ensuring the provision of their services and contributes to meeting the needs identified.
- Change in water quality. Provision of clean drinking water is one of the important need identified in the basin. The most sustainable way of supplying clean drinking water is to ensure water quality is preserved. Ecosystems and the services that they provide, also depend on the maintenance of good water quality.
- Changes to GHG emissions. While the development projects aim at reducing people vulnerability to climate change, containing GHG emissions indirectly and partly contributes to tackle the problem at its root cause. “Controlling greenhouse gases (GHG) emissions and increasing human, environmental and ecosystem resilience are fundamental for future growth and for delivering on the sustainable development goals (SDGs)” (United Nations Sustainable Development Summit 2015, 2015)
- Transboundary cooperation. Implicit in the concept of IWRM is management at the level of the catchment. With respect to transboundary cooperation, this means that both countries need to be cooperatively involved in both management and development to ensure that benefits are shared and negative impacts avoided. Development can support transboundary cooperation in a number of ways including contributing to national and regional economic development and growth.

CONTRIBUTION OF THE STRATEGIC OBJECTIVES TO THE SSEA ANALYTICAL FRAMEWORK

By definition, the strategic objectives are inherently based on the needs to be met and the key issues to be addressed.

As presented above, the SSEA analytical framework has been built as a tool to ensure the needs identified can be met over time and over the different sub-basin of the BAS.

4.3 DESCRIPTION/CHARACTERISTICS OF THE PROPOSED PLAN

4.3.1 Generic content of the IWRDMPlan

The Plan aims to set out the actions that are required to move towards an agreed vision of the basin. However, it is important to note that the plan has a timeframe of 25 years but that the Vision represents something a bit further into the future, perhaps 40 or 50 years. Indeed, the economic analysis of the different options has been based on a 40 year timeline. The Plan includes the following key elements:

- A Vision and associated strategic objectives. The vision represents the desired future state for the basin to be achieved (at least in a large part) by implementation of the Plan
- Strategic actions. These are the strategic level actions that will have to be carried out to realise each strategic objective. They may be direct, infrastructure-orientated actions or actions that are aimed at supporting or providing an enabling environment.
- Specific actions. As their name suggests, these actions are specific in nature. Direct infrastructure type specific actions will include the implementation of specific infrastructure projects such as large dams and associated multipurpose projects (hydropower, irrigation, water supply etc.). Clearly the choice of which projects and when (prioritising) depends to a large extent on the SSEA and options analysis.

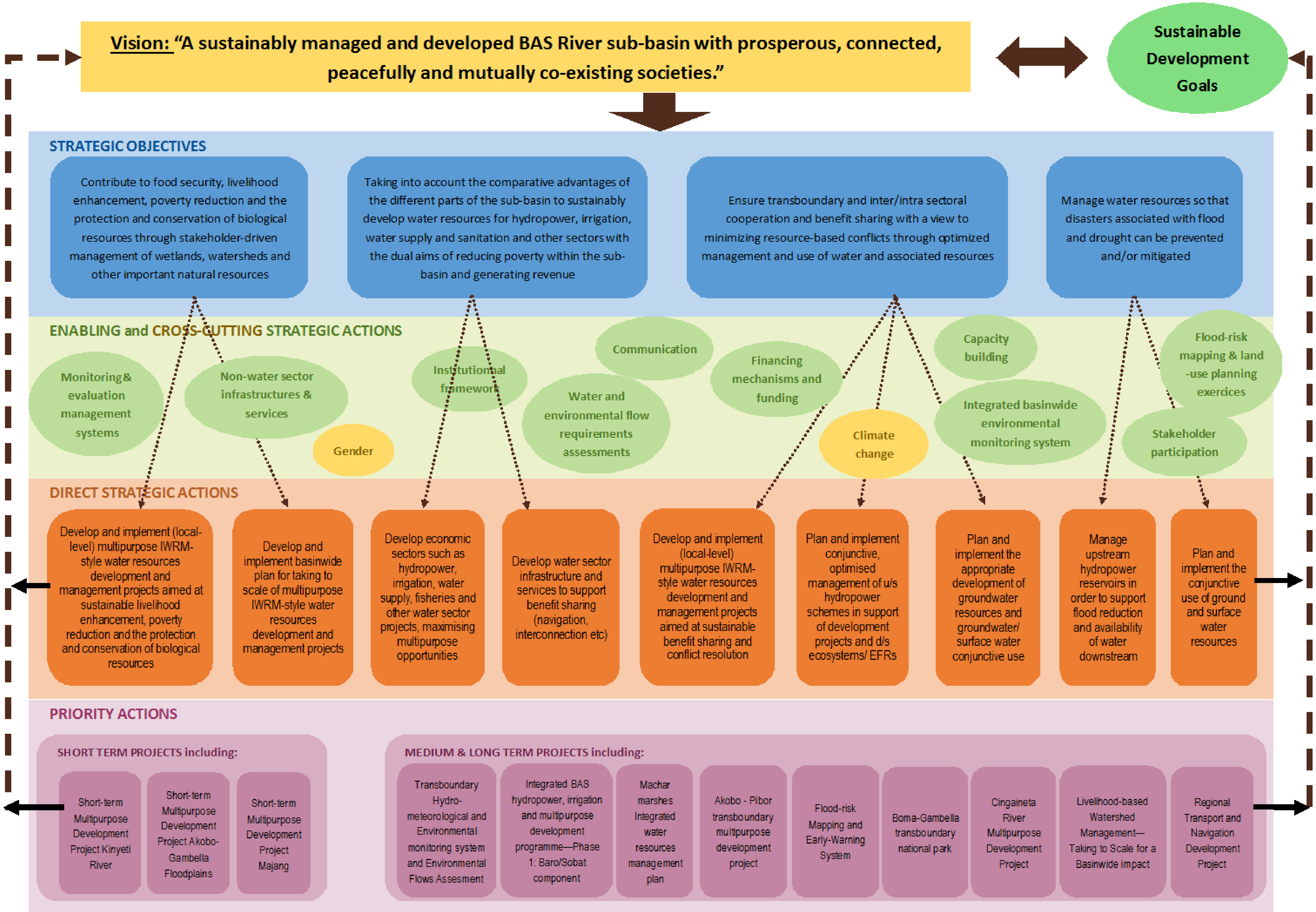
  However, specific actions also include the specific actions that are required to support the implementation of direct actions. These could include, for example, actions relating to capacity and institutional aspects.
- Implementation strategy and plan. The Plan includes both a strategy for implementation and a plan with a timeline. Much of the strategy relates to the findings of the SSEA.
- Institutional framework. The Plan requires a suitable institutional framework at all levels. For this Plan, which has a high level, transboundary focus, the high level institutional framework is of particular interest.
- Monitoring and evaluation and adaptive management. A key component of the Plan is its monitoring and evaluation framework. The main purpose of this framework is to ensure that implementation of the Plan is leading to the desired outcome and ultimately the future vision of the basin.

4.3.2 Overview of the IWRDMPlan

The strategic framework of the IWRDMPlan and its main components are summarized in the figure next page. It shows some specific actions which will be implemented during the 1st phase of the Plan in order to illustrate the strategic framework with concrete examples. In this figure, these actions are thus called “priority actions”. To get a comprehensive overview of the Plan which includes all projects and actions, please refer to the report specifically dedicated to it.

NB: Medium and long-term projects have not been selected by the stakeholders yet. The schematic will be thus finalized after the coming workshop.

Figure 4-1: Overview of the IWRDMPlan



5. PRESENTATION OF THE SSEA ANALYTICAL FRAMEWORK

5.1 INTRODUCTION

THE SSEA ANALYTICAL FRAMEWORK: A CENTRAL TOOL OF THE SSEA

The SSEA analytical framework is the tool used for the multi-dimensional analysis conducted in the SSEA.

It consists of key environmental and social criteria, called dimensions and sub-dimensions, which have been defined and weighted as part of the framework's elaboration. For each criteria, a threshold have been defined, which represents the limit of the sustainable development space. For each option, these criteria are quantified and valued (when possible) via indicators, resulting in the option comparison and impact assessment. For each criteria, margin of errors have been applied to reflect the uncertainties of the assessment.

The resulting tool is presented in Table 5-1 in Section 5.3.

A MULTI-DIMENSIONAL ANALYSIS: INTEGRATIVE AND CUMULATIVE BY NATURE

The sustainable development space is considered as multidimensional, the dimensions representing the key socio-economic and environmental issues that need to be assessed when investigating the overall sustainability of the proposed development programme from a social and environmental perspective.

The dimensions include:

- Socio-economic development;
- Change in riverine ecosystem services;
- Loss of natural/ existing ecosystem through land use conversion of project (infrastructure) footprints;
- Contribution to transboundary cooperation;
- Change in water quality;
- Change in GHG emissions.

Cumulative impacts are at the core of the analysis. The proposed assessment is thus cumulative by nature:

- The SSEA does not look at single project but assess the overall impacts of a combination of projects (various options for the IWRDMPlan). It mainly shows that the effect of certain option might be higher than the sum of each individual project. It also allows the examination of transboundary effects, something which is rarely done at the project scale.
- The SSEA analytical framework is multi-dimensional and looks at the cumulative impacts of the dimensions. The cumulative character of the analysis is especially evident for health, food security, riverine ecosystems, impacts on vulnerable populations and conflicts.
- The Cost Benefit Analysis (CBA) is integrative and cumulative by nature, since it converts most of the risks and benefits identified as part of the SSEA into a single economic indicator.

DEFINING THE BOUNDARIES OF THE MULTI-DIMENSIONAL ENVELOP: AN ITERATIVE PROCESS

The thresholds, which must be set for each dimension (or sub-dimension) reflect the estimated limits beyond which the sustainability is threatened and therefore delimit the sustainable development space. They are presented in Table 5-1 in Section 5.3.

Before being used as part of the analysis of development options (scenarios) presented in this report in Section 7, it was used to investigate different levels of development intensity (Step 2 of SSEA) with the **aim of defining the available space for sustainable development**, that is to say **defining the thresholds**. As part of that Step 2 of the SSEA, the SSEA analytical framework has been thus developed, tested and fine-tuned. To do so, it has been applied to contrasting levels of development intensities in order to understand how the system reacts, to calibrate the SSEA analytical framework and to define the development space.

5.2 LEVEL OF INTENSITIES INVESTIGATED

The aim of the first steps of the SSEA (as covered in the first draft SSEA report) was to define the limits of the development space. It implied understanding how the system reacts to various levels of development intensity. Different levels of development intensity have been used to test contrasting situations of development to assess their related environmental and social potential threats and highlight the limits. They were designed to understand the respective effects of irrigation development, irrigation storage, hydropower and irrigation and hydropower combined together.

NB: It is important to keep in mind that the different levels of intensity investigated do not reflect potential future options/alternatives for the IWRDMPlan but shall reflect extremes situations of development to be tested to define the limits of the development space.

In order to calibrate the assessment, one reference situation was defined:

- **Level 0 (current): Baseline / Reference** situation. This level of development intensity represents the current situation in which the large-scale development of water resources is minimal. As indicated in the Baseline Report, the current situation is one in which the environment remains relatively pristine in much of the basin but where poverty, food insecurity and conflict dominate.

The following five levels reflected the main contrasting situations to be investigated:

- **Level 1 (+ 25 years): Business as Usual**. This can also be seen as the “do nothing” situation in which today’s trends continue at the historically observed rates (including the historical acceleration of these rates). This means that water resources are developed at a slow rate and the utilization and encroachment of natural resources continues in a way that is neither managed nor suddenly altered by large developments. It also assumes that Governments do little or nothing to react even if impacts become severe.
- **Level 2 (+25 years):** Maximizing consumptive demand
  - **Level 2A: Without water resources development infrastructure**. This level of intensity is represented by the full development of irrigation but without any reservoirs constructed to provide storage. This is the sort of situation which could develop if irrigation development takes place on an unplanned basis with each scheme planned on the assumption that there is sufficient water in the river that they depend on.
  - **Level 2B: With water resources development infrastructure**. This level of intensity is represented by the full development of irrigation accompanied by reservoirs constructed to provide storage. It therefore assumes a certain degree of management, but an approach that is perhaps unisectoral/narrow and which does not take into account upstream/downstream linkages (OR and which is based on national interests)
- **Level 3 (+25 years): Maximizing both consumptive demand and hydropower generation.** This level of intensity is aimed at investigating the limits of the system in terms of the available

water resources and the environment. What happens is the two sectors which are the most dependent on water are fully developed.

- **Level 4 (+25 years): Full hydropower generation,** but no large-scale irrigation development. This level of intensity is aimed at investigating the impacts of development driven by a heavy emphasis on large-scale hydropower impact and therefore a low level of consumption and a very high degree of regulation.

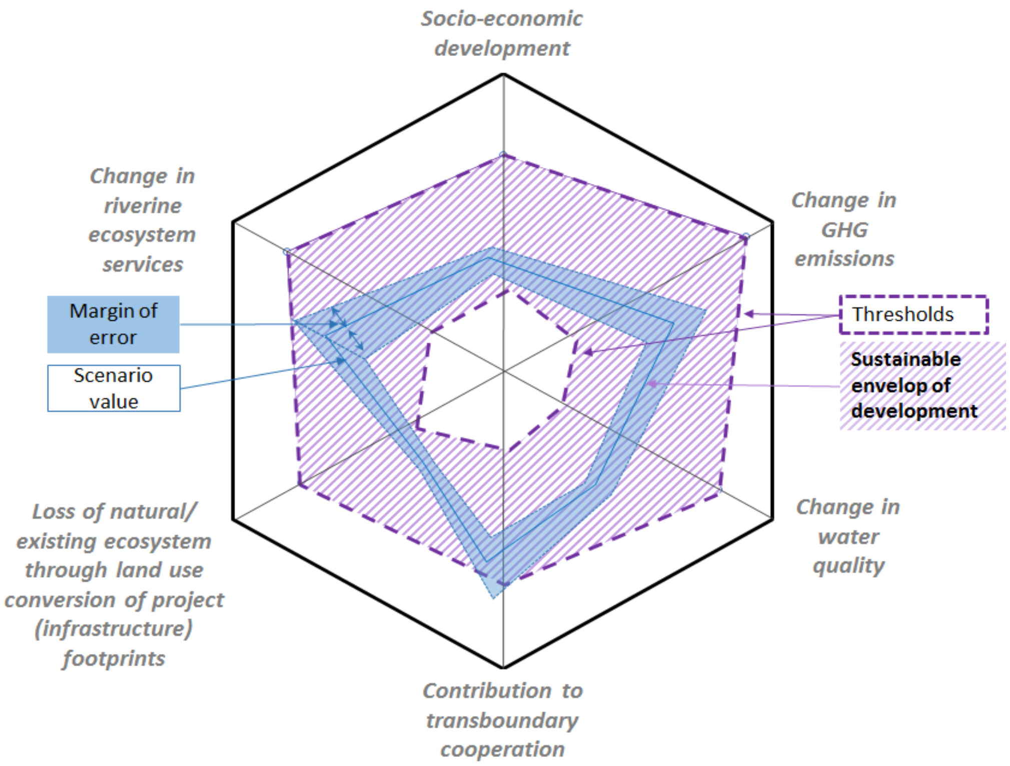
5.3 THE CALIBRATED SSEA ANALYTICAL FRAMEWORK

The application of the SSEA analytical framework to the levels of development intensities allowed a better understanding of the potential effects of water developments and testing of the tool. The analysis and its presentation to the stakeholders at the SSEA workshop in Adama (22-23 August 2016) indeed led to improvements of the SSEA analytical framework, which is effectively now a calibrated version taking into account:

- The relative importance of the dimension (weighting);
- The level of confidence in assessing the threshold, leading to a relaxation of the development space in some cases (see explanation below);
- The level of confidence in assessing the impacts / in quantifying the indicator (see explanation below);
- The opportunities for enhancement and mitigation.

The figure below illustrates the related concept.

Figure 5-1: The concept of the calibrated SSEA analytical framework



Given the poor availability of accurate and consistent (in terms of spatial and temporal coverage) socio-economic, environmental and hydrological data in the basin, the Consultant has had to make several assumptions to conduct the required analysis within each dimension. Where necessary, the data limitations and the related assumptions have been presented in the concerned sections of the report. For more readability, they are summarized in a dedicated annex (Annex 4: data limitation and level of confidence in assessing the threshold and in quantifying the indicator).

It is of critical importance to appreciate the significance of **data limitations and accuracy**. Conclusions must be made in full consideration of these limitations and acknowledging the fact that recommendations must include the appropriate margins. This is particularly true when it comes to recommendations on thresholds and to quantification of indicators. Where the development of a dimension and its sub-dimensions has been based on data with potentially significant margins of error, it is important that these **margins of error are reflected in the "width" of the threshold and in the quantification of indicator.** Essentially this means that the threshold, or tipping point, and indicators will not be a single value but rather a range of values. The result is that development would not be restricted on the basis of questionable conclusions. These aspects are further detailed in the Annex 4. At the same time the **identification of data limitations and their impact on the quality of the analysis provides clear direction on priorities for improving data collection programmes in the future**.

The calibrated SSEA analytical framework and relaxed development space are presented in the scoreboard below.

Table 5-1: Calibrated SSEA analytical framework

Dimension	Sub-dimension	Nature of the change	Associated potential social benefits or risks	Associated potential environmental benefits or risks	Indicator used for the assessment	Margin of error to be applied to the quantification of indicator	Thresholds		Opportunities for enhancement and mitigation				
							Calculated / available	Proposed limit (taking into level of confidence of the threshold / necessary leeway)	Enhance-ment	Avoid-ance	Minimiz-ation	Restor-ation	Offset
Socio-economic development	Food security	• Increased agricultural land • Change in water available downstream for food production	• Increased food production in the basin leading to an increase of food available for the BAS population and at national and regional scales • Increased opportunities for aquaculture and fisheries in reservoirs, • Potential reduction of fish productivity in rivers and wetlands, yields of recession agriculture and livestock population relying on downstream rivers and wetlands. • Potential improvement in availability of water for livestock watering	• Change in pressure on natural resources	• Level of food self-sufficiency	15 %	100%						
	Employment	• Creation of employment opportunities	• Creation of direct and indirect job opportunities around infrastructure (electricity, irrigation schemes). This includes opportunities associated with development of urban poles and improved transport infrastructure		• Number of jobs created by irrigation schemes and dams		300,000						
	Energy security	• Increased electricity production	• Increased access to electricity and related positive effects on the development of all other sectors. Social benefits related to time saved on collection of wood or charcoal	• Reduction of pressure on natural ecosystems such as forests and bushes	• Population of the basin connected to national grid		70%						
	Access to water	• Increased storage capacity • Change in downstream water availability	• Increased quantity of water stored and therefore available all year round for various water uses opportunities at dam locations: drinking water, irrigation, aquaculture and fisheries development, water-related tourism; • Change in water availability downstream reservoirs and related consequences on downstream users • Increased adaptation to climate change (reduction of vulnerability due to climate change)		• Population of the basin with access to improved water sources		80%						
	Health	• Change in repartition of stagnant water in the basin; • Change in access to water	• Increased artificial stagnant water due to construction of reservoirs and irrigation schemes; • Decreased natural stagnant water due to reduction of wetland surface area. • Change in access to improved drinking water sources • Improved availability of health services, access to clean water etc.	No indicator	• qualitative	Not applicable							
	Flood reduction	• Increased storage capacity and flood control	• Increased safety, reduced loss of life and property • Increased adaptation to climate change (reduction of vulnerability due to climate change)	• Reduction of spills to wetlands	• Qualitative at this stage	Not applicable							

Dimension	Sub-dimension	Nature of the change	Associated potential social benefits or risks	Associated potential environmental benefits or risks	Indicator used for the assessment	Margin of error to be applied to the quantification of indicator	Thresholds		Opportunities for enhancement and mitigation				
							Calculated / available	Proposed limit (taking into level of confidence of the threshold / necessary leeway)	Enhance-ment	Avoid-ance	Minimiz-ation	Restor-ation	Offset
Change in riverine ecosystem services	Changes to hydrological regimes affecting aquatic extensions / wetlands	• Increased water abstractions, resulting in lower water availability downstream in the river system and its aquatic extensions (wetlands), • Modification of the flow temporal distribution due to upstream storage, mainly leading to flood reduction, reduction of spills to aquatic extensions and river morphology dynamics, but also possible increased low flows and increased flow variability at a daily scale due to dam releases.	• Change of quality and yield of forage, as important grazing for nomadic herds and wildlife during the dry season: previously productive perennial grasslands might be replaced by annual-grass dominated stands, limiting regrowth in the dry season and reducing the carrying capacity for wildlife and livestock; • Change of migration routes, due to change in water and food availability; • Increasing conflicts due to change in forage resources quality and distribution; • Change of water available for water supply during the dry season for communities, livestock and wildlife watering; • Change of recession agriculture areas; • Change of availability of riparian plants used for material or for food; • Change in fish productivity.	• Change of habitat for species / modification of species distribution, with risks of reduction or extinction of species population; • Modification of natural functionalities of wetlands, with potential biodiversity losses; • Change in relative cover of existing plant communities, resulting in a different vegetation patterns.	• Average annual maximum surface area; • Average annual minimum surface area; • Average annual surface area amplitude	20%	Specific to each wetland	Same as calculated					
	Changes to hydrological regime affecting instream flow / the river system itself				• Number of navigable months for an average year • Number of months under the 1/10 daily ranked flow (=duration of the severe low flows period) • Average mean monthly flow from December to May • Mean annual daily flow of the White Nile at Malakal • Mean amplitude between the wettest month and the driest month of a year	20%	Specific to each river nodes	Same as calculated					
	Geomorphological changes	• Change in cross section can appear directly downstream of dams. Because the water released from dams has poor sediment loads, it can lead to bank erosion and river bed incision. According to (Brandt S. Anders, 2000), most of the rivers reached half of their total depth change within 7 years. On the contrary, dam emptying releases extremely high sediment loads, which are likely to conduct to river siltation. • Change in longitudinal section can also appear downstream of dams. The main potential patterns that can be affected are: the capacity to meander due to flood abatement, the loss of large sediments circulation and fish circulation between upstream and downstream reaches. • Change in river facies can happen upstream and downstream of dams. These changes are mainly due to the reduction of the flow velocity and the lack of large sediment.	• Modification of navigable reaches; • Change vulnerability to floods because of modification of the flood line and loss of connection to natural expanding flood areas; • Change of groundwater recharge, groundwater table deepening and related reduction of groundwater availability; • A decrease of water oxygenation causing a decrease of water quality for the water uses (addressed as part of the dimension "Change in water quality");	• Loss of fish habitats, breeding grounds and fish diversity; • Loss of riparian vegetation due to bed and water table deepening; • Loss of connectivity with aquatic extensions due to bed deepening; • Loss of fish circulation.	• Controlled watershed surface area by the combination of dams compared to the overall watershed surface area	0%	30%	40%					

Dimension	Sub-dimension	Nature of the change	Associated potential social benefits or risks	Associated potential environmental benefits or risks	Indicator used for the assessment	Margin of error to be applied to the quantification of indicator	Thresholds		Opportunities for enhancement and mitigation				
							Calculated / available	Proposed limit (taking into level of confidence of the threshold / necessary leeway)	Enhance-ment	Avoid-ance	Minimiz-ation	Restor-ation	Offset
Loss of natural/ existing ecosystem through land use conversion of project (infrastructure) footprints	Loss of settlements	• Conversion from an existing ecosystem (natural or urban) into an irrigation scheme or a dam, in which previous uses of the land is not possible anymore	• Population resettlement and displacement • Increased population densities around new infrastructure with associated social benefits (improved accesses to services etc.) and risks • Loss of access to natural resources (for livestock grazing, non-wood and wood forest product harvesting, thatching, hunting…) people used to rely on (from the land converted into reservoirs or irrigation schemes), leading to search for other places with equivalent natural resources, economic displacement, potential conflicts and encroachment or overuse of other areas; • Loss or reduction of other services such erosion control, carbon sequestration, flood attenuation provided by the natural ecosystems will • Loss of nature-based tourism opportunities;	• Loss of accessibility for several wildlife species (except for birds), restraining their distribution area; • Loss of flora and fauna (especially fauna with no opportunity to escape) • Encroachment of protected areas; • Creation of barriers, cutting of migration corridors for wildlife and livestock and cut of circulation routes of local communities.	• Population affected by the project combination (population to be resettled) • Existing agricultural and grazing land converted	30%	Not applicable						
	Loss of natural ecosystems				• Surface area of protected areas within projects footprint • Surface area of forests and upstream wetlands within projects footprint • Surface area of wildlife migration corridors within projects footprint	15%	≤ 0 %						
						30%	≤ 1,6% of remaining BAS forests / mountain wetlands	Calculated +15%					
						30%	≤ 5% of dry season crucial areas	Calculated +15%					
Contribution to transboundary cooperation	Contribution to regional and national economic growth	• Development in the basin, especially of large-scale irrigation and hydropower should have benefits beyond the limits of the basin and can thus contribute to national and regional development • Development of navigation, potentially linking Ethiopia through to South Sudan and beyond could contribute to to national and regional development	• Hydropower development in the basin would feed into the national and regional grids and thus contribute significantly to national and regional economic development. • The development of commercial irrigation with commercially viable cash crops can contribute to the national economies	• The development of hydropower and an associated interconnection between (at least) Ethiopia and South Sudan can have a major impact on the reduction of deforestation and environmental degradation in both countries	• Change in revenue generated from hydropower • Change in revenue generated from large-scale irrigation	15%	To be calculated and applied in 2nd draft SSEA						
	Level of transboundary cooperation and management required	• Integrated development of the basins water resources taking into account upstream/downstream linkages will require and promote transboundary cooperation. Unilateral planning and development would have the opposite effect	• The effective transboundary planning, design and operation, as well as potentially the sharing of benefits could provide numerous social benefits associated with improved cooperation. Lack of transboundary cooperation is have the opposite effect and to exacerbate existing conflicts.	• The effective management of the environment, in particular important wetlands and floodplains and their associated ecosystem services is highly dependent on transboundary cooperation at the planning, design and operation and management stages.	• Degree of cross-border cooperation required in system operation	Not applicable							
	Impact on flows downstream of Sobat/White Nile confluence	• The magnitude of change to flows entering the White Nile can be considered as a factor contributing positively or negatively to transboundary cooperation at the regional Eastern Nile level	• A major decrease in the contribution of the Sobat River could have negative socio-economic consequences downstream. Similarly a small decrease or an increase could be considered as a positive impact. • A change in the minimum flow in the White Nile as a result of reduced or increased contribution from the Sobat could have negative or positive impact on navigation and those who depend on it.	• In view of the contribution of the White Nile, these are unlikely to be significant unless the contribution of the Sobat is drastically reduced.	• Change in MAR entering White Nile • Change in average minimum flow in White Nile d/s of Sobat confluence	10%	Median Values	10%					

Dimension	Sub-dimension	Nature of the change	Associated potential social benefits or risks	Associated potential environmental benefits or risks	Indicator used for the assessment	Margin of error to be applied to the quantification of indicator	Thresholds		Opportunities for enhancement and mitigation				
							Calculated / available	Proposed limit (taking into level of confidence of the threshold / necessary leeway)	Enhance-ment	Avoid-ance	Minimiz-ation	Restor-ation	Offset
Change in water quality		• Change in agricultural practices. Large scale irrigation is planned throughout the basin, especially in the Ethiopian part of the sub-basin and will be likely followed by an increased use of fertilizers and pesticides; • Change in deforestation patterns due to project footprint and to changes in access to electricity; • Change in storage / retention time due to construction of dams and modification of natural flows and associated risks of eutrophication; • Change in capacity of auto-epuration.	• Increased need for water treatment / decrease quality of drinking water • Modification of fish production; • Proliferation of invasive aquatic plants and related effects on navigation, pumping systems, canals, fish productivity, …	• Decrease of existing aquatic fauna diversity.	• [N] loads in rivers, reservoirs and wetlands	20%	1 mg/L	50 mg/L					
					• [P] loads in rivers, reservoirs and wetlands	20%	1 mg/L	Around 1 mg/L (no restriction – guide value only)					
Change in GHG emissions		• Changes in emissions due to flooding of reservoirs, • Changes in emissions due to land clearing and burning for the development of irrigation, • Changes in emissions due to deforestation, • Changes in emissions due to N2O release in agriculture, • Changes in emissions due to change of wetlands areas.	• Increased emissions from the basin; • Avoidance of higher emissions from other energy production technologies; • Increased extreme climatic / hydrological events.	• Potential reduction in emissions resulting from deforestation for fuelwood and charcoal	• Co2 eq emitted due to water developments	60%	5 MT/year by 2020 for the Ethiopian part of the basin	5 MT/year by 2060 for the Ethiopian part of the basin					

6. PRESENTATION OF THE ALTERNATIVES CONSIDERED

6.1 INTRODUCTION

The purpose of this chapter is to describe the identified proposed IWRDMPlan development options or alternatives which have been evaluated and compared as part of the SSEA and economic and financial analyses.

The identification of alternatives is a core element of the SSEA because it forms the basis of the assessment.

According to the AfDB guidelines, "the nature and range of the relevant options will naturally be determined by the specific PBO in question. Options may consist of any of the following:

- Alternative policy reform objectives and instruments.
- Alternative budget objectives and allocation criteria.
- Alternative sectoral strategies, objectives or delivery modes.
- Alternative scenarios for patterns of downstream investments.
- Alternatives target geographical areas.
- Alternative technologies or processes." (AfDB, 2014)

Because the IWRDMPlan focuses on water infrastructure development, the nature of the identified alternatives is specific to this study. They should be consistent with the objectives identified for the BAS as part of the baseline phase, which are themselves consistent with the NBI policies and the SDGs.

The overall goal of the BAS project is to foster a sustainable socio-econonic development, and especially (but not exclusively) develop the production of energy and enhance food security through the river basin development.

As such, starting from first pinciples (is the development of water resources the most appropriate basic strategy?) it is useful first to screen alternative sectoral strategies (alternative energy-generation technologies and alternative means to increase agricultural production) to broadly :

- assess the added-value of water development in reaching these objectives;
- stress the need to consider more comprehensive leverage actions than water infrastructures exclusively;
- stress the need of articulation with other existing sectoral strategies.

Once these strategic considerations have been discussed, alternatives can focuss on various options for the IWRMDPlan itself, in order to identify an optimal alternative, which best addressed the water-related issues of the BAS while being environmentally, socially and economically acceptable.

This is why the core of the analysis examine first various degrees/intensities (levels of intensities) and then realistic options of water development in the basin (scenarios). They are formed by a certain combination of development projects that have been identified within previous studies and summarized as part of the baseline phase (see section 2.3 Water development opportunities).

6.2 ALTERNATIVES IDENTIFICATION: AN ITERATIVE AND PARTICIPATORY PROCESS

As explained above, the identification of alternatives has been conducted step by step:

- First, alternative sectoral strategies (alternative energy generation technologies and alternative means to increase agricultural production) have been analyzed;
- Secondly, since water development has been identified as the most interesting alternative, various **level of intensities of water development** have been investigated because there is a wide range of water of development opportunities in the BAS. These investigations have made it possible to understand the respective effects of irrigation development, irrigation storage, hydropower and irrigation and hydropower combined together. As such, they allowed putting in place the calibrated SSEA analytical framework and defining the sustainable development space. It has also guided the identification of the scenarios to be further analyzed (see below);
- Thirdly, specific combinations of projects (**scenarios**) have been analyzed in order to investigate the benefits associated with major enhancement and mitigation opportunities.

ALTERNATIVE ENERGY-GENERATION TECHNOLOGIES AND ALTERNATIVE MEANS TO INCREASE AGRICULTURAL PRODUCTION

Alternative energy-generation technologies

This section briefly analyses the spectrum of alternative energy generation technologies from various energy sources and their potential in BAS basin. This is an important step to justify the water resources development approach that has been adopted in addressing key development challenges, especially energy and food security.

- ***From coal, gas and other hydrocarbons:*** power production from fossil energies is not considered as an option in the *Ethiopian Climate-Resilient Green Economy Strategy* for energy production. Since this multi-purpose project aims at promoting regional integration and regional development, and to comply with national and regional priorities, this alternative has been disregarded.
- From hydropower: the BAS basin is considered to have a significant and untapped hydropower potential. In addition, hydropower development, as well as non-hydro renewable energies listed below, is considered as very consistent with regional and national strategies towards the development of climate-resilient and sustainable energy production policies.
- ***From wind energy:*** it shall be noted that the mean annual wind speed or power density at 50m or 80m height in the BAS basin is relatively low (around 3 m/s) compared to other region where large-scale wind farms are implemented (Northern Ethiopia for instance enjoys 6 m/s or more). Therefore developing wind farms in the area is not considered worthwhile.
- ***From geothermal energy:*** the BAS basin is located in a geological are considered not suitable area for such kind of energy production. At regional level, the Rift valley is much more attractive for such an alternative.
- ***From solar energy:*** besides several constraints related to the huge area needed for installing an equivalent solar power plant, the BAS basin lies in a low to moderately attractive area in terms of direct Normal Solar Radiation (3 to 4 kWh/m²/day) compared to other areas in Ethiopia and South Sudan, where Normal Solar Radiation can reach up to 8 kWh/m²/day.

Alternative technologies for agricultural production increase

Food production for both food security, livelihood development and revenue generation is a critical stake in BAS basin. Leverage actions to enhance and increase agricultural production are multiple:

- ***Enhancing and sustaining rainfed agriculture***. This includes developing better weather forecasting at all tiles-scales) for agricultural development, optimization of crop calendars, crop selection, improved management of soil erosion, agroforestry, etc. ;
- ***Developing sustainable irrigation***. This strategy relies on water resource availability, abstraction potential and local climate (temperature, rainfall, evapotranspiration). In this regard, the BAS basin shows a high and untapped potential for irrigation development. Crop water supply and management enables potential double-cropping, generates higher crop yields, opens further options for crop diversification, strengthens the climate resilience of the production, especially with respect to drought, and provides local communities with opportunities for cash cropping, agroprocessing and value addition, and market development.
- ***Support to livestock farming and pastoralism.*** Developing livestock farming provides local communities with a sustainable source of meat and dairy and prevents further degradation of surrounding ecosystems due to bush meat hunting. Additional support to pastoralism includes the implementation of pastoral water infrastructure for cattle water supply, development and organization of cattle migration patterns, etc. The creation of urban poles associated with irrigation and the availability of electricity in settlements, will provide better market opportunities for meat and dairy production and will incentivize farmers towards a more commercial approach to livestock farming and a move towards more sedentary farming. There are socioeconomic benefits that should accompany this including improved access to education, health and other services.
- ***Developing sustainable aquaculture:*** Sustainable aquaculture, including both fisheries in open water bodies and fish farming, boosts inland cost-effective fish production with a low impact on resources and ecosystems.

The above considerations highlight the need for the IWRDMPlan to include other actions than irrigation development such as **support to livestock farming and pastoralism through a better access to food and water resources, fisheries and fish farming development and ways to increase yields in rainfed agriculture**.

LEVELS OF DEVELOPMENT INTENSITIES (STEP 2)

As part of the Step 2 of the SSEA, contrasting levels of water development intensities were investigated in order to calibrate the assessment tool ("the SSEA analytical framework") and to define a development space "ensuring" satisfaction of needs and sustainability. These levels of intensities were designed to understand the respective effects of irrigation development, irrigation storage, hydropower and irrigation and hydropower combined together. A detailed description of the levels of intensity investigated during Step 2 is presented in Chapter 5.2

Assessment of the levels of water development intensities using the SSEA analytical framework allowed the identification of the magnitude of potential impacts and preliminary opportunities to enhance positive effects and avoid and/or minimize negative effects early in the IWRDMPlan development process. This is central to the parallel SSEA/plan development process. These preliminary opportunities include:

- Enhancement opportunities, which mainly consist of testing the potential positive effects of dam operation rules aiming at maximizing either irrigation or hydropower production;
- Avoidance opportunities which mainly consist of testing the potential positive effects of:
  - The avoidance of sensitive areas such as forests, wetlands, migration corridors and protected areas though a relevant irrigation projects selection;
  - The avoidance of over-regulation of flows and related consequences on river reaches and annexes though a relevant dam projects selection;
- Minimization opportunities which mainly consist of testing the potential positive effects of dam operations aiming at conserving some natural/flow patterns (e.g.: managed flood releases).

SCENARIOS/OPTIONS (STEP 3 OF THE SSEA PROCESS)

Unlike levels of development intensities, scenarios should investigate realistic development options. All of the scenarios investigated include irrigation, livestock, fisheries, water supply and hydropower development as well as flood reduction. They have been designed keeping in mind the enhancement, avoidance and minimization opportunities identified as part of Step 2. They should allow assessing the benefits and constraints associated with these enhancement and mitigation (avoidance and minimization) opportunities in order to identify a “preferred” option or development pathway for the development of the water resources of the BAS.

The scenarios investigated as part as Step 3 are presented in the next sub-section of this report.

6.3 DESCRIPTION OF THE SCENARIOS

6.3.1 Identification of projects included in the scenarios

The scenarios analyzed as part of step 3 of the SSEA consist of various combinations of the identified water resources development infrastructure projects. These projects have been identified as part of the baseline phase via:

- The review the existing sectoral Master Plans and strategies;
- Stakeholder interviews aiming, among others, at assessing further potential development projects and areas.

The resulting list of projects and their location is presented in section 2.3 “Water development opportunities”. Among this list:

1. Projects likely to have significant positive and negative social and environmental impacts at the BAS scale have been considered within the SSEA and the economic and financial analysis (projects forming the various scenarios). These projects have been incorporated into the water resources modelling. They include main important water development infrastructures (mainly hydropower dams, irrigation dams, multipurpose dams, irrigation schemes and main associated water development opportunities such as livestock development, flood control, fisheries and water supply). These projects are mapped below:

NB: Two additional projects concepts in South Sudan have been added at a later stage of the study following a stakeholders’ workshop since the related Master plans did not cover some areas of the Basin. These include the development of irrigation in the Akkobo/Pibor area and the development of hydropower on the upper Akobo river (see map next page). These projects are taken into account in the SSEA in a qualitative manner but there is not enough information for them to be included in the water resources modelling or economic and financial analysis at this stage.

Figure 6-1: Additional irrigation and hydropower potential conceptual project identified in South Sudan

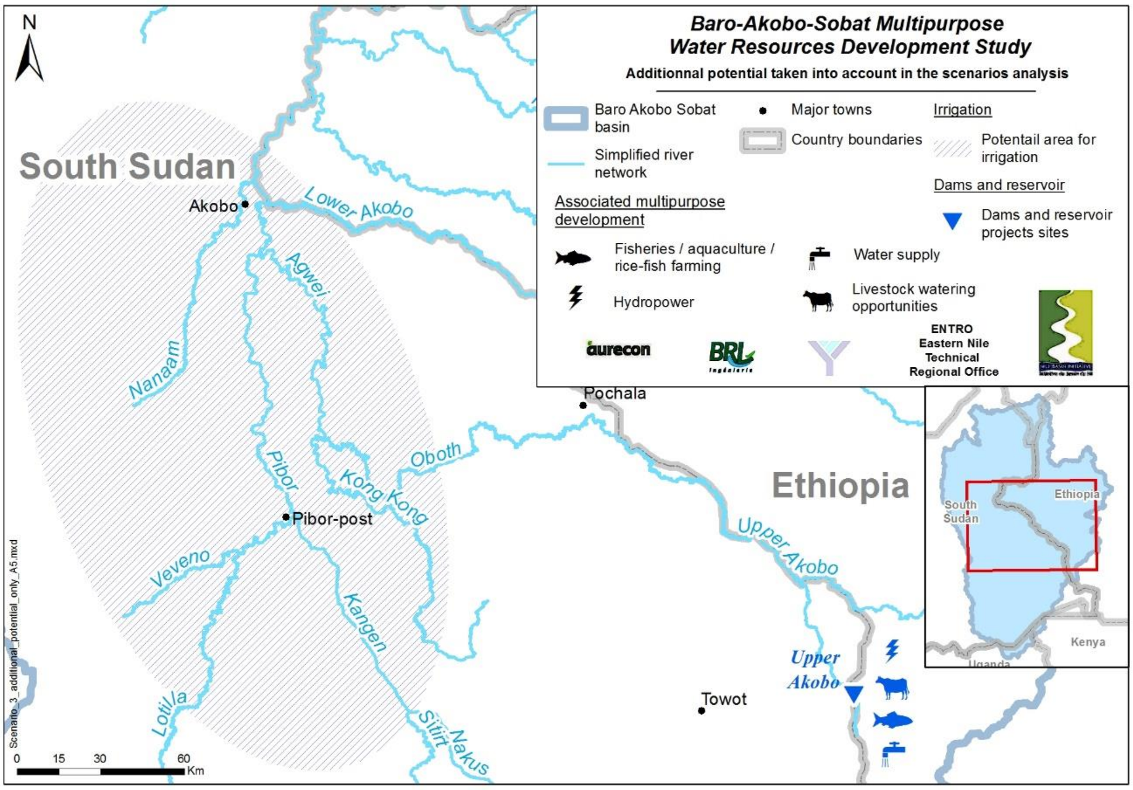
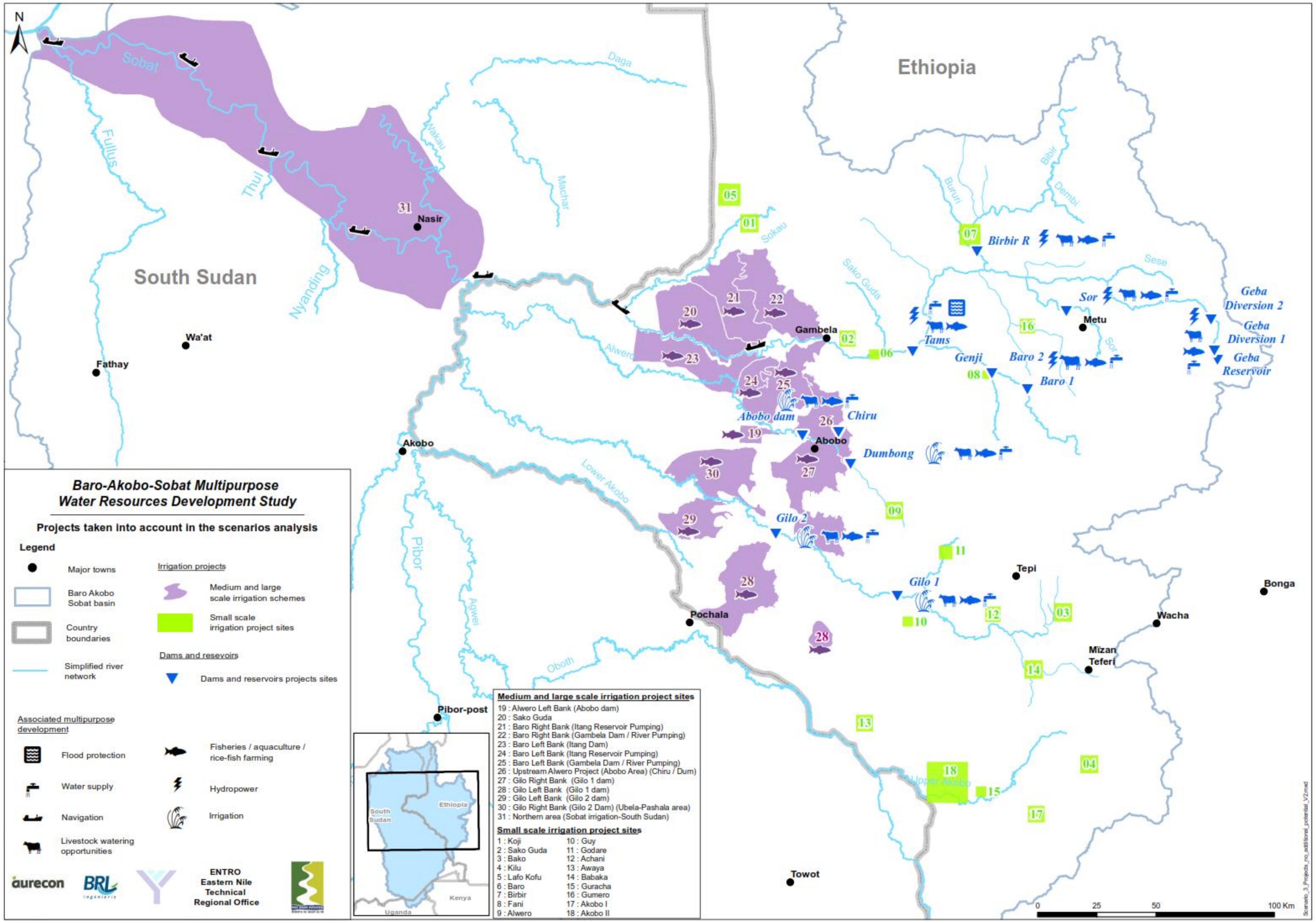
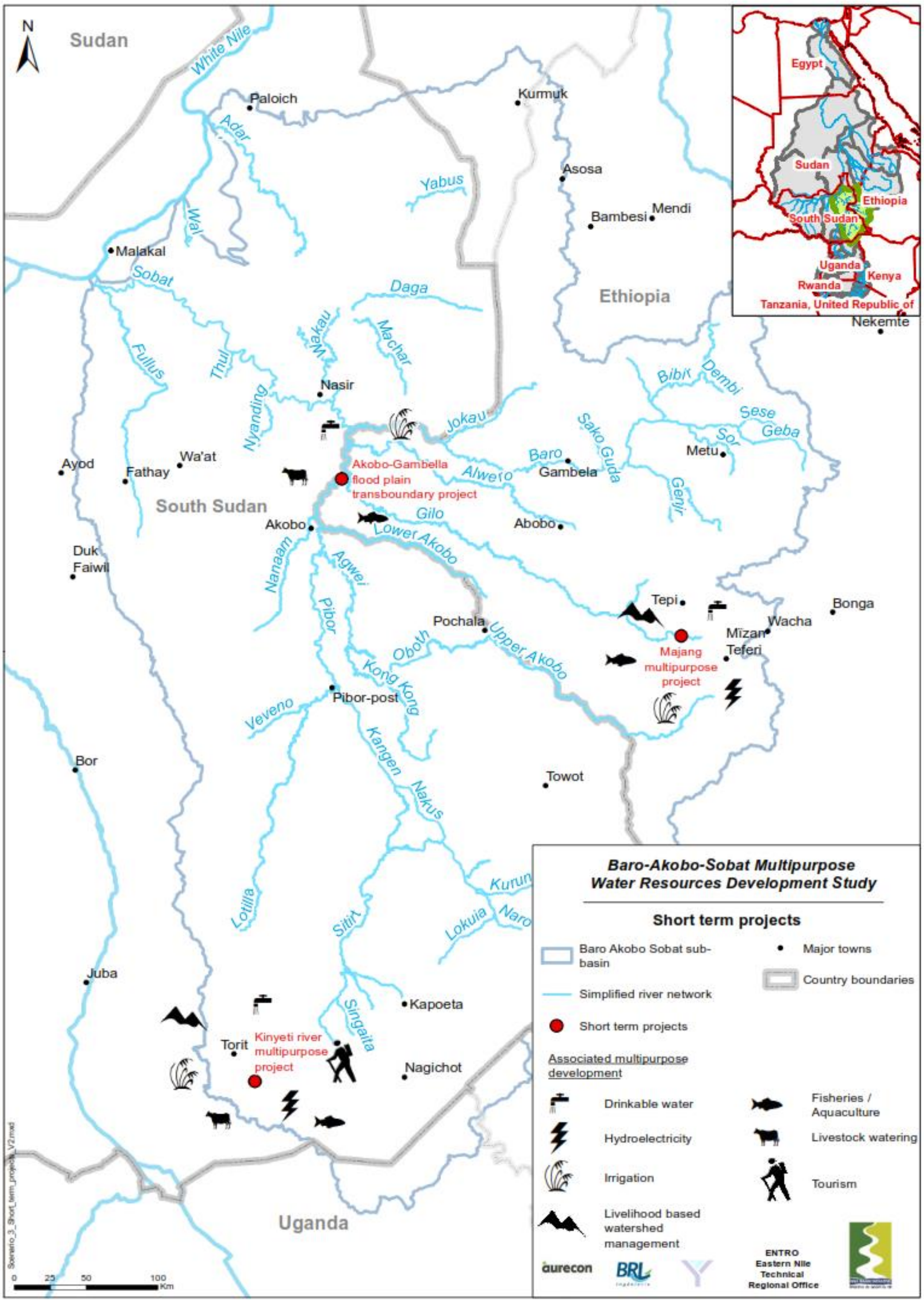


Figure 6-2: Projects included in the scenarios analysis



2. Multi-purpose and easy to implement opportunities have been gathered under short-term projects. These small-scale projects are likely to have moderate localized environmental and social impacts. They have been analysed through feasibility and ESIA studies. The three selected short-term project are located on the map below.

Figure 6-3: Short-term multipurpose projects



In the end, all projects are included in the IWRDMPlan but have been assigned different levels of priority.

6.3.2 Enhancement and mitigation opportunities included in the scenarios

The identification of the magnitude of potential impacts and preliminary opportunities to enhance positive effects and avoid and/or minimize negative effects via the assessment of the levels of water development intensities (step 2) has guided the design of scenarios for the options analysis as pointed out below. As it has already been mentioned, main identified enhancement and mitigation opportunities include:

- Enhancement opportunities, which mainly consist of testing the potential positive effects of dam operation rules aiming at maximizing either irrigation or hydropower production;
- Avoiding opportunities which mainly consist of testing the potential positive effects of:
  - The avoidance of sensitive areas such as forests, wetlands, migration corridors and main protected areas though a relevant irrigation projects selection (see map and table below);
  - The avoidance of over-regulation of flows and related consequences on river reaches and annexes though a relevant dam projects selection;
- Minimization opportunities which mainly consist of testing the potential positive effects of dams operation aiming at conserving some natural/flow patterns (eg: managed flood releases).

The investigation of development intensities also showed that a **significant level of irrigation and hydropower development is essential in order to support the minimum acceptable levels of socioeconomic growth in the BAS.**

The map and table below illustrate the application of avoidance measures on irrigation schemes.

Figure 6-4: Encroachment of irrigation schemes into sensitive areas (area in light blue on the map)

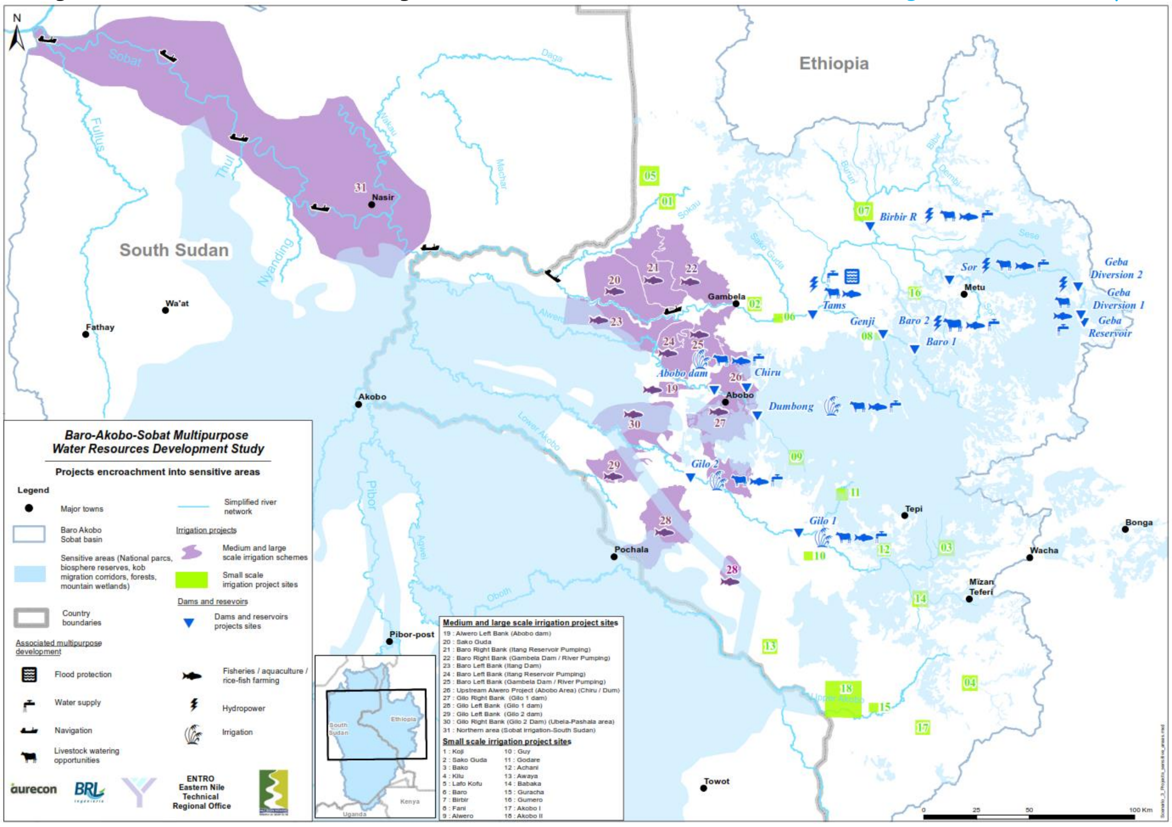


Table 6-1: Application of avoidance measures concerning irrigation (S No 1 to 18: small-scale projects; S No 19 to 31: large scale projects)

S. No	Name	Total area (Sc 3b, 4a & 4b)		Resulting area (after exclusion of sensitive areas) (Sc 1, 2 & 3a)	
		Gross Area (ha)	Net Area (ha)	Net Area (ha)	% of net total area
1	Koji	6 000	4 590	4 590	100%
2	Sako Guda	4 600	3 519	3 519	100%
3	Bako	6 000	4 590	-	0%
4	Kilu	5 600	4 284	4 182	98%
5	Lafo Kotu	9 000	6 885	6 885	100%
6	Baro	2 000	1 530	1 530	100%
7	Birbir	8 000	6 120	5 373	88%
8	Fani	1 200	918	282	31%
9	Alwero	5 500	4 208	0	0%
10	Guy	1 800	1 377	1 377	100%
11	Godare	3 300	2 525	666	26%
12	Achani	4 300	3 290	911	28%
13	Awaya	5 000	3 825	3 825	100%
14	Babaka	6 000	4 590	803	18%
15	Guracha	2 000	1 530	1 530	100%
16	Gumero	4 000	3 060	1 307	43%
17	Akobo I	5 000	3 825	3 825	100%
18	Akobo II	30 000	22 950	22 950	100%
19	Alwero, Abobo Dam, gravity	13 600	10 404	10 404	100%
20	Baro River, right bank, Itang Dam, gravity conveyance	66 581	50 949	50 949	100%
21	Scheme 2 + relift p/station + additional canal	57 495	43 984	43 984	100%
22	Scheme 3A (Baro River, right bank, Gambella Dam, gravity conveyance) +	67 740	51 821	51 821	100%
23	Baro River, left bank, Itang Dam, gravity conveyance	61 900	47 354	17 888	38%
24	Baro River, left bank, Itang Dam p/station, canal	15 832	12 111	12 111	100%
25	Baro River, left bank, Gambella Dam, gravity conveyance	57 018	43 619	43 619	100%
26	Alwero River, right bank, Chiru + Dumbong Dam, gravity conveyance	34 665	26 550	20 781	78%
27	Gilo River, right bank, Gilo 1 Dam, gravity	81 346	62 230	29 437	47%
28	Gilo River, left bank, Gilo 1 Dam, gravity	79 652	60 934	8 945	15%
29	Gilo River, left bank, Gilo 2 Dam, gravity	33 855	25 899	1 791	7%
30	Gilo River, right bank, Gilo 2 Dam, gravity	61 325	46 914	12 861	27%
31	Sobat	94 118	72 000	69 032	96%

6.3.3 Content of each scenario

The scenarios analyzed as part as step 3 of the SSEA consist of various combinations of the identified projects and include the various enhancement and mitigation opportunities identified as part of step 2:

- **Scenario 0 or Baseline scenario:** it is the status quo, which provides a benchmark for the SSEA. The Baseline case includes current domestic and livestock water use, current small-scale irrigation, 10 400 ha irrigation from Abobo Dam and 5 MW Sor Hydropower Dam. The following refinements were made to the Baseline model as used during the 1st Draft SSEA phase:
  - Improved level-area-volume relationship at Lower Baro “dummy dam” wetland;
  - Revised domestic and livestock water use (split Sobat and Lower Pibor);
  - Revised small-scale irrigation water use (sub-basin split).
- **Scenario 1:** It was agreed that the inclusion of a scenario with no or very little irrigation and hydropower development serves no purpose since it would not even provide the minimum required levels of socio-economic growth. Instead, Scenario1 is the “**Precautionary Principle”** case, using reduced but significant irrigation areas (small-scale and large-scale) with no encroachment into environmentally sensitive areas. Irrigation dam storage volumes were also reduced where possible to account for the reduction in irrigation water requirements when this was the case. All potential hydropower dams were included, **except Tams Dam and Birbir Dam**. These two dams were excluded in order to limit the potential downstream effects of “over-regulation”. **This scenario therefore aims at supporting “no regret” development with impacts that stay within the thresholds of the key dimensions**.
- **Scenario 2:** This is an extension of the Precautionary Principle case, similar to Scenario 1, except that Tams Dam and Birbir Dam are included. One of the **main aims is to understand the extent the flow regulation that is driven by these two large reservoirs have an impact on riverine ecosystem services**
- **Scenario 4a:** This is a Full-development case, with Tams Dam **operated to maximise hydropower production.** All future small-scale and all identified potential large-scale irrigation schemes are included. All identified potential hydropower schemes are also included. It is important to understand the positive and negative impacts of full development. The maximization of hydropower development equates to a unilateral or unisectoral approach to development
- **Scenario 4b:** This is a Full-development case, with Tams Dam operated to **optimise irrigation and flood control.** All future small-scale and all identified potential large-scale irrigation schemes are included. All identified potential hydropower schemes are also included. A key aim of this scenario is to evaluate the relative benefits of an optimized approach which includes transboundary and inter-sectoral cooperation.

The specific details of Scenarios 3, the “intermediate or “trade-off” scenarios were only developed after a preliminary analysis of the outputs of Scenarios 1, 2 and 4.

- **Scenario 3a:** This is an intermediate case, similar to Scenario 2, but with environmental water releases imposed on all dams in order to conserve natural flow patterns.
- **Scenario 3b:** This is an intermediate case, similar to Scenario 4a, but with environmental water releases imposed on all dams in order to conserve natural flow patterns.
- All scenarios (except the baseline scenario) also include **livestock development, fisheries development in reservoirs** and **fish farming development in irrigation schemes**. They also include **water supply** requirements related to the projected population increase in 2041

Table 6-2: Alternatives considered - Inputs parameters in the water model

	Baseline	Precautionary principle options		Intermediate options		Full development options	
	Scenario 0	**Scenario 1**	**Scenario 2**	**Scenario 3a**	**Scenario 3b**	**Scenario 4a**	**Scenario 4b**
Irrigation demand							
Irrigation -general principles	Existing irrigation	Irrigation avoiding sensitive areas	Irrigation avoiding sensitive areas	Irrigation avoiding sensitive areas	All irrigation	All irrigation	All irrigation
Irrigation - small-scale	Existing diffuse (117 692 ha)	Existing diffuse (117 692 ha) + 76% identified potential (63 555) = 181 247 ha	Existing diffuse (117 692 ha) + 76% identified potential (63 555) = 181 247 ha	Existing diffuse (117 692 ha) + 76% identified potential (63 555) = 181 247 ha	Existing diffuse (117 692 ha) + 100% identified potential (83 616) = 201 307 ha	Existing diffuse (117 692 ha) + 100% identified potential (83 616) = 201 307 ha	Existing diffuse (117 692 ha) + 100% identified potential (83 616) = 201 307 ha
Irrigation - large-scale	Almost existing 10 400 ha (Alwero scheme)	Alwero scheme + 67% identified potential (363 219 ha) = 373 623 ha	Alwero scheme + 67% identified potential (363 219 ha) = 373 623 ha	Alwero scheme + 67% identified potential (363 219 ha) = 373 623 ha	Alwero scheme + 100% identified potential (544 365 ha) = 554 769 ha	Alwero scheme + 100% identified potential (544 365 ha) = 554 769 ha	Alwero scheme + 100% identified potential (544 365 ha) = 554 769 ha
Irrigation dams	Existing Abobo dam	Only as required to support irrigation (reduction of Full Supply Level of Gilo 1 and Gilo 2)	Only as required to support irrigation (reduction of Full Supply Level of Gilo 1 and Gilo 2)	Only as required to support irrigation (reduction of Full Supply Level of Gilo 1 and Gilo 2)	No Baro storage (without Gambella & Itang dams)	No Baro storage (without Gambella & Itang dams)	No Baro storage (without Gambella & Itang dams)
Irrigation - total demand (ha)	128 092	554 870	554 870	554 870	756 076	756 076	onl 756 076
Irrigation - total annual demand (BCM)	0.176	6.44	6.258	6.619	9.46	9.098	9.001
Hydropower capacity							
Hydropower - general principles	Existing Sor dam	All hydropower dams except Tams&Birbir	All hydropower dams	All hydropower dams with conservation of some natural flow patterns	All hydropower dams with conservation of some natural flow patterns	All hydropower dams with operation aimed at maximising hydropower production	All hydropower dams with operation aimed at maximising irrigation and flood reduction
Hydropower - total installed capacity (MW)	10	1 243	2 710	2 710	2 710	2 710	2 710
Storage capacity							
Combined theoretical storage capacity of hydropower, irrigation and multipurpose dams (BCM)	0.1	8.2	20.9	20.9	20.9	20.9	20.9
Water supply							
Water supply requirements (BCM/year)	0.11	0.24	0.24	0.24	0.24	0.24	0.24
Livestock watering							
Water requirements (BCM/year)	0.05	0.08	0.08	0.08	0.08	0.08	0.08
Livestock sector development	Current	Deemed to be developped as an indirect consequence of the water development in the Basin					
Aquaculture and fish farming							
Sector development	Current	Fish farming : 1% of irrigated areas Rizipisciculture : 1 % of rice irrigated areas					

NB: In the table above, the scenarios are described as inputs of the water model. It is important to note that input paramaters are not the only of describing scenarios. For a more comprehensive visualisation of a scenario, the reader has to refer also to the outputs of the model which are presented in the next chapter (section 7.2- technical results). For example, the **targeted irrigation surface area leads to the calculation of the irrigation demand** (how much water is required to irrigate the targeted surface area) is an input of the water model. **As an output, the model gives information about how much water is available which is then converted into an irrigable surface area** (the surface area which can be effectively irrigated when one takes into account the water deficits). For hydropower, the input consist of the **installed capacity (MW)** of the sum of dams included in the scenarios. Once the model has been run, it gives, as **an output, the energy that can be produced (GWh/year) according to the water available for each scenario**

Moreover, a certain number of qualitative parameters, such as indirect benefits associated with water development (the development) are not detailed here but are taken into account in the assessment of the alternatives and in the economic and financial analysis. In particular, positive externalities of scenarios are described and included in the economic and financial anaysis (see dedicated Annex). For instance, as navigation is not a consumptive water use, it is not part of the input parameters of the water model. However, the navigation sector is included in the analysis through the asssement of the navigable period (which depends on the river flows modifications specific to each scenario). Another example is that the development of infrastructure such as roads, schools, hospitals, ect. associated with the development of irrigation schemes is also taken into account in the analysis.

7. EVALUATION OF THE ENVIRONMENTAL AND SOCIAL IMPACTS OF EACH ALTERNATIVE AND CONCLUSIONS REGARDING THEIR SIGNIFICANCE: APPLICATION OF THE CALIBRATED SSEA ANALYTICAL FRAMEWORK

7.1 INTRODUCTION

This chapter aims at comparing the potential environmental and social impacts of each scenario and assessing the feasibility of mitigating these impacts, where there are negative and significant. The analytical framework used for this comparison is the *calibrated SSEA analytical framework* (presented in chapter 5.3).

For each of the SSEA analytical framework sub-dimensions, the following analysis comprises:

- **Impact overview**: This section describes the nature of the impact (potential benefits and / or risks) and how it relates to potential changes generated by water development. Given the integrative dimension of water resources, impacts are usually related to another. Reference to other dimensions and sub-dimensions are made consequently.
- **Scenario comparison**: this section assesses the significance of the impact according to each scenario.
- **Need for further acquisition on uncertain factors**: this section highlights the uncertainties and the need for further investigations before IWRDMPlan implementation;
- **Enhancement and mitigation opportunities**: this section only focuses on avoidance and minimization options. Offset options will be analysed as a last resort once the preferred options will have to be defined.
- **Residual significance**: the residual significance defines the impact significance considering enhancement and mitigation options.

*NB: The AfDB guidelines mention that alternatives should be both technically and economically feasible: The technical feasibility of individual projects has been assessed in previous studies, in which these projects were identified, and in feasibility studies, when existing for some of the projects. The technical feasibility of the project combination and/or of the option is assessed using the BAS water model which informs about water shortage for key water uses in the basin. A summary of the technical assessment is provided in the coming section**Erreur ! Source du renvoi introuvable.**.*

The economic feasibility is assessed as part of the Assessment of options, especially through the Cost Benefit Analysis, the main results of which are summarized in chapter 7 and presented in the annex entitled “Assessment of Options; Cost-benefit Analysis”.

7.2 SUMMARY OF THE TECHNICAL ASSESSMENT

7.2.1 Results overview

The analysis of the potential environmental and social impacts is based on the technical results generated by the BAS water model. Each scenario was simulated and the technical results are presented below:

Table 7-1: Technical results for each scenario – outputs of the water model

	Baseline	Precautionary principle options		Intermediate options		Full development options	
	Scenario 0	**Scenario 1**	**Scenario 2**	**Scenario 3a**	**Scenario 3b**	**Scenario 4a**	**Scenario 4b**
Irrigation demand							
Irrigation -general principles	Existing irrigation	Irrigation avoiding sensitive areas	Irrigation avoiding sensitive areas	Irrigation avoiding sensitive areas	All irrigation	All irrigation	All irrigation
Irrigation - total demand (ha)	128 092	554 870	554 870	554 870	756 076	756 076	onl 756 076
Irrigation - total annual demand (BCM)	0.176	6.44	6.258	6.619	9.46	9.098	9.001
Irrigation demand which can be satisfied on average							
Irrigation demand which can be satisfied most of the time (BCM/year)	0.133	4.456	6.102	2.85	4.475	7.75	8.595
% of the irrigation demand which can be satisfied	76%	69%	98%	43%	47%	85%	95%
Hydropower capacity							
Hydropower - general principles	Existing Sor dam	All hydropower dams except Tams&Birbir	All hydropower dams	All hydropower dams with conservation of some natural flow patterns	All hydropower dams with conservation of some natural flow patterns	All hydropower dams with operation aimed at maximising hydropower production	All hydropower dams with operation aimed at maximising irrigation and flood reduction
Hydropower - total installed capacity (MW)	10	1 243	2 710	2 710	2 710	2 710	2 710
Hydropower - Energy produced							
Hydropower - Energy produced (GWh/year)	42	3 946	12 274	11 246	11 246	12 303	11 428
Storage capacity							
Combined theoretical storage capacity of hydropower, irrigation and multipurpose dams (BCM)	0.1	8.2	20.9	20.9	20.9	20.9	20.9
Water supply							
Water supply requirements (BCM/year)	0.11	0.24	0.24	0.24	0.24	0.24	0.24
Livestock watering							
Water requirements (BCM/year)	0.05	0.08	0.08	0.08	0.08	0.08	0.08
Livestock sector development	Current	Deemed to be developped as an indirect consequence of the water development in the Basin					
Aquaculture and fish farming							
Sector development	Current	Fish farming : 1% of irrigated areas Rizipisciculture : 1 % of rice irrigated areas					

The above table gives the outputs of the water model. It is worth noting that:

- For a same capacity (MW), the scenarios lead to various energy production rates (GWh/year). This is due both to:
  - Various water demands by other water uses (the irrigation demand varies among scenarios);
  - Various dam operation rules (In Sc 4a, hydropower dams operate to maximise hydropower production, whereas they operate to maximise irrigation in Sc 4b; in Sc 3a and 3b, hydropower dams operations aim at conserving some natural flow patterns).

  It can be noted that avoidance of sensitive areas do not really impact electricity production (for the same installed capacity, power generated is relatively stable) (Sc 2 and 3a to be compared with Sc 3b, 4a and 4b).
  - Implementing dams operation rules aiming at conserving some natural flow patterns lead to a significant impact on the water available for irrigation. The surface area irrigable under these conditions is lower.
- The water demand satisfaction for irrigation (in % of the water demand) differs across the scenarios. This is due to:
  - Different initial water demands (the targeted irrigation surface area is lower for Sc1, 2 and 3a than for Sc3b, Sc4a and Sc4b, since these scenarios have been designed to avoid encroachment in sensitive areas);
  - Different dams operations rules (the conservation of some natural flow patterns in Sc3a and 3b, by reducing the amount of water stored during the irrigation periods, lead to higher water deficits than for the other scenarios).

  Above all, even if the BAS is known for its productive rivers, the hydrological system is still limited. The irrigation water demand can indeed hardly be totally satisfied on average (1 year out of 2). It means that the surface area which can be effectively irrigated is lower than what has been indicated in the previous irrigation studies. This can be indeed only underlined once one conducts a comprehensive analysis as it is the case within the IWRDMPlan study. However, potential water savings due to improved irrigation efficiencies and less restrictive environmental water requirements lead to higher rates of irrigation water demand satisfaction but also to higher potential ecological stress especially on Machar Marshes. The detailed results of the related sensitivity analysis are presented in section 7.2.3.
- **If properly managed**, Tams dam can support the development of Sobat irrigation in South Sudan:
  - Without Tams dam, there would be major deficits for the Sobat irrigation, especially if there is a strict environmental flow imposed on the Sobat during the dry season;
  - Tams dam can favour Sobat irrigation, especially where adequate environmental flows are defined for Baro and Sobat rivers (to allow that more water can go down to support irrigation);
  - With an adequate release from Tams dam, Sobat irrigation will be more limited by an environmental flow trying to match with the natural dry season low flow than by the Ethiopian large scale irrigation on the Baro, Gilo, Alwero.

7.2.2 Water balance results

The following schematics highlight the main results in terms of water balance (annual mean figures) for each scenario.

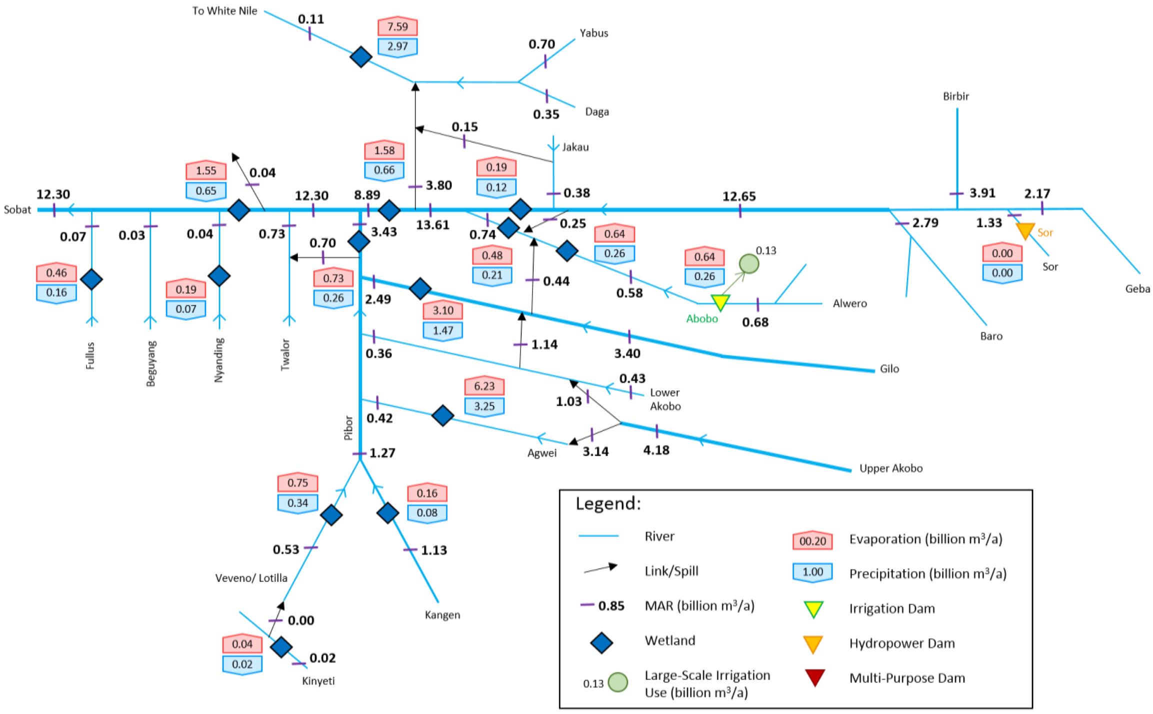
The main objective of the water balance modelling is to quantify the available water in the basin in both space and time, to evaluate the potential benefits in terms of hydropower, water supply, irrigation etc., and to analyse the hydrological and associated socio-economic and environmental impacts – both positive and negative - linked to development interventions and management alternatives.

The water balance modelling entailed the calibration and validation of a rainfall-runoff model using readily available hydro-meteoroligical data, the simulation of long-term flow sequences at key nodes throughout the basin and water balance analyses of various combinations of identified projects, including enhancement and mitigation opportunities. It is important to note that the water balance scenarios which were evaluated represent possible future (2041) development states of the basin, i.e. the water balance and associated hydrological, socio-economic and environmental impacts are assessed at a particular future point in time and no allowance has been made for incremental or phased implementation of projects during model simulation. Although the water balance model focuses on surface water, the NAM rainfall runoff model which was used to generate long-term flow sequences across the basin is a deterministic, lumped, conceptual model that operates by continuously accounting for the moisture content in three different and mutually interrelated storages that represent overland flow, interflow and base flow. Consequently, albeit conceptually, **the model does account for the interaction between groundwater and baseflow**. Furthermore, the groundwater supply potential for the entire study area was determined as part of the Baseline phase of this study (refer to Baseline Report and to Annex 3 of this report) and involved collating, checking and sorting existing data, extrapolating data to areas without data, developing a system to group and rank similar groundwater areas and finally quantifying potential groundwater yields across the basin.

The schematics below present the results of the water balance analyses for each scenario in diagrammatic format and indicate the connectivity and mean annual flow in the main river network, including inter-catchment spills, the locations of wetlands and major dams including mean annual precipitation and evaporation associated with these storage areas, and large scale irrigation abstractions. It shows the extent of floodplains and wetlands along the lower Alwero, Gilo, Pibor and Baro rivers, along the Sobat River and the location of the Machar marshes along the right bank of the lower Baro River. It also indicates the extensive spills and interconnectivity in the Gambela floodplain with spills/links from the Lower Akobo to the Gilo River, from the Gilo to the Lower Alwero, from the lower Pibor to the Twalor and from the lower Baro to the Alwero and the Machar Marshes. Furhermore, depending on certain thresholds, significant spills also occur from the Upper Akobo into the Agwei River and wetlands.

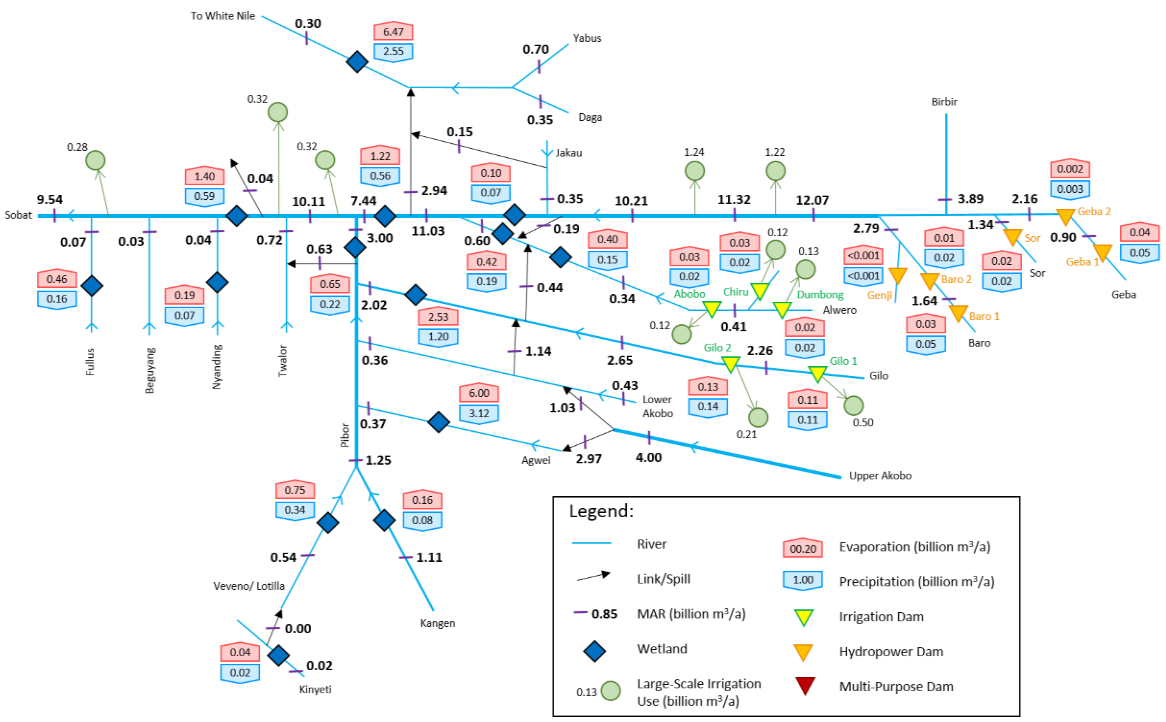
Scenario 0: This scenario represents the status quo in the basin in terms of current water use and level of development. The current water use is very limited and includes diffuse domestic, livestock and small-scale irrigation throughout the basin as well as one large-scale irrigation scheme in the Alwero catchment (Abobo Dam). Furhthermore, there is a small hydropower installation on the Sor River – an upper tributary of the Baro River.

Figure 7-1: Water balance schematic of Scenario 0



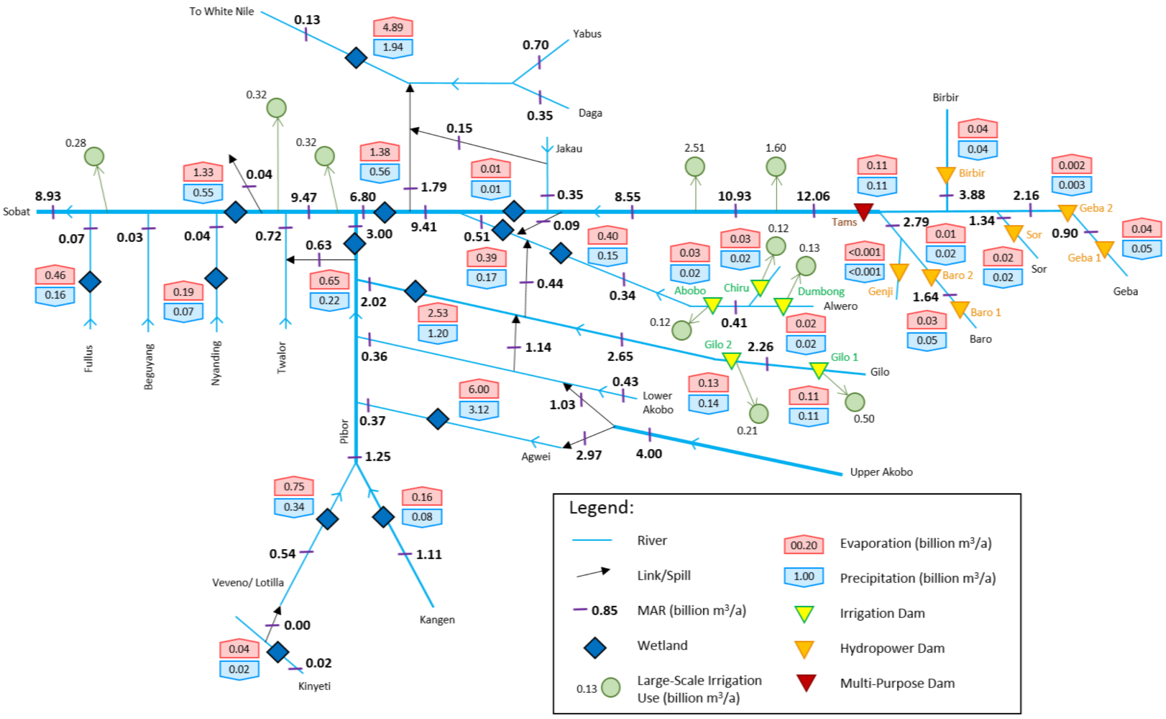
Scenario 1: This scenario represents the “Precautionary Principle” case, using reduced but significant irrigation areas (small-scale and large-scale) with no encroachment into environmentally sensitive areas, and excluding Tams Dam and Birbir Dam in order to limit the potential downstream effects of “over-regulation” linked to hydropower. Irrigation dams along the Gilo and Alwero Rivers are included. However, their storage volumes were reduced where possible to account for the reduction in irrigation water requirements when this was the case. Due to the regulation provided by the hydropower dams (all of which are situated in the upper Baro catchment), the Gambela and Itang irrigation dams on the lower Baro River were found to be no longer necessary.

Figure 7-2: Water balance schematic of Scenario 1



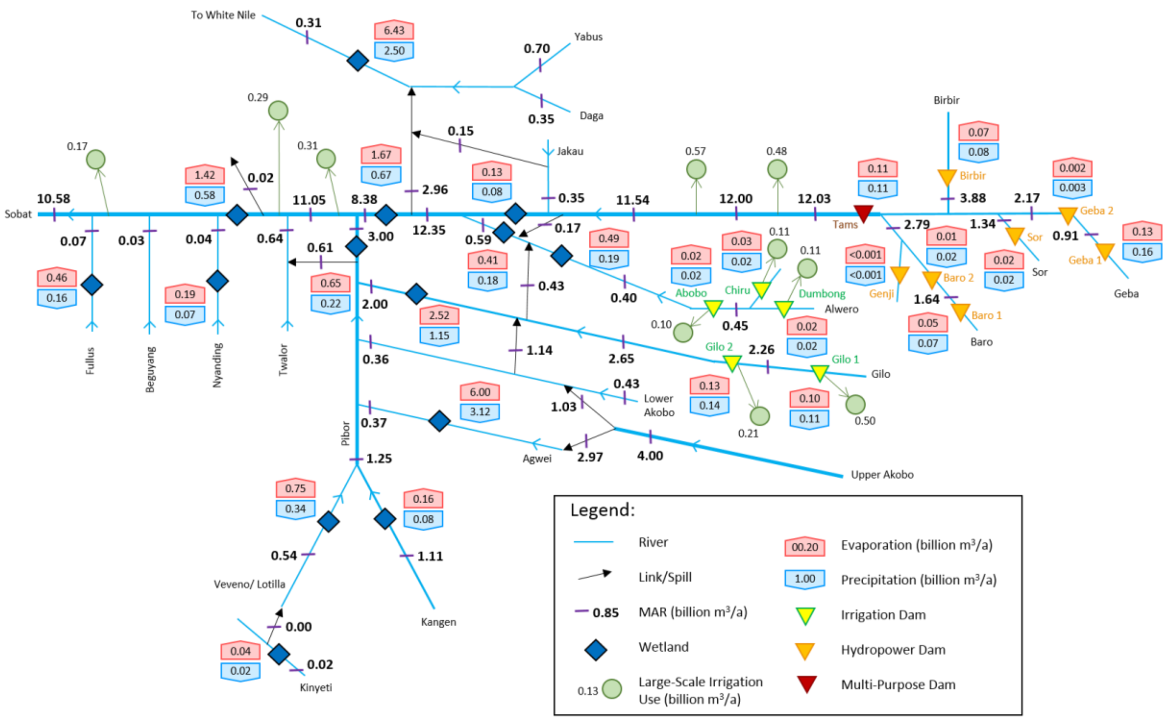
Scenario 2: This scenario is an extension of **Scenario 1**, except that Tams Dam and Birbir Dam are included in order to assess the potential incremental impacts and benefits of these two large reservoirs compared to the "Precautionary Principle" case (Scenario 1).

Figure 7-3: Water balance schematic of Scenario 2



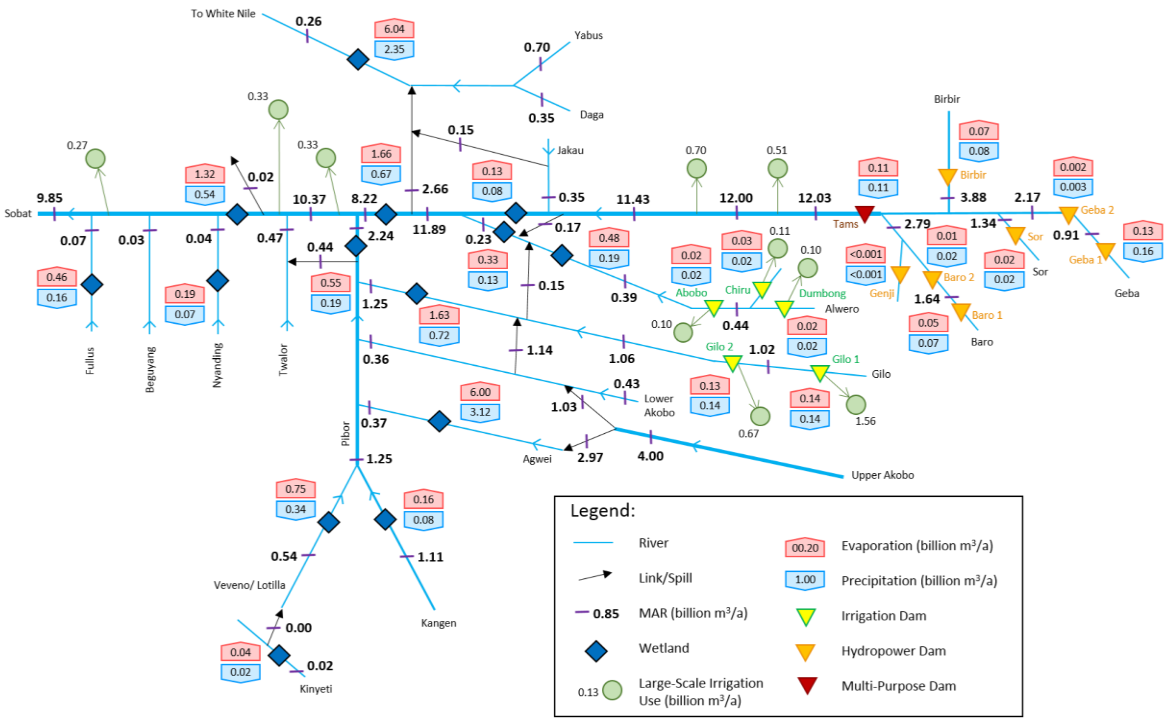
Scenario 3a: This is an Intermediate scenario - similar to **Scenario 2**, but with environmental water releases imposed on all dams in order to conserve natural flow patterns. In the absence of the time or specialist expertise resources to undertaken more detailed studies, a preliminary, low confidence "desktop estimate" of environmental water releases was obtained by using the RESDSS model developed by the Institute for Water Research (IWR) at Rhodes University South Africa (Hughes and Münster, 1999). In essence, the model estimates annual totals and seasonal distributions of environmental flow requirement components (e.g. low (base) flows and high flows during normal (maintenance) and/or drought years) based on the hydrological characteristics of the natural flow sequence at the site of interest. In addition, the model allows the development of rules that combine the different EFR components into continuous assurance or frequency curves, which, in conjunction with a time series of natural flows, allow the construction of a representative time series of reserve requirements. Three environmental classes were considered viz: A: Natural unmodified; B: Largely natural with few modifications - minor loss of habitat; and C: Moderately modified - some loss of habitat (refer to Section 7.2.3.1).

Figure 7-4: Water balance schematic of Scenario 3a



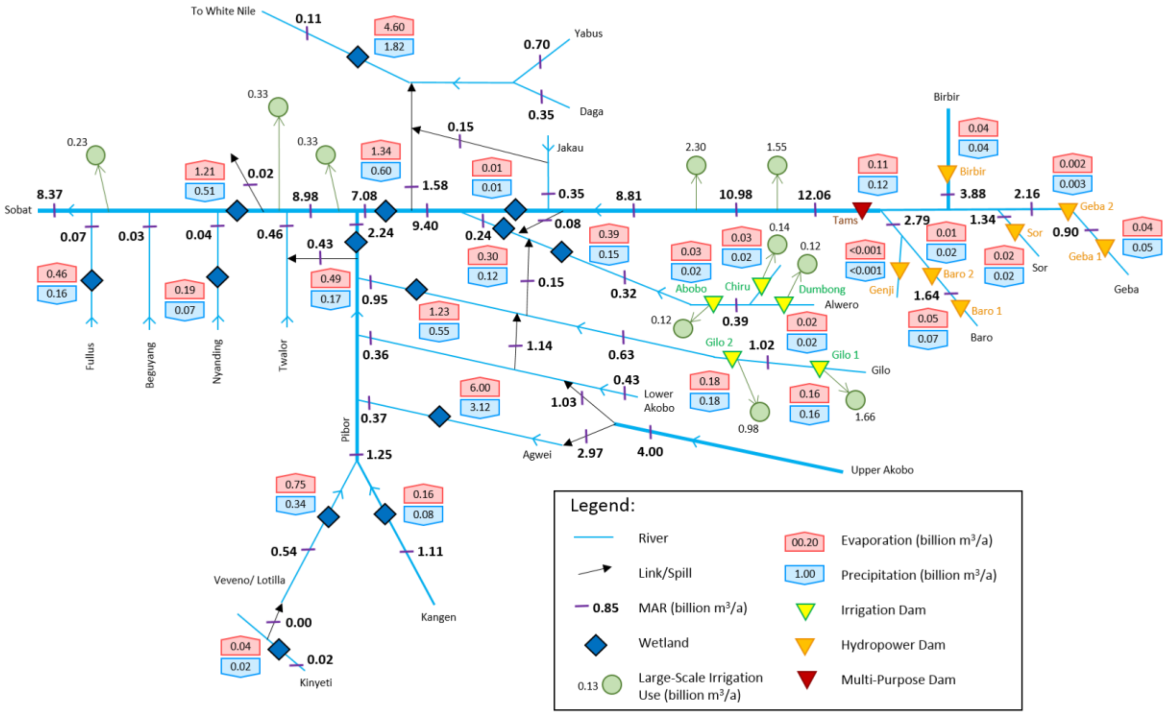
Scenario 3b: This is an Intermediate scenario - similar to Scenario 4a, but with environmental water releases imposed on all dams in order to conserve natural flow patterns.

Figure 7-5: Water balance schematic of Scenario 3b



Scenario 4a: This full-development scenario represents a future case where all of the small-scale irrigation, all identified potential large-scale irrigation and all major hydropower schemes will be developed without any environmental constraints. This development will be accompanied by various major dams which support either irrigation and/or hydropower. This particular scenario reflects a unisectoral approach to development with the multipurpose Tams Dam operated to maximise hydropower production and aims to understand the positive and negative impacts of full development.

Figure 7-6: Water balance schematic of Scenario 4a



Scenario 4b: This scenario is also a full development scenario, similar to **Scenario 4a**, exept that Tams Dam is operated to optimise irrigation and flood control, with hydropower generation at the dam as a secondary priority.

Figure 7-7: Water balance schematic of Scenario 4b

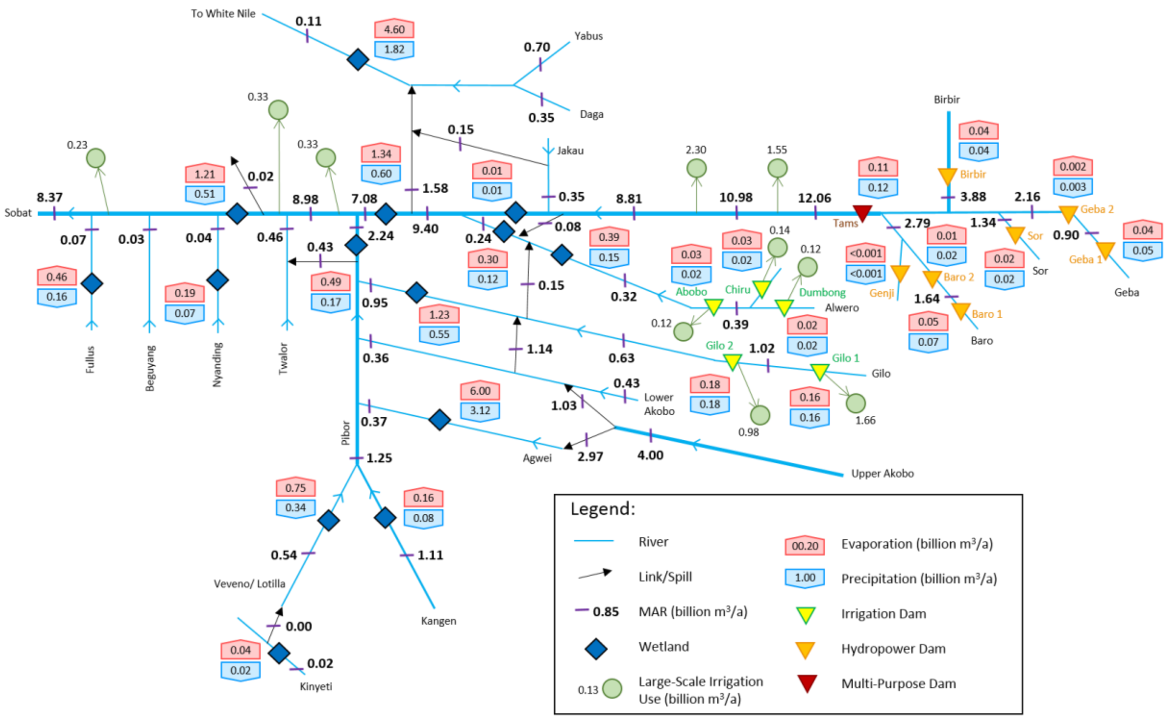


Table 7-2 summarises the water balance per subcatchment for the baseline scenario and the fully developed scenario (Scenario 4a). It shows that under baseline conditions, the total runoff which is generated in the catchment equals about 26 BCM/a, while the total outflow to the White Nile via the Sobat River and as spills from the Machar Marshes equals only 12.7 BCM/a. Most of these "losses" are due to the very high net evaporation from the wetlands and floodplains, which equate to about 13 BCM/a under baseline conditions. For the fully developed scenario, net evaporation from the wetlands and floodplains reduce to less than 10 BCM/a due to less water entering the lower reaches of the rivers during the wet season and consequently less spills entering the floodplains from where the water evaporates. This is as a result of increased consumptive water use and more storage in the upper catchments which reduces high flows into the Gambella floodplains and Machar Marshes and provides an indication of the potential "saving" which can be achieved through increased regulation in the upper part of the catchment.

Table 7-2: Water balance results per sub-basin for baseline (0) and fully developed (4A) scenarios

BAS: Sub-basin water balance (BCM/a): Scenario 0													
					Precipitation		Evaporation		Water use				
Sub-basin	Runoff generated in sub-basin	Runoff from upper catchments	Spills in	Spills out	Dams	Wetlands / Floodplains	Dams	Wetlands / Floodplains	Domestic/ Livestock	Small-scale Irrigation	Large-scale Irrigation	Net runoff out of sub-basin	% Change in runoff
Upper Baro	12.442	0.000	0.000	0.000	0.001	0.000	-0.001	0.000	-0.043	-0.313	0.000	12.087	-3%
Upper Alwero	0.692	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.005	-0.009	0.000	0.677	-2%
Upper Gilo	3.408	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.011	-0.001	0.000	3.396	0%
Upper Akobo	4.181	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.005	0.000	0.000	4.175	0%
Upper Pibor	1.799	0.000	0.000	0.000	0.000	0.448	0.000	-0.953	-0.030	0.000	0.000	1.265	-30%
Lower Baro	0.755	12.764	0.380	-4.049	0.000	0.779	0.000	-1.772	-0.010	-0.020	0.000	8.827	-35%
Lower Alwero	0.156	0.677	0.682	0.000	0.024	0.478	-0.029	-1.121	0.000	0.000	-0.133	0.734	-12%
Lower Gilo	0.015	3.396	1.142	-0.436	0.000	1.468	0.000	-3.096	0.000	0.000	0.000	2.488	-27%
Lower Akobo	0.475	1.034	0.000	-1.142	0.000	0.000	0.000	0.000	-0.005	0.000	0.000	0.362	-76%
Agwei	0.279	3.141	0.000	0.000	0.000	3.249	0.000	-6.233	-0.003	0.000	0.000	0.433	-87%
Lower Pibor	0.063	4.549	0.000	-0.701	0.000	0.257	0.000	-0.734	-0.003	0.000	0.000	3.431	-26%
Sobat	0.645	12.259	0.725	-0.041	0.000	0.881	0.000	-2.213	-0.010	0.000	0.000	12.246	-5%
Machar Marshes	1.188	0.000	3.956	0.000	0.000	2.972	0.000	-7.590	-0.004	0.000	0.000	0.523	-56%
Total	**26.098**	**37.819**	**6.885**	**-6.368**	**0.025**	**10.533**	**-0.030**	**-23.712**	**-0.129**	**-0.343**	**-0.133**	**50.645**	
Total outflow to White Nile		**12.769**											

BAS: Sub-basin water balance (BCM/a): Scenario 4A													
					Precipitation		Evaporation		Water use				
Sub-basin	Runoff generated in sub-basin	Runoff from upper catchments	Spills in	Spills out	Dams	Wetlands / Floodplains	Dams	Wetlands / Floodplains	Domestic/ Livestock	Small-scale Irrigation	Large-scale Irrigation	Net runoff out of sub-basin	% Change in runoff
Upper Baro	12.442	0.000	0.000	0.000	0.179	0.000	-0.157	0.000	-0.085	-0.319	0.000	12.061	-3%
Upper Alwero	0.692	0.000	0.000	0.000	0.040	0.000	-0.048	0.000	-0.008	-0.024	-0.259	0.393	-43%
Upper Gilo	3.408	0.000	0.000	0.000	0.340	0.000	-0.340	0.000	-0.022	-0.094	-2.638	0.655	-81%
Upper Akobo	4.181	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.010	-0.168	0.000	4.002	-4%
Upper Pibor	1.799	0.000	0.000	0.000	0.000	0.448	0.000	-0.953	-0.044	0.000	0.000	1.251	-30%
Lower Baro	0.755	12.453	0.353	-1.659	0.115	0.610	-0.113	-1.351	-0.014	-0.050	-3.853	7.246	-45%
Lower Alwero	0.156	0.393	0.226	0.000	0.020	0.271	-0.026	-0.688	0.000	0.000	-0.119	0.234	-57%
Lower Gilo	0.015	0.655	1.137	-0.147	0.000	0.547	0.000	-1.227	0.000	0.000	0.000	0.979	46%
Lower Akobo	0.475	1.029	0.000	-1.137	0.000	0.000	0.000	0.000	-0.011	0.000	0.000	0.357	-76%
Agwei	0.279	2.974	0.000	0.000	0.000	3.125	0.000	-5.995	-0.005	0.000	0.000	0.378	-88%
Lower Pibor	0.063	2.965	0.000	-0.432	0.000	0.170	0.000	-0.490	-0.005	0.000	0.000	2.272	-25%
Sobat	0.645	9.518	0.456	-0.031	0.000	0.742	0.000	-1.867	-0.017	0.000	-0.883	8.563	-16%
Machar Marshes	1.188	0.000	1.733	0.000	0.000	1.821	0.000	-4.598	-0.005	-0.024	0.000	0.116	-90%
Total	**26.098**	**29.987**	**3.906**	**-3.405**	**0.694**	**7.734**	**-0.684**	**-17.169**	**-0.225**	**-0.679**	**-7.751**	**38.507**	
Total outflow to White Nile		**8.679**											

7.2.3 Irrigation and environmental flow sensitivity analysis

Following the IWRDMPlan workshop, held on the 12th and 13th of January 2017, at which the 2nd draft SSEA was presented, a sensitivity analysis has been conducted in order to identify and assess the impacts of potential water savings due to **improved irrigation efficiencies and less restrictive environmental water requirements** on wetland areas, irrigation deficits and hydropower generation within the basin. This analysis focused on the Baro irrigation, since this is where the water deficits arising from the water modelling exercise appeared to be the highest.

7.2.3.1 Approach

Two water saving measures were considered, namely improved irrigation water use efficiency and a reduced environmental class for environmental water releases in the upper and lower Baro catchments.

This sensitivity analysis was carried out using the following approach:

1. Quantify potential savings in irrigation water demands across the basin due to improved irrigation efficiencies.
2. Determine environmental water requirements for compliance with new (less restrictive) environmental classes in the Baro sub-basin.
3. Change existing water resources simulation models to reflect different combinations of the above scenarios.
4. Run each model and extract from the simulation results relevant information on wetland areas, irrigation use, irrigation deficits and hydropower generation at key locations.
5. Compare the results and assess the relative impact of the identified water saving measures and take lessons forward.

IRRIGATION WATER USE EFFICIENCY

The current and proposed improved irrigation water use efficiencies for various crop types are shown in Table 1. It was assumed that the current irrigation return flow of 10% of water abstracted does not change under improved irrigation methods. The improved irrigation water use efficiency for each irrigation scheme was calculated using the efficiencies in the table below and assumed cropping patterns for each scheme as shown in Annex 5 (see assumptions used for the Cost Benefit Analysis).

Table 7-3: Current[26] and improved[27] irrigation water use efficiencies

Crop type	Current		Improved	
	Irrigation method	Efficiency (%)	Irrigation method	Efficiency (%)
Rice	Flood irrigation	50	Flood irrigation with improved levelling and monitoring	60
Vegetable	Flood irrigation	50	Drip irrigation	90
Other crops	Flood irrigation	50	Sprinkler	70

26 In this section, “current” refers to the water use efficiency (or environmental class) used in the water modelling exercice, while modelling Scenarios 0 to 4b.

27 In this section, “improved” or “proposed” refers to the water use efficiency (or environmental class) specifically used for the sensitivity analysis, while modelling Options 3B-0 to 3B-3.

REDUCED ENVIRONMENTAL CLASS

The current and proposed environmental classes[28] are shown in the table below. A reduction in environmental class from Class A [29]to Class B was proposed for the upper Baro (Birbir, Geba, Sor, Baro) and lower Baro catchments.

Table 7-4: Current and proposed environmental classes

River	Location	Current environmental class	Proposed environmental class
Birbir	Downstream of Birbir HP Dam	A	B
Geba	Downstream of Geba 1 HP Dam	A	B
	Downstream of Geba 2 HP Dam	A	B
Sor	Downstream of Sor HP Dam	A	B
Baro	Downstream of Baro 1 HP Dam	A	B
	Downstream of Baro 2 HP Dam	A	B
	Downstream of Genji HP Dam	A	B
	Downstream of Tams HP Dam	A	B
Gilo	Downstream of Gilo 1 Irrigation Dam	C	C
	Downstream of Gilo 2 Irrigation Dam	C	C
Alwero	Downstream of Abobo Irrigation Dam	C	C
	Downstream of Chiru Irrigation Dam	C	C
	Downstream of Dumbong Irrigation Dam	C	C
Sobat	Downstream of Nasir	C	C

28 The environmental flows were estimated using the RESDSS model developed by the Institute for Water Research (IWR) at Rhodes University South Africa (Hughes and Münster, 1999).•This model estimates what should be the environmental flow according to the natural flow regime. Depending on how much it seems acceptable to degrade the natural regime (Class A, B, C, etc.) the environmental flow requirements are more or less strict.

29 Class A refers to almost unmodified natural conditions; Class B to largely natural conditions with few modifications; Class C to moderately modified conditions.

7.2.3.2 Description of options tested

The options tested as part of the sensitivity analysis consist of different variants of Scenario 3b.

Table 7-5: Description of options tested as part of the sensitivity analysis

Option 3B-0	Option 3B-1
Option 3B-0 imposes the environmental flow requirements downstream of the Baro large-scale irrigation schemes (Gambella and Itang), rather than along the entire Baro River reach. This means that the **section of the Baro River between Tams Dam and the Itang large-scale irrigation scheme does not have an environmental flow restriction, and therefore higher releases can be made from Tams Dam during the dry season to reduce the irrigation deficit along the Baro River.** This option allows for Class A environmental flows in the upper Baro catchments and on the Baro River downstream of the Baro large-scale irrigation schemes, and Class C environmental flows in the Gilo, Alwero and Sobat catchments.	This option is a variation of Option 3B-0. Option 3B-1 is the improved irrigation water use efficiency option. Option 3B-0 applies a 50% water use efficiency across the entire study area, while Option 3B-1 **applies an improved water use efficiency of 60% for rice, 90% for vegetables and 70% for all other crops**. The irrigation return flows are assumed to remain at 10% for both options.
Option 3B-2	**Option 3B-3**
This option is a variation of Option 3B-0. Option 3B-2 **reduces the class of the environmental flows in the upper Baro catchments and on the Baro River downstream of the Baro large-scale irrigation schemes from Class A to Class B**.	This option is a combination of the Option 3B-1 and 3B-2 variations. **Improved water use efficiency** of 60% for rice, 90% for vegetables and 70% for all other crops is applied, and the class of the environmental flows in the upper Baro catchments and on the Baro River downstream of the Baro large-scale irrigation schemes is also **lowered from Class A to Class B.**

7.2.3.3 Results

The results of the sensitivity analysis are provided in the following tables. The results of the Baseline (Option 0) and Option 3B are included for comparison.

Table 7-6: Large-scale irrigation demand per sub-basin for fully developed scenario

Sub-Basin	Large-scale irrigation demand (billion m³/a)	
	Current irrigation water use efficiency (50%)	Improved irrigation water use efficiency (60-90%)
Alwero	0.621	0.470
Gilo	3.055	2.311
Baro	5.275	3.990
Sobat	1.109	0.772
Total	**10.060**	**7.543**

Table 7-7: Irrigation water use and deficit per sub-basin

Parameter	Irrigation Scheme	Option 0	Option 3B	Option 3B-0	Option 3B-1	Option 3B-2	Option 3B-3
Used Water (BCM)	Alwero	0.133	0.308	0.308	0.292	0.308	0.292
	Gilo	-	2.227	2.227	1.989	2.227	1.989
	Baro	-	1.205	3.407	3.285	3.407	3.285
	Sobat	-	0.735	0.740	0.569	0.74	0.569
	Total Used Water:	**0.133**	**4.475**	**6.682**	**6.135**	**6.682**	**6.135**
Deficit (BCM)	Alwero	0.043	0.270	0.270	0.139	0.270	0.139
	Gilo	-	0.550	0.550	0.078	0.550	0.078
	Baro	-	3.882	1.436	0.301	1.436	0.301
	Sobat	-	0.283	0.277	0.133	0.277	0.133
	Total Deficit:	**0.043**	**4.985**	**2.533**	**0.651**	**2.533**	**0.651**

Table 7-8: Percentage of large-scale irrigation demand satisfied per sub-basin

Sub-Basin	Option 0	Option 3B	Option 3B-0	Option 3B-1	Option 3B-2	Option 3B-3
Alwero	-	53%	53%	68%	53%	68%
Gilo	-	80%	80%	96%	80%	96%
Baro	-	24%	70%	92%	70%	92%
Sobat	-	72%	73%	81%	73%	81%

Table 7-9: Hydropower generation per hydropower scheme

Parameter	HP Dam	Option 0	Option 3B	Option 3B-0	Option 3B-1	Option 3B-2	Option 3B-3
Generated HP (Gwh/a)	Tams	-	5,225	4,245	4,269	4,633	4,658
	Birbir R	-	2,176	2,176	2,180	2,176	2,180
	Sor	42	72	72	72	72	72
	Geba 1 and 2	-	975	975	975	999	999
	Baro 1, 2 and Genji	-	2,798	2,798	2,798	2,798	2,798
	Total GWh/a:	**42**	**11,246**	**10,266**	**10,294**	**10,675**	**10,705**

Table 7-10: Change in wetlands' size downstream of irrigation schemes

Indicator	Wetland	Option 0	Option 3B	Option 3B-0	Option 3B-1	Option 3B-2	Option 3B-3
Average annual max surface area (km²)	Gambella Plains	6,023	4,433	4,405	4,593	4,405	4,593
	Sobat Wetlands	1,995	1,750	1,715	1,735	1,715	1,735
	Machar Marshes	5,303	4,288	3,519	3,642	3,517	3,640
Average annual min surface area (km²)	Gambella Plains	824	695	745	796	745	796
	Sobat Wetlands	541	540	540	540	540	540
	Machar Marshes	2,371	1,906	1,584	1,640	1,584	1,639
Average annual surface area amplitude (km²)	Gambella Plains	5,199	3,738	3,660	3,797	3,660	3,797
	Sobat Wetlands	1,454	1,210	1,175	1,195	1,175	1,195
	Machar Marshes	2,932	2,382	1,935	2,002	1,933	2,001

Table 7-11: Change in wetlands' size downstream of irrigation schemes (cells in red indicate that thresholds are overpassed)

Indicator	Wetland	Threshold	Option 3B	Option 3B-0	Option 3B-1	Option 3B-2	Option 3B-3
Change in average annual max surface area (%)	Gambella Plains	-15%	-26%	-27%	-24%	-27%	-24%
	Sobat Wetlands	-29%	-12%	-14%	-13%	-14%	-13%
	Machar Marshes	-17%	-19%	-34%	-31%	-34%	-31%
Change in average annual min surface area (%)	Gambella Plains	-37%	-16%	-10%	-3%	-10%	-3%
	Sobat Wetlands	-8%	0%	0%	0%	0%	0%
	Machar Marshes	-17%	-20%	-33%	-31%	-33%	-31%
Change in average annual surface area amplitude (%)	Gambella Plains	-11%	-28%	-30%	-27%	-30%	-27%
	Sobat Wetlands	-37%	-17%	-19%	-18%	-19%	-18%
	Machar Marshes	-16%	-19%	-34%	-32%	-34%	-32%

7.2.3.4 Discussion

RESULTS OF OPTION 3B-0

The main difference between Option 3B and Option 3B-0 is that Option 3B-0 has a significantly lower irrigation deficit for the irrigation along the Baro River. The percentage of large-scale irrigation demand satisfied along the Baro River **increases from 24% for Option 3B to 70% for Option 3B0**. This is due to that, in order to maintain the natural flow pattern of the Baro River between Tams Dam and the Itang irrigation scheme, Option 3B limits the releases made from Tams Dam during the dry season which leads to increased irrigation deficit. Option 3B-0 only maintains the natural flow pattern of the Baro River only downstream of the Itang irrigation scheme, and therefore higher releases can be made from Tams Dam to satisfy the irrigation along the Baro River. **Because more water is released for irrigation** from Tams Dam for Option 3B-0, the dam's water level draws down (which reduces the head), and the **hydropower generated is reduced from 5 225 to 4 245 GWh/a.** A **higher impact on the wetland areas** is also evident for Option 3B-0 because of the increased amount of water which is abstracted for irrigation compared to Option 3B.

RESULTS OF OPTION 3B-1

The main difference between Option 3B-0 and Option 3B-1 is that the improved irrigation efficiency used in Option 3B-1 leads to a significantly higher percentage of large-scale irrigation demand satisfied for all of the irrigation schemes in the study area. The total irrigation **water demand deficit for the study area drops from 2.53 to 0.65 million m^3/a** due to the improved irrigation efficiency. There is no significant impact on the hydropower generation because the water released for irrigation is still passed through the hydropower turbines before being used. The **improved irrigation efficiencies have a slightly positive impact on the wetland surface areas** due to the reduction in total irrigation demand on the system.

RESULTS OF OPTION 3B-2

Option 3B-2 gives almost identical results to Option 3B-0. The environmental flows, estimated at desktop level, provide minimum low-flows and minimum high-flows. The minimum low-flows do not change for different environmental classes, while the high-flows do change for different environmental classes. Although the environmental high-flows for Class A are higher than for Class B with a resultant increase in dam releases during the wet season, the increased environmental demand on the dams are negligible and do not significantly impact the long-term availability of water for irrigation. Furthermore, the environmental low-flows for Class A and Class B are the same and consequently do not impact differently on water availability during the dry season, when irrigation deficits occur. The small increase in hydropower generation for Option 3B-2 is due to the reduced environmental releases in the wet season, which allows the water level in the dam to increase and therefore the head to increase.

RESULTS OF OPTION 3B-3

Option 3B-3 gives almost identical results to Option 3B-1, because both of these options use improved irrigation water use efficiencies, and the change of environmental class has little impact (as explained in the section above).

7.2.3.5 Conclusions

The following can be concluded from this Sensitivity Analysis:

- Applying the environmental flow constraint on the Baro River directly downstream of Tams Dam has a highly negative effect on the percentage of irrigation water demand satisfied along the Baro River. Moving this environmental flow constraint downstream of the Itang irrigation scheme makes a significant improvement to the percentage of irrigation water demand satisfied along the Baro River (an increase from 24% to 70%), however, this negatively impacts on the wetland areas downstream of the irrigation due to more water abstracted from the system as a whole.
- Improving the irrigation water use efficiency has a positive impact on the percentage of irrigation water demand satisfied across the entire study area. This also has a positive impact on the wetland areas downstream of the respective irrigation schemes due to the decreased irrigation demand imposed on the system (a reduction from 10 to 7.5 billion m3/a demand).
- Reducing the environmental class from Class A to Class B for the upper and lower Baro catchments does not make any significant impact on wetland areas or irrigation supply. However, it does reduce the maintenance (high flow) component of the environmental flow release which could have potentially more severe ecological impacts.

As part of the IWRDMPlan implementation, the definition of a minimum wet season and dry flow should be designed at the various key nodes of the BAS according to the BAS specifities in terms of environmental and socio-economic water requirements.

7.2.4 Climate change

Given the paucity of the BAS climatic and hydrological data and the resulting important uncertainties on the modelling exercise, it is not relevant to introduce further uncertainties at this stage via the modelling of climate change. This is why this section only aims at presenting global future climatic trends on the BAS, potential associated risks and potential benefits from the IWRMDPlan.

SOURCES OF INFORMATION

Two sources of data were used to study climate change projections in the BAS:

- The “Climate Wizard” of the World Bank, available online on :
- The “Climate Change Knowledge Portal” of the World Bank, available online on *http://sdwebx.worldbank.org/climateportal/*

The 1st source compiles results from the 4th Assessment report. It has been used in this section to show a synthesis of climate change projections in the entire BAS on maps.

The 2nd source compiles more recent data (representative subset of the full CMIP5[30] distribution (Taylor et al. 2012) used by the Intergovernmental Panel on Climate Change (IPCC) in the 5th Assessment Report released in 2009). It shows the same trend but has been used to present more detailed results on 4 specific areas of the BAS. These detailed results are presented in Annex 7.

[30] CMIP5 is “the fifth iteration of a globally coordinated experiment collection which reflects different possible futures of distinct emissions, landuse change, and associated atmospheric radiative forcing.”(Metadata of the Climate change knowledge portal)

KEY RESULTS

A synthesis of the results of the various models (ensemble) has been extracted from the "Climate Wizard" and are presented below:

- Historical average temperature and rainfall in the BAS from 1961 to 1990 (see figure below);
- Projected change of average high temperature – projection from 2040 to 2055: Average high temperature are supposed to increase by around 2°C on the entire BAS area compared to the reference period 1986-2005 (see figure next page).

NB: Concerning average low temperature, an increase of around 2°C is projected on the entire BAS area.

- Projected change of total rainfall– projection from 2040 to 2055: Annual rainfall is deemed to increase in the South-eastern part and slightly decrease in the North-western part of the BAS compared to the reference period 1986-2005 (see figure next page). However, if this is highly hypothetic since individual climatic models (as presented in annex 7) show contrasting results (increase and decrease at the same location for the same period of the year).

Figure 7-8: Historical average high temperature and rainfall in the BAS from 1961 to 1990;

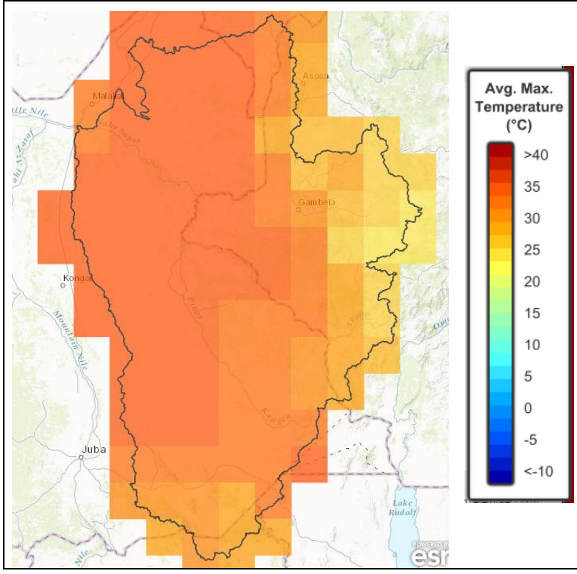
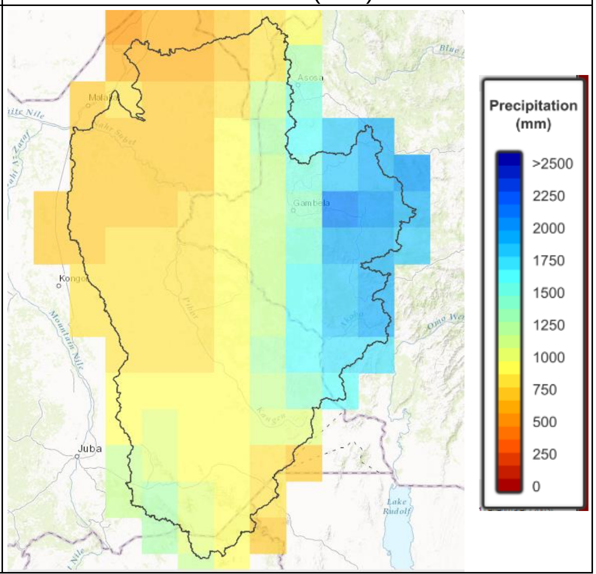
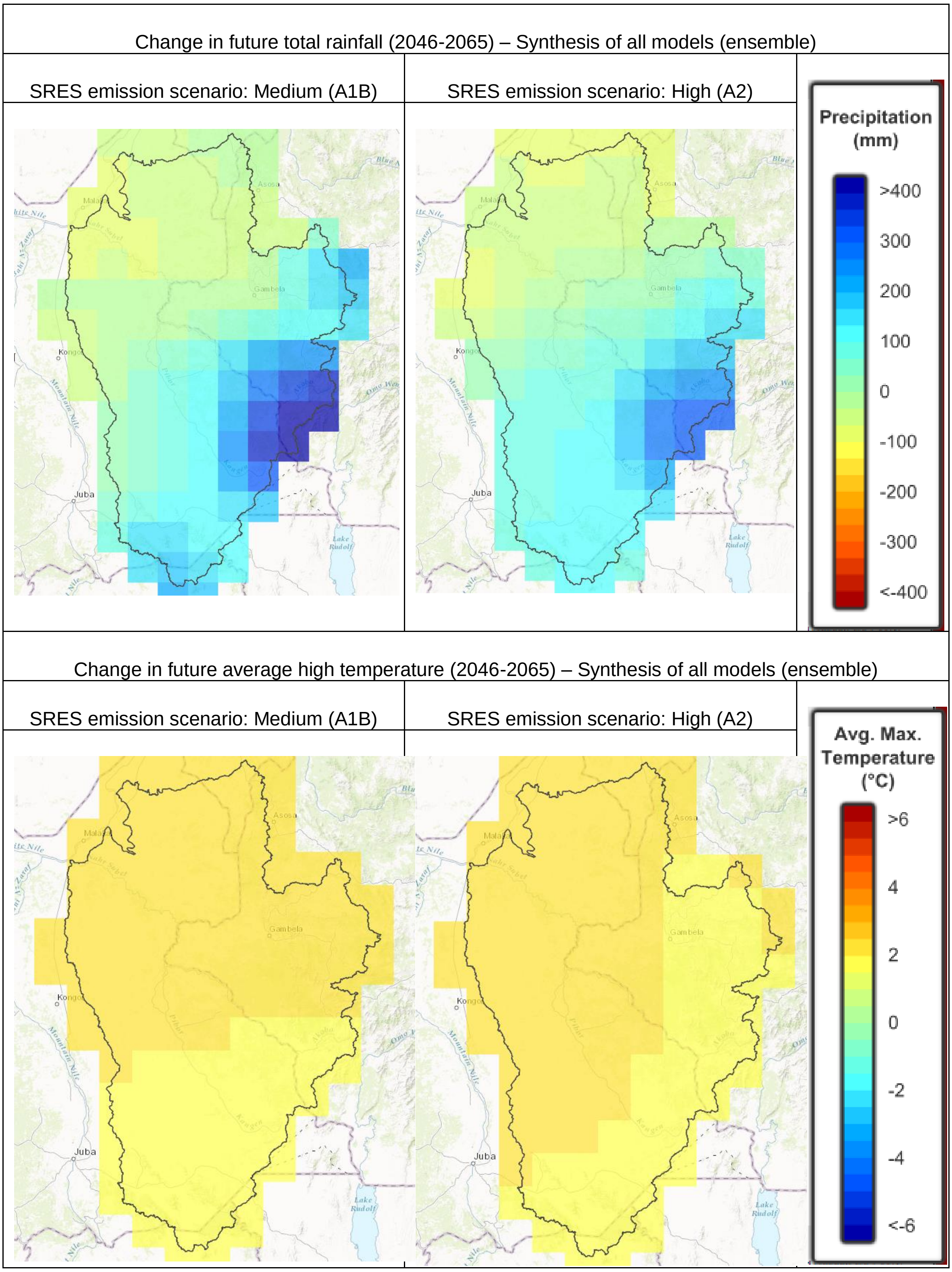
Historical average high temperature (1961-1990)	Historical average total rainfall (1961-1990)
Model: ensemble, SRES emission scenario: Medium (A1B)	Model: ensemble, SRES emission scenario: Medium (A1B)
	

Figure 7-9: Climate change projections: change in rainfall and temperature for 2046-2065 compared to 1986-2005



POSSIBLE IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES AND WATER USES

Impacts of higher temperature

As seen above, in the entire BAS area, the mean, maximum and minimum temperatures could increase from 0 to 2°C for the period 2040-2059 compared to the reference period 1986-2005.

Temperature increase could lead to increase the vulnerability of the existing water uses of the BAS (hypothesis with no change in rainfall patterns):

- Increase of evapotranspiration could negatively impact the production/yields of rain fed agriculture and increase the water demand for the irrigated agriculture.
- Increase of evaporation could negatively impact reservoirs, aquaculture ponds, but also the various wetlands of the BAS, whose size may then decrease faster during the dry season.

It should be noted that the temperature increase is projected to be higher in areas of the BAS where there are already issues during the dry season.

Impacts of change in rainfall

There is a very high level of uncertainty regarding rainfall as the results from the different models vary considerably.

Although the combination of the various models (ensemble) shows that total rainfall could increase in the South-eastern part and slightly decrease in the North-western part of the BAS, detailed monthly results presented in Annex 7 show this increase is likely to occur from September to January, that is to say during the beginning of the dry season. This could lead impact positively or negatively the cropping calendar in rainfed agriculture and potentially lead to a reduction of the irrigation demand during this period.

However, the decrease in total rainfall shown by the combination of the various models for the North-western part of the BAS could have negative effects since this area already face shortage of rainfall, increasing the risk of desertification of the northern lowlands of the BAS.

Impacts of extreme events

Effects of climate change on extreme events are still uncertain but are likely to lead to an increased occurrence of extreme events such as floods and droughts, to which the BAS is already confronted.

Possible benefits from the IWRDM Plan

The main potential positive contributions of the IWRDMPlan in tackling the above described risks can be summarized as follows:

- Implementation of an environmental monitoring system, which should also foster the implementation an early warning system (for droughts and/or floods) on the medium-term;
- Projects of dams in most efficient storage areas - where total rainfall are expected to increase (even if very uncertain) and where increase of temperature should be limited compared to other parts of the BAS –: improvement of storage capacity and ability to ensure access to water for vital needs during droughts.
- Interventions aimed at implementing (and supporting the implementing of) small-scale IWRM type projects at the local level. These interventions are “win-win” for both the communities who reap the benefits of best practices and enhanced climate resilience, and the environment. While the environmental benefits are localized at first, as the concepts are taken to scale through experience sharing, the environmental benefits can become highly significant.

However, climate change might exacerbate the potential negative effects of water development projects included in the IWRDMPlan (as detailed later in chapter 7). Some significant negative effects could also increase the vulnerability of the population and the ecosystems to climate change.

Need for acquisition of further information on uncertain factors

As soon as the environmental monitoring system will be implemented and the issue of the data paucity tackled it could be interesting to further investigate the potential impacts of climate change in the BAS, especially regarding:

- The potential effects on hydrology: this would require hydrological simulations including various climate change scenarios;
- The potential effects on agriculture: this would require plants growth simulations to assess the potential change regarding cropping calendar and yields. It would be also interesting to see whether projected future climatic conditions could benefit to existing and potentially new pests.

7.3 SOCIO-ECONOMIC DEVELOPMENT

Under the socio-economic development dimension, the following sub-dimensions are analysed in this section:

- Flood protection;
- Food security;
- Energy security;
- Employment;
- Access to water;
- Health.

7.3.1 Flood reduction

7.3.1.1 Impact overview

In the Baro Akobo Sobat basin, almost all river reaches located in the lowland part of the basin are prone to flooding. In the Gambella region, the main contributors to flood are the Baro, Akobo, Gilo and Alwero rivers. Severe flood damages have been recorded in Gambella and Itang town in 1988 (estimated to be equivalent of the 50-year flood). A recent study (Abaya et al, 2009) reports that flood frequency and magnitude has increased rapidly during the last decade in the Gambella region, mainly due to climate change and changes in land use, specifically deforestation[31]. The reported main impacts of flooding on human health were deaths, injuries, diseases such as malaria and diarrhoea and malnutrition (as a consequence of crop destruction).

On the contrary, floods with smaller recurrence intervals are deemed to be essential for pastoralism and wildlife.

In comparison to the baseline situation (scenario 0), all scenarios are expected to reduce the risk of flood as a result of the flow regulation resulting mainly from the development of hydropower dams.

Hydropower dam projects are located on the Baro river or on Baro tributaries (Geba river, Birbir river). Flood reduction will mainly occur on the Baro river reach located from Gambella town to around 80 km downstream of Gambella since downstream this point, the Baro river indeed spills to several floodplains, starting from Gambella plains and Machar Marshes further downstream. These areas behave as flood extension area and therefore protect downstream reaches of the Baro and Sobat rivers.

The flood risk will also be reduced further downstream on the Baro and Sobat rivers, as well as on the Gilo and Alwero rivers but the effect will be less significant.

<u>NB:</u> the hydropower potential identified on the upper Akobo river should also contribute to reduce the flood risk in the Gambella plains in Ethiopia but also in the Agwei catchment in South Sudan.

[31] Other studies in the region have shown that impacts on hydrology (peak floods and base flows in particular) are probably considerably more as a result of land use changes, specifically deforestation and poor farming practices in increasingly marginal farming areas

7.3.1.1 Scenario comparison

Changes of the wet season maximum monthly flows as given by the water resources simulation model are presented in Figure 7-11:

Figure 7-10: Areas of the basin which will benefit from flood reduction

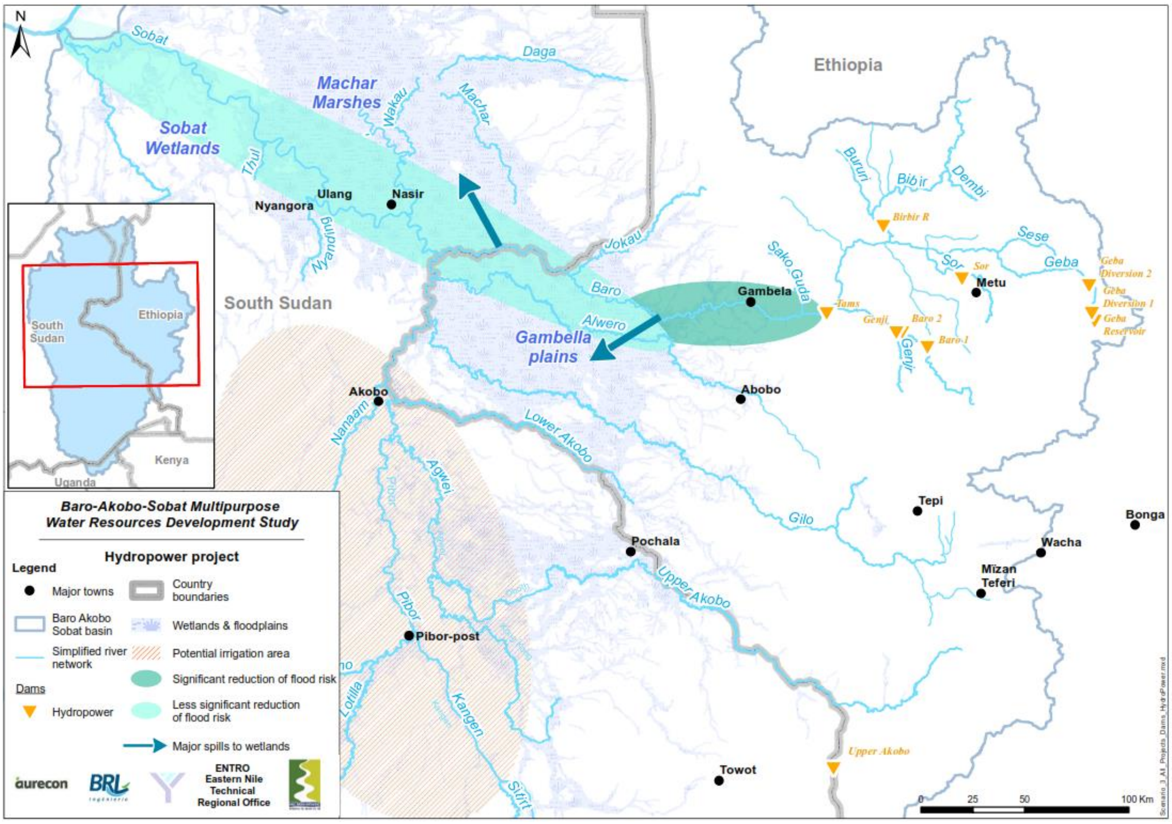
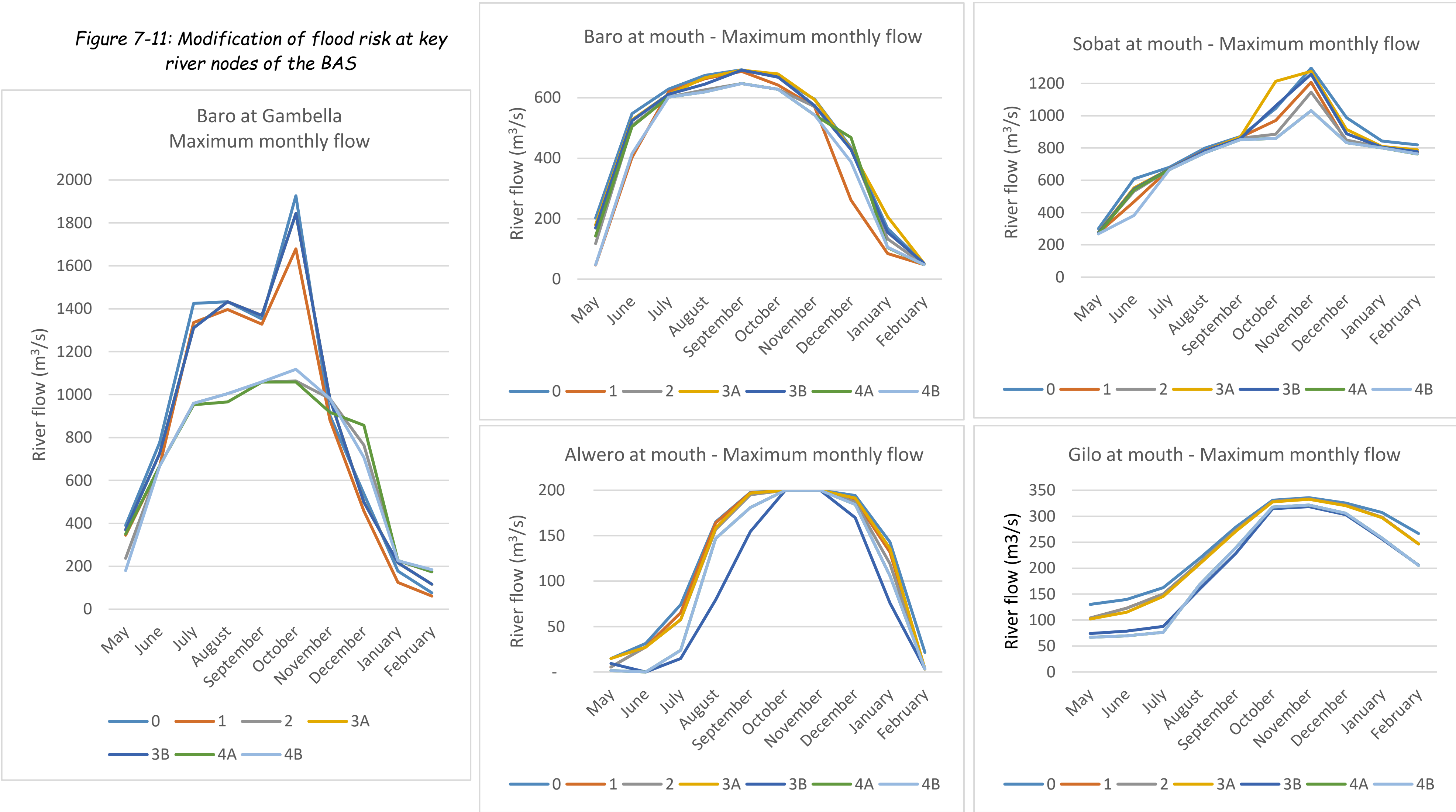


Figure 7-11: Modification of flood risk at key river nodes of the BAS



The figures above confirm that the main reduction of the flood risk is expected at Baro at Gambella.

The table below details the expected reduction of flood risk at Gambella compared to the baseline.

Table 7-12: Reduction of the flood risk at Gambella

Return Period	% Decrease in Flood Peak relative to Baseline at Gambella					
	Option 1	Option 2	Option 3a	Option 3b	Option 4a	Option 4b
20	11%	55%	13%	13%	55%	55%
50	11%	57%	15%	15%	57%	57%
100	11%	59%	17%	17%	59%	58%
200	11%	60%	19%	19%	60%	59%
Median of AMS	12%	47%	2%	2%	47%	47%

Source: Water resources model

Scenarios 2, 4a, and 4b have higher flood protection capacities since all hydropower dams projects are included **without any specific flood management releases**. Scenarios 3a and 3b also include all hydropower dams projects but include flood management releases. As a result the flood reduction is statistically minimized compared to scenarios 2, 4a and 4b. **In reality, scenarios 3a and 3b have the same capacity to protect Gambella from damaging since the difference only comes from dam operation rules**.

In Scenario 1, Birbir and Tams dams are not implemented. The comparison with the other scenarios shows that these dams play a major role in flood protection as a result of their large storage capacities.

7.3.1.2 Need for acquisition of further information on uncertain factors

Investigations will have to be conducted in order to ascertain the likely level of damage associated with floods of different return periods.

The current level of knowledge is indeed only based on the 1988 flood experience, reported in the Baro-Akobo Basin Master Plan Study (Selkhozpromexport, 1990) and the Baro-Akobo River Basin Integrated Development Master Plan Study (TAMS & ULG, 1997).

As such, **a flood risk mapping exercise is required to differentiate damaging floods from beneficial ones.** This should be **an early-implemented activity in the IWRDMPlan**. This information will be very useful to define the environmental flows requirements, something which has to be done as soon as possible.

NB: the hydrography and hydrology of the Akobo river is currently poorly known. Upstream of Poachala, the river seems to divide into the lower Akobo in Ethiopia and the Oboth in South Sudan. The identification of hydropower potential on the upper Akobo strengthen the need to put in place an overall environmental monitoring system in the BAS, especially on this transboundary area.

7.3.1.3 Enhancement and mitigation options

Only benefits are taken into account for this dimension. As such, no enhancement and mitigation options are identified.

7.3.1.4 Residual significance

Not applicable since no enhancement and mitigation options are identified.

7.3.2 Food security

7.3.2.1 Impact overview

In comparison to the baseline situation (scenario 0), all scenarios are expected to have a positive impact on food security from a long-term perspective as a result of:

- Increased food production through development of irrigation on existing agricultural land (small-scale irrigation schemes) and irrigation of additional arable land (large-scale irrigation scheme);
- Increased dairy and meat production due to forage production through the development of irrigation schemes and improved access to water around reservoirs;
- Increased fish production as a result of:
  - the development of capture fisheries in reservoirs,
  - the construction of fish ponds as part of irrigation development,
  - the development of aquaculture in rice irrigation schemes.

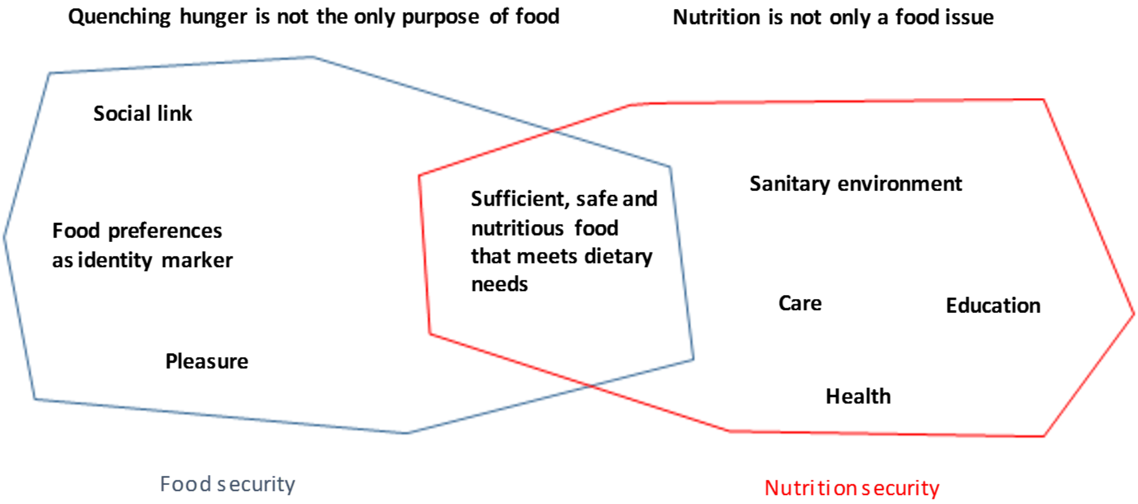
However, improved food production does not lead automatically to improved food and nutrition security. According to FAO, “food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (1996). This definition points to the following dimensions (Policy Brief, FAO, 2006):

- Food availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid).
- Food access: Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources).
- Utilization: Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. This brings out the importance of non-food inputs in food security.
- Stability: To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability can therefore refer to both the availability and access dimensions of food security.

The concept of nutrition security has always been related to food security but has been developed in the last fifteen years. FAO developed the following formulation in 2012 : *Nutrition security exists when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care.*

Those definitions form the concept of food and nutrition security which can be figured as below:

Figure 2-20: Food and nutrition security



Source: Adapted from N.Bricas, C, Aspe, CIRAD. 2013

Trends in several recent studies have highlighted that the development of irrigation can, in some cases, deteriorate food and nutrition security. Indeed, while the development of irrigation area can increase and diversify agricultural products, it can also modify the physical, economic and sociological environment. These changes can disturb, at least for a certain amount of time, the local environment and can interfere negatively in food and nutrition security.

For example, an increase of the agricultural income can negatively affect the nutrition security as a result of:

- Potential evolution of the others sources of income (decrease of the non-agricultural income for example) and thus a total income decreased compared to the pre-project situation;
- Non-food use of the extra income;
- Seasonal income (a low but regular income is more easily used for food than a seasonal income);
- A risk (dependence) in case of specialization in one crop in particular;
- …

By modifying the ecosystems and diminishing the resources dedicated to the food crops, the development of cash crops/commercial crops can affect the diet and increase the risk of deficiency in micro-nutrients.

Likewise, increasing the agricultural production can affect the nutrition as a result of the increase of the workload for the farmers.

Moreover the agricultural projects can deepen some inequalities by favouring for technical, political or economic reasons the largest farms.

In addition to the above quoted effects, water development can also negatively affect food security downstream of irrigation and hydropower projects as a result of:

- The reduction of natural fish production of wetlands and rivers: Laë, R & C. Levêque, (1999) in Zwarts et al, (2005) have showed that the annual fish production is correlated to the maximum inundated area in the main African floodplains. Regulation of rivers (araising from dam construction) will lead to a reduction of the maximum inundated area by reducing the peak flood;
- The reduction of productive land available for recession agriculture as a consequence of the reduction of inundation;
- The reduction of the forage and water resources for livestock as a consequence of floodplain and wetlands reduction;
- The conversion of existing ecosystems (savannahs, wetlands, forests, pasture lands) into reservoirs and irrigation schemes, depriving households of part of their current sources of food (bush meat, fishes, honey, roots, livestock).

These are all risks which have to be guarded against during implementation. The evaluation of food security in this analysis has assumed that these risks are appropriately sidelined.

NB: A detailed analysis showing case studies of social impacts of water developments, especially of hydropower and irrigation, on access to natural resources and consequently on food security is presented in Annex 8.

7.3.2.2 Scenario comparison

METHOD

In order to have a global picture on the effects on food security, the following effects have been taken into account:

- **The additional food production due to projects:** The potential additional food production from irrigation, development of fish farming and fisheries in reservoirs, and livestock development has been calculated and converted into kilocalories for each sub-basin and each scenario. The amount of kilocalories has been divided by the population of each sub-basin to assess the % of additional persons fed thanks to water development. *Additional food production is shown in green in the Figure 7-13.*
- **The losses of food due to negative impacts of projects:** A similar assessment has been conducted to calculate the reduction of food production by the ecosystems that will be impacted through project footprints and through changes to riverine ecosystem services (recession agriculture, fisheries in wetlands, pasture areas, …). *Reduction of food production is shown in orange in the Figure 7-13.*

The net results (additional food production – reduction of food production) are presented in Figure 7-12. It has been assumed that 70% of cereals and 70% of other cash crops will be exported.

RESULTS

Additional food production at the scale of the BAS

At the scale of the BAS, the additional food production due to projects is shown in the table below.

Table 7-13 : additional food production generated by projects

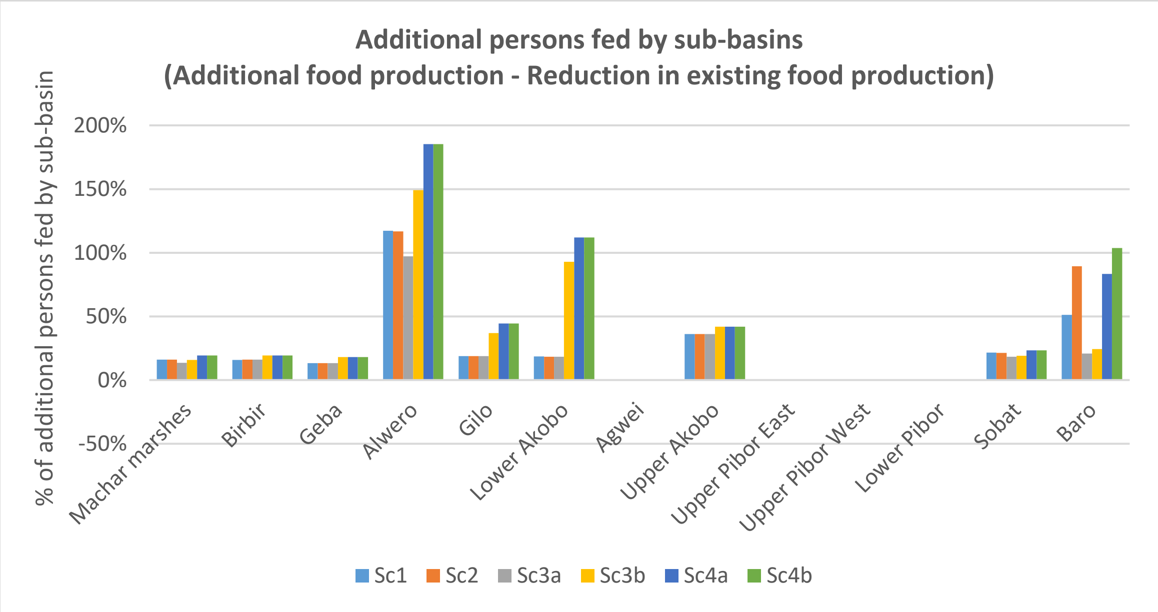
Tons / year	Sc 0	Sc1	Sc2	Sc3a	Sc3b	Sc4a	Sc4b
Meat	0	43 816	44 325	39 731	54 879	62 771	63 104
Milk	0	753 643	762 523	685 061	947 290	1 080 948	1 086 767
Fish	0	13 771	16 951	12 591	11 978	15 537	16 490
Cereals / rootcrops / fruits / bananas	0	1 484 668	1 706 891	1 214 727	1 623 296	2 166 488	2 283 770

Hypothetical net additional food available per sub-basins of the BAS

The analysis shows that all scenarios lead to significant increase of the food production in most sub-basins (see figure below).

However, no additional food production is expected in the Agwei, Upper Pibor East, Upper Pibor West and Lower Pibor sub-basins[32]. A reduction of the food available is even expected for all scenarios in the Lower Pibor sub-basin because of negative environmental effects resulting from upstream sub-basins (Gilo, Baro, and Alwero).

Figure 7-12: Additional persons fed by sub-basins – all scenarios



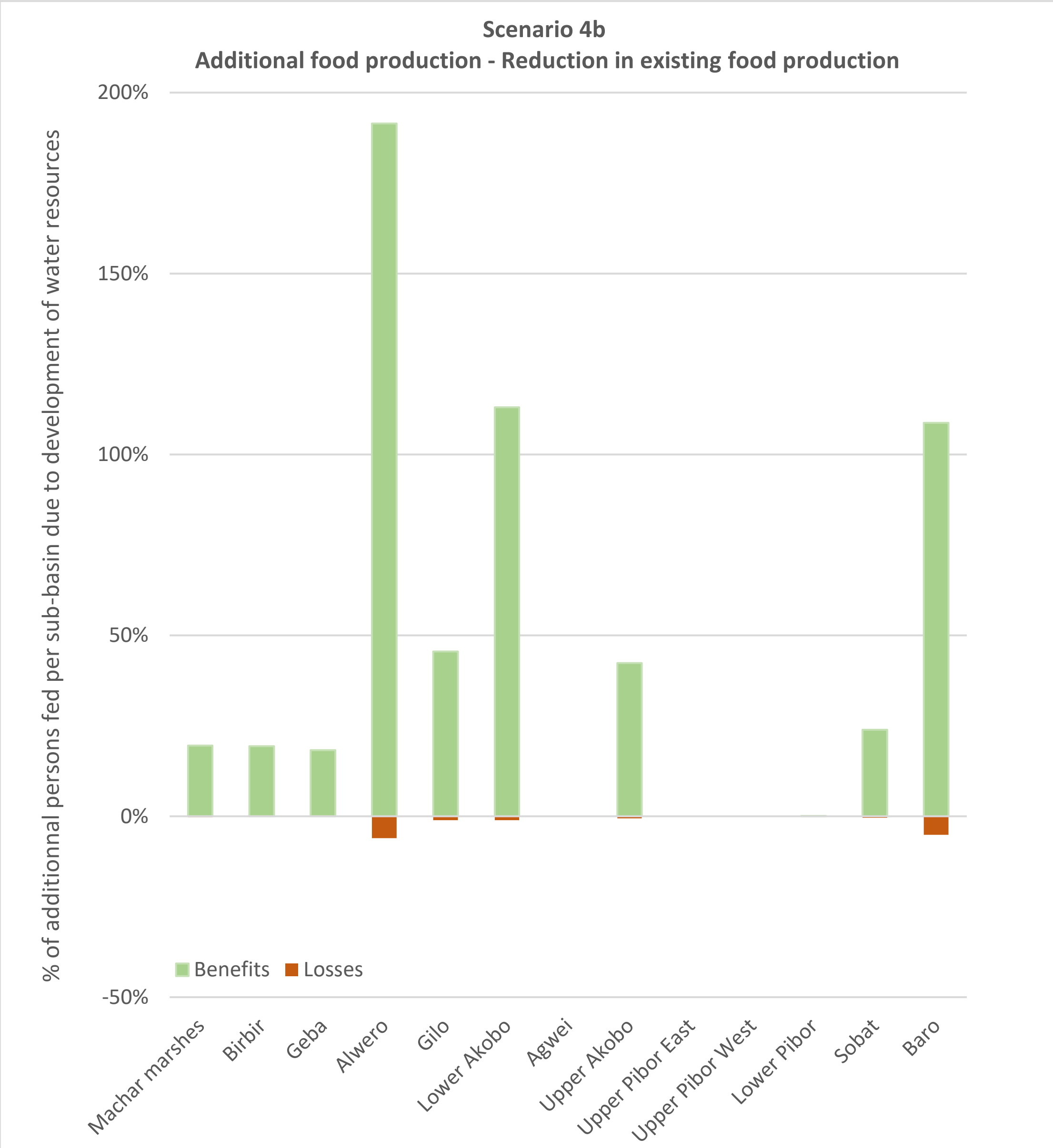
NB: The above results are based on cropping patterns, livestock and fisheries/aquaculture development hypothesis described as part of the Cost Benefit Analysis (Annex 5). One should note that cropping patterns hypothesis assume less non-food agricultural production in large-scale irrigation schemes than the investment type described in the leases of agricultural land to investors in Gambella region for Ethiopia and in Sobat region for South Sudan. The latest information is presented in section 7.5.1 of this report.

[32] The potential Akobo Multipurpose project would see the development of irrigation in the lower Pibor/Akobo area. This is not shown in this analysis

Looking at one scenario in particular, for example scenario 4b (see figure below), it appears that even in sub-basins where a significant increase of food available per capita is expected thanks to water development, a reduction of the food available from the existing resources is expected.

Even if this reduction is very small compared to the increase of food production due to projects, it stresses the fact that a degradation of food security is at risk, **especially for vulnerable populations who might not benefit from the overall increase of food production**. Generally, it can be said that pastoralist populations as well as shifting cultivators are more vulnerable to changes in land allocation and use than more sedentary populations. In addition, the poorest mainly rely on fish resources for protein intake and might therefore be especially affected by the potential reduction of fish resources related to the reduction of wetlands and changes in river flows.

Figure 7-13: Additional persons fed by sub-basins – detailed scenario 4b



At the basin (BAS) level, the total additionnal persons that can be fed for each scenario is presented in the table below. Again, these are estimates based on the considtent application of assumptions and rather highligh a potential than a direct contribution to food security.

Table 7-14: Additional persons fed at the scale of the BAS for each scenario

Net food production		Sc1	Sc2	Sc3a	Sc3b	Sc4a	Sc4b
Without export	TOTAL additional persons fed	2 405 718	2 683 907	2 009 661	2 727 186	3 525 706	3 677 535
	% of the BAS population 2056	15%	17%	13%	17%	22%	23%
With export	TOTAL additional persons fed	5 814 960	6 730 676	4 684 740	6 434 316	8 726 938	9 214 528
	% of the BAS population 2056	37%	42%	29%	40%	55%	58%

NB: Additional irrigation potential identified in South Sudan is not included in the above results. However, it can be said that this will lead to increase food production in the Agwei, Lower Akobo and Lower Pibor water catchments.

7.3.2.3 Need for acquisition of further information on uncertain factors

No specific needs have been identified.

7.3.2.4 Enhancement and mitigation options

ENHANCEMENT OPTIONS

In order to ensure that the significant increase in food production will lead to an increase of the food security, two types of enhancement measures have been identified:

- Inclusion of food security criteria into the IWRDMPlan such as:
  - the proportion (and type) of the food production to be dedicated to local market and to export;
  - the operating system of the irrigation schemes: small-holders, commercial farming, etc.
  - the enhancement of rainfed agricultural techniques to improve yields;
  - the enhancement of access to food.
- **Specific attention will have to be paid to food and nutrition security as part of irrigation project design.** An ex-ante evaluation questionnaire developed by the French agricultural research and international cooperation organization (CIRAD) has been tested on 41 projects of the French Development Agency (AFD). It aims to support the project promoters in their thinking regarding the potential impacts of projects on food and nutrition security. This kind of questionnaire is an interesting tool for supporting the design of a project. It aims to ask critical questions, pay particular attention to the food and nutrition security issues and thus to go over the commonly-used ideas. This questionnaire will be included in the Terms of Reference for MT/LT projects prepared in another component of this study.
- **The implementation of monitoring and evaluation systems dedicated to food and nutrition security.** Several guide books from NGOs, International entities or donors, are available. What must be kept in mind is the fact that despite an objective of ensuring food security in most part of the agricultural/irrigation projects, very few data regarding food and nutrition security are collected when a monitoring and evaluation system exists. The monitoring and evaluation of agricultural projects for their impact on household food insecurity and nutrition is important given the paucity of data documenting successes and failures in such projects, and because possible adverse effects in such projects need to be identified and addressed rapidly (Levinson 2011, Herforth et al. 2012).

MITIGATION OPTIONS

Commercial farming in South Sudan and to a large extent in Ethiopia does not focus on food crops, but rather on cash crops that can be processed and sold for profit on regional markets. In Ethiopia some foreign investors grow food for export to their home countries, for example in the Middle East and India. (Bossio et al.) describe this phenomenon in their article called: " Water implications of foreign direct investment in Ethiopia's agricultural sector.

Renegotiating the commercial farming agreements to ensure that sufficient food crop can be sold on local markets should significantly reduce risks of aggravation of food security around large-scale irrigation schemes.

Mitigation options identified to reduce the negative impacts due to project footprint and related to riverine ecosystem services are also valid here.

Cooperation between upstream and downstream sub-basins is also required to ensure that increase of food production will also benefit to sub-basins where no increase is expected.

7.3.2.5 Residual significance

The residual significance is linked to the farming system that will be put in place.

If enhancement and mitigation options are effectively implemented, the overall impact of all scenarios on food security is expected to be positive.

However, if farming systems to be put in place turn out to be similar to the type of crops described in the existing commercial leases in Gambella, residual effects on food security might remain significantly negative.

7.3.3 Energy security

7.3.3.1 Impact overview

Energy security can be seen as the association between economic development and the availability of natural resources for energy consumption to support a county's, area's or group's development. Access to affordable and sustainable energy has become essential to the functioning of societies and economies. However, the uneven distribution of and access to energy supply among and within countries and social groups has led to significant vulnerabilities

In addition to food, poverty is also defined by access to and use of sources of energy, which can vary in availability, cost, reliability and efficiency. The link between poverty, energy security and water is mainly through access and connectivity to electricity generated from hydropower.

Even where wood, charcoal, straw, grasses, cow dung, crop residues and other forms of biomass are available and accessible, the use of these forms of energy is time-consuming and requires considerable effort to obtain or process. This is a burden, especially for women who are the main collectors of firewood and other locally available sources of energy. The development of water infrastructure, **in particular, the generation of electricity from hydropower developments, has the potential to improve the livelihoods and productivity of the population in the Sub-basin by reducing energy dependence on charcoal, firewood and other forms of biomass**.

7.3.3.2 Scenario comparison

The table below shows the energy produced and the estimated proportion of the population with access to electricity for each scenario.

All scenarios lead to a significant increase of the energy production. Scenario 1 produces less energy than scenarios 2 to 4b because of the absence of Birbir and Tams dam which have both significantly higher installed capacity than the other dams.

Table 7-15: Energy production and % of the population with access to electricity for each scenario

Parameter	HP Dam	Baseline	Precautionary Principle		Compromise		Full Development	
		Sc 0	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Generated HP (Gwh/a)	Tams	-	-	5 594	5 225	5 225	5 624	4 749
	Birbir R	-	-	2 734	2 176	2 176	2 733	2 733
	Sor	42	88	88	72	72	88	88
	Geba 1	-	527	527	530	530	527	527
	Geba 2	-	487	487	445	445	487	487
	Baro 1	-	546	546	592	592	546	546
	Baro 2	-	1 685	1 685	1 601	1 601	1 685	1 685
	Genji	-	613	613	605	605	613	613
Total GWh/a:		42	3 946	12 274	11 246	11 246	12 303	11 428
% of the 2056 BAS population with access to electricity considering 20% of the energy produced is used in the BAS and 80% is exported elsewhere in Ethiopia and in the neighboring countries		0%	47%	146%	134%	134%	146%	136%

*<u>NB1:</u> The above table does not take into account the energy which could be generated through the Kinyeti multipurpose short-term project, and which has been assessed around **5.79 GWh/annum.***

<u>NB2:</u> Additional hydropower potential has been identified in South Sudan on the upper Akobo River. However, the current level of knowledge of the Akobo river hydrography and hydrology does not allow to quantitatively assess the hydropower production capacity at this stage. This assessment is planned as part of the priority actions of the IWRDMPlan.

7.3.3.3 Need for acquisition of further information on uncertain factors

No specific needs have been identified apart from the assessment of the hydropower potential on the upper Akobo.

7.3.3.4 Enhancement and mitigation options

ENHANCEMENT OPTIONS

Cooperation between upstream and downstream countries is required to ensure that the energy produced in upstream sub-basins will benefit to the entire Baro-Akobo-Sobat basin.

7.3.3.5 Residual significance

All scenarios are supposed to have a positive impact on energy security, especially scenarios 2 to 4b.

7.3.4 Employment

7.3.4.1 Impact overview

Hydropower and irrigation development will create direct and indirect jobs which is deemed to have a positive impact on employment and income:

- A large number of jobs would be created provided that a significant portion of the irrigation schemes are focused on food security, in-basin consumption and on-site agro-processing value adding activities. On average, it has been estimated that 0,3 direct jobs will be created per ha of developed irrigation scheme. In addition, approximately 80% additional indirect jobs would be created for upstream and downstream activities.
- Hydropower development is deemed to create around 0, 2 direct jobs per GWhour produced. In addition, it has been estimated that 3 additional indirect jobs will be created for every direct job.
- The development of fisheries in reservoirs and fish farming in irrigation schemes will also create jobs estimated at 3 direct jobs per ton of fish produced and 1 additional 1 indirect jobs for each direct job created.

Most of the jobs created by irrigation projects will be created around the projects areas. As such the positive impact on income will be much localized in the basin. However, indirect benefits such as the increase of livestock live weight and take-off rates should also have a more widespread positive impact on income even if it does not directly lead to job creation. Therefore in addition to the total job creation linked to projects, it has been estimated that additional 20% of jobs will be created in other sectors.

However, project footprints might have a negative impact on income around project areas by reducing the available land people use to earn from (even when offset measures will be implemented).

In addition, this might have an impact on the gendered division of labor, with possible additional workload for women and children. Important increased demand for labor can also encourage increased in-migration.

7.3.4.2 Scenario comparison

Around 80% of the jobs created will be created in Ethiopia and around 20% in South Sudan.

All scenarios lead to a significant number of job creation compared to a situation without projects. Full development scenarios will create more jobs than precautionary principle scenarios since they include more projects. Compared to Sc 2, Sc1 will create less jobs since Sc 1 does not include Tams and Birbir dams.

Table 7-16: Estimated number of jobs created for each scenario

Jobs creation		Precautionary Principle		Compromise		Full Development	
		Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Irrigation	Direct employment - Ethiopia	91 297	91 297	91 297	170 957	170 957	170 957
	Downstream indirect employment - Ethiopia	45 649	45 649	45 649	85 479	85 479	85 479
	Upstream indirect employment - Ethiopia	27 389	27 389	27 389	51 287	51 287	51 287
	Direct employment - South Sudan	51 584	51 584	51 584	52 792	52 792	52 792
	Downstream indirect employment - South Sudan	25 792	25 792	25 792	26 396	26 396	26 396
	Upstream indirect employment - South Sudan	15 475	15 475	15 475	15 838	15 838	15 838
Hydropower	Direct employment	19 520	61 160	61 160	61 160	61 160	61 160
	Undirect employment	58 560	183 480	183 480	183 480	183 480	183 480
Fish farming (ponds)		4 032	4 032	4 032	5 740	5 740	5 740
Fish farming (rice irrigation schemes)		159	159	159	256	256	256
Fisheries in reservoirs	Direct employment	1 359	1 730	1 730	1 730	1 730	1 730
	Undirect employment	1 359	1 730	1 730	1 730	1 730	1 730
Jobs creation in other sectors due to overall development		68 435	101 895	101 895	131 369	131 369	131 369
TOTAL - Ethiopia		**303 653**	**416 206**	**416 206**	**561 219**	**561 219**	**561 219**
TOTAL - South Sudan		**106 957**	**113 649**	**113 649**	**121 899**	**121 899**	**121 899**
TOTAL BAS		**410 610**	**529 855**	**529 855**	**683 118**	**683 118**	**683 118**

NB1: the above table does not take into account irrigation deficit which might lead to reduced irrigation area and commensurate reduced employment rates.

NB2: Additional irrigation and hydropower potential identified in South Sudan will also lead to important job creation even if this can't be quantitatively asssessed at this stage.

Using the estimated additional employment created by each scenario as shown in the previous table - whose social aspect is expressed as the demand for labour, an assessment of the likely distribution of the additional labor requirement has been undertaken. The following table presents a gender and age breakdown of how additional demand for labor in each scenario will possibly be met when treating the family as a labour unit.

Table 7-17: Hyptothesized distribution of labour by scenario

Labor Unit	Scenario					
	1	2	3a	3b	4a	4b
Adult male	211,092	358,726	358,726	420,031	420,031	420,031
Adult female	133,012	114,086	114,086	175,391	175,391	175,391
Child	66,506	57,043	57,043	87,696	87,696	87,696
Total	410,610	529,855	529,855	683,118	683,118	683,118

Note 1: Additional employment generated by hydropower development is assigned only to adult males
Note 2: A child labor unit is calculated at 0.5 of an adult labor unit.

Experience elsewhere, particularly in areas where formal irrigation has been introduced, but also in the case of fisheries, has shown that an additional workload is created for adult women and children to meet the additional demand for labour from these developments.

It can be seen from the above table that the hypothesized labor requirement for adult males in scenarios 3b, 4a and 4b is almost double that in scenario 1 and about one and a half times that required for scenarios 2 and 3a. It is unlikely that an increased demand for labor of this magnitude can be met from within the basin itself. In Ethiopia, these conditions provide a strong incentive for increased in-migration of labour from the more densely populated highlands.

In the case of South Sudan, it is likely that it will be extremely difficult for the additional demand for labour with sufficient knowledge and skills to be met, especially when considering the displacement of large numbers of people due to ongoing conflicts, It therefore seems reasonable to assume that in the case of South Sudan, there will be strong barriers to meeting the potential additional demand for labour created by the development of water resources, which is likely to result in an even higher workload for women and children with its associated adverse social and health impacts. This situation can provide a strong incentive for having larger families (i.e. more children as addition to the family's labour force) - and even polygamy.

7.3.4.3 Need for acquisition of further information on uncertain factors

No specific needs are identified concerning employment.

7.3.4.4 Enhancement and mitigation options

ENHANCEMENT OPTIONS

Training and employment of local staff will have higher benefits and is therefore recommended.

7.3.4.5 Residual significance

Considering that the majority of job created will be local jobs, the impact of all scenarios is significantly positive.

7.3.5 Access to water

7.3.5.1 Impact overview

Access to water for humans, animals and useful plants is one of the most obvious and important determinants of poverty, particularly for the sub-dimensions of food security, incomes and human health. An increase in the quantity of water in an area alone as a result of the development of water infrastructure for water supply, irrigation and hydropower can have positive effects on the amount of water used for human consumption, livestock watering and other productive purposes as well as personal hygiene and sanitation.

Access to water is equally, if not more important for the maintenance of livestock herds, which are important for the livelihoods, social status, payment of bride price and sources of milk and meat and cash in lean times. Therefore, it is important that water supply for domestic use and sanitation and livestock watering are included as components of water development. Boreholes fitted with hand pumps which use groundwater are an appropriate solution for improving access to safe drinking water in rural and peri-urban area, provided that due attention is given to water quality. Water quality issues include the presence of salt, fluoride and nitrates in groundwater as well as biological contamination from human and animal activity at or near the borehole.

The introduction of water infrastructure such as dams and associated reservoirs can have adverse impacts by inundating traditional sources of drinking water and water for livestock. In addition, access to reservoirs may be restricted for certain uses. Also, upstream water storage can affect the water available for downstream uses if not properly managed. In order to comprehensively compare access to water, the two following aspects are analysed for each scenario:

- The overall storage capacity of the BAS (section below);
- Access to water for social groups of the BAS (section below). This includes hydrological and footprints considerations developed respectively in sections 7.4.1 and 7.5.1 of this report (Changes to hydrological regimes affecting instream flows / the river system itself and Physical and economical displacement).

7.3.5.2 Scenario comparison

STORAGE CAPACITY

Table 7-18: Total storage capacity of each scenario

Scenario	Total storage capacity (BCM)
Scenario 0	0.1
Scenario 1	8.2
Scenario 2	20.9
Scenario 3a	20.9
Scenario 3b	20.9
Scenario 4a	20.9
Scenario 4b	20.9

The table opposite shows the storage capacity of the combination of dams for each scenario.

All scenarios lead to a significant increase of the storage capacity. Scenario 1 has a lower storage capacity than scenarios 2 to 4b because of the absence of Birbir and Tams dams. The above described increase should lead to as improved access to water resources around reservoirs. However, since all scenarios lead to a significant reduction of the dry season river flows (except for Baro at Gambella), the access to water downstream water infrastructure could be problematic (see section below and section 7.4.1 for a detailed analysis).

<u>NB$_1$:</u> The above analysis does not take into account the relatively minor storage capacity of the Kinyeti multipurpose project and other existing small storage schemes, which is deemed to be around 45 million m^3.

<u>NB$_2$:</u> The storage capacity resulting from the hydropower potential identified on the upper Akobo river in South Sudan cannot be quantitatively assessed at this stage

ACCESS TO WATER FOR SOCIAL GROUPS OF THE BAS

NB: The analysis presented below is mainly based on existing local case studies of social impacts of developments on access to water. These case studies are detailed in Annex 8. The analysis presented below also integrates hydrological and footprints considerations developed respectively in sections 7.4.1 and 7.5.1 of this report (Changes to hydrological regimes affecting instream flows / the river system itself and Physical and economical displacement).

The analysis presented in the table below aims at:

- Assessing the risks of interruptions in or increased competition over access to water for productive and other purposes associated with the scenarios;
- Assessing the associated degree of social risk of conflicts and displacement arising from changes of access to water for social groups of the BAS.

Table 7-19: scenarios' impact on access to water for social groups of the BAS

Scenario	Description	Risks of interruptions in or increased competition over access to water	Associated risks of conflicts
1	Reduced irrigation areas (small-scale and large-scale) with no encroachment on environmentally sensitive areas. Irrigation dam storage reduced to account for the reduction in irrigation water demand. All hydropower dams included except Tams Dam and Birbir.	Hydropower located in the Ethiopian highlands where there is already high population density and pressure on arable land. Access to rivers and reservoirs and flows are likely to be affected. Pastoralists are likely to experience problems in accessing traditional water sources and grazing areas for their livestock. Estimated involuntary resettlement of 124,319 people who are likely to experience interruptions in access to water for productive and other purposes.	The Omo, Nuer and other pastoralists and shifting cultivators in western Oromia, SNNPR, eastern Gambella and in the Akobo-Pibor area in Jonglei State are likely to experience interruptions in access to water and increased conflicts with sedentary farmers and government, but on a smaller scale than in the other scenarios. Displaced people are likely to experience conflicts with host communities and government, but on a smaller scale than in the other scenarios.
2	Full development of irrigation with reservoirs to provide storage. All potential hydropower dams included, also Tams and Birbir.	An estimated 126,190 people are to be resettled who are likely to experience serious interruptions in access to water for productive and other purposes. For pastoralists such as the Nuer, Murle, Omo, Bari, Toposa and others even when water for livestock is considered, access to grazing, pasture and fodder is equally necessary and important. Control of flooding along the Baro and Akobo rivers in Gambella could have implications for the productivity of recession agriculture practiced by the Anuak and Nuer.	This scenario has a high risk of escalating insecurity and displacement of people in Jonglei State who will become IDPs and refugees in Gambella. Conflicts between already competing ethnic groups over access to water and between displaced people, host communities and government are likely to intensify. Populations around reservoirs may also lead to conflict regarding access to reservoirs for watering livestock. Reservoirs may also attract herders and pastoralists to the area, thereby increasing competition and conflicts between groups.
3a	Full development of irrigation with reservoirs for storage. Environmental water releases from all dams to conserve natural flows.	Same as above. An estimated 126,190 people to be resettled who are likely to experience interruptions in access to water for productive and other purposes.	Same as above, except that environmental releases from dams will provide more water and better sustain the ecosystem for downstream users.
3b	All potential hydropower schemes included. Tams Dam operated to maximise hydropower production. All future small-scale and large-scale irrigation schemes included. Environmental water releases from all dams to conserve natural flows	Estimated resettlement of 178,241 people who are likely to experience interruptions in access to water for productive and other purposes. See also description of social issues under Scenarios 4a and 4b below.	Same as above, but with a larger area and number of people displaced and affected and a higher risk of conflicts of displaced people with host communities and with government.
4a	All future small-scale and large-scale irrigation schemes included. All identified potential hydropower schemes included. Tams Dam operated to maximise hydropower production.	The potential large-scale irrigation scheme identified in the Akobo-Pibor area has a very high risk of causing more serious and disruptive conflicts between the pastoral Nuer and sedentary Anuak and possibly also the Murle. Estimated resettlement of 178,241 people who are likely to experience serious interruptions in access to water and grazing areas.	Similar to Scenario 3b, but with a higher impact on downstream users and higher risk of escalating conflicts between already competing ethnic groups due to reduced access to water and grazing areas for livestock for pastoral groups, e.g. Nuer, Murle and Toposa.
4b	All small-scale and potential large-scale irrigation schemes and potential hydropower schemes included. Tams Dam operated to optimise irrigation and flood control.	Estimated resettlement of 178,241 people who are likely to experience serious interruptions in access to water and grazing areas. Decrease in flooding at Gambella may have implications for soil fertility and therefore the productivity of recession agriculture and the replenishment of marshes and wetlands which provide water for livestock and other important livelihood resources, especially for the pastoral Nuer	Same as above, but with more positive impact for downstream irrigated farms. Control of flooding could have adverse impacts on the productivity of recession agriculture practiced by the Anuak, Nuer and other groups.

NB: Implementation of the Upper Akobo HP dam and reservoir, and the Akobo-Pibor irrigation scheme will have a high risk of reducing access to water and seasonal grazing areas for livestock for the pastoral Nuer and thereby fueling already existing ethnic and political conflicts between the pastoral Nuer, Dinka and Murle in Jonglei State in South Sudan and the sedentary Anuak in the Gambella Region in Ethiopia.

7.3.5.3 Need for acquisition of further information on uncertain factors

No specific needs have been identified.

7.3.5.4 Enhancement and mitigation options

MITIGATION OPTIONS

See mitigation options developed in section 7.4.1 (changes to riverine ecosystem services).

7.3.5.5 Residual significance

See residual significance identified in section 7.4.1 (changes to riverine ecosystem services).

7.3.6 Health

7.3.6.1 Impact overview

In comparison to the baseline situation (scenario 0), all scenarios are expected to have a positive impact on health from a long-term perspective.

Health improvement should indeed mainly come from:

- **Improvement of food security,** as a consequence of irrigation, fisheries and aquaculture development. However, it has been shown in section 7.3.2 that raising food production does not systematically lead to raising food security for many reasons. It has also been shown that the conversion of existing ecosystems due to project footprint will reduce access to natural resources people used to rely on for food and that changes to hydrological regimes will have a significant negative impact on downstream water-related food resources such as fish, grass and water for livestock. These negative impacts might essentially affect vulnerable populations. The poorest indeed mainly rely on fish resources for protein intake.
- **Development of infrastructure** (roads, schools, hospital), as a consequence of water development (especially electricity production) which should indirectly lead to better access to health services and improved awareness of basic hygiene rules.
- **Improvement of access to water**: the development of dams will increase water storage and therefore water availability until the end of the dry season at the dam location. The improvement is expected especially in the lowland areas, on Alwero and Gilo rivers. However, significant improvement of access to improved water sources does not only depend on water availability and rely on adequate development of water supply infrastructure. A detailed analysis about access to water is provided in section 7.3.5.
- **Reduction of flood risk**: the development of dams on the Baro, Gilo and Alwero river is expected to reduce the occurrence of damaging floods, especially in the area of Gambella town which is regularly prone to floods. Inundation of downstream areas like Gambella plains, Machar Marshes and Sobat wetlands is also likely to decrease. A detailed analysis about access to water is provided in section 7.3.1.

Although important benefits are expected from water development concerning health issues, water development is also associated with several risks, including:

- **Drowning into irrigation canals**: this risk is potentially highly significant in areas around irrigation schemes. Head, primary and secondary canals have usually high water velocity. When canals are lined, it is almost impossible to get out of water up to the other bank. Therefore, head primary and secondary canals are indeed deemed to be very dangerous for people, especially for children, as well as for livestock and wildlife. All in all, large-scale and small-scale irrigation projects include around 1350 km of head, primary and secondary irrigation canals.
- **Drowning into rivers**: Crossing rivers is essential as per of people daily movement, pastoralism activities, wildlife migration, etc. In the lowland areas of the basin, most rivers can be usually crossed during the dry season. The development of hydropower dams on the Baro river will lead to higher flow during the dry season and will impede or hinder river crossing, with potential risks of drowning (see section 7.4.1 which presents changes to dry season flows). This risk is located on the Baro river on around 80 km downstream Gambella town. In addition to increasing average flow during the dry season, hydropower dams peak releases will lead to fast and immediate increases of water levels which are additional risks of drowning.
- **Water quality degradation**: The development of irrigation is deemed to increase use of fertilizers and their flushing into the river systems. Further degradation of the water quality is expected from dam development. Operational water treatment and its adequate delivery are very rare in the basin. People indeed mainly use rivers and wetlands as sources of drinking water. This is why a degradation of the water quality can have direct negative impacts on the health of the BAS population located downstream of irrigation schemes and dams. A detailed analysis about water quality is provided in section 7.6.
- **Development of water-borne diseases**: Development of water-borne diseases in irrigation schemes occurs when drainage systems are not sufficiently cleaned leading to the development of aquatic vegetation and stagnant water.

7.3.6.2 Scenario comparison

Each of the above described factors affecting health are assessed in the table next page. A detailed analysis of these factors is provided in dedicated sub-dimensions.

Table 7-20: Effects on health for each scenario

Factor impacting health	Indicator	Baseline	Precautionary principle options		Intermediate options		Full development options	
	Qualitative comparison	Sc. 0	Sc. 1	Sc. 2	Sc. 3a	Sc. 3b	Sc. 4a	Sc. 4b
Improvement of food security	Additional food production		+	++	++	++	++	++
Development of infrastructure	Electricity production (GWh/a)	42	3 946	12 274	11 246	11 246	12 303	11 428
			+	++	++	++	++	++
Improvement of access to water	Around reservoirs		+	++	++	++	++	++
	Downstream of reservoirs except for the Baro at Gambella		-	-	-	-	- -	- -
Reduction of flood risk	% Decrease in Flood Peak relative to Baseline at Gambella (flood of return period of 50 years)	0%	11%	57%	15%	15%	57%	57%
			+	++	+	+	++	++
Drowning into irrigation canals	Additional main irrigation canals (km)	0	853	853	853	1356	1356	1356
			- -	- -	- -	- -	- -	- -
Drowning into rivers	Increase of flows during the dry season (average monthly flow from Dec to May (m^3/s)) for Baro at Gambella	75	52	166	89	89	133	187
	Additional hydropower dams (risk of peak releases)	0	4	6	6	6	6	6
			-	-	- -	-	- -	- -
Water quality degradation	[N] in water bodies (mg/L)		-	-	-	- -	- -	- -
Development of water-borne diseases	Net irrigated surface area (ha)	128 092	554 870	554 870	554 870	756 076	756 076	756 076
			- -	- -	- -	- -	- -	- -

7.3.6.3 Need for acquisition of further information on uncertain factors

Please refer to information acquisition needs required for the sub-dimensions linked to health.

7.3.6.4 Enhancement and mitigation options

ENHANCEMENT OPTIONS

Please refer to enhancement options required for the sub-dimensions contributing to health improvement.

MITIGATION OPTIONS

The options presented in this section are specific to health. However mitigation options required for the sub-dimensions affecting health will also be necessary to reduce the overall negative impact on health.

Above all, **health monitoring** is required, especially around reservoirs and irrigation schemes.

Minimization options to reduce risks of drowning in canals include:

- Prohibition of access to canals to avoid crossing;
- Restoration of access by constructing bridges (minimum one bridge each km).

Minimization options to reduce risks of water-related disease around reservoirs and irrigation schemes include:

- Elaboration and implementation of water supply and sanitation management plans around irrigation schemes to prevent contamination of water bodies with faeces and to ensure supply of safe and clean;
- Operational drainage system, managed to avoid stagnant water and allow regularly fluctuating water levels, periodic rapid drying of irrigation canals;
- Removal of aquatic plants that vectors feed on, introduction of aquatic plants that repel vectors;
- Lining canals with plastic and concrete, combined with flow velocity beyond 0.3-0.4 m/s;
- Varying water level in reservoirs to prevent malaria: faster drawdown of the reservoir at the end of the wet season was found to dry out puddles long reservoir shores, leaving the larvae high and dry.

7.3.6.5 Residual significance

The implementation of enhancement and mitigation options should significantly improve benefits and reduce risks to health whatever the scenario. In any case, the enhancement and mitigation options will have to be adapted over the projects life according to the results of health monitoring.

7.4 CHANGES TO RIVERINE ECOSYSTEM SERVICES

7.4.1 Changes to hydrological regimes affecting instream flows / the river system itself

7.4.1.1 Impact overview

The main physical changes affecting instream flows and its social and environmental risks are listed below:

- At intra daily scale: water abstractions in the river or water releases from dams is likely to affect the hydrology directly downstream the infrastructure, especially during low flows, resulting in rapid flow increase or decrease, compared to natural conditions. These rapid flow disturbances can have the following environmental and social implications:
  - Fish mortality;
  - Loss of habitat for aquatic species;
  - Loss of fish diversity.
- At the monthly / annual scale, water developments are likely to affect the hydrology downstream in the basin and outside the BAS (White Nile and Nile river). These changes can have the following environmental and social implications:
  - Loss of connection with aquatic extensions/wetlands and related loss of breeding areas, impoverishment of genetic diversity of aquatic species;
  - Loss of spills to wetland (addressed in the category “Changes to hydrological regimes affecting aquatic extensions/wetlands”);
  - Loss of aquatic habitat and related loss in fish and other aquatic species biodiversity;
  - Loss of riparian habitat;
  - Loss of water resources for wildlife during the dry season and potential related change of migration routes;
  - Modification of water availability for downstream uses such as: domestic water supply, livestock watering, small-scale irrigation;
  - Modification of the navigable period;
  - Modification of the flood extension (addressed in the dimension “Socio-economic development”);
  - Modification of the hydrology downstream the BAS, through the modification of the contribution of the BAS to the White Nile and the Nile and potential related conflicts with the countries downstream.

7.4.1.2 Scenario comparison

The evolution of the river flows in the different scenarios at five gauging stations monitoring the main tributaries of the basin, from upstream to downstream: Baro at Gambella, Baro at mouth (with Sobat), Gilo at mouth with Akobo, Alwero at mouth with Akobo, Sobat at mouth with White Nile. The river flows for each scenario are featured in hydrographs in Figure 18. The hydrological impact of each scenario has been assessed using a number of parameters:

- Impact on navigability;
- Impact on water availability for downstream uses based on the duration of the severe low flow period and the average monthly flows during the low flow period;
- Impact on intra-annual flows and related ecosystems perturbations.

NB: The results below do not include the additional irrigation and hydropower potential identified in South Sudan. Without presuming the results of a complementary modelling exercise that will have to be conducted as part of the IWRMDPlan implementation, some qualitative findings can still be drafted and have been included at this stage:

- A hydropower dam on the upper Akobo would regulate flows of the Upper Akobo and especially lead to a reduction of wet season flows and higher dry season flows. Depending on the spill rules (not known at this stage, since the project is entirely conceptual), this effect could be seen either on both lower Akobo (Ethiopia) and the Oboth (South Sudan) or affect more one river branch. Change in distribution between the two branches is indeed a potential effect.
- Development of irrigation on the Akobo/Pibor area will lead to a reduction of the dry season minimum flow of the Pibor and or the Akobo depending on the location of the water abstraction. Impact on dry season flow could be minimized and irrigation supported by adequate releases from the upper Akobo hydropower dam. However, this would still lead to a reduction of the flow reaching the Pibor at its confluence with NB2the Baro and ultimately the Sobat.

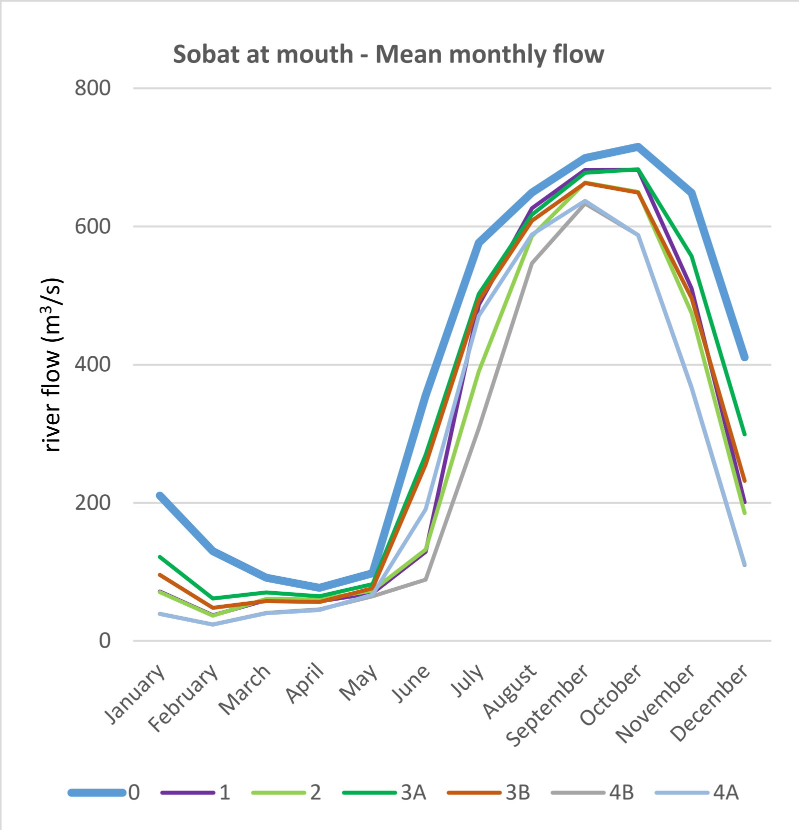
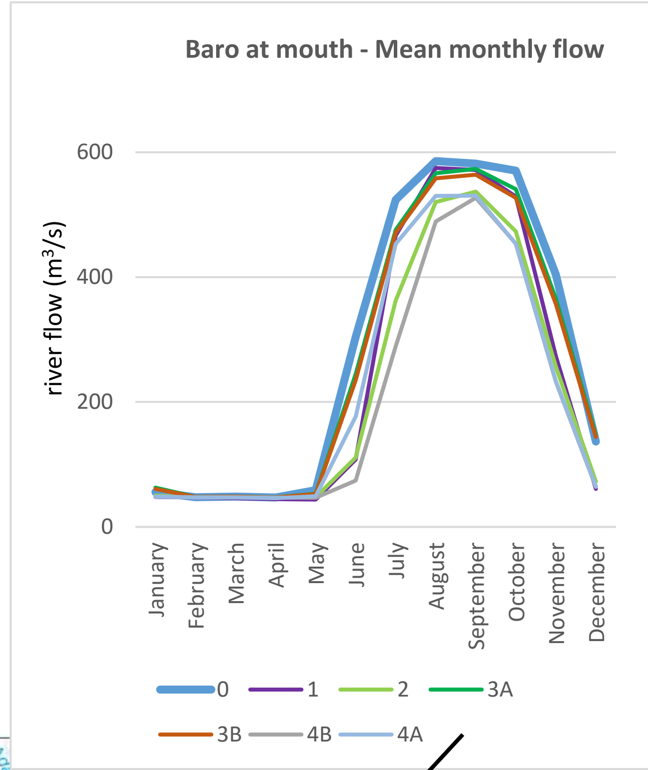
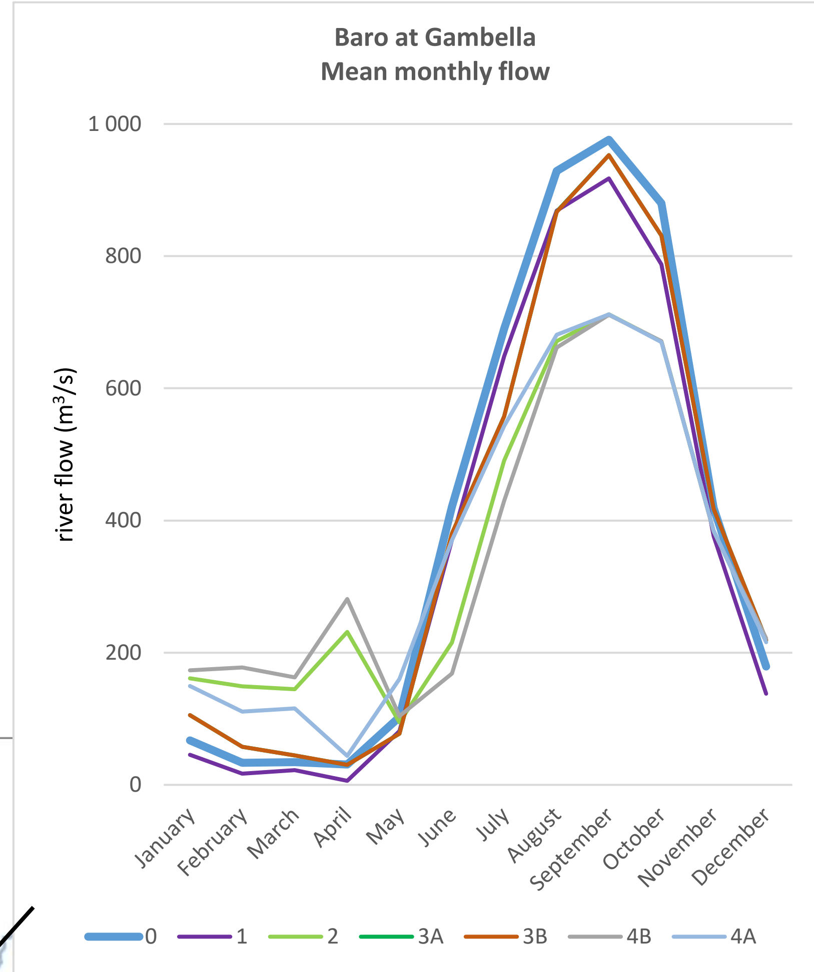
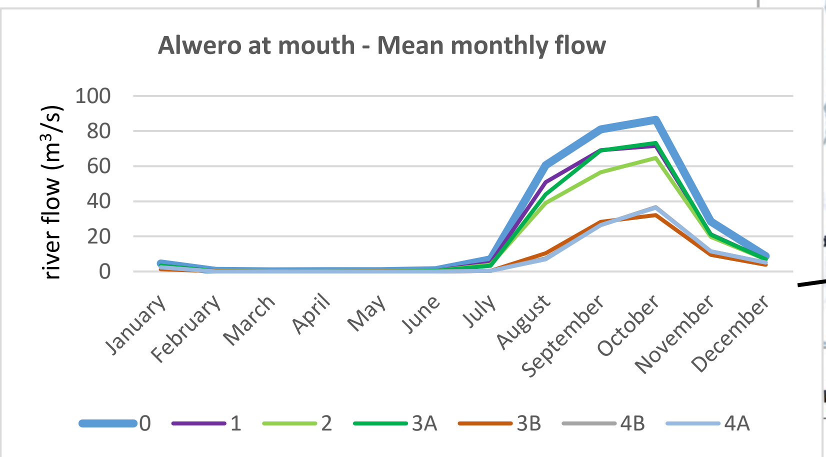
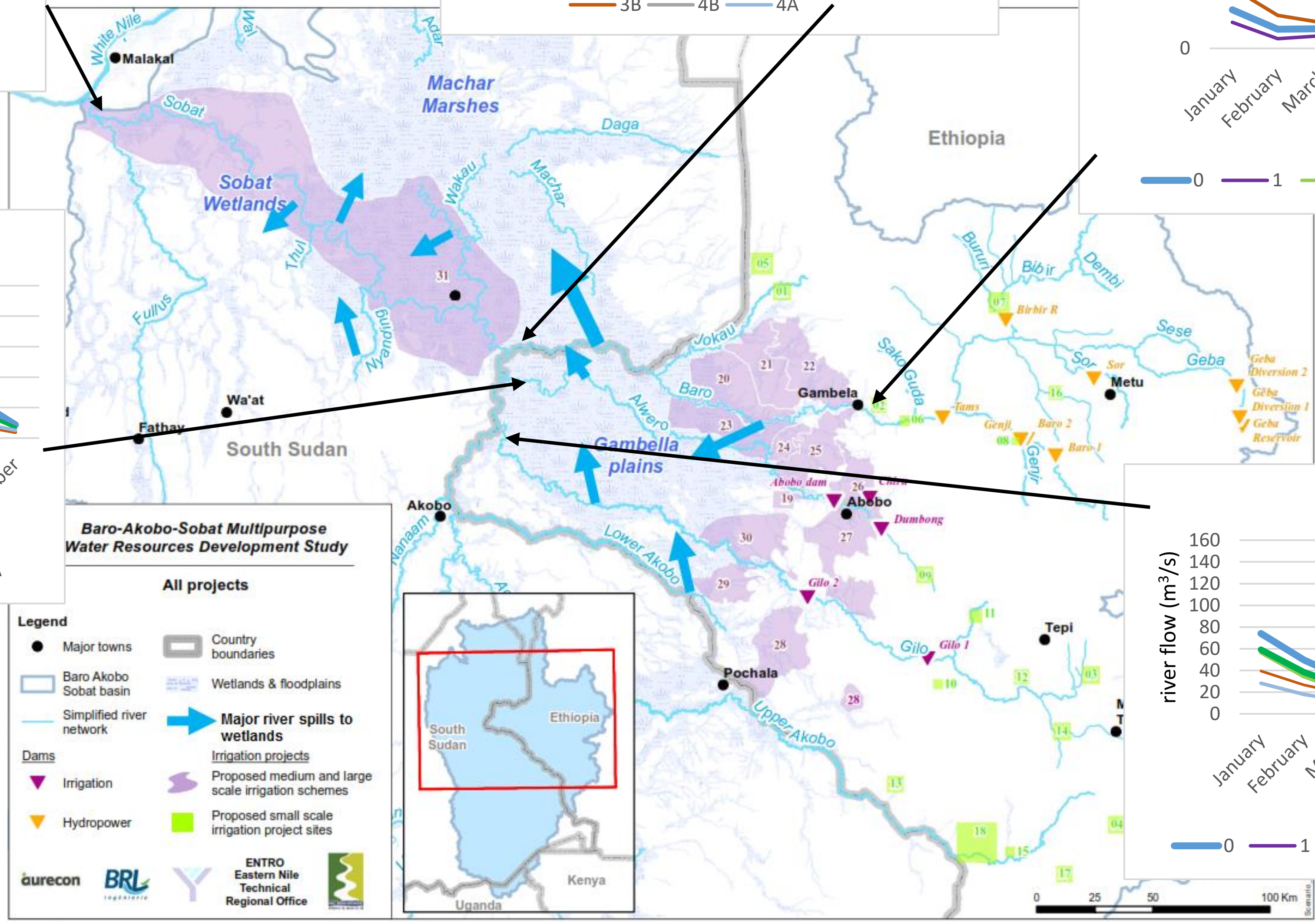


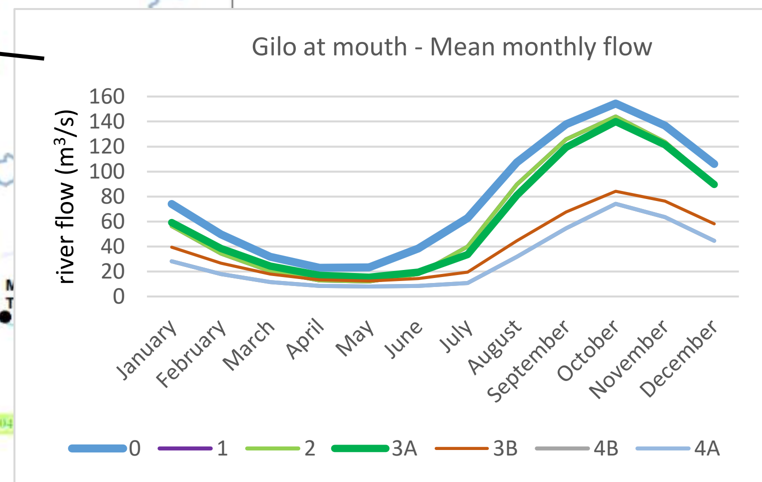
Figure 7-14: Changes on river flows for each scenario











NAVIGATION

The impact of the development scenarios on navigation is assessed based on the number of navigable days, which gives the number of days for which the navigation is possible for boats with a significant draft. The figures are provided in table 10.

Gambella-Itang (Baro at Gambella)

On the Gambella-Itang reach, **every scenario should improve the navigability**. Precautionary and comprise scenarios (Scenarios 1 to 3b) would generate a slight increase of navigable days whereas full development scenarios (Scenarios 4a and 4b) would induce a significant improvement of the navigability (up to +40% of navigable days). The impact of the scenarios on the navigability of this reach is therefore significantly positive.

Itang – Baro at its confluence with the Sobat (Baro at mouth)

On the Itang – Baro reach, the impact of the scenarios on navigability is rather negative. Every scenarios induce a slight decrease in navigable days, from -20% for scenarios 1, 3a and 3b to -40% for scenario 4b.

Sobat downstream its confluence with the Baro – Sobat at its confluence with the White Nile

On the downstream Sobat reach, the impact of the scenarios on navigability is rather negative. Every scenarios induce a slight decrease in navigable days, from -20% for scenarios 1, 3a and 3b to -35% for scenario 4b.

Overall expected impact on navigation

Despite a reduction of navigable days (based on the currently accepted flow thresholds) for most of the scenarios on the river reach between Itang (Baro river) and the Sobat at its confluence with the White Nile, the overall impact on navigation is expected to be positive. A major increase of navigable days between Gambella and Itang could act as a catalyst for measures to improve the navigability in the lower Baro and Sobat since the incentive would be access to markets for the large level of agricultural production created under the scenarios. Such **an improvement advocates for the development of navigation facilities all along the navigable stretch. The development scenarios will therefore positively foster navigation at the overall basin scale**.

WATER AVAILABILITY FOR DOWNSTREAM WATER USES, AQUATIC LIFE AND RIPARIAN VEGETATION

Figure 7-15: Changes in minimum monthly flows for each scenario

The analysis of the above graphs and of the dedicated section in Table 10 leads to the following conclusions:

- ***Baro at Gambella:*** overall, the scenarios increase the water availability in the upstream Baro catchment. Despite Scenario 1 induces a slight decrease in the average monthly flow during the dry period (December to May) and a slight increase in the severe low flow period duration, the 6 other scenarios significantly increase the average monthly flow during the dry period and significantly decrease the duration of the severe low flow period.
- ***Baro at mouth:*** Precautionary and Full Development scenarios negatively impact the water availability in the lower Baro catchment. The average monthly flow during the dry period and the average monthly flow during the dry period are indeed worsened by 20 to 25%. Intermediate Scenarios however make it possible to maintain downstream water availability at a similar level compared to the Baseline situation.
- ***Gilo at mouth:*** Despite a slight decrease in water availability, the impact of the Precautionnary and Intermediate Scenarios could be considered as not too significant (they remain above the defined threshold for the average monthly during low period and they barely break the threshold for the duration of the severe low flow period). On the contrary, the Full Development Scenarios induce a significant decrease in the downstream water availability.
- ***Alwero at mouth***: overall, the development scenarios maintain the water availability in the upstream Alwero catchment at a similar level compared to the Baseline situation. Despite a slight increase in the duration of the severe low flow period for Full Development Scenarios (at the level or just above the defined threshold, the 6 other scenarios do not impact significantly the average monthly flow during the dry period and the duration of the severe low flow period.
- ***Sobat at mouth:*** Each scenario induces a significant increase in the duration of the severe low flow period (two to three times longer compared to the baseline situation). With respect to the average monthly flows during the dry period, the impact is a little slighter. The low flows feature a significant decrease (-30% to -50%) for the Precautionary and Intermediate Scenarios, whereas this decrease is much stronger for the Full Development Scenarios (-70%)

<u>NB:</u> Significant impacts on the Alwero and especially on the Gilo river might lead to significant effects on the lower Pibor since the above quoted rivers are main contributors to the lower Pibor flows during the dry season.

Overall, the more the water development for irrigation is intense, the more the downstream water availability is negatively impacted.

INTRA – ANNUAL AMPLITUDE

Sc 4a and Sc 4b could be problematic for the aquatic fauna diversity and regarding the development / expansion of invasive aquatic plants such as the water hyacinth since these scenarios lead to a regulation of flows of the Baro, the Gilo, the Sobat and the Alwero, resulting in a reduction of the flows intra-annual amplitude. Sc 2 could also be problematic with regard to the Baro river.

Table 7-21: Changes on river flows and their potential social and environmental implications for each scenario

Social and environmental implications	Indicator	Wetlands	Threshold	Baseline			Precautionary Principle						Compromise						Full Development					
			Baseline (Sc 0) dry values	-20%	Option 0	+20%	-20%	Option 1	+20%	-20%	Option 2	+20%	-20%	Option 3a	+20%	-20%	Option 3b	+20%	-20%	Option 4a	+20%	-20%	Option 4b	+20%
Navigation	Number navigable of days for an average year	Baro at Gambella	196	168	210	252	160	200	240	199	249	299	173	216	259	173	216	259	207	259	311	238	297	356
		Baro at mouth	121	113	141	169	93	116	139	78	98	118	98	122	146	95	119	143	80	100	120	70	87	104
		Sobat at mouth	172	158	197	236	126	158	190	120	150	180	145	181	217	138	173	208	123	154	185	104	130	156
Water availability for downstream water uses, aquatic life and riparian vegetation in the BAS	Number of months under the 1/10 daily ranked flow (= duration of the severe low flows period)	Baro at Gambella	3	1	1	2	2	3	4	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
		Baro at mouth	2	1	1	2	4	4	5	2	3	3	1	1	1	1	1	1	3	3	4	3	3	4
		Sobat at mouth	3	1	2	2	4	5	6	4	5	6	3	4	5	3	4	5	4	5	7	5	6	7
		Gilo at mouth	3	1	2	2	3	4	5	3	4	5	3	4	5	4	5	6	6	8	9	6	8	9
		Alwero at mouth	10	6	8	9	8	9	11	8	10	12	8	9	11	8	10	12	8	11	13	8	10	13
	Average mean monthly flow from December to may (m3/s)	Baro at Gambella	47	60	75	89	41	52	62	133	166	200	71	89	107	71	89	107	106	133	159	149	187	224
		Baro at mouth	52	53	66	79	39	48	58	42	52	63	54	68	81	54	67	80	40	50	61	40	50	60
		Sobat at mouth	82	136	170	203	66	82	99	65	81	97	93	116	140	75	94	113	43	54	65	43	54	65
		Gilo at mouth	28	41	51	62	30	38	45	30	38	45	33	41	49	22	28	34	16	20	24	16	20	24
		Alwero at mouth	0	2	2	3	1	2	2	1	2	2	1	2	2	1	1	1	1	1	2	1	1	2
Intra – annual amplitude (with risk of important changes on aquatic life diversity and overdevelopment of invasive aquatic plants)	Mean amplitude between the wettest month and the driest month of a year (m3/s)	Baro at Gambella	818	756	945	1134	729	912	1094	494	617	741	738	923	1107	738	923	1107	535	668	802	486	607	729
		Baro at mouth	513	431	539	646	425	531	637	392	490	588	421	526	631	413	517	620	388	485	581	384	480	576
		Sobat at mouth	615	511	638	766	516	645	774	502	627	752	497	621	745	492	615	738	491	613	736	488	609	731
		Gilo at mouth	99	105	131	158	106	132	158	106	132	158	100	125	149	57	72	86	53	66	79	53	66	79
		Alwero at mouth	42	69	86	104	57	72	86	52	65	78	59	73	88	26	32	39	29	36	44	29	37	44

The red cells highlight values below the threshold and therefore indicate a problematic situation.

7.4.1.3 Need for acquisition of further information on uncertain factors

The BAS lacks both robust climatic and hydrological data. **As a result, the above presented results consist of the best estimates given the current level of knowledge.**

A **sensitivity analysis** was carried out on the baseline model in order to estimate the margin of error in assessing wetland size and spill volumes due to the limited data available and the modelling assumptions made. The uncertainty of the simulated stream flows as well as the modelled spill thresholds and channel capacities were investigated.

The main outcomes of the sensitivity analysis can be synthesized as follows:

- The baseline inherent variability, defined as the *(mean annual flow/surface area – dry mean annual flow/surface area) / mean annual flow/surface area)*, is not affected by changes on flows or on channel capacity. As a result, the threshold is a single value (no margin of error is applied to the threshold) in the calibrated SSEA analytical framework.
- The average percentage change on mean annual flows/wetlands surface area is around +/- 20%. As a result, a margin of error of +/- 20% is be applied to the results (used to quantify indicators).

The results presented in the previous section show that when the potential margins of error in the calculated results are taken into account, it is possible that some scenarios could be problematic even if the calculated value is below the threshold. By the same argument, some scenarios may no longer be problematic when the potential margins of error in the calculated results are taken into account,

Clearly it will be important to improve the accuracy of the various estimates made before implementation of potentially harmful projects is undertaken. Fortunately, since the implementation of so much infrastructure will be spread over several decades, there is an opportunity to start with implementation of low/no regret projects first, and at the same time putting in place a robust climatic and hydrological monitoring system. This is an absolute priority for the BAS.

In addition, the current level of knowledge on riverine biology and existing uses and especially their adaptability against low flows is very low. As a result, these fields have to be investigated in order to define adequate environmental flows and to validate and adjust the proposed thresholds.

<u>NB:</u> additional irrigation and hydropower potential identified in South Sudan will have to be included in complementary water modelling exercice as part of the IWRMDPlan implementation.

7.4.1.4 Enhancement and mitigation options

MITIGATION OPTIONS

Possible mitigation options include:

- The avoidance of flows over-regulation through and associated extreme changes on river flows and on wetlands size through adequate selection of dam selection and implementation of environmental flows to conserve natural patterns and to ensure sufficient flooding;
- The avoidance of extreme infra-daily variation of river flow immediately downstream hydropower dams through adequate design and construction of a small regulation dam directly downstream the main dam. The regulation dam should be able to store the volume released during one day and then release a smoothed flow to the river;
- Water saving measures, at least for the most consumptive uses (irrigation) through the choice of adequate crops, the design and construction of efficient water conveyance infrastructure, the efficient irrigation management and elaboration of meteorological information system to optimize water used; the selection of efficient irrigation technics and the investigation of reuse opportunities;

- The assessment of water requirements of aquatic ecosystems, including water demand, seasonal dynamics, and sediment patterns.

7.4.1.5 Residual significance

The impact magnitude varies significantly across the scenarios. As a result, the impact residual significance is highly variable.

Sc 1 to 3b already include some of the mitigation options listed above.

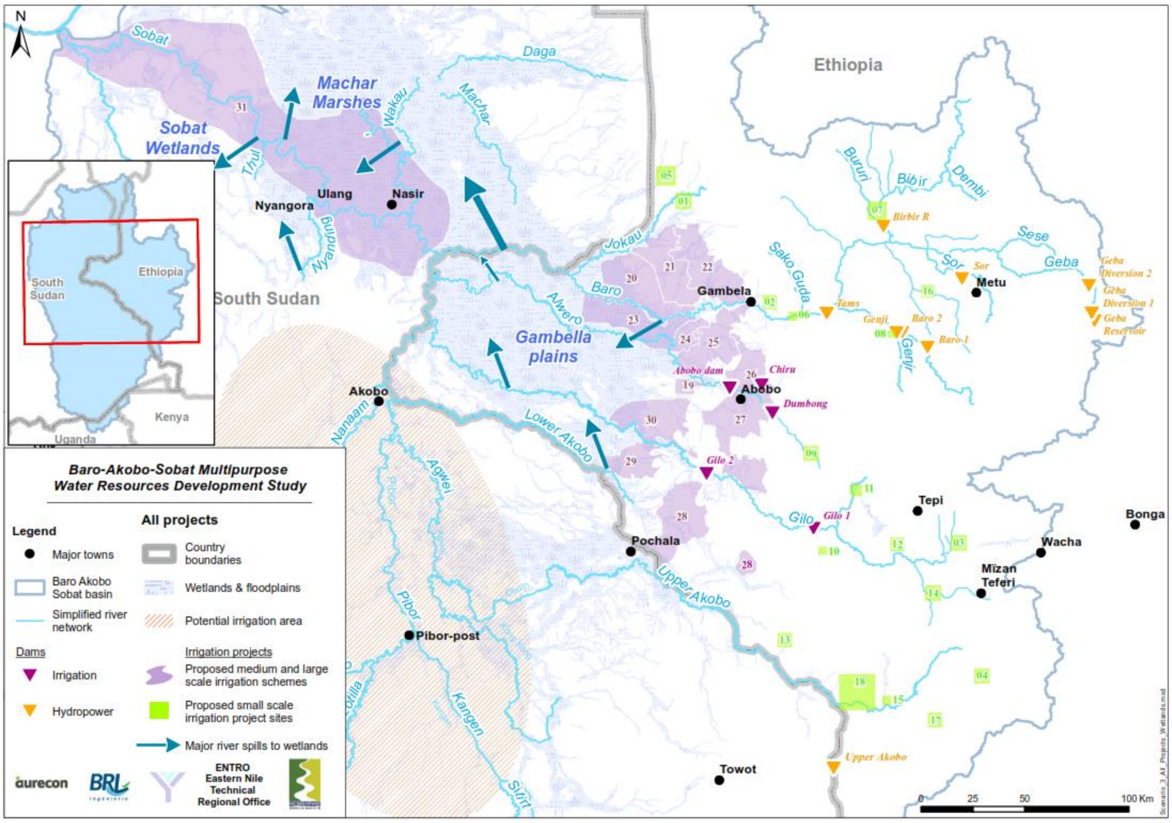
The previous analysis has shown that the tested mitigation measures significantly reduce the impact for certain indicators and locations. It is especially true when mitigation measures are combined (such as for scenario 3a). In case only parts of the mitigation measures are implemented (scenario 2 and 3b), the impact remain significant for a certain number of cases.

7.4.2 Changes to hydrological regimes affecting aquatic extensions / wetlands

7.4.2.1 Impact overview

By affecting rivers flows, hydropower and irrigation projects will affect the volume of water spilled into wetlands. The main wetlands which depend on impacted rivers flows are Gambella plains, Machar Marshes and Sobat wetlands. These wetlands and their dependence on river flows are summarised in the figure below.

Figure 7-16: Wetlands impacted by changes of river flows due to hydropower and irrigation development



In the BAS lowlands, people rely heavily on wetlands for water supply, fish resources, water and forage resources for livestock and bush meat. The BAS wetlands support large population of migrating water birds and wildlife. The BAS wildlife migration (mainly Kob, Tiang, Waterbuck) is known as one as one the major wildlife migration of Africa, equivalent of the Masaï-Mara Serengeti migration, with around 1 million animals migrating each year.

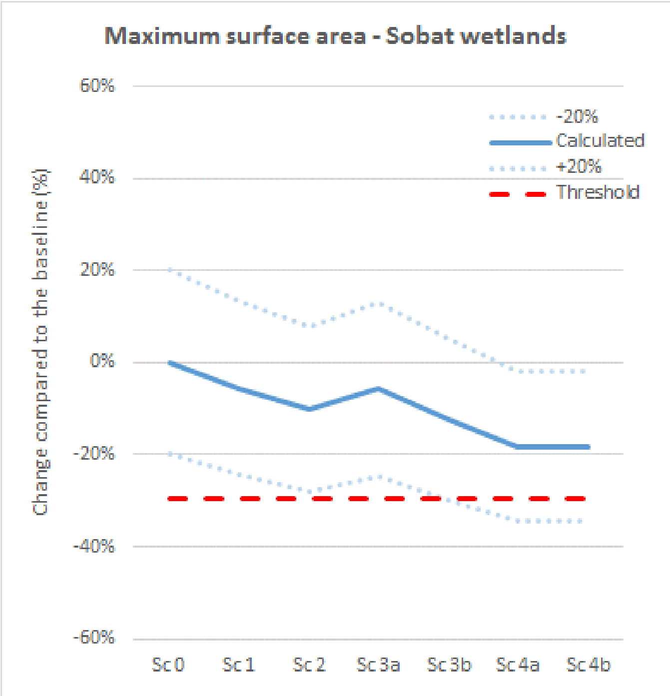
A reduction of wetland size directly threatens the above described ecosystem services:

- A reduction of wetland minimum surface area directly will impact the water available at the heart of the dry season for domestic water supply and livestock and wildlife watering. It will also impact the availability of plants that need to be permanently inundated and which are used the essential material for thatching.
- A reduction of the maximum surface area will impact the fish productivity of wetlands and river systems.
- A reduction of the intra-annual surface area amplitude (difference between the maximum and the minimum surface area) will impact the surface area of land suitable for recession agriculture and on forage resource surface area available for livestock and wildlife during the dry season.

7.4.2.2 Scenario comparison

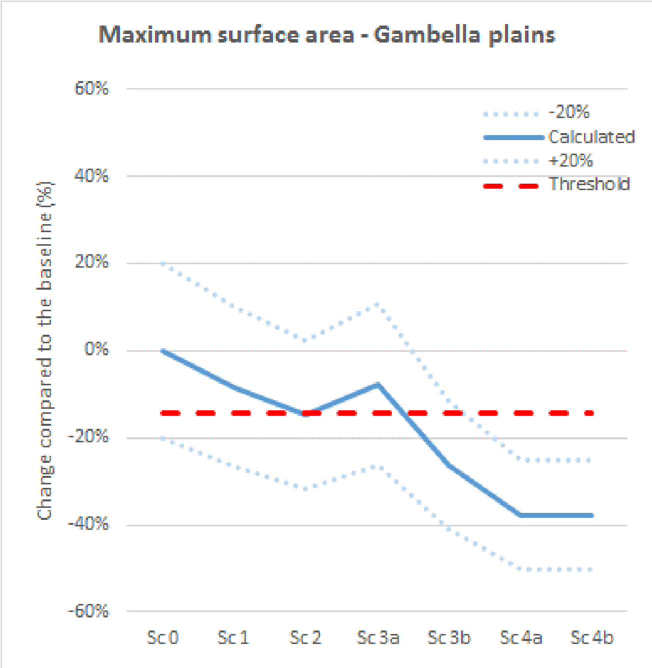
All scenarios lead to a reduction of wetlands surface area. However, the reduction intensity significantly varies among scenarios and among wetlands. The **impact is assumed to be significant when the reduction of surface area due to projects is higher than the dry (occurring 1 year out of 5) surface area under baseline conditions**.

The changes in maximum surface area are presented in the following figures:



For Sobat wetlands, none of the 6 scenarios lead to a reduction in the surface area below the threshold (red dotted line).

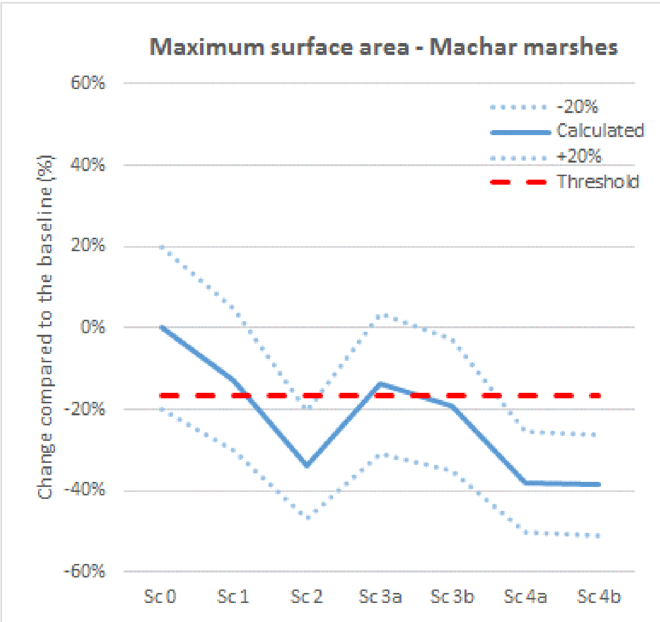
However, when the potential margins of error in the calculated results for each scenario (see dotted blue lines) are taken into account, it is possible that Scenarios 4a and 4b could be also problematic.



For Gambella wetlands, only Scenarios 3b, 4a and 4b lead to a reduction in the surface area below the threshold (red dotted line).

However, when the potential margins of error in the calculated results for each scenario (see dotted blue lines) are taken into account, it is possible that Scenarios 1, 2 and 3a could be also problematic.

The avoidance of sensitive areas while implementing irrigation schemes (Sc 1, 2 and 3a) also plays a positive role on Gambella plains conservation. The conservation of environmental flows (Sc 3a and 3b to be respectively compared to Sc 2 and 4b) also significantly reduces the negative impact of hydropower and irrigation projects by restoring the natural flow patterns of the Baro River to some extent.



For Machar Marshes, only Scenarios 2, 4a and 4b lead to a reduction in the surface area below the threshold (red dotted line).

However, when the potential margins of error in the calculated results for each scenario (see dotted blue lines) are taken into account, it is possible that Scenarios 1, 3a and 3b could be also problematic.

The avoidance Tams and Bibir dams implementation (Sc 1 to be compared to Sc 2) significantly reduce the negative impact of hydropower and irrigation projects by conserving some natural flow patterns. Sc 3a and 3b (to be respectively compared to Sc 2 and 4b) also allow some restoration of natural flow patterns of the Baro river.

However, for Machar Marshes, the benefits of avoiding of sensitive areas while implementing irrigation schemes (Sc 2 to be compared to Sc 3a and 3b) are not as high as for Gambella plains and Sobat wetlands. This is mainly due to the fact that Gambella plains and Sobat wetlands also rely on flows the Gilo and Alwero rivers whereas Machar Marshes mainly rely on Baro flows and therefore does not benefit from the reduction of irrigation schemes surface areas.

Changes in minimum surface area and change in annual surface area amplitude are quite similar to changes in maximum surface area. The comprehensive detailed results are presented in the tables next page.

The first table shows the wetlands surface areas (in km^2) for each scenario. The second table shows the change (mainly reduction) in surface area in comparison to the baseline situation (negative value shows an increase of the surface area compared to the baseline. The red cells highlight values below the threshold and therefore indicate a problematic situation.

NB: The results presented in this section do not include the additional irrigation and hydropower potential identified in South Sudan. Without presuming the results of a complementary modelling exercice that will have to be conducted as part of the IWRMDPlan implementation, some qualitative findings can still be drafted at this stage:

- As a consequence of the Upper Akobo hydropower dam, the reduction of high wet season flows will lead to a reduction of Gambella plains wetlands in Ethiopia and the Gwom wetland in South Sudan, which are both located in National Parks (Gambella National Park in Ethiopia and Boma National Park in South Sudan) and which both support some of the most important biodiversity features of the BAS (inc. wildlife migrations) and livelihoods in the area.
- Development of irrigation on the Akobo/Pibor area will lead to a reduction of the dry season minimum flow of the Pibor and or the Akobo depending on the location of the water abstraction. As a consequence it could lead as well to a reduction of the size of the associated wetlands in the dry season.

Table 7-22: Wetlands surface areas under each scenario

Social and environmental implications	Indicator	Wetlands	Threshold	Baseline			Precautionary Principle						Compromise						Full Development					
			Baseline (Sc 0) dry values	-20%	Sc 0	+20%	-20%	Sc 1	+20%	-20%	Sc 2	+20%	-20%	Sc 3a	+20%	-20%	Sc 3b	+20%	-20%	Sc 4a	+20%	-20%	Sc 4b	+20%
Fish productivity, water birds population	Average annual maximum surface area (km²)	Gambella plains	5 147	4 818	6 023	7 228	4 412	5 515	6 618	4 105	5 131	6 157	4 443	5 554	6 665	3 546	4 433	5 320	3 000	3 750	4 500	3 001	3 751	4 501
		Sobat wetlands	1408	1596	1995	2 394	1507	1884	2 261	1436	1795	2 154	1506	1882	2 258	1400	1750	2 100	1306	1633	1960	1306	1633	1960
		Machar marshes	4 419	4 242	5 303	6 364	3 698	4 623	5 548	2 810	3 513	4 216	3 662	4 578	5 494	3 430	4 288	5 146	2 631	3 289	3 947	2 606	3 257	3 908
Water availability for domestic uses, livestock and wildlife watering	Average annual minimum surface area (km²)	Gambella plains	518	659	824	989	357	446	535	422	527	632	608	760	912	556	695	834	325	406	487	346	433	520
		Sobat wetlands	496	433	541	649	430	538	646	431	539	647	432	540	648	432	540	648	399	499	599	399	499	599
		Machar marshes	1963	1897	2 371	2 845	1614	2 017	2 420	1237	1546	1855	1619	2 024	2 429	1525	1906	2 287	1164	1455	1746	1154	1442	1730
Livestock and wildlife forage resources, suitable land for recession agriculture, wild rice stocks for human consumption	Average annual surface area amplitude (km²)	Gambella plains	4 629	4 159	5 199	6 239	4 055	5 069	6 083	3 683	4 604	5 525	3 835	4 794	5 753	2 990	3 738	4 486	2 675	3 344	4 013	2 654	3 318	3 982
		Sobat wetlands	912	1163	1454	1745	1077	1346	1615	1005	1256	1507	1074	1342	1610	968	1210	1452	907	1134	1361	907	1134	1361
		Machar marshes	2 456	2 346	2 932	3 518	2 085	2 606	3 127	1574	1967	2 360	2 043	2 554	3 065	1906	2 382	2 858	1467	1834	2 201	1452	1815	2 178

Table 7-23: Change in wetlands surface area in comparison to the baseline situation

Social and environmental implications	Indicator	Wetland	Threshold	Baseline			Precautionary Principle						Compromise						Full Development					
			Baseline (Sc 0) dry values	-20%	Sc 0	+20%	-20%	Sc 1	+20%	-20%	Sc 2	+20%	-20%	Sc 3a	+20%	-20%	Sc 3b	+20%	-20%	Sc 4a	+20%	-20%	Sc 4b	+20%
Fish productivity, water birds population	Change in average annual max surface area (%) compared to the baseline	Gambella Plains	15%	20%	0%	-20%	27%	8%	-10%	32%	15%	-2%	26%	8%	-11%	41%	26%	12%	50%	38%	25%	50%	38%	25%
		Sobat Wetlands	29%	20%	0%	-20%	24%	6%	-13%	28%	10%	-8%	25%	6%	-13%	30%	12%	-5%	35%	18%	2%	35%	18%	2%
		Machar Marshes	17%	20%	0%	-20%	30%	13%	-5%	47%	34%	21%	31%	14%	-4%	35%	19%	3%	50%	38%	26%	51%	39%	26%
Water availability for domestic uses, livestock and wildlife watering	Change in average annual min surface area (%) ompared to the baseline	Gambella Plains	37%	20%	0%	-20%	57%	46%	35%	49%	36%	23%	26%	8%	-11%	33%	16%	-1%	61%	51%	41%	58%	47%	37%
		Sobat Wetlands	8%	20%	0%	-20%	20%	1%	-19%	20%	0%	-20%	20%	0%	-20%	20%	0%	-20%	26%	8%	-11%	26%	8%	-11%
		Machar Marshes	17%	20%	0%	-20%	32%	15%	-2%	48%	35%	22%	32%	15%	-2%	36%	20%	4%	51%	39%	26%	51%	39%	27%
Livestock and wildlife forage resources, suitable land for recession agriculture, wild rice stocks for	Change in average annual surface area amplitude (%) compared to the bas	Gambella Plains	11%	20%	0%	-20%	22%	3%	-17%	29%	11%	-6%	26%	8%	-11%	42%	28%	14%	49%	36%	23%	49%	36%	23%
		Sobat Wetlands	37%	20%	0%	-20%	26%	7%	-11%	31%	14%	-4%	26%	8%	-11%	33%	17%	0%	38%	22%	6%	38%	22%	6%
		Machar Marshes	16%	20%	0%	-20%	29%	11%	-7%	46%	33%	19%	30%	13%	-5%	35%	19%	3%	50%	37%	25%	50%	38%	26%

7.4.2.3 Need for acquisition of further information on uncertain factors

Same as for section 7.4.1.3 (Changes to riverine ecosystem services affecting instream flows /the river system itself).

In addition to what has been developed in section 7.4.1.3, it is worth noting that wetlands have to be included in the hydrological monitoring of the BAS to be developed.

Environmental and socio-economic surveys also have to be conducted in order to better understand the biology and the uses of the potentially affected wetlands and their adaptability to size and volume reduction.

7.4.2.4 Enhancement and mitigation options

Same as for section 7.4.1.4 (Changes to riverine ecosystem services affecting instream flows /the river system itself).

7.4.2.5 Residual significance

Same as for section 7.4.1.5 (Changes to riverine ecosystem services affecting instream flows /the river system itself).

7.4.3 Geomorphological changes

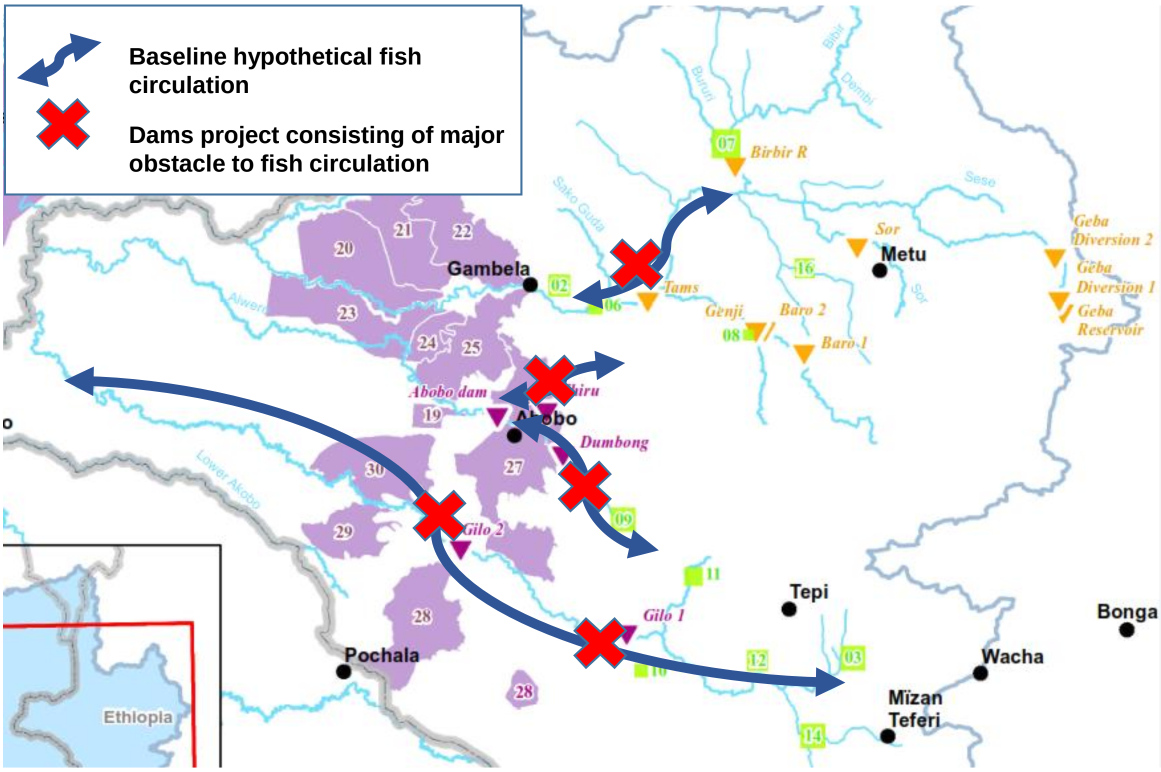
7.4.3.1 Impact overview

Dams are significant disruptions to river longitudinal connectivity. Loss of connectivity affects both the free circulation of fishes and sediments and can lead to loss of fish habitat and diversity as well as geomorphological changes, mainly downstream of dams. Geomorphological changes have numerous social and environmental implications such as changes in river morphology (bed deepening, siltation), bank instability, loss of capacity to meander, loss of connection with aquatic annexes, etc.

FISH CIRCULATION

According to Baro and Geba dams ESIA studies, BAS fish populations seem to be less diverse and important in the Ethiopian highlands and escarpments compared to foothills/piedmonts and plains. In addition, highlands and escarpments are endowed with natural waterfalls hindering fish circulation. For these reasons, dams located in highlands and escarpments (Baro 1, Baro 2, Genji, Birbir, Geba reservoir, Geba 1 and Geba 2) will have limited impacts on migratory species but will impact local fish populations. However, dams located in foothills/piedmonts and plains (Tams, Chiru, Dumbong, Gilo 1 and Gilo 2) might have significant impacts on both migratory species and local fish population with risks of population decrease if spawning areas are not accessible anymore and loss of diversity.

Figure 7-17: schematic representation of potential major obstacle for fish circulations



However, impediment of sediment circulation and modification of flows will also lead to loss of spawning grounds and alteration of fish habitat downstream of dams, whatever their locations. The implementation of cascades of dams may therefore affect fish habitats over several kilometres of Baro, Alwero and Gilo rivers.

With regards to food security, these impacts can be outweighed by the development of capture fisheries in the same reservoirs, aquaculture ponds or aquaculture within irrigation schemes since alteration of fish habitat should occur close to areas were capture fisheries and aquaculture will be developed. However, decrease of fish population / production due to flow modifications (see sub-dimension changes to riverine ecosystem services affecting wetlands) might occur further downstream and might therefore not be outweighed by fisheries and aquaculture development (see section 7.3.2 on food security for more details).

With regards to biodiversity conservation, the impacts described above can't be outweighed by fisheries and aquaculture development, which can also have negative impact on local population if non-native species are introduced.

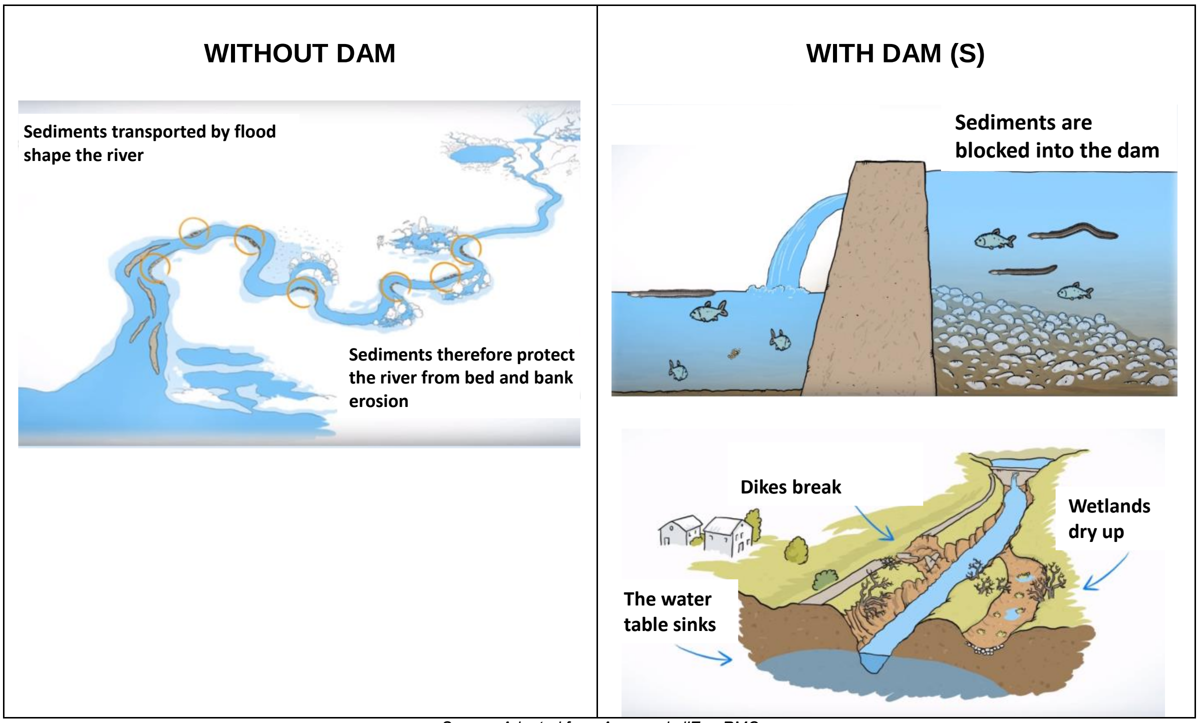
Opportunities for impact minimization include the integration of fish ladders in dams design but since costs might be prohibitive, a case-by-case assessment will have to be conducted as part of ESIA individual projects to assess the relevancy of this measure.

Sediment circulation

Obstacles to sediment circulation might cause the following changes:

- **Change in cross section:** The change in cross section can appear directly downstream of dams. Because the water released from dams has poor sediment loads, it can lead to bank erosion and river bed incision. According to (Brandt S. Anders, 2000), most of the rivers reached half of their total depth change within 7 years. On the contrary, dam emptying releases extremely high sediment loads, which are likely to conduct to river siltation. These changes can lead to the following social and environmental implications:
  - Modification of navigable reaches;
  - Loss of fish habitats, breeding grounds and fish diversity;
  - Loss of riparian vegetation due to bed and water table deepening;
  - Loss of connectivity with aquatic annexes due to bed deepening;
  - Increased vulnerability to floods because of modification of the flood line and loss of connection to natural expanding flood areas;
- **Change in longitudinal section (river planform):** The change in longitudinal section can also appear downstream of dams. The main potential patterns that can be affected are: the capacity to meander due to flood abatement, the loss of large sediments circulation and fish circulation between upstream and downstream reaches. These changes can lead to the following social and environmental implications:
  - Loss of groundwater recharge, groundwater table deepening and related reduction of groundwater availability;
  - Loss of riparian vegetation;
  - Loss of fish circulation;
  - Loss of fish habitat and diversity;
  - Loss of natural flood attenuation.
- **Change of the river facies:** The change in river facies can happen upstream and downstream dams. These changes are mainly due to the reduction of the flow velocity and the lack of large sediment. They can lead to the following social and environmental implications:
  - A decrease of water oxygenation causing a decrease of water quality for the water uses (addressed as part of the dimension "Change in water quality");
  - A loss of qualitative habitats for aquatic species and a loss of the river productivity;
  - An increased vulnerability to climate change.

Figure 7-18: Summarize of the effects of dam on geomorphology



Source: Adapted from Agence de l'Eau RMC

7.4.3.2 Scenario comparison

The more that dams are located downstream, the more they accumulate sediments and the less sediments can be transported further downstream. We also shown previously that the more dams are located downstream, the more it will affect fish biodiversity given the riverine ecological conditions of the BAS.

On the Baro river, Tams Dam might have therefore more impacts on sediments transportation than the combined effect of all upstream dams (Geba, Baro, Genji, and Birbir). As such, scenario 1 has less adverse effects on sediment circulation on the Baro river than the 5 other scenarios.

The following table shows the surface area of the watershed controlled by each of the dam projects.

Table 7-24: Surface area of the watershed controlled by each of the dam projects

Sub-basin	Total surface area (km²) (A)	Dam name	Controlled watershed surface area (km²) (B)	(B) / (A)
Baro	30,925	Birbir R	6,734	22%
		Sor	1,867	6%
		Baro 1	2,217	7%
		Baro 2	2,339	8%
		Geba reservoir	997	3%
		Geba Diversion 1	1,016	3%
		Geba Diversion 2	1,561	5%
		Gengi	1,380	4%
		Tams	21,118	68%

Sub-basin	Total surface area (km²) (A)	Dam name	Controlled watershed surface area (km²) (B)	(B) / (A)
Alwero	9,388	Abobo Dam	2,220	24%
		Dumbong	1,109	12%
		Chiru	74	1%
Gilo	12 081	Gilo 1	7,327	61%
		Gilo 2	9,354	77%

The following table shows the surface area of the watershed controlled by each of the dam projects.

Table 7-25: Surface area of the watershed controlled for each scenario

Surface area controlled (%)	Threshold	Proposed limit	Sc 0	Sc 1	Sc 2	Sc3a	Sc3b	Sc4a	Sc4b
Baro	30%	40%	6%	23%	68%	68%	68%	68%	68%
				-	--	--	--	--	--
Gilo	30%	40%	0%	77%	77%	77%	77%	77%	77%
				--	--	--	--	--	--
Alwero	30%	40%	24%	24%	24%	24%	24%	24%	24%
				-	-	-	-	-	-

On Gilo and Alwero rivers, all scenarios will have the same impacts on river sediment and fish circulation compared to the baseline situation since all irrigation dams are included in these scenarios.

All scenarios will have significant impacts on Gilo river.

Scenarios 2 to 4b will have major impacts on the lower Baro and Sobat rivers since an important part of the sediments will be retained into the numerous dams projects planned on the upper Baro catchment. In addition, Scenarios 4a and 4b will reduce the lower Baro and Sobat rivers capacity to mobilize and convey sediments since they will reduce peak flows (around 20% reduction of peak flow of the Sobat). In case of significant modification of the geomorphology of the lower Baro and Sobat rivers, the White Nile could also be affected.

On the contrary to other scenarios, Scenario 1 will have less impacts on the lower Baro and Sobat rivers.

Summary of cumulative and transboundary effects

The implementation of all projects of dams in the entire BAS, including Kinyeti multipurpose project and the hydropower potential on the Upper Akobo river, would mean that all major rivers of the sub-basins, except the Kangen, will be dammed. This would result in an important threat for the ecological and morphological integrity of the BAS river system. In addition, since the Sobat is deemed to be an important contributor of the White Nile sediment balance, a drastic reduction of the sediment inputs from the BAS sub-basin could affect the White Nile and the Nile, and have negative morphological effects such as river bank erosion or river bed incision in South Sudan and even in Egypt.

7.4.3.3 Need for acquisition of further information on uncertain factors

Geomorphological changes are difficult to predict and even more difficult to quantify. These changes mainly rely on hydrology and sediment transport but also depend on other several factors. According to the dam location in the basin and the related geomorphology, but also to the dam management policies, to the watershed erodibility and to the presence of one or several dams in sequence, the changes may vary.

The current level of knowledge on the river geomorphology of the BAS is close to zero. As part of this study, various types of meandering streams have been identified and mapped using satellite images as part of the baseline exercise. However this is not sufficient to assess the impacts of the various scenarios on the river geomorphology. As part of the SSEA, what is important is to assess the order of magnitude of changes and to compare the changes significance according to the various scenarios. This is why a simple but robust method has been developed to cope with the data limitation.

However, further investigations are required to allow a detailed assessment of the potential impacts and the mitigation options before any dam implementation.

7.4.3.4 Enhancement and mitigation options

MITIGATION OPTIONS

Regarding geomorphological impacts, opportunities for impact minimization usually include conservation of flows allowing sediment transport downstream the dam (dam operation) and sediment flush systems or artificial sediment transport to be included in dam design. However, they are rather complex to implement and do not allow to mitigate the effects completely.

Regarding fish circulation, implementation of fish ladders can theoretically be an option. Fish ladders are usually implemented for dam heights below about 10 m. Above 10 m height, the implementation of fish ladders is more complex, more costly and its effectiveness becomes uncertain. However, in case the ESIA confirms the need to restore the river longitudinal connectivity, the design of specific fish ladder should be considered for the most impacting dams (Tams, Gilo 1, Gilo 2, Dumbong, Chiru).

7.4.3.5 Residual significance

The above described mitigation options are complex and costly to implement. In addition they only partly reduce the impacts. As a result, the impacts of all scenarios remain significant on Gilo, lower Baro and Sobat rivers.

7.5 LOSS OF NATURAL / EXISTING ECOSYSTEM THROUGH LAND USE CONVERSION OF PROJECT

7.5.1 Physical and economical displacement and associated risks of conflicts

7.5.1.1 Impact overview

All scenarios will lead to resettlement of people displaced by the flooding of land and homes (due to reservoir impoundment) and by the implementation of irrigation (construction of canals, irrigated lands, etc.). In addition population densities are expected to increase around irrigation schemes or reservoirs because of the opportunities they offer (employment, increased production, fish farming, water available for livestock, fisheries in reservoirs …).

The potential changes in population densities as well as in demographic/ethnic composition may lead to social unrest, malnutrition, conflicts between communities, etc. if affected population are not provided with adequate compensation and / or if sufficient infrastructure provision have not been considered at the project planning stage.

In addition to physical displacement, lands usually used for subsistence farming and livestock grazing will also be impounded or irrigated. The creation of lakes due to reservoir impoundment and irrigation canals will also impede the access to non-impacted lands.

Likewise, if affected population are not provided with adequate compensation and / or if sufficient infrastructure provision have not been considered at the project planning stage, this may lead to an increase of poverty, malnutrition and conflicts.

Ethnic groups potentially impacted, current conflicts and existing population movements are presented in maps on the following pages.

These risks are potentially very high in the BAS given its social context and the lack of implementation of social mitigation and compensation measures in similar recent projects in Ethiopia and South Sudan. Case studies detailing the effective social impacts of similar projects are presented in Annex 8.

Annual pastoral migration routes described in the literature have been summarized on a map (see pages below). Even if this is not exhaustive, this map shows that large-scale irrigation schemes on the Sobat are on an important pastoral migration route. Regarding cumulative impacts, pastoral migration could also be further disrupt rapid flow increase in case hydropower dams do not include a downstream regulation dam.

Generally, it can be said that pastoralist populations as well as shifting cultivators are more vulnerable to changes in land allocation and use than more sedentary populations.

The Gambella Region in particular experiences in-migration of the pastoral Nuer and refugees from South Sudan, largely from Jonglei State. The ethnic and national identities of inhabitants of the border areas in Gambella and neighboring Jonglei State is very fluid, and cross-border migration of the pastoral Nuer, Anuak refugees fleeing to Sudan, and South Sudan refugees fleeing to Ethiopia is changing the ethnic population balance in the border area between Gambella and Jonglei State, perhaps permanently. Therefore, planned developments in these areas are likely to be adversely affected by insecurity and instability.

NB: A detailed analysis showing case studies of social impacts especially of water developments such as irrigation and hydropower is presented in Annex 8.

Figure 7-19: Ethnic groups to be likely affected by project footprints

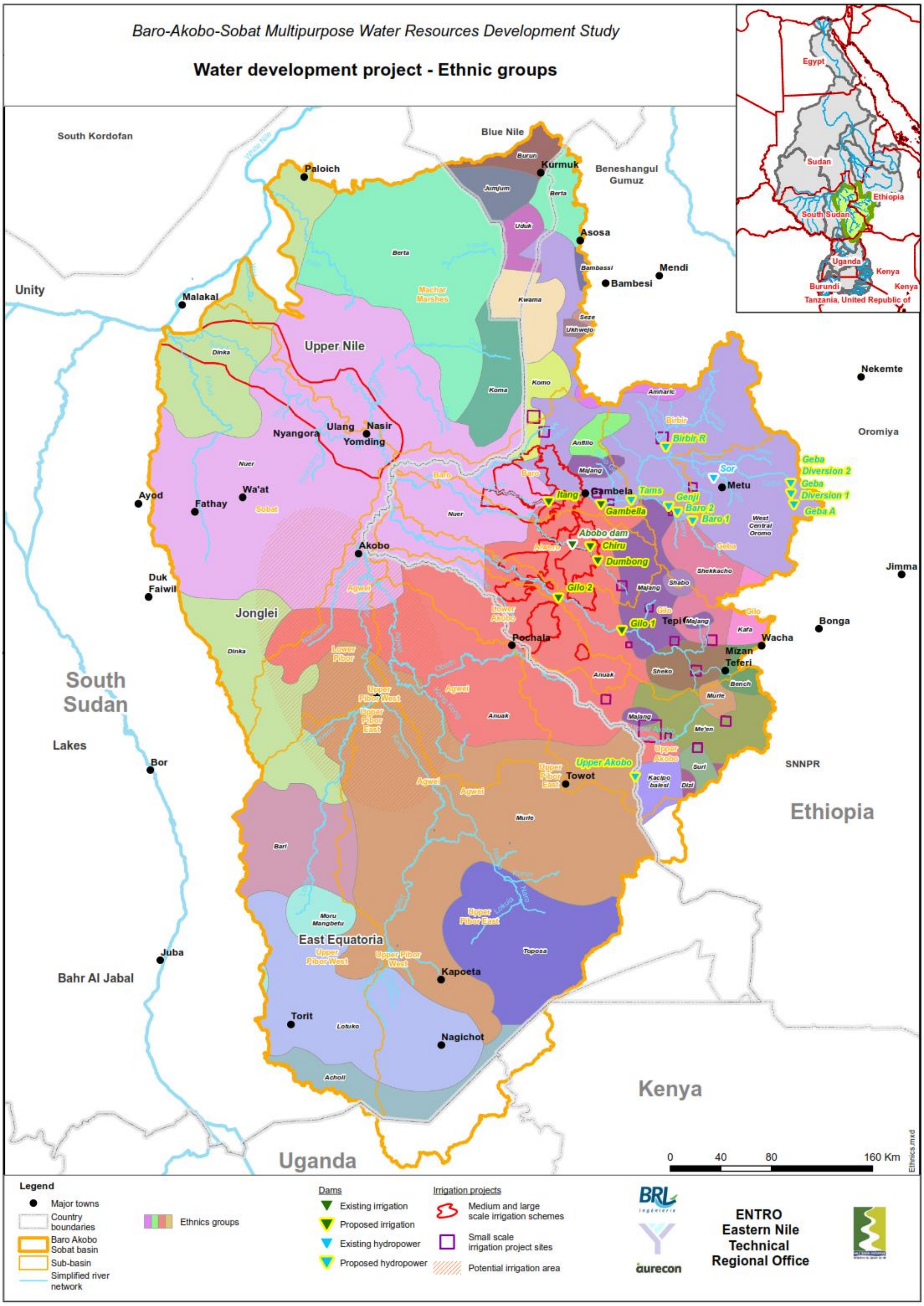


Figure 7-20: Location of water development projects and existing conflicts and population movements in the BAS

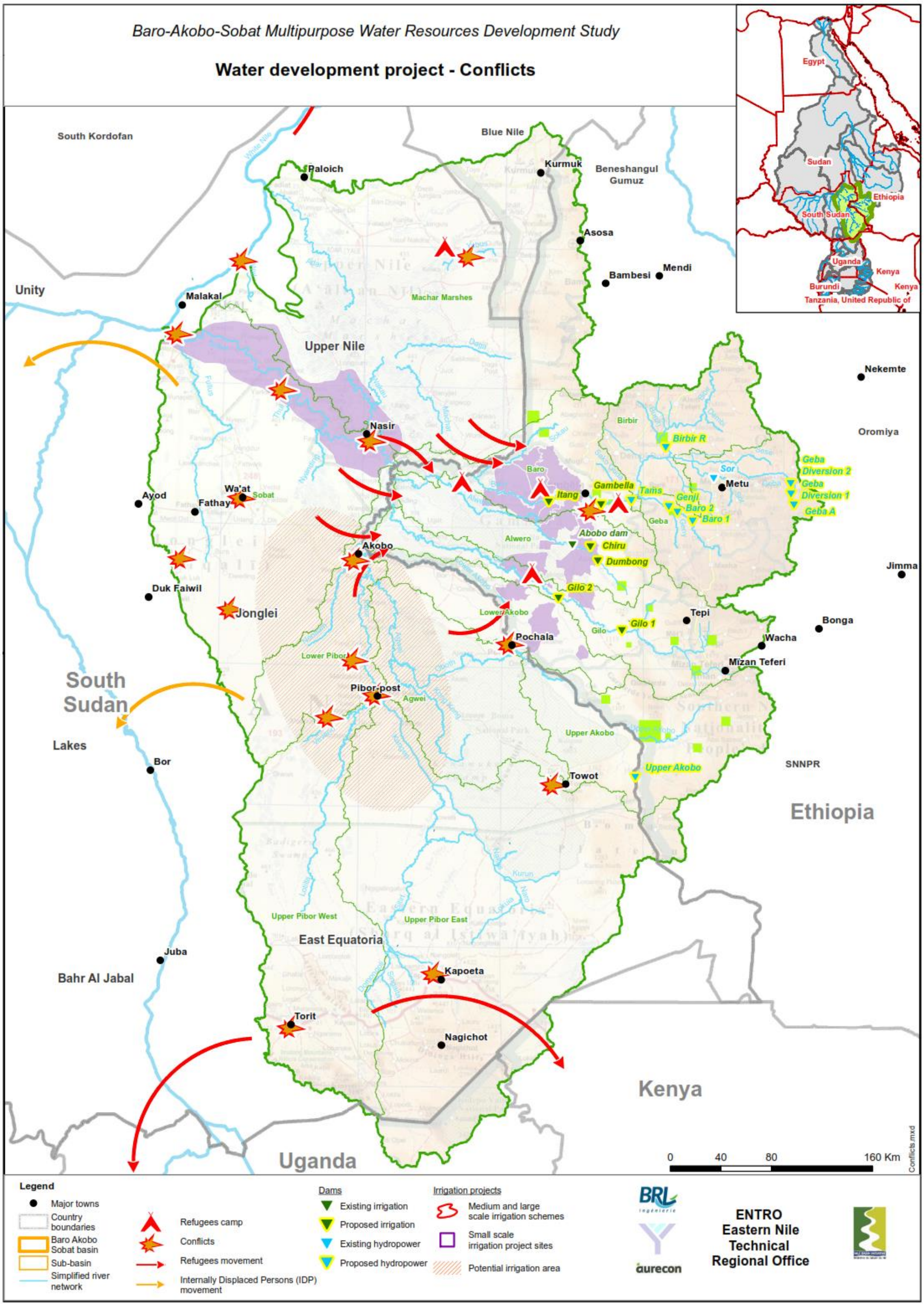
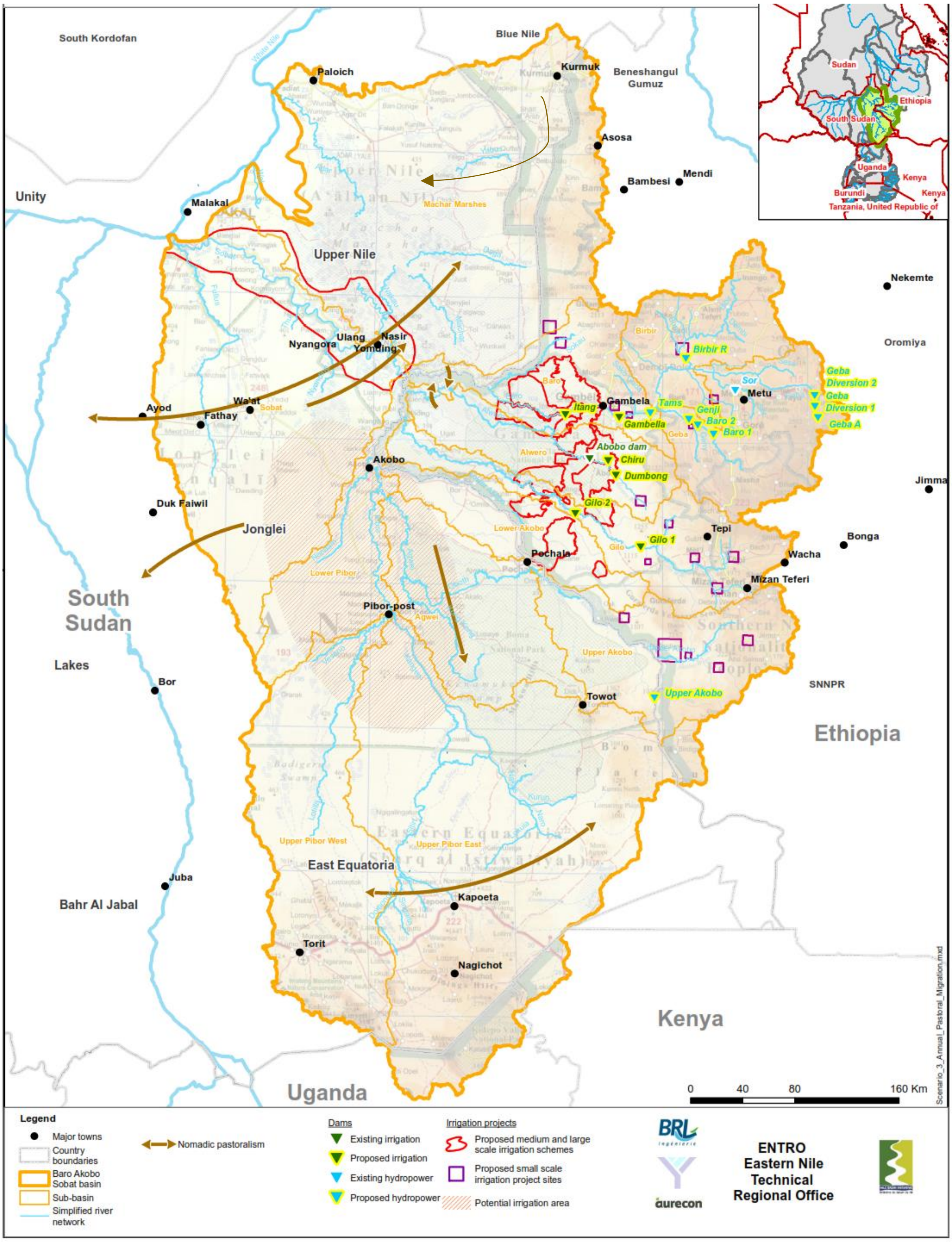


Figure 7-21: pastoralist migration (non-exhaustive) likely to be affected by project footprint



7.5.1.2 Scenario comparison

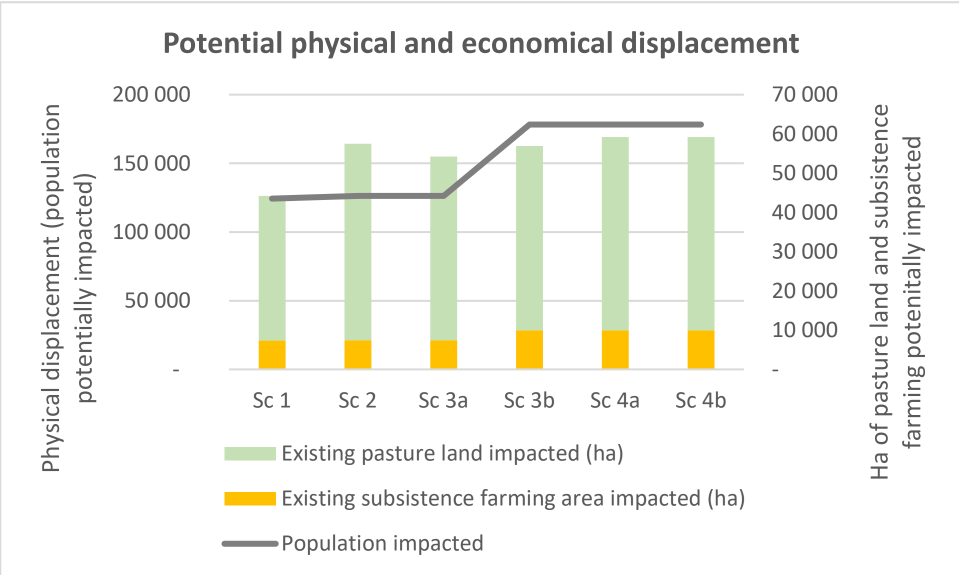
MAGNITUDE OF PHYSICAL AND ECONOMICAL DISPLACEMENT

Physical displacement has been estimated according to average population densities within projects footprint. Existing pasture land and subsistence farming areas impacted have been estimated according to land use patterns within projects footprints.

The population to be resettled and the surface area of pasture land and subsistence farming impacted are commensurate with the total footprint of each scenario. Land use patterns within project footprint are presented in Figure 7-25 in section 7.5.2.

As the full-development case with dams operations aiming at maximizing, the Scenario 4b lead to the highest population to be displaced and surface are of pasture and subsistence farming impacted. The population potentially impacted by this scenario accounts for 1.1 % of the 2056 BAS population. Pasture land and subsistence farming areas potentially impacted account for 3.1 % and 0.8 % respectively of the total pasture land and subsistence farming areas of the BAS.

Figure 7-22: potential physical and economical displacement for each scenario



*NB$_1$: It should be noted that the numbers presented for population impacted in the above table takes into account the population in the project footprint only. If one considers the **cumulative impacts of projects footprints and changes to water availability**, the **total population potentially indirectly impacted** is estimated to be around **2.7 million people** for scenario 4a and 4b**.** This is based on the assumption that social impacts could be felt up to 25 km away from project footprints and that all riverine and wetlands population located downstream projects might be impacted as well. This is a very rough estimates which will have to be fine-tuned as part of each ESIA projects.*

NB$_2$: The above figure does not take into account the footprint of additional irrigation and hydropower potential identified in South Sudan. The foreseen site for the Upper Akobo hydropower dam is located in a low populated area covered by dry savannah predominantly. The foreseen areas for the development of additional irrigation in the Pibor/Akobo has an average population density of 25 hab/km2 even if not homogenous on the whole foreseen area. The area is also predominantly covered by dry savannah but is also endowed with floodplains of the Oboth, Kong Kong, Pibor and Veveno rivers and with the Gwom wetlands. These areas are mainly used for nomadic pastoralism. Like in other areas of the BAS, large footprints of large-scale irrigation might lead to similar social issues than the one developed in this section.

POTENTIAL RELATED IMPACTS ON SOCIAL GROUPS

The human population in the BAS basin encompasses a large number and diversity of ethnic groups, livelihoods and relationships with the basin's physical and natural environments.

Ethnic groups and livelihoods likely to be affected by proposed development of water resources in the BAS basin are shown in the following table.

Table 7-26: Ethnic Groups and Livelihoods Affected by Type of Development

Country / Development	Ethnic Group	Present Livelihood(s)
Ethiopia		
Irrigation	Anuak	Sedentary, subsistence agriculture
	Komo/Kwama	Shifting cultivation, hunting
	Majang	Shifting cultivation, forest products/honey
	Sheko	Sedentary, subsistence agriculture, hunting and gathering forest products
	Me'en	Sedentary, subsistence agriculture
	Suri	Sedentary livestock and subsistence agriculture
Hydropower	Oromo	Sedentary agriculture/livestock/trading
	Shekkacho	Sedentary agriculture/livestock/coffee
South Sudan		
Irrigation	Nuer	Semi-nomadic pastoralists, subsistence agriculture, trading, wild foods
	Dinka	Agro-pastoralists, seasonal migration
	Murle	Semi-nomadic pastoralists, subsistence agriculture
Hydropower	Murle	Semi-nomadic pastoralists, subsistence agriculture
Mixed irrigation and hydropower (Kinyeti)	Lotuko	Agro-pastoralists

It can be seen from the above table that there are a wide diversity of ethnic groups and livelihoods that are likely to be affected by the development of water resources in the BAS basin. Some of these groups have long histories of conflicts with each other and external authorities, e.g. the Nuer, Dinka and Murle over cattle and access to grazing, between the Toposa and the Didinga and Turkana over cattle and access to grazing land, between the Anuak and recent settlers and, more recently, between the Oromo and the federal government.

Groups relying on subsistence agriculture for their livelihoods are likely to be sensitive to any changes in the availability of or access to fertile land for cultivation. Likewise, pastoral groups relying on cattle and herding for their livelihood are vulnerable to changes in the availability of and access to land and water for grazing cattle. Therefore, it is hypothesized that the likelihood that the livelihoods of these groups will be negatively impacted will be directly related to the extent that hydropower dams and reservoirs encroach on traditional farming and grazing lands.

In the case of irrigation, it can be hypothesized that groups (both nomadic pastoralists and sedentary herders) that depend mainly on cattle and other livestock for their livelihood will find it difficult if not impossible to adapt to sedentary agriculture required by formal irrigation schemes. Leasing previously customarily farmed land to outside investors, fencing of land, limiting access to water sources and other measures associated with formal irrigation are likely to disadvantage groups that depend mainly on livestock for their livelihoods. The well-documented case of the conflict between the Masaï and sedentary farmers in northern Tanzania serves to illustrate the serious social and political consequences this type of conflict can have.

On the positive side, it can be hypothesized that groups already engaged in sedentary agriculture and who cultivate crops for which there is a demand and that can be traded on wider markets will be better able to adapt to and benefit from small-scale formal irrigation schemes, especially if the scheme is located near an urban center or main transportation route which will facilitate access to markets for produce.

On the other hand, the optimal development of large-scale irrigated agriculture requires access to capital, management skills, wage labor and markets, which, with the possible exception of labor, only very few members of the above groups have. Seen in the present context, those indigenous groups who are in the best position to take advantage of large-scale irrigation schemes would be the Oromo in Ethiopia and the Nuer in South Sudan.

A conclusion from the above discussion is that even in areas where biophysical and hydrometric conditions are deemed to be favorable for the introduction of hydropower schemes and irrigated agriculture, such initiatives can founder on social barriers in the form of deep-seared historical and more recent political conflicts between ethnic groups in the basin and between ethnic groups and central governments, as well as the lack of capital, skills and access to wider markets where surplus produced can be sold.

POTENTIAL RELATED IMPACTS OF RESETTLEMENT ON CONFLICTS BETWEEN HOST AND DISPLACED GROUPS

Displacement and resettlement associated with the development of hydropower and inundation of potentially fertile agricultural land primarily in river valleys in the highlands and escarpment zone of the basin, which are already experiencing high pressure on land and other resources pose a significant risk for conflicts with regional and federal authorities as well as between ethnic groups competing for land, grazing, water and other resources. In addition to loss of fertile land, pastoralists are likely to seek access to reservoirs and water courses as a source of water for their livestock.

While small-scale irrigation does not have as significant an impact on ethnic and social relations as larger irrigation schemes, there is still a risk of heightened conflicts with groups whose livestock may encroach on and damage the fences, fields and crops of sedentary farmers and seek watering for their animals in irrigation channels.

Resettlement is more likely to produce conflicts in the case of nomadic and semi-nomadic pastoral groups and shifting cultivators who are not used to living in permanent settlements or who need access to larger tracts of land in order to rotate their crops and fallow land. Also, the historic trend of settlers from the Ethiopian Highlands in Gambella and Benishangul-Gumuz is likely to be exacerbated by the loss of land to hydropower schemes in the highlands and the increase in employment opportunities created in the lowlands.

It is assumed that the likelihood and extent of conflicts resulting from resettlement and lack of access to important livelihood resources will be positively correlated with such factors as the number of people to be resettled, the size of the area involved and the likelihood that the new interventions will restrict the movements and access - and therefore the livelihoods - of pastoralists and groups practicing shifting cultivation. These indicators can be quantified and distributed across scenarios and then ranked to obtain a conflict risk index as shown in the following table.

Table 7-27: Estimation of possible conflict risk due to irrigation and HP development by scenario

Indicator	Precautionary principle options		Intermediate options		Full development options	
	Sc. 1	Sc. 2	Sc. 3a	Sc. 3b	Sc. 4a	Sc. 4b
Irrigable area (ha) Rank	383,929 4	541,038 3	238,915 6	357,658 5	644,052 2	721,972 1
Hydropower reservoir storage capacity (Mm^3) Rank	9,444 2	22,144 1	22,144 1	22,144 1	22,144 1	22,144 1
Size of affected population Rank	124,3193	126,190 2	126,190 2	178,241 1	178,241 1	178,241 1
Irrigation/HP schemes in areas used by pastoralists and shifting cultivators Rank	11 2	12 1	12 1	12 1	12 1	12 1
Sum of ranks	**11**	**7**	**10**	**8**	**5**	**4**

Note 1: It is assumed that irrigable areas will not be accessible for pastoralists and shifting cultivators

Note 2: It is assumed that the inundated area is positively correlated with the storage capacity of the HP reservoirs

Note 3: The lowest the rank the higher the risk

According to the above table, and not surprisingly, the full development scenarios (4a and 4b) have the highest risk of conflicts, followed by scenarios 2, 3b and 3a in that order, with scenario 1 having the lowest risk of conflicts.

In the present emergency and heightened inter-ethnic tensions in Oromia and parts of Benishangul-Gumuz and Gambella regions, and political and ethnic conflicts in South Sudan, resettlement schemes associated with government sponsored hydropower or irrigation projects risk being perceived negatively by the local population as attempts to encroach on ancestral land and/or to discriminate against certain ethnic groups and to benefit others.

Also, sites suitable for hydropower development are located in the Ethiopian highlands, which are the most densely populated areas in the basin. To the extent that fertile agricultural land in valleys is lost due to inundation, associated infrastructure and buffer zones, actual and potential agricultural productivity will be adversely affected. Groups who depend on livestock for their livelihoods are likely to demand access to reservoirs and channels to water their livestock, which will necessitate some degree of accommodation. Past experience with government-sponsored resettlement schemes associated with large-scale irrigation projects has been mixed, particularly in Gambella and South Sudan due among other things, to the slow pace of resettlement, inadequate information and consultation and lack of appropriate and timely inputs and services for the displaced population.

The village of Bildak in Gambella region. The semi-nomadic Nuer that were moved there left because there was no suitable water source for their cattle.

As of 2012, about 250,000 Ha of land in Gambella Region has been leased to a number of domestic and foreign investors. The table next page gives details of agricultural leases issued to Investors in Gambella region up to 2012.

Land availability and security of tenure is another physical precondition for market linkage. As mentioned previously, a successful contract farming scheme requires unrestricted access for the contracted farmers to the land they farm. Land in the region is on the hands of the government. There is no secure land tenure system that guarantees farmers ownership titles and free accessibility.

The government's resettlement program carries big risks at different levels. It may in principle provide a good basis to organize farmers in groups when they are resettled in villages; however, without adequate infrastructure it is very difficult to achieve. Since the new villages are located some distance apart, cooperation and access to markets is difficult. On the other hand, the newly established villages create a need for a secure title to land to individual families in the new resettlement areas.

Figure 7-23: Leases of agricultural land to investors in Gambella Region up to 2012

Investor Name/ Company Name	Nationality	Region	Investment Type	Land Transfer	Capital registered	Land Rent	Agreement
				Area of Ha	/Mill Birr/	Per Year (Birr)	Signed Date/G.C
Ruchi	Indian	Gambella	Soya bean	25000	1451	2,775,000.00	27-Jul-2009
BHO	Indian	Gambella	Edible Oil Crops	27000	918	2,997,000.00	03-Sep-2009
Sannati	Indian	Gambella	Rice	10000	160	1,580,000.00	24-Jan-2010
Verdanta	Indian	Gambella	Tea	3012	631	334,332.00	13-Aug-2009
Karuturi Agro Products PLC	Indian	Gambella	Palm, Cereals, Rice & Sugar Cane	100000	2110	2,000,000.00	26-Feb-2010
Saudi Star Agricultural Development	Saudi	Gambella	Rice	10000	37640	300,000.00	22-Feb-2010
Toren Agro Industries Plc	Turkey	Gambella	Cotton and Soya bean				
Huana Dafengyuan Agriculture	China	Gambella	Sugar cane Cane	25000	2973	3,950,000.00	05-Nov-2009
Saber Farm PLC	Indian	Gambella	Cotton & Soya bean	25000	436	3,950,000.00	02-Sept-2010
Green Valley Agro Plc	Indian	Gambella	Cotton Farming & Related Activities	5000	171	555000	25-Jan-2012
JVL Overseas Pvt Ltd	Indian	Gambella	Cotton Farming and Related Activity	5000	74	790000	25-June-2012

Source: MoA (2012) , accessed on Feb. 24/2013

Similar information is not available for irrigation projects located in the south Sudan part of the BAS.

7.5.1.3 Need for acquisition of further information on uncertain factors

No specific needs have been identified at this stage. However, these aspects will have to be investigated into details as the ESIA stage.

7.5.1.4 Enhancement and mitigation options

In order to reduce people resettlement on irrigation schemes, mitigation opportunities include:

- Gathering of scattered villages close to existing and planned infrastructure (schools, roads, etc.) based on affinities
- Exclusion of dense / gathered settlement or villages from irrigation schemes.

In addition, small-holder irrigation schemes will limit economical displacement compared to commercial irrigation schemes.

7.5.1.5 Residual significance

Even if adequate compensation is provided to affected population, experiences on similar projects shown that compensation is usually not sufficient to offset the negative effects on population especially on vulnerable communities. The residual significance is therefore deemed to be high.

7.5.2 Encroachment into natural ecosystems

7.5.2.1 Impact overview

The identified water resources development projects involve the conversion from an existing ecosystem into an irrigation scheme or a dam, leading to a complete transformation of fauna and flora of the affected area and to a loss of its previous uses and ecosystem services. Project footprints that include natural ecosystem will indeed be transformed into an anthropic managed ecosystem, leading to the following potential social and environmental implications:

- Loss of natural resources (for livestock grazing, non-wood and wood forest product harvesting, thatching, hunting…) people use to rely on, leading to search for other places with equivalent natural resources, economical displacement, potential conflicts and encroachment or overuse of other areas;
- Loss of accessibility for several wildlife species (except for birds), restraining their distribution area;
- Loss of flora and fauna (especially fauna with no opportunity to escape)
- Loss or reduction of other services such erosion control, carbon sequestration, flood attenuation provided by the natural ecosystems will
- Loss of nature-based tourism opportunities;
- Encroachment of protected areas;
- Creation of barriers, cut of migration corridors for wildlife and livestock and cut of circulation routes of local communities.

7.5.2.2 Scenario comparison

The figures presented in this section are based on GIS analysis.

ENCROACHMENT OF NATURAL ECOSYSTEMS

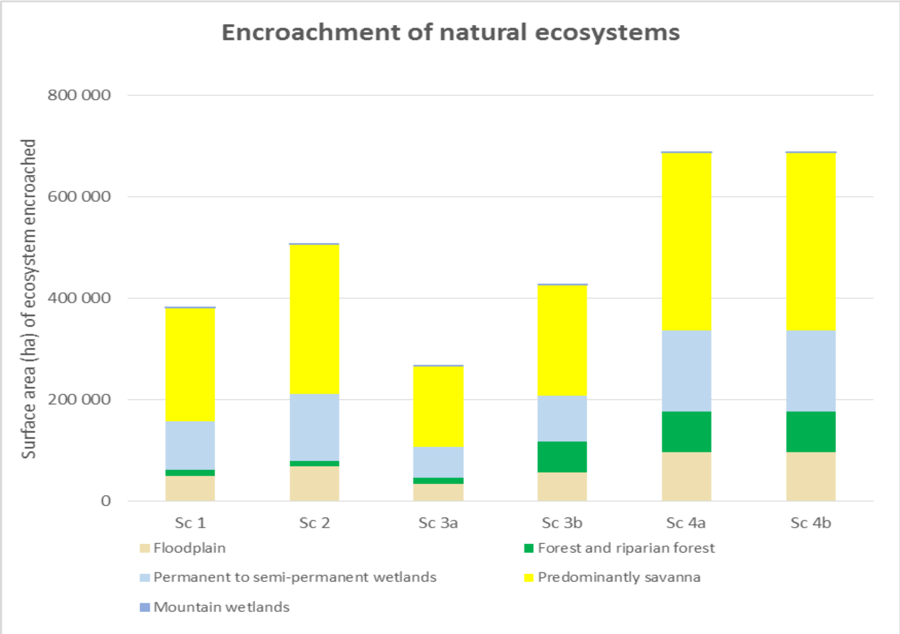
Land use patterns within each project footprint are shown in Figure 7-25 next page.

The figure below (Figure 7-24) features the magnitude of the encroachment for each scenario. The total surface area encroached is commensurate with the total footprint of each scenario. Compared to Sc 4a and Sc 4b, Sc 3b leads to less ecosystem encroachment since the implementation of an environmental flow results of less water available for irrigation and therefore less irrigated land. Compared to Sc 3b, Sc 4a and 4b, Sc 1, 2 and 3a lead to less encroachment of forests since irrigation schemes have been resized to avoid any forest areas. The residual forest encroachment of Sc 1; 2 and 3a are due to reservoir footprints. For these scenarios, the total area encroached is lower because irrigation schemes have been resized to avoid other sensitive areas as well, such as protected areas and migration corridors.

In Sc 2 Tams and Birbir dams lead to increased dry season flows of the Baro at Gambella, which is not the case in Sc 1 (including all hydropower dams except Tams and Birbir dams) and does not allow to irrigate as much land as in Sc 2.

The total surface area encroached for the intermediate cases (Sc 3a and 3b) is lower than for Sc 2 and Sc 4b respectively, since the implementation of an environmental flow reduce the surface area that can be irrigated.

Figure 7-24: encroachment of natural ecosystems for each scenario



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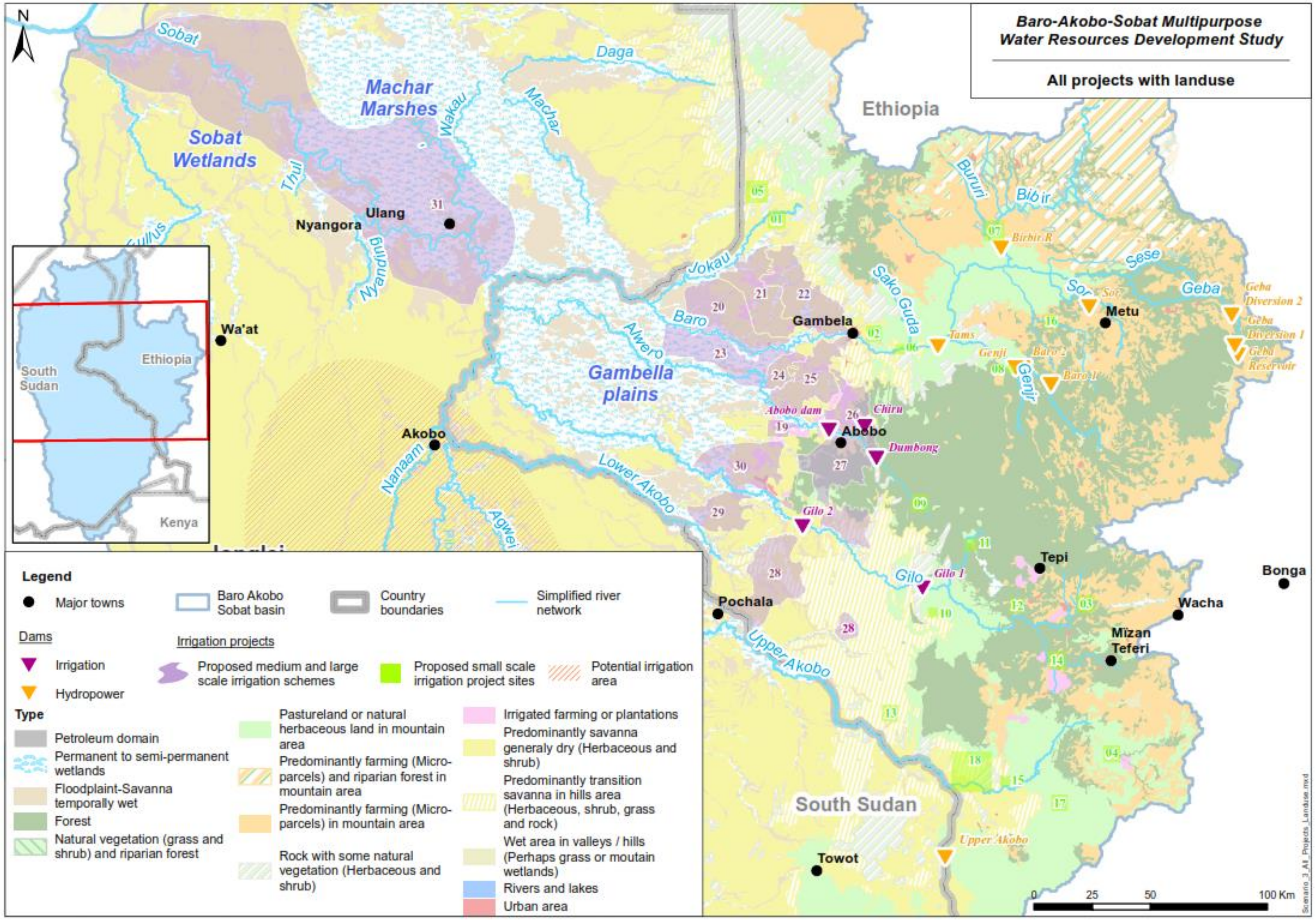


Figure 7-25: land use patterns within project footprints

ENCROACHMENT OF MIGRATION CORRIDORS

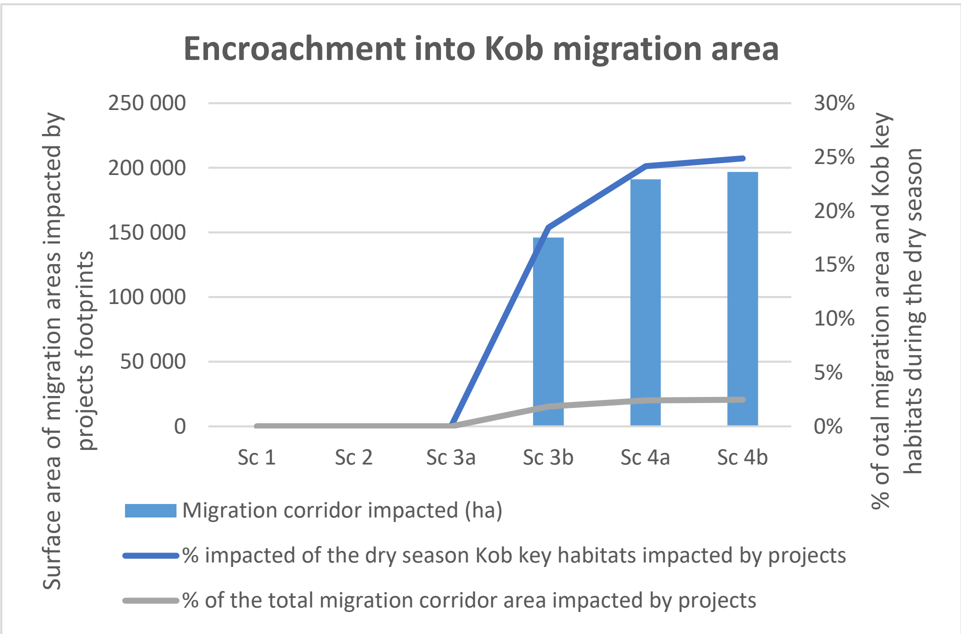
The following large-scale irrigation schemes are located within the Kob migration area (see Figure 7-27):

- Baro left bank – scheme No 23;
- Gilo left bank (Gilo 1 dam) - scheme No 28;
- Gilo right bank (Gilo 2 dam) - scheme No 30;
- Gilo left bank (Gilo 2 dam) - scheme No 29;
- Sobat irrigation scheme- scheme No 31.

The total surface area of Kob habitat encroached by projects footprints for each scenario is presented in the figure below. Wetlands are key habitats for Kob during the dry season as they provide water and forage resources. Project footprints encroach up to around 25% (Sc 4b) of these areas.

Sc 1, 2 and 3a do not encroach at all in Kob migration areas since these areas have been excluded from irrigation schemes when designing these scenarios.

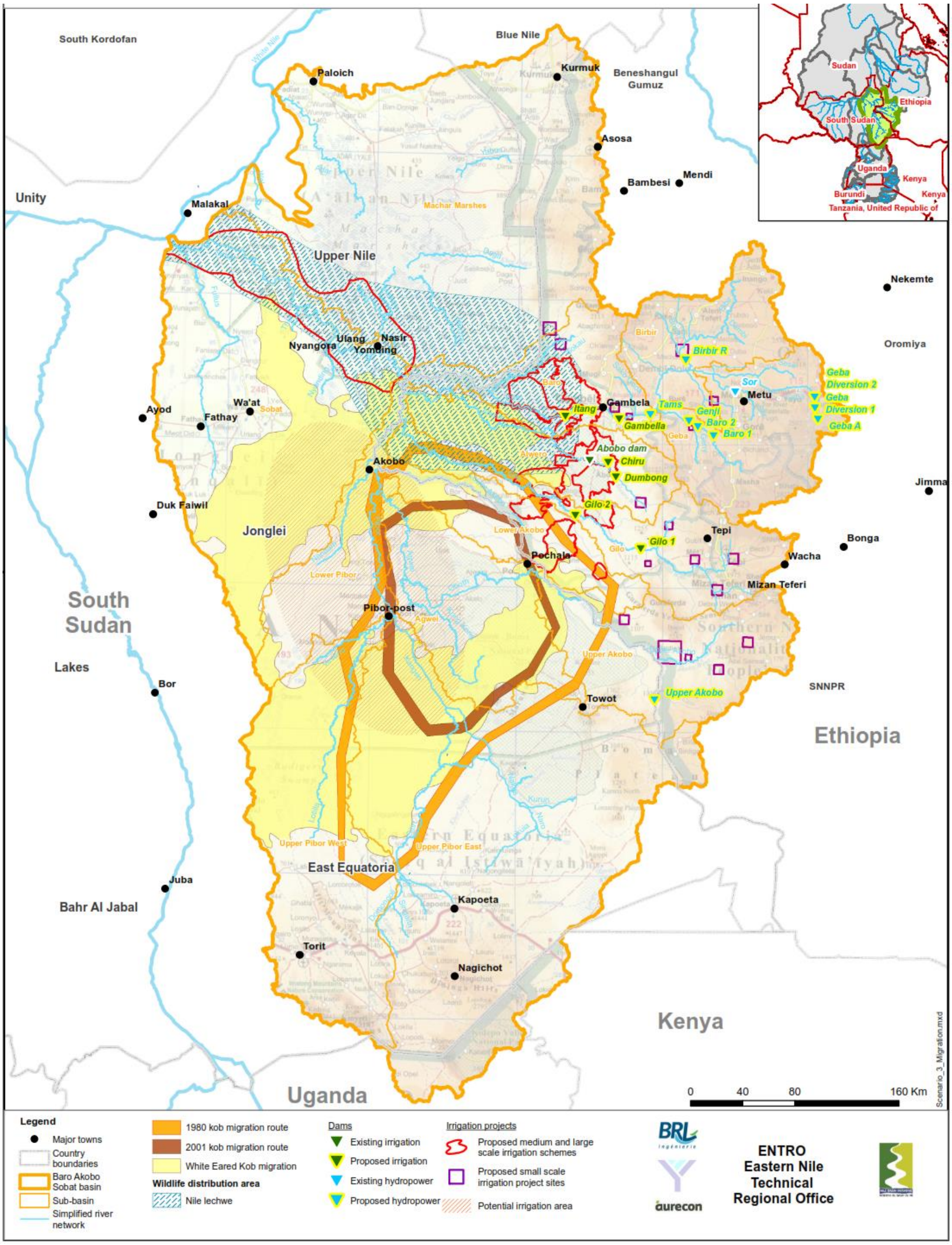
Figure 7-26: Encroachment into Kob migration area



The map presented in Figure 7-27 also shows the interferences between Nile lechwe habitats. Unlike Kob habitats which have been mapped several times thanks to collars, the Nile lechwe habitat is deemed to be less reliable essentially because the Sobat and Machar areas have almost never been investigated as far as wildlife is concerned.

Despite these uncertainties, the literature states that the South Sudan residual Nile lechwe population is located in the wetlands around the Sobat river and in the Machar Marshes. As such the Sobat irrigation scheme could be also a source of disturbance in addition to the disturbance caused by hydrological changes in the area (see sections 7.4.2 and 7.4.1). The Nile lechwe, which is endemic to the Sudd wetlands and the BAS wetlands indeed relies on fringing waters.

Figure 7-27: Location of large scale irrigation schemes and Kob and Nile Lechwe habitats

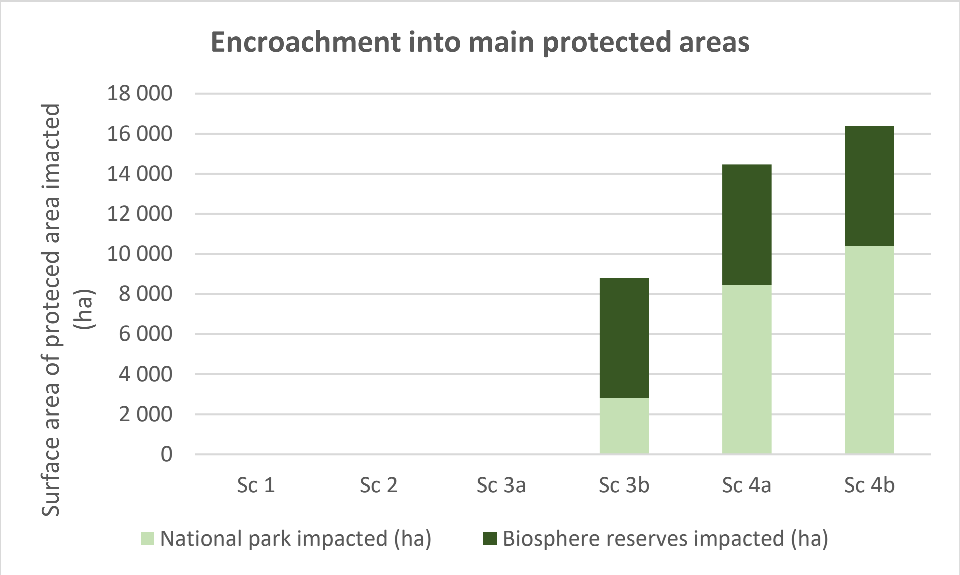


According to the available littérature, Elephant migration routes seem to be located outside of the impacted areas.

ENCROACHMENT OF PROTECTED AREAS

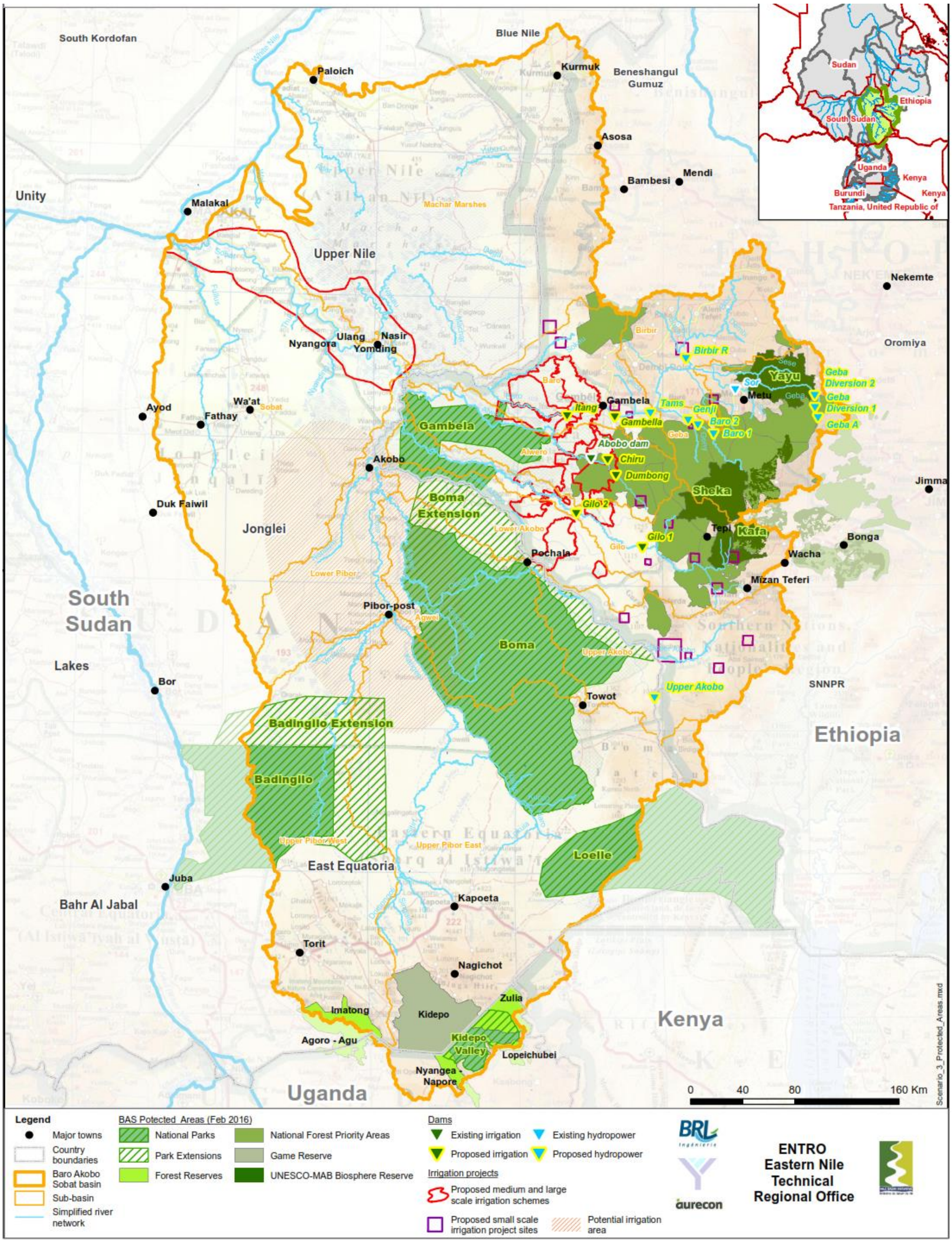
Apart from several irrigation projects encroaching into National forest priority areas, the main protected areas potentially impacted are Gambella National Park (around 7 500 encroached by the Baro Left Bank – Scheme No 23 project) and Sheka Biosphere Reserve (around 4 600 ha encroached by the Bako small-scale project). The interference between projects and protected areas is presented in Figure 7-29.

Figure 7-28: Surface area of protected areas potentially impacted by each scenario



Sc 1, 2 and 3a do not encroach at all into protected areas since these areas have been excluded from irrigation schemes when designing these scenarios.

Figure 7-29: Encroachment into protected areas



CUMULATIVE AND TRANSBOUNDARY IMPACTS ON WETLANDS AND THEIR POTENTIAL SOCIAL AND ENVIRONMENTAL IMPLICATIONS

Cumulative impacts on wetlands are essentially due to:

- Encroachment from project footprint;
- Hydrological changes leading to a reduction of the wetland size.

The table below gives a global picture of the total surface area of wetlands which could be affected through each scenario.

In the following analysis, the term "wetlands" include both floodplains and semi-permanent to permanent wetlands. Highland wetlands are not included in the following analysis.

Table 7-28: Cumulative impacts on wetlands

	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Loss of permanent to semi-permanent wetland due to project footprint (ha)	94 497	130 828	61 066	90 863	158 900	158 900
Loss of permanent to semi-permanent wetland due to hydrological changes	73 500	112 400	41 200	59 500	137 600	136 200
Loss of floodplains due to project footprint (ha)	50 750	68 614	34 262	57 472	97 811	97 811
Loss of floodplains due to hydrological changes (ha)	56 400	175 800	89 500	225 500	327 300	331 800
TOTAL surface area of wetland impacted (ha)	**275 147**	**487 642**	**226 028**	**433 336**	**721 611**	**724 711**
Wetlands total surface area in the BAS (ha)	3 049 793	3 049 793	3 049 793	3 049 793	3 049 793	3 049 793
% of total BAS wetlands impacted by the scenario	4%	8%	4%	7%	12%	12%
Total loss of wetlands in Gambella National Park (ha)	88 600	118 900	53 300	171 900	269 100	266 300
Wetlands total surface area in Gambella national park (ha)	392 896	392 896	392 896	392 896	392 896	392 896
% of wetlands of Gambella National Park impacted by the scenario	23%	30%	14%	44%	68%	68%
Total loss of wetlands in migration corridors	100 000	139 100	64 700	342 647	500 749	503 588
Wetlands total surface area in migration corridors	791 564	791 564	791 564	791 564	791 564	791 564
% of wetlands in migration corridors impacted by the scenario	13%	18%	8%	43%	63%	64%

NB$_2$: The above figure does not take into account the footprint of additional irrigation and hydropower potential identified in South Sudan. The foreseen site for the Upper Akobo hydropower dam is covered by dry savannah predominantly. The foreseen areas for the development of additional irrigation in the Pibor/Akobo is also predominantly covered by dry savannah but is also endowed with floodplains of the Oboth, Kong Kong, Pibor and Veveno rivers and with the Gwom wetlands. The latest are located within the heart of wildlife migration corridors and do encroached into the Boma National Park and its extension. The impacts on wildlife could therefore be significant. This will have to be considered while designing the irrigation scheme in order to mitigate them.

Potential consequences on wildlife

During wet years, wetlands (floodplains and semi-permanent to permanent wetlands) can account for 75% of the Gambella national park surface area and are deemed to consist of the Park core wildlife areas. The previous table shows that full-development scenario can lead to a reduction of 68% of these core areas, which could have a significant impact on wildlife population of the National Park.

However it is not possible to quantitatively assess to potential reduction of wildlife population in the BAS nor in Gambella National Park since the relationship between habitat degradation and wildlife population is not linear and that wildlife population depend on several factors. However, it is worth reminding here the impacts on wildlife population caused by the Maga dam in the Waza Logone Floodplain (Cameroun). Scholte (2005) indeed states that a reduction of 1,500 km2 of the floodplain (from an original size of around 8,000 km2) had the following consequences:

- Reduced Kob population: “Despite the above-mentioned count biases, major impacts of (man-made) droughts have been detected, especially on Kob. The Kob population dynamics show the intrinsic link between stress from periods of low rainfall and man-made droughts, induced by the Maga dam construction.” (Scholte, 2005).
- Wildlife extinction: “The disappearance of Waterbuck that used to occur in the floodplain, yet in small numbers since the early 1970s, appears to be linked to the hydrological changes. […] The extinct Bushbuck and Red-flanked Duiker used to occur in the wooded parts of Waza NP that experienced a loss of tree cover due to lack of flooding from upland water courses, the low rainfall in the 1970s and early 1980s as well as an increasing impact of Elephant” (Scholte, 2005).

The impact on waterbirds population is also deemed to be significant based on birds reliance to wetlands in similar areas:

- In the Niger delta, Zwarts et al (2005) indicates a positive correlation between the waterbirds population and flood levels. The waterbirds feeding conditions consist of an underlying factor since an important part of waterbirds relies on fish and mollusc population. These populations are themselves correlated to the flooding patterns.
- In the Waza-Logone area, (Scholte, 2005) showed that the 10,000 Black-crowned Crane population drop down to 2,000-2,500 individuals because of the Maga dam construction. Black-crowned Crane indeed depends on moist grassland habitat during the crucial nesting and dry season periods. More generally (Scholte, 2005) showed that perennial grasslands and 20-40 cm deep water habitats were crucial for waterbirds.

Similarly, according to (IGAD, 2015), recent large-scale commercial agricultural development activities in the Gambella Region and consequent modification of the river flow of the Alwero has put the Duma wetland under high pressure. The Nile Lechwe and Shoebill Stork are confined in the resulting fragmented wetland and their habitat is therefore potentially highly threatened.

Potential consequences on food security

Cumulative impacts on wetlands and their potential consequences on fish population and grazing areas are taken into account in the food production losses presented in the section dedicated to food security (7.3.2).

7.5.2.3 Need for acquisition of further information on uncertain factors

Information available on the BAS biodiversity features and ecosystem services is very poor with the exception in some isolated areas such as the Ethiopian highland forests located in Biosphere reserves.

There is a need for further cooperation with managers of protected areas and with wildlife specialists in order to acquire further information on wildlife population and their dependency on wetlands especially.

7.5.2.4 Enhancement and mitigation options

The most effective way to reduce impacts caused by project footprints lies in the avoidance of sensitive areas in the design of irrigation schemes. There may be opportunities for re-siting the command areas of the most affected irrigations schemes.

In addition, concerning the cumulative on wetlands, mitigation options identified in section 7.4.2 could significantly reduce the impacts due to hydrological changes.

7.5.2.5 Residual significance

Avoiding all sensitive areas (forests, wetlands, protected areas, and Kob habitat) makes it possible to significantly reduce the residual significance.

7.6 Transboundary cooperation

The contribution to transboundary cooperation of each scenario has been investigated through the following indicators:

- The contribution to regional and national economic growth (Additional revenue from main sectors has been calculated according to the results of the economic and financial analysis as the sum between the Financial Net Present Value and the value of the additional employment).
- The level of transboundary cooperation and management required (qualitative assessment according to the type of projects involved in each scenario and the magnitude of the potential positive and negative impacts);
- The impact on flows downstream of Sobat/White Nile confluence (the results have been extracted from the water simulation model).

The table next page compares the scenarios according to the various indicators.

Contribution to regional and national economic growth

Results are commensurate with the technical results presented in the summary of the technical assessment (section 7.2).

They directly fit in the cost benefit analysis (part of the economic and financial analysis) CBA (see section 8.2 and Annex 5).

Level of transboundary cooperation and management required

Preliminary consideration: an important degree of collaboration is already needed within each country to successfully implement and serve the population interests

Development in the present Study is envisaged as an externally-initiated intervention in the existing natural and social environments in the BAS basin as described in the Study's Baseline Report. The purpose of the identified interventions is to realize positive and sustainable changes in the physical and social environments in the BAS basin. Implementing these changes will require a collaborative effort between groups of stakeholders, i.e. various levels of government, professionals, technicians and extension services and the intended beneficiaries of developments in the basin.

The following table presents a qualitative assessment of the likely changes in relations between these groups for each scenario.

Table 7-29: Qualitative Assessment of Likely Changes in Relations between Main Stakeholder Groups by Scenario

Stakeholder Group	Scenario					
	1	2	3a	3b	4a	4b
Government	Low	Low	Moderate	Moderate	Negative	Negative
Technicians	Low	Low	Moderate	Moderate	Negative	Negative
Beneficiaries	Moderate	Moderate	Moderate	Moderate	Negative	Negative

Note1: "Government" includes all levels of government, i.e. national, state/regional and local

Note 2: Technicians include all categories of technical and professional staff and extension services

Note 3: Beneficiaries include rural and urban populations in the basin that are target groups for the development of water resources in the basin

It can be seen from the above table that the two precautionary scenarios (scenarios 1 and 2), while sustainable in the short term, are likely to have negative impacts on the relationship between government and beneficiaries and technicians and beneficiaries in the long term due to increasing and unfulfilled demands/expectations from beneficiaries, even when technical capacity is adequate to meet the relatively low level and scope of development activities supported by the government. In the two precautionary scenarios, government continues to be critically under resourced and relatively unresponsive to beneficiaries' needs and demands and viewed at best as ineffective by beneficiaries. Another consequence of the precautionary scenarios is that the environment is better conserved than in the other scenarios.

The two full development scenarios (4a and 4b), while implying a higher level and pace of socio-economic development, are likely to have negative impacts on relations between government, technicians/extension services and the intended beneficiaries in both the short and long term due to unrealistic promises from government, capacity constraints among technical personnel, and unrealistic expectations from beneficiaries, or a combination of these factors. In addition, the scope and pace of development is likely to be unsustainable in the long term, as the government faces growing challenges from the very interests it seeks to promote.

The two intermediate scenarios (3a and 3b) represent an incremental step or "middle path" between the precautionary and full development scenarios which, while requiring a higher level of investment/financial resources and technical capacity and secure land tenure than at present, takes into account the need to consider the environmental impact of water-related development activities in the basin.

Transboundary considerations

The geographical configuration context of the BAS, with **major rivers coming from the Ethiopian plateau flowing down to Ethiopian floodplain and South Sudan floodplains and wetlands further downstream makes transboundary cooperation and management a prior necessity**.

Flow regulation and water abstractions in Ethiopia will have an impact on both:

- River flows of the Sobat, modifying flooding patterns, water available for existing riverine water uses, water available to develop irrigation, navigation and river crossing periods;
- River flow of the lower Baro and it spill to South Sudan wetlands, the Machar Marshes, resulting in a reduction up to around 40% of its surface area;
- River flow of the Pibor, essentially downstream of its confluence with the Gilo.

On the other hand, hydropower development on the upper Akobo in South Sudan might affect lower Akobo and Gilo (via two successive spills) rivers and their associated wetlands (which are part of the Gambella plains complex) in Ethiopia. However, it is not possible to have an idea of the impact magnitude at this stage. In addition, the hydrology of the Akobo river is poorly known and very complex which still makes a qualitative analysis difficult.

The higher the potential magnitude of downstream hydrological change, the higher degree of required transboundary cooperation and management.

Impact on flows downstream of Sobat/White Nile confluence

The contribution of the BAS hydrology to the White Nile after its confluence with the Sobat is significantly affected in all scenarios, apart from scenario 3a.

While the magnitude of this impact could be estimated (modulo the margin of errors), the assessment of significance of this impact (in South Sudan, Sudan and Egypt) falls beyond the technical boundaries of this study. These possible impacts would have to be investigated in the context of the whole Nile Basin, taking into account ongoing and potential development in the Nile Equatorial Lakes (NEL) sub-basin. This will have to be studied in detail as part of implementation of the IWRMDPlan, especially when designing the integrated BAS hydropower, irrigation and multipurpose development programme – Phase 1: Baro / Sobat component.

Table 7-30: Potential implications for Transboundary Cooperation

Sub-dimension	Indicator	Threshold	**Baseline**	**Precautionary principle options**						**Compromise options**						**Full Development**					
			Scenario 0	**Scenario 1**			**Scenario 2**			**Scenario 3a**			**Scenario 3b**			**Scenario 4a**			**Scenario 3**		
		Calculated	**Calculated**	-	Calc'd	+	-	Calc'd	+	-	Calc'd	+	-	Calc'd	+	-	Calc'd	+	-	Calc'd	+
Contribution to regional and national economic growth	Additional revenue generated from hydropower - Ethiopia	Not applicable			2 438			10 537			9 286			9 286			10 574			9 486	
	Additionnal revenue generated from large-scale irrigation - Ethiopia				1 473			2 827			116			1 081			3 301			3 831	
	Additionnal revenue generated from large-scale irrigation - South Sudan				1 690			2 030			1 361			1 432			1 908			2 044	
Level of transboundary cooperation and management required	Degree of cross-border cooperation required in system operation				Medium			High			Medium			High			High			High	
Impact on flows downstream of Sobat/White Nile confluence	Change in MAR entering White Nile (BCM)	**10.27**	12.30	8.586	9.54	10.49	8.04	8.93	9.82	9.52	10.58	11.64	8.87	9.85	10.84	7.53	8.37	9.21	6.79	7.54	8.29
	Change in average minimum flow in White Nile d/s of Sobat confluence (m^3/s)	**408**	600	480	533	586	481	534	587	509	565	622	499	554	609	470	522	574	468	520	572

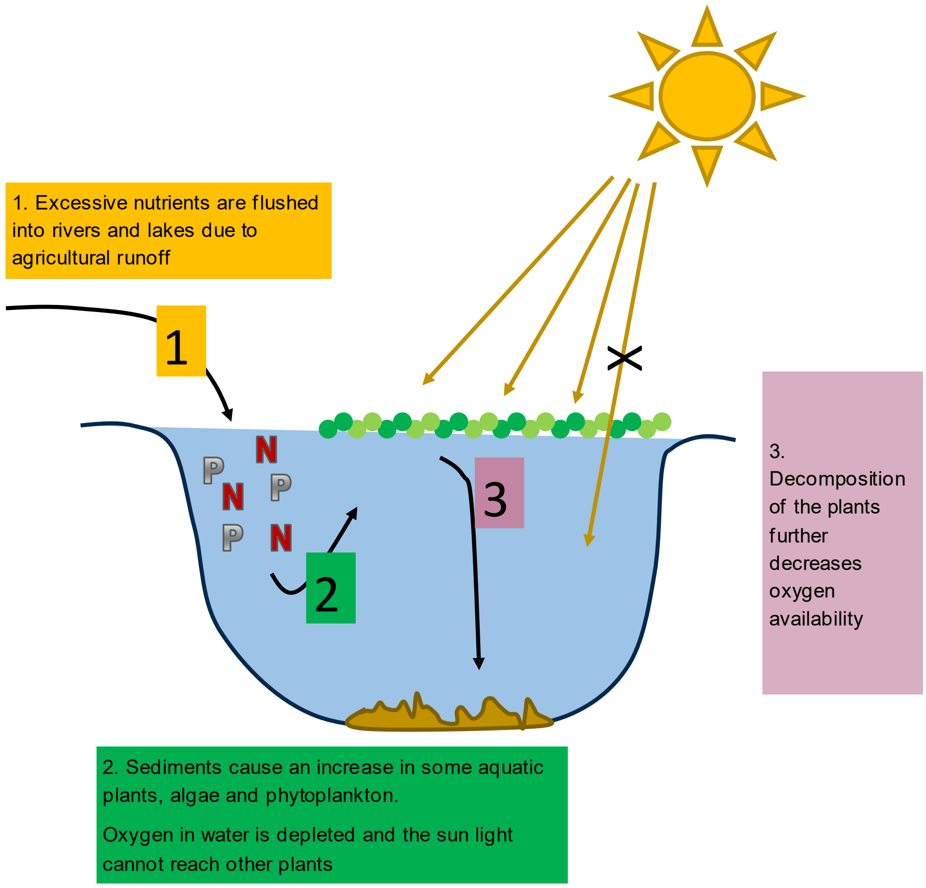
7.7 Change in Water Quality

7.7.1.1 Impact overview

Water resources development could be problematic for water quality in some of the BAS water bodies as a result of the following changes:

- **Agricultural practices.** Large scale irrigation is planned throughout the basin, especially in the Ethiopian part of the sub-basin and might be followed by an increased use of fertilizers and pesticides and poor management of drainage water. Water pollution from agricultural practices impacts groundwater through infiltration of the pollutants and surface waters through run-off of agricultural drainage waters. Run-off is usually increased by:
  - Significant slopes
  - High rainfalls
  - Surface irrigation
  - Poor management of run-off waters

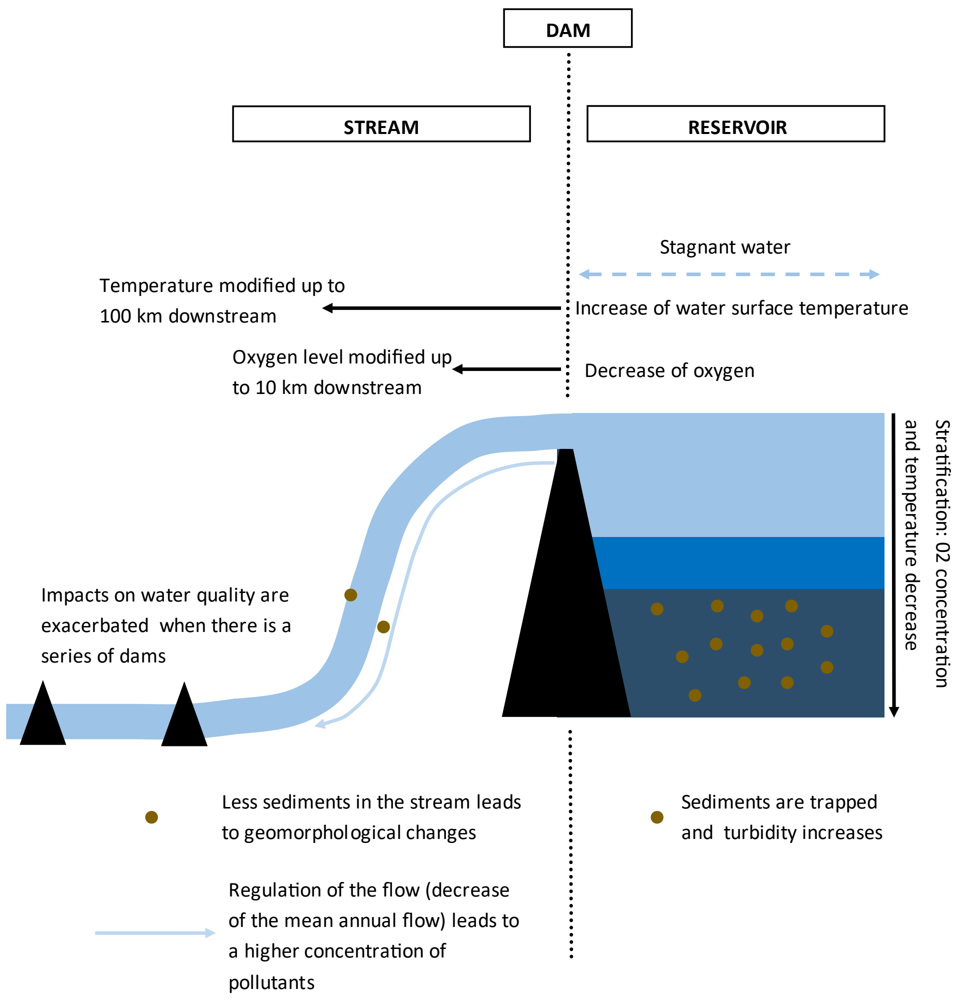
Figure 7-30: Explanation of the eutrophication effect



- **Construction of dams** and modification of natural flows. As emphasized in the baseline report, a major issue in all of the Baro-Akobo-Sobat sub-basin concerns suspended solid loads in surface waters due to erosion. High sediment loads in rivers are the result of high topographic slopes, high intensity rainfall patterns, poor farming practices and deforestation due to population pressure and commercial exploitation of wood resources. Scenarios will all lead to vegetation clearance of important surface areas for both dams and irrigation schemes construction. However, they are deemed to have a global positive impact on deforestation through the improvement of food and energy security.

In addition, construction of dams will be a physical barrier against sediment transport. This will have geomorphological impacts downstream of the dam (refer to the dimension "geomorphological changes") but also it will increase the turbidity in the reservoirs, impacting the ecosystems. Dams will also impact oxygenation and temperature of water in the reservoir but also downstream.

Figure 7-31: Major impacts of dams on water quality



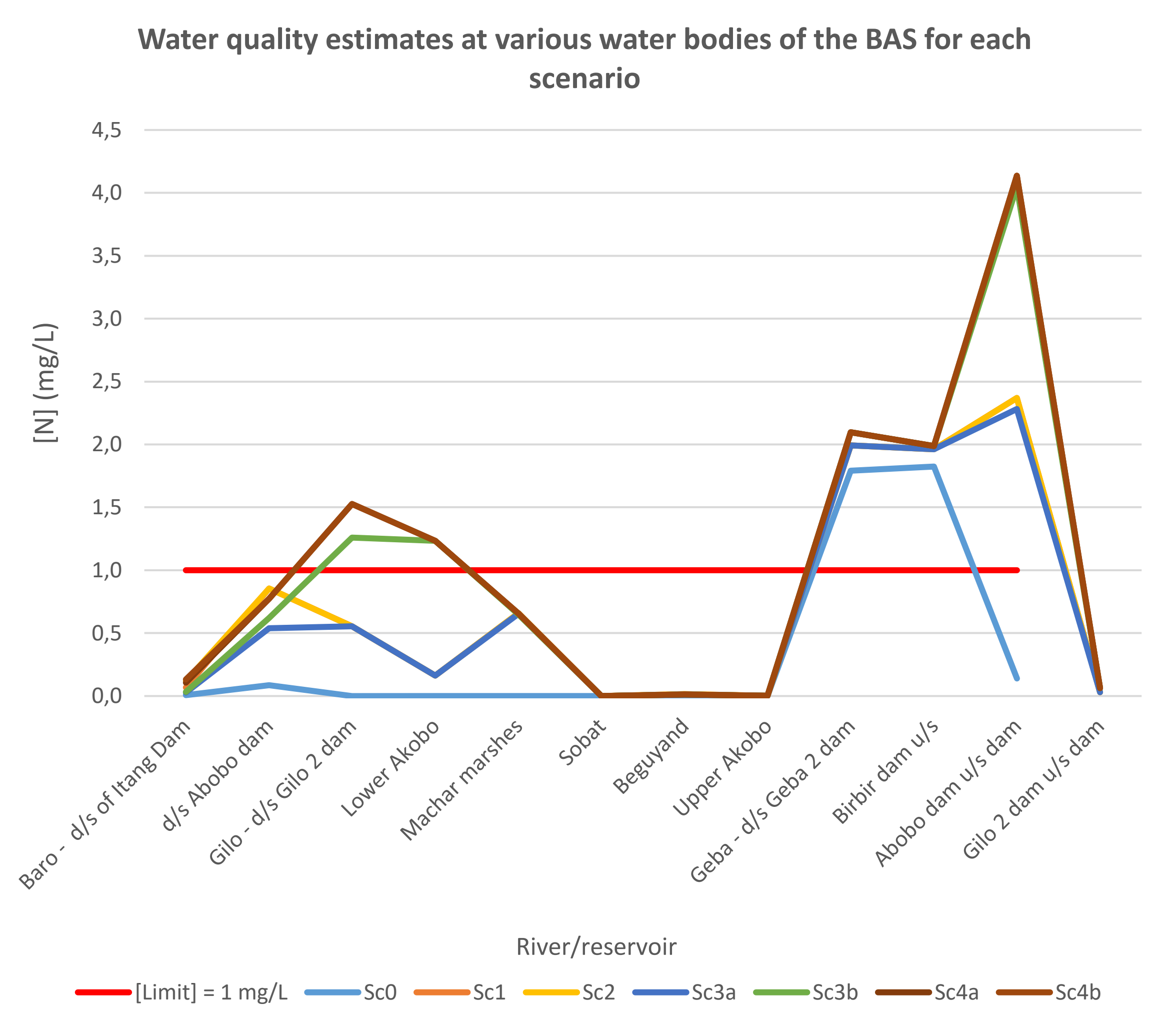
The main consequences on human health are linked to the consumption of water which does not fulfil the WHO potable water standards. For instance, the consumption of water with excessive concentration of nitrate can lead to respiratory issues. Stomach and oesophagus cancers have also been reported (Bisson and Gaudreau, 1992).

High concentrations of phosphate and nitrate can lead to the eutrophication of water bodies.

7.7.1.2 Scenario comparison

The figure below features the assessment of the water quality of various tributaries for each development scenario. The water quality at each reference point in BAS basin is assessed using simulated estimates of the nitrates [N] and phosphates [P] loads for each scenario. The pollutant load is then compared to the related WHO standard, displayed in red on the graphic.

Figure 7-32: Water quality estimates at various water bodies of the BAS for each scenario



The analysis of the graphs leads to the following conclusions:

- The baseline scenario (0) shows that the concentration of nitrate due to irrigation may currently be a problem during certain periods of the year in the Geba and Birbir rivers. This can be explained by the fact that there are already around 40,000 ha irrigated in Geba catchment and around 70,000 ha irrigated in Birbir catchment. These catchments are characterised by high topographic slopes thus significant agricultural run-off.
- Scenarios 1, 2 and 3a might slightly worsen the water quality issues observed in the baseline in Giba and Birbir rivers. Sudden rises of the nitrates loads might be also observed downstream at Abobo dam and in a smaller extent further downstream (downstream Abobo dam, lower Abobo, Machar Marshes, etc.), remaining below the WHO limit though. This is a direct impact of the development of small-scale (180,000 ha) and large-scale (370,000 ha) irrigation schemes for the three scenarios.

- Scenarios 3b, 4a and 4b all consist in a greater irrigation development (+200,000 ha of small scale schemes and +550,000 ha of large-scale schemes). This strategy might generate acute water quality issues (up to 4 mg/mL around Abobo dam) in the upstream catchments, with steeper slopes and subsequent higher agricultural run-off. These high pollutant loads will be slowly diluted downstream but still fostered by pollution generated by irrigation schemes to be implemented in the lower part of the basin. The water quality issues identified in the baseline scenario might me slightly worsen at Gilo dam and lower Akobo, with nitrates loads higher than the WHO standards.
- On a separate note, the construction of weirs and dams will create physical barriers against sediment transport in the sub-basin: it will increase turbidity in the reservoirs, reduce oxygenation and modify the temperature of water in the reservoir and downstream. In the different scenarios, there are dams in series on the Baro river (Gambella and Itang dams), on the Alwero river (Dumbong, Chiru and Alwero dams) and on the Gilo river (Gilo 1 and 2 dams). This should be taken into account during the design of the development management options as the construction of dams in series exacerbates the impacts on water quality.

The possible water quality issue identified shall require the implementation of mitigation measures. Such measures include the development of a water quality monitoring network in each tributary of the BAS basin to monitor pollutant load evolution and the dissemination and implementation of good practices to reduce the discharge of waste water in the environment (reducing the use of fertilizers, efficient irrigation systems, improved waste management, etc. See subsequent section).

NB: the above results do not take into account the potential effects of the identified additional potential for irrigation and hydropower in South Sudan, which might also lead to potential issues of water quality issues if not properly managed.

7.7.1.3 Need for acquisition of further information on uncertain factors

As emphasized by Merid (2005) in his study on water quality in the BAS sub-basin, changes in water quality remain a field of very limited knowledge and understanding in the basin.

The analyses that were conducted during the Environmental Impact Assessment of the feasibility study for Baro 1 & 2 hydropower dams (Norplan, Norconsult and Lahmeyer, 2006) (one sample was realised at several locations in February/March 2004) consist of the single data available for the BAS.

Merid (2005) also stresses that the lack of data about domestic solid waste and effluent volumes constrained the assessment of pollution of water supply sources and, hence, knowledge about domestic waste management was identified as a gap to be filled in the future.

Since most of the scenarios could be problematic with regard to water quality degradation, at least for some locations of the BAS, a water quality monitoring system is required in order to assess the potential changes and allow to adapt the ESMP consequently.

Monitoring of quality will require cooperation agreements between the two countries.

7.7.1.4 Enhancement and mitigation options

In order to reduce potential water quality degradation, the following mitigation options might be required (to be adapted depending on the water quality monitoring results):

- Design and implementation of a water quality monitoring at the BAS scale;
- Prevention of water quality issues associated with dams implementation;
  - Thorough removal of organic matter form areas prior to inundation to reduce initial eutrophication issues;
  - Erosion prevention upstream of dams water catchments to avoid sediment accumulation within dams, silt load and long-term eutrophication issues;
  - Installation of air draughts in the water-release ports to boost oxygen levels by aerating released water;
- Prevention of water quality issues associated with irrigation schemes implementation in vulnerable parts of the basin;
  - Optimization of irrigation to limit water discharges and infiltration after field application. Indeed the efficient application of irrigation water, aimed at mimimizing the quantity of water that infiltrates past the root zone supports reduces wastage of fertilizer and the discharge of pollutants into the return flows
  - Minimization of the use of fertilizers and pesticides, especially in vulnerable areas;
- Prevention of water quality issues associated with increased population density;
  - Elaboration and implementation of sanitation and waste water management plans in all urban centres and dense settlements;
  - Elaboration and implementation of sanitation and waste water management plans around irrigation schemes.

7.7.1.5 Residual significance

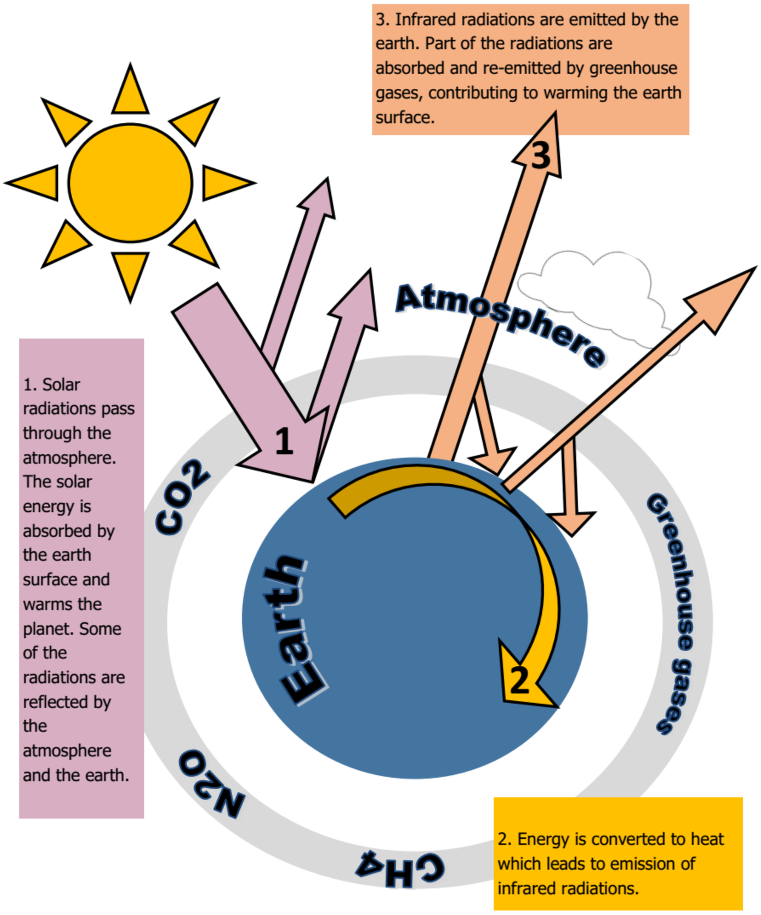
The implementation of mitigation measures should significantly reduce risks to water quality, whatever the scenario. In any case, the mitigation options will have to be adapted over the projects life according to the results of water quality monitoring all over the BAS basin.

7.8 CHANGE IN GHG EMISSIONS

7.8.1.1 Impact overview

According to the Intergovernmental Panel on Climate Change (IPCC)[33], greenhouse gases (GHG) are "*those gaseous constituents of the atmosphere, **both natural and anthropogenic**, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere*". The greenhouse effect is involved in climate change and the link between these phenomena is briefly explained in the figure hereafter.

Figure 7-33: Explanation of the greenhouse effect



It is shown in the baseline report that effects of climate change in the BAS sub-basin will likely lead to an increased occurrence of extreme events such as floods and droughts. It is important to emphasize the fact that contrary to the other dimensions of the SSEA, GHG emissions cannot be controlled at basin scale, they are a global threat. As such, limitation of GHG emissions in the basin is part of a global approach which aims at reducing GHG emissions to mitigate climate change. Impacts of BAS water resources development on climate change must be studied through national objectives of GHG emissions reduction and/or stabilisation.

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33 The Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988.

NB: It should be **noted that BAS vulnerability to climate change is addressed, when relevant, in the other dimensions**. Environmental and social risks which can increase BAS vulnerability to climate change are the following:

- Decrease of water quality;
- Decrease of flooding areas as important forage resources for livestock during the dry season;
- Decrease of water availability for downstream uses;
- Decrease of wetlands functionalities and services due to hydrological stress;
- Loss of evaporation from wetlands that partly contribute to the regional climate regulation;
- Loss of natural geomorphology of the river system, etc.…

7.8.1.2 Scenario comparison

METHODOLOGY

In order to assess the anthropogenic emissions of GHG related to water resources development in the basin, focus has been on the development of hydropower and irrigation[34]. In order to account for the different existing GHG, the results are presented in "CO_2 equivalent (CO_2eq)" which is the concentration of CO_2 that would have the same radiative impact than the different emitted GHG together.

The different sources of GHG emissions related to water resources development taken into account in the analysis are the following:

- Emissions due to flooding of reservoirs,
- Emissions due to land clearing and burning prior to irrigation scheme construction,
- Avoided emissions due to a reduction of deforestation thanks to irrigation and hydropower development. It has been indeed assumed that one's can expect that the shift from charcoal use to electricity will be rapid as a result of low electricity prices.

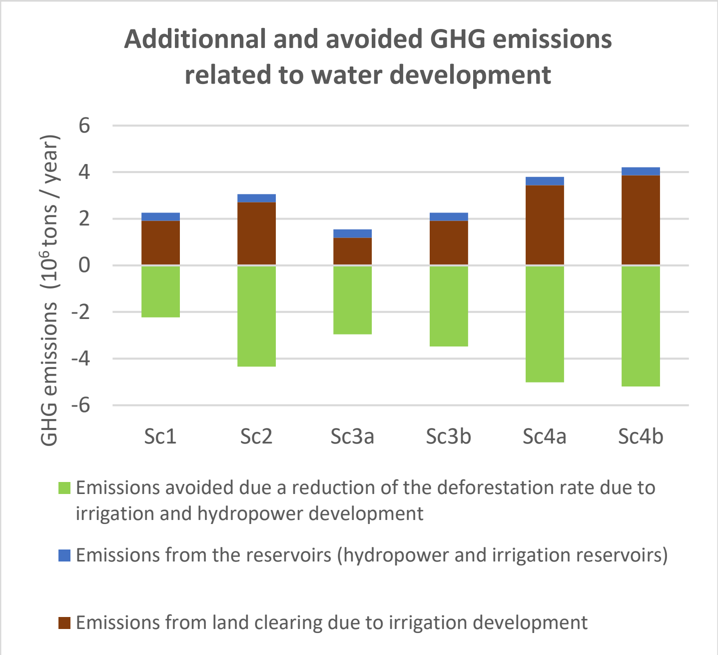
GHG emissions of scenarios are compared with a no-go scenario (2041) which suppose that rainfed agriculture has been developed to satisfy the food security. This leads to higher deforestation rates since rainfed agriculture is deemed to be less productive than irrigation. In this no-go scenario, deforestation is also supposed to increase due to increasing needs of charcoal and firewood due to the fact that hydropower has not been developed.

In this case, emissions due to N_2O releases due to irrigation development are not taken into account since these emissions are deemed to be equivalent of N_2O releases due to rainfed development.

[34] Livestock development has not been studied here but it should be noted that the impact of livestock husbandry on GHG emissions is potentially highly significant.

RESULTS

Figure 7-34: Additional and avoided emissions due to water development



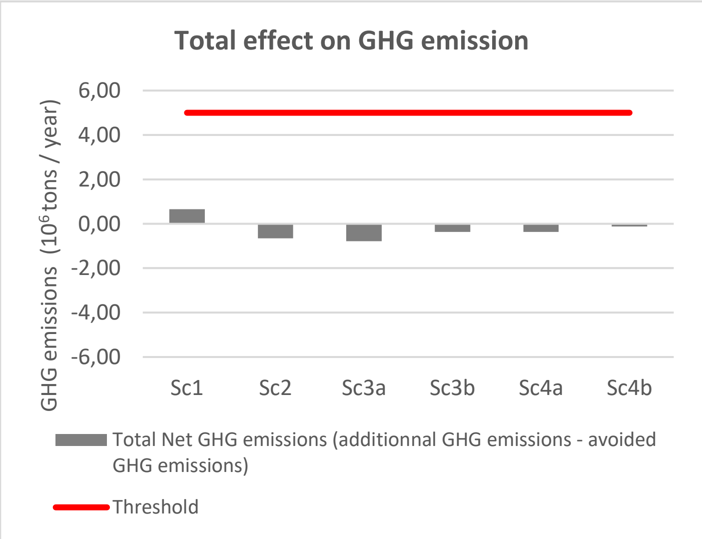
Emissions due to reservoirs are estimated at 0, 33 10^6 tons/year for scenario 1 compared to 0, 35 10^6 tons/year for scenario 2 to 4b. This is due to the absence of Tams and Birbir dam in scenario 1.

The avoidance of sensitive area in the irrigation schemes as implemented in scenarios 1, 2 and 3b allows a significant reduction of the GHG emissions due to land clearance since only 76% of small-scale and 67% of full potential irrigation is implemented.

Avoided emissions are maximum for full development scenarios (4a and 4b) since they generate more electricity and lead to higher agricultural productions than the other scenarios.

Compared to Scenario 2, Scenario 1 produces less electricity and has higher irrigation deficit since due to the absence of Tams dam which regulates the flow of the Baro and allows more water intakes from the river for irrigation. As such, the avoided deforestation is less important for Scenario 1 than for Scenario 2. Sc 3a and 3b produce quite as much electricity as Sc 2 and 4b respectively. However, they require an environmental flow which reduces the water available for irrigation. The avoided deforestation is therefore less important for intermediate scenarios than for Sc 2 and 4b.

Figure 7-35: Total effect on GHG emission due to water development



Looking at the total effect on GHG emissions related to water development (additional emissions – avoided emissions), all scenario should lead to an overall reduction of the GHG emissions compared to the hypothetical no-go scenario except Sc 1. Sc 1 does not lead to enough electricity generation to compensate usual deforestation.

Referring to the Ethiopian GHG emissions targets for 2040, the total effect of the IWRDMPlan is deemed to be positive except for scenario 1.

<u>NB:</u> the above results do not take into account the potential effects of the identified additional potential for irrigation and hydropower in South Sudan, which might also lead to additional emissions if not properly managed.

7.8.1.3 Need for acquisition of further information on uncertain factors

No specific needs have been identified concerning GHG emissions.

7.8.1.4 Enhancement and mitigation options

Even if almost scenarios lead to a reduction of the net GHG emissions, additional emissions will still occur. As a result, mitigation options to minimize GHG emissions are required and include:

- The control of vegetation clearance operations in reservoirs prior to inundation in order to reduce methanization risks and GHG emissions due to vegetation burning. Among others, it requires:
    - A total vegetation clearance of the reservoir surface area which will be flooded,
    - Exploitation of the woody biomass resulting from land clearance (timber, material to build houses etc.) to avoid vegetation burning;
    - The prohibition of burning of vegetative waste following vegetation clearance.
- The control of vegetation clearance operations prior to the construction of irrigation schemes to conserve trees of interest and reduce GHG emissions due to vegetation burning. Among others, it requires:
    - A selective clearance of the vegetation during scheme construction to conserve native trees of interest for biodiversity and landscape conservation;
    - Exploitation of the woody biomass resulting from land clearance (timber, material to build houses etc.) to avoid vegetation burning;
    - The prohibition of burning of vegetative waste following vegetation clearance.

7.8.1.5 Residual significance

Once the above mitigation options implemented, the overall impact is supposed to be not significant.

8. RESULTS OF THE COMPARISON OF ALTERNATIVES: SUMMARY OF KEY FINDINGS OF THE SSEA

8.1 INTRODUCTION

The points highlighted and the preliminary findings presented over the following pages are aimed at facilitating stakeholder discussion, not at attempting to impose the Consultant's opinion which would be contrary to the principles of the SSEA.

It should also be noted that the designs of Scenarios 1, 2, 4a and 4b are widely based on the findings of the first draft SSEA and subsequent stakeholder discussion and comments. The design of Scenarios 3a and 3b was purposely deferred until the preliminary findings from the running of Scenarios 1, 2, 4a and 4b were available so that these scenarios could be used to investigate alternatives that could be closer to a realistic preferred option scenario that takes into account the identified socio-economic and environmental shortcoming and/or challenges of Scenarios 1, 2, 4a and 4b.

As already mentioned in the previous chapters, it should be reminded that the critical data paucity in the BAS leads a number of uncertainties (detailed in chapter 5.3 and related annexes). Even if this is reflected in the margin of error in calculating the indicator or in the threshold, it is important to keep in mind that the results and conclusions drawn concerning potential social and environmental impacts are therefore indicative and provisional. As a result, the **IWRMDPlan implementation strategy has been mainly based on this principle**. It indeed recommends:

- To improve the general knowledge in the basin as a top priority for the IWRDMPlan;
- To **implement no-regret actions first.** Proceeding with caution should indeed allow the generation of critical data to ascertain the results for an improved and more informed analysis of main issues related to many of the proposed development projects.

8.2 PERFORMANCE OF ALTERNATIVES IN TERMS OF THE ECONOMIC AND FINANCIAL ANALYSIS

The detailed methodology and results of the economic and financial analysis are presented in the Annex entitled "Assessment of options; economic and financial analysis". In this section, only the overall results are presented.

PURPOSE AND CONTENT OF THE COST BENEFIT ANALYSIS

The cost-benefit analysis (CBA), which is the main tool used in the analysis, determines the financial and economic relevance of a project (or programme) by evaluating the differential of costs and benefits between the situation with project (Sc 1 to 4b) and the situation without project (baseline scenario).

In the current study, the CBA aims at assessing the financial and socio-economic feasibility of each scenario:

- Are the benefits higher than the costs?
- Which scenario appears the most relevant economically?

The CBA distinguishes the financial part of the scenario (i.e. the profitability from the investors' point of view) and the economic part (i.e. the "profitability" or relevance of the scenario from the whole society's point of view). Two analyses were therefore conducted:

- A financial analysis which allows the assessment the profitability of the projects in the investors' point of view. The analysis takes into account the financial costs and benefits, i.e. the investments and O&M costs and the revenues of the activity implemented (hydropower, irrigation, fish farming or rizipisciculture);
- An economic analysis which evaluates the viability of the scenario in the society's point of view. This analysis takes into account the financial costs and benefits plus the externalities of the projects.

An externality is a cost or benefit generated by an activity and that affects a party that did not choose to incur this cost or benefits (e.g. degradation of downstream wetlands due to a modification of flows from a hydropower plant, indirect employment created from a new activity, etc.). The analysis distinguishes the environmental, social and economic externalities. It makes it possible to appreciate the relevance of a scenario for the society as a whole.

For both analysis, three main indicators are computed:

- The Net Present Value (NPV) by summing the positive and negative discounted cash flows over the time period;
- The Benefits/Costs ratio : It should be superior to 1 for the project to be viable;
- The Internal Rate of Return (IRR), which determines the discount rate that would make the NPV equal to zero. It should be superior to the discount rate applied in the analysis (10% for the financial cash flows and 5% of the externalities).

The CBA distinguishes different levels of analysis:

- Geographically: the analysis distinguishes the impacts for the Ethiopian part of the BAS and the South Sudan part of the BAS;
- By economic sector: the analysis presents the financial and economic relevance for each economic sector that are developed in the scenarios: hydropower, irrigation, fish farming and rizipisciculture. It is assumed that the projects are implemented progressively according to the priority of the master plans.

LINKS WITH THE SSEA

As explained above, in order to appreciate the relevance of a scenario for the society as a whole, the economic analysis of the CBA combines the financial costs and the benefits of projects and positive and negative externalities.

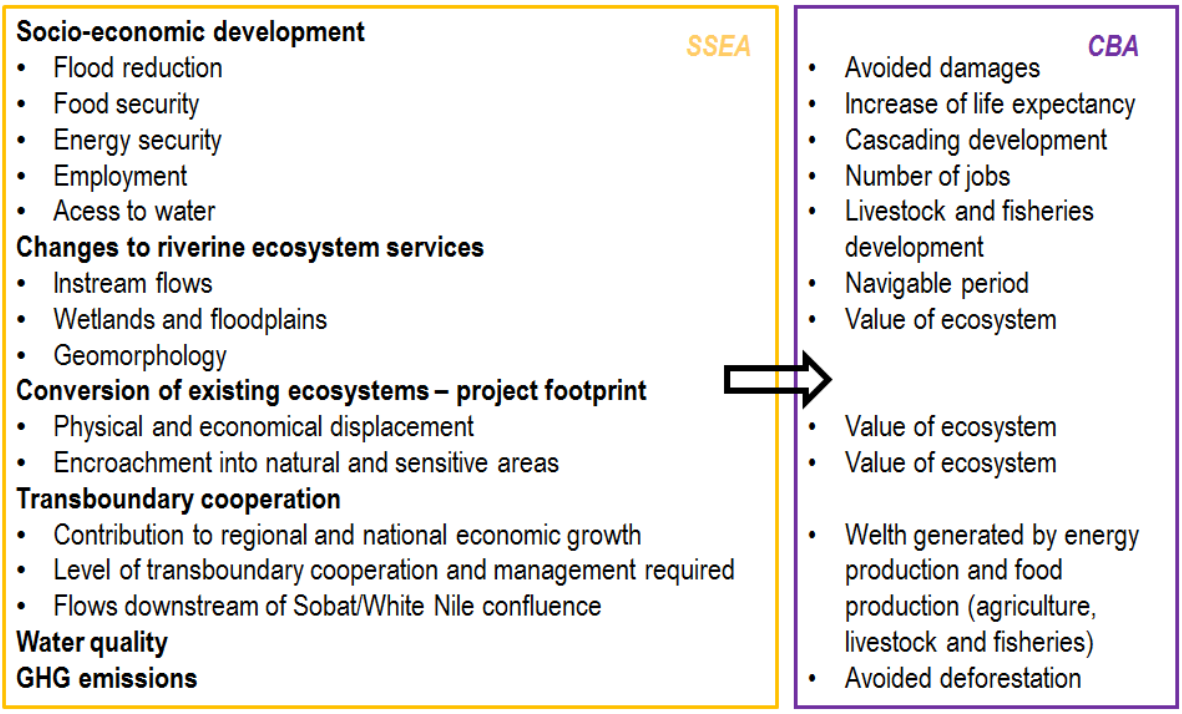
The benefits of projects (energy production, agricultural production) are assessed and presented as part of the SSEA and the CBA.

Positive (eg. Jobs created, fisheries development in reservoirs) and negative (eg. loss of wetlands, …) externalities are assessed as part of the SSEA and then converted into a monetary value as part of the CBA.

As a result, the **combination of the SSEA and the CBA replaces a Multicriteria analysis.** This approach is deemed to allow a **better objectification**, while avoiding the subjective weighting which implies a multicriteria analysis.

The figure below highlights the links between the SSEA and the CBA.

Figure 8-1: Monetarization of the environmental and social benefits and risks identified within the SSEA in the economic analysis of the CBA



<u>NB1:</u> Although the economic analysis monetarizes most of the social and the environmental impacts it is important to keep in mind some impacts cannot reasonably be included in the economic analysis.

<u>NB2:</u> The Economic Internal Return Rate (EIRR) and the Economic Net Present Value (ENPV) are not sufficient to appreciate the relevance of the projects. Thus the results of the economic analysis should be put in perspective with the SSEA results.

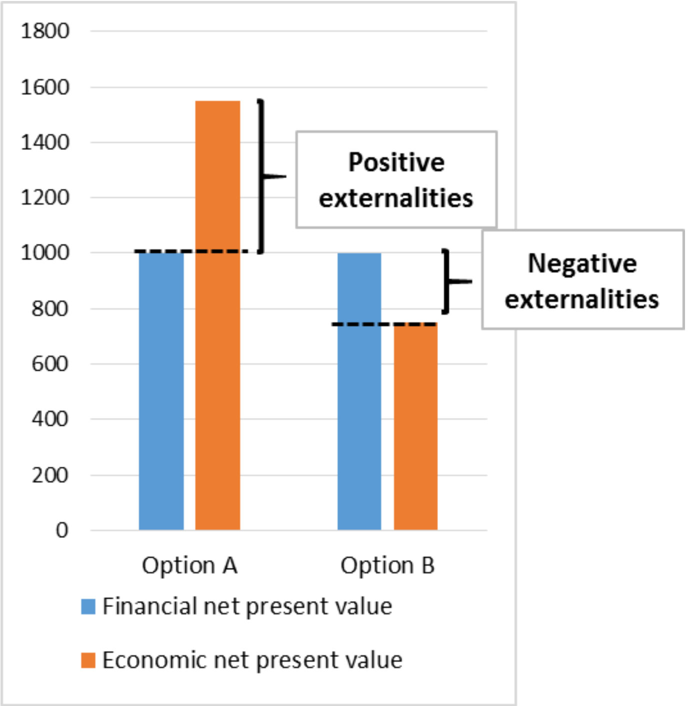
KEY RESULTS

If we look at the overall results, all the scenarios appear to have a positive Financial Net Present Value (FNPV)[35] and Economic Net Present Value (ENPV)[36]. The difference between the FNPV and the ENPV corresponds to the externalities.

35 The FNPV gives an indication of the profitability from the investors' point of view.

36 The ENPV gives and indication of the "profitability" or relevance of the scenario from the whole society's point of view.

Figure 8-2 : Example of FNPV and ENVP with positive and negative externalities



The table next page shows the environmental and social externalities of the 6 investigated scenarios. It shows that Sc 2, 4a and 4b have negative overall discounted externalities, while Sc 3a and 1 have significantly higher total discounted externalities. This is due to the fact that Sc 3a has encouraging positive social and economic externalities and, at the same time, very low environmental negative externalities compared to the other scenarios for which the resulting balance is less competitive.

Detailed results for of each environmental and social externalities are presented in Annex 5.

Table 8-1: Externalities of the project on the time period for each scenario (Millions 2016USD)
In red: the negative externalities and in black the positive externalities

	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Environmental externalities						
Avoided costs of deforestation HP	277	897	828	828	899	829
Avoided costs of deforestation - Irrigation	363	435	291	347	479	513
Total environmental footprint	-11 007	-14 196	-8 058	-11 068	-16 756	-18 303
Degradation of downstream wetlands	-4 657	-16 438	-7 386	-15 497	-25 623	-25 811
Rise of GHG emissions	-2 619	-2 404	-2 472	-3 148	-2 937	-2 902
Total environmental externalities	**-17 643**	**-31 705**	**-16 798**	**-28 539**	**-43 938**	**-45 673**
Total discounted environmental externalities	***-4 356***	***-9 773***	***-4 292***	***-8 064***	***-13 766***	***-14 370***
Social externalities						
Fisheries employment	25	35	35	35	35	35
Fish farming employment	40	49	31	39	53	56
Rizipisciculture employment	1	2	1	1	2	2
Agricultural employment in Ethiopia	953	1 879	184	1 183	2 429	2 747
Agricultural employment in South Sudan	1 607	1 607	1 490	1 209	1 550	1 644
Hydropower employment	1 259	4 403	4 022	4 022	4 414	4 094
Other employment	777	1 595	1 153	1 298	1 696	1 716
Flooding protection	10	52	14	14	52	52
Health improvement	8 126	16 109	13 952	15 308	17 750	17 272
Total Social externalities	**12 798**	**25 730**	**20 882**	**23 108**	**27 980**	**27 618**
Total discounted social externalities	***4 199***	***8 583***	***6 974***	***7 661***	***9 226***	***9 075***
Economic externalities						
Meat production in Ethiopia	450	455	408	402	460	462
Meat production in South Sudan	1 276	1 291	1 154	1 134	1 300	1 307
Milk production in Ethiopia	1 042	1 055	947	935	1 068	1 074
Milk production in South Sudan	2 726	2 759	2 476	2 445	2 793	2 808
Fisheries (indirect HP profits)	23	32	32	32	32	32
Increase in the number of navigable days	71	71	71	71	71	71
Total economic externalities	**5 588**	**5 664**	**5 088**	**5 020**	**5 724**	**5 755**
Total discounted economic externalities	***1 854***	***1 880***	***1 680***	***1 657***	***1 902***	***1 912***
Total externalities	**743**	**-311**	**9 172**	**-411**	**-10 233**	**-12 300**
Total discounted externalities	**1 697**	**691**	**4 363**	**1 254**	**-2 639**	**-3 383**

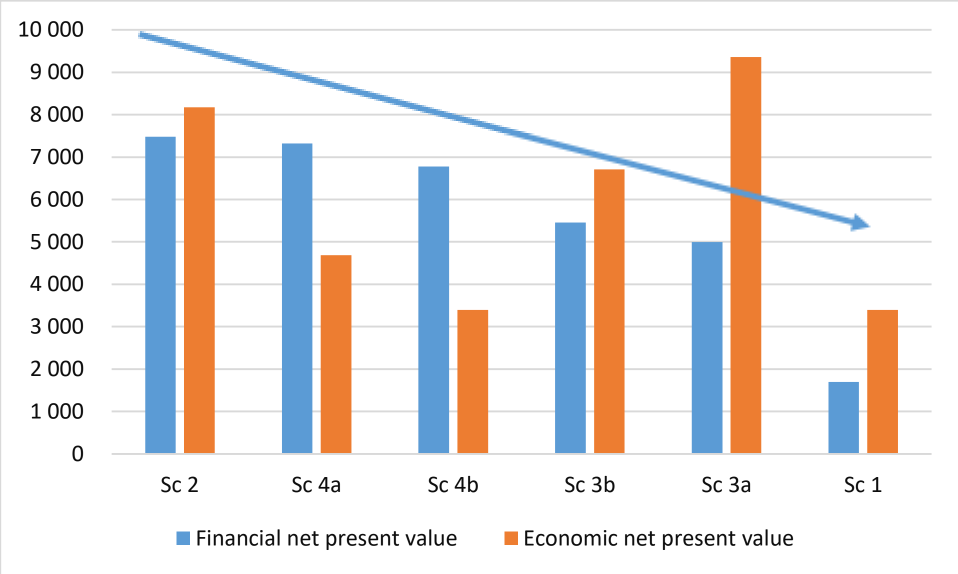
The second chart sorts the scenarios according to the FNPV (**in blue**) and the third chart sorts the scenario according to the ENPV (**in orange**).

Financially speaking (that is to say from the investors' point of view) the best scenarios are Scenario 2 and Scenario 4a:

- **Scenario 2** corresponds to an irrigation of 541 000 ha and a production of 12 274 GWh/year with a conservation of sensitive areas. The results emphasizes the large financial impact of Tams dam: if we compare Scenario 2 to Scenario 1 (without Tams dam), it appears that its FNPV is almost four times higher than in Scenario 1.
- **Scenario 4a** considers full development of the projects which explains a high financial profitability. Scenario 4b which also plans a large development is very close to the Scenario 4a in terms of profitability but little behind as it favors irrigation over hydropower while hydropower is more profitable.

Scenarios 3a and 3b_present a moderate FNPV due to the fact that management rules are implemented in order to regulate the flows and thus preserve the downstream wetlands. Even if the impact on hydropower generation is relatively low, the financial impact is significant as the added value of hydroelectricity is high. The low profitability is also explained by the fact that less than 50% of the irrigation water demand is satisfied.

Figure 8-3 : Scenarios sorted according to the FNPV from the highest to the lowest (in blue)



Economically speaking (that is to say, considering all the impacts on the environment, the local economy and the welfare of the population), the best scenario is Scenario 3a and the "second best" is Scenario 2:

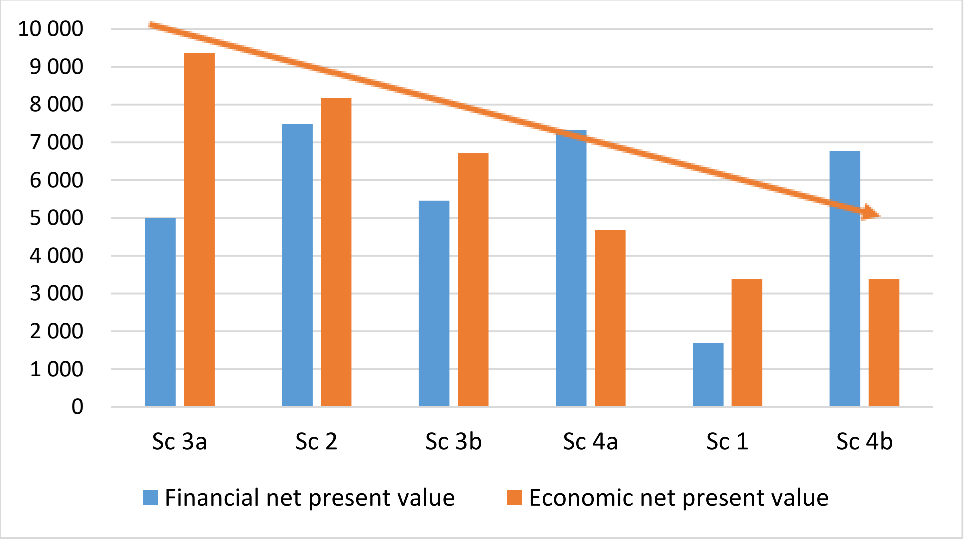
- **Scenario 3a** is the one which takes the more into account the environment as it plans to conserve the sensitive areas and implement a regulated management of dams' flows to guarantee a sufficient amount of water to the downstream wetlands.
- **Scenario 2** appears to be quite satisfying at the economic level as it conserves the sensitive areas while assuring a large development of irrigation and hydropower, which both generate positive social and economic externalities (employment, improvement of health, etc.).

Scenario 3b is placed third. In this scenario there is no conservation of protected areas but the implementation of management measures to regulate the flows and allow a sufficient amount of water for the downstream wetlands. Scenario 3b and 3a are very close financially speaking but quite different in terms of indirect impacts. The difference of the ENPV is mainly due to the conservation of sensitive areas in Scenario 3a.

Scenarios 4a and 4b present an ENPV lower than the FNPV. It indicates that in these scenarios the negative externalities are higher than the positive ones.

In conclusion, the Scenario 2 appears to be interesting for investors with an acceptable impact on the environment and the society.

Figure 8-4 : Scenarios sorted by the ENPV from the highest to the lowest (in orange).



8.3 ALTERNATIVES PERFORMANCE WITH RESPECT TO THE THRESHOLDS DEFINED BY THE SSEA ANALYTICAL FRAMEWORK

Scenarios have all been designed with a view to achieving the vision and strategic objectives of the BAS. However, they show different magnitudes of water resources development and degrees of mitigation of some of the anticipated important negative effects. The aim is to find the right balance that will lead to significant livelihood improvement through water resources development and reduced associated negative effects both for social groups of the BAS and for the environment. This balance will not necessarily be achieved by a specific tested alternative, but the results of the assessment of alternatives should provide the necessary answers to define the most appropriate way forward.

The table on the next page summarizes the main outcomes of Chapter 7 “Evaluation of the environmental and social impacts of each alternative”. It shows, through the main sub-dimensions of the SSEA analytical framework, how scenarios are suited to achieve the vision and strategic objectives of the BAS. In this table, colours refer to the impact magnitude and/or significance. The impact is expected to be very significant when the calculated value of the indicator goes beyond the threshold as defined by the sustainable envelop of development. The schematic below shows how the table next page has to be interpreted:

- Positive impact:
  - Light green significant
  - Dark green: very significant
- Negative impact:
  - Light orange: significant
  - Dark orange: very significant

Figure 8-5: Example of scenario positioned on the SSEA analytical framework

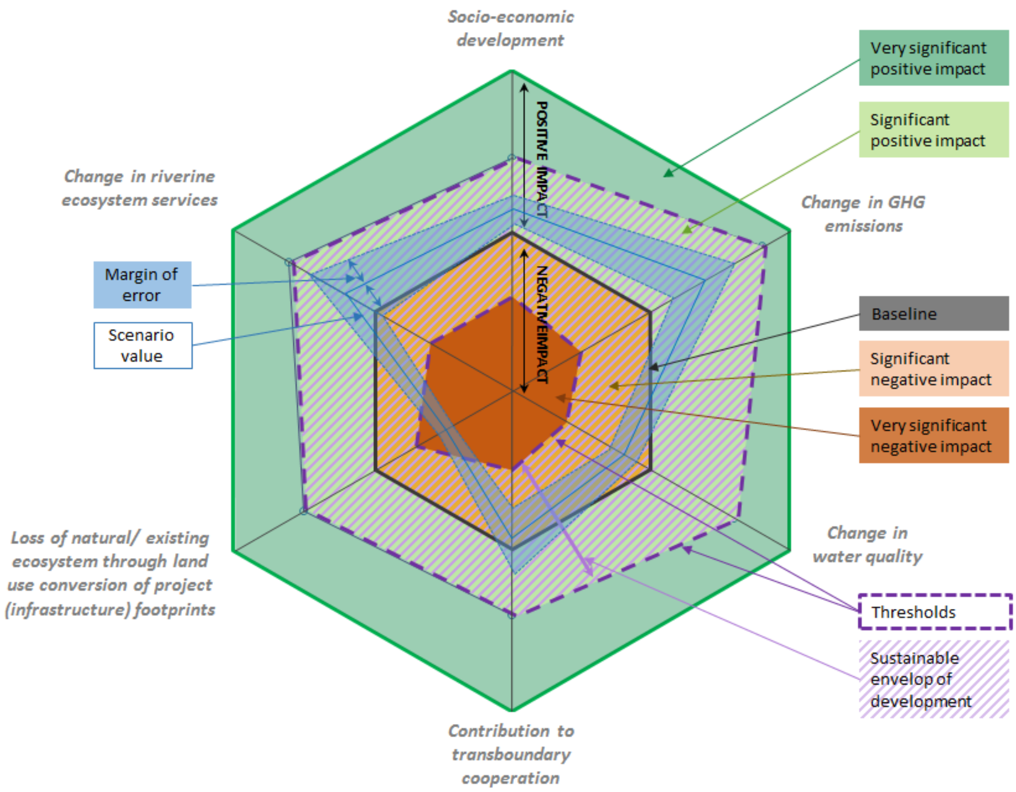


Table 8-2: Summary of main positive and negative environmental and social impacts of each alternative

	Baseline	Precautionary principle options		Compromise options		Full development options	
	Sc 0	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Irrigation demand							
Irrigation - total demand (ha)	128 092	554 870	554 870	554 870	756 076	756 076	756 076
Irrigation demand which can be satisfied most of the time							
% of the irrigation demand which can be satisfied	76%	69%	98%	43%	47%	85%	95%
Additional food production							
Cereals / rootcrops / fruits / bananas production (tons/year)	0	43 816	44 325	39 731	54 879	62 771	63 104
Livesotock production - meat (tons/year)	0	753 643	762 523	685 061	947 290	1 080 948	1 086 767
Livesotock production - milk (tons/year)	0	13 771	16 951	12 591	11 978	15 537	16 490
Aquacutlure, fisheries and fish farming production (tons/year)	0	1 484 668	1 706 891	1 214 727	1 623 296	2 166 488	2 283 770
Contribution to food security							
Total additional persons fed		2 405 718	2 683 907	2 009 661	2 727 186	3 525 706	3 677 535
% of additional persons fed compared to the BAS total projected population in 2056		15%	17%	13%	17%	22%	23%
Hydropower - Energy produced							
Hydropower - Energy produced (GWh/year)	42	3 946	12 274	11 246	11 246	12 303	11 428
Storage capacity							
Combined theoretical storage capacity of hydropower, irrigation and multipurpose dams (BCM)	0.1	8.2	20.9	20.9	20.9	20.9	20.9
Access to water for social groups and associated risks of conflicts							
Degree of risks of interruptions in or increased competition over access to water for productive and other purposes and associated risk of conflicts and displacement		-	- -	-	- -	- - -	- - -
Physical and economical displacement and associated risks of conflicts							
Estimation of No of people to be resetled		124 319	126 190	126 190	178 241	178 241	178 241
Estimation of possible conflict risk due to irrigation and HP footprints (the lower the rank the higher the impact)		11	7	10	8	5	4
Cumulative impacts on wetlands							
Total surface area of wetland impacted (ha)		- 275 147	- 487 642	- 226 028	- 433 336	- 721 611	- 724 711
% of wetlands of Gambella National Park impacted		23%	30%	14%	44%	68%	68%
% of wetlands in Kob migration corridors impacted		13%	18%	8%	43%	63%	64%
Encroachment into protected areas							
Total encroachment into main protected areas (ha)		-	-	-	8 803	14 463	16 388
Encroachment into forests							
Enchroachment into forests (incl. riparian forests) (ha)		11 930	11 930	11 930	59 750	79 864	79 864
% of BAS current forest surface area		1%	1%	1%	3%	4%	4%
Transboundary cooperation							
MAR entering the White Nile (BCM)	12.30	9.54	8.93	10.58	9.85	8.37	7.54
Geomorphological changes							
% of the Baro catchment surface area controlled by dams	6%	23%	68%	68%	68%	68%	68%
Flood reduction							
% Decrease in Flood Peak relative to Baseline at Gambella for a 50-years flood		11%	57%	15%	15%	57%	57%

The main findings of Step 3 can be summarized as follows:

- The absence of Tams and Birbir dams (Sc0 and Sc1) significantly reduce the impact on wetlands surface area compared with a situation including Tams and Birbir without any specific management rules (Sc2).
- The absence of Tams and Birbir dams significantly reduce the potential negative impacts on Baro and Sobat geomorphology, since these dams are located downstream on the Baro compared to the other hydropower dams.
- The absence of Tams and Birbir dams **significantly** reduce the hydropower generation opportunities since these dams have the highest potential capacity and biggest reservoirs.
- The exclusion of sensitive areas (protected areas, Kob migration areas, forests areas) from irrigation schemes significantly reduce the impacts on these areas and also allows a reduction of the hydrological impact on wetlands, especially on Gambella plains.
- The introduction of dam operating/reservoir management rules aiming at conserving some natural flow patterns allows a **significant reduction** of the hydrological impacts on wetlands and therefore makes it possible for the scenario to remain within the limits of the sustainable development space for the relevant dimensions.
- At the same time, the introduction of dam operating/reservoir management rules aiming at conserving some natural flow patterns **does not result in a major reduction** in energy production compared with the management of the dams aimed at maximizing hydropower.
- However, the introduction of dam operating/reservoir management rules aiming at conserving some natural flow patterns **reduce the water available** for irrigation.
- Dam operating/reservoir management rules aiming at either maximizing hydropower or irrigation lead to **very similar performances** and environmental and social impacts.

Bearing in mind the **caveat that this is based on best estimates which have to be improved as part of implementation of the IWRDMPlan** Step 3 has thus allowed a better understanding of the **limits of the system**, which can be summarized as follows:

- If all hydropower dams are implemented, the conservation of wetlands (reduction which remains in the "sustainable development space") is associated with an irrigable area (large-scale irrigation) of between 250 000 (Sc 3a) and 350 000 ha (Sc 3b).
- If Tams and Birbir are not implemented, the conservation of wetlands (reduction which remains in the sustainable development space) is associated with an irrigable area of around 400 000 ha (Sc1).
- If all hydropower dams are implemented, the avoidance of encroachment into protected areas, forests and Kob migration areas is associated with an irrigable area of around 550 000 ha. However this **option does not allow the conservation of wetlands**.
- Irrigation water saving measures lead to **higher satisfaction** of the irrigation water demand and allow better conservation of the Gambella wetlands but lead **to higher negative impacts** on the Machar Marshes.
- If properly managed, Tams dam can support the development of Sobat irrigation in South Sudan.

From a technical point of view, the feasibility of irrigation projects can be discussed, especially through the following considerations:

- Although not desirable from an environmental point of view, the encroachment of irrigation schemes into floodplains and other wetlands is not straightforward from a technical point of view. In these specific areas, crops are prone to flooding and meccanization may be complicated by waterlogged soils.
- Previous irrigation master plans had already dismissed some of the irrigation schemes whose implementation costs were prohibitive. This should be taken into consideration when

prioritising implementation so that the least feasible schemes are left till last, when the best information may be able to judge their real feasibility

- During the design phase, the surface area under irrigation should be revised to match with the volume of water available considering other upstream and downstream water uses and environmental flows. This should lead to higher irrigation water demand satisfaction rates. This highlights the absolute for coordinated and integrated cross-sectoral planning form the earliest stages.

More generally, it can be noted that avoidance of sensitive areas (Sc 1, 2 & 3a, compared to Sc 3b, 4a and 4b) also directly leads to less irrigation water demand. This combination has successive and linked positive effects both on:

- the sensitive areas themselves, meaning that the proportion encroached is significantly reduced[37];
- the number of people to be resettled;
- the cumulative impacts on Gambella plains, Machar marshes and Sobat wetlands (both due to avoidance and reduced impacts on water flows and subsequent spills to wetlands);
- the MAR of the Sobat entering the White Nile.

Apart from its potential important impacts on sediment transport and circulation of aquatic life, Sc 3a has less negative cumulative environmental impacts than other scenarios. This results from the combined effects of avoidance of sensitive areas and dams management rules aimed at conserving some natural flow patterns. In addition, it is the only scenario which shows a MAR entering the White Nile higher than the dry baseline MAR. However, whereas hydropower production remains very high, the satisfaction of the irrigation demand appears to be quite low (especially for the Baro irrigation) for this scenario and more generally for intermediate cases (Sc 3a and 3b) because they imply the imposition of an environmental flow. Socio-economic optimization of intermediate cases have been investigated via the following single or combined variations of Sc 3b[38] (see section 7.2.3):

- Imposition of the environmental flow downstream of the Baro large-scale irrigation schemes instead of directly downstream Tams dam;
- Improved irrigation water efficiency;
- Reduction of the environmental flow class.

The combined above optimization measures lead to significant improvement of the irrigation water demand satisfaction (rising from 24% up to 70%) but worsened impacts on wetlands up to additional 15% reduction of the Machar marshes (except concerning Gambella Plains minimum surface area). This could imply that a performing [39] intermediate case, both from an environmental and socio-economi//c point of view is closer to an optimized Sc 3a than to Sc 3b (optimized or not).

Regarding social aspects more specifically, the scenario comparison (chapter 7) has highlighted the main following considerations:

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[37] In case avoidance measures are not implemented (Sc 3b, 4a and 4b), the encroachment into sensitive areas is very high and includes encroachment into: Gambella National Park, Sheka Biosphere Reserve, (and potentially into Boma National Park depending on the delination of the Akobo - Lower Pibor irrigation scheme command area), Abobo-God, Godere, Sele Anreacha, Shako, Yaku, Yeki, Sibu-Tole-Kobo, Sigmo-Geba National forest priority areas and around 197 000 ha of the White-eared Kob migration area, leading to the conversion of around 86 000 ha of forest and around 257 000 ha of wetlands and floodplains. While sensitive areas can be avoided in most cases (by adapting irrigation schemes command areas), this is a priori not possible or limited when it comes to dams and reservoirs. Reservoirs' footprints do not encroach into National parks and Biosphere reserves but do encroach into forest ecosystems (10 000 ha), into some of the Forest National Priority Areas (8 000 ha) and into mountain wetlands (300 ha) which are of primary importance for the conservation of biodiversity features of the BAS and of the ecosystem services they provide to the population and to water resources (quality and quantity).

[38] The effect magnitude of the optimization trials are deemed to be similar for Sc 3a

[39] With regard to the sustainable envelop of development which itself refers to the vision and objectives and to the environmental limits beyond which the sustainability is deemed to be seriously threatened.

- The improvement of food security at the BAS level will depend strongly on the type of the planed agricultural production. In case only cash crops and crops for export are cultivated (as currently indicated in the agricultural leases available in the Gambella region), no improvement of food security is expected. In addition, a degradation is at stake considering the loss of access to existing agricultural and pasture land. This is especially true for Sc 2, 4a and 4b which have the most important footprints. On the contrary, if a significant and sufficient area is allocated to local farmers and dedicated to local markets, irrigation development is deemed to have an overall positive effect on food security.
- Most hydropower is located in the Ethiopian highlands where there is already high population density and pressure on arable land.
- Population increase around reservoirs may also lead to conflict regarding access to reservoirs for watering livestock. Reservoirs may also attract herders and pastoralists to the area, thereby increasing competition and conflicts between groups.
- Pastoralists are likely to experience problems in accessing traditional water sources and grazing areas for their livestock due to important project footprints. This is especially true for Sc 2, 4a and 4b which have the most important footprints and do not include dams management rules aimed at conserving some natural flow patterns.
- In general, displaced people are likely to experience conflicts with host communities and government. The higher the number of displaced people, the total project footprint, the consequent loss of access to subsistence means and the risk of rivers drying up, the higher the risk of conflicts. With regard to these considerations, Sc 4a and 4b are the scenarios associated with the highest risks of conflicts.
- Decrease in flooding of main rivers (Baro, Alwero, Gilo, Akobo, Sobat, lower Pibor) and subsequent decrease of Gambella plains and Machar Marshes may have implications for soil fertility and therefore the productivity of recession agriculture and the replenishment of marshes and wetlands which provide water for livestock and other important livelihood resources. This will impact especially for the sedentary Annuak, the pastoral Nuer, the Berta and other pastoral ethnic groups from South Sudan migrating to the Machar Marshes during the dry season. With regard to these considerations, Sc 3a and 1 are the less impacting, followed by Sc 2 and 3b.

NB: Implementation of the Upper Akobo HP dam and reservoir, and the Akobo-Pibor irrigation scheme will have a high risk of reducing access to water and seasonal grazing areas for livestock for the pastoral Nuer and thereby fuelling already existing ethnic and political conflicts between the pastoral Nuer, Dinka and Murle in Jonglei State in South Sudan and the sedentary Anuak in the Gambella Region in Ethiopia.

The potential implications of climate change can be summarized as follows:

- Average high temperature are supposed to increase by around 2°C on the entire BAS area from 2040 to 2055 compared to the reference period 1986-2005. This will lead to higher evapotranspiration and therefore increase the water demand for agriculture in case annual rainfall patterns remain stable.
- There is no such explicit trend for rainfall patterns since climatic model show similar increase and decrease at the same time. However, the temporal and geographical distribution of rainfall patterns might change, which could affect the cropping calendars of both rainfed and irrigated agriculture.

Climate change will also lead to a higher frequency of extreme events such as floods and droughts.

Given the above considerations, it means that the more the BAS-sub-basin will be resilient, the better it will be able to adapt to climate change. A better management and valorisation of the water resources should contribute to enhance the BAS resilience. However, anticipated negative impacts on the ecosystems and on access to people subsistence means are deemed to significantly reduce the BAS resilience to climate change. As a result, intermediate scenarios (3a and 3b) are deemed to better perform regarding climate change.

In any case, the IWRMD Plan will have to include response mechanism to address these major risks.

8.4 SUMMARY OF KEY FINDINGS OF THE SCENARIO COMPARISON

The development of large dams and irrigation schemes will impact on downstream hydrological regimes and the ecological services provided by rivers and associated wetlands in the BAS sub-basin. The potential impacts include loss of aquatic and riverine habitats, impact on migration routes, impact on grazing for livestock, impact on availability of water for downstream uses such as, domestic water supply, livestock watering, small-scale irrigation, river navigation, and reduction contribution of the BAS to the White Nile and the Nile and potential related conflicts with downstream countries.

Based on the findings of the SSEA Scenario 3a, which includes the establishment of the Tams and Birbir Dam and avoidance of sensitive areas, combined with environmental water releases to conserve natural downstream flow patterns, provides the most sustainable option for meeting the vision of for the BAS sub basin and the associated strategic objectives, specifically "to contribute to food security, livelihood enhancement, poverty reduction and the protection and conservation of biological resources through stakeholder-driven management of wetlands, watersheds and other important natural resources".

Scenario 1, 2 and 3a do not encroach into existing protected areas in the BAS sub-basin and or White Eared Kob migration corridors as these areas were excluded when designing the scenarios. Scenario 1, 2 and 3a therefore adhere to the SSEA mitigation hierarchy criteria of avoidance. Scenario 3a also has the least impact on natural ecosystems, followed by Scenario 1 and Scenario 3b. Scenario 4a and 4b have the highest impact and encroach on more than two times the area affected by Scenario 3a (~700 000 ha vs. 280 000 ha).

Critically Scenario 3a also results in the least reduction in the MAR (BCM) downstream of the Sobat / White Nile confluence. Scenario 3a will result in a 14% reduction (10.58 vs. 12.30 BCM) in the MAR, compared to a reduction of 39% for Scenario 4b, 32% for Scenario 4a and 27% for Scenario 2. Scenario 3a therefore adheres to the SSEA mitigation hierarchy criteria of minimisation measures that are aimed at developing scenarios that will fit into the sustainable development envelope.

The findings of the CBA, specifically the assessment of environmental, social and economic externalities, also indicate that Scenario 3a has the highest positive total combined discounted externality. The social and economic externalities (benefits) associated with Scenario 3a therefore outweigh the environmental externalities (costs). The combined discounted environment, social and economic externality for Scenario 3a is also 61% greater than Scenario 1, the second highest ranked positive Scenario. The combined discounted environment, social and economic externality for Scenario 4a and 4b are both negative. The environmental externalities (costs) associated with Scenario 4a and 4b therefore outweigh the social and economic externalities (benefits) associated with these two scenarios.

Scenario 4a and 4b (the full development options) both have the most significant benefit in terms of food and energy security, and also create the most employment opportunities. However, the development of large dams and irrigation schemes, specifically the full development options associated with Scenario 4a and 4b, may impact negatively on downstream food security due to the changes in the hydrological system and the impact on wetlands and floodplains.

In terms of energy, Scenario 4a and 4b only generate 8% more energy (GWh/year) than Scenario 3a. In terms of employment, while Scenario 4a and 4b generate more employment opportunities, the majority of these opportunities are likely to be in Ethiopia (approximately 76%). This raises the question of equity in terms of both benefits and impacts. As expressed by stakeholders during the SSEA workshops, development should benefit all the countries, so it is important that the benefits and impacts for both upstream and downstream stakeholders properly take into account the issue of equity. Clearly there are major benefits for upstream stakeholders as a result of the establishment of large hydropower dams and irrigation schemes. At the same time, most of the potential risks will be faced by the downstream communities living in the lowlands of the BAS sub-basin. The issue of who benefits and who gains is a key issue that must be addressed when considering trans-boundary impacts.

The full development scenarios (Scenario 4a and 4b) also have the highest risk of conflicts due to displacement, followed by Scenarios 2, 3b and 3a in that order, with Scenario 1 having the lowest risk of conflicts. Scenario 2, 4a and 4b also pose the highest risk to downstream flow regimes. Climate change resulting in an increase in temperature and evaporation would there increase the risk posed by these scenarios on downstream flow regimes.

The table next page summarizes the main risks and opportunities associated with each scenario, the significance of the residual impacts informed by the mitigation hierarchy and the degree of suitability to achieve the vision and strategic objectifs of the BAS sub-basin.

	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a	Scenario 4b
Main characteristics	• Represents the "Precautionary Principle" option • Involves reduced but significant irrigation areas (small-scale and large-scale) with no encroachment into environmentally sensitive areas. =>Total irrigation demand: 550 000 ha • All potential hydropower dams were included, except Tams Dam and Birbir Dam.	• Extension of the "Precautionary Principle" option, except that Tams Dam and Birbir Dam are included	• Same as Scenario 2, but with environmental water releases imposed on all dams in order to conserve natural flow patterns	• Same as Scenario 4a (full development option), but with environmental water releases imposed on all dams in order to conserve natural flow patterns =>Total irrigation demand: 755 000 ha	• Is the full-development option, with Tams Dam operated to maximise hydropower production. • All future small-scale and potential large-scale irrigation schemes are included. =>Total irrigation demand: 755 000 ha • All identified potential hydropower schemes are also included.	• Represents the full-development option as per Scenario 4a, with Tams Dam operated to optimise irrigation and flood control.
Main opportunities	• Significant additional hydropower (3,950 GWh/year) and agricultural & fish production (2.3 million tons/year) • Rather low satisfaction of the water demand for irrigation: 69% • Significant reduction of the flood risk: 11% (relative to baseline at Gambella for a 50-year flood) • Significant storage capacity: 8.2 BCM	• Very high additional hydropower (12,300 GWh/year) and agricultural & fish production (2.5 million tons/year) • High satisfaction of the water demand for irrigation: 98% • Significant reduction of the flood risk: 57% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 11,300 GWh/year • Significant additional agricultural & fish production: 2.0 million tons/year • Rather low satisfaction of the water demand for irrigation: 43% • Significant reduction of the flood risk: 15% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 11,300 GWh/year • Significant additional agricultural & fish production: 2.6 million tons/year • Rather low satisfaction of the water demand for irrigation: 47% • Significant reduction of the flood risk: 15% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 12,300 GWh/year) • Very high additional agricultural & fish production: 3.3 million tons/year • High satisfaction of the water demand for irrigation: 85% • Significant reduction of the flood risk: 57% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM	• Very high additional hydropower production: 11,400 GWh/year • Very high additional agricultural & fish production: 3.5 million tons/year • High satisfaction of the water demand for irrigation: 95% • Significant reduction of the flood risk: 57% (relative to baseline at Gambella for a 50-year flood) • High storage capacity: 20.9 BCM
Main risks and cumulative impacts	• Limited risks on sediment transport and aquatic movements compared to the other 5 scenarios • Major displacement of people (124,000) and limited encroachment into natural and protected areas compared to scenarios 3b, 4a and 4b • Significant modification of the hydrological regime and the wetlands surface areas but stay within the thresholds of sustainability • Major cumulative impacts on wetlands: - 275,000 ha • Major reduction of the MAR entering the White Nile: -22% • Lowest risks of conflicts	• Major risks on sediment transport and aquatic movements • Major displacement of people displacement (126,000) and limited encroachment into natural and protected areas compared to scenarios 3b, 4a and 4b • Important modification of the hydrological regime and the wetlands surface areas but overpass the thresholds of sustainability for Machar marshes • Significant cumulative impacts on wetlands: - 488,000 ha • Important reduction of the MAR entering the White Nile: 27% • Important risks of conflicts	• Important risks on sediment transport and aquatic movements • Major displacement of people(126,000) and limited encroachment into natural and protected areas compared to scenarios 3b, 4a and 4b • Significant modification of the hydrological regime and the wetlands surface areas but stay within the thresholds of sustainability • Moderate cumulative impacts on wetlands: - 226,000 ha • Limited reduction of the MAR entering the White Nile: 14% • Limited risks of conflicts	• Major risks on sediment transport and aquatic movements • Very major displacement of people(178,000) and encroachment into natural and protected areas • Major modification of the hydrological regime and the wetlands surface areas • Significant cumulative impacts on wetlands: - 433,000 ha • Major reduction of the MAR entering the White Nile: 20% • Major risks of conflicts	• Major risks on sediment transport and aquatic movements • Very major displacement of people(178,000) and encroachment into natural and protected areas • Very high modification of the hydrological regime and the wetlands surface areas • Very high cumulative impacts on wetlands: - 722,000 ha • Very major reduction of the MAR entering the White Nile: 32% • Highest risks of conflicts	• Major risks on sediment transport and aquatic movements • Very major displacement of people(178,000) and encroachment into natural and protected areas • Very high modification of the hydrological regime and the wetlands surface areas • Very high cumulative impacts on wetlands: - 725,000 ha • Very major reduction of the MAR entering the White Nile: 39% • Highest risks of conflicts
Residual impact after implementation of the main potential trade-offs	• Moderate: the mitigation hierarchy has been implemented in the design of the scenario. As such, major avoidance and reduction measures are efficient.	• High: only part of major potential trade-offs are implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as the one included in the design of scenario 3a.	• Moderate: the mitigation hierarchy has been implemented in the design of the scenario. As such, major avoidance and reduction measures are efficient.	• High: only part of major potential trade-offs are implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as the avoidance and reduction measures included in the design of scenario 3a.	• Very high: trade-offs are not implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as avoidance and reduction measures included in the design of scenario 3a.	• Very high: trade-offs are not implemented in the design of the scenario. Implementing additional mitigation measures will contribute to reduce the negative impacts and enhance positive impacts but won't be as efficient as avoidance and reduction measures included in the design of scenario 3a.
Level of economic return	• Low	• High	• Very high	• Fair	• Low	• Low
Level of financial return	• Low	• Very high	• High	• High	• Very High	• High
Contribution towards achieving the vision and strategic objectives for the sub-basin	• Moderate: socio-economic needs can only be partly met while ensuring a relative sustainable management and limited risks of conflicts.	• Moderate : socio-economic needs can be met for a significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts	• High : socio-economic needs can be met while ensuring a relative sustainable management and limited risks of conflicts.	• Moderate + : socio-economic needs can be met for significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts	• Moderate - : socio-economic needs can be met for a significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts	• Moderate - : socio-economic needs can be met for a significant proportion of the population but a substantial part of it might be impared given to the high environmental and social residual negative impacts

Table 8-3: Summary of main opportunities and riks associated with each scenario and the potential trade-offs

8.5 Moving from the main findings of the SSEA and the Economic and Financial Analysis to the IWRDM Plan

The above quoted SSEA and CBA findings have been presented and discussed among stakeholders during the IWRDMPlan workshop held in Debre Zeit, Ethiopia, on the 12 and 13 January 2017.

The following bullets summarize the Consultant's understanding of the consensus reached. This consensus is seen as allowing the finalization of both the SSEA (especially to complete chapters 9 to 12) and the IWRDM Plan.

The consensus reached can be summarized as follows:

- The SSEA does not recommend a preferred scenario among the six analyzed scenarios for taking forward to the IWRDM Plan since a preferred scenario cannot be conclusively agreed given the paucity of hydro-environmental and socio-economic data of the BAS, resulting in important uncertainties in the SSEA findings. It is agreed that the scenario analysis has been used to guide the understanding of the sustainable development space within the sub-basin and to make a number of recommendations to be taken up in the IWRDM Plan. This understanding has made it possible to identify a large number of beneficial development projects with, to some extent, manageable negative impacts.
- It is agreed that the aim of the Plan (and its future revisions and extensions, bearing in mind that 25 years is a relatively short period of time) is to maximise sustainable development, without causing significant harm[40] downstream. This is in line with the agreed vision and strategic objectives.
- The SSEA makes a number of recommendations to guide the design of the plan. These include the following:
  - With respect to large-scale hydropower and irrigation, the SSEA recommends:
    - To further identify project characteristics, design and implementation modalities that maximise multipurpose and transboundary benefits and minimize social and environmental negative impacts.
    - Once identified, that the implementation of the IWRDM Plan should start with the projects and actions of limited negative impact. As such, for irrigation, with respect to irrigation, the priority is given to projects which do not encroach into sensitive areas (no-regret projects). This would include implementation of large-scale hydropower development on the Baro River (managed on the principles of transboundary cooperation) and irrigation in both Ethiopia and South Sudan supported by the resultant flow regulation.
  - None of the identified development should be excluded from the plan, all projects identified in the various scenarios, or simply potential not yet identified in the form of projects such as on the Baro, Akobo or Pibor Rivers). Projects or combinations of projects which have been shown to result in more negative impacts will be included in the IWRDM Plan (without timeline) and indicated as "deferred" until the system is better understood in terms of their environmental and socio-economic impacts (+ve and -ve) and possible mitigation and conservation measures.

[40] Based on current knowledge, it has been assumed that the changes generated by projects should not cause "significant harm" if the indicators remain within the thresholds defined for each dimension. This appreciation should be fine-tuned during the IWRDMPlan implementation, as part of the environmental monitoring system and the medium and long-term projects which will contribute to improve the understanding of the potential impacts significance.

- The IWRDM Plan should be developed in detail (in terms of proposed sequencing and scheduling) only for the projects and actions of limited negative impact.
- Following on from the above point, the IWRDM Plan should include, as a top priority action, the detailed design and implementation of a basin wide environmental monitoring programme aimed at a major improvement in the understanding of the environmental (and socio-economic) functioning of the BAS sub-basin.
- The IWRDM Plan is to be developed as a “living Plan”, with explicit provision for adaptation in response to results as indicated by strong monitoring and evaluation and adaptive management systems.

The resulting phasing consists of a development pathway for the plan, on which is based the assessment of the expected residual effects (see coming chapter 9 – Expected residual effects).

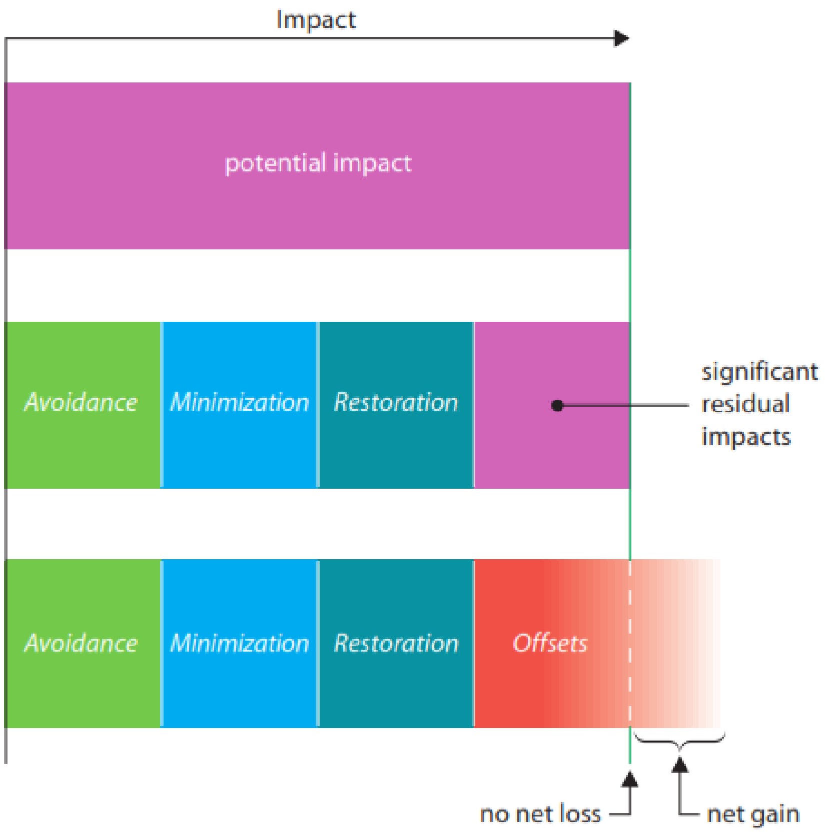
9. EXPECTED RESIDUAL EFFECTS

9.1 INTRODUCTION

According to the AfDB guidelines, this section aims at identifying "the net impacts of the optimal alternative in light of the mitigation and enhancement measures that are recommended" (AfDB, 2015).

The residual impacts are the remaining impacts once the enhancement, avoidance, minimization and restoration measures have been implemented (see figure below as a reminder).

Figure 9-1: Application of the mitigation hierarchy components



Source: (The Biodiversity Consultancy, 2015)

Main enhancement, avoidance and minimization measures have been concisely described in each dimension and sub-dimension of chapter 7. These measures are detailed in the coming chapter 10, as they essentially form the backbone of the Environmental and Social Management Plan (ESMP).

Identifying the (cumulative) residual impacts **aims at tailoring the requirements in terms of offsets**. As such, **residual effects only deal with negative impacts**. Offsets measures will also be taken up as part of the ESMP (coming chapter 10).

9.2 EXPECTED RESIDUAL EFFECTS

From the evaluation of scenarios (chapters 7 and 8), two main important facts have been highlighted:

- While the development of water resources in the BAS is associated with large benefits, a number of social and environmental risks have been identified;
- While the nature, characteristics and magnitude[41] of the social and environmental risks have been clearly assessed (in most cases), the significance[42] of these risks remain uncertain at this stage, given:
  - The complexity of the interactions between the planned water developments and the physical, biological, cultural and human environment which makes these interactions difficult to model;
  - The paucity of hydro-environmental and socio-economic data of the BAS, which makes complex to ascertain the magnitude of certain effects and which makes almost impossible to quantitatively assess the significance of most of the identified impacts.

This has led to recommend a phased approach[43], enabling both:

- To further work and progress toward the implementation of national priority projects as well as projects with minimum encroachment into sensitive areas;
- Data acquisition and analysis, to further assess the significance of the main environmental and social risks and further investigate the project characteristics, design and implementation modalities that maximise multipurpose and transboundary benefits and minimize social and environmental negative impacts.

With respect to the residual effects, the uncertainties over:

- the final projects characteristics and modalities (which have to be fine-tuned during the first phase of the IWRMDPlan implementation);
- the significance of the identified environmental and social risks;
- the satisfactorily implementation of the enhancement, avoidance, minimization and restoration measures (even if the ESMP, including its monitoring plan aims at achieving this goal);

make it difficult to quantify the net residual impacts at this stage.

However, it is still possible to identify the areas where there will be residual impacts, whatever the outcomes of future investigations and projects fine-tuning process. These are notably cumulative and transboundary impacts, which might not be tackled at the ESIA scale.

They are reminded below (for more detail, please refer to chapters 7 & 8):

- Impacts on downstream river flows and wetlands: while optimized dams operating rules and water saving measures will significantly reduce the potential negative effects, the resultant hydrological modifications should still lead to:
  - a reduction of wetland size up to around 20-30% in the most optimistic case[44] (compared to 40-50% without avoidance and minimization measures);
  - double or even triple the duration of the severe low flows period of some rivers (mainly Sobat and Gilo) from 2 months to 4 to 5 months in the most optimistic case;
  - a reduction of dry season average mean monthly flow by 30-45% for the Sobat and by 20-45% for the Gilo.

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[41] The magnitude refers to the degree of change that the impact is likely to impart upon the resource/receptor, based on its defined characteristics (AfDB, 2015).

[42] The significance takes into account the sensitivity/vulnerability/importance of the resource/receptor (AfDB, 2015).

[43] This implies that, even if expected residual effects are informed by the environmental and social investigations conducted for each scenario (chapters 7 and 8), they apply to the phased approach and not specifically for one specific scenario.

[44] Refers to Sc 3a and 3b.

- A reduction of the MAR entering the White Nile from 10.58 (Sc 3a) to up to 7.54 BCM (Sc 4b) compared to a baseline value of 12.30 BCM.

- Alteration of the sediment transport and fish circulation patterns due to the construction of dams. Even if some of the effects can be mitigated through minimization measures, significant adverse residual effects are inevitable. This is why dams must be implemented where there is no other options to improve the population livelihoods. Knowledge improvement measures planned as part of the ESMP of the IWRDMPlan will have to include data acquisition and analysis activities dedicated to this thematic so that residual significance can be quantitatively assessed and adequate offset measures defined.

- While sensitive areas can be avoided in most cases[45] (by adapting irrigation schemes command areas), this is *a priori* not possible or limited when it comes to dams and reservoirs. Reservoirs footprints do not encroach into National parks and Biosphere reserves but do encroach into forest ecosystems (10 000 ha[46]), into some of the Forest National Priority Areas (8 000[47] ha) and into mountain wetlands (300 ha).

- In addition to sensitive areas, the conversion of natural ecosystems due to project footprints result in a loss of these ecosystems up to 350 000 to 600 000 ha according to the scenario.
  - The significance of these residual impacts should be assessed as part of the ESIA of each individual projects and offsets measures tailored consequently. However, the cumulative feature/dimension which might lead to the interruption of wildlife movement and people migration due to aggregated schemes, forming three main physical barriers[48], must be addressed as part of the ESMP of the SSEA.

- Resettlement and alternative means of livelihoods are supposed to be tackled at the ESIA scale. However, it is worth pointing out that these measures are rarely satisfactorily implemented and that residual adverse impacts might persist. Because of this and because the scope of the ESIA does not take into account cumulative effects of several projects (up to around 180 000 people potentially displaced, up to 2.7 million people potentially indirectly impacted by cumulative impacts of the IWRDMP, increasing risks on vulnerable population, increasing risks of conflicts), these considerations must be addressed as part of the ESMP of the SSEA.

- In case minimization measures are not sufficient to mitigate adverse effects on water quality, and lead to a significant degradation (which would be very problematic and should be carefully avoided), offsets measures such as water treatment plants and compensation should be considered.

- The implementation of minimization measures should significantly reduce GHG emissions. As such, significant residual impacts should only persist in case the control of vegetation clearance operations could not be implemented on the overall area.

[45] As a reminder, in case avoidance measures are not implemented (Sc 3b, 4a and 4b), the encroachment into sensitive areas is very high and includes encroachment into: Gambella National Park, Sheka Biosphere Reserve, (and potentially into Boma National Park depending on the delination of the Akobo - Lower Pibor irrigation scheme command area), Abobo-God, Godere, Sele Anreacha, Shako, Yaku, Yeki, Sibu-Tole-Kobo, Sigmo-Geba National forest priority areas and around 197 000 ha of the White-eared Kob migration area, leading to the conversion of around 86 000 ha of forest and around 257 000 ha of wetlands and floodplains. While sensitive areas can be avoided in most cases (by adapting irrigation schemes command areas), this is *a priori* not possible or limited when it comes to dams and reservoirs. Reservoirs' footprints do not encroach into National parks and Biosphere reserves but do encroach into forest ecosystems (10 000 ha), into some of the Forest National Priority Areas (8 000 ha) and into mountain wetlands (300 ha) which are of primary importance for the conservation of biodiversity features of the BAS and of the ecosystem services they provide to the population and to water resources (quality and quantity).

[46] It approximatly corresponds to a third of the current annual deforestation and to 1% of the total surface area of forests within the BAS.

[47] Which are already included into the 10 000 ha of forests.

[48] One along the river banks of the Sobat, mostly impeding northen-southern movements; one from the Jokau to the Akobo, forming a dense northen-southern and eastern-western barrier; and one on the Pibor axis around Akobo

From the above analysis of the potential residual impacts, the following conclusions towards the ESMP can be drawn:

- The ESMP of the IWRDMPlan has an overall responsibility in ensuring that residual significance will be satisfactorily assessed:
  - At the global scale, through adaptation in response to strong monitoring and evaluation and adaptive management frameworks;
  - At the project scale, through guidance and supervision of the ESIA of individual projects, to ensure that avoidance, minimization and restoration are given first priority, that residual impacts are assessed in a comprehensive and rigorous way and that adequate offset measures are proposed and effectively implemented.

10. ESMP, INCLUDING MANAGEMENT MEASURES, ACTIONS, ROLES AND RESPONSIBILITIES, TIMEFRAME, MONITORING AND COST OF IMPLEMENTATION

10.1 INTRODUCTION

PURPOSE OF THE ESMP

The purpose of the ESMP is to set out the action plan of environmental and social management measures to be implemented by the responsible entities. These measures should aim to achieve the avoidance, minimization, restoration and offset or compensation, of adverse environmental and social impacts, as well as to enhance potential benefits of the IWRDMPlan.

SCOPE OF THE ESMP

According to the AfDB guidelines, the scope of an ESMP should be "determined by the assessment of the magnitude and significance of the environmental and social risks and impacts of the project and should be commensurate with these anticipated risks and impacts. The management measures should be feasible and cost-effective and phased with scheduled activities of the project (AfDB, 2014)."

This step also requires the evaluation of uncertainties and the determination of the means to acquire further information on uncertain factors. A monitoring programme should also be included to follow-up on these management measures and provide a feedback mechanism to determine the effectiveness of the SSEA process, and identify further changes that may be needed to improve the IWRDMPlan.

As such, the ESMP should be seen as a dynamic instrument as its management actions may be subject to change as a result of feedback received during project implementation and/or in response to unexpected impacts or impacts with a magnitude different to that predicted at the time the SSEA was finalized.

LINKS WITH THE IWRDMPLAN

Most of the needs to acquire further information on uncertain factors are already part of the IWRDMPlan components and priority projects.

The management measures and the monitoring plan will also be part of the IWRDMPlan implementation, since ESMP will act the environmental and social road map of the IWRDMPlan.

10.2 Generic recommendations

In addition to recommendations formulated towards the IWRDMPlan, the following proposed actions are highlighted:

- Design and implement research and monitoring programs to fill existing knowledge gaps in the basin (see section 10.4 – Need for acquisition of further information on uncertain factors);
- Conduct detailed ESIA studies once knowledge is improved as per the ToRs recommended by this study;
- Revise existing ESIA studies in light of knowledge improvement and to fulfil the ToRs recommended by this study. A review of existing ESIA of major hydropower dams projects has indeed shown that some thematics are not covered and that transboundary effects are not even mentioned.
- Revise the ESMP in light of knowledge improvement to take into account the cumulative impacts that, by nature, can't be covered in individual ESIA.

10.3 Management measures

Management measures encompass:

- Enhancement measures, aiming at maximising expected benefits
- Avoidance measures;
- Minimisation measures;
- Restoration measures;
- Offset / compensation measures.
- Disaster risk management
- Conflict resolution and emergency response

Offset / compensation measures aim at mitigating significant residual adverse effects. The identification of residual effects is based on the important assumption which considers that **avoidance, minimization and restoration measures have been dully implemented**. As already mentioned in chapter 9, residual impacts and their significance will have to be ascertained and further investigated as a result of the monitoring, evaluation and adaptative management of the ESMP and of the IWRDMP.

Management measures and their implementation requirements are presented in the table on the next page.

They are aggregated by type of impacts / by sub-dimensions or dimensions to enable the visualization of the logical flow from avoidance to offset.

Table 10-1: Environmental and social management measures

Anticipated social and environmental benefits / risks	Mitigation hierarchy (avoidance, minimization, restoration, compensation/offset) / enhancement	Proposed management measure(s) and objective of management measure(s)	Technical and operational requirements of management measure(s)	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs
Food security	**Maximization / enhancement of positive impacts**	**Enhancement of food and nutrition security in and around irrigation projects**: Experience from several irrigation projects showed that there is no clear direct link between food security and irrigation development or yield increase. This is why it is important to take this into account at each stage of projects development to ensure projects will ultimately contribute to food security.	IWRMDP to include conditions on project, that should be then be reflected into feasibility studies and detailed design of irrigation schemes, such as: • Smallholder irrigation schemes are encouraged • Sharing between local markets and export allows significant improve in access of food on local markets, • Increased access to improved sources of drinking water and sanitation. Monitoring of the IWRDMPlan to include monitoring measures on food and nutrition security.	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government in Ethiopia; States/Counties in collaboration with national of GoSS. • Responsible Institutions: Federal Ministry of Agriculture; Ministry of Water, Irrigation, Energy and Electricity; and Water and Agriculture Bureaus/Offices at the local levels in Ethiopia. Ministry of Agriculture; Ministry of Water; Agriculture and Water Departments in State/country in South Sudan. Coordination and collaboration with various stakeholders and developers/private sectors.		
	Offset	**Provision of alternative subsistence and livelihood**				
Improved employment rate	**Maximization / enhancement of positive impacts**	**Enhancement of local employment in all projects**	IWRMDP to include conditions on project, that should be then reflected into feasibility studies and detailed design of projects, such as: • Smallholder irrigation schemes • Capacity building and hiring of local staff • Close cooperation with local authorities to ensure development of value added opportunities, social needs etc. Monitoring of the IWRDMPlan to include monitoring measures on employment.	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government in Ethiopia; States/Counties in collaboration with national of GoSS. • Responsible Institutions: Ministry of Labour and Social Affairs; Ministry of Agriculture; Ministry of Water, Irrigation, Energy and Electricity; Labour and Social Affairs Bureaus/offices, Water and Agriculture Bureaus/Offices at the local levels in Ethiopia. Ministry of Labour; Ministry of Agriculture; Ministry of Water; Agriculture and Water Departments in States/counties in South Sudan. And other various stakeholders and developers.	Duly attention to these aspects has to be paid at each of the following stages: • Conditions on projects while drafting the IWRDP; • Feasibility studies and detail design; • IWRMDP monitoring plan	Measures' costs are not directly quantifiable
Improved energy security	**Maximization / enhancement of positive impacts**	**Enhancement of energy security**	IWRMDP to include conditions on project, that should be then reflected into feasibility studies and detailed design of projects, such as: • Improved connection to the national grid for urban poles and extensive rural electrification programmes • Attractive electricity prices to encourage the use electricity instead of charcoal/wood Monitoring of the IWRMDP to include monitoring measures on energy security	• Implementation Arrangement: Regional/Local Governments in collaboration with Ethiopian Electric Corporation in Ethiopia; States/Counties in collaboration with Ministry of Energy in S. Sudan. Coordination and collaboration with various stakeholders and developers/private sectors. • Responsible Institutions: Ethiopian Electric Corporation in Ethiopia. Ministry of Energy South Sudan		
Increased water-related diseases close to dams and irrigation schemes	**Minimization**	**Control of water-related diseases development through adequate design, construction and management of irrigation schemes**	Operational drainage system, managed to avoid stagnant water and allow regularly fluctuating water levels, periodic rapid drying of irrigation canals	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government in Ethiopia; States/Counties in collaboration with national of GoSS. Coordination and collaboration with various stakeholders and developers/private sectors. • Responsible Institutions: Federal Ministry of Health; Ministry of Water, Irrigation, Energy and Electricity; Health, Water and Agriculture Bureaus/Offices at the local levels in Ethiopia. Ministry of Agriculture; Ministry of Water; Health, Agriculture and Water Departments in States/counties in South Sudan	To be included in project design	To be included in costs of design
			Removal of aquatic plants that vectors feed on, introduction of aquatic plants that repel vectors		Hydraulic and aquatic plants management of the irrigation scheme to prevent prevalence of water-diseases belong to daily scheme operations have to be incorporated into ToRs	4 USD / ha irrigated / year
			Lining canals with plastic and concrete, combined with water velocity > 0.3-0.4 m/s		To be included in project design	500 USD / ml primary canal with an average water flow of 5 m^3/s
			Elaboration and implementation of water supply and sanitation management plans around irrigation schemes to prevent contamination of water bodies with faeces and to ensure supply of safe and clean		To be included in project design	Sewerage: For 15 villages around large scale irrigation schemes: =>Sewerage master plan: 15* 25,000 euros =>Establishment of the recommended sewerage system: 540,000 euros per village for the network

Anticipated social and environmental benefits / risks	Mitigation hierarchy (avoidance, minimization, restoration, compensation/offset) / enhancement	Proposed management measure(s) and objective of management measure(s)	Technical and operational requirements of management measure(s)	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs
						and 50, 000 euros per village for the treatment NB: according to the local context, individual sanitation systems might be more relevant. <u>Water supply:</u> Master plan: same as for sewerage Investment : Simple water treatment: 550 euros / m3/day + Functioning: 0,2 euros / m3/day
		Control of water-related diseases through dam operations by disrupting the reproductive cycle of disease vectors, eventually resulting in mortality	Varying water level in reservoirs and dams Eg: to prevent malaria, faster drawdown of the reservoir at the end of the wet season was found to dry out puddles long reservoir shores, leaving the larvae high and dry		Specific operation rules to be tested / investigated and defined in parallel to water- borne diseases vector monitoring during the first years of the project implementation	To be assessed as a result of the test. Could be optimized via adequate synchronization with intakes for irrigation or electricity demands.
	Offset	**Reduction of exposure to water-related diseases**	Health education		Health education should be done on a regular basis from project implementation until eradication of water-borne diseases.	Cost of existing health campaigns. Eg: a nominal sum of USD 130,000 was dedicated to malaria control and health monitoring for Megech irrigation scheme (4,000 ha).
			Mosquito proofing of houses		Mosquito proofing of houses should occur at the construction stage.	
			Improvement of access to health services		Improved access to health services should occur at the construction stage.	
Decreased water quality in vulnerable parts of the basin	**Minimization**	**Prevention of water quality issues associated with implementation of dams**	Thorough removal of organic matter from areas prior to inundation to reduce initial eutrophication issues	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS • Responsible Institutions: Federal Ministry of Health; Ministry of Water, Irrigation, Energy and Electricity; Health and Water Bureaus/Offices at the local levels in Ethiopia. Ministry of Health; Ministry of Water; Health and Water Departments in States/counties in South Sudan. :	Erosion prevention measures should start as soon as possible, and take place before dams construction; Irrigation and fertilisation management will have to be defined as part of the project detailed design.	
			Erosion prevention upstream of dams water catchments to avoid sediment accumulation within dams, silt load and long-term eutrophication issues			Afforestation only: 300 USD/ha Afforestation + hillside terraces/structures : 630 USD / ha Study to investigate the surface area and location to be treated: USD 20,000
			Installation of air draughts in the water-release ports to boost oxygen levels by aerating released water (when relevant)			
		Prevention of water quality issues associated with irrigation schemes implementation in vulnerable parts of the basin	Optimisation of irrigation to limit water releases and infiltration after filed application			

Anticipated social and environmental benefits / risks	Mitigation hierarchy (avoidance, minimization, restoration, compensation/offset) / enhancement	Proposed management measure(s) and objective of management measure(s)	Technical and operational requirements of management measure(s)	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs
			Minimization of the use of fertilizers and pesticides, especially in vulnerable areas			1 USD / ha irrigated / year
		Prevention of water quality issues associated with increased population density	Elaboration and implementation of sanitation and waste water management plans in all urban centres and dense settlements		To be started right after the IWRMDP approval	For a secondary town (around 50, 000 inhabitants): =>Sewerage master plan: 200,000 euros =>Establishment of the recommended sewerage system: 10 million euros for the network and 20 million for the treatment
	Offset	**Provision of all communities using the river as the main source of supply for fresh water with reliable clean alternative**	All communities using the river as the main source of supply for fresh water must be provided with reliable clean alternatives During the time when water quality will be impaired (based on water monitoring see aquatic section), all affected villages shall be sensitized about the fact that water in the River will not be drinkable		Supply must be available prior to construction commencing and last 3 years after reservoir impoundment (subject to change based on water quality monitoring)	Cost shall include 4 years of water supply (3 years of construction + 2 to 3 year after reservoir impoundment) (subject to change based on water quality monitoring)
Risks of drowning in irrigation canals (people, cattle, wildlife)	Minimization	**Prevention of drowning in irrigation canals** (people, cattle, wildlife)	Include the mitigation of this risk into the design of irrigation schemes (especially as part of canals lining options) Prohibit access to canals to avoid crossing (dangerous and can alter the canal). Organize prevention campaigns	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS. • Responsible Institutions: Ministry of Environment, Forest and Climate Changes; Ministry of Water, Irrigation, Energy and Electricity; Environment, Health and Water Bureaus/Offices at the local levels in Ethiopia. Ministries of Environment, Health and Water; Environment, Health and Water Departments in States/counties in South Sudan	To be studied at the ESIA stage	Included in the design costs
	Restoration	**Access restoration**	Restore access by constructing bridges for people, cattle and wildlife			For population and cattle :2 bridges each km for people (USD 15,000 - USD 30,000 per bridge) For wildlife: to be studied specifically.
Risks of conflicts on transboundary water resources	Avoidance	**Definition and respect of targets for river flows at key river nodes, downstream of projects** ⇨ Corresponds to one of the main important outcomes of this study.	Defining key river nodes, eg: • Baro at its confluence with the Pibor • Gilo at its confluence with the Pibor • Sobat at its confluence with the White Nile • Main Nile downstream of the confluence with the Blue Nile Defining target flows at each of the river nodes	• Implementation Arrangement: With ENTRO the two states (GoE and GoSS). Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS. • Responsible Institutions: Joint Committees of the two states: Ministry of Environment, Forest and Climate Changes; Ministry of Water, Irrigation, Energy and Electricity; Environment, Health and Water Bureaus/Offices at the local levels in Ethiopia. Ministries of Environment, Health and Water; Environment, Health and Water Departments in States/counties in South Sudan	To be started right after the IWRMDP approval as part of the environmental monitoring system of the BAS	Included in the IWRDMPlan study
	Minimization	**Implementing "upstream-downstream" common**	Initiate discussions on benefit sharing Eg : rural electrification and interconnection between countries producing electricity and countries impacted by upstream hydropower development Initiate discussions on risks sharing Eg: Costs of mitigation measures being taken over by upstream countries where development occurs			
Changes to riverine ecosystem services Geomorphological changes	Avoidance	**Avoidance of extreme infra-daily variation of river flow immediately downstream hydropower dams**	**Design and construction of a small regulation dam directly downstream of the main dam.** **The regulation dam should be able to store the volume released during one day and then release a smoothed flow to the river.**	• **Implementation Arrangement: With ENTRO the two states (GoE and GoSS). Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS.** • **Responsible Institutions: Joint Committees of the two states: Ministry of Environment, Forest and Climate Changes; Ministry of Water, Irrigation, Energy and Electricity; Environment, Health and Water Bureaus/Offices at the local levels in Ethiopia. Ministries of Environment, Health and**	To be studied and included at feasibility and detailed design stage	
	Minimization	**Conservation of flood flows downstream dams to ensure that an adequate area is flooded each year (managed flood releases)**	**Dams operation rules designed to allow adequate flooding**		Feasibility stage: define objectives for flood release and assess overall technical and financial feasibility; Design stage: develop stakeholder participation and technical expertise; define links between floods and the ecosystem; define	To be included into project costs

Anticipated social and environmental benefits / risks	Mitigation hierarchy (avoidance, minimization, restoration, compensation/offset) / enhancement	Proposed management measure(s) and objective of management measure(s)	Technical and operational requirements of management measure(s)	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs
				Water; Environment, Health and Water Departments in States/counties in South Sudan .	flood release options; assess impacts of flood options; select the best flood option; Implementation stage: design and build engineering structures; make releases; and monitor, evaluate and adapt release programme.	
		Water saving measures, at least for the most consumptive uses (irrigation)	• **Choice of adequate crops;** • **Design and construction of efficient water conveyance infrastructure;** • **Choice of efficient irrigation methods;** • **Study reuse opportunities**		To be studied at feasibility stage	To be included into project costs
			Definition of efficient irrigation management and elaboration of meteorological information system to optimize water used		To be studied at feasibility stage	To be included into project costs
		Definition of environmental flows downstream each project	• **Assessment of requirements of aquatic ecosystems, including water demand, seasonal dynamics, and sediment patterns** • **Definition of environmental flows**		To be studied at feasibility stage as per of ESIA of projects	Per project: Inventory of species and habitats (length of river reach to be investigated depends on the type of species. If local species, 1 or 2 km if migratory species, over 10 km. Study without inventories: USD 50,000
	Offset	**Study emblematic, endangered or protected species related to water to better understand how they can be affected by changes in flow regimes and wetlands size**	**See section 10.3 Need for acquisition of further information on uncertain factors**		Analysis to be based on the data collected through the environmental monitoring system of the BAS	Included in the costs of the environmental monitoring system
		Management and restoration of existing and unprotected wetlands	Delimitation and mapping of wetlands Ecological, hydrological and socio-economic assessment of existing wetlands (see next table)			To be tailored once environmental flows have been defined
			Restoration of degraded wetlands			
			Protection of unprotected wetlands through adequate protection tools and management of high value mountain and lowland wetlands			
			Financing conservation initiatives / programs through NGOs activities			
			Ratification of the Ramsar Convention by Ethiopia			
		Restoration of river crossing points for cattle and wildlife to offset crossing issues due to high regulated low flows	Define the maximum flow for pastoralist to cross rivers with their cattle Design and construct bridges when necessary			To be determined as part of individual ESIA studies
		Financing conservation initiatives / programs through NGOs activities	To be tailored once environmental flows have been defined.			To be determined as part of individual ESIA studies Financial contribution to be determined according to the residual effects
		Preventive and curative treatment of invasive aquatic plants	**Removal of existing water hyacinth (physical, mechanical, biological control : 2 species of weevil are efficient)**		To be included in TORs.	To be included in projects costs.

Anticipated social and environmental benefits / risks	Mitigation hierarchy (avoidance, minimization, restoration, compensation/offset) / enhancement	Proposed management measure(s) and objective of management measure(s)	Technical and operational requirements of management measure(s)	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs
			Prohibit water hyacinth introduction to new places such as in new dams (especially during dam operation) **Ensure nutrient levels remain low**			
	Minimization	**Definition of an "environmental sediment regime"**	**Included in the environmental monitoring system of the BAS**		To be started right after the IWRMDP approval as part of the environmental monitoring system of the BAS	Included in the costs of the environmental monitoring system of the BAS
	Minimization	**Inclusion of tools to allow periodic flushing of sediments within dam design to implement the recommended "environmental sediment regime"**	**To be studied as part of ESIA of projects**		To be studied at feasibility stage as per of ESIA of projects	Inlcuded in the design costs
	Minimization	**Inclusion of fish ladder within dam design**				
	Restoration	**Transfer of coarse sediment stored / stopped from upstream the dam to downstream the dam**				
	Restoration	**Mobility space of rivers, lateral erosion leading to alluvial sediment recharge**				
	Restoration	**Reconnection of annexes (wetlands, ponds, floodplain) to the river in case of severe bed incision**				
Conversion of arable land and population impacted by projects footprints	Minimization	**Scattered villages to be gathered close to existing infrastructure (schools, roads, etc.) based on affinities to minimize resettlement**	Irrigation scheme command area to be revised / tailored to avoid dense/gathered settlement/villages	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS. • Responsible Institutions: Ministry of Environment, Forest and Climate Changes; Ministry of Water, Irrigation, Energy and Electricity; Environment and Water Bureaus/Offices at the local levels in Ethiopia. Ministries of Environment and Water; Environment and Water Departments in States/counties in South Sudan.	To be studied at feasibility stage as per of ESIA of projects	To be determined as part of RAP for each project
	Minimization	**Exclusion of dense/ gathered settlement/villages from irrigation schemes**				
	Minimization	**Conservation of communal grazing areas and conservation of access to grazing areas outside project footprints**				
	Offset	**Provide access of irrigation areas to ensure equivalent yields or to equivalent land**				
Conversion of natural ecosystems	Avoidance	**Avoidance of protected areas and other sensitive areas**	Abandon or relocation of projects or parts of projects located within protected areas and other sensitive areas as far as possible		Project design	Study to find alternative project sites: 100 000 USD
	Minimization	Conservation of ecological corridors within irrigation schemes / Project delineation to reduce habitat fragmentation	See section 10.3 Need for acquisition of further information on uncertain factors		To be studied as part of the environmental monitoring system of the BAS	To be determined as per of the ESIA of individual projects
	Minimization	Conservation of important species	Implementation of procedures to safeguard or retain species and material (seeds, rootstock and medicines) used by local communities, during implementation of vegetation clearance programs		Before project construction	To be determined as per of the ESIA of individual projects
	Offset	Financing conservation initiatives / programs through NGOs activities	To be tailored as part of the ESIA of specific projects		To be tailored as part of the ESIA of specific projects	Financial contribution to be determined according to the significance of residual effects
Increased GHG emissions	Minimization	**Development of agro-forestry within irrigation schemes and valorisation of vegetation resulting from land clearance to reduce GHG emissions due to vegetation burning**	Selective clearance of the vegetation during scheme construction to conserve native trees of interest	• Implementation Arrangement: With ENTRO the two states (GoE and GoSS). Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS. • Responsible Institutions: Ministry of Environment, Forest and Climate Changes; Ministry of Water, Irrigation, Energy and Electricity; Environment and	Before project construction	If sufficient commercial trees can be extracted, cost of deforestation can be balanced by trees valorisation. Other vegetation types can be removed by communities but the dam operator often
			Trees plantation, management and harvesting			

Anticipated social and environmental benefits / risks	Mitigation hierarchy (avoidance, minimization, restoration, compensation/offset) / enhancement	Proposed management measure(s) and objective of management measure(s)	Technical and operational requirements of management measure(s)	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs
			• **Valorisation of vegetation resulting from land clearance (timber, material to build houses) to avoid vegetation burning** • **Prohibition of burning of vegetative waste following vegetation clearance**	Water Bureaus/Offices at the local levels in Ethiopia. Ministries of Environment and Water; Environment and Water Departments in States/counties in South Sudan		refuse to let them take the wood.
	Minimization	**Control of vegetation clearance to reduce methanization risks and to reduce GHG emissions due to vegetation burning**	• **Total vegetation clearance of the reservoir surface area which will be flooded,** • **Valorisation of vegetation resulting from land clearance (timber, material to build houses) to avoid vegetation burning** • **Prohibition of burning of vegetative waste following vegetation clearance**		Before project construction	
	Offset	**Afforestation and forest restoration to offset NO_2 releases due to agriculture development**	**To be tailored once the command area of individual irrigation projects has been validated**		To be started right after the IWRDMPlan approval	300 USD / ha (afforestation for erosion) 20 USD / ha afforestation program (NAMA – Ethiopia) 6000 USD / ha – Eric Malawi
	Offset	**Enhancement of existing measures to reduce usual deforestation in order to offset remaining GHG emissions due to land clearing and reservoirs**	**The Oromia sub-national REDD+ pilot project: This project was just initiated with support from the World Bank and the Norwegian Government. This pilot project will seek to promote activities that lead to reduced emissions from deforestation and forest degradation, in addition to carbon stock enhancement, in the regional state of Oromia. The Ministry of Agriculture and the Oromia Forest and Wildlife Enterprise lead the project design.** **The Ethiopia Global Climate Change Alliance (GCCA-E) project: Coordinated by the GIZ SLM Program, the main objective of the project is to contribute towards the construction of a carbonneutral and climate-resilient economy. Piloting climate-smart agricultural activities is currently implemented in 34 districts in the areas of the SLM program (http://www.gcca.eu/nationalprogrammes/africa/gcca-ethiopia).**		To be started right after the IWRDMPlan approval	Financial contribution to be determined according to the residual effects
Displacement and loss of life, property and assets resulting from natural disasters in the basin	**Avoidance**	**Preparation and adoption of disaster management plans at national, state and local levels**	**Implementation of disaster management plans and early warning systems, humanitarian aid coordination system functioning at national and state levels**	Implementation arrangements: • Ethiopia: Disaster Prevention and Preparedness Commission and humanitarian aid agencies • South Sudan: Ministry of Humanitarian Affairs and Disaster Management and humanitarian aid agencies Institutional responsibility: • Ethiopia: Disaster Prevention and Preparedness Commission • South Sudan: Ministry of Humanitarian Affairs and Disaster Management Consultation required between governments and humanitarian agencies	The timing, duration and frequency depend on the occurrence of natural disasters in the basin	TBD from allocations from national budgets and budgets of humanitarian agencies
	Minimization	**Same as above**	**Same as above**			
	Offset	**Provision of basic necessities and health care for affected people**	**Pre-position relief supplies and transport in state centres and field locations in areas prone to natural disasters** **Collaboration between governments and humanitarian agencies**			
Displacement and loss of life, property and assets resulting from ethnic, social and political conflicts in the basin	**Avoidance**	**Governments increase responsiveness to issues and concerns of ethnic and social groups, decrease use of force as a response to conflicts**	**In Ethiopia, ethnic and social conflicts have long historical roots and are deep-seated and are not readily avoidable in the present circumstances, Lifting the emergency and enter into talks to find ways to accommodate the concerns and issues of ethnic groups.** **In South Sudan Implement Peace Agreement of August 2015, between government, and SPLA signed by President Kir and former VP Machar. Implement crisis response plan[49] and agreement between government and UN agencies.**	Implementation arrangements: • Ethiopia: Federal and regional governments, armed forces, representatives of ethnic groups and humanitarian agencies • South Sudan: Government of National Unity, Security Services, ethnic organizations, UNMISS, Regional Protection Forces and humanitarian aid agencies Institutional responsibility: • Ethiopia: Federal and regional governments • South Sudan: National Unity Government and National Security Services	The timing, duration and frequency depend on the nature of the incidents of conflicts	TBD from allocations from national budgets and budgets of humanitarian agencies
	Minimization	**Same as above**	**Same as above**			
	Offset	**Designation of safe areas/ reception centres/camps for IDPs and refugees**	**Operation and providing security for safe areas/reception centres and camps for IDPs and refugees**			
		Provision of basic necessities and health care for affected people, support to returnees	Plan and supply logistics/transport for assistance under agreements for humanitarian assistance with governments			

49 South Sudan Crisis Response Plan, United Nations, 2014

10.4 NEED FOR ACQUISITION OF FURTHER INFORMATION ON UNCERTAIN FACTORS

Uncertainties in assessing the scenarios have been pointed out in the SSEA analytical framework (see chapter 4), in a dedicated annex and through out the process. In order to mitigate these uncertainties, margins of error have been applied to the results and thresholds have been given some leeway for certain dimensions.

However, these uncertainties still make it difficult to quantify the significance of the potential impacts and to quantify the net residual impacts at this stage.

This is why the **acquisition of further information on uncertain factors is crucial** in the case of the IWRDMPlan. This should be the **Plan's first priority** since its phasing is based on this principle.

The main needs for acquisition of further information on uncertain factors have been presented for each sub-dimension and dimension as part of chapter 7. They are summarized below together with their implementation modalities.

NB: *It does not cover the specific needs for data acquisition related to each ESIA. Requirements for project-specific ESIA studies will be addressed as part of the Term of references that will be developed for three selected medium and long-term projects.*

Table 10-2: Need for acquisition of further information on uncertain factors

Anticipated social and environmental benefits / risks		Uncertain factor	Need for acquisition of further information	Technical and operational requirements	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs	Feedback mechanisms
Changes to riverine ecosystem services	Changes to the river system itself and to wetlands	Threshold – impact significance	Vulnerability and adaptability of the population and the ecosytems to decrease in wetlands size and volume / to decrease in river flows	• Ecological assessment: inventories and expertise; • Social assessment: mainly surveys and interviews • Discussions with institutions involved in biodiversity and wildlife conservation in the Basin The outcomes should be confronted with the results of the environmental and hydrological monitoring system	• Implementation Arrangement: With ENTRO the two states (GoE and GoSS). Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS. • Responsible Institutions: Joint Committees of the two states: Ministry of Environment, Forest and Climate Changes; Ministry of Water, Irrigation, Energy and Electricity; Environment, Health and Water Bureaus/Offices at the local levels in Ethiopia. Ministries of Environment, Health and Water; Environment, Health and Water Departments in States/counties in South Sudan.	• Timing: to be launched during the 1st year of implementation of the IWRMDP • Duration: 2 years • Frequency: once at the beginning of the IWRMP + once after 10 years of implementation (after main projects implementation)	1% of the overall project cost.	Monitoring report Related results should be incorporated: • in the definition of dams operation rules • in the revision of the plan
		Impact magnitude	Need to ascertain the results from the water modelling exercise	Design and implementation of an environmental and hydrological monitoring system[50]		• Timing: to be launched during the 1st year of implementation of the IWRMDP • Duration: minimum 10 years • Frequency: frequency of data acquisition to be defined as part of the design of the monitoring system		
	Geomorphological changes	Impact magnitude	Assessment of watershed contribution to sediment transport: need to assess how much sediment could be trapped in the dams and therefore not longer be available for the river downstream	• Desk work: analysis of the following parameters: ✓ Slope of the controlled watershed; ✓ Density of the hydrographic network of the controlled watershed; ✓ Land use patterns of the controlled watershed; ✓ Rainfall erodibility; ✓ Reservoir capacity; ✓ Average inflow to the reservoir. • Acquisition of data : main rivers' turbidity[10]		• Throughout the project phase	0.5% of the overall project cost.	Same as above
		Impact significance	Assessment of the vulnerability of the rivers geomorphology to changes in sediment transport	Geomorphological study		• Same as above		Same as above
	Changes in aquatic fauna circulation	Impact significance	Assessment of the vulnerability of the rivers fauna and flora to dams	Hydrobiological surveys on river reaches concerned by projects of dams		• Same as above	0.5% of the overall project cost.	Same as above
Conversion of natural ecosystems as a result of projects footprints		Impact significance	Assessment of the vulnerability of each type of sensitive areas (and their ecological patterns: eg White-eared kob migration) and other ecosystems regarding encroachement	• Discussions with institutions involved in biodiversity and wildlife conservation in the Basin • Strenghening of the environmental monitoring in place (either the Basin-wide environmental monitoring system as part of the BAS or the existing environmental monitoring system of the countries)	• Same as above	• Same as above	1.5% of the overall project cost.	Same as above
Risk of degradation of water quality		Impact magnitude	Acquisition of baseline data and monitoring	Design and implementation if a water quality monitoring system[51]	• Implementation Arrangement: Regional/Local Governments in collaboration with Federal Government Ministries in Ethiopia; States/Counties in collaboration with national ministries in GoSS	• Same as above	1.5% of the overall project cost.	Adaptation of the ESMP (measures to mitigate degradation of water quality, frequency of monitoring

[50] Part of the Basin-wide (transboundary) environmental monitoring system which will include climate, surface and groundwater hydrology (including wetlands' hydrology: size, depth, spills into wetlands, backwater), water quality, river and wetlands ecology (it is essential to get a dynamic picture of this in order to be able to relate this dynamic to various hydrological conditions), sediment transport and water related socio-economic parameters (consumptive and non-consumptive water uses, water-borne diseases, …). Ground-based monitoring and remote sensing)

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Anticipated social and environmental benefits / risks	Uncertain factor	Need for acquisition of further information	Technical and operational requirements	Implementation arrangements and overall institutional responsibilities	Time schedule (timing, duration, frequency)	Approximate costs	Feedback mechanisms
				• Responsible Institutions: Federal Ministry of Health; Ministry of Water, Irrigation, Energy and Electricity; Health and Water Bureaus/Offices at the local levels in Ethiopia. Ministry of Health; Ministry of Water; Health and Water Departments in States/counties in South Sudan.			measures, …) according to the results
Disaster risk management	Frequency, location and magnitude	Longitudinal and time series data on frequency, location and magnitude of natural disasters	Preparation and implementation of a Disaster Management Plan for the Basin	• Implementation arrangements: ○ Ethiopia: Disaster Prevention and Preparedness Commission and humanitarian aid agencies ○ South Sudan: Ministry of Humanitarian Affairs and Disaster Management and humanitarian aid agencies • Overall institutional responsibility: ○ Ethiopia: Disaster Prevention and Preparedness Commission ○ South Sudan: Ministry of Humanitarian Affairs and Disaster Management	The timing, duration and frequency depend on the occurrence of natural disasters in the basin	TBD from allocations from national budgets and budgets of humanitarian agencies	Reporting from government and humanitarian agencies
Conflict resolution and emergency response	Frequency, location and magnitude	Historical data on frequency, location and magnitude of conflicts	Preparation and implementation of a conflict resolution and emergency response plan for the basin	• Implementation arrangements: ○ Ethiopia: Federal and regional governments, armed forces, representatives of ethnic groups and humanitarian agencies ○ South Sudan: Government of National Unity, Security Services, ethnic organizations, UNMISS, Regional Protection Forces and humanitarian aid agencies • Overall institutional responsibility: ○ Ethiopia: Federal and regional governments ○ South Sudan: National Unity Government and National Security Services	The timing, duration and frequency depend on the nature of the incidents of conflicts	TBD from allocations from national budgets and budgets of humanitarian agencies	Regular reporting from government and humanitarian agencies

10.5 MONITORING PLAN

The monitoring plan aims at guiding the follow up of the management measures and means to acquire further information on uncertain factors. It is there to ensure that the management measures are satisfactorily implemented and that the agreed targets for environmental and social protection are achieved. According to the monitoring results, it should allow to adapt the management measures as part of the feedback mechanism.

Table 10-3: Monitoring plan

Type of measures		Who is in charge of the overall monitoring?	What has to be checked?	What are the required means to monitor?	When ?	Cost of overall monitoring
Environmental and social management measures (cf section 10.3)	Measures to be implemented at the basin scale, as part of the IWRDMPlan	Ministry of environment, forest and climate change in Ethiopian side, and Ministry of Environment from South Sudan side. ENTRO will play a coordination role and funding.	✓ Maintenance of agreed flow to downstream use, ✓ Water quality at designated water quality monitoring sites, ✓ Maintenance of national parks and protected areas including wetlands and wildlife migratory routes.	✓ Water quality tests at the designated sample sites to be conducted quarterly. ✓ Flow measurements at gage stations daily, extent of protected wetland areas and forest areas once annually ✓ Wetland areas using satellite imagery in monthly basis, etc.	Throughout the project duration and beyond	It varies based on the number of monitoring sites to be determined as the projects progress.
	Measures to be implemented at project scale, mainly as part of the feasibility and ESIA studies	ESIA recommendation made at feasibility level must be implemented by the project owners and monitored by independent environmental consultants. ENTRO should follow up and arrange consultants. The implementers of the project in both countries should conduct internal monitoring as per the monitoring plan specified under each project ESIA report.	✓ Parameters to be checked depend on type of the project to be implemented. These parameters can be found in the ESIA report of each project	ESIA results/reports	During the feasibility studies of projects	5% of each project cost.
Need for acquisition of further information on uncertain factors (cf section 10.4)	As part of the IWRDMPlan	ENTRO to coordinate the inputs of the various stakeholders in charge of the implementation	✓ Flow data of tributaries and main rivers, water quality data of tributaries and main rivers, variability of wetlands and impact of development projects on the wetland ecosystem, encroachment into national parks and protected areas, etc.	Annual reports	Throughout the project duration and beyond	It varies depending on the level of uncertainties
	As part of the project-specific ESIA	Relevant ministries to report to ENTRO	✓ Compliance of the environmental mitigation measures as compared to the recommended standards ✓ Parameters specified in the ESIA of each project	ESIA results/reports	Same as above	5% of the specific project cost

11. INSTITUTIONAL CAPACITIES AND STRENGTHENING PLAN

The aim of this chapter is to assess whether the institutions designated to implement the ESMP have the required capacities and to propose strengthening measures to address the potential needs/gaps identified. According to the AfDB guidelines, the institutional strengthening plan shall indeed "address weaknesses identified at the environmental and social management level. Initiatives that could be considered, among others, include training for existing staff, hiring new employees, reorganizing units or agencies and redefining roles and responsibilities for strengthening environmental and social management".

BRIEF REMINDER OF THE INSTITUTIONAL CONTEXT OF THE BAS

Table 11-1: Institutional context of the BAS sub-basin

Issues	Existing Issues	Issues related to potential change (Potential Impacts of Change)
Transboundary Cooperative framework	• The Cooperative Framework Agreement has not yet been put into force.	• This is certainly a gap in itself and beyond this situation, it appears that very little institutional reorganization has been developed since 2010. This situation is not counterbalanced by other mechanisms such as possible bilateral agreement relating to development based on water resources, nor future management and operation of activities having transboundary effects
Security and instability	• The ongoing security situation in many parts of South Sudan is the single largest constraint to institutional development at all levels, but especially at the local level. • Within the Ethiopian portion of the basin there are also security issues, especially in Gambella Region, but also in part of Oromia. These also have an impact on the effectiveness of regional and local level institutions • The security situation has a knock-on effect on other institutional aspects indicated further in this table.	• Project implementation will require a stable situation free from political conflict. • This has been assumed in formulation of the Plan so should no- be considered as an issue related to potential change. Indeed, it is assumed that this improved situation will support institutional change
Lack of capacity/ experience in (MPP) project implementation	• The planning, development, implementation and management of multipurpose projects are relatively new concepts. ENTRO has experience in planning of projects, including the multipurpose concept (MSIOA, watershed management etc) • National and local level experience in the development and implementation of projects is minimal and existing arrangements tend to support unilateral sectoral development. Capacity and experience at the national levels is limited, largely because implementation tends to take place along sectoral lines..	• There is a gap with respect to multipurpose project implementation and especially operation and maintenance, bearing in mind that there will be a high level of sectoral inter-dependence in terms of shared infrastructure, water resources management etc. • Absence of the cooperative framework of similar transboundary tool will be a challenge
Capacity of local government institutions and Water Users	• The capacity of local government institutions within both countries is weak. This represents one of the major issues when it comes to implementation	• This represents one of the major issues when it comes to implementation

Issues	Existing Issues	Issues related to potential change (Potential Impacts of Change)
Lack of inter-sector coordination and cooperation	• Sectoral developments including the required associated water resources development are currently being conceived and planned almost independently.	• The lack of inter-sector coordination, necessary right at the beginning of the project cycle will be an unacceptable hindrance to the most efficient use of water resources and the early identification and planning of multipurpose projects which could build on cross-sectoral planning and capitalise on shared spending from the earliest possible time
Planning based on limited consultation	• Due, amongst others, to the security challenges in South Sudan in recent years, there is little preparedness for large developments based on water in general. Despite progress in drawing up master plans at national scale (agriculture, irrigation…), it is doubtful that adequate grass roots level consultation of stakeholders was possible.	• The project situation assumes peace and stability so this problem should be resolved
Inadequate water resources data/monitoring	• One major weakness is relating to data, for water resources and many other items. Much data are old or missing and the literature references often cross quote each other. This is both a technical issue and an organizational issue when considering that developing a much more extensive and reliable monitoring network should be put at the top of the list of priorities (hydro-meteorology especially). As an example, the Machar Marshes are almost not known at al and yet their consideration will be central to any water resources modelling exercise..	• This can only be envisaged in the frame of a close cooperation between the two countries, through: exchange of data, water information system, global ESIA (not case by case) etc. This is an institutional and policy matter
Land security/land tenure issues	• There are significant land security and tenure issues with respect to the rights of indigenous people.	• These rights and land tenure issues are relevant when designating land for any type of development (commercial farm; large scale irrigation, hydropower, national parks, protected areas).

INSTITUTIONAL CAPACITIES AND STRENGTHENING PLAN

The Institutional capacities and strengthening plan is summarised overleaf.

NB: When reading this institutional plan, one should keep in mind that the NBI Secretariat has recently launched the Nile Basin Trans-boundary Wetlands Project and the inaugural Nile Basin Wetlands Forum. This project aims at strengthening the technical and institutional capacities of the NBI and its 10 Member States for the sustainable management of wetlands and wetlands of trans-boundary significance in the Nile Basin. As such, the related capacities of the regional and national stakeholders involved in the ESMP are deemed to be significantly strengthened in the coming months as a result of this project.

Table 11-2: Institutional capacities and strengthening plan

Institutions	Responsibility in implementing the ESMP	Does the institution have the required capacity to satisfatorily implement the ESMP?	Proposed strengthening measures to address the gaps / needs identified
ENTRO	✓ Implementation of management measures and data acquisition as part of the IWRDMP ✓ Overall supervision	Yes	None
Ministries related agriculture and livestock development in the Two Countries	✓ Overall supervision ✓ Cooperate with other stakeholders and respect the protected areas, national parks, wildlife migratory corridors while developing agriculture and livestock resources. ✓ Promote type of agriculture that maintains the health of watershed, that involves soil and water conservation, wetland conservation, afforestation and reclamation of degraded areas, protecting major river sources from degradation, excluding investment projects at priority forest areas and wetlands. ✓ Improve livestock quality and productivity through provision of adequate water supply and grazing and reduce number of livestock unit so that overgrazing and land degradation will be minimized. ✓ Improve market access for livestock and dairy products. Promote agro-industries that add value on agriculture and livestock products and improve livelihood of the basin population and improve overall environment.	No	Build capacity of experts working on improved agriculture and livestock improvement, promote research to come up with better breeds and improved productivity. Build capacity of experts looking for livestock health.
Ministries related to water and irrigation development in the Two Countries	✓ Overall supervision ✓ Implement irrigation projects in such a way that it minimizes environmental damage. ✓ Avoid water quality deterioration by the irrigation input and treat irrigation return water before discharging into receiving water body or reuse it.	Though there is responsible institution at ministerial level in both countries, still the capacity is not adequate.	Capacity building mainly advanced training for young employees and equipping data collection and processing equipment for instance meteorological data acquiring instruments and training of technicians on data acquiring and experts in data analysis and reporting.
Ministries related to Environmental Protection and Natural Resources Conservation in the Two Countries	✓ Overall supervision ✓ Issue policies, guidelines and standards, ✓ Monitor the implementation of policies, guidelines and standards. ✓ Promote awareness creation regarding environmental protection in the basin. ✓ Formulate bilateral agreements on the conservation of trans boundary wildlife conservation areas, Wildlife migratory corridors, ✓ Conduct research and determine ecological flow. ✓ Establish a joint BAS sub basin environmental advisory team/committee under ENTRO or as a separate entity.	Though there is responsible institution at ministerial level in both countries, still the capacity is not adequate.	Capacity building mainly providing advanced training for young employees and equipped monitoring facilities such as water and soil quality laboratories, Remote sensing facilities and skills, etc.

Institutions	Responsibility in implementing the ESMP	Does the institution have the required capacity to satisfatorily implement the ESMP?	Proposed strengthening measures to address the gaps / needs identified
Ministries/agencies related to Energy Development in the two countries	✓ Overall supervision ✓ Preparation of dam operation rules for the Transboundary dams. ✓ Preparation of dam simulation models, ✓ Establishing dam safety and early warning system ✓ Establish water allocation and equitable use of water for the benefit of the sub basin population. ✓ Promote use of hydropower for electrification and for all the energy consumption. ✓ Reduce or avoid the tradition of using forest/trees for fuel and instead promote use of electricity from hydropower and solar sources.	No	✓ Build capacity on dam safety and early warning system and dam operation modelling, ✓ Conduct monitoring studies to capture environmental impacts caused by theimplementation of the proposed development projects and recommend improvement or mitigation measures and implement these measures in coordination with other stakeholders.
Regional/local bureaus /offices/ departments related to agriculture and livestock development (in Ethiopia) State/county level departments related to agriculture and livestock development (in South Sudan	✓ Implementation of management measures and data acquisition as part of the IWRDMP ✓ Promote agriculture extension works. ✓ Conduct soil and water conservation works.	No	✓ Training on monitoring and evaluation. ✓ Experience sharing in ESM practices.
Regional/local bureaus /offices/ departments related to Environmental Protection and Natural resources conservation (in Ethiopia) State/county level to Environmental Protection and Natural resources conservation (in South Sudan	✓ Implementation of management measures and data acquisition as part of the IWRDMP ✓ Conduct ESIA before implementing development projects in their respective areas of influence.Work in coordination with vertical and horizontal organizations.	Ditto	✓ Training in Impact Assessments ✓ Training on monitoring and evaluation of Impact mitigation Measures. ✓ Build capacity on conducting ESIA. ✓ Experience sharing in ESM practices

Institutions	Responsibility in implementing the ESMP	Does the institution have the required capacity to satisfactorily implement the ESMP?	Proposed strengthening measures to address the gaps / needs identified
Regional/Local bureaus /offices/ departments related to water development and irrigation (in Ethiopia). State/county level departments related to water development and irrigation (in South Sudan).	✓ Implementation of management measures and data acquisition as part of the IWRDMP. ✓ Conduct irrigation development in cooperation with country level offices and ENTRO in such a way that it conserves protected areas, wildlife migratory corridors, wetlands, and river buffer zones, etc.	Ditto	✓ Capacity building in Data acquisition, Management and Reporting
Regional/Local departments related to energy development (in Ethiopia). State/county level departments related energy development (in South Sudan)	✓ Implementation of management measures and data acquisition as part of the IWRDMP ✓ Develop rural electrification to reverse deforestation ✓ Introduces energy saving mechanisms, ✓ Promote solar energy in rural areas.	Ditto	✓ Capacity building in Data acquisition, Management and Reporting. ✓ Training on monitoring and evaluation of Impact mitigation Measures
Joint BAS sub basin environmental advisory team/committee	✓ Coordinate SSEA and ESIA studies of the basin; ✓ Assess and evaluate Environmental situation of the basin and prepare annual environmental status reports, ✓ Monitor agreed environmental and social parameters of the basin; ✓ Supervise overall environmental and social situation of the basin, ✓ Advise the two countries and ENTRO regarding environmental and social issues of the sub basin.	Not yet established	Establish within the first phase of the plan implementation.

ANNEXES

Annex 1: Communication and consultation plan

See Communication and consultation plan.

Annex 2: List of consulted documents, including programme-related reports

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Annex 3: Baseline data referred to in the Report

INTRODUCTION

OVERVIEW OF THE STUDY AND PREVIOUS ACTIVITIES

The objective of the consultancy services is to assist ENTRO in preparing an Integrated Water Resources Development and Management Plan (IWRDMP) based on a Strategic Social and Environmental Assessment (SSEA), and further develop investment packages for cooperative development in the Baro-Akobo-Sobat sub-basin. The study is divided into four components.

- Component 1, which runs throughout the study and culminates in the production of the Integrated Water resources Development and Management Plan (IWRDMP). It includes the following steps:
  - Scoping of work for the baseline phase. This step has been completed
  - Establishment of a baseline, including the identification of potential development interventions (identified and otherwise). Understanding of issues, challenges and opportunities.
  - Screening of development and management options through a SSEA developed as part of the study. A draft SSEA framework has been prepared.
  - Stakeholder-driven development of an Integrated Water Resources Development and Management Plan (IWRMDP).
- Component 2 is aimed at fast-tracking the preparation of a limited number of short-term projects. A Concept Note covering at 7 potential projects has been prepared and the next step will be the screening of projects and selection of 3 projects for project preparation and climate proofing
- Component 3 comprises the identification and profiling of medium and long-term projects. This activity will follow directly on from the development of strategic actions and will be in line with the strategic objectives. Medium to long-term projects are seen as mainly large infrastructure projects that will require a significant amount of preparation and associated cost. Compilation of terms of reference (ToR), comprising ToR for feasibility studies and ToR for Environmental
- Component 4 concerns the provision of Project Implementation Support and stakeholder participation.

BASELINE, DEVELOPMENT POTENTIALS, KEY ISSUES AND OBJECTIVES REPORT

The main purposes of this report, the **Baseline, Development Potentials, Key issues and Objectives report** are i) to ensure that the required information is available to build the SSEA and ii) is to reach consensus on the vision and strategic objectives required to develop water resources in the Baro-Akobo-Sobat Basin and iii) provide insight into possible short-term interventions. For greater clarity, this report has been divided in three parts:

- Part 1: Baseline Study

  The baseline study aims at providing a clear view on the current situation in the basin in terms of bio-physical (supported by a water balance model), socio-economic and legal/institutional environments. This situational analysis, has been combined with a review of the ongoing initiatives to develop water resources uses in the basin.
- Part 2: Potential developments in the Baro-Akobo-Sobat basin

  A sectoral approach has been developed to list the existing development projects and identify new projects and the potential for development. The key output of Part 2 is to identify the water related opportunities in the basin.
- Part 3: Summary of the findings – key issues and objectives for the Baro-Akobo-Sobat basin

  Part 3 aims at integrating the information from Parts 1 and 2 in order to propose a vision and strategic objectives for the basin. It should be noted that the vision and strategic objectives for the basin must be agreed and shared by the key stakeholders in the basin to ensure that the proposed IWRDMPlan will be implemented. This will be one of the objectives of the baseline workshop.

PART 1: BASELINE

SPATIAL AND TEMPORAL LIMITS

Spatial boundaries

The study area is the Baro-Akobo-Sobat Basin as defined by its hydrographic boundaries. The existing boundaries were reviewed during the baseline and some modifications made. Although minor, they did result in the Kinyetti River, which takes its source in the Imatong Mountains now being included in the basin.

It is important to recognize that the development and management of water resources cannot take place in isolation of other parts of the countries in which the basin is situated. Influences such as the location of export markets, communication and transport infrastructure, electrical interconnection and the location of administrative and commercial centres outside of the basin have to be taken into consideration.

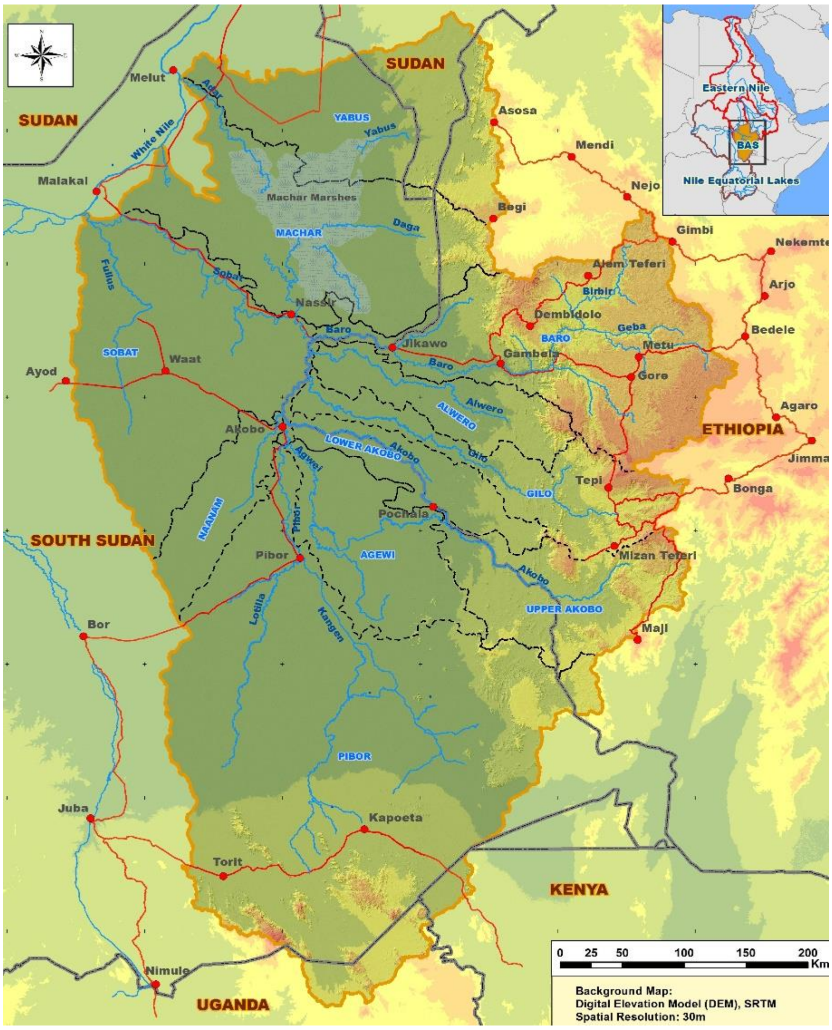


Figure 11-1: Drainage and Relief of the Baro-Akobo-Sobat Basin, showing basin limits

Temporal limits

The planning horizon for the IWRDMPlan has been taken as 25 years. Within this time frame "short-term" is taken as up to 5 years, "medium term" as 5 to 15 years and "long-term" as 15-25 and beyond.

Biophysical Environment

Physical Environment

The Baro-Akobo-Sobat Basin can be delineated into 10 primary sub-basins as shown in the adjacent table. The Baro, Gilo and Akobo River originate from the south-western part of the Ethiopian Plateau and then flow westward where they join the Pibor River flowing from the south. As these rivers enter the low-lying plains, they disperse through small channels in some areas or spill into floodplains and wetlands and even across into adjacent catchments during high flow events. Downstream of Gambella, the Baro River is joined by the Jokau stream from the north. Along the same reach, the Baro River bifurcates into the Adura River to the south, which joins the Baro River again upstream of its confluence with the Pibor River.

Along this reach, the Baro River also spills its banks towards the Alwero River to its south, which later on joins the Baro River. The Baro River discharges significant water volumes through the Khor Machar and by means of overbank spills to the Machar Marshes during the high flood season. The Machar Marshes, which has a maximum area of around 8 000 km^2, lies to the north of the main channel of the Baro River and from local runoff via the “eastern torrents”, which originate on the Ethiopian escarpment. In the rainy season these wetlands expand to cover a large area east of Malakal and north of the Baro River. Small amounts of water from the Machar Marshes occasionally enter the White Nile northeast of Malakal through the Khor Adar.

Sub-basin	Area (km^2)
Baro	31,234
Alwero	7,368
Gilo	12,081
Upper Akobo	14,980
Agwei	14,388
Lower Akobo	7,920
Pibor	77,309
Nanaam	7,403
Sobat	34,625
Machar	46,753
TOTAL	254,061

Climate and Climate Change

The Baro-Akobo-Sobat Basin is characterised by distinct wet and dry seasons. The spatial variation of precipitation across the basin is considerable due to the range of elevations. The mean annual precipitation across the basin is shown on the adjacent map.

Across the basin, July and August are typically the wettest months, although September can also still have significant rainfall. In the eastern highlands and Gambella Plains, the rainfall is concentrated between May and September, with about 80% to 90% of the rainfall occurring during these months. Towards the southern part of the basin, the rainfall season tends to be slightly longer, extending from April to October.

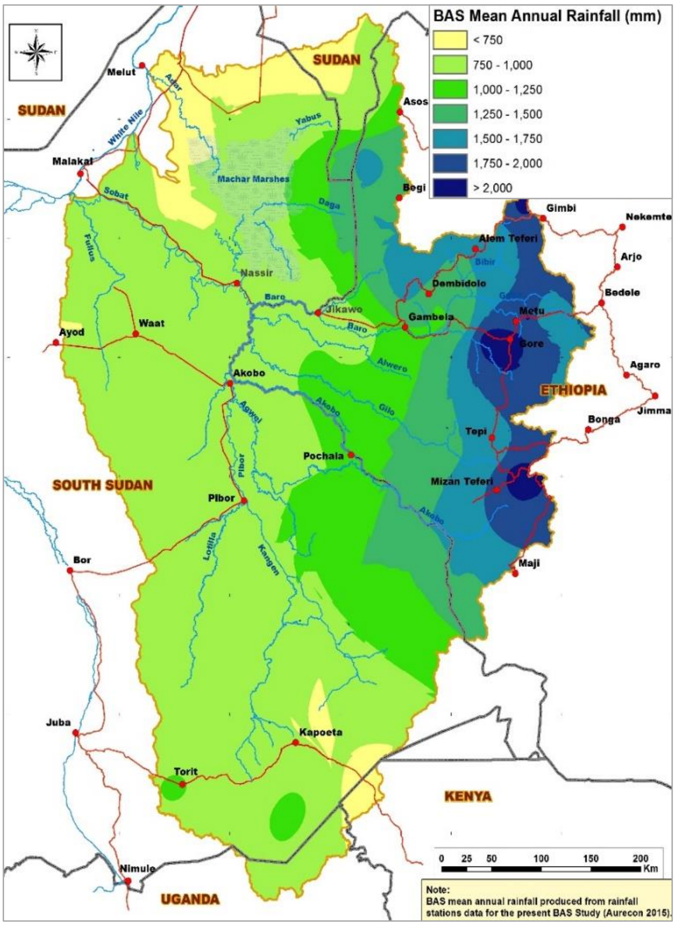


Figure 11-2: Mean annual precipitation across the Baro-Akobo-Sobat Basin

The IPCC Fifth Assessment Report (AR5) indicates significant increases in temperature across the Baro-Akobo-Sobat basin by the end of this century, particularly under the higher emissions scenario (RCP8.5). However, the report provides no certainty on the projected precipitation changes.

Kassa (2013) considered the potential impacts of climate change over the Baro-Akobo-Sobat basin using a global circulation model (CGCM3.1) as well as a regional climate model (REMO), both downscaled using statistical downscaling methods. The results showed:

- A general incremental increasing trend of annual maximum temperature. The projected trend change also appears to increase with decreasing altitude in the basin.).
- A general increase in mean annual precipitation across all stations up to 22% by 2050 except for a potential slight reduction in the MAP for the Metu and Bure stations). No significant trend with altitude was observed.

Surface Water

A critical component related to the development of the Baro-Akobo-Sobat Basin concerns the potential impacts of development interventions and management options on the surface water regime in the basin, both in terms of quantity and spatial and temporal impacts. The mean annual outflow of the Baro-Akobo-Sobat Basin into the White Nile of 12.56 billion m^3/a contributes about half of the flow of the White Nile at Malakal and about a sixth of the flow of the Main Nile at Aswan. The Baro-Akobo-Sobat Basin has distinct hydrological regions, with most of the runoff being generated in the mountainous, high rainfall areas of the Ethiopian Highlands. Due to overbank spillage and evaporation, significant losses occur in the Gambella Plains, the *Machar Marshes* and the wetlands and swamps in the southern and central parts of the Pibor sub-basin.

In terms of flow volume, the Baro River constitutes the main river in the basin. At Gambella, the Baro River has a mean annual flow of about 12.9 billion m^3/a. Downstream of Gambella, this volume gets significantly reduced as the Baro River frequently overtops its banks during the wet season with spills onto the Gambella floodplains and also to the *Machar Marshes*, while the river receives some inflow from the Alwero River. At is confluence with the Pibor River, the mean annual flow of the Baro River has reduced to 9.69 billion m^3/a. Figure 11-4 displays the seasonal flow patterns at key locations in the major rivers within the basin and also provides information on the mean annual flow at each location.

Groundwater

The groundwater supply potential for the entire study area has not previously been determined. A new approach was developed and involved collating, checking and sorting existing data, extrapolating data to areas without data, developing a system to group and rank similar groundwater areas and finally developing an approach to quantify these areas. The yields shown in Figure 11-3 are considered the 'best estimate' at this stage.

There is considerable variation in water quality over the project area as a result of different physical and geochemical processes. The available literature indicate that generally groundwater quality is good throughout the Blue Nile Basin part of the study area. The water is generally "fresh" and suitable for most uses. There are, however, localized exceptions. Contamination is greatest in areas with highly permeable unconsolidated sediments, and where water is drawn from hand-dug wells and unprotected springs.

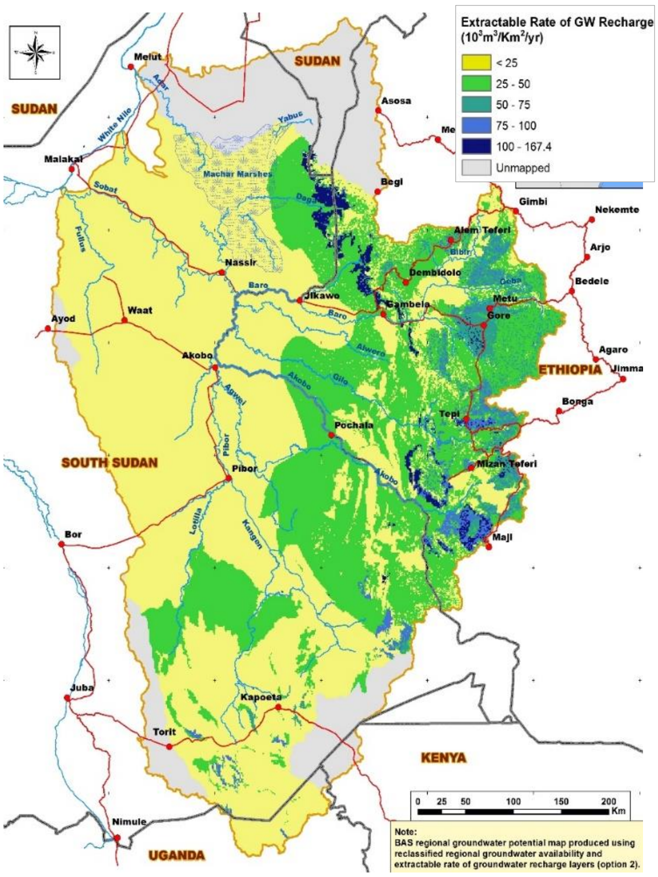
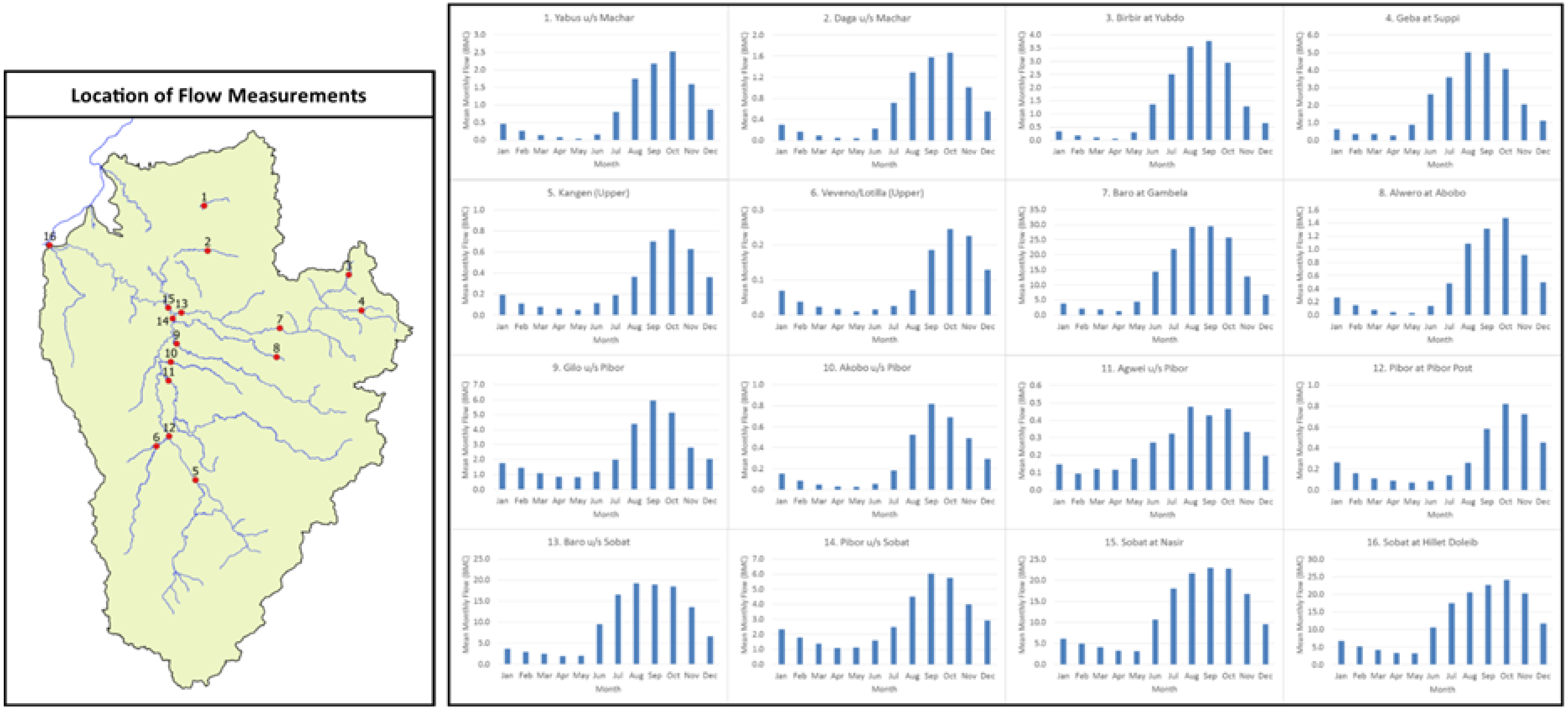


Figure 11-3: BAS regional groundwater potential



Mean Annual Runoff in BCM							
1 Yabus u/s Machar	0.91	5 Kangen (Upper)	0.31	9 Gilo u/s Pibor	2.46	13 Baro u/s Sobat	9.69
2 Daga u/s Machar	0.64	6 Veveno/Lotilla (Upper)	0.01	10 Akobo u/s Pibor	0.28	14 Pibor u/s Sobat	2.92
3 Birbir at Yubdo	1.43	7 Baro at Gambela	12.90	11 Agwei u/s Pibor	0.26	15 Sobat at Nasir	12.04
4 Geba at Suppi	2.18	8 Alwero at Abobo	0.54	12 Pibor at Pibor Post	0.31	16 Sobat at Hillet Doleib	12.56

Figure 11-4: Hydrology of the Baro-Akobo-Sobat Basin

Water Quality and sedimentation

Water quality

There is no form of regular water quality monitoring in the basin. Surface and groundwater quality data have been collected on an ad hoc basis for various studies but these have not been collated into a central database that is accessible to water resources managers and to consultants alike. The ENTRO One System Inventory report (ENTRO, 2007) concluded that water quality in the Baro-Akobo-Sobat sub-basin was not threatened. Although water quality is not yet a problem in the Baro-Akobo-Sobat system, there are worrying signs of impacts that could, cumulatively, start to have a negative impact on water users in the basin. These include localised impacts of solid waste and wastewater impacts from urban and rural settlements, oil exploration and extraction in the Marchar Marches, deforestation in the Ethiopian highlands and the impacts on sediment loads in the rivers draining the highlands, artisanal gold mining in the highlands and the impacts on sediment loads and trace metal pollution, and invasive aquatic weeds starting to impede navigation and impacting on the dissolved oxygen concentrations in the water.

It is recommended that routine flow and water quality monitoring be implemented as recommended by the current NBI Hydromet Project (NBI, 2014a) in order to improve the water quality knowledge base in the Baro-Akobo-Sobat sub-basin and to provide a platform for the early identification and investigation of potential water quality problems in the sub-basin.

ENTRO (2007) identified malaria as a major concern that was increasing as it was difficult to control. Other water related diseases included Schistosomiasis, Typhoid, Diarrhoea, Helminthiasis, Leshimaniasis, and Onch ocerchiasis. Outbreaks appeared to be associated with the seasonal flooding of the low-lying areas.

Sedimentation

A major issue in all of the Baro-Akobo-Sobat Basin concerns suspended solid loads in surface waters as a result of erosion. The high sediment loads in the rivers are the results of high topographic slopes, high intensity rainfall patterns, poor farming practices and deforestation due to population pressure and commercial exploitation of wood resources.

There is no sediment database available in the basin and available data are too limited to deduce any meaningful sediment yield-discharge relationships. Consequently, the SHETRAN model (Ewen et al., 2000) was used to develop a sediment yield map for the basin and the results are summarised in Figure 11-5.

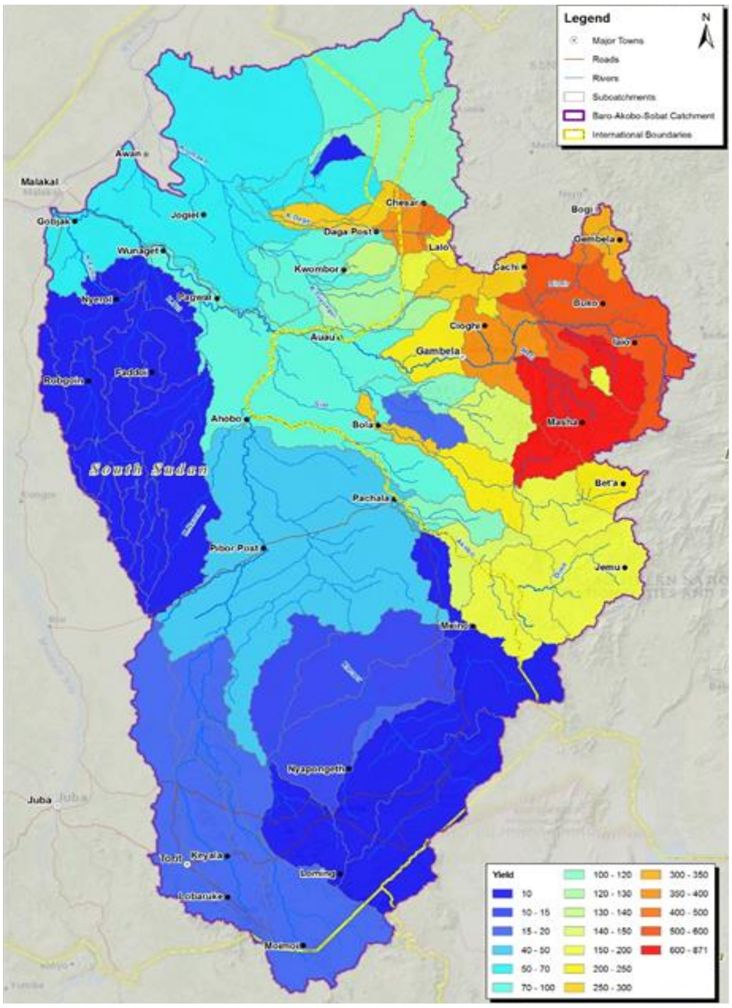


Figure 11-5: Cumulative sediment yield in the basin in t/km2/a

Floods and droughts

The Gambella Plains to the west of Gambella flood almost every year. This flooding is mainly caused by the limited conveyance capacity of the mild sloping Baro, Alwero, Gilo and Akobo rivers and is exacerbated by the backwater effects from the Pibor and Sobat Rivers, direct heavy rainfall over the flood plains and deforestation in the upper catchment areas, which increases the flood runoff response and flood volumes and also leads to excessive sedimentation. The flooded area can be extensive, in 1988, an area close to 10,000 km^2 was inundated along the Gambella Plain during October and November. Apart from the seasonal flooding along the plains, there are also occasional flash floods, especially in the southern and south-western parts of the basin in South Sudan. Extreme floods in the region have occurred in 1934, 1946, 1962, 1996, 2007 and 2010.

The regularly flooded areas within the plains are mainly used as pastures and for recession agriculture and many people in the Gambella region live along the river banks. Structures within the floodplain include cattle enclosures, isolated tukuls and several large villages, especially along the Baro River. During the 1988 flood, a significant portion of Gambella and almost the entire town of Itang were flooded with severe socio-economic impacts. Although the flooding has severe negative impacts including loss of life, structural damage to infrastructure, displacement, health risks and water logging of pastures and crops, the annual floods also support recession agriculture and provide fertile pastures to support the extensive cattle farming in the area.

The flood season in the upper part of the Gambella Plain typically extends from July to October, but due to the attenuating affects of the floodplains, the flood season along the lower part of the Plain can last up to November and even December. Figure 11-6 shows the progression and extent of inundation in the Gambella Plains and *Machar Marshes* for the period July to Dec 2007.

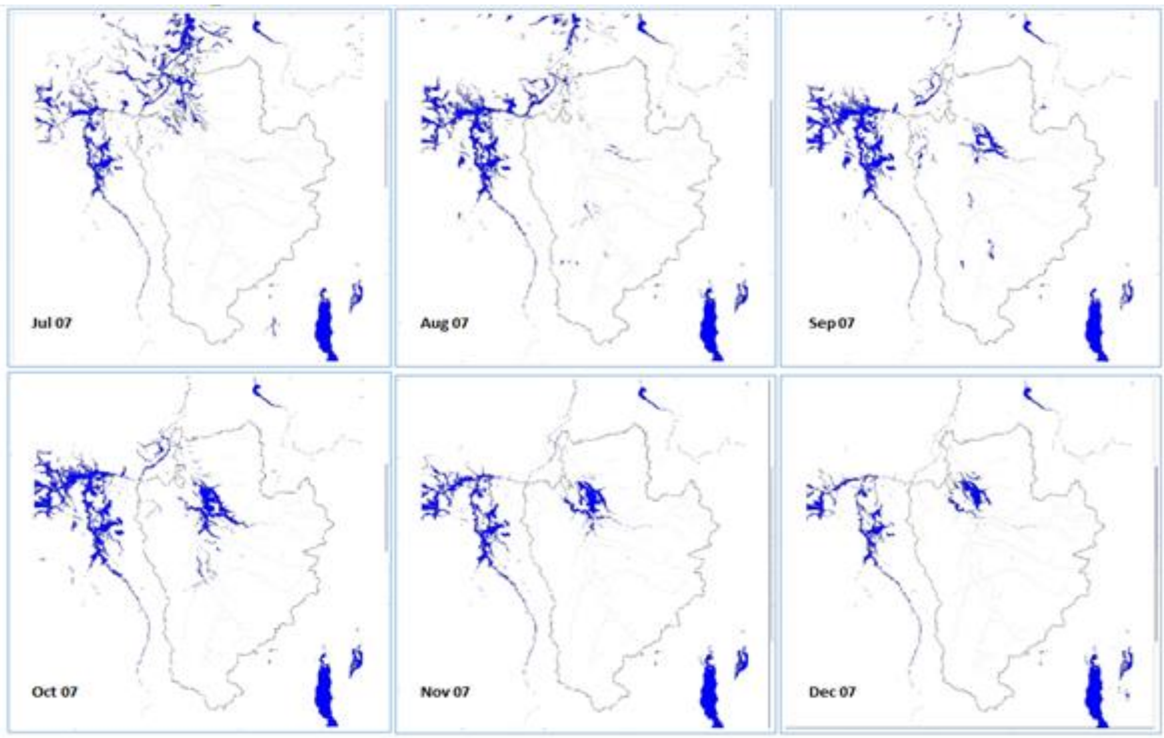


Figure 11-6: Flood progression in the Gambella Plains and Machar Marshes during the 2007 floods

(Miolane et al., 2015)

Flood protection measures along the Gambella Plain should ideally involve a combination of structural measures (e.g. dikes or upstream flood attenuation dams) and non-structural measures aimed at reducing the impacts of flooding in vulnerable areas. It is imperative that flood protection works are constructed to adequately protect future developments within the Gambella Plain such as commercial agriculture schemes, from flooding, and that the cost of these protective measures are included in the economic and financial evaluation of these schemes.

The potential impacts of droughts are many and varied and have environmental, agricultural, health, economic and social consequences. The effect varies according to vulnerability. It affects humanity in a number of ways including loss of life, crop failures and food shortages which may lead to famine in many regions, malnutrition, health issues and mass migration in search of food and water. It also causes damage to infrastructure and the environment and is regarded as a major cause of land degradation, aridity and desertification. Within the Baro-Akobo-Sobat Basin, the main livelihoods systems include pastoralism, farming and ex-pastoralism – those who have dropped out of pastoralism and now survive on petty income-earning activities. Subsistence farmers and pastoralists have attempted to build resilience to meteorological droughts by selecting crops that are more sturdy to survive in stressed climatic conditions or by migrating to areas less affected by droughts. However, this causes social and political tensions.

The spatial variation of rainfall in the Baro-Akobo-Sobat Basin is considerable due to the significant variation in elevation across the basin. High altitudes (above 2000 masl) are characterised by high moisture and longer wet periods than the lower lying areas (less than 500 masl). On the Gambella Plain, only about six years in ten have a dependable rainfall of at least four months, which is required to support good yields of most annual crops (ENTRO, 2014). Inter-annual variability is much higher around Gambella than in the highlands.

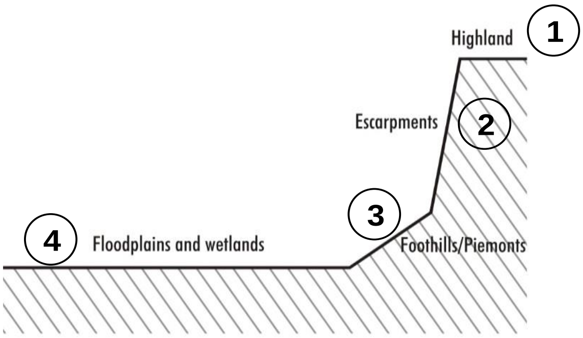
South Sudan and Ethiopia, including the Baro-Akobo-Sobat Basin, have experienced recurring droughts followed by food shortages and famines over the last fifty years. Droughts occurred in 1965, 1969, 1972/3, 1980, 1983/4, 1987, 1990, 1989, 1991, 1997, 2000, 2003, 2006, 2008, 2009 and 2012.

BIOLOGICAL ENVIRONMENT

Flora and Fauna, Land Use and biodiversity features

INTRODUCTION/DELINEATION OF BIOPHYSICAL AREAS

The baseline information concerning environmental features of the BAS is organized by biophysical areas. This should allow a better understanding of the BAS environment functionalities and their interlinkages with water resources and uses than a classical thematic approach.



Biophysical area of the BAS	Surface area (km^2)	% of the BAS
Escapments	57439	22%
Highlands	13956	5%
Piedmont / FootHills	65563	25%
Flood plain and plain	125668	48%
Total basin	262626	100%

Figure 11-7: Proposed biophysical area in the BAS

HIGHLANDS

These mountains areas are characterised by very high rainfall (from 2000 to 2500 mm per year) and moderate evapotranspiration compared to floodplains. They are the sources areas for significant rivers such as the Baro, Alwero, Gilo, Akobo and Kineti and the population density is very high.

The Ethiopian highlands of the BAS are part of the **Ethiopian Upper Montane Forests, Woodlands, Bushlands and Grasslands ecoregion** and South Sudan highlands are part of the **East African Montane Forests ecoregion**.

Currently, the highland areas are still largely covered with forest, even if forests have been severely encroached by agriculture. Elsewhere in the ecoregion (outside the BAS), these forests have almost disappeared. These forest remnant areas in the highlands are playing a crucial role in regulating river flows.

The main threats to the BAS Highlands can be summarised as follows:

- Global threats to the BAS Highlands: The Ethiopian Upper Montane Forests, Woodlands, Bushlands and Grasslands ecoregion as a whole is severely threatened. Very high population density (1,000 hab/km^2 and associated subsistence farming, demand for more land natural products are the predominant reasons for the widespread loss of vegetation.
- Specific threats to highlands forest ecosystems: Highland areas of the basin were formerly covered with high forest. Natural forest has significantly depleted with only a small part intact. .
- Annual average deforestation rate in the basin is expected to be around 1.2 - 1.6 %. The recent estimated rate of loss of highland forests reaches 80,000 - 200,000 ha/year in the Kafa region, a rate that would imply complete disappearance of natural forest within 10 years. Drivers or deforestation Kafa are:
  - “Agriculture expansion: Mainly observed at forest borders, with harvested wood used as an additional income (fire wood, or charcoal) or for own consumption.
  - Resettlement: Widespread illegal/uncontrolled use, conversion of forest land for settlement.
  - Concessions (coffee): Large scale coffee investment (coffee investment area).
  - Property rights: The unsecure defined allocation of property rights and the land tenure system
  - Unsustainable use of forest resource: Legal and illegal forest use is increasing since customary user rights have been replaced by state sanctioned rights.
- Specific threats related to highland wetlands ecosystems: Several studies have revealed that wetlands have been drained for growing food crops for more than a century. Highland wetlands also support other important uses for local communities, but even these traditional uses can, when not properly managed, can contribute to wetlands degradation.

ESCARPMENT

The area supports East African evergreen and semi-evergreen forests, woodlands, and shrublands. Moister sites in southwest forest patches are dominated by tall trees, chiefly *Aningeria* and other Sapotaceae, species of Moraceae, and species of *Olea* (Burgess N. & al, 2004). Transitional forests occur between 500 and 1,500 m in Illubator and Kefa and have rainfall close to 2,000 mm per annum. These transitional forests change to Afromontane forests at approximately 1,500 m altitude in the southwest, where the rainfall is between 700 and 1,500 mm. *Coffea Arabica* is the dominant natural understory shrub and wild coffee is harvested.

The Ethiopian Lower Montane Forests, Woodlands, and Bushlands ecoregion supports a variety of forest types with associated bushland and woodland habitats and consequently have high species richness and endemic species. For example, the Mejang area is characterized by a very rich biodiversity, many rare and endemic species and endemic plants (three are endangered). *Coffea Arabica* grows naturally in the escarpments, contrary to higher areas, where it has been transplanted.

The main threats to the BAS Escarpments can be summarised as follows:

- For the time being, there is no significant pressure and human encroachment in the very steep parts of this area. They are covered with woody grass land and are used for grazing and wildlife habitat. This is why the escarpments host the largest areas of natural forest found in the Ethiopian Lower Montane Forests, Woodlands, and Bushlands ecoregion. However, with the development of access roads and the increasing demand for fuel wood and charcoal, people could start exploitation of fuel wood and charcoal that would deplete woodland and cause degradation.
- In accessible parts of the escarpments, all natural habitats are highly threatened because they have been reduced to small patches and are severely fragmented.
- Specific causes of deforestation in Mejang area are identified expansion of coffee plantation, Settlements and Agricultural expansion,Logging, Fire ,and Local wood consumption.

The BAS escarpments ecosystems have been long poorly protected. As already mentioned, recent biosphere reserves on both highlands and escarpments have been created in the basin:

- Government of Ethiopia has adopted biosphere reserve approach for the first time in 2010 by creating the Yayu Coffee Forest in Oromia and the Kafa in SNNP regional states;
- The neighboring Sheka Forest has also become the third biosphere reserve in 2012 initiated and supported by MELCA Ethiopia (MELCA, 2014).

National Forest Priority Areas theoretically cover the entire forests areas of BAS highlands, escarpments and Foothills but do not provide effective protection and are not known at local level.

FOOTHILLS / PIEDMONTS

Foothills or Piedmonts are situated between 700 and 1,100 m and form a transition area between escarpments, characterized by very steep slopes and flood plains which are extremely flat. The rainy season lasts from April to September. The foothills areas are part of the eastern block of **East Sudanian Savanna ecoregion** in Ethiopia and southern part of the basin and **Northern Accacia Commiphora Bushland an Thicket ecoregion** in the southwestern part of South Sudan. Both ecoregions belong to the Tropical and Subtropical Grasslands, Savannas, shrublands and Woodlands Biome. They are mainly covered by shrubs, dry savannas and Woodlands.

These ecoregions have low rates of faunal endemism, but are importants area for endemic plants. Threatened mammal species include elephants (Loxodonta Africana), wild dog (Lycaon pictus), cheetah (Acinonyc jubatus), and lion (Panthera leo). The roan antelope’s (Hippotradus equinus) can also be found.

Main threats to the BAS Foothill ecosystems include seasonal shifting of cultivation, overgrazing by livestock, cutting of trees and bushes for wood, burning of woody materials for charcoal and and uncontrolled wild fires.

The main threats to the species come from overgrazing, poaching and overhunting for meat. Climate change is an additional threat exacerbating these impacts.

FLOOD PAINS AND WETLANDS

Situated between 370 and 700m, this biophysical area covers more than the half of the BAS. It comprises very flat clay plains that stretch from northwards South Sudan foothills and westwards from Ethiopia foothills to the Sobat river. Vertisols have developed in the waterlogged conditions over these nutrient poor sediments, although fluvisols and patches of luvisols can be found along the river courses. This biophysical area is included in the two following ecoregions:

- The East Sudanian Savanna, which belongs to the Tropical and Subtropical Grasslands, Savannas, Shrublands, and Woodlands biome
- The Sudd Flooded Grasslands, which consists of Flooded Grasslands and Savannas.

The floodplain ecosystem supports a variety of plant species ranging from those adapted to wet environments, under water during several months in a year, to those adapted to more dry environments, occasionally flooding or only by rainfall. Seasonal floodplains, up to 25 km wide, are found on both sides of the main swamps. Wild rice (*Oryza longistaminata*) and *Echinochola pyramidalis* grasslands dominate the seasonally inundated floodplains. Wild rice support a flooded period from 5 to 9 months, whereas *Echinochola pyramidalis* is inundated during less than 3 to 4 months in a year. The seasonally river-flooded grassland forms the 'toich', which yields dry season grazing areas important to the Nuer and Dinka agro-pastoralists. Yield is affected by the duration, timing and intensity of the flood, varying from 1 tonne/ha when non inundated to 7 tonne/ha when inundated.

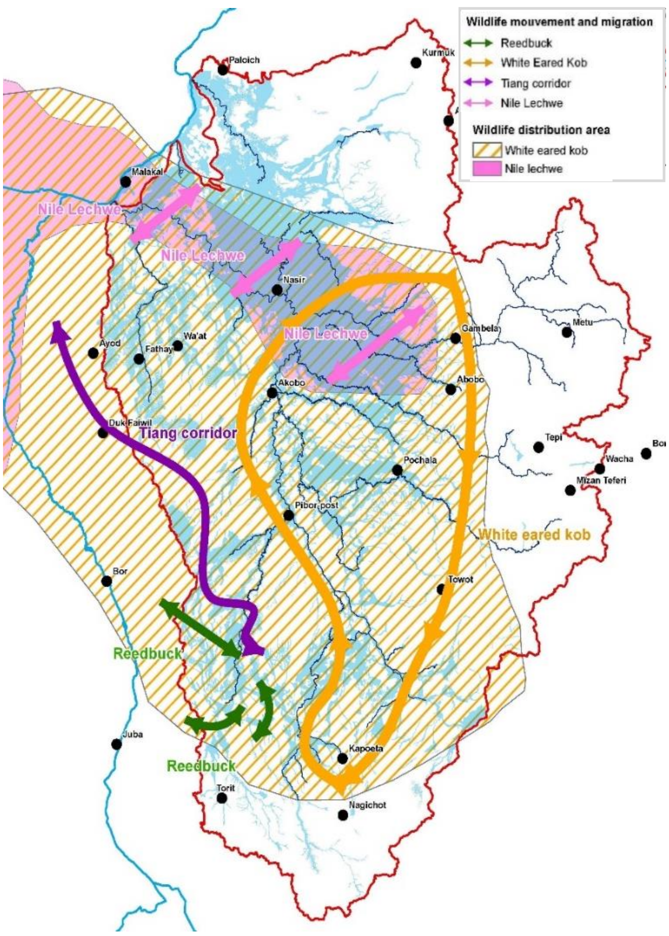


Figure 11-8: Emblematic mammal species habitats and migratory routes of the BAS

White-eared Kob population estimates range between 0.75 up to 1.2 million. Migration routes **are highly correlated with hydrological patterns** and other critical resources. Apart from the White-eared Kob, the migration consists of tiang, Mongalla gazelle and East African eland all followed by lion, jackal and hyena.

The BAS hosts the **Nile lechwe (endangered),** present only in the Sudd swamps, *Machar Marshes* and Gambella region. The lechwe's primary habitat is swamps and marshes subject to seasonal inundation. **Local patterns of flooding have the most influence on the species** as they follow fluctuating margins between floodwaters and drier ground, moving up and down the flood tide lines with the seasons.

The BAS is situated on the major birds migratory routes between Africa and Europe and hosts an very large population and diversity of birds.

The basin waters and wetlands host a high diversity of fishes (from around 90 to more than 100 species depending on sources).

Main threats to the BAS Floodplains and wetlands ecosystems include:

- Specific threats concerning wildlife: The main threats to the mammal migrating species come from overgrazing, poaching and overhunting for meat.
- The recent and planned development of huge mechanized farms in Gambela can be a major threat to wildlife migration and habitat.
- Oil exploitation and exploration is limited to the South Sudan part of the basin, in Upper Nile State where there are 3 oil fields in activity: Water quality issues have an impact on local communities which usually rely on surface water for drinkable water and to provide water for the livestock.
- Poor sanitation and waste management leads to lead to local water quality problems.
- Siltation of the rivers;.
- Invasive species in waterbodies; Water hyacinth was observed during the site visit in Baro River below the Baro bridge at Gambella town. It is also mentioned during the discussion with South Sudan Transport office as a barrier for boat movement in Sobat River.

Ecosystem Services provided by the BAS Ecosystems

Introduction

The BAS natural resources are the main source of livelihood of the major part of the BAS population. In each biophysical areas of the basin, communities rely heavily on natural resources for food resources, construction material, fuel, coffee and timber production.

Domestic water use and food resources

- Wetlands are vital for domestic water use once rivers start to dry up.
- An large part of highland wetlands have been drained and are used for cultivation.
- In some parts of the lowlands of the basin, recession agriculture occur.
- In western Ethiopia, the production from wetlands has been estimated to contribute up to 50 – 60% of the household’s food security. Harvesting can be after the end of the dry season
- Floodplains and wetlands are key resources for livestock in the dry season since they provide high quality grass and water for cattle grazing and watering. The main valuable plants for grazing are flooded grasslands such as:
  - Oryza providing high quality grazing for much of the year and which has a much higher yield (7x) where flooded for long periods and can also be used as a crop at the end of the dry season when other sources of food become rare.
  - Echinochloa pyramidalis which also grows even during the dry season providing year-round pasture

  According to (Hailu A, 2006), it “would be no exaggeration to claim that the survival of the country’s livestock is directly linked to the abundance of wetlands”.
- Waterbodies and other wetlands provide important fish resources. Fish is the main source of protein for Agnuak communities, who live along the banks of the Baro and Gillo Rivers.
- In the southern part of the basin, wildlife also provide sources of proteins and a source of income.
- Afromontane natural forests also provide a variety of food products such as honey, spices, palm, wildfruits. In the Akobo catchment around Bench-Maji and Sheka zones, edible roots like Taro and Enset are common and support livelihood of people. These edible roots are drought resistance and also help to soil conservation. Wild honey produced in the forest by the Sheka lakes a major contribution to livelihoods and the associated customary forest management (Kobbo) is effective.
- Sale of wild coffee, growing under Afromontane highland and lowland Ethiopian forests
- Medicinal plants are also found especially in highland wetlands.

Construction materials

- Sedges (carex) found in the BAS wetlands are widely used for thatching. In Illubabor Zone it is estimated that an estimated 85% of the local households use sedges or *cheffe* for roofing.
- Bamboo forest are also used for construction in western and southern part of the basin.
- Brick making is also reported in Oromia wetlands (EWNRA, 2008) and in South Sudan.

Energy

- Charcoal is considered as the main source of fuel used in the BAS urban centres and play an important role in forest and bushland degradation.

Timber

- Afromontane highlands and lowlands forests offer large old high quality wood from *Daniellia oliveri* and *Khaya senegalensis* trees for instance. Asseffa (2007) has estimated that households from Sheka forests generate about 44% of their income from forest and forest products.

Headwater catchment forests and Hydrological Services

Headwater catchments, wetlands and forests play an important role in flood regulation, micro-climate regulation and erosion control. Given potential water resources developments downstream, the natural regulation and reduced sediment load provided by these services can play a major role in reducing the costs of infrastructure.

- It is reported that before deforestation and wetland drainage intensified in Highland Illubabor there was no history of flooding in the neighboring Gambella Township. Now it is a major threat.
- Local experts in Majang zone revealed that some streams which were permanent some years back have now become seasonal as a result of deforestation and land use change.
- At the basin-scale, highlands and escarpment forests also play a critical role in carbon sequestration. The following figure illustrates impacts of deforestation on carbon sequestration and emission:

Rich biodiversity of flora and fauna

The BAS ecosystems support habitats hosting a rich flora and fauna, characterised by a high rate of endemism in the mountain and large endangered and threatened herds of mammals in the plains.

Flood patterns influence wildlife habitats and play a critical role in their migration

- Flood patterns have a major influence on the Nile lechwe.
- Birds habitats are also directly linked to flood recession areas.
- The entire socio-economic organization and livelihood of the plains depend on floodplains and wetlands seasonal variations.

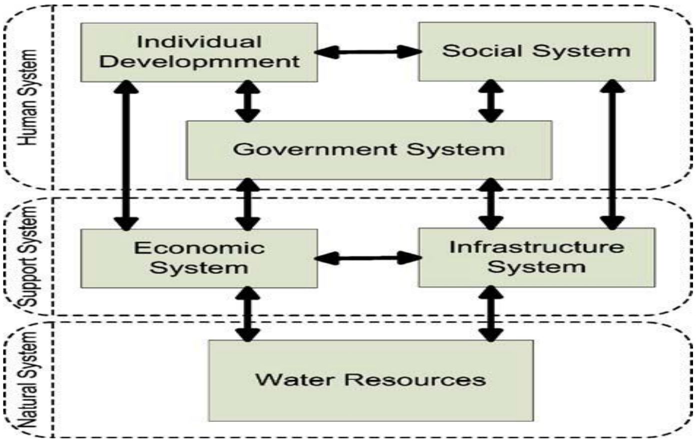
Biodiversity, pristine landscapes and tourism

- The variety of ecosystems of the BAS, its relatively pristine, the importance of the mammal and bird migration offer a huge potential for natural-resources based tourism.
- Wildlife experts consider that the mammal migration of the BAS is equal to that of the Massai Mara – Serengeti. Between 300,000 and 400,000 tourists visit this transboundary park annually.

SOCIO-ECONOMIC ENVIRONMENT

Introduction

The socio-economic environments presents the main demographic and socio-economic features of the BAS basin, including population dynamics, Education and Health , Gender Relations, Ethnic Groups and Relations, Conflicts, Humanitarian Assistance, Livelihoods, Poverty and markets. In view of the focus of water in this project it is useful to conceptualize the complex interrelationships between water resources and the social and economic domains of human life.



The focus here is on the social system.
The social system is a domain where government, economics and individual development systems merge, interact and are ”rationalized” and harmonized to form the foundations of a nation, society or social group. The social system is characterized by Reproduction, identity, kinship roles, socialization of individuals, moral values

Demographic and Social Drivers of Change

The main socio-economic drivers of change in the basin include the following:

- Population dynamics (Population density and growth rates, Migration, displacement and resettlement
- Government policies/actions (Ethnic relations, Allocation of land and other resources)
- Conflicts (Interethnic, Political)
- Food security
- Market forces (Linkages, Disruption)

Population dynamics

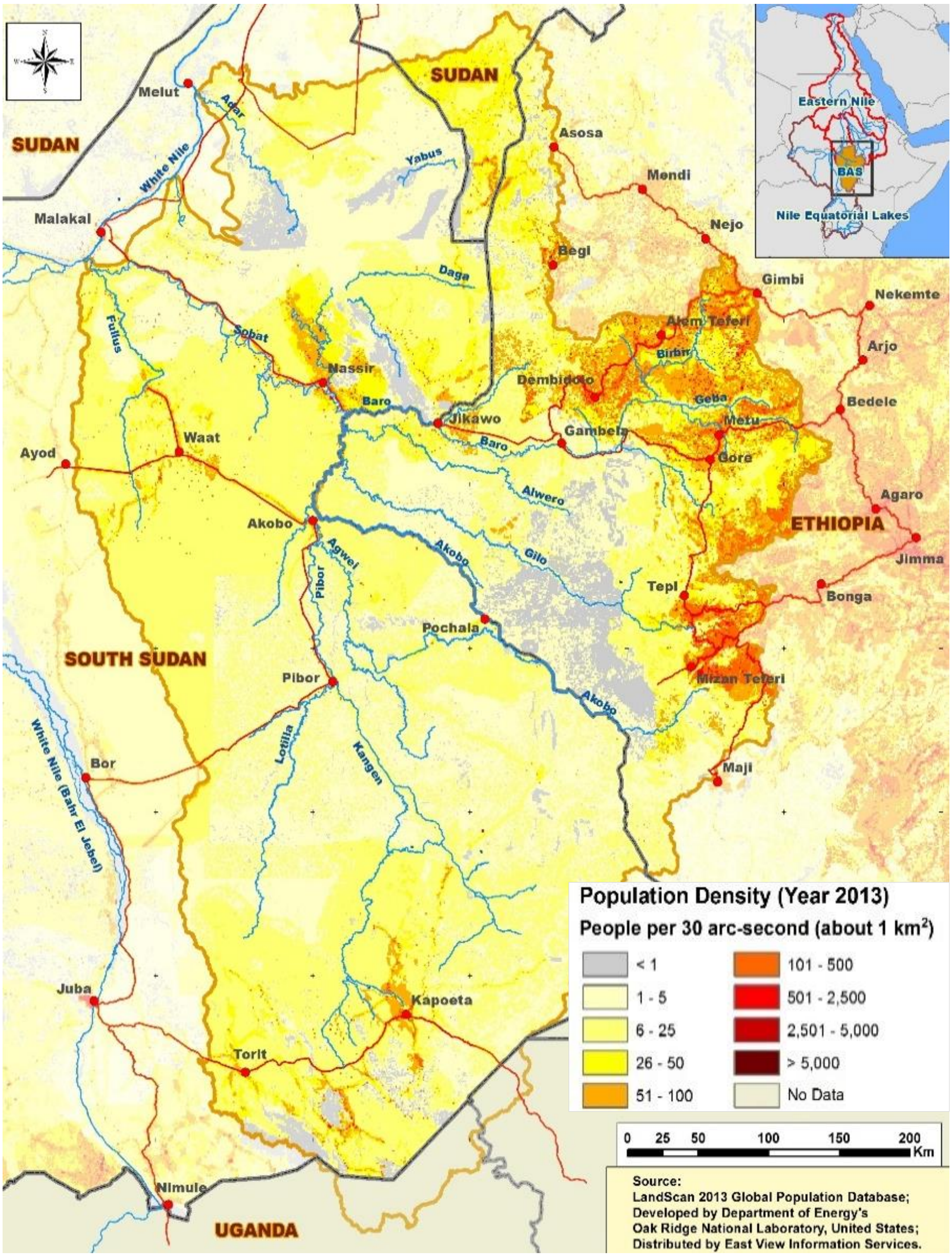
- The population is in the western part of the basin in Jonglei and Upper Nile state in South Sudan and parts of Benishangul-Gumuz and Assosa regions in is highly dynamic, being affected by layered conflicts and resulting displacement.

The population is estimated to at 8,592,103, 2,911,805 in South Sudan, 5,680,298 in Ethiopia. The is overwhelmingly young, nearly half is under 15 years old. Fertility and birth rates are also high, averaging 5 births per woman and a birth rate of over 40 per 1,000 population.

The population is unevenly distributed across the basin, and its density within the basin shows considerable variation.

- Population mobility includes migration, resettlement, internal displacement and refugees and can be voluntary, or involuntary. The most common movements are migration from the eastern highlands to the lowlands in Gambella Region and internal displacement due to ethnic and political conflicts. Over 250,000 people in the basin have been affected by internal displacement since the outbreak of political conflicts in South Sudan in December 2013. The areas most affected by displacement due to political and ethnic conflicts are Jonglei and Upper Nile States in South Sudan and Gambella and parts of Benishangul-Gumuz regions in Ethiopia.

Figure 11-9: Population density in the Baro-Akobo-Sobat Basin



Gender Relations and Gender Inclusion

In most parts of the basin the female population is legally disenfranchised, socially limited and excluded from important economic activities and resources such as property as well as effective political representation. Conditions vary but there are some common issues.

- Equality in access to education: Women are only half as likely (19%) to be as literate as men. The gap is narrowing but significant in secondary, vocational and higher education.
- Access to employment is limited in the formal public and private sectors by a combination of restrictive social norms and lack of formal educational qualifications and skills.
- Access to wealth, measured in ownership of land, shelter, cattle or cash, is severely curtailed for women in the basin. Women have very few resources that confer social status and political power.
- Inheritance rights are limited for women. This has disinherited widows and divorcees, especially those from polygamous relationships, as well as their children.

Opening up economic opportunities for women, especially the most marginalized, is critical for the rights and aspirations of future generations of Southern Sudan as well as the future of economic growth.

Health

The health status of a human population is important in determining the development potential of an area or group and their ability to respond to opportunities. The general picture of the health status of the basin's population is poor. The conditions are not amenable to rapid change or quick results and will require a concerted effort and considerable resources to improve. Particularly alarming are the high maternal mortality rates, especially in South Sudan, the high birth rates in both countries, and low life expectancy, especially in South Sudan, and access to improved sanitation facilities in both countries. A rare positive item is the relatively high health expenditure in Ethiopia as a percentage of the country's GDP.

Ethnic groups

Introduction

The basin is home to over 150 ethnic groups and sub-groups who exhibit a wide range of cultures, values, norms and practices. They encompass nomadic pastoralists, agro-pastoralists, hunters and gatherers, sedentary farmers, gardeners, fishermen, traders, warriors, raiders and soldiers. Languages spoken by these groups are in most cases not mutually understandable, and bridge languages such as Arabic and English are necessary to communicate and conduct business across ethnic boundaries.

Traditional practices and a string dependence on natural resources for livelihoods for the vast majority of the population highlights the importance of ecosystem services. Details are provided in the main report for each of the ethnic groups in the basin.

Implications of Ethnic Diversity for the Future development of the basin

The high degree of ethnic diversity found in the basin is an issue in itself and has a number of important implications for development objectives and potentials in the basin, among which are:

- Ethnic diversity coupled with population growth, depletion of natural resources and unequal political power and patronage creates the conditions for increasing tensions and conflicts in the basin.
- In Ethiopia, some areas in the basin such as Gambella and Behishangul Gumuz have recently been prioritized for development by the government, resulting in the influx of outsiders as investors and settlers which has increased tensions and conflicts with the existing ethnic groups in the area. In Oromia, the largest population in the basin, some of the federal government's development policies have been effectively opposed by local ethnically-based organizations.

- In South Sudan, political power and patronage is closely correlated with ethnicity, with dominant ethnic groups controlling the allocation of state resources and means of violence. As long as this situation persists, there will be little chance of achieving the broad-based stability and security necessary for sustainable development in the basin.
- As long as ethnicity remains the primary, and in some cases, the sole identity for the largest number of people the basin, national governments will not be able to forge a common identity, sense of purpose and support for development priorities and programs, which are often seen as zero-sum games with few winners and many losers.
- Any relevant, effective and sustainable development effort should not be imposed from outside and should be planned in close consultation with local ethnic groups, respect their identities and livelihoods and obtain the consent of their representatives.

Conflicts

Conflicts in the basin occur as interrelated and mutually reinforcing layers consisting of three main types of conflicts.

- Resource-based conflicts in South Sudan are not only over oil resources, but also about the management, allocation and control over land and water resources.
- Resource allocation conflicts between national and state/regional governments and indigenous people over land allocation policies and practices..
- Historical pastoralist conflicts: cattle raids, communal clashes, revenge attacks and selective violence in the Jonglei and Upper Nile areas in South Sudan) and in the Akobo area bordering Gambella in Ethiopia. The frequency and intensity of these conflicts has increased.
- Political conflicts in the basin take two forms. In the area of the basin in South Sudan, there are political rivalries accompanied by armed conflicts, occurring in Jonglei and Upper Nile states. In the area of the basin in Ethiopia, the fault lines are between the national Government and Oromo people in Oromia region and the Anurak people in Gambella.

The breakdown of customary means of conflict resolution means that governance structures on managing and allocating land and water resources need to be strengthened and applied equitably if a fair distribution of resources and benefits is to be achieved. Legal and institutional frameworks to address issues such as land tenure, water rights and conflict resolution need to be developed and implemented.

Humanitarian Assistance

Various forms of humanitarian assistance are a major feature of the basin and have been so for many years, dating back to the decades-long conflict between South Sudan and Sudan. This assistance is provided by such agencies and UNHCR, WFP, FAO, OCHA, UNICEF and many others. This assistance is wide-ranging, consisting of food aid, shelter in reception centres along the borders of South Sudan and in refugee camps in Gambella and Benishangul-Gumuz regions in Ethiopia, medical care, mother and child health and nutrition programs, water supply and sanitation, basic supplies and perhaps most importantly, protection and security.

At the end of February 2016, there were 268,352 registered refugees in South Sudan, of which 131, 871 were in Upper Nile State. In the beginning of February 2016 there were 270,942 refugees from South Sudan in Gambella, of whom 237,946 were in six camps and 33,026 were living with host communities (UNHCR, 2016). Some 180,000 of these refugees were under 18 years old.

Livelihoods

Introduction

Security, resilience and adaptability of livelihoods are important aspects of vulnerability. There is a highly diverse and complex mix of livelihood systems in the basin. These have been mapped. as can be seen in Figure X.

The large number and variation in livelihood characteristics are defining features of the basin, and present a complex and demanding challenge to development planners. Standard, top-down approaches to development planning are very likely to create more losers than winners. Therefore, a culturally sensitive and consultative approach is a necessary condition for a relevant, efficient and sustainable plan for managing water resources the basin.

Characteristics of the major livelihood zones in the basin are described in greater detail in Annex 3.

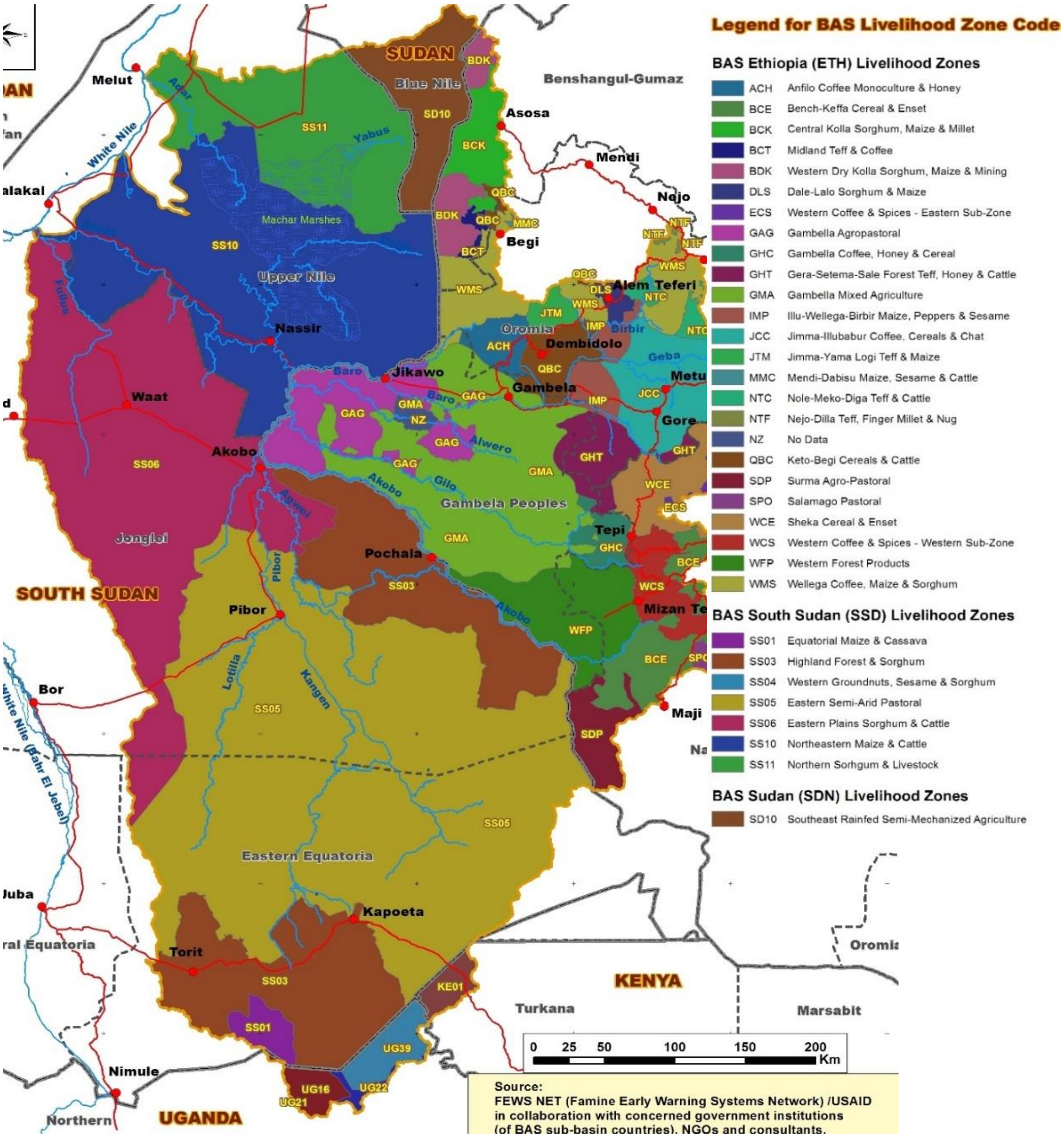


Figure 11-10: Main Agricultural and Livelihood Systems in the Basin

Poverty

Poverty in the basin is both pervasive and deep, but is also differentially distributed across the basin. Any future development and investment plan for the basin will have addressing and alleviating poverty as a central objective

The differential distribution of poverty in the basin states in South Sudan and basin regions in Ethiopia are shown in Table 11-3. It can be seen from that poverty is unevenly distributed in the basin states and regions, with the basin regions in Ethiopia having generally lower poverty headcounts than those in South Sudan and that the basin regions have a somewhat higher headcount than the national average. Gambella Region has a somewhat higher poverty headcount than the other basin regions. In South Sudan, Eastern Equatoria has a large arid pastoral area, which may account for its high poverty levels. Upper Nile State has oil resources, perhaps explaining its relatively low poverty level.

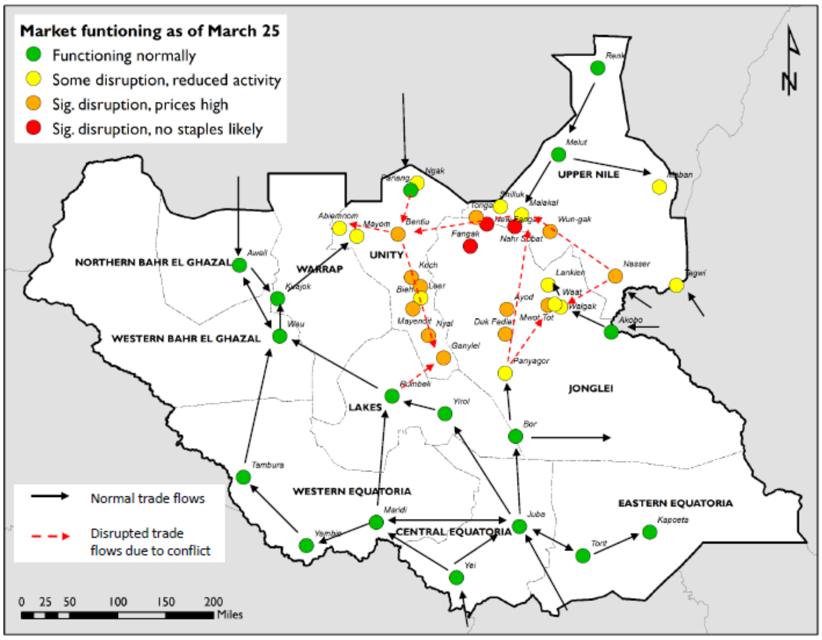
Table 11-3: Poverty Headcount Ratios in the BAS

South Sudan[1]		Ethiopia[2]	
xLocation	**Headcount (%)**	**Location**	**Headcount (%)**
Upper Nile	26.0	Oromia	28.7
Jonglei	48.0	Gambella	32.0
Eastern Equatoria	50.0	SNNP	29.6
South Sudan	**50.6**	B. Gumuz	28.9
		Ethiopia	**25.7**

.

.The above information suggests that the root causes of poverty in Jonglei and Eastern Equatoria states need to be further understood and addressed in future development programs and projects in the basin.

Agricultural Markets



Markets for agricultural produce in the basin are stratified into local, regional and international markets. The linkages between these levels and access are important to stimulate production, to connect urban demand with rural source of supply and to generate more cash income to farmers.

Market status and disruptions in the South Sudan part of the basin (Jonglei, Upper Nile and Eastern Equatoria states) are shown in

Figure 11-11: Market functioning in South Sudan, March 2015

Institutional Arrangements

Institutional and organizational arrangements, based on relevant legal grounds as well as policy and strategy documents, are a key issue when it comes to practical considerations of implementation of such an ambitious and complex IWRDM plan for the Baro Akobo Sobat river basin. The most prominent questions to be addressed are:

- How to address the multipurpose (i.e. inter-sectoral) nature of the Plan?
- How to properly and efficiently cooperate when activities with transboundary effects are planned?
- How to address the short, medium and long terms for a Plan which will certainly be developed over several decades?
- Can we imagine an arrangement which is at the same time robust and flexible and which could also be adapted in the medium and long term if necessary?

The main report provides an assessment of the current institutional background and framework at national and international scale, and then identifies key issues as well as preliminary ideas for the future. These ideas are aimed at being discussed with stakeholders and further developed in the Plan itself. In this summary only the strengths, weakness, opportunities and threats are discussed:

- Strengths

  The major strength lies obviously in the existence of NBI/ENSAP/ENTRO. This is at the same time a legal framework and a source of various services. The existence of ENTRO as a major strength. It is endowed with full legal status and is able to conduct directly or to steer numerous and various activities.

  Another strength is that the BAS river basin is almost pristine. This keeps the door wide open for formulating development strategies and organizational arrangements to support such strategies.

  The BAS river basin is also endowed with multiple natural resources, not only water but also land, the natural environment, fishes etc. This brings the idea in mind that a real IWRM process can be imagined and set up with a true integrated approach. There is the potential to address the nexus food-energy-environment, with significant benefits shared by the two countries and various categories of stakeholders.

- Weaknesses

  Purely from an institutional point of view, it is to be stressed that the Cooperative Framework Agreement has not been put into force.

  Due, among others, to the insecure situation of South Sudan in the most recent years, there is little preparedness for large developments based on water in general. Despite several master plans have been issued recently at national scale (agriculture, irrigation…), it is doubtful that grass root level consultation of stakeholders was possible..

  One major weakness is relating to data, for water resources and many other items. A lot of data are old or totally missing and the literature references often cross quote each other. This is first a technical issue, but not only. This is also an organizational issue when considering that developing a much more extensive and reliable monitoring network should be put at the first rank of priorities (hydro-meteorology especially).

- Opportunities

  Mutual confidence of the two countries and comparable arrangements for water management and development

  Shared idea of keeping flexible with ad hoc arrangement depending on the nature of activities/investments

- Threats

  In such an ambitious endeavour, threats are potentially numerous and of high impact. Some of them deserve to be identified.

  Case by case approach and implementation remaining in charge of each country separately: several stakeholders expressed this idea during consultations. If this idea may prove efficient for some "simple" activities (for instance, developing drinking water supply on basis of boreholes), as soon as the transboundary nature of the BAS is concerned, this will be much more complex or even hazardous (example of a series of big dams). A series of activities are to be carefully planned and conducted at river basin scale, such as:
  - Feasibility studies, ESIA
  - Detailed design, in depth mitigation measures, regime of storage/release, environmental flows, cost benefit analysis and optimal/equitable sharing of effects
  - Decision to do the considered development
  - Financial resources mobilization
  - Construction
  - Operation and maintenance
  - Another important threat is related to possible lack of attention to the long term..

    The present study is addressing strictly the BAS; the original idea and intention was to incorporate the White Nile up to Khartoum, as previously done in preliminary studies. For financial resources obstacles, this was not made possible. The question remains of the relationship and fair discussions with the downstream countries along the Nile. The suggestion is that this could be organized at early stage when the first drafts of the Plan are available

DEVELOPMENT OF WATER RESOURCES: CURRENT SITUATION

Rainfed Agriculture

South Sudan

Over 95% of the territory of South Sudan is arable and 50% of it is prime agricultural land suitable for various crops" but that only 3.8% is utilised. Almost all crop-farming is rainfed, with the main crops cultivated being sorghum, maize (in the north), cassava, groundnuts, sesame, pearl and finger millets, beans, peas, sweet potato and rice. Sorghum is the staple food and is widely grown countrywide. About 78% of households are engaged in agriculture and the average area harvested per household is about 1.12ha. The majority are subsistence farmers using traditional methods, seed of variable quality and generally low-yielding.

Crop-farmers in South Sudan are categorised into three main types (CAMP, 2015):

- Subsistence farmers. These represent the large majority of crop farmers. Average yields (1t/ha) are low and the areas harvested (2feddans) per household too small. Other challenges include lack of financial resources, scarcity of labour, outdated and inefficient farming methods and large post-harvest losses.
- Medium scale commercial farmers (progressive farmers). The CAMP presents a positive picture of this sub-sector and indicates that there is already relatively rapid expansion and a potential for further rapid expansion.
- Large-scale commercial farmers. In Renk County, Upper Nile State in the Eastern Flood Plains Zone and outside of the BAS basin.

Ethiopia

While it was reported that many famers have indicated that they need access to at least some supplementary irrigation, there has been a major increase in productivity in recent years. This is largely due to progress with the generalisation of improved farming practices and access to credit.

The highland areas of the basin are extensively and intensively cultivated. Due largely to population pressures and improved access roads, cultivation in the highlands is still expanding, in places (close to roads etc) very rapidly. This is leading to the cultivation of increasingly marginal lands and the clearing of woodland.It should be noted that there are large plantations of coffee and tea in the basin highly profitable.

Irrigated Agriculture

Existing infrastructure and irrigation in the basin

There is one dam/reservoir on the Alwero River, in Ethiopia. The reservoir was initiated in 1987 for agriculture purposes, but the proposed irrigation scheme never completed. The construction of 21 km long main canal and associated field irrigation faculties for a command area of 10,000 ha is currently ongoing. The Baro-Akobo Master Plan Study in Ethiopia (MoWR, 1997), had also identified 5 dams/reservoirs for irrigated agriculture development purpose out of which one was multi-purpose.

Twenty river diversion head-works for small scale irrigation schemes are available in the upper most part of the basin in Gambella region and West Wollega, Qelem Wollega and Illubabor zones of Oromia region. Small scale pumps irrigation schemes (10hp -20hp) that use surface water from rivers for irrigation purposes are also found in the areas.

According to the South Sudan Comprehensive Agricultural Master Plan, key infrastructure for crop production and marketing such as main roads, feeder roads, irrigation facilities, storage, drying yards and market facilities are not well developed in either the public or private sectors in the entire South Sudan.

- Large Scale Irrigated Schemes

  There is no existing operational large scale irrigated agriculture in the basin apart from the ongoing development of Alwero irrigation project.

- Small Scale Irrigation Schemes

  Within Ethiopia, both traditional irrigated farming is practised and communal owned modern small scale irrigation is also practised in the basin, The development of traditional irrigation has been practised in different parts of the upper part of the basin in the highlands of Oromia for a century. Wetland edge cultivation with residual moisture locally called 'Bone' is widely practised in the Oromia region part of the basin.

Table 11-4: Summary of Irrigated Area under Small Scale and Production (2014/15)

Region	Area (Ha)	ton	HH	% Area	% Production
GMB	3,052.00	23,710.00	3,470	4.71	2.83
SNNP	8,016.17	161,729.69	43,702	12.38	19.29
Oromia	53,705.98	653,158.21	132,823	82.91	77.89
Total	**64,774.15**	**838,597.90**	**179,995**	100.00	100.00

Source: Computed from field survey, March, 2016

The total crop production from the irrigated area was 838,597.90 tonnes. .

Four categories of small Scale Irrigation (SSI) schemes are recognized in the basin based on water sources and abstraction system. These include (1) traditional (2) Modern (3) pump and (4) Hand dug well. Wetland Farming in the Bench Maji zone around Mizan Teferi, and in Sheka zone around Tepi is also practised.

Operation and maintenance of the Small Scale Irrigation Schemes is as follows:

- Traditional schemes: The responsibility for operating and maintaining the schemes lies on the beneficiary farmers. Traditionally, the beneficiaries organize themselves into associations led by elected leaders, the "Aba-Laga", who coordinate irrigation turns and annual maintenance works:
- Modern Schemes: Operation and maintenance of small scale irrigation scheme is the responsibility of the beneficiaries through their Water User Association (WUAs) and technically supported by district agricultural offices' subject matter specialists. T

Hydropower and Interconnection

Ethiopia occupies a key position within the EAPP. The country is one of the main sources of power generation either existing or planned to be developed in the next 20 years and located strategically to provide interconnection between the Southern part of the region (Kenya) and the Northern part (Sudan, Egypt). With respect to the study basin, BAS, a major effort has taken place to connect the main load centres of the country to the integrated network.

With reference to the BAS sub-basin the extension of the 230 kV network to the south west has been completed along the route Gilgel Gibe-Jimma-Agaro-Bedele-Metu-Gambela and is currently being commissioned. This represents the major infrastructure in the sub-basin.

Once the 230 kV line to Gambela is fully functional, it will represent the major energy source of the basin. Connected to this line is the existing small scale Sor HPP (5MW).

With the exception of urban centres, most of the basin is not connected to the grid. The BAS sub-basin is one of the least developed areas of the country hence the rural population has access to traditional sources of energy, mainly biomass fuel.

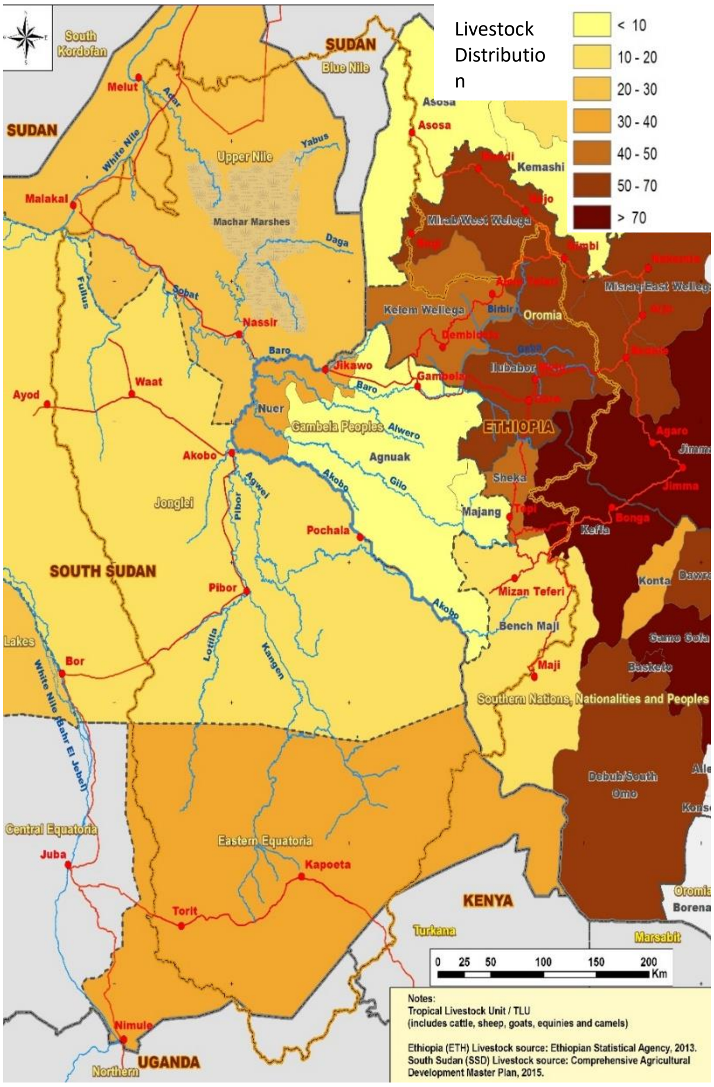
The South Sudan portion of the sub-basin is also in the same condition, without access to an integrated power network. Only one per cent of the South Sudan population has access to power, though intermittently during a 24-hour period. Only seven per cent of the urban areas in South Sudan are electrified and virtually no rural areas have electricity.

The level of rural electrification in the BAS sub-basin is currently nil, although with the new interconnector to Gambela, the situation may change at least in the medium term in Ethiopia. The Rural Electrification Fund (REF) with its loan programmes for diesel-based and renewable energy based projects is the main implementing institution. With an initial budget of €29 million, REF has been supporting 180-200 rural micro-hydropower and photovoltaic (PV) mini-grids for educational and health care facilities.

No information could be identified that provides the MW capacity of the line to Gambela. However the most recent transmission planning study specifies that the Metu-Gambela leg of the 230 kV line consists of a single circuit on double circuit carrying poles, indicating that a second line can be installed as the need arises. This single line size can typically carry around 200 MW. It should also be noted that this line will eventually be extended to Malakal in South Sudan where part of the power carried by the line will be exported.

Livestock Farming

Overview



Three production systems are observed in the Baro-Akobo-Sobat (BAS) basin namely pastoral, agro-pastoral and mixed farming systems. In all of these production systems, livestock play multitude of economic and socio-cultural functions. They are the means for store wealth and providers of food and income. Milk is the most important nutritious diet derived from livestock in both production systems.

The distribution of livestock around the basin is shown in Figure 11-12

Although some level of variability exists amongst different livelihood and ethnic groups, the application of improved livestock husbandry practices is very much limited throughout the basin. Change is vital for improving the socio-economic benefit of livestock to their owners, and the conservation of water and the sustainable management of livestock and the grazing resources

Figure 11-12:Distribution of livestock around the BAS

Irrespective of the parts of the basin, feed shortage constrains livestock production in all parts.

In the agro-pastoral areas of the lower basin, seasonal flooding and the absence of tradition to conserve excess fodder in the form hay is the major cause for the imbalance of the feed supply. For the pastoral systems, overgrazing around watering points and inaccessibility of rangelands distant from watering-points are the major problems.

Absence of watering facilities such as troughs that help to physically separate livestock of different species and age groups along the perennial rivers and other natural water sources does also compromise domestic animals' state of health as it encourages disease transmission.

The trading of livestock products specifically those of milk and butter literally is highly under developed in the BAS basin. Trade of live animals takes place throughout the basin, although the level of its development varies amongst the socio-economic groups and production systems. The major challenge for livestock marketing is price fluctuation. Livestock prices fluctuation from year to year and within the year, and this was identified as the major problem.

Stock watering

The problem of seasonal water shortage is specifically critical for pastoral communities of residing within the basin. Here, pastoralists are forced daily to trek their animals longer distances to watering points under high temperature and often insecure conditions. Water supply sources for these households and their animals are mainly perennial rivers. As these water sources are often polluted and lack mechanism to refine them, the communities are predisposed to water-borne diseases such as diarrhoea, bilharzia, and amoebic dysentery. No less serious is the livestock water supply in the agro-pastoral and mixed farming areas. Here, too, the problem of livestock water scarcity escalates during the dry season. Estimated livestock water requirements have been estimated and are included in the main report.

Fisheries and Aquaculture

The main fish markets are the major towns in Gambella closer to water bodies (Gambella Town, Itang, Abobo and Pugnido). In these towns it appears that there is great demand for fish, far in excess of availability. Fish processing (value addition) is rarely practised and in most cases, the fishers sell whole fish which brings low price at landing sites as well as secondary markets. Transport issues are a major constraint to the development of fisheries.

Fish appear to be one of the major protein sources for the people who live in nearby major water body of the region. The existing food culture for these people depend on predominantly on fish and they strongly desire fish for daily consumption.

It appears that currently there is no aquaculture practised in the region, despite favourable conditions for development of the sector (abundant water and land, low altitude and high temperature, appropriate and proven indigenous fish species for aquaculture, inexpensive labour and compacted clay soil that can retain water for long). Aquaculture will produce more fish year round and also reduce the pressure that could otherwise be exerted on the natural system.

Ecotourism

Currently, tourism and ecotourism are largely underdeveloped in the BAS despite the huge potential offered by its rich natural resources, especially by water resources. Since 2001, International visitor arrivals in Ethiopia have shown a strong upward trend. Ethiopia has become a quite important tourism destination in Africa, not far behind Kenya in terms of tourism and travel’s direct and total contribution to GDP. However, the Ethiopian part of the basin does not benefit yet from tourism growth, mainly because of a lack effort to develop infrastructure at all levels that facilitate tourism and lack of coordinated management.

In South Sudan, tourism has emerged recently but is currently insignificant for security reasons.

Water Supply and Sanitation

South Sudan

The Water, Sanitation & Hygiene (WASH) Sector Strategic Framework of the Ministry of Water Resources and Sanitation dated August 2011 prioritised the strategic approach for each of the main WASH subsectors and indicated the current status at that time which is similar to the current status on account of the war:

- Water Resources Management: These requirements were not being taken into account.
- Sanitation and Hygiene: Access to sanitation was 14.6% one of the lowest worldwide.
- Rural Water Supply: The average consumption was 6 l/capita/day, only 20% of the population contributed to operation and maintenance costs and between 20% and 50% of water points were not operational.
- Urban Water Supply: Technology only exists in some parts of Juba and a few regional capitals.

Limited data available indicates that the majority of potable water is supplied from boreholes but that a large proportion are not functional due to maintenance issues.

Ethiopia

The general objective of GTP II water supply sector is to provide access to safe, sustainable, efficient and reliable water supply service to all Ethiopian Citizens by the Year 2020 using appropriate technologies at affordable cost and improve waste water management capacity of major cities and towns that contribute to the country's vision of reaching at the level of middle income countries. By the Year 2020, GTPII plans to:

- Meet the universal target of providing access to safe and sustainable water supply for all citizens of the country in the planning period as per the minimum water supply access standard level set for GTP-1, i.e. for rural water supply 15 liter per capita/day within a distance up to 1.5 km and for urban water supply 20 l/c/day within a distance up to 0.5 km particularly for Somali and Afar regions that would have un-served rural population by the end of the 2015.
- Provide 85% rural water supply access coverage with upgraded minimum service level of 25 l/c/day within a distance of 1 km from the water delivery point, out of this coverage 80% are beneficiaries of tap water service
- Provide 75% urban water supply access coverage with upgraded minimum urban utilities service levels of 100 l/c/day, 80 l/c/day, 60 l/c/day, 40 l/c/day and 30 l/c/day for category 1, 2, 3, 4, and 5 towns/cities respectively,

One WaSH National Program (OWNP): This is the Government of Ethiopia's (GoE) instrument for achieving the goals set out for Water Supply, Sanitation and Hygiene (WaSH) in the Growth and Transformation Plan (GTP). The Program's Development objective is to improve the health and well-being of communities in rural and urban areas in an equitable and sustainable manner by increasing access to water supply and sanitation and adoption of good hygiene practices. The intermediate objectives of the program are directed towards attaining:

- GTP targets of 98% and 100% access to safe water supply for rural and urban areas respectively
- Access to basic sanitation to all Ethiopians having:
    1. 77% of the population practicing hand washing at critical times, safe water handling and water treatment at home, and
    2. 80% of communities in the country achieving open defecation free (ODF) status.

The program was designed to be implemented in two Phases: Phase I from July 2013 to June 2015 and Phase II from July 2015 to June 2020.

Navigation

The river corridors in the BAS basin are used during the rainy season for transporting goods and passengers into South Sudan from Ethiopia through the Baro and Sobat Rivers via Nassir to Malakal and along the White Nile to join Khartoum in Sudan. On the other hand, there are navigational waterways stretching from Khartoum in Sudan up to Juba in South Sudan. The river is serviceable throughout the year and a key element of the transport network.

Table 11-5: Summary Chart for the navigable rivers along the White Nile and the Baro River

Country	River corridors	Main Port	Periods of navigability	Storage Total Capacity (tonnes)	Available Open Area (m²)	Status / remarks
Ethiopia	Baro River	Gambella	From July to October	Information required	Informatio n required	
		Itang	From July to November			
		Matar	From July to December			
		Burbe	All year long			
South Sudan	Baḥr al-Jabal (White Nile)	Malakal	All year long	400	-	Need complete rehabilitation for good functionality
		Juba	All year long	200	1500	
Sudan	White Nile	Kosti	All year long	400	6000	
		Khartoum	All year long	-	-	

There are four river ports in Gambella Region, Gambella : accessible from July to October; Itang : accessible from July to November (distance from Gambella : 50 km), Matar : accessible from July to December (distance from Gambella : 152 km) and Burbe : accessible all year (distance from Gambella : 185 km). Depending on water levels, in dry season, the standard barges used on Baro River have a capacity of 30 to 50 tonnes and in rainy season, it is possible to utilize a larger barge that can carry up to 1600 tonnes.

Floods and Drought Mitigation

The impacts of floods in the basin are numerous. These impacts are mostly negative (loss of life, damages to infrastructure, etc.) but it should be kept in mind that annual floods also support the livelihood of many farmers who rely on recession agriculture and cattle farming. Finally, these floods are also an essential component for the good status of the wetlands. The main existing programme for flood mitigation in the basin is the Flood Preparedness and Early Warning project (FPEW). This project was launched in 2007 by ENTRO to support national, regional and local authorities on flood preparedness.

As for floods, droughts can have devastating impacts: on agriculture, on potable water supply, on health, etc. In order to mitigate the impacts of droughts, several actions are already implemented in the basin. These actions are based on securing access to potable water with boreholes, use of new crops resilient to drought, development of irrigation, etc.

Livelihood-based watershed management

Total soil eroded in the Baro-Akobo Catchment is estimated to be 43.7 million tons per annum and that from cultivated land 21.5 million tons per annum

In the Ethiopian part of the basin, a few livelihood-based watershed management projects under SLMP2 (World Bank) and Government funded mass mobilisation. In South Sudan, ogoing livelihood-based watershed managemen projects in the Imatong Mountains (supported by AWF) “Improving South Sudan’s Livelihoods and Ecosystems Through Water Management in the Imatong mountains”

Biodiversity, habitats and landscape conservation

Around 30% of the basin surface area is covered by protected areas. The BAS includes over 30 protected areas which are briefly presented in the table below. Despite this large number and important coverage, important issues have been identified:

- Important (for biodiversity and livelihoods) and threatened ecosystems are not covered by any type of specific protection. This is for example the case of the *Machar Marshes*
- Effective protection is quasi-absent insignificant in the basin. However, recent planning initiatives may bring some change to this situation.
- Little general updated information is available, especially concerning National Forest Priority Areas, Forest reserves, and Game reserves;

WATER BALANCE MODEL

The main objective of the water balance modelling component as part of the baseline phase of this study is to quantify the available water within the study basin in both space and time. During subsequent phases of this study, the configured water balance model will be used as an analytical tool to assess the hydrological impacts of development interventions and management options, which can then be translated into relevant social, environmental and economic indicators to inform scenario evaluation. A two-step modelling approach was used. Firstly, a rainfall-runoff model was calibrated against observed stream flows at selected flow gauging stations in the basin. Secondly, the calibrated rainfall-runoff model was used to generate long-term monthly flows at various key locations within the basin. The modelling procedure involved seven sequential tasks, 1) Evaluation of flow records, 2) Delineation of model subcatchments, 3) Pre-processing of climate data, 4) Quantification of existing water demands and identification of existing water resources infrastructure, 5) Calibration of the rainfall-runoff model, 6) Configuration and validation of the water balance model, 7) Simulation of long-term flow sequences and conducting a water balance, 8) Using the calibrated rainfall runoff model in conjunction with the validated MIKE HYDRO Basin model, long-term flow sequences were simulated at key locations across the basin. The simulation period, which extended from 1905 to 2014, was dictated by the length of the catchment rainfall files. Figure 11-13 displays a schematic representation of the simulated water balance in the study basin, and provides information on the mean annual runoff volumes along main rivers, in key tributaries, and at spill locations and inter-catchment links along the floodplains.

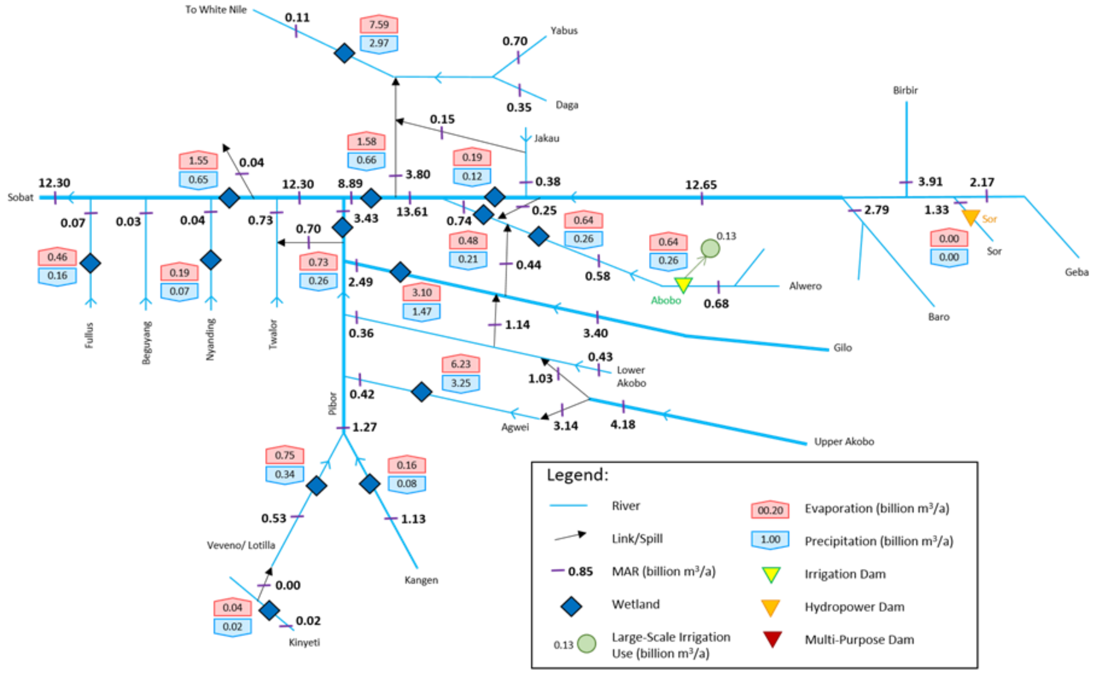


Figure 11-13: Water balance of the Baro-Akobo-Sobat basin

PART 2: DEVELOPMENT POTENTIALS

INTRODUCTION

Identification of the potential developments in the Baro-Akobo-Sobat basin serves three related purposes:

- The potential developments are based on needs and potentials identified for the different sectors. This has been particularly important to define the key water related opportunities in part 3 of this report. Identification of these opportunities was then integrated with the key issues and challenges to all propose strategic objectives to be discussed during the baseline workshop.
- The potential developments will be part of development and managelent scenarios which will be screened through the multicriteria analysis in order to propose medium and long term projects that will help achieve the desired vision for the basin, agreed during the baseline workshop.
- The identification of the seven short term projects proposed in a separate report is based on the potential developments identified in this report.

SUMMARY OF THE MAIN FINDINGS PER SECTOR

The key findings per sector are illustrated on the map hereafter. The map identifies the existing development projects in the basin and the projects proposed as part of this study. Some of these projects have been selected as part of the short term projects.

OPPORTUNITY TO DEVELOP MULTIPURPOSE PROJECTS

It is widely recognised that multipurpose projects usually cost more that single sector oriented projects. However, if well designed and implemented, the projects can generate higher incomes and thus have a more significant impact on poverty reduction and development of the economy.

The projects proposed in this report are mostly single sector oriented. They aim at representing the numerous development opportunities in the basin but it should be stressed that these projects can often be turned into multipurpose projects. This exercise has been realised in the concept note for the short term projects (separate report): the proposed infrastructure or development plans have been designed in such a way that it/they can be shared by a number of development sectors (potable water supply, livestock watering, small scale irrigation, fisheries, hydropower, etc.).

An important task of elaboration of the IWRDMPlan will be to integrate the projects into medium and long term multipurpose projects, in order to propose different development scenarios to reach the desire vision for the basin.

PART 3: KEY ISSUES AND OBECTIVES FOR THE BARO-AKOBO-BASIN

INTRODUCTION

The purpose of this Part of the overall Baseline, Development Potentials, Key Issues and Objectives Report is to move forward from an appreciation of the key issues and development potential within the BAS basin towards the development of a vision and the strategic objectives that will underpin the IWRDM Plan.

This section of the overall report starts with a rapid overview of the key issues, challenges, cause and impacts and then summarised the key water-related opportunities that can support development within the basin. It is understanding of these two opposing aspects that leads to the development of the vision. The vison is a picture of a future state of what the basin will look like after implementation of the IWRDMPlan.

KEY ISSUES, CHALLENGES, CAUSES AND IMPACTS

A key aim of the baseline work has been to understand the status of the basin from a number of perspectives, and to appreciate the relayed issues and challenges. The issues are grouped into environmental, socio-economic and institutional issues. The issues of availability of water is also relevant but this can be considered as something that cuts across environmental, social and institutional areas. Similarly, “technical issues” can be seen as cross-cutting in nature.

Bio-physical environment: Key issues identified

The key issues identified have been identified as follows:

- Stress on Wetlands
- Loss of biodiversity
- Unsustainable hunting of wildlife
- Loss of natural forest
- Soil erosion
- Scattered settlements
- Poor agriculture extension and poor credit facilities
- Flood and drought
- Lack of peace and security
- Poor physical and social infrastructure
- Climate change
- Lack of knowledge

Socio-economic environment: key issues identified

The key issues identified are summarized as follows:

- Poverty and Food Insecurity
- Low level of well-being
- Lack of peace and security
- Low level of provision of social services
- Vulnerable groups
- Gender inequality
- Scattered settlements
- Poor agriculture extension and poor credit facilities
- Recurrence of various forms, intensity, duration and impacts of conflicts
- Potential for influx of people
- Risks
- Flood and drought
- Land security/land tenure issues
- Basin population dynamics place heavy pressure on natural resources
- Climate change
- Weak institutions, poor coordination and cooperation among existing institutions

Institutional Aspects: key issues identified

- Transboundary Cooperative framework
- Security and instability
- Lack of capacity/ experience in (MPP) project implementation
- Capacity of local government institutions and Water Users
- Lack of inter-sector coordination and cooperation
- Planning based on limited consultation
- Inadequate water resources data/monitoring
- Land security/land tenure issues

Development of water resources in the basin: current situation

The status of development of water resources in the basin has been presented in Part 1 of the baseline. This assessment is the basis for the understanding of the status of development in the basin. A summary is provided in the main report.

Key water-related Opportunities

Refer to the maps of development potentials presented earlier.

Annex 4: Data limitation and level of confidence in assessing the thresholds and quantifying the indicators

DATA LIMITATION

The data limitation and the related assumptions used to conduct the required analysis for each dimension is presented in the table below. By way of a summary, the estimated reliability of the analysis is presented in the last column.

Table 11-6: data limitation and the related assumptions used to conduct the required analysis for each dimension

Dimension	Sub-dimension	Indicator used	Data limitation	Assumptions made	Estimated reliability	Margin of error (to apply on the results)
Socio-economic development	Food security	• Level of food self-sufficiency in the basin	Lack of uniform data on: • plant based calories currently produced in the basin; • current rainfed agriculture area; • current agricultural yields. • Cropping patterns of irrigation projects are not fixed yet.	• Plants represent 80% of the required calories intake; • Plant based calories currently produced in the basin is calculated assuming the following situation: ○ Ethiopia: 5% of the population have 50% of the required calories intake, 50% have 100% and 45% have 70% ○ South Sudan: 35% of the population have 50% of the required calories intake, 35% have 100% of the required calories and 30% have 70% of the required calories • Yield varies from 1,5 T/ha to 10 T/ha according to the scenario and cultivation methods;	Fair *NB: food security relies on a combination of factor, not only food self-sufficiency. The creation of employment will obviously also allow people to buy food which can be imported from outside of the basin. However, given that these positive factors are taken into account elsewhere this proxy indicators is considered useful*	15%
	Employment	• Number of jobs created by projects	No data on staff required to run the projects	Employment rate assumptions are: • Irrigation : 0,25 (direct) + 1 (indirect) person / ha • Hydropower: 0,6 (direct) + 1,8 (indirect) person /GWh	Fair *Changes to existing traditional livelihood/ employment opportunities not taken into account*	+/-15%
	Energy security	• Number and proportion of people/households connected to the national electricity grid	No quantitative data on: • planned connection to the national electricity grid; • planned distribution / beneficiaries of energy produced.	It is assumed that 20% of the electricity generated within the sub-basin will be available within the sub-basin; A medium level demand of 150KWhours/cap/annum has been used to calculate the % of the population with access to the national electricity grid.	Sharing /distribution hypothesis is central *Per capita demand (where electricity is available) in both countries is very low. Currently 100 KWhours/ cap/annum in Ethiopia (cf 500 for sub-saharan Africa)*	+/-15%
	Access to water	• % of people with access to improved drinking water sources for human use.	• Baseline figures known Level of detail does not include individual water supply schemes	• It is assumed that access to water will improve with increased water storage and the urbanisation that would accompany the development of large-scale irrigation.	Fair	+/-15%
	Health	qualitative	No direct relationship between the water stored in dams, water spread in irrigation schemes and the prevalence of water-related diseases.	Qualitative approach adopted. It is assumed that the urbanisation and availability of services (health centres, pharmacies, access to water) that goes with it will more than offset the impact of water-borne diseases that may accompany the development of development of storage and irrigated areas.	Even if a qualitative approach has been adopted at this stage, the reliability is considered to be fair.	No margin of error applied on qualitative indicator
	Flood reduction	qualitative	Lack of information relating river discharges to inundation levels	Qualitative approach adopted	Even if a qualitative approach was adopted at this stage, the order of magnitude is adequate at this stage	No margin of error applied on qualitative indicator
Change in riverine ecosystem services	Changes to hydrological regimes affecting aquatic extensions / floodplains / wetlands	• Average annual maximum surface area; • Average annual minimum surface area; • Average annual surface area amplitude	Lack of hydrological data on rivers and no hydrological data on wetlands Inundated areas shown on historical satellite imagery is incomplete and not related to water levels Almost no current and historical detailed biological and socio-economic data on potentially impacted wetlands	Spills rules: • Baro spill to Machar: the flow threshold assumed for the Lower Baro after which spill to Adura Junction occurs is 510 m3/s; 78% of the flow in the Adura Junction spills to Machar. • Baro spill to Alwero: the Baro does not spill up to 940 m³/s, after which it breaks its banks and spills 60 m³/s to the Alwero. • Gilo spill to Alwero: The Gilo River has a capacity of 250 m³/s, after which it spills surplus flow to the Alwero. • Pibor spill to Twalor: The Lower Pibor has a capacity of 250 m³/s, after which it spills surplus flow to the Twalor. • Upper Akobo to Agwei: The Upper Akobo spills a maximum of 200 m³/s into the Lower Akobo, and the surplus spills into the Agwei. • Akobo spill to Gilo: The Lower Akobo River has a capacity of 25 m³/s, after which it spills surplus flow to the Gilo. • Sobat spill to Wal: The Sobat River has a capacity of 1 400 m³/s, after which it spills surplus flow to the Wal.	Fair enough to guide decision making at strategic level, but there is a significant impact on the confidence in the thresholds provided. *NB: There is major room for improvement here. A few years of monitoring may be sufficient to significantly improve the spill rules and the wetland level-area-volume.* *Socio-economic and biological survey conducted in parallel with hydrological monitoring could also significantly improve the understanding of environmental and social implications of modifications to the hydrological regime.*	+/-20%

Dimension	Sub-dimension	Indicator used	Data limitation	Assumptions made	Estimated reliability	Margin of error (to apply on the results)
				Wetlands are modelled as one single reservoir for Machar Marshes and several reservoirs for Gambella plains and Sobat wetlands. Their level-area-volume relationships are detailed in Annex 3 and have been based on the examination of satellite imagery and available mapping and literature. Biological and social uses of wetlands are assumed to be similar to other important sahelian wetlands.		
	Changes to hydrological regime affecting instream flow / the river system itself	• Number of navigable months for an average year • Number of months under the 1/10 daily ranked flow (=duration of the severe low flows period) • Average mean monthly flow from December to May • Mean annual daily flow of the White Nile at Malakal • Mean amplitude between the wettest month and the driest month of a year	Lack of hydrological data; Almost no current and historical detailed data on riverine biology and uses.	See assumptions used to build the water resources model.	Same as above.	+/-20%
	Geomorphological changes	• Surface area of watershed controlled by the dam / Surface area of the entire sub-basin	No integrative study on the BAS geomorphology	No assumption had to be made for the use of the proposed indicator.	Fair for guiding decision making at strategic level. *NB: the proposed indicator is i) simple to use and to understand; ii) integrative and iii) doesn't rely on unreliable/unavailable data.*	0%
Loss of natural/ existing ecosystem through land use conversion of project (infrastructure) footprints		• Population affected by the project combination (population to be resettled) • Surface area of protected areas within projects footprint • Surface area of forests and upstream wetlands within projects footprint • Surface area of wildlife migration corridors within projects footprint	For dams and small-scale irrigation projects, the spatial extent is not known, only the approximate location (one single coordinate) is available. The scale of the land use map used to identify the kind of ecosystem located within project footprint is 1/100 000	Spatial extent has been mapped assuming: • Small-scale irrigation scheme are configured as a square, with centre located as per the location available in the literature; • Dam reservoirs are configured as a rectangle, located upstream from the designated location of the dam wall	Good *NB: Detailed ecosystem mapping and assessment should be conducted at the ESIA stage to better qualify the implications of projects implementation.*	+/- 30% +/- 15% +/- 30% +/- 30%
Contribution to transboundary cooperation	Contribution to regional and national economic growth	• Change in revenue generated from hydropower • Change in revenue generated from large-scale irrigation		• Assumptions made on selling rates for electricity • Assumptions made on the 80% crops to be grown for commercial purposes	Fair	+/- 15%
	Level of transboundary operation and management required	• Degree of cross-border cooperation required in system operation	Qualitative	• Assumed to be maximised when the operation of upstream hydropower dam is managed to fully support downstream irrigation requirements and environmental flow requirements • Assumed to be minimised when national and sectoral water resources development (especially hydropower and irrigation) are managed unilaterally	Fair at the strategic level	No margin of error applied on qualitative indicator
	Impact on flows downstream of Sobat/White Nile confluence	• Change in MAR entering White Nile • Change in average minimum flow in White Nile d/s of Sobat confluence	Dependant on accuracy of water resources modelling (see "change in riverine ecosystems services above")	See assumptions used to build the water resources model (see "change in riverine ecosystem services above")	Fair	+/- 10%
Change in water quality		[P] and [N] loads in rivers, reservoirs and wetlands	Lack of data on domestic solid waste and effluent volumes.	Fertilizers to be used in irrigation schemes will have around the same P and N loads.	Fair enough to guide decision making at strategic level.	20%
Change in GHG emissions		Co_2eq emitted due to water developments	No similar exercise conducted in the region for comparison. Data on density of biomass is mapped at global scale and might not capture local specificities.	For emissions due to flooding of reservoirs, land clearing and burning for the development of irrigation , deforestation, the assumptions and equations used are recommended by the standardized methodology from the IPCC or from other critical references. For emissions due to N2O release in agriculture, data are taken from the *Intended Nationally Determined Contribution (INDC) of the Federal Democratic Republic of Ethiopia.*	Fair enough to guide decision making at strategic level.	60%

LEVEL OF CONFIDENCE IN ASSESSING THE THRESHOLDS AND IN QUANTIFYING THE INDICATORS

The previous table gives the level of accuracy / confidence is in question for some of the dimensions and sub-dimensions. As a consequence, a **margin of error has to be reflected**:

- either in the calculation of thresholds, implying that threshold covers a range of values rather than being a single point
- or in the calculation of indicators (calculated from the outputs of the modelling runs), in order to illustrate the level of confidence (or lack thereof) in the data on which they are based.

The paragraphs below detail how the above described inaccuracies have been taken into account in the calculation of the threshold and indicators for each of the dimension.

Socio-economic development

Threshold:

Thresholds for the socio-economic dimension refer to targets for the IWRMDP. There is therefore no point in giving leeway to it. These are targets which are essentially at the heart of the development drive.

Quantification of indicator:

Apart from the sub-dimension dedicated to health and flood reduction, the effects of water developments on food security, employment created, energy security, access to water, flood reduction have been assessed in a quantitative manner. However, positive effects on health, food security, energy security do not exclusively depend on the projects / infrastructure characteristics but also on the way benefits will be shared and on efforts to connect settlements to the national grids, to improve the access to markets, to improve access to improved source of water and sanitation. The IWRMDPlan will thus have to include additional actions (in addition to water infrastructures) to ensure that progress will reach the beneficiaries. In addition, the main projects are located in the Ethiopian part of the basin. Sub-basin and transboundary cooperation will be required to maximise the expected benefits. Adverse effects such as the loss of arable and grazing land due to project footprints or reduction of fish productivity due to changes to riverine ecosystem services will also affect food security and stress the need for benefit sharing.

Changes to riverine ecosystem services

- Changes to hydrological regime affecting aquatic extensions/wetlands

Threshold:

Because of the lack of socio-economic and ecological data in the BAS low lands, it is not possible to accurately define the tipping points beyond which the system collapses, i.e values for which ecological patterns are starting to be affected or for which a lack of forage resources lead to livestock losses or to conflicts.

However, the inherent variability under current “natural” conditions gives indications on the inherent changes that the natural system has managed to deal with over the past 100 years.

For instance, in comparison to the average situation under baseline conditions, the dry (2 years out of 10) situation under baseline conditions gives indications on changes that the natural system copes with 20 out 100 years.

We therefore propose to define the acceptable maximum variability (corresponding to the baseline inherent variability) as follows:

Acceptable maximum variability = (Average situation under baseline conditions – Dry situation under baseline conditions) / Average situation under baseline conditions

A sensitivity analysis has been conducted to investigate the results sensitivity to uncertainties on river flows and on river channel capacities. It shows that the inherent baseline variability is almost not affected by changes of baseline flows nor by channel capacity. As a result, the threshold is a single value (no margin of error is applied to the calculated threshold.

Quantification of indicator:

According to the sensitivity analysis, the margin of error to be applied to model results is around 20%.

- Changes to hydrological regime affecting instream flow / the river system itself

Threshold:

A sensitivity analysis has been conducted to investigate the results sensitivity to uncertainties on river flows and on river channel capacities. The sensitivity analysis is detailed in the Annex 3: Water resources modelling. It shows that the inherent baseline variability is almost not affected by changes of baseline flows nor by channel capacity. As a result, the threshold is a single value (no margin of error is applied to the calculated threshold.

Quantification of indicator:

According to the sensitivity analysis, the margin of error to be applied to model results is around 20%.Importance of the sub-dimension

- Geomorphological changes

Threshold:

As already stated, the potential geomorphological changes resulting from dams can vary according to the dam location within the same sub-basin and among different sub-basins. The social and environmental implications of geomorphological changes also depend of the baseline environmental and social conditions upstream and downstream the dams projects.

According to the literature (BRL ingénierie, 2000), the river system is **significantly disturbed** when the surface area of the watershed controlled by a dam exceeds **30%** of the total sub-basin surface area.

The above threshold of 30% relies on geomorphological expertise on general cases. Since the associated geomorphological changes can be very contrasting depending on local conditions, it is assumed that the threshold beyond which the river system is significantly disturbed might rather range from 20% to 40% according to the situation.

Quantification of indicator:

Because the calculation of the indicator “Surface area of the watershed controlled by the dam / Total surface area of the sub-basin” relies on reliable data (location of dams and sub-basin surface area) and does not include any assumptions, the related assessment is assumed to be sound.

Loss of natural / existing ecosystem through land use conversion of project (infrastructure) footprints

Threshold:

The level of confidence of threshold values for forests, mountain wetlands and white-eared kob migration area is assumed to be around 15% since these values depend on:

- Land-use mapping at the scale of the BAS;
- Collaring surveys / aerial surveys on a small proportion of wildlife population.

Quantification of indicator:

Sources of errors in estimating the ecosystem conversion is twofold:

- Inaccuracy of the land use map which has been elaborated at the scale of the BAS and not at the scale of individual projects. Mapping of White-eared kob distribution rely on 3 years of observation / collaring. Limits of protected areas are supposed to be exact;
- Area impounded by reservoirs have been represented as rectangle at this stage. Irrigation schemes delineation is only preliminary and represent gross surface are only.

As a consequence, the margin of error is assumed to be around 30% for land-use and migration corridors and is assumed to be around 15% for protected areas.

Contribution to transboundary cooperation

As already indicated the transboundary cooperation dimension include the three sub-dimensions of:

- Contribution to regional and national economic growth: In this first stage of the SSEA, the contribution of development is considered simply in terms of GWhours produced for national and regional consumption (by hydropower) development and the number of hectares that have been developed for commercially-orientated irrigation.
- Level of transboundary cooperation and management required: This is a qualitative assessment of the level of transboundary cooperation that is required
- Impact on flows downstream of Sobat/White Nile confluence. This is a straightforward assessment of the impact on flows entering the White Nile and the impact on flows in the White Nile

Threshold:

Thresholds for the two quantifiable sub-dimension can be seen as targets so there is no need to give leeway to them. For the level of transboundary cooperation and management required, the qualitative estimate is seen as an obligation since a lack of transboundary cooperation would lead to negative impacts downstream. No leeway is proposed.

Quantification of indicator:

A potential error in the contribution to regional and national economic growth is taken at 15%.

The potential error in the calculation of mean annual flow and median minimum flow is taken at 10% as per assumption used in building the water resources model.

Change in GHG emissions

Threshold:

Allowing the same budget for CO_2eq emissions for all sub-basins in Ethiopia is a rough assumption which could deserve to be fine-tuned. In the absence of adequate data, this is however not possible within this study.

It is understood that the development of hydropower should, on a long-term perspective, contribute to significantly reduce GHG emissions. As such, the above threshold could be postponed to 2060 instead of 2030.to give some leeway for necessary development.

Quantification of indicator:

Quantifying future potential emissions is a challenge. Even if done rigorously thanks to internationally approved calculation methods, inaccuracies might be still significant. IPCC guidelines on how to calculate and account for greenhouse gases indeed suggest that uncertainties "for carbon dioxide are up to 10 per cent for electricity generation, 10 per cent for industrial processes including cement and fertiliser production, and up to 60 per cent for land use change and forestry. For methane the margins of error are even higher, and for nitrous dioxide they are 50 per cent for industrial processes." (IPCC, 2006 b).

Based on the above facts, the following margin of error will be applied to the various types of GHG emissions:

- Land clearing and burning for irrigation development: 60%
- Emissions due to N2O release in agriculture: 50%
- GHG emissions from the reservoirs: 10%
- Emissions due to usual deforestation: 60%

As a result, the margin of error on the total GHG emissions is around 60%.

Change in water quality

Threshold:

A possibility to give some leeway on the threshold of 1 mg/L for [N] and [P] is to consider that water can be treated, even if treatment facilities are not currently available in most part of the BAS. This allows higher [N] concentrations but is not less restrictive for [P]. Apart from this, there is no possible leeway on the threshold itself.

Indicator quantification:

Since nutrient concentration varies a lot over time and space and since nutrient input from agriculture and their washout into water bodies are difficult to predict, the margin of error in assessing nutrient loads might be significant and it assumed to be around 20%.

Assumptions on potential mean nutrient load and [N] and [P] input balance will be fine-tuned as part of the 2nd draft SSEA to assess whether there is room for improvement of [P] concentrations in water bodies of the BAS.

Annex 5: Assessment of options; Economic and Financial Analyses

ASSESSMENT OF SCREENED OPTIONS – ECONOMUC AND FINANCIAL ANALYSIS

1. METHODOLOGY OF THE COST-BENEFIT ANALYSIS

1.1 OBJECTIVE AND METHOD

The economic and financial analyses have been based on a cost-benefit analysis (CBA). The CBA determines **the financial and economic relevance of a project** (or programme) by evaluating the differential of costs and benefits between the situation with project and the situation without project (baseline scenario). In the current study, the CBA aims at assessing the financial and socio-economic feasibility of each scenario (i.e. *Are the benefits higher than the costs?*) and comparing each scenario against another (i.e. *Which scenario appears the most relevant economically ?*).

Two analysis are conducted:

- a financial analysis which allows the assessment the profitability of the projects in the investors'point of view. The analysis takes into account the financial costs and benefits, i.e. the investments and O&M costs and the revenues of the activity implemented (hydropower, irrigation, fish farming or rizipisiculture). This analysis is presented in paragraph 2.1.
- an economic analysis which evaluates the viability of the projects in the society's point of view. This analysis takes into account the financial costs and benefits plus the externalities of the projects.

An externality is a cost or benefit generated by an activity and that affects a party that did not choose to incur this cost or benefits (e.g. degradation of downstream wetlands due to a modification of flows from a hydropower station, indirect employment created from a new activity, etc.). The analysis distinguishes the environmental, social and economic externalities. It makes it possible to appreciate the relevance of the project for the society as a whole. It is presented in paragraph 2.2.

NB: It is important to keep in mind that the economic analysis does not allow the monetarization of all the impacts of the scenarios. The Economic Internal Return Rate (EIRR) and the Economic Net Present Value (ENPV) are not sufficient to appreciate the relevance of the projects. Thus the results of the economic analysis should be put in perspective with the SSEA results.

For both analysis, three main indicators are computed:

- The Net Present Value (NPV) by summing the positive and negative discounted cash flows over the time period,
- The Benefits/Costs ratio : It should be superior to 1 for the project to be viable,
- The Internal Rate of Return (IRR), which determines the discount rate that would make the NPV equal to zero. It should be superior to the discount rate applied in the analysis (10% for the financial cash flows and 5% of the externalities).

The CBA distinguishes different levels of analysis:

- Geographically: the analysis distinguishes the impacts for the Ethiopian part of the BAS and the South Sudan part of the BAS.
- By economic sector: the analysis presents the financial and economic relevance for each economic sector that are developed in the scenarios: hydropower, irrigation, fish farming and rizipisiculture.

1.2. GENERAL ASSUMPTIONS

1.2.1. Time period

The analysis is conducted over a 40 years period. It has been assumed that all the identified infrastructure development can be put in place during this period.

1.2.2. Inflation rate

The costs and benefits are in USD2016. The TP01 Index is used to update costs of hydropower and irrigation projects.

1.2.3. Exchange rate

The currency used is the US dollar. The fluctuations of the exchange rates are not taken into account. The assumption on the exchange rate is 1 USD = 22.26 ETB (4th November 2016). Due to extreme exchange change fluctuations in South Sudan, costs and benefits are estimated directly in USD.

1.2.4. Discount rate

Two discount rates are used for the calculation of costs and benefits:

- For the financial costs and benefits: 10%/year
- For the externalities: 5%/year

2. DETAILS OF CALCULATION

The second part of the report presents the assumptions and the main results for the financial analysis (paragraph 2.1) and the economic analysis (paragraph 2.2).

2.1. FINANCIAL COSTS AND BENEFITS

The financial analysis concerns the economic sectors that are planned to be developed in the scenarios, that is to say: hydropower, irrigation, fish farming and rizipisiculture. The projects are implemented progressively according to the priority of the master plan.

The economic sectors that are indirectly impacted (fishery in dams' reservoirs and livestock through improvement of water and food provision) are externalities of the projects and thus assessed in the paragraph 2.2.

2.1.1. Assumptions

2.1.1.1. Hydropower

Nine hydropower dams are studied. The investment costs and O&M costs are presented in the following table. It is assumed that the O&M costs represent 1% of the investment costs and that the mitigation costs represent 3% of the investments costs except for TAMs for which it is 6%. The benefits of hydropower are computed using the amount of electricity produced and the price of 0.1 USD/Kwh (*Source: TAMs Feasibility study, 2014*).

The lifetime of the infrastructure is assumed to be 40 years. The non-depreciated amount of the investment is recognized as a gain at the end of the study period.

The order of priority of each project and the starting date are used to spread the costs and benefits over the time period. The order of priority is consistent with the master plans.

The implementation order is based on the SSEA findings and what is already happening on the ground (call for tenders for implementation of TAMS and work starting on Geba).

Table 11-7 : Investment and O&M costs for hydropower projects

Site	Type (dams/run of river)	Existing/proposed	Storage capacity (Mm3)	Installed Capacity (MW)	TOTAL INVESTMENT COST 2016 USD	O&M Cost (USD/Year)	Year of Cost Estimation	Source
Sor	R-o-R	Existing	0	5	Existing dam			
Sor	Dam	Proposed/Upgra	311	10	36 182 000	212 000	1996	Tams project, 1997
Bibir R	Dam	Proposed	2 700	467	431 376 000	2 523 000	1996	Tams project, 1997
Geba Diversion 1	R-o-R	Proposed	0	215	470 543 000	3 607 000	2005	Annexe C feasibility study, 2005
Geba Diversion 2	R-o-R	Proposed	0	157	196 070 000	1 503 000	2005	Annexe C feasibility study, 2005
Baro 1	Dam	Proposed	1 337	166	414 146 000	3 352 000	2006	Annex 3G Detailed cost estimate, feasibility study, 2006
Baro 2	Dam	Proposed	73	479	387 477 000	3 136 000	2006	Annex 3G Detailed cost estimate, feasibility study, 2007
Genji	Dam	Proposed	1,5	216	142 127 000	1 150 000	2006	Annex 3G Detailed cost estimate, feasibility study, 2008
Tams	Dam	Proposed	10 000	1 700	2 998 879 000	31 220 000	2014	Feasibility study, Vol. 9, 2014
Geba A	Dam	Proposed	860	0	102 430 000	599 000	1996	Tams project, 1997

Table 11-8 : Project priority and energy generation

Dam name	Reservoir surface area (km2)	Energy production (GWh/year)						Starting date	Ending date
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a	Scenario 4b		
Sor (existing)	11								
Sor (upgraded)	11	46	46	30	30	46	88	2017	2018
Birbir R	37		2734	2176	2176	2733	2733	2032	2036
Geba Diversion 1	0	527	527	530	530	527	527	2017	2020
Geba Diversion 2	0	487	487	445	445	487	487	2017	2020
Baro 1	23	546	546	592	592	546	546	2028	2031
Baro 2	9	1685	1685	1601	1601	1685	1685	2028	2031
Genji	0,19	613	613	605	605	613	613	2023	2026
Tams	77		5594	5225	5225	5624	4749	2017	2021
Geba A	68							2017	2020

2.1.1.2. Irrigation schemes

19 small-scaled irrigation projects (including diffuse projects) and 13 large-scaled irrigation projects are studied. The tables below present the investment and O&M costs, the cropping pattern and the gross margin for each crop.

The sequencing of implementation takes into account the findings of the SSEA and assumes an optimistic rate of development of around 12,000ha per annum for large-scale irrigation in parallel with the development of small-scale irrigation. This is a faster rate than has been achieved in either country in the past in any catchment.

Table 11-9 : Investment costs, O&M costs and order of priority for irrigation projects

Site	Country	Type of project	Investment cost USD2016)	Annual O&M cost (USD/years)	orden of Priority	Starting date	end date
Diffuse	Ethiopia	Small-scale	448 491 000	4 485 000	1	2017	2014
Koji	Ethiopia	Small-scale	103 872 000	1 039 000	2	2021	2021
Sako Guda	Ethiopia	Small-scale	35 894 000	359 000	2	2021	2021
Bako	Ethiopia	Small-scale	65 178 000	652 000	3,7	2026	2026
Kilu	Ethiopia	Small-scale	42 840 000	428 000	3,6	2025	2025
Lafo Kotu	Ethiopia	Small-scale	988 686 000	9 887 000	2	2022	2022
Baro	Ethiopia	Small-scale	18 819 000	188 000	3,9	2026	2026
Bibir	Ethiopia	Small-scale	101 592 000	1 016 000	3,2	2024	2024
Fani	Ethiopia	Small-scale	21 298 000	213 000	3,1	2024	2024
Alwero	Ethiopia	Small-scale	161 166 000	1 612 000	3,8	2026	2026
Guy	Ethiopia	Small-scale	105 478 000	1 055 000	3,1	2024	2024
Godare	Ethiopia	Small-scale	43 430 000	434 000	3,11	2026	2026
Achani	Ethiopia	Small-scale	41 783 000	418 000	3,4	2024	2024
Awaya	Ethiopia	Small-scale	128 520 000	1 285 000	2	2022	2022
Babaka	Ethiopia	Small-scale	70 686 000	707 000	3,5	2025	2025
Guracha	Ethiopia	Small-scale	26 928 000	269 000	2	2021	2021
Gumero	Ethiopia	Small-scale	55 998 000	560 000	3,3	2025	2025
Akobo I	Ethiopia	Small-scale	47 813 000	478 000	2	2022	2022
Akobo II	Ethiopia	Small-scale	589 815 000	5 898 000	2	2022	2023
Alwero, Abobo dam	Ethiopia	Large-scale	0	0			
Baro River, right bank, Itang Dam, gravity conveyance	Ethiopia	Large-scale	398 528 000	3 985 000	1	2017	2018
Baro River, right bank, pumping from Itang Dam, gravity conveyance + relift p/station + additional canal	Ethiopia	Large-scale	549 588 000	5 496 000	1	2021	2022
Scheme 3A (Baro River, right bank, Gambella Dam, gravity conveyance) + high lift p/stations + additional canals	Ethiopia	Large-scale	588 641 000	5 886 000	1	2025	2026
Baro River, left bank, Itang Dam, gravity conveyance	Ethiopia	Large-scale	421 580 000	4 216 000	3	2051	2051
Baro River, left bank, Itang Dam p/station, canal	Ethiopia	Large-scale	118 763 000	1 188 000	1	2029	2029
Baro River, left bank, Gambella Dam, gravity conveyance	Ethiopia	Large-scale	446 215 000	4 462 000	1	2030	2031
Alwero River, right bank, Chiru + Dumbong Dam, gravity conveyance	Ethiopia	Large-scale	235 602 000	2 356 000	2,1	2034	2034
Gilo River, right bank, Gilo 1 Dam, gravity	Ethiopia	Large-scale	873 905 000	8 739 000	2,2	2036	2037
Gilo River, left bank, Gilo 1 Dam, gravity	Ethiopia	Large-scale	961 020 000	9 610 000	2,4	2045	2045
Gilo River, left bank, Gilo 2 Dam, gravity	Ethiopia	Large-scale	315 863 000	3 159 000	2,5	2051	2051
Gilo River, right bank, Gilo 2 Dam, gravity	Ethiopia	Large-scale	410 522 489	4 105 000	2,3	2041	2041
Sobat	South Sudan	Large-scale	769 384 441	7 694 000	1	2017	2019

Table 11-10 : Net surface area for irrigaton schemes (ha)

Site	SC1	SC2	SC3.a	SC3.B	SC4.a	SC4.B
Diffuse	117 692	117 692	117 692	117 692	117 692	117 692
Koji	4 590	4 590	4 590	4 590	4 590	4 590
Sako Guda	3 519	3 519	3 519	3 519	3 519	3 519
Bako	0	0	0	4 590	4 590	4 590
Kilu	397	397	397	4 284	4 284	4 284
Lafo Kotu	6 885	6 885	6 885	6 885	6 885	6 885
Baro	1 530	1 530	1 530	1 530	1 530	1 530
Bibir	5 373	5 373	5 373	6 120	6 120	6 120
Fani	282	282	282	918	918	918
Alwero	0	0	0	4 208	4 208	4 208
Guy	1 377	1 377	1 377	1 377	1 377	1 377
Godare	666	666	666	2 525	2 525	2 525
Achani	911	911	911	3 290	3 290	3 290
Awaya	3 825	3 825	3 825	3 825	3 825	3 825
Babaka	803	803	803	4 590	4 590	4 590
Guracha	1 530	1 530	1 530	1 530	1 530	1 530
Gumero	1 307	1 307	1 307	3 060	3 060	3 060
Akobo I	3 825	3 825	3 825	3 825	3 825	3 825
Akobo II	22 950	22 950	22 950	22 950	22 950	22 950
Alwero, Abobo dam	7 179	10 196	4 474	4 890	8 843	9 884
Baro River, right bank, Itang Dam, gravity conveyance	35 155	49 930	21 908	23 946	43 307	48 402
Baro River, right bank, pumping from Itang Dam, gravity conveyance + relift p/station + additional canal	30 349	43 104	18 913	20 672	37 386	41 785
Scheme 3A (Baro River, right bank, Gambella Dam, gravity conveyance) + high lift p/stations + additional canals	35 756	50 785	22 283	24 356	44 048	49 230
Baro River, left bank, Itang Dam, gravity conveyance	12 343	17 530	7 692	22 256	40 251	44 986
Baro River, left bank, Itang Dam p/station, canal	8 357	11 869	5 208	5 692	10 294	11 505
Baro River, left bank, Gambella Dam, gravity conveyance	30 097	42 747	18 756	20 501	37 076	41 438
Alwero River, right bank, Chiru + Dumbong Dam, gravity conveyance	14 339	20 365	8 936	12 479	22 568	25 223
Gilo River, right bank, Gilo 1 Dam, gravity	20 311	28 848	12 658	29 248	52 896	59 119
Gilo River, left bank, Gilo 1 Dam, gravity	6 172	8 766	3 846	28 639	51 794	57 887
Gilo River, left bank, Gilo 2 Dam, gravity	1 236	1 755	770	12 173	22 014	24 604
Gilo River, right bank, Gilo 2 Dam, gravity	8 874	12 603	5 530	22 050	39 877	44 568
Sobat	47 632	67 652	29 684	33 840	61 200	68 400

Table 11-11: Cropping pattern for large-scaled schemes, small-scaled schemes and rainfed area

WS : Wet season, DS : Dry season, RF : Rainfed, Ir : Irrigated

	Large scale		Small scale				Rainfed	
Concerned area	**Dumbog/Abodo/ Gilo1/Gilo2/Baro/Itang**	**Sobat**	**Birbir**	**Gaba**	**Alwero/Gillo/Baro**	**Irrigation diffuse**	**Rainfed Ethiopia**	**Rainfed South Sudan**
Maize (grain) WS ,RF	5%	40%	30%	25%	35%	30%	38%	40%
Maize (grain) DS, Ir	7%	30%	30%	35%	35%	33%		
Rice WS , RF								
Rice WS, Ir	25%							
Rice DS, Ir	25%							
Sorghum (grain) WS, RF		21%	11%	0%	25%	12%	30%	21%
Sorghum (grain) DS, Ir		25%	0%	0%	25%	8%		
small grains WS, RF			25%	0%	0%	8%		
Wheat WS, RF			0%	25%	0%	8%		
Teff WS, RF			0%	30%	0%	10%		
Sugarcane , Ir	35%							
Cotton, Ir	15%							
Groundnut WS , Ir	4%	10%	0%	0%	11%	4%		10%
Groundnut DS, Ir		5%						
Soybean WS , Ir	5%						3%	
Soybean DS, Ir	11%							
Vegetables WS, Ir		1%						1%
Vegetables DS, Ir	1%	10%	0%	22%	0%	7%		
Small vegetable WS, Ir			0%	0%	1%	0%		
Small vegetable DS, Ir			0%	0%	10%	3%		
Tomato DS, Ir			0%	18%	0%	6%		
Dry beans WS, Ir		13%	7%	0%	13%	7%	7%	13%
Dry beans DS, Ir		20%	8%	0%	20%	9%		
Peppers WS, Ir			15%	10%	0%	8%		
Peppers DS, Ir			30%	20%	0%	17%		
Potato DS, Ir							9%	
Fodder, RF	1%							
Fruit			2%	0%	0%	1%	2%	
Banana, Ir		5%		0%	5%	3%	1%	5%
CROPPING INTENSITY	**134%**	**180%**	**158%**	**185%**	**180%**	**175%**	**90%**	**90%**

The gross margin is computed for each crop of the cropping pattern. It equals the gross product (USD/ha) minus the exploitation costs (USD/ha).

Table 11-12 : Gross margin (USD/ha)

WS : Wet season, DS : Dry season, RF : Rainfed, Ir : Irrigated

Crop	Gross margin USD/ha
Maize (grain) WS ,RF	304
Maize (grain) DS, Ir	-90
Rice WS , RF	753
Rice WS, Ir	329
Rice DS, Ir	329
Sorghum (grain) WS, RF	162
Sorghum (grain) DS, Ir	-240
small grains WS, RF	1 009
Wheat WS, RF	632
Teff WS, RF	800
Sugarcane , Ir	8 080
Cotton, Ir	2 224
Groundnut WS , Ir	1 331
Groundnut DS, Ir	1 331
Soybean WS , Ir	337
Soybean DS, Ir	337
Vegetables DS, Ir	12 361
Vegetables WS, Ir(RF Garlic)	12 361
Small vegetable WS, Ir(RF Head cabbag	1 958
Small vegetable DS, Ir	602
Tomato DS, Ir	5 035
Dry beans WS, Ir(RF)	150
Dry beans DS, Ir	150
Peppers WS, Ir(RF)	1 830
Peppers DS, Ir	1 830
Potato DS, Ir	2 772
Fodder, RF	1 395
Fruit	4 629
Banana, Ir	4 629

Fish farming

The assumptions for the evaluation of fish farming costs and benefits are as follows:

- Fish farming represents 1% of irrigated areas,
- The average yield is 2.5 tonnes/ha/year,
- The investment costs equals 159 USD/ton,
- The gross margin which represents the turnover minus the exploitation costs, equals 276 USD/tonne.

Rizipisiculture

Hereafter are the assumptions for the evaluation of rizipisiculture costs and benefits:

- Rizipisiculture represents 1% of irrigated areas of rice,
- The average yield is 650 kg/ha/year,
- The investment costs equals 159 USD/tonne,
- The gross margin which represents the turnover minus the exploitation costs, equals 276 USD/tonne.

2.1.2. Main results

Almost all the projects have a positive Financial Net Present Value (FNPV) *(sum of all discounted cash flows over the time period),* which means that they are profitable in any scenario (see chart and table below). The large-scaled irrigation schemes are not profitable in scenarios 3a and 3b. Scenario 1 is not very profitable whereas Scenarios 2 and 4a are the most profitable for every sectors.

Figure 11-14 : Financial Net Present Value (Millions 2016 USD) for each sector and scenario

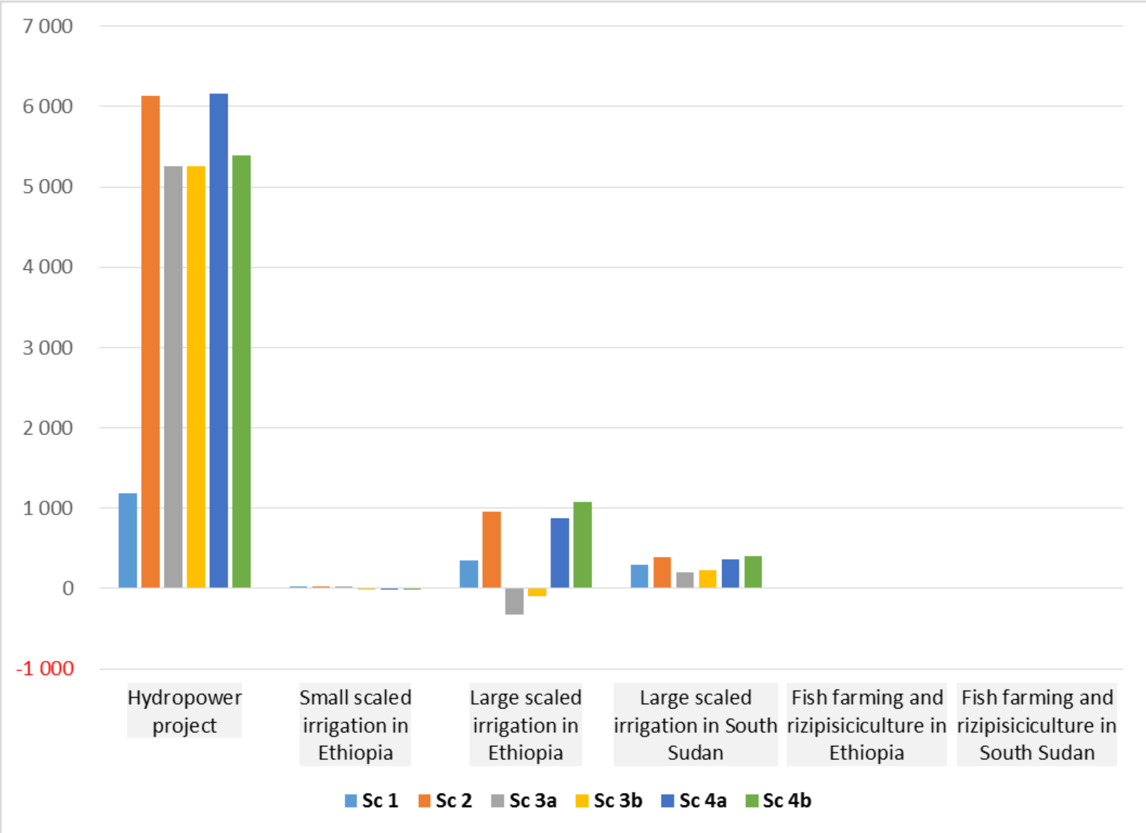


Table 11-13 : Financial Net Present Value (Millions 2016 USD) and Financial Internal Rate of return for each sector and scenario

Sector	Indicator	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Hydropower project	FNPV (M$)	1 179	6 134	5 264	5 264	6 160	5 392
	FIRR	24%	46%	39%	39%	47%	40%
Small scale irrigation in Ethiopia	FNPV (M$)	31	31	31	-1	-1	-1
	FIRR	11%	11%	11%	10%	10%	10%
Large scale irrigation in Ethiopia	FNPV (M$)	344	961	-319	-102	872	1 084
	FIRR	14%	18%	6%	9%	20%	18%
Large scale irrigation in South Sudan	FNPV (M$)	301	396	204	223	358	400
	FIRR	20%	20%	19%	20%	20%	20%
Fish farming and rizipisiciculture in Ethiopia	FNPV (M$)	9	10	8	9	11	11
	FIRR	NR	NR	NR	NR	NR	NR
Fish farming and rizipisiciculture in South Sudan	FNPV (M$)	2	2	1	1	2	2
	FIRR	42%	32%	64%	51%	32%	32%

2.2. EXTERNALITIES

Hydropower and irrigation projects generate different externalities for the environment, the local economy and the population. Due to their very nature (they are not priced in the market), externalities are difficult to monetarize. Only some externalities have been evaluated in the CBA. The following table presents the externalities of the projects and either or not they are taken into account in the CBA.

Table 11-14 : Summary of Externalities of the scenario and method of evaluation

Externality	Details	Positive/Negative impact	Taken into account in the CBA analysis	Method of evaluation
ENVIRONMENTAL EXTERNALITIES				
Avoided cost of deforestation	The installation of hydropower dams will induce a reduction in deforestation as charcoal is the primary source of energy used in the region. In addition, the irrigation schemes, (as they provide a better crop yield than rainfed agriculture), will favour a reduced rate of agricultural expansion and thus limit deforestation.	Positive externality	**Yes**	Economic value of forest per ha*Conserved area of forest over the time period **For hydropower:** Conserved area = production of biomass per ha*conversion coefficient (weight of wood equivalent to one GWh) **For agriculture:** Conserved area = surplus of agricultural area in the scenario without project * % of forested area * inertia coefficient
Environmental footprint	The land use for dams and irrigation schemes jeopardize a part of natural land	Negative externality	**Yes**	Economic value of the different land use per ha*Destroyed area
Degradation of downstream wetlands	The modification of flows impacts the downstream flooded areas and the state of wetlands	Negative externality	**Yes**	Economic value of wetlands per ha*Destroyed area
Degradation of downstream rivers services	The modification of flows impacts the services of downstream rivers	Negative externality	No	*Not evaluated*
GHG emissions	The GHG emissions increase due to the projects (creation of the reservoirs and the irrigation schemes)	Negative externality	**Yes**	Increase in GHG emissions*Carbon price
ECONOMIC EXTERNALITIES				
Local development due to new infrastructures (roads, …)	The construction of new infrastructures will stimulate the local economy with new services (school, hospital, shops, etc.)	Positive externality	No	*Not evaluated*
Development of fisheries in the reservoir	The dams' reservoirs will allow to develop fishery	Positive externality	**Yes**	Production of fish*Gross margin
Improvement of livestock conditions	The dams will favour the access to water for livestock and the large-scaled irrigation schemes will produce fodder and secure the livestock feeding. This leads to a change from pastoralism towards agro-pastoralism practices, a better weight of the livestock and an increase of the off-take rate. This will be supported by the urbanization process	Positive externality	**Yes**	Increase in the amount of meat and milk produced*Price
Navigation	The dams will regulate the flows and impact the number of navigable days	Positive externality	**Yes**	Avoided investment costs of the construction of a road between Gambella and Baro mouth
SOCIAL EXTERNALITIES				
Employment	Development of agriculture, hydropower, fisheries employment	Positive externality	**Yes**	Average labour costs*number of created jobs
Flooding protection	The hydropower dams will regulate the flows and reduce the flooding hazards	Positive externality	**Yes**	Average annual avoided costs of flooding
Health improvement	The development of the local economy, the provision of water, food and electricity will improve the health of the population	Positive externality	**Yes**	Increase in the life expectancy*Average salary
Energy security	Hydropower projects will favor the access to energy/electricity	Positive externality	No	*Not evaluated*

2.2.1. Assumptions and methods

2.2.1.1. Environmental externalities

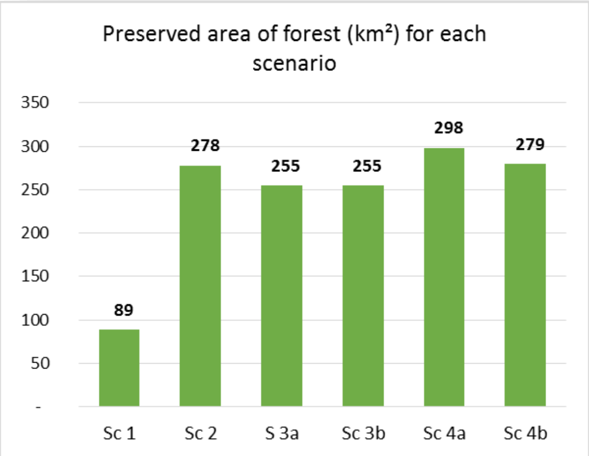
AVOIDED COSTS OF DEFORESTATION DUE TO HYDROPOWER

The construction of hydropower dams will provide energy at the regional level. As the current main source of energy used is charcoal and wood, it can be assumed that the hydropower projects will generate a reduction of deforestation. It is assumed that the beneficiary population will adapt their practices (notably for cooking) rapidly to substitute electricity to wood and charcoal.

The reduction of deforestation is evaluated from the following data:

- Conversion coefficient: 1 tonne of humid wood equals 0.0022 GWh (source: CRPF Limousin)
- Total economic value of Ethiopian forests: 1000 USD/ha (source: BRLi from CEEPA, Accounting for the value of the environment, 2010 and TEEB, 2007),
- The biomass coefficient for Ethiopian forest: 200 tonnes/ha,
- The generation of electricity per year over the time period.

Figure 11-15: Surface of preserved forest corresponding to or all the hydropower projects, for each scenario(km²)



AVOIDED COSTS OF DEFORESTATION DUE TO IRRIGATION SCHEMES

The irrigation schemes will provide a better crop yield than rainfed agriculture. They will favor a reduction of land use for agriculture and thus limit deforestation. The following assumptions are made:

- The irrigated crop yield is on average 1.4 higher than the rainfed crop yield,
- The forested area that is destroyed represent 10% of the extra agricultural areas,
- The economic value of forest equals 1000 USD/ha (see: Table 11-15).

ENVIRONMENTAL FOOTPRINT

The environmental footprint of the projects is evaluated from the total economic value of each type of land use destroyed and the surface destroyed. The value of the land uses concerned are shown in the following table.

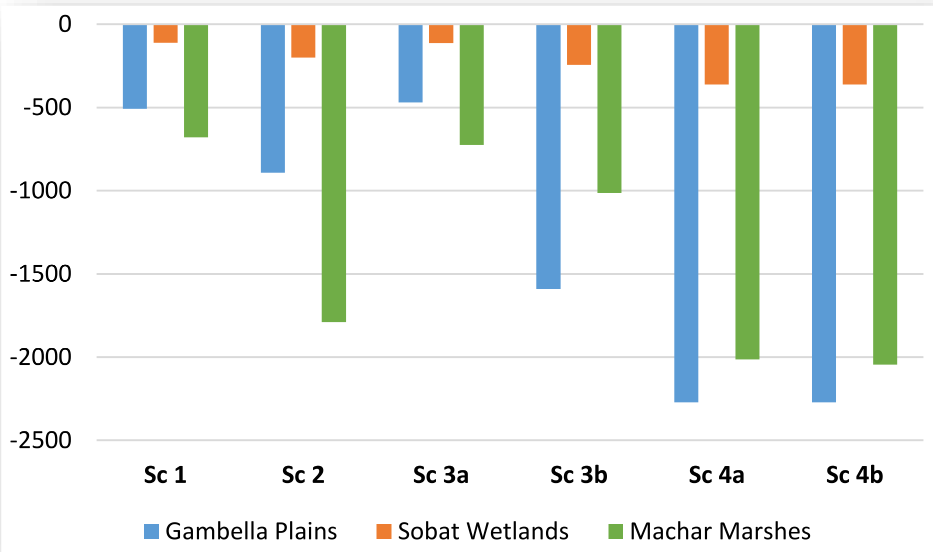
Table 11-15 : Economic value of each land used concerned by the projects' footprint

Type of land use	Total economic value (USD/ha)	Source
Forest	1 000	BRLi from CEEPA, 2010 and De Groot et al, 2010
Wetlands	890	BRLi from Gowdy, 2008
Savanna	752	De Groot et al, 2010
Pastureland	430	BRLi (yield of pastureland*fodder price)
Irrigated areas	860	BRLi (average of small scaled schemes' gross margin)

DEGRADATION OF DOWNSTREAM WETLANDS SERVICES

Three main downstream wetlands which are potentially impacted by the regulation of the flows by the dams are: Gambella plains, Sobat wetlands and Machar Marshes. Their surface area will decrease due to the reduction of the peak floods.The following chart shows the loss of the average annual maximum flooded surface for each scenario. The economic analysis uses this loss (of the maximum area) to monetarize the impact as the wetlands services depend on this surface area.

Figure 11-16 : Loss of the average annual maximum flooded area (km²) for the three downstream wetadans imapcted



The costs of the degradation of the downstream wetlands services is evaluated from the economic value of wetlands (see table above: 890 USD/ha).

RISE IN GHG EMISSIONS

The clearing and the burning of lands during the construction and the creation of the dams' reservoirs will rise the GHG emissions. This externality is assessed from the quantity of GHG emission and the lowest carbon price on the market at the international level (1 USD/tonne; World Bank, 2015).

Table 11-16 : Emission of CO_2 eq for each scenario

Tonnes of CO2eq emissions per year (10^6 T)		
Scenarios	Land clearing for irrigation development	GHG emissions from the reservoirs
Sc0	0,04	0,01
Sc1	2,78	0,33
Sc2	2,78	0,35
Sc3a	2,78	0,35
Sc3b	4,05	0,35
Sc4a	4,05	0,35
Sc4b	4,05	0,35

2.2.1.2. Social externalities

INCREASE IN EMPLOYMENT

The projects will create employment. The analysis distinguishes direct and indirect employment. The global assumptions are:

- The number of working days per year is assumed to be 242,
- The average labour cost equals 2 USD/day,
- The fishermen earning is 1.8 USD/day.

For the hydropower sector, it is assumed that the number of full time job per GWh marketed is 0.2 and for the fisheries and the fish farming sector, it is assumed that one fisherman is needed for the production of 3 tonnes of fish per year.

The direct employment for the agricultural sector is evaluated from a ratio of full time equivalent per hectare per year for each crop. The assumptions are summarised in the following table:

Table 11-17 : Full time equivalent workers/ha/year for each crop

WS : Wet season, DS : Dry season, RF : Rainfed, Ir : Irrigated

Crops	Full time equivalent workers/ha/year
Maize (grain) WS ,RF	0,14
Maize (grain) DS, Ir	0,14
Rice WS , RF	0,29
Rice WS, Ir	0,29
Rice DS, Ir	0,29
Sorghum (grain) WS, RF	0,14
Sorghum (grain) DS, Ir	0,14
small grains WS, RF	0,14
Wheat WS, RF	0,14
Teff WS, RF	0,14
Sugarcane , Ir	0,17
Cotton, Ir	0,62
Groundnut WS , Ir	0,41
Groundnut DS, Ir	0,41
Soybean WS , Ir	0,37
Soybean DS, Ir	0,37
Vegetables DS, Ir	0,37
Vegetables WS, Ir(RF Garlic)	0,37
Small vegetable WS, Ir(RF Head cabbage)	0,37
Small vegetable DS, Ir	0,37
Tomato DS, Ir	0,37
Dry beans WS, Ir(RF)	0,37
Dry beans DS, Ir	0,37
Peppers WS, Ir(RF)	0,37
Peppers DS, Ir	0,37
Potato DS, Ir	0,37
Fodder, RF	0,14
Fruit	0,37
Banana, Ir	0,37

The assumptions concerning the indirect employment are showned in the table below :

Table 11-18 : Assumptions for the assessment of the creation of indirect employment

Sector	Indirect job creation
Agriculture	30% of direct agricultural employment upstream and 50% downstream
Hydropower	300% of direct hydropower employment
Fisheries	100% of direct fishery employment
Other indirect employment	20% of all employments

FLOODING PROTECTION

The reduction of the peak flood will lead to a diminution of flooding damages at Gambella. These benefits (avoided costs of flooding damages) are evaluated from the past data on flooding in Ethipopia:

- During the 1988 flood on the Baro river (a 50 years return period flood), all the building of Gambella and Itang were damaged and the crops damages were evaluated around 6 Millions 2016 USD.
- During the 2006 flood in Dire Dawa, Ethiopia, the housing damages were estimated around 7 800 USD/house. This figure is used for estimating the damages in Gambella and Itang.

Assuming that the damages are proportional to the magnitude of the flood, the average annual avoided damage is computed for each return period. The formula for the average annual avoided costs is the following:

$$\frac{\text{\% of decrease in flood peak} * (\text{Housing damages} + \text{crops damages})}{\text{Return period}}$$

Table 11-19 : % of decrease in flood peak relative to baseline at Gambelle

Return Period of Floods	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
20	11%	55%	13%	13%	55%	55%
50	11%	57%	15%	15%	57%	57%
100	11%	59%	17%	17%	59%	58%
200	11%	60%	19%	19%	60%	59%

IMPROVEMENT OF HEALTH

The access to electricity, the improvement of the access to water and to food security will lead to a better general health of the beneficiary population (cf. Table 11-20). It is considered that over the first twenty years of the project the life expectancy will increase of one year in the case of a full development of both hydropower and irrigation.

Table 11-20 : Part of the population who benefots from the projects per basin

Sub-basin	Part of the population who benefits from HP	Part of the population who benefits from the irrigation schemes
Machar marshes	13%	20%
Birbir	10%	15%
Geba	9%	16%
Alwero	1%	30%
Gilo	5%	40%
Lower Akobo	2%	8%
Agwei	6%	0%
Upper Akobo	5%	11%
Upper Pibor East	18%	0%
Upper Pibor West	9%	0%
Lower Pibor	4%	0%
Sobat	14%	26%
Baro	5%	33%

The benefits of the increase of the life expectancy is evaluated from the average salary (2 USD/day) and the life expectancy (63 years in Ethiopia (World Bank)). This benefits is weighted for each scenario by the importance of the development of hydropower and irrigation (see table below).

Table 11-21 : Weighting of the life expectancy benefit for each scenario

	Sc1	Sc2	SC3a	SC3b	SC4a	SC4b
Weighting for hydropower	16%	50%	46%	46%	50%	47%
Weighting for the irrigation schemes	33%	37%	28%	37%	48%	50%

2.2.1.3. Economic externalities

Improvement of livestock conditions

The creation of the dams' reservoirs and the fodder crop development will favour the livestock productivity and associated urbanisation will encourage a change of practices from pastoralism towards agro-pastoralism. Currently the split between pastoralism and agropastoralism is 75% - 25% and we make the assumption that the project will lead to a repartition 70%-30%.

The basins concerned are: Machar Marshes, Birbir, Geba, Alwero, Gilo, Lower and Upper Akobo, Sobat and Baro. The externality depends on the part of irrigation demand that is satisfied and the area under cultivation under each scenario.

The other changes are the increase in the off-take rate (from 2% to 5% for pastoral system and from 5% to 10% for agro-pastoral system). The weight of the livestock will increase as well (see table below) and the production of milk also.

Table 11-22 : Assumptions for meat production

	Without scenario				With scenarios			
	Cattle	Sheep	Goats	Chicken	Cattle	Sheep	Goats	Chicken
Average alive weight (kg)	300	25	25	1	450	35	35	1
Rate weight meat/alive weigth	0,4	0,4	0,4	0,7	0,4	0,4	0,4	0,7

Table 11-23 : Assumptions for milk production

	Without scenario	With scenario
% of female for cattle	50%	50%
% of dairy cow milk among female cattle	30%	60%
Average production/head/day (l)	1,0	2,5
Number of days of production/year	263	263

Increase of the number of navigable days between Gambella and Baro mouth

The number of navigable days on the Baro river between Gambella and the confluence with the Sobat will increase. This benefit is evaluated from the avoided investment cost of the construction of a road between Gambella and Baro mouth, that represents 160 km. The investment cost of a road is around 444 000 USD/km (updated cost from M. Abebe, 2003, Barge operation capacity assessment for the Republic of Sudan, 17 p.).

2.2.2. Main results

To sum up, the environmental externalities are the avoided costs of deforestation due to the development of hydropower and irrigation (+), the environmental footprint of the projects (-), the degradation of downstream wetlands due to the reduction of the peak flood (-) and the rise of GHG emissions caused by the construction of the reservoirs and the irrigation schemes (-).

The social externalities are all positive: they concern the creation of direct and indirect employment; the reduction of flooding damages and the improvement of the health of the beneficiary population.

The economic externalities are also all positive. The projects will favor better conditions for livestock and the development of navigation on the Baro river between Gambella and Baro's mouth.

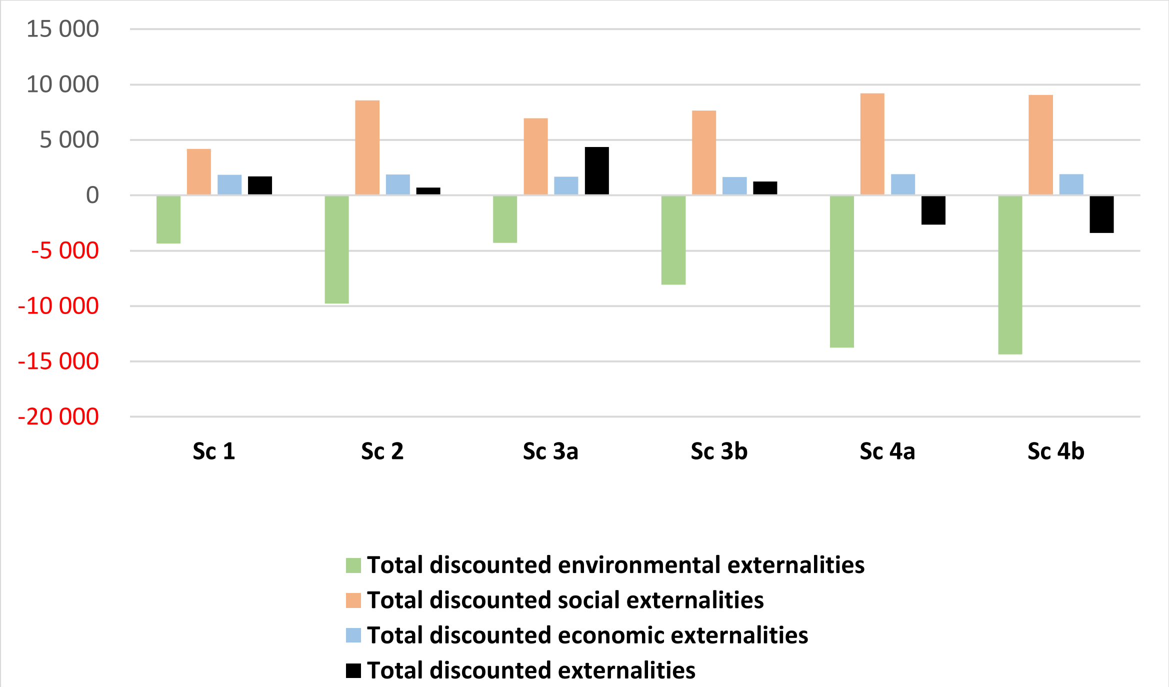
The sum of the externalities over the time period (40 years) is presented in the following chart and the table. The environmental externalities are negative but the social and economic externalities are positive in all scenarios. The environmental externalities are the most variable between scenarios: the scenarios 2, 4a and 4b impact the most the environment.

Table 11-24 : Externalities of the project on the time period for each scenario (Millions 2016USD)

In red: the negative externalities and in black the positive exterlities

	Sc 1	Sc 2	Sc 3a	Sc 3b	Sc 4a	Sc 4b
Environmental externalities						
Avoided costs of deforestation HP	277	897	828	828	899	829
Avoided costs of deforestation - Irrigation	363	435	291	347	479	513
Total environmental footprint	-11 007	-14 196	-8 058	-11 068	-16 756	-18 303
Degradation of downstream wetlands	-4 657	-16 438	-7 386	-15 497	-25 623	-25 811
Rise of GHG emissions	-2 619	-2 404	-2 472	-3 148	-2 937	-2 902
Total environmental externalities	**-17 643**	**-31 705**	**-16 798**	**-28 539**	**-43 938**	**-45 673**
Total discounted environmental externalities	***-4 356***	***-9 773***	***-4 292***	***-8 064***	***-13 766***	***-14 370***
Social externalities						
Fisheries employment	25	35	35	35	35	35
Fish farming employment	40	49	31	39	53	56
Rizipisciculture employment	1	2	1	1	2	2
Agricultural employment in Ethiopia	953	1 879	184	1 183	2 429	2 747
Agricultural employment in South Sudan	1 607	1 607	1 490	1 209	1 550	1 644
Hydropower employment	1 259	4 403	4 022	4 022	4 414	4 094
Other employment	777	1 595	1 153	1 298	1 696	1 716
Flooding protection	10	52	14	14	52	52
Health improvement	8 126	16 109	13 952	15 308	17 750	17 272
Total Social externalities	**12 798**	**25 730**	**20 882**	**23 108**	**27 980**	**27 618**
Total discounted social externalities	***4 199***	***8 583***	***6 974***	***7 661***	***9 226***	***9 075***
Economic externalities						
Meat production in Ethiopia	450	455	408	402	460	462
Meat production in South Sudan	1 276	1 291	1 154	1 134	1 300	1 307
Milk production in Ethiopia	1 042	1 055	947	935	1 068	1 074
Milk production in South Sudan	2 726	2 759	2 476	2 445	2 793	2 808
Fisheries (indirect HP profits)	23	32	32	32	32	32
Increase in the number of navigable days	71	71	71	71	71	71
Total economic externalities	**5 588**	**5 664**	**5 088**	**5 020**	**5 724**	**5 755**
Total discounted economic externalities	***1 854***	***1 880***	***1 680***	***1 657***	***1 902***	***1 912***
Total externalities	**743**	**-311**	**9 172**	**-411**	**-10 233**	**-12 300**
Total discounted externalities	**1 697**	**691**	**4 363**	**1 254**	**-2 639**	**-3 383**

Figure 11-17 : Externalities of the projects for each scenario over the time period (Millions 2016USD)



3. COMPARATIVE ANALYSIS

3.1. BY SECTOR

In the financial point of view (i.e. *is the project profitable for the investor?*) the best scenarios for hydropower is clearly Scenario 2 and Scenario 4a. The large-scaled irrigation seem economically viable except for Scenarios 3a and 3b for which the FNPV is negative in Ethiopia. Scenario 2 and 4a and 4b appear to be the best. The small-scaled irrigation schemes, the fish farming and rizipisiculture have a very low FNPV (see table below).

Figure 11-18 : Financial Net Present Value (Millions 2016 USD) for each sector and scenario

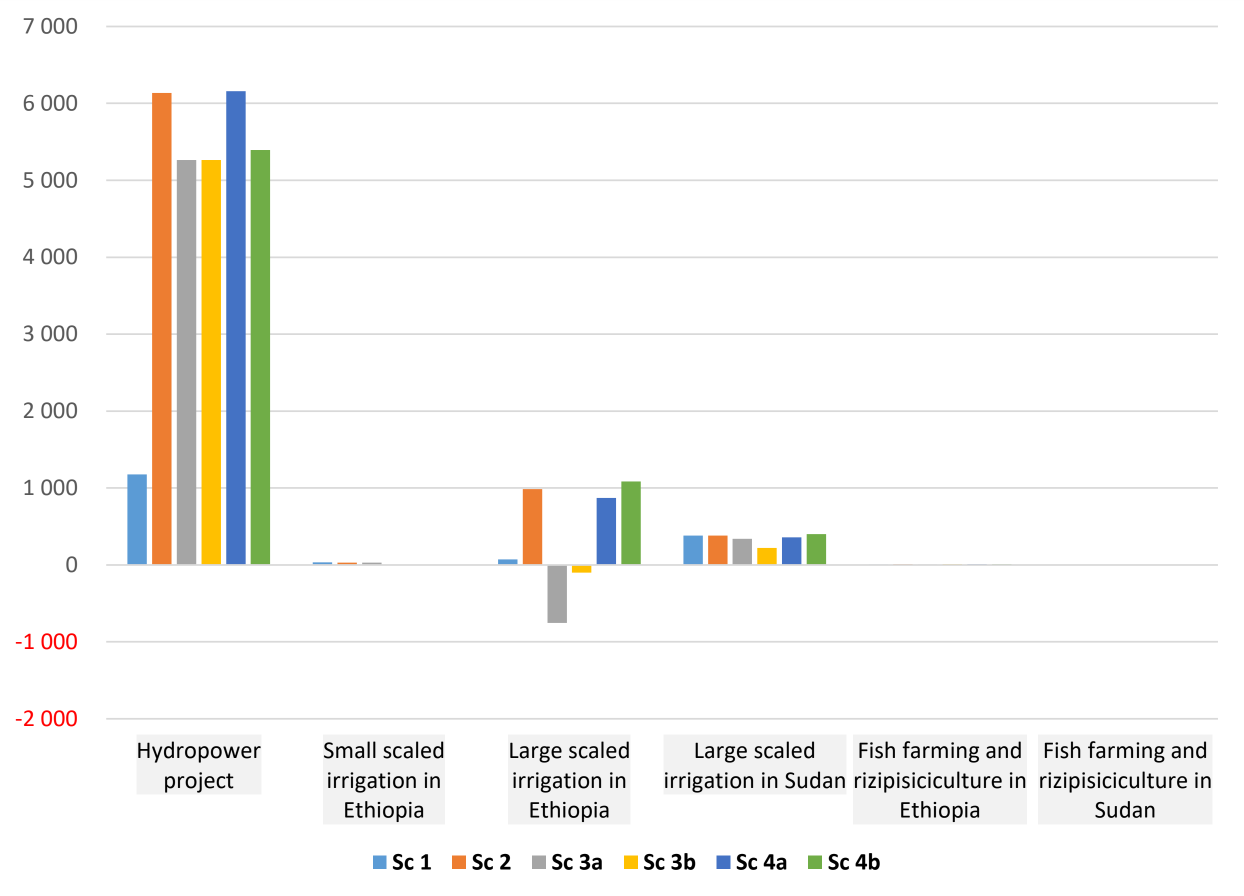


Table 11-25 : Financial Net Present Value (Millions 2016 USD) and Financial Internal Rate of return for each sector and scenario

FNPV							
Sector	**Indicator**	**Sc 1**	**Sc 2**	**Sc 3a**	**Sc 3b**	**Sc 4a**	**Sc 4b**
Hydropower project	FNPV (M$)	1 179	6 134	5 264	5 264	6 160	5 392
	FIRR	24%	46%	39%	39%	47%	40%
Small scaled irrigation in Ethiopia	FNPV (M$)	33	31	31	-1	-1	-1
	FIRR	11%	11%	11%	10%	10%	10%
Large scaled irrigation in Ethiopia	FNPV (M$)	72	987	-754	-102	872	1 084
	FIRR	11%	18%	1%	9%	17%	18%
Large scaled irrigation in Sudan	FNPV (M$)	384	384	340	223	358	400
	FIRR	20%	20%	20%	20%	20%	20%
Fish farming and rizipisiciculture in Ethiopia	FNPV (M$)	9	10	7	9	11	11
	FIRR	NR	NR	NR	NR	NR	NR
Fish farming and rizipisiciculture in Sudan	FNPV (M$)	2	2	2	1	2	2
	FIRR	32%	32%	37%	51%	32%	32%

From the economic point of view (i.e. *Is the project viable/sustainable for the society?),* the hydropower and the large–scaled irrigation in Ethiopia and the fish-farming/rizipisiculture have a positive ENPV. The large-scaled irrigation in South Sudan and the small-scaled irrigation seem not viable. **It is important to keep in mind that these economic results are not sufficient to judge of the relevance of the projects as not all the impacts have been taken in account in the Costs-Benefits Analysis.**

Figure 11-19 : Economic Net Present Value (Millions 2016 USD) for each sector and scenario

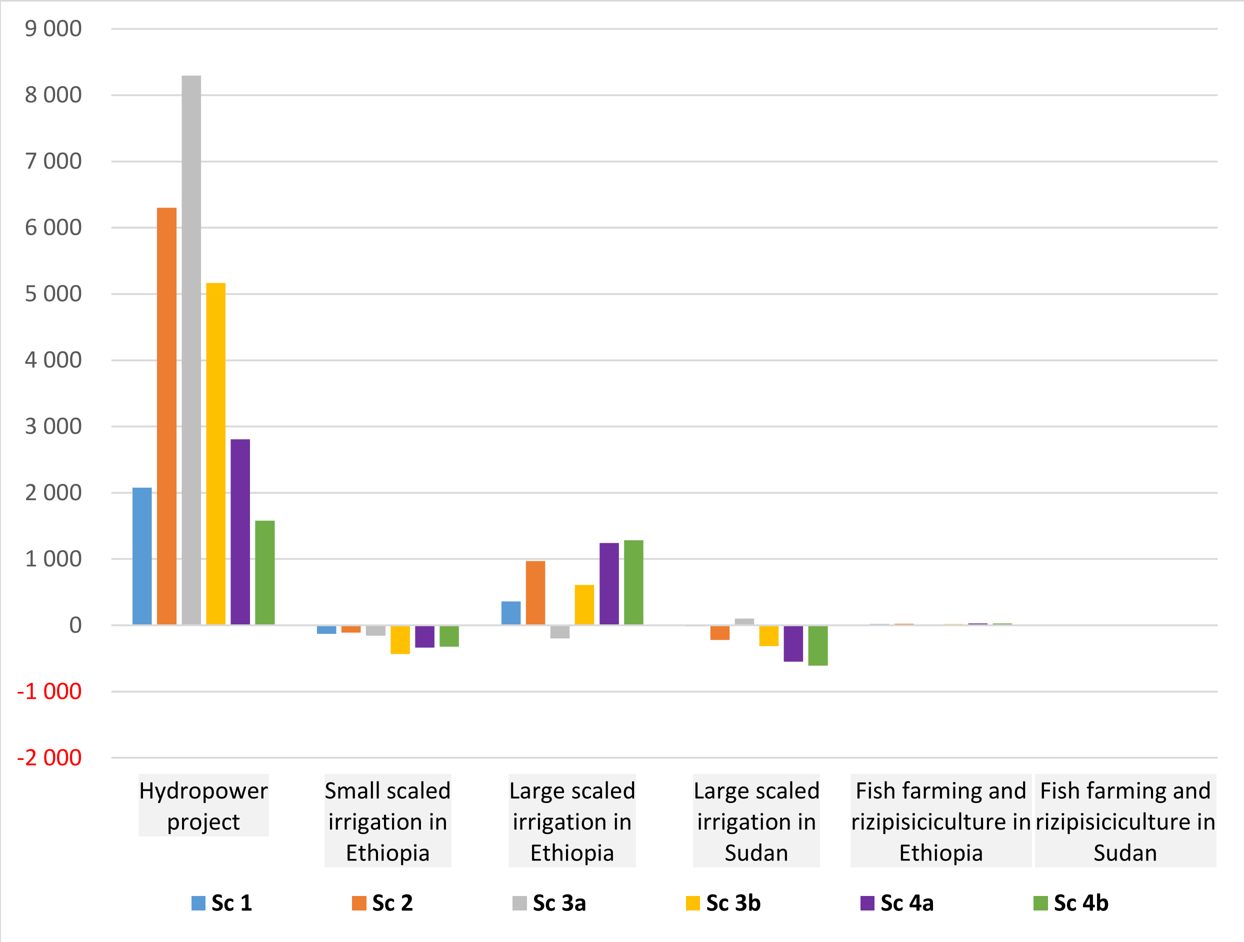


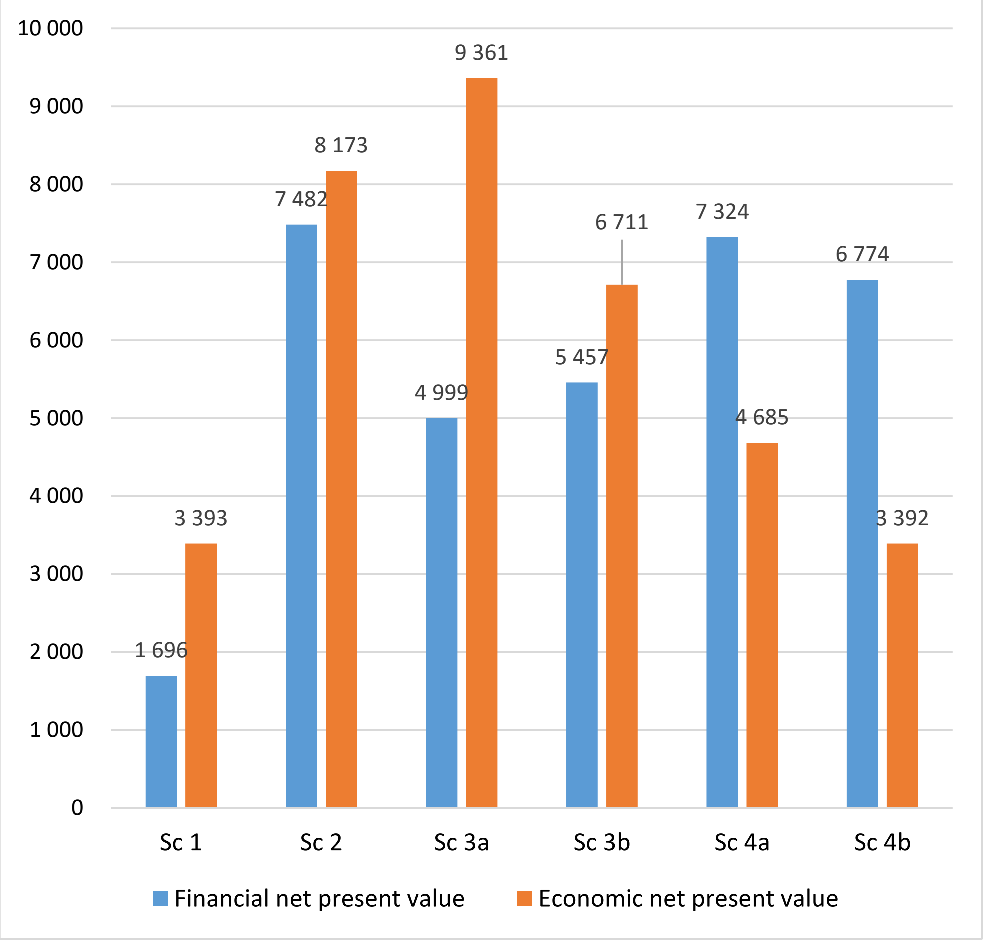
Table 11-26 : Economic Net Present Value (Millions 2016 USD) and Economic Internal Rate of return for each sector and scenario

ENPV								
Sector	**Indicator**	**Sc 1**	**Sc 2**	**Sc 3a**	**Sc 3b**	**Sc 4a**	**Sc 4b**
Hydropower project	ENPV (M$)	2 078	6 301	8 293	5 167	2 806	1 580
	EIRR	23%	33%	39%	28%	24%	20%
Small scaled irrigation in Ethiopia	ENPV (M$)	-127	-112	-157	-432	-337	-325
	EIRR	9%	10%	9%	7%	8%	8%
Large scaled irrigation in Ethiopia	ENPV (M$)	360	971	-200	611	1 242	1 281
	EIRR	12%	18%	4%	13%	20%	20%
Large scaled irrigation in Sudan	ENPV (M$)	-15	-223	103	-312	-548	-608
	EIRR	13%	11%	15%	7%	7%	7%
Fish farming and rizipisiciculture in Ethiopia	ENPV (M$)	20	24	16	21	26	27
	EIRR	NR	NR	NR	NR	NR	NR
Fish farming and rizipisiciculture in Sudan	ENPV (M$)	5	5	4	3	4	5
	EIRR	38%	38%	44%	62%	38%	38%

3.2. GLOBAL ANALYSIS

If we look at the overall results, all the scenarios appear to have a positive Financial Net Present Value (FNPV)[52] and Economic Net Present Value (ENPV)[53]. The difference between the FNPV and the ENPV corresponds to the externalities.

Figure 11-20 : FNPV and ENPV (Million 2016 uSD) for each scenario



The second chart sorts the scenarios according to the FNPV (**in blue**) and the third chart sorts the scenario according to the ENPV (**in orange**).

Financially speaking (that is to say from the investors' point of view) the best scenarios are Scenario 2 and Scenario 4a:

- **Scenario 2** corresponds to an irrigation of 541 000 ha and a production of 12 274 GWh/year with a conservation of sensitive areas. The results emphasizes the large financial impact of Tams dam: if we compare Scenario 2 to Scenario 1 (without Tams dam), it appears that its FNPV is almost four times higher than in Scenario 1.
- **Scenario 4a** considers full development of the projects which explains a high financial profitability. Scenario 4b which also plans a large development is very close to the Scenario 4a in terms of

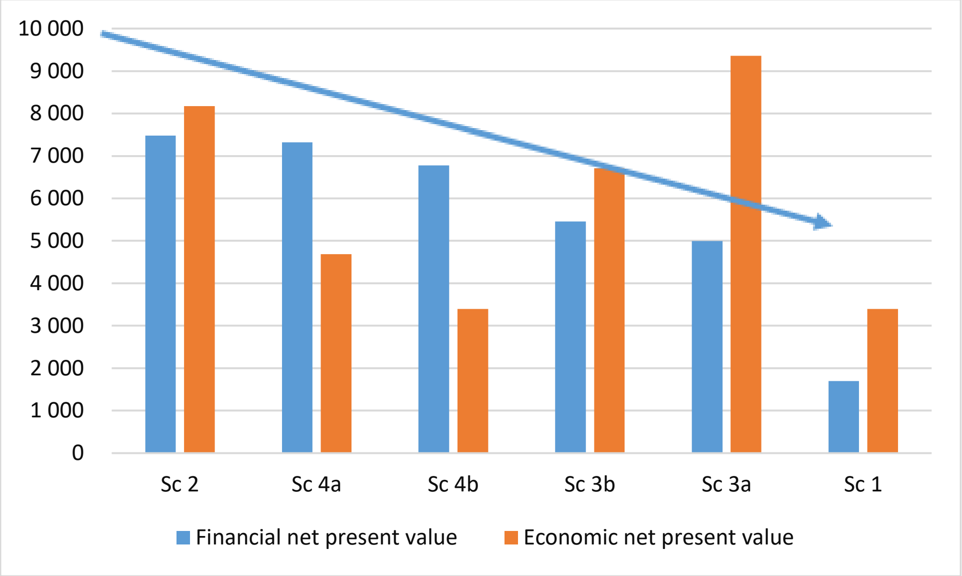
52 The FNPV gives an indication of the profitability from the investors' point of view.

53 The ENPV gives and indication of the "profitability" or relevance of the scenario from the whole society's point of view.

profitability but little behind as it favors irrigation over hydropower while hydropower is more profitable.

Scenarios 3a and 3b present a moderate FNPV due to the fact that management rules are implemented in order to regulate the flows and thus preserve the downstream wetlands. Even if the impact on hydropower generation is relatively low, the financial impact is significant as the added value of hydroelectricity is high. The low profitability is also explained by the fact that less than 50% of the irrigation water demand is satisfied.

Figure 11-21 : Scenarios sorted according to the FNPV from the highest to the lowest (in blue)



Economically speaking (that is to say, considering all the impacts on the environment, the local economy and the welfare of the population), the best scenario is Scenario 3a and the "second best" is Scenario 2:

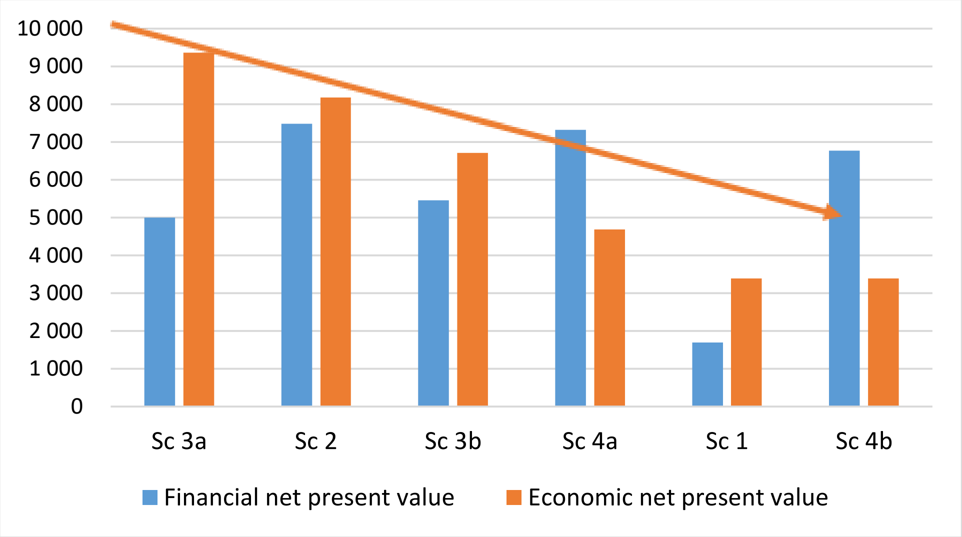
- **Scenario 3a** is the one which takes the more into account the environment as it plans to conserve the sensitive areas and implement a regulated management of dams' flows to guarantee a sufficient amount of water to the downstream wetlands.
- **Scenario 2** appears to be quite satisfying at the economic level as it conserves the sensitive areas while assuring a large development of irrigation and hydropower, which both generate positive social and economic externalities (employment, improvement of health, etc.).

Scenario 3b is placed third. In this scenario there is no conservation of protected areas but the implementation of management measures to regulate the flows and allow a sufficient amount of water for the downstream wetlands. Scenario 3b and 3a are very close financially speaking but quite different in terms of indirect impacts. The difference of the ENPV is mainly due to the conservation of sensitive areas in Scenario 3a.

Scenarios 4a and 4b present an ENPV lower than the FNPV. It indicates that in these scenarios the negative externalities are higher than the positive ones.

In conclusion, the Scenario 2 appears to be interesting for investors with an acceptable impact on the environment and the society.

Figure 11-22 : Scenarios sorted by the ENPV from the highest to the lowest (in orange).



Annex 6: Water resources modelling

BARO-AKOBO-SOBAT MULTIPURPOSE WATER RESOURCES DEVELOPMENT STUDY PROJECT

Water Resources Modelling – Draft Report

ACRONYMS AND ABREVIATIONS

BAS	Baro-Akobo-Sobat
CRU	Climatic Research Unit
ENTRO	Eastern Nile Technical Regional Office
FAO	Food and Agricultural Organization
GCM	Global Climate Models
GHCN	Global Historical Climate Network
IWRDMP	Integrated Water Resources Development and Management Plan
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NBI	Nile Basin Initiative
NBRP	Nile Basin Research Program
SMHI	Swedish Meteorological and Hydrological Institute
SSEA	Strategic Social and Environmental Assessment

1. INTRODUCTION

The objective of the Baro Akobo Sobat Multipurpose Water Resources Development Study is to assist ENTRO in preparing an Integrated Water Resources Development and Management Plan (IWRDMP) based on a Strategic Social and Environmental Assessment (SSEA), and further develop investment packages for cooperative development in the Baro-Akobo-Sobat sub-basin.

A key element of the Study relates to an understanding of the hydrological characteristics of the basin, in both space and time, and how this will be impacted under different development and management scenarios. As part of the Baseline Phase of the Study, a Water Balance Model was developed for the current (baseline) conditions in the basin. This Water Resources Modelling – Final Report provides an overview of the modelling of the baseline model.

2. MODELING APPROCH AND OBJECTIVES

The main objective of the water balance modelling component as part of the baseline phase of this study is to quantify the available water within the study basin in both space and time. During subsequent phases of this study, the configured water balance model will be used as an analytical tool to assess the hydrological impacts of development interventions and management options, which can then be translated into relevant social, environmental and economic indicators to inform scenario evaluation. A two-step modelling approach was used. Firstly, a rainfall-runoff model was calibrated against observed stream flows at selected flow gauging stations in the basin. Secondly, the calibrated rainfall-runoff model was used to generate long-term monthly flows at various key locations within the basin. The modelling procedure involved seven sequential tasks:

1. Evaluation of flow records
2. Delineation of model sub-catchments
3. Pre-processing of climate data
4. Quantification of existing water demands and identification of existing water resources infrastructure
5. Calibration of the rainfall-runoff model
6. Configuration and validation of the water balance model
7. Simulation of long-term flow sequences and conducting a water balance.

The NAM model was used for rainfall-runoff modelling, while MIKE HYDRO Basin was used for the water balance model. As far as possible, the configurations of both of these models made use of data and information from existing models which were evaluated in detail during the Scoping Phase of this Study.

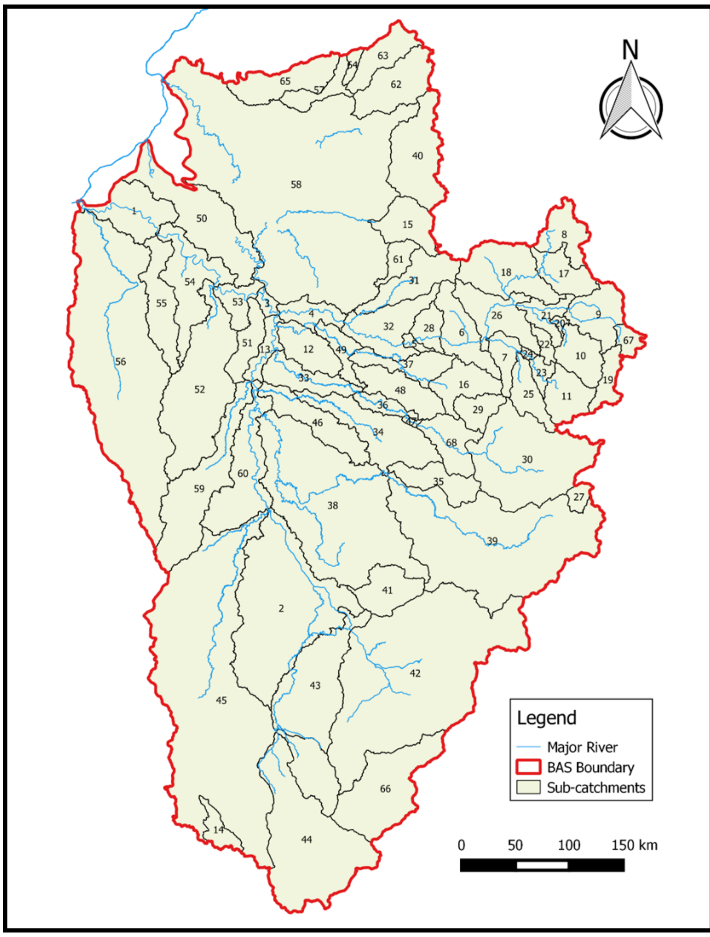
3. EVALUATION OF FLOW RECORDS

Historically, an extensive river gauging network existed in the Baro-Akobo-Sobat sub-basin, with most of the major rivers and spills having been gauged at some time - even though it might have been only for short or intermittent periods. Flow data at stations in the basin are available from various sources including the Nile Basin Encyclopedia, the Ethiopian Master Plan Reports, the Nile Basin Research programme, the Nile Basin Initiative, ENTRO databases, the Ethiopian Ministry of Water, Irrigation and Energy and previous studies. Most of the stations have very little data available and are characterised by extensive periods of missing or incomplete data. It should be noted that several stations have more than one flow record from different sources. The spatial coverage of flow gauging stations also varies considerably across the basin. The upper Baro sub-basin as well as the lower Sobat River has good coverage of flow gauging stations, while the Gilo, Akobo and Agwei rivers are poorly gauged. There are no flow gauging stations located in the upper part of the Pibor sub-basin. Currently, there are three active flow gauging stations in the Ethiopian part of the basin namely the Baro at Itang, the Geba near Suppi and the Alwero at Dumbong Village, and only one in South Sudan at Hillet Doleib (NBI, 2014).

Time series plots, single mass plots, chronograms and unit runoff analyses were used to evaluate the quality of the available flow data in terms of stationarity, missing data and flow correlation (see Annex A.1). Based on the outcome of the data quality control task, 28 stations were initially selected for further scrutiny. After further evaluation and consideration, a final selection of flow gauging stations and flow record periods were made to take forward in the hydrological analysis. These are highlighted in Annex A.1, while a map showing the locations of the stations is also included in this Annex.

4. DELINEATION OF MODEL SUB-CATCHMENTS

In order to ensure that the rainfall-runoff and water balance models accommodate the climate and physiographic variability across the Baro-Akobo-Sobat sub-basin, the basin was divided into smaller sub-catchments for modelling purposes based on geographical, meteorological and drainage network considerations. The delineation of these sub-catchments were further refined based on the locations of stream flow gauges, inter-catchment spills, wetlands, and future infrastructure developments. Figure 11-23 displays a map of the model sub-catchments, while Annex A.4 provides relevant information for each sub-catchment.



ID	Sub-catchment	ID	Sub-catchment
1	Hillet Doleib	35	Akobo/Aculla
2	Residual Pibor Post	36	u/s Gilo Flood Dam
3	Nasir	37	Alwero 2
4	Baro at Burebeiy	38	Agwei Flood Dam
5	Baro at Itang	39	Upper Akobo
6	Baro at Gambella	40	Yabus Bridge
7	Baro at Kella	41	Upper Kenamuke
8	Birbir at Yubdo	42	Kobowen
9	Geba at Suppi	43	Lower Kenamuke
10	Sor at Metu	44	Upper Domongo
11	Baro at Masha	45	Veveno/Lotilla
12	Piyor	46	Lower Akobo
13	Lower Pibor	47	Pignudo
14	Torit	48	Alwero 1
15	Daga Post	49	Lower Alwero
16	Abobo Dam	50	Wal
17	Birbir A	51	Twalor
18	Birbir R	52	Nyanding
19	Geba 1	53	Sobat u/s Nyanding
20	Sor	54	Sobat u/s Beguyang
21	Geba R	55	Beguyang
22	Gumero	56	Fullus
23	Baro 1	57	*Drains out of study area
24	Baro 2	58	Machar Marshes
25	Genji	59	Into Lower Pibor
26	Tams	60	Upper Pibor
27	Kashu	61	Lau R at Kigille
28	Itang	62	Tombak R at Nela
29	Dumbong	63	Ahmar R at Kofa
30	Gilo 1	64	Agab at Kofa
31	Jakau	65	*Drains out of study area
32	Baro Flood Dam	66	*Drains out of study area
33	d/s Gilo Flood Dam	67	Geba 2
34	Akobo Flood Dam	68	Gilo 2

Figure 11-23: Sub-catchment delineation of the Baro-Akobo-Sobat sub-basin

5. PRE-PROCESSING OF CLIMATE INPUT DATA

5.1. Derivation of Catchment Rainfall

5.1.1. Monthly Rainfall

For the calibration of the rainfall-runoff model as well as for the simulation of long term flow sequences, reliable rainfall records are required. The primary source of rainfall data for this study was the database of patched monthly rainfall values across the Nile Basin for periods extending from 1904 to 2011 at some stations (NBI, 2014). The data originated from the Nile Basin Encyclopedia, the Ethiopian Masterplan Studies, the Global Historical Climate Network (GHCN) database, the Food and Agricultural Organization (FAO) climate database, the Ministry of Water and Energy in Uganda (MWE), the Nile Basin Research Program (NBRP) and previous recent studies. From this dataset, rainfall stations located within the Baro-Akobo-Sobat sub-basin as well as stations adjacent to the basin boundary were selected. Annex A.2 provides information about the selected stations (125 in total) in tabular format and also includes a chronogram showing the record length and data availability for both the raw and patched datasets. Locations of rainfall stations are also displayed on a map in Annex A.2.

Each of the observed rainfall records was tested for stationarity, and assessed to ascertain the extent of any missing data. Two stations (Saiyo and Fangak) were identified as non-stationary, while two other stations (Alge and Dembi Dollo) had significant periods of missing data. All four stations were removed from the dataset. In addition, the Mean Annual Precipitation (MAP) at each station was checked against adjacent station MAPs to highlight possible spatial anomalies. Two stations were found to be comparatively inaccurate: Dembi Dollo, with a low MAP of 544 mm, and Mizan Teferri, with a high MAP of 2293 mm. These two stations were also excluded from the dataset.

Although the monthly patched values provide a comprehensive dataset in the upland areas of the main sub-catchments, spatially, there is a paucity of rainfall stations in the Pibor, lower Gilo, Akobo and Sobat sub-catchments as well as in the Machar Marshes. Furthermore, except for six stations, the majority of the rainfall records do not extend beyond 2004.

In order to extend the rainfall to 2014, the global high resolution, land precipitation gridded rainfall dataset from the Climatic Research Unit (CRU) at the University of East Anglia was used (Harris et al., 2014). The CRU dataset has a resolution of 50 km by 50 km and monthly CRU rainfall data are available from 1901 to 2014. The CRU monthly rainfall data were compared to the observed monthly rainfall data for overlapping periods. A selection of these comparisons is shown in Figure 11-24 for various model sub-catchments. The correlation between the CRU and observed annual rainfall values vary in space and time within the study area and appears to be stronger pre-1980 when more accurate rainfall data were probably available for improved meteorological modelling. The CRU data were not used to generate rainfall in parts of the basin which are lacking in observed rainfall data, due to concerns about the representativeness of the CRU data and interpolation between existing stations was preferred.

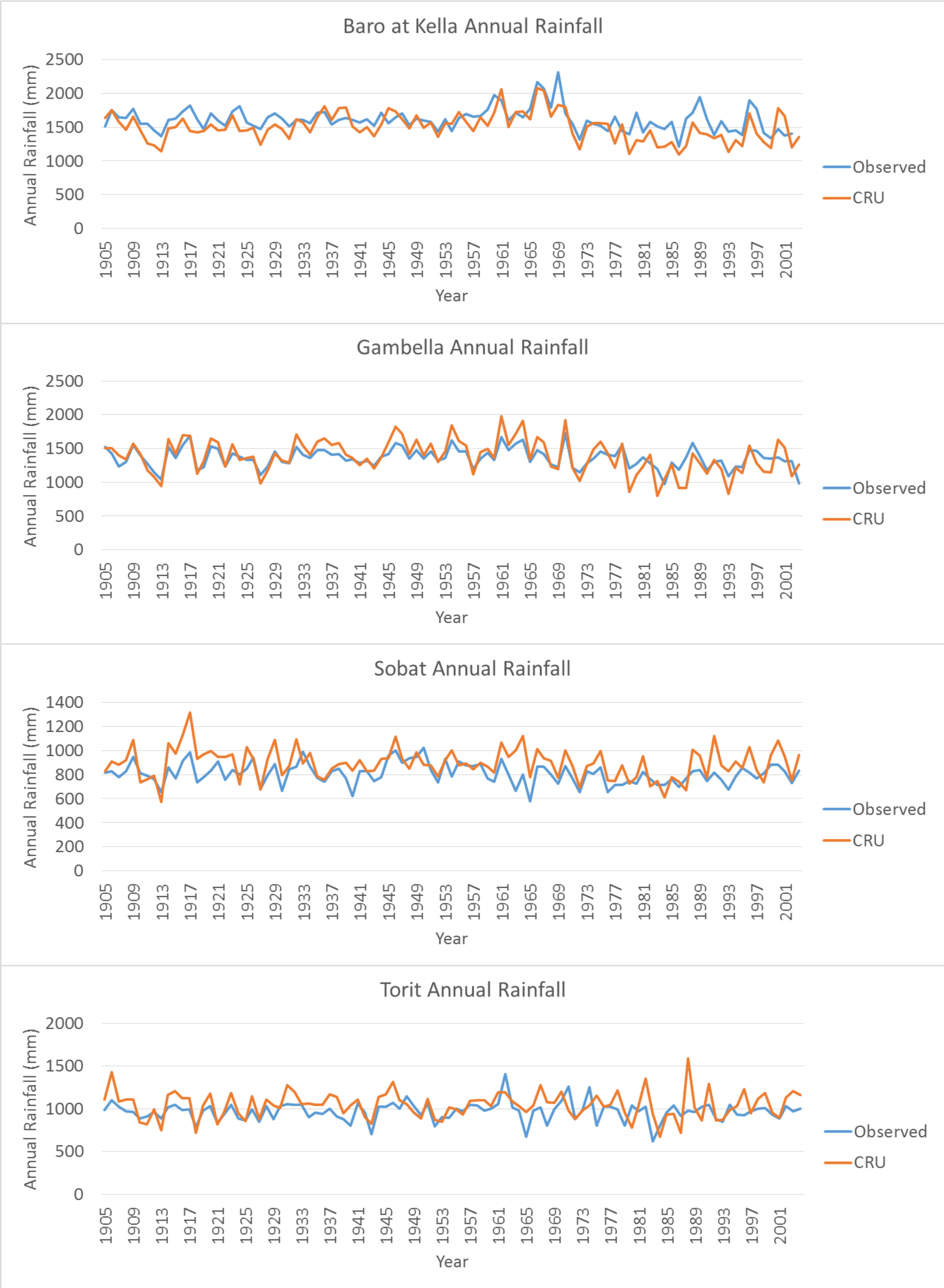


Figure 11-24: Comparison of CRU and Observed monthly rainfall data

5.1.2. Daily Rainfall

An important input to the deterministic rainfall-runoff modelling undertaken as part of this study is daily rainfall depths. However, very limited daily rainfall data are available within the study area. Daily rainfall values at only four stations within the Baro-Akobo-Sobat sub-basin, from 1951 to 1991, were obtained from the Global Historical Climatology Network (GHCN) at Gore, Jimma, Juba and Malakal. These stations, however, are not spatially representative of the whole study basin, and also include missing values throughout the record period. In order to supplement the paucity of daily rainfall data, daily modelled rainfall data from the Swedish Meteorological and Hydrological Institute (SMHI) database at the locations of key stations within the basin were used to disaggregate monthly rainfall to representative daily rainfall patterns. The SMHI dataset is at a 45 km by 45 km resolution and provides daily rainfall values from 1951 to 2005. The datasets are downscaled from Global Climate Models (GCMs) which have been forced by known or estimated climate parameters from CMIP5 historical data. Since the SMHI data only extends from 1951 to 2005, an average daily distribution was used for the period between 1905 and 1950 and post 2006.

5.1.3. Catchment Rainfall

Daily catchment rainfall files (expressed as percentage of MAP) for each of the model sub-catchments were calculated using a Thiessen Polygon approach which weighted the contributions of selected rainfall stations within the vicinity of sub-catchments based on the proximity of each station to that sub-catchment. Annex A.4 provides information about the combination of rainfall stations which were used to generate monthly catchment rainfall files for each of the model sub-catchments. The stations which were used to disaggregate the monthly rainfall for each sub-catchment into daily patterns are also listed in the Annex.

A Mean Annual Precipitation (MAP) surface for the study basin was generated based on the MAPs of all selected rainfall stations using Kriging, as shown in Figure 11-25. Based on the MAP surface, an MAP value was calculated for each model sub-catchment (see Annex A.4), after which the daily percentage MAP file for each sub-catchment was multiplied by this value to obtain a time series of daily rainfall.

5.2. Evaporation Estimates

Average monthly evaporation values in the vicinity of the Baro-Akobo-Sobat sub-basin were available from the Ethiopian Master Plan studies and the Global FAOClim database. In addition, location specific observed and calculated datasets were sourced from previous study reports. Very little evaporation data are available in the southern part of the basin and particularly in South Sudan.

In order to supplement this data, the FAO Penman-Monteith ET0 Calculator was employed to calculate monthly average evaporation values using climate data at key station locations. Maximum and minimum daily temperatures and relative humidity were used as input to the Calculator, and were extracted from the SMHI climate dataset. The Calculator was used to determine the evapotranspiration at three additional locations, namely Pibor Post, Torit and Malakal. Annex A.3 includes a table which summarises the average monthly evaporation values at the available stations and sites as obtained from the above sources. The Mean Annual Evaporation (MAE) for each available station was compared to adjacent stations, and anomalous stations were not used for the purpose of this study. Stations with missing evaporation data were also excluded. The stations which were ultimately used in the hydrological modelling are highlighted in Annex A.4. Using these stations' data, a Mean Annual Evapotranspiration surface was generated for the study area using Kriging, as shown in Figure 11-26. In order to calculate monthly reference evapotranspiration values for each model sub-catchment, a representative evaporation station was assigned to each model sub-catchment. The monthly values at each station were expressed as a percentage of the MAE and, based on the MAE value for each sub-catchment as determined from the MAE surface, monthly percentage MAE values were converted to absolute monthly values. Estimates of open water evaporation, which was assumed to characterise the marshes and floodplains during the wet season, were based on an adjustment of +20% to the FAO Penman-Monteith ET0 values (USGS, 2013). Annex A.4 provides information about the reference MAE values for sub-catchments as well as the representative evaporation stations assigned to each sub-catchment.

BARO-AKOBO-SOBAT (BAS) SUB-BASIN: MEAN ANNUAL RAINFALL

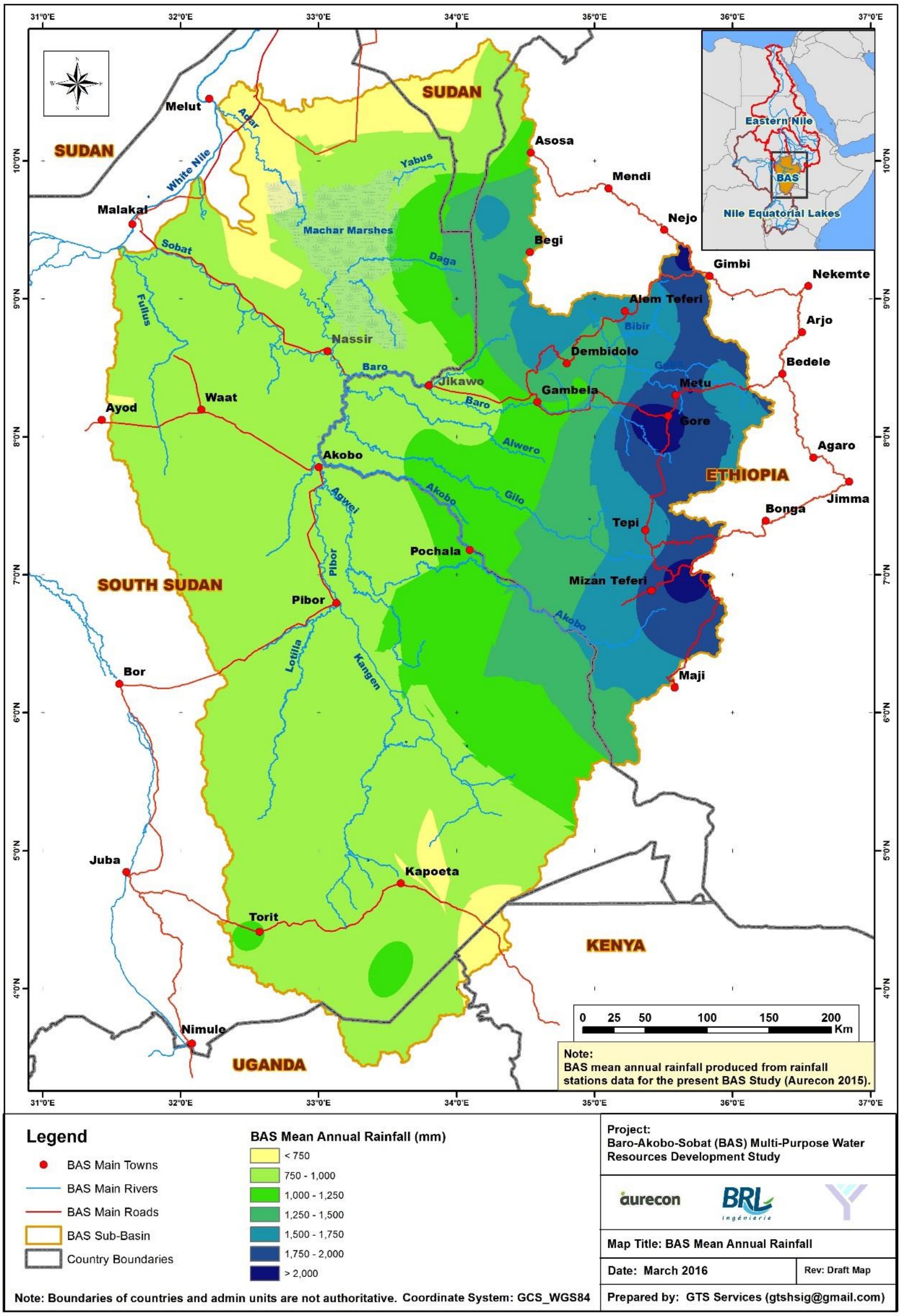


Figure 11-25: Mean Annual Rainfall across the Baro-Akobo-Sobat sub-basin

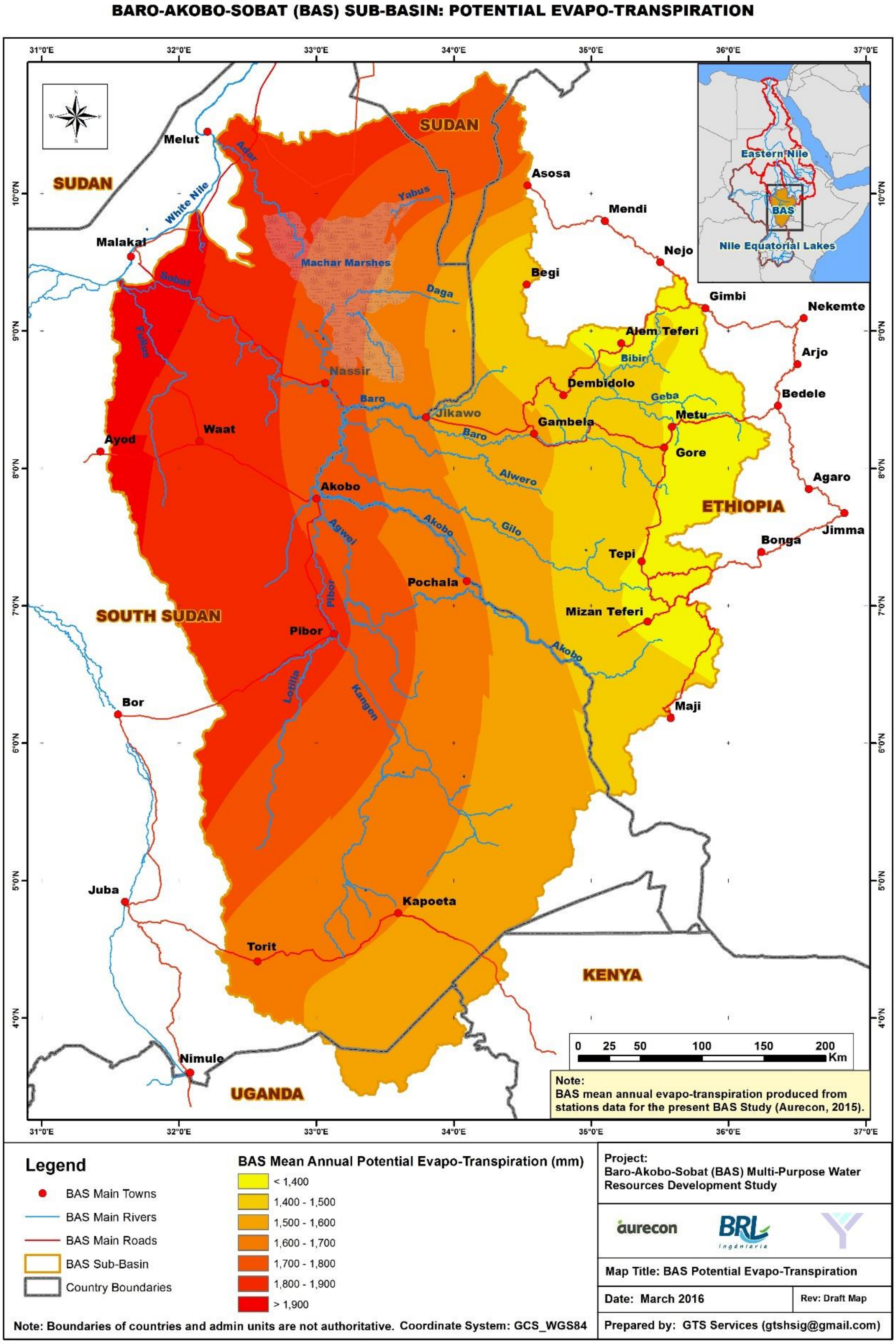


Figure 11-26: Mean Annual Evapo-Transpiration across the Baro-Akobo-Sobat sub-basin

6. EXISTING SURFACE WATER USE AND WATER RESOURCES INFRASTRUCTURE

The Baro-Akobo-Sobat sub-basin is largely undeveloped. The only major scheme in the basin is the Abobo Irrigation Scheme. This is fed from the Abobo Dam, which is situated on the Alwero River. Construction of the dam began in the early 1980s and it was completed in 1997. The dam was intended for the development of large-scale irrigated agriculture, however, the dam was never used for its intended purpose. An irrigation potential of over 10,000 ha has been estimated for the dam. In 2013, two agricultural projects were initiated in the Gambella region, including a large-scale rice farm near Abobo and a large-scale sugar-cane and corn farm. These farms have shown interest in moving towards irrigated agriculture using water from the Abobo Dam or Baro River. There are no other existing commercial irrigation or hydropower installations in the basin.

Water from the rivers is used for domestic and livestock water requirements by riparian communities, while recession agriculture along the banks of rivers is also very important in certain areas. During the wet season, the domestic and livestock water demands are negligible compared to the average daily flows in the rivers. However, during the dry season, especially in certain parts of the basin, these demands cannot always be satisfied using run-of-river supply. The Anuwak, Opo and Komo peoples cultivate the banks of the Baro, Akobo and Sobat Rivers with mainly maize, beans and sorghum. The Shilluk people farm along the banks of the White Nile and Sobat Rivers with sorghum, maize, groundnuts, beans, vegetables and tobacco. Small-scale irrigated cropping also exists within the basin. Along the White Nile, small-scale irrigators pump water directly from the river to water mainly cereals and vegetables.

Rain-fed crop cultivation is the principal livelihood activity in the regions of the basin which receive adequate rainfall. The economy is subsistence oriented, implementing simple manual agricultural methods. Maize and sorghum are the main crops farmed. In the Ethiopian Highlands, the Mocha people produce mainly enset, cereals and tubers.

The South Sudan part of the basin has a high concentration of cattle, sheep and goats. In Ethiopia, and particularly the Gambella region, the possession of livestock is considered prestigious. Livestock watering is an issue, particularly in the dry season. In South Sudan, roughly 80 to 90% of the population live in agro-pastoralist communities. In 2012, the following populations were recorded for the agro-pastoralist communities of South Sudan: 36 million inhabitants, 11.7 million cattle, 12.4 million goats and 12 million sheep. This livestock was estimated to grow by 2 to 3% every year. During dry seasons, pastoralists travel long distances in order to find water for their livestock, often causing conflict between communities due to livestock movement across tribal boundaries.

7. CALIBRATION OF THE NAM RAINFALL-RUNOFF MODEL

The NAM rainfall-runoff model (Nielsen and Hansen, 1973) was used as the deterministic model for generating synthetic flow sequences. The model is based on physical processes and accounts for moisture in four inter-related storage zones, whilst it requires limited data inputs (rainfall and evaporation). In order to calibrate the NAM model at the location of a stream flow gauge, concurrent flow and rainfall data in the upstream catchment are required. After careful consideration of the availability and quality of the existing historical flow records within the study basin, only two gauges viz. Baro at Gambella and Alwero at Abobo were selected for model calibration.

7.1. BARO AT GAMBELLA

The Gambella streamflow gauge has an upstream catchment area of 23 541 km^2 and provides a good quality flow record which is relatively long and continuous. The Gambella sub-catchment also has a sufficient number of rainfall stations, offering good spatial coverage, and represents the highlands part of the catchment where a significant volume of water is generated. Using a combination of the available flow records from various sources, a record period from 1906 to 1989 was compiled and through an iterative process of NAM simulations, a calibration period from 1952 to 1959 was selected. The final NAM calibration parameters are listed in Table 11-27, while the calibration statistics are summarised inTable 11-28. The observed and simulated flows for this period are shown in Figure 11-27, which shows a good overall agreement in terms of the shape of the hydrographs. A coefficient of determination of 0.92 was achieved, which indicates a good fit. The seasonality also shows a good fit between the observed and simulated average monthly flows, as shown in Figure 11-28, with the observed and simulated peaks occurring in September.

Table 11-27: Calibration parameters for Baro at Gambella

L_{max}	U_{max}	QOF	TIF	TOF	TG	CKOF	CKIF	CKBF	CQOF	CQIF
550	30	0.7	0.75	0	0	2	20	50	0.5	0.1
mm	mm	m^3/s	-	-	-	days	days	days	-	-

Table 11-28: Calibration statistics for Baro at Gambella

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m^3/a)	13 091	13 434	+2.6%
Standard Deviation of Monthly Flows (m^3/s)	386	374	-3.0%
R^2	0.92		

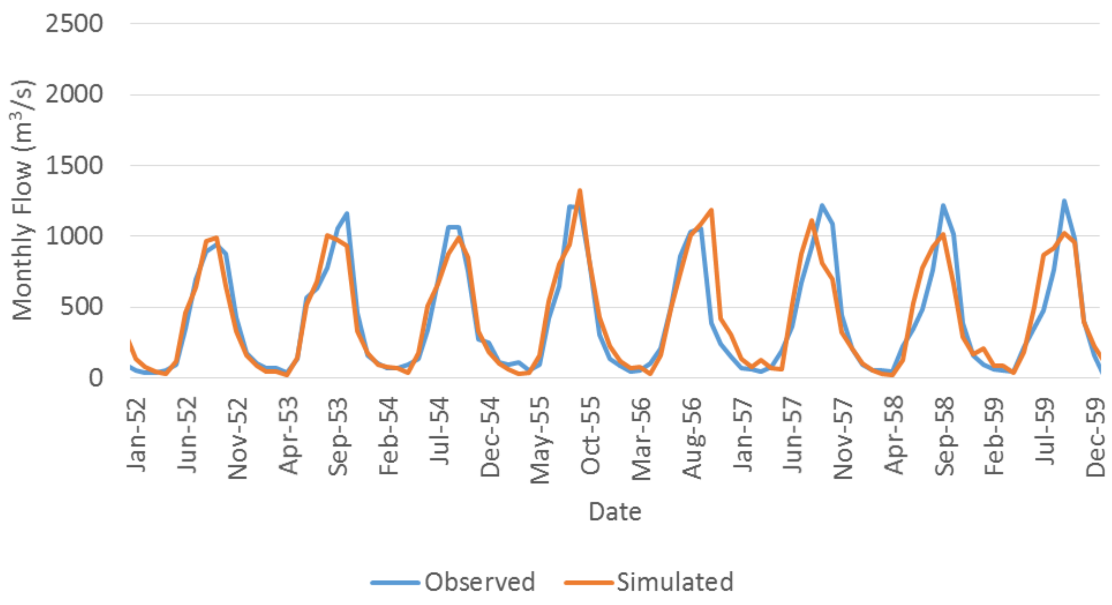


Figure 11-27: Monthly flows in Baro River at Gambella

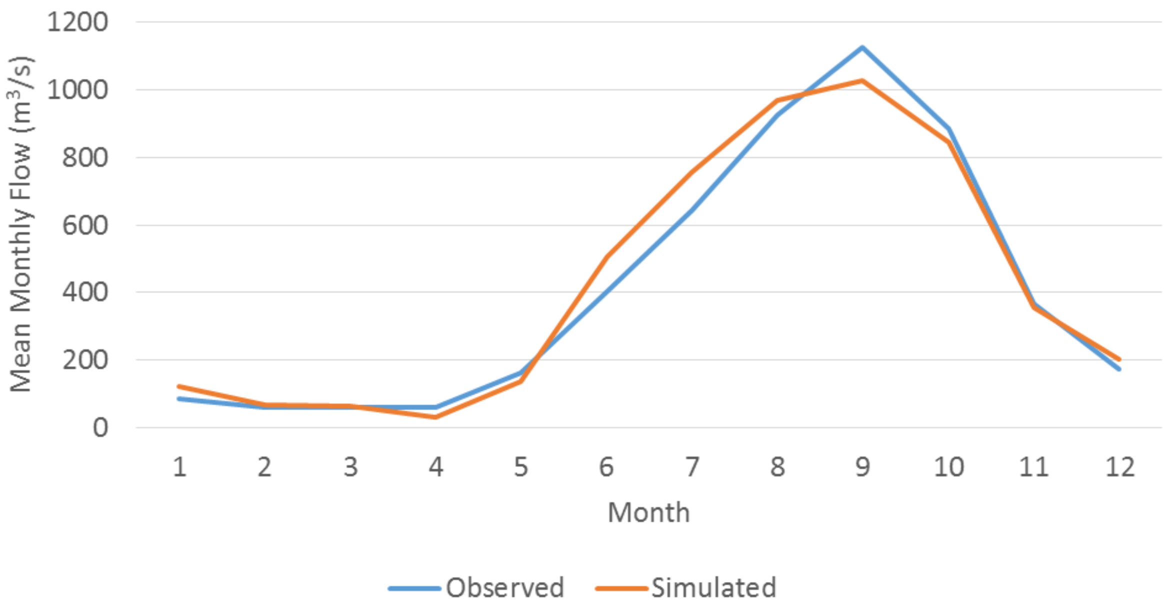


Figure 11-28: Seasonal flows in Baro River at Gambella

7.2. Alwero at Abobo

The Alwero at Abobo streamflow gauge provides a reasonable flow record for calibration, with a relatively good flow record compared to nearby flow gauges. The catchment area of 2 859 km^2 is representative of a lowlands catchment with elevations below 500 masl. Through an iterative process of NAM simulations, a calibration period from 1976 to 1989, excluding the years from 1982-1987, was selected. The final NAM calibration parameters are listed in Table 11-29. The observed and simulated flows for this period are shown in Figure 11-29, which shows a good overall agreement in terms of the shape of the hydrographs, although there is a tendency to over simulate peaks. The calibration statistics (excluding the missing years) are summarised in Table 11-30. A coefficient of determination of 0.85 was achieved, which indicates a good fit. Figure 11-30 shows a reasonable fit between the observed and simulated average monthly flows, although the simulated flows seem to lag behind the observed flows to some extent.

Note: For the purposes of the calibration, the capacity of the Alwero River in the vicinity of the gauge was set equal to 55 m^3/s. According to Sutcliffe and Parks (1999), the river starts breaking its banks at this flow. Therefore, in order to compare observed and simulated in-channel flows, the simulated daily flows were truncated at 55 m^3/s.

Table 11-29: Calibration parameters for Alwero at Abobo

L_{max}	U_{max}	QOF	TIF	TOF	TG	CKOF	CKIF	CKBF	CQOF	CQIF
700	40	0.7	0.75	0	0	0.5	20	50	0.5	0.1
mm	mm	m^3/s	-	-	-	days	days	days	-	-

Table 11-30: Calibration statistics for Alwero at Abobo

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m^3/a)	577	599	+3.8%
Standard Deviation of Monthly Flows (m^3/s)	14	16	+15.3%
R^2	0.85		

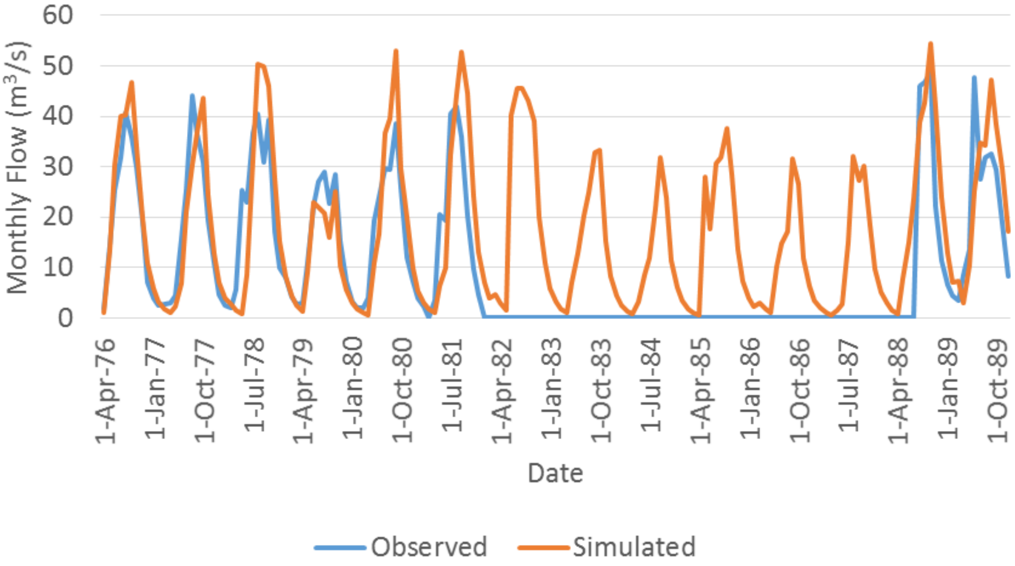


Figure 11-29: Monthly flows in Alwero River at Abobo

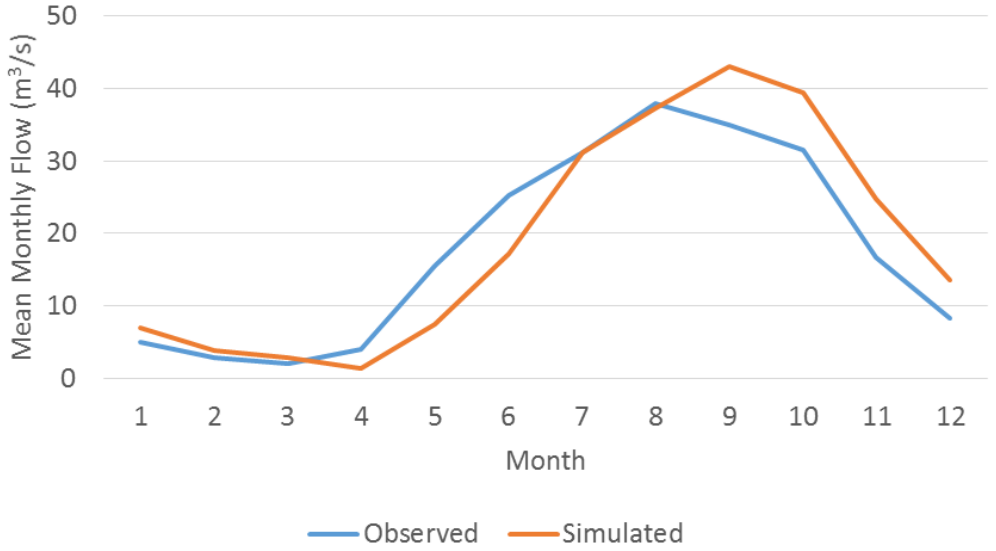


Figure 11-30: Seasonal flows in Alwero River at Abobo

7.3. YABUS AT YABUS BRIDGE

The Jonglei Investigation Team (1954) conducted flow measurements over a five year period (1950 to 1955) in the Yabus River at Yabus Bridge, one of the so-called eastern torrents which drains to the Machar Marshes from the Ethiopian Highlands. Unfortunately, it was not possible to obtain the raw time series data. However, from Sutcliffe and Parks (1999), the mean monthly values of the recorded flows were available and used for calibration of the catchment upstream of Yabus Bridge using observed rainfall during the period 1950 to 1955. The results of the comparison between simulated and observed mean monthly flows for the calibration period is shown in Figure 11-31. The NAM calibration parameters for the Yabus catchment upstream of Yabus Bridge are listed in Table 11-31.

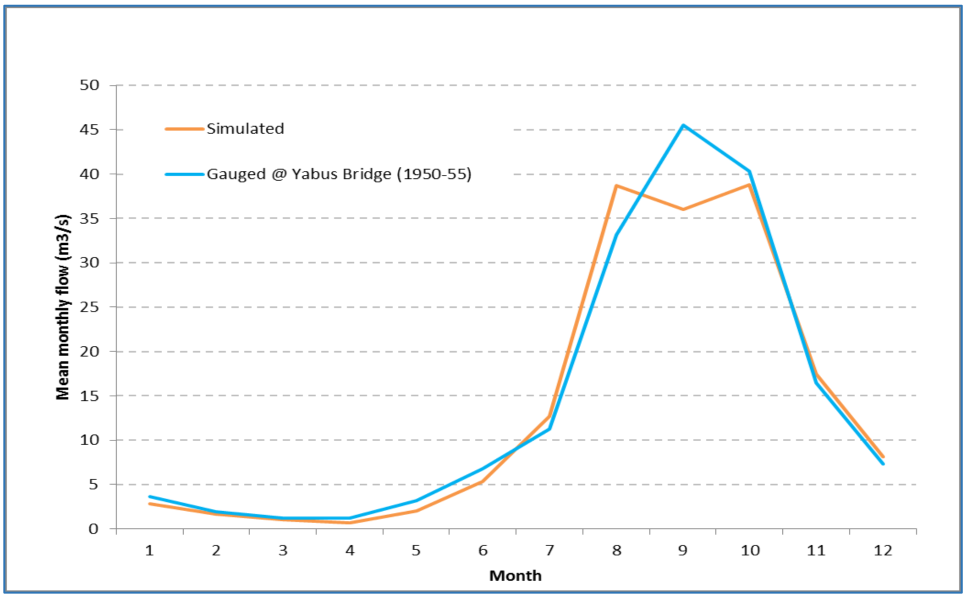


Figure 11-31: Seasonal flows in Yabus River at Yabus Bridge

Table 11-31: Calibration parameters for Yabus at Yabus Bridge

L_{max}	U_{max}	QOF	TIF	TOF	TG	CKOF	CKIF	CKBF	CQOF	CQIF
815	40	0.7	0.5	.05	0.35	0.5	15	65	0.3	0.1
mm	mm	m^3/s	-	-	-	days	days	days	-	-

7.4. DAGA AT DAGA POST

The Jonglei Investigation Team (1954) conducted flow measurements over a four year period (1950 to 1954) in the Daga River at Daga Post, one of the so-called eastern torrents which drains to the Machar Marshes from the Ethiopian Highlands. Unfortunately, it was not possible to obtain the raw time series data. However, from Sutcliffe and Parks (1999), the mean monthly values of the recorded flows were available and used for calibration of the catchment upstream of Daga Post using observed rainfall during the period 1950 to 1954. The results of the comparison between simulated and observed mean monthly flows for the calibration period is shown in Figure 11-32. The NAM calibration parameters for the Daga catchment upstream of Daga Post are listed in Table 11-32.

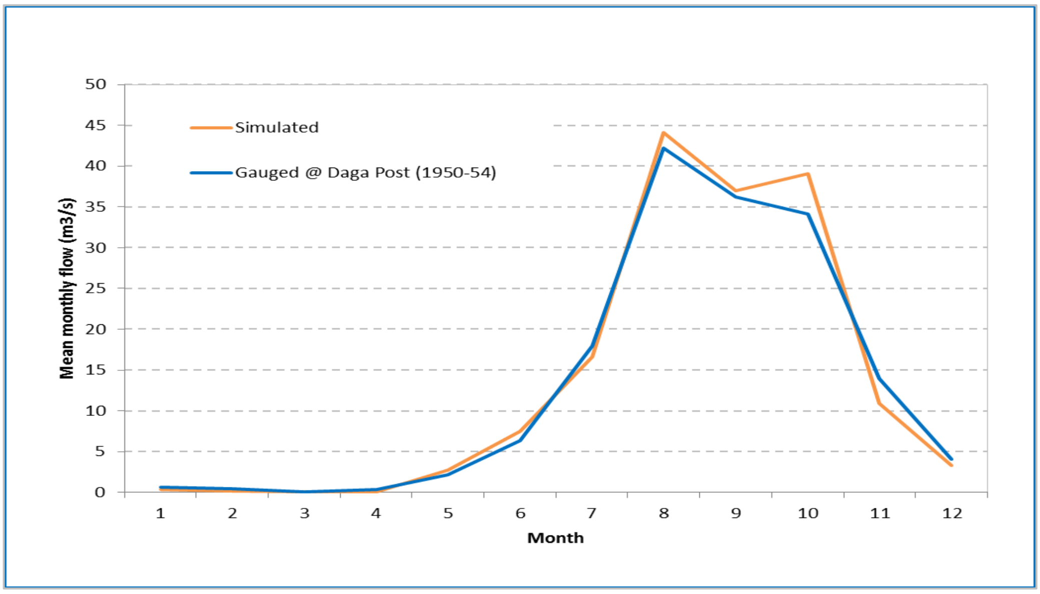


Figure 11-32: Seasonal flows in Daga River at Daga Post

Table 11-32: Calibration parameters for Daga at Daga Post

L_{max}	U_{max}	QOF	TIF	TOF	TG	CKOF	CKIF	CKBF	CQOF	CQIF
1000	40	0.7	0.5	.05	0.7	0.5	10	50	0.3	0.1
mm	mm	m^3/s	-	-	-	days	days	days	-	-

8. CONFIGURATION AND VALIDATION OF THE MIKE HYDRO BASIN MODEL

A critical aspect of the water balance model which was configured for the Baro-Akobo-Sobat sub-basin relates to the accurate representation of the interaction between the main river system, smaller tributaries, spills, floodplains, marshes and wetlands as well as attenuation and evaporation and infiltration losses along floodplains.

8.1. MODEL CONFIGURATION

The configuration of the baseline water balance model for the Baro-Akobo-Sobat sub-basin entailed four key elements:

- Constructing the model network in MIKE HYDRO Basin using a combination of model components.
- Generating flow sequences for specific validation periods in all of the model sub-catchments using the calibrated NAM rainfall-runoff model.
- Refining the model network in an iterative manner through the representation of wetlands, floodplain storage, inter-catchment links and spills onto the floodplains and marshes, including attenuation and losses due to evaporation. This process was informed by remote sensing data and information from maps, previous study reports and literature.
- Validation of the model.

Using the NAM rainfall-runoff model along with catchment rainfall files, evaporation estimates and calibration parameters for each model sub-catchment, monthly flow sequences for specific periods were simulated for each sub-catchment. The Gambella NAM parameters were transferred to all of the sub-catchments in the upper Baro sub-basin, the upper Akobo and the upper Gilo sub-catchments, while the Alwero parameters were employed to simulate runoff in the lower Gilo, Alwero, lower Akobo, lower Sobat and Pibor sub-catchments. The Yabus and Daga parameters were used to simulate runoff from the Machar eastern torrents. Annex A.4 provides information about the NAM parameters which were transferred to each model sub-catchment.

Inter-catchment spills were modelled using bifurcation nodes and link channels. Bankfull channel capacities and spill locations were based on information from literature and by interrogating maps and historical satellite images of the study basin. In order to accommodate lags, evaporation and infiltration losses and attenuation in the wetlands, marshes and floodplains, dummy dams were introduced and modelled as rule-curve reservoirs to represent storage in these areas. In some cases, the outlet capacities of these dams were set equal to the downstream river channel capacities. Coarse storage-elevation-area relationships for wetlands and marshes in the basin were estimated based on historical inundation extents from satellite images, previous study reports and various global inundation datasets. Historical observed inundation areas during specific flood events were used to refine the assumptions regarding channel capacities, spill locations and spill volumes. Annex A.5 provides a summary of the information and sources that were used to refine the model structure in terms of floodplains, inter-catchment links and spills, as well as the level-area-volumes relationships used.

A schematic of the conceptual representation of floodplain links, spills, wetlands and storage areas in the Baro-Akobo-Sobat sub-basin is shown in Figure 11-33.

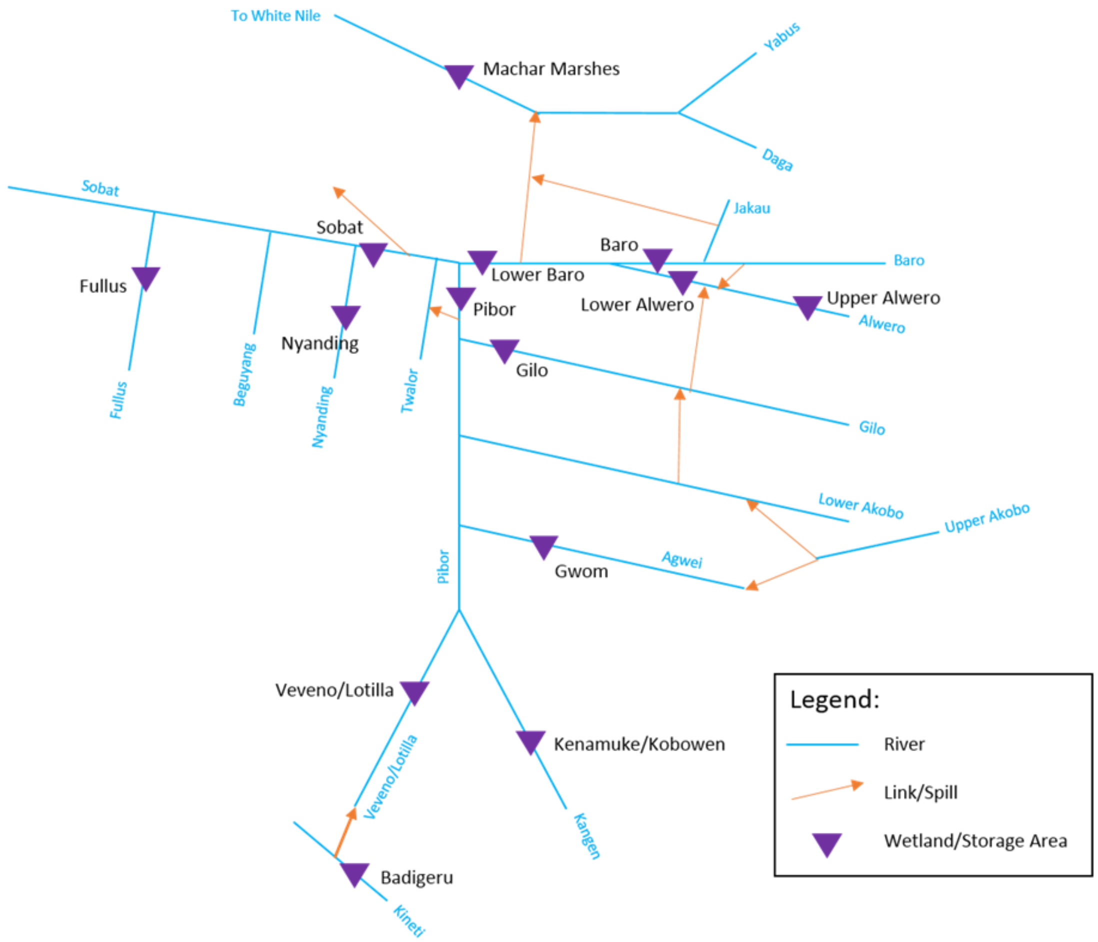


Figure 11-33: Conceptualisation of floodplain dynamics in lower Baro, Pibor and Sobat catchments

The final MIKE HYDRO Basin baseline model for the Baro-Akobo-Sobat basin is shown in**Erreur ! Source du renvoi introuvable.** Figure 11-34. The existing Abobo Dam on the Alwero River was included in the baseline model. The Abobo Dam was completed in 1997, and was therefore modelled to be effective from 1997 onwards. A total of 10 400 ha of irrigation was also included as an offtake from Abobo Dam. The existing Sor Hydropower Dam (run-of-river) was included in the model, with an installed capacity of 5 MW. Current domestic and livestock water use was included in the model, as well as existing small-scale irrigation use. The current water use in the study area, as modelled in the baseline model, is described in more detail in the *Assessment of Scenarios* Report.

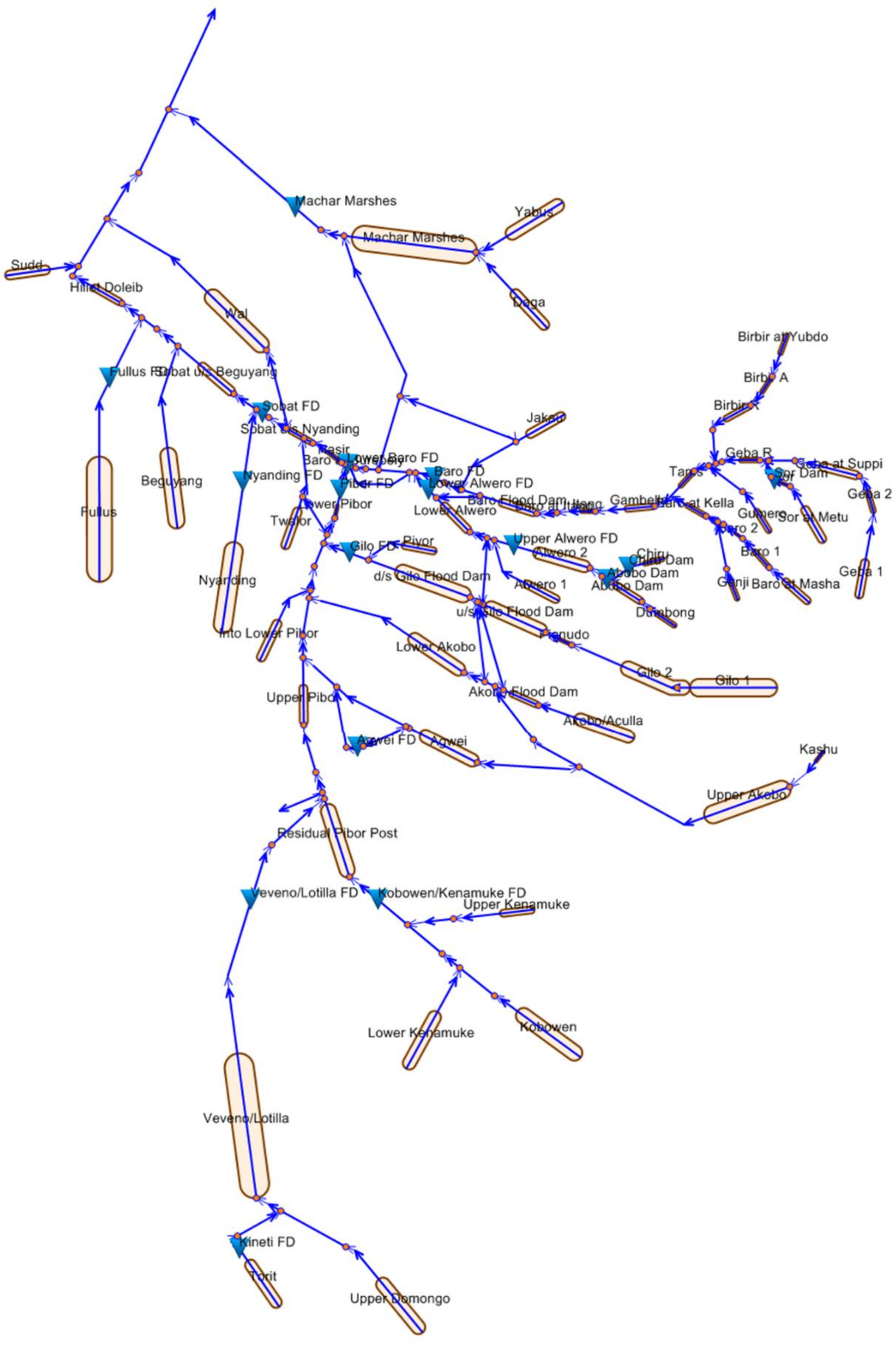


Figure 11-34: MIKE HYDRO Basin model network

8.2. MODEL VALIDATION

The Hillet Doleib and Nasir gauges on the Sobat River were identified as key validation gauges - specifically with regard to the assumptions related to the spills, evaporation and infiltration losses modelled along the extensive floodplains upstream of these gauges. In addition, a validation of the simulated model flows was done at Gambella based on the summation of all of the incremental upstream model subcatchment flows, while the limited flow record on the Baro River upstream of its confluence with the Pibor River also provided a useful check on the validity of the model.

8.2.1. Baro at Gambella

Flows were simulated for a validation period of 1970 to 1989. The observed and simulated flows for the validation period are shown in Figure 11-35, and display a high coefficient of determination of 0.95. The seasonality of the observed and simulated flows, as shown in Figure 11-36, also shows a good fit. The validation statistics for Gambella are presented in Table 11-33. The 9.2% difference between the observed and simulated MAR is largely due to the difference in observed and simulated peak flows of 1988. There was a recorded flood at Gambella in 1988, which agrees with the large simulated peak flow for this year, which may not have been measured accurately by the gauge at Gambella.

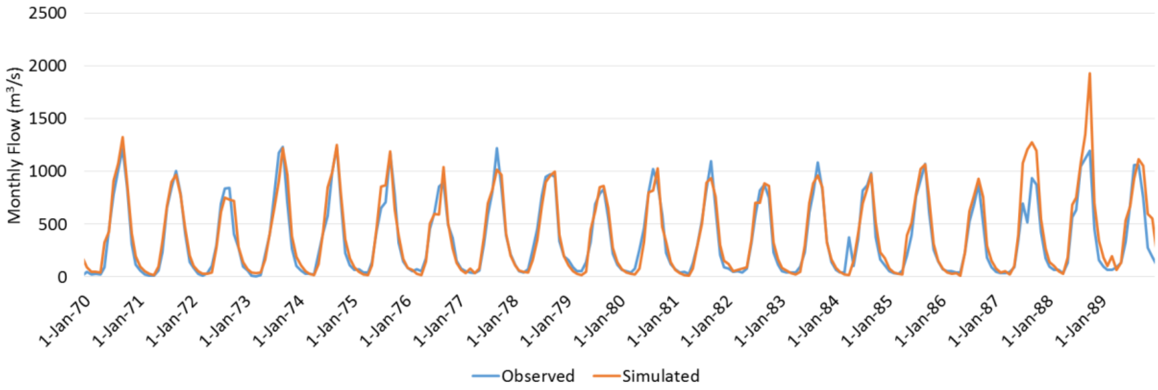


Figure 11-35: Validation of simulated flows at Baro at Gambella

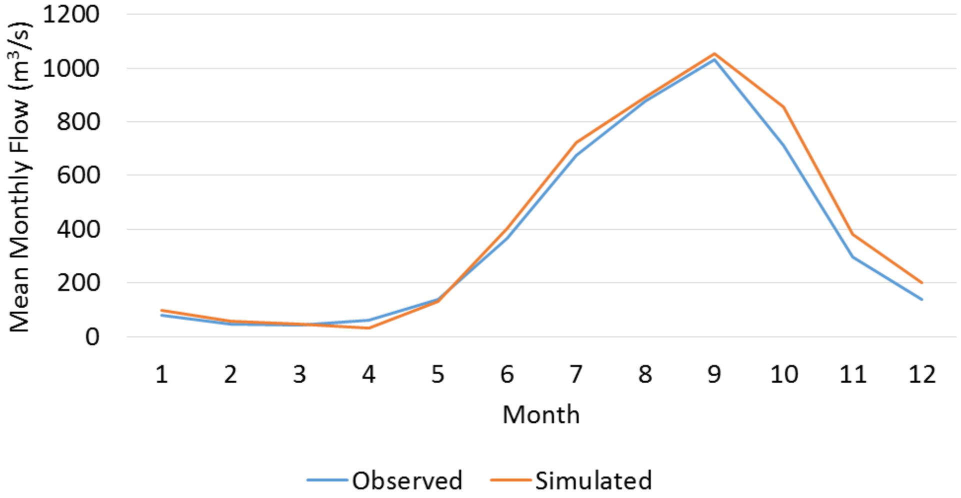


Figure 11-36: Validation of seasonality of flows at Baro at Gambella

Table 11-33: Validation statistics for Baro at Gambella

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m^3/a)	11 788	12 868	9.2%
Standard Deviation of Monthly Flows (m^3/s)	358	384	7.6%
R^2	0.95		

8.2.2. Sobat at Nasir

Flows were simulated for a validation period from 1929 to 1963. The observed and simulated flows for the validation period are shown in Figure 11-37**Erreur ! Source du renvoi introuvable.**, and display a high coefficient of determination of 0.93. The seasonality of the observed and simulated flows, as shown in Figure 11-38, also displays a good fit. The validation statistics for Nasir are presented in Table 11-34.

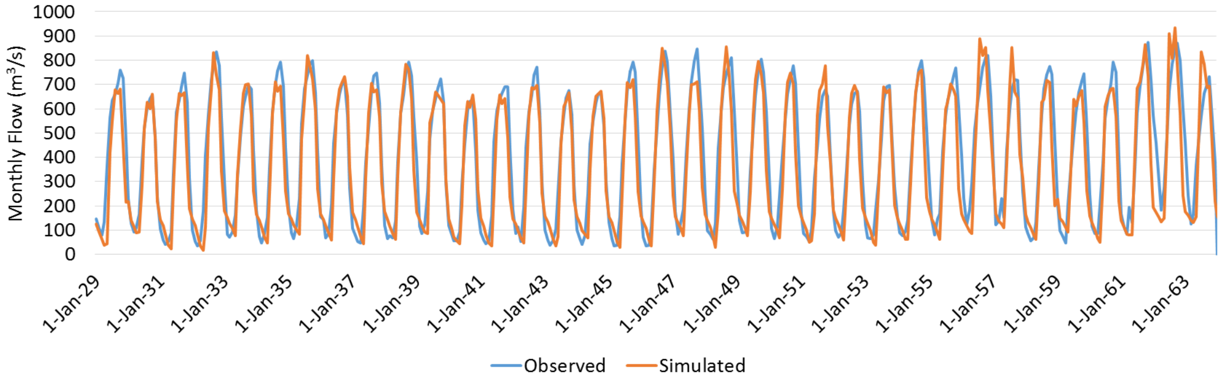


Figure 11-37: Validation of simulated flows at Sobat at Nasir

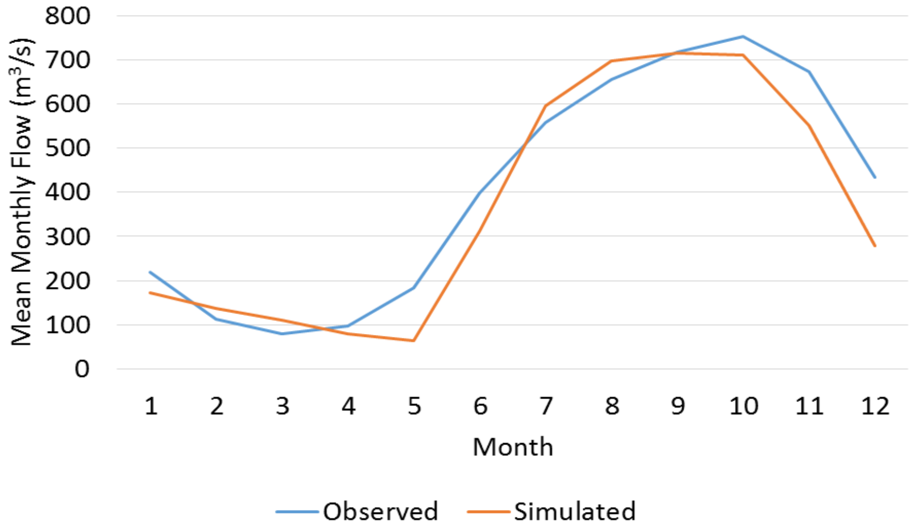


Figure 11-38: Validation of seasonality of flows at Sobat at Nasir

Table 11-34: Validation statistics for Sobat at Nasir

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m^3/a)	12 885	11 669	-9.4%
Standard Deviation of Monthly Flows (m^3/s)	262	262	-0.1%
R^2	0.93		

8.2.3. Sobat at Hillet Doleib

Flows at Hillet Doleib were simulated for a validation period from 1929 to 1963. The observed and simulated flows for the validation period are shown in Figure 11-39 and display a high coefficient of determination of 0.89. The seasonality of the observed and simulated flows, as shown in Figure 11-40, also shows a relatively good fit. The validation statistics for Hillet Doleib are presented in Table 11-35.

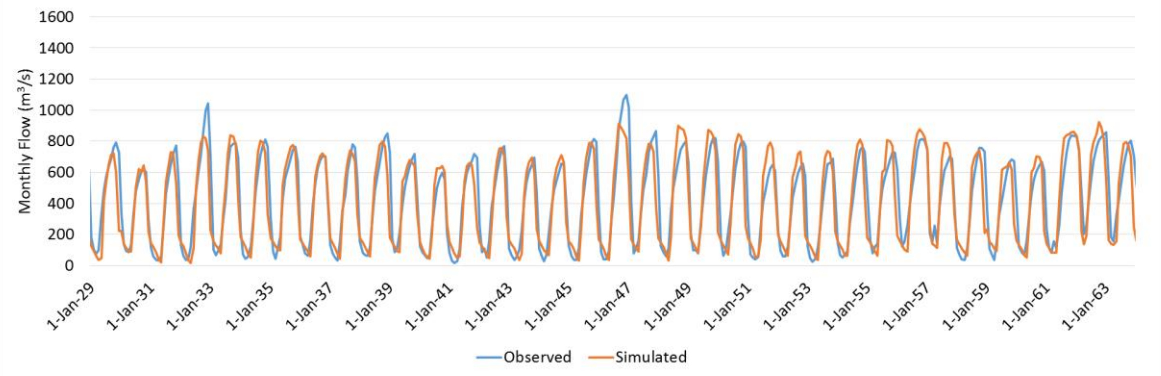


Figure 11-39: Validation of simulated flows at Sobat at Hillet Doleib

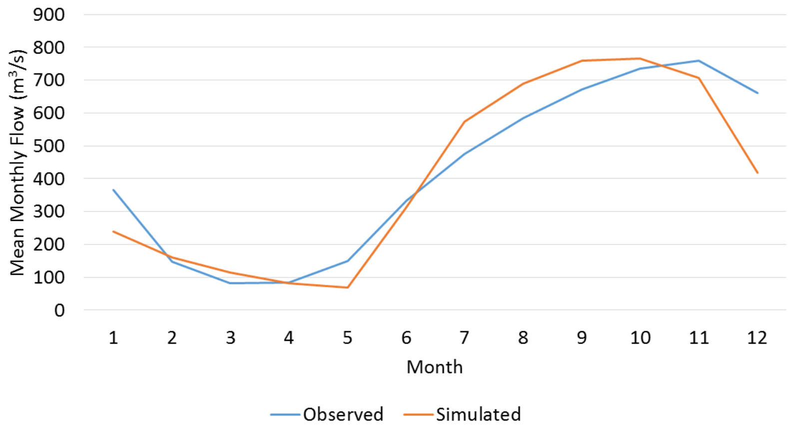


Figure 11-40: Validation of seasonality of flows at Sobat at Hillet Doleib

Table 11-35: Validation statistics for Sobat at Hillet Doleib

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m^3/a)	13 324	12 907	-3.1%
Standard Deviation of Monthly Flows (m^3/s)	277	286	+3.3%
R^2	0.89		

8.2.4. Baro at its Mouth into Sobat

Flows were simulated for a validation period from 1929 to 1932. The observed and simulated flows for the validation period are shown in Figure 11-41, and display a high coefficient of determination of 0.93. The seasonality of the observed and simulated flows as shown in Figure 11-42, shows a good fit. The validation statistics for Baro at its mouth into Sobat are presented in Table 11-36.

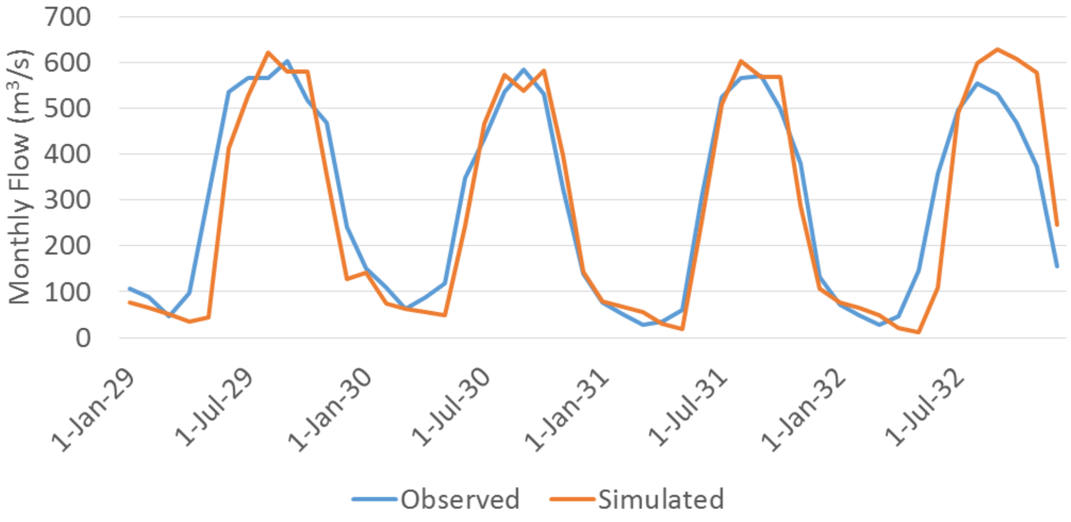


Figure 11-41: Validation of simulated flows at Baro at Baro Mouth

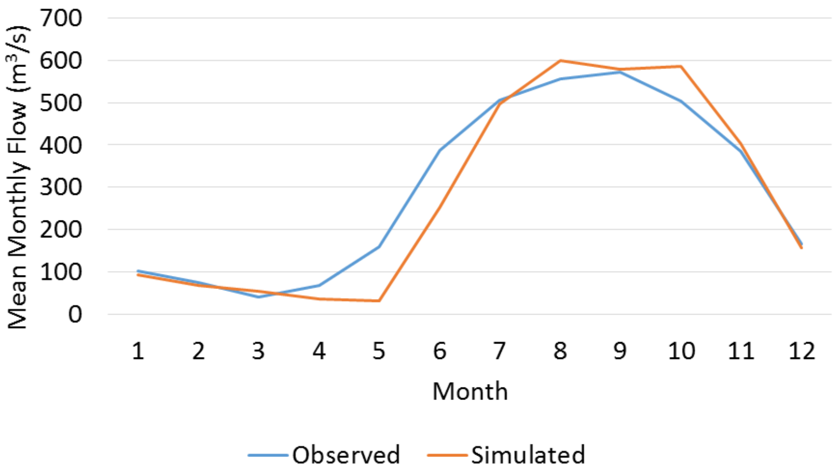


Figure 11-42: Validation of seasonality of flows at Baro at Baro Mouth

Table 11-36: Validation statistics for Baro at Baro Mouth

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m³/a)	9 287	8 863	-4.6%
Standard Deviation of Monthly Flows (m³/s)	209	234	+11.9%
R^2	0.93		

8.2.5. Pibor at its Mouth into Sobat

Flows were simulated for a validation period from 1929 to 1932. The observed and simulated flows for the validation period are shown in Figure 11-43, and display a good coefficient of determination of 0.73. The seasonality of the observed and simulated flows, as shown in Figure 11-44, shows a good fit. The validation statistics for Pibor at its mouth into Sobat are presented in Table 11-37.

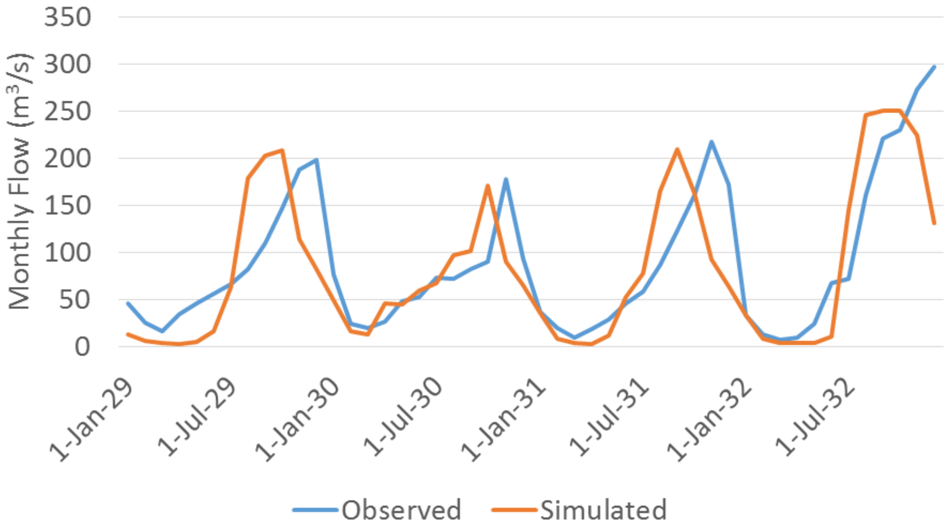


Figure 11-43: Validation of simulated flows at Pibor at Pibor Mouth

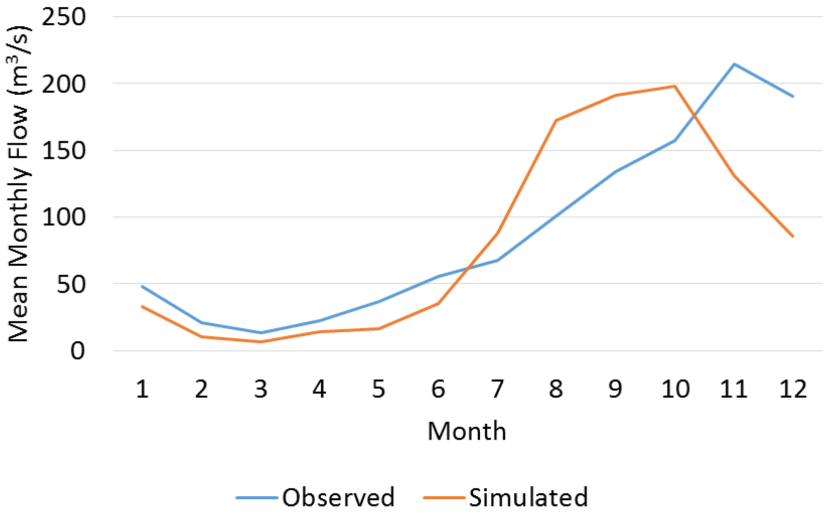


Figure 11-44: Validation of seasonality of flows at Pibor at Pibor Mouth

Table 11-37: Validation statistics for Pibor at Pibor Mouth

Statistic	Observed	Simulated	Difference
Mean Annual Runoff (million m^3/a)	2 806	2 595	-7.5%
Standard Deviation of Monthly Flows (m^3/s)	76	79	+4.7%
R^2	0.73		

9. SIMULATION OF LONG-TERM FLOW SEQUENCES FOR THE BASELINE SCENARIO

Using the calibrated rainfall-runoff model in conjunction with the validated MIKE HYDRO Basin model, long-term flow sequences were simulated at key locations across the basin. The simulation period, which extended from 1905 to 2014, was dictated by the length of the catchment rainfall files.

Annex A.4 summarises the Mean Annual Runoff (MAR) per model sub-catchment and also lists the runoff coefficients calculated for each sub-catchment. Figure 11-45 provides a long-term water balance of the basin in terms of inflows, spills, gross evaporation and precipitation.

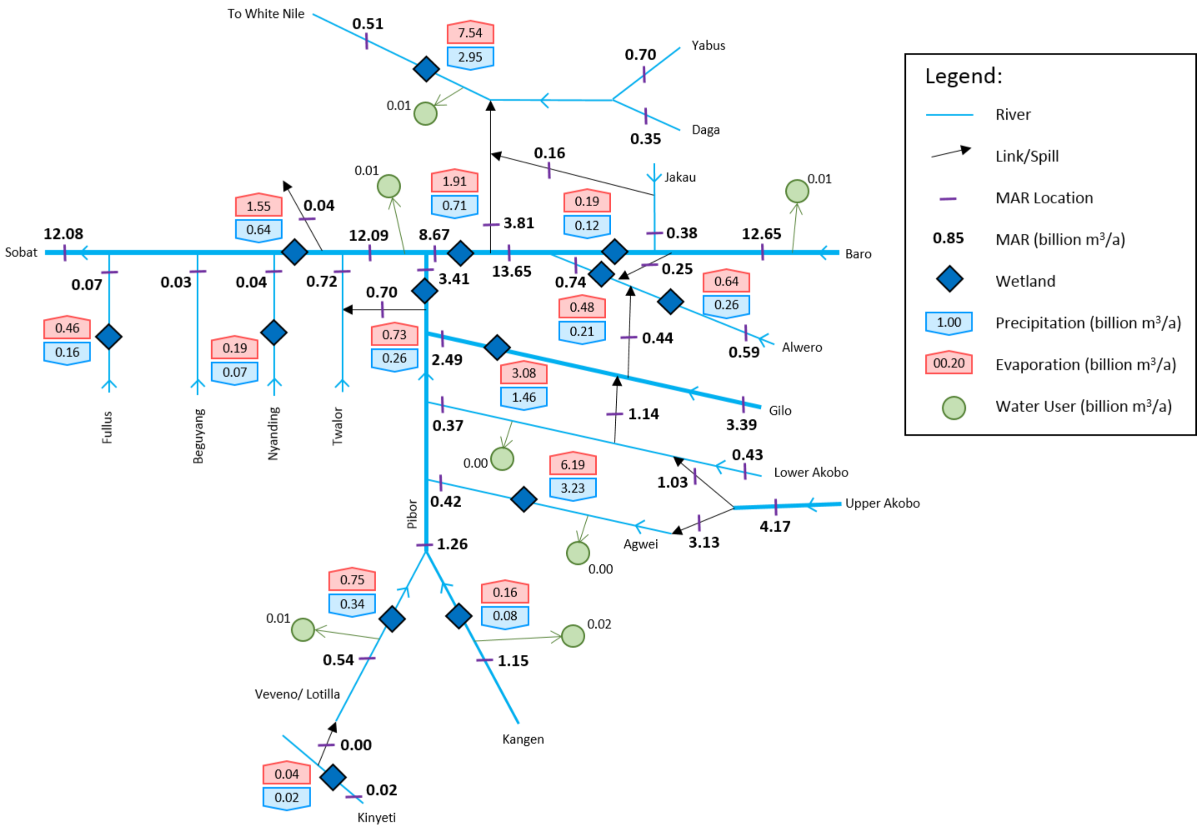


Figure 11-45: Water balance of the Baro-Akobo-Sobat sub-basin

10. SENSITIVITY ANALYSIS

A sensitivity analysis was carried out on the baseline model in order to estimate the margin of error in assessing wetland size and spill volumes due to the limited data available and the modelling assumptions made. The uncertainty of the simulated streamflows as well as the modelled spill thresholds and channel capacities were investigated. Five cases were considered for the sensitivity analysis, namely:

1. No change to the baseline model (Baseline)
2. Adding 20% to all streamflows (Flows +20%)
3. Subtracting 20% from all streamflows (Flows -20%)
4. Adding 20% to all main river channel capacities (Cap +20%)
5. Subtracting 20% from all main river channel capacities (Cap +-0%).

The effect of these five cases on the simulated average area of the main wetlands is given in Table 11-38, while the simulated dry area of the main wetlands (the 20th percentile, or the value occurring 1 year out of 5 years) is given in Table 11-39.

The effect of these five cases on the simulated mean annual flows at key locations is given in Table 11-40, while the simulated dry annual flow (the 20th percentile, or the value occurring 1 year out of 5 years) is given in Table 11-41.

Table 11-38: Sensitivity analysis on average wetland surface areas

Indicator	Wetland	Baseline	Flow +20%	Flow -20%	Cap +20%	Cap -20%
Ave annual minimum surface area (km^2)	Machar	2372	3244 (+37)	1615 (-32)	1763 (-26)	3192 (+35)
	Gambella plains	837	1107 (+32)	622 (-26)	827 (-1)	853 (+2)
	Sobat	541	554 (+2)	529 (-2)	542 (+0)	541 (0)
Ave annual maximum surface area (km^2)	Machar	5304	6744 (+27)	3659 (-31)	3851 (-27)	6913 (+30)
	Gambella plains	6025	6801 (+13)	5118 (-15)	6447 (+7)	6037 (+0)
	Sobat	1996	2249 (+13)	1613 (-19)	2119 (+6)	1602 (-20)
Amplitude (km^2)	Machar	2932	3500 (+19)	2044 (-30)	2088 (-29)	3722 (+27)
	Gambella plains	5188	5695 (+10)	4495 (-13)	5620 (+8)	5184 (-0)
	Sobat	1455	1695 (+17)	1085 (-25)	1577 (+8)	1062 (-27)

Note: Values in brackets represent percentage change relative to the Baseline case. Green cells represent an increase relative to the Baseline, and orange cells represent a decrease relative to the Baseline.

Table 11-39: Sensitivity analysis on dry wetland surface areas

Indicator	Wetland	Baseline	Flow +20%	Flow -20%	Cap +20%	Cap -20%
Ave annual minimum surface area (km^2)	Machar	1963	2655 (+35)	1310 (-33)	1438 (-27)	2624 (+34)
	Gambella plains	527	659 (+25)	401 (-24)	517 (-2)	531 (+1)
	Sobat	496	500 (+1)	493 (-1)	497 (+0)	496 (0)
Ave annual maximum surface area (km^2)	Machar	4420	5726 (+30)	2939 (-33)	3096 (-30)	6194 (+40)
	Gambella plains	5147	5999 (+17)	4119 (-20)	5206 (+1)	5103 (-1)
	Sobat	1408	1559 (+11)	1003 (-29)	1543 (+10)	823 (-42)
Amplitude (km^2)	Machar	2456	3071 (+25)	1629 (-34)	1658 (-32)	3570 (+45)
	Gambella plains	4621	5340 (+16)	3717 (-20)	4689 (+1)	4572 (-1)
	Sobat	912	1058 (+16)	510 (-44)	1046 (+15)	327 (-64)

Note: Values in brackets represent percentage change relative to the Baseline case. Green cells represent an increase relative to the Baseline, and orange cells represent a decrease relative to the Baseline.

Table 11-40: Sensitivity analysis on mean annual flows

Indicator	Flow Location	Baseline	Flow +20%	Flow -20%	Cap +20%	Cap -20%
Mean annual flow (m^3/s)	Baro at Gambella	399	480 (+20)	318 (-20)	399 (0)	399 (0)
	Baro Mouth into Sobat	282	315 (+12)	243 (-14)	327 (+16)	226 (-20)
	Gilo u/s of Wetlands	130	159 (+22)	101 (-22)	127 (-2)	133 (+2)
	Gilo Mouth into Pibor	79	98 (+24)	71 (-10)	77 (-3)	81 (+3)
	Alwero u/s of Wetlands	18	23 (+28)	14 (-22)	18 (0)	18 (0)
	Sobat at Nasir	382	442 (+16)	331 (-13)	439 (+15)	321 (-16)
	Sobat at Hillet Dolieb	389	451 (+16)	324 (-17)	429 (+10)	334 (-14)

Note: Values in brackets represent percentage change relative to the Baseline case. Green cells represent an increase relative to the Baseline, and orange cells represent a decrease relative to the Baseline.

Table 11-41: Sensitivity analysis on dry mean annual flows

Indicator	Flow Location	Baseline	Flow +20%	Flow -20%	Cap +20%	Cap -20%
Mean annual flow (m^3/s)	Baro at Gambella	34	41 (+21)	27 (-21)	34 (0)	34 (0)
	Baro Mouth into Sobat	47	48 (+2)	47 (0)	47 (0)	47 (0)
	Gilo u/s of Wetlands	17	21 (+24)	14 (-18)	17 (0)	17 (0)
	Gilo Mouth into Pibor	24	32 (+33)	18 (-25)	23 (-4)	25 (+4)
	Alwero u/s of Wetlands	0	0 (0)	0 (0)	0 (0)	0 (0)
	Sobat at Nasir	103	117 (+14)	93 (-10)	107 (+4)	106 (+3)
	Sobat at Hillet Dolieb	78	91 (+17)	66 (-15)	78 (0)	77 (-1)

Note: Values in brackets represent percentage change relative to the Baseline case. Green cells represent an increase relative to the Baseline, and orange cells represent a decrease relative to the Baseline.

The main outcomes of the above sensitivity analysis can be synthetized as follows:

- The baseline inherent variability, defined as the *(mean annual flow/surface area – dry mean annual flow/surface area) / mean annual flow/surface area)*, is not affected by changes on flows or on channel capacity. As a result, the threshold will be represented as a single value (no margin of error will be applied to the threshold) in the calibrated SSEA analytical framework.
- The average percentage change on mean annual flows/wetlands surface area is around +/- 20%. As a result, a margin of error of +/- 20% will be applied to the results (quantification of indicators).

These outcomes are presented in the main report of the revised 1st draft SSEA.

ANNEX A: SUPPLEMENTARY MODELLING DATA

Annex A provides additional information with regards to the modelling of the Baro-Akobo-Sobat Basin. This includes – for flow, rainfall and evaporation – availability of data, data quality checks and the selected data for modelling. More detailed information on the model sub-catchments is provided, including incremental MARs and runoff coefficients. The available sources of information on the floodplains and wetlands are discussed, and the modelling of the wetlands is presented in more detail.

A.1 Flow Data

A.2 Rainfall Data

A.3 Evaporation Data

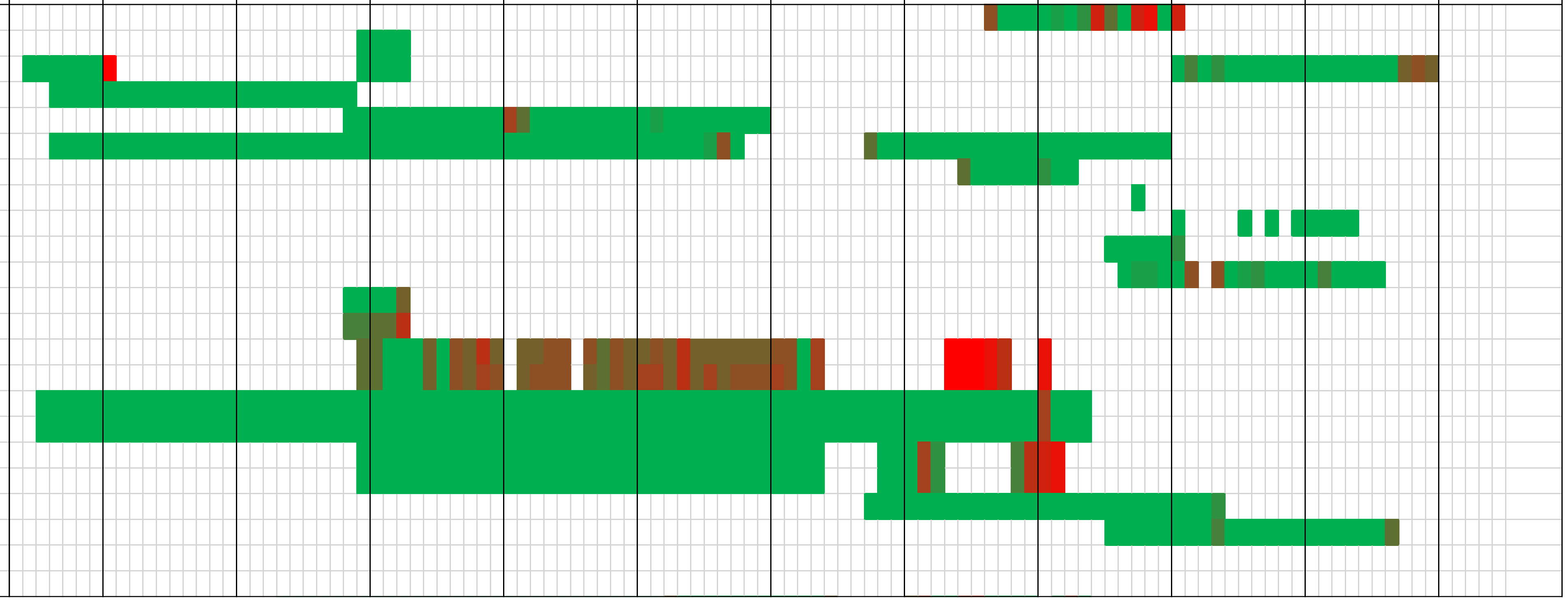
A.4 Model Sub-Catchments

A.5 Floodplains, Wetlands and Marshes

A.1: Flow Data

Flow Data Chronogram

	FLOW STATION NAME	SOURCE	CALENDER YEAR											
			1903-09	1910-19	1920-29	1930-39	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99	2000-09	2010-2015
To be used for calibration	Alwero at Abobo	EMP												
	Baro at Burebeiy	NBRP												
	Baro at Gambela	NBI												
	Baro at Gambela	NBRP												
	Baro at Gambella	NBE-NBI												
	Baro at Gambella	EMP												
	Baro at Itang	NBI												
	Baro at Kella	NP												
	Baro at Masha	NP												
	BirBir at Yubdo	NBI												
	Geba at Suppi	NBI												
	Pibor at Pibor Post	NBE												
	Pibor at Pibor Post	NBE-NBI												
	Pibor upstream of Khor Gila mouth	NBE												
	Pibor upstream of Khor Gila mouth	NBE-NBI												
	Sobat at its mouth into White Nile (at Hillet Doleib)	NBE												
	Sobat at its mouth into White Nile (at Hillet Doleib)	NBE-NBI												
	Sobat at Nasser	NBE												
	Sobat at Nasser	NBE-NBI												
	Sor at Metu	EMP												
	Sor at Metu	EMWE												
	Yabus Bridge	Sutcliffe and Parks												
	Daga at Daga Post	Sutcliffe and Parks												

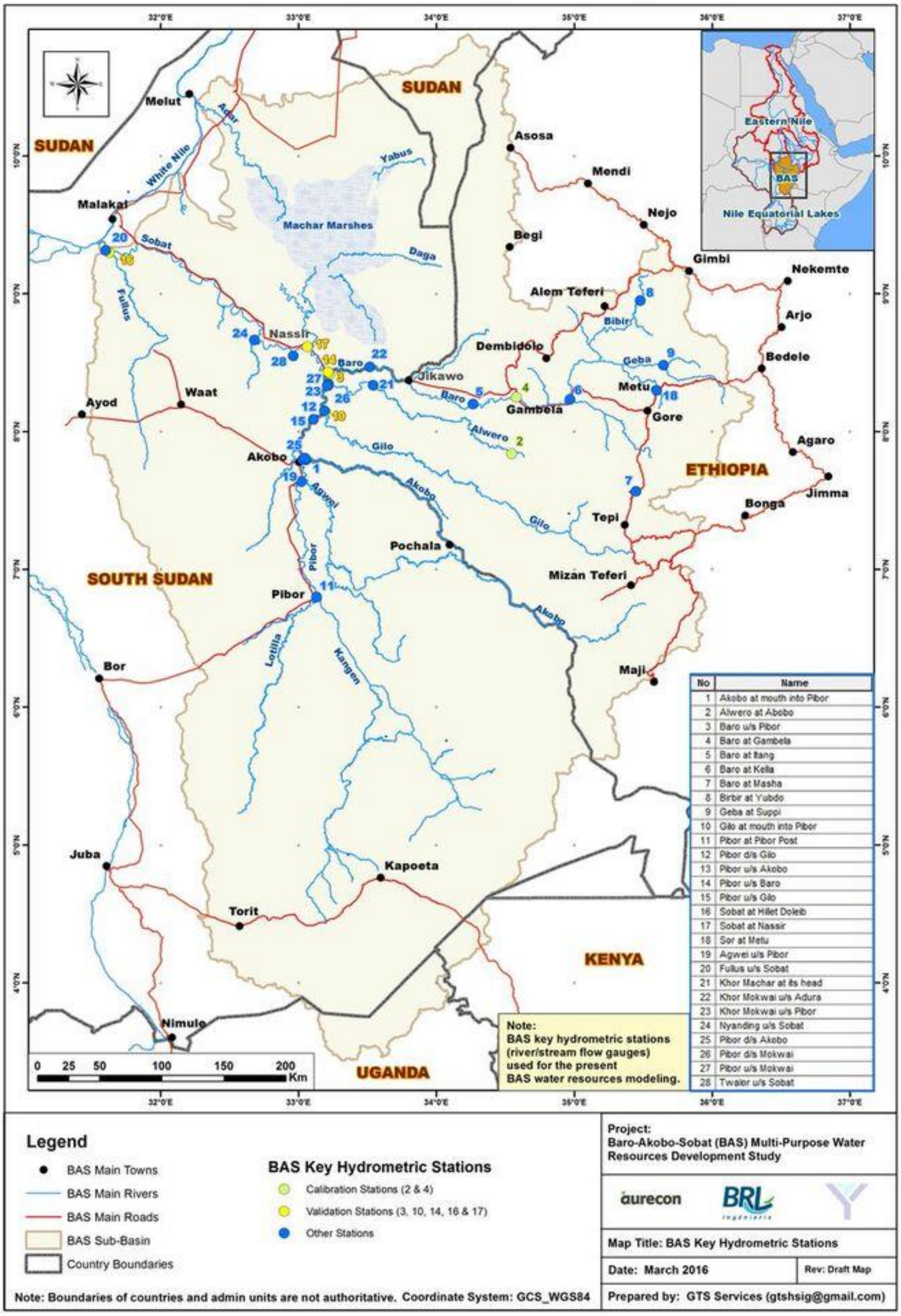


LEGEND	
(green)	All Months Data Available
(brown)	6 Months Data Available
(red)	1 Months Data Available
(white)	No Data Available

Auxiliary Stations

Abu Tong cut at its mouth into White Nile	NBE-NBI
Adura at its head downstream of Baro-Adura bifurcation	NBE-NBI
Adura downstream of Khor Makwai mouth	NBE-NBI
Agwei at its mouth into Pibor	NBE-NBI
Akobo at its mouth into Pibor	NBE-NBI
Assua at its mouth into Bahr el Jebel	NBE-NBI
Baro at its mouth into Sobat	NBE-NBI
Baro downstream of Baro-Adura bifurcation	NBE-NBI
Baro downstream of Baro-Adura junction	NBE-NBI
Baro downstream of Khor Jakau mouth	NBE-NBI
Baro downstream of Khor Machar head	NBE-NBI
Baro downstream of Khor Makeir head	NBE-NBI
Baro upstream of Baro-Adura bifurcation	NBE-NBI
Baro upstream of Baro-Adura junction	NBE-NBI
Baro upstream of Khor Jakau mouth	NBE-NBI
Baro upstream of Khor Makwai head	NBE-NBI
Khor 18 kms upstream of Machar head at head	NBE-NBI
Khor 18.5 kms upstream of Machar head at head	NBE-NBI
Khor 3.5 kms upstream of Machar head at head	NBE-NBI
Khor 4.3 kms downstream of Machar head at head	NBE-NBI
Khor 4.8 kms upstreamof Machar head at head	NBE-NBI
Khor 6.5 kms upstream of Khor Jakau mouth at its head	NBE-NBI
Khor Atar at its tail into White Nile	NBE-NBI
Khor Barakwich at its mouth into Baro, 7 kms d/s Machar	NBE-NBI
Khor Fullus at its mouth into Sobat	NBE-NBI
Khor Geni at its mouth into Pibor	NBE-NBI
Khor Gila at its mouth into Pibor	NBE-NBI
Khor Jakau at its mouth into Baro	NBE-NBI
Khor Lolle at its mouth into White Nile	NBE-NBI
Khor Macap at its mouth into Pibor	NBE-NBI
Khor Machar at its head (offtake from Baro)	NBE-NBI
Khor Makeir at its head	NBE-NBI
Khor Makwai at its mouth into Adura	NBE-NBI
Khor Mokwai at its mouth into Pibor	NBE-NBI
Khor Nyanding at its mouth into Sobat	NBE-NBI
Khor Twalor at its mouth into Sobat	NBE-NBI
Khor Wakau at its mouth into Sobat	NBE-NBI
Pibor at its mouth into Sobat	NBE-NBI
Pibor downstream of Akobo mouth	NBE-NBI
Pibor downstream of Khor Gila mouth	NBE-NBI
Pibor downstream of Khor Makwai mouth	NBE-NBI
Pibor upstream of Akobo mouth	NBE-NBI
Pibor upstream of Khor Makwai mouth	NBE-NBI
Sobat at 2 kms downstream of Nyandig mouth	NBE-NBI
Sobat at its head	NBE-NBI
Sobat downstream of Khor Twalar mouth	NBE-NBI
Sobat upstream of Khor Twalar mouth	NBE-NBI
White Nile At Kosti	NBE-NBI
White Nile at Malakal	NBE-NBI
White Nile at Melut	NBE-NBI
White Nile at Mogren (Khartoum)	NBE-NBI
White Nile at Renk	NBE-NBI
White Nile downstream of Jebel Aulia Dam	NBE-NBI
White Nile downstream of Lake No	NBE-NBI
White Nile upstream of Maya Berboi head	NBE-NBI
White Nile upstream of Maya Sinyora Gauge	NBE-NBI

BARO-AKOBO-SOBAT (BAS) SUB-BASIN: KEY HYDROMETRIC STATIONS



INITIAL SELECTION OF FLOW GAUGES

Flow Gauging Station	Source	Catchment Area (km^2)	Lat	Long	Record Period (Unpatched)	Analysis Period
Agwei at its mouth into Pibor	NBI	13 727	7.64	33.02	1934-1939, 1942-1944	
Alwero at Abobo	EMP	2 859	7.84	34.55	1976-1990	1976-1990
Baro at Burebeiy	NBRP	38 602	8.42	33.23	1929-1932	1929-1932
Baro at Gambela	NBI	23 541	8.25	34.58	1904-1910, 1929-1932, 1990-2009	1904-1957, 1967-2009
	NBRP	23 541	8.25	34.58	1906-1928	
	EMP	23 541	8.25	34.58	1906-1957, 1967-1989	
Baro at Itang	NBI	24 692	8.18	34.27	1974-1982	
Baro at its mouth into Sobat	NBI	38 602			1929-1933, 1941-1963, 1967-1970, 1972-1981	1929-1932
Baro at Kella	NP	4 737	8.23	34.97	1987	
Baro at Masha	NP	1 729	7.57	35.48	1990, 1995, 1997, 1999-2003	
BirBir at Yubdo	NBI	1 858	8.95	35.48	1985-1990	
Fullus at its mouth into Sobat	NBI	17 492	9.31	31.60	1929-1931, 1933-1934, 1938-1939	
Geba at Suppi	NBI	3 735	8.48	35.65	1986-1991, 1993-2005	1986-1991, 1993-2005
Gilo at its mouth into Pibor	NBI	12 081	8.14	33.20	1929-1939, 1941-1944, 1946-1960, 1962-1963, 1973-1977	1929-1933
Khor Machar at its head	NBI	-	8.47	33.52	1928-1939, 1941-1963, 1968-1970, 1972, 1974-1978	
Khor Mokwai at its mouth into the Adura	NBI	7 572	8.34	33.54	1946-1956	
Khor Mokwai at its mouth into Pibor	NBI	1 814	8.33	33.22	1929-1933, 1943-1963, 1974-1977	
Nyanding at its mouth into Sobat	NBI	7 197	8.67	32.68	1934, 1938-1939, 1941-1962, 1969-1970, 1978-1980	
Pibor at mouth into Sobat	NBI	132 041	8.14	33.20	1929-1933	
Pibor at Pibor Post	NBE	71 426	6.80	33.13	1928-1932	
Pibor d/s of Akobob mouth	NBI	117 179	7.81	33.05	1929-1933	
Pibor d/s of Gilo mouth	NBI	129 260	8.15	33.19	1929-1933	
Pibor d/s of Mokwai mouth	NBI	132 041	8.35	33.22	1929-1933	
Pibor u/s of Akobo mouth	NBI	89 266	7.80	33.03	1929-1939, 1941-1945	
Pibor u/s of Khor Gila mouth	NBE	117 179	8.13	33.19	1929-1939, 1941-1944, 1946-1963, 1973-1977	
Pibor u/s of Mokwai mouth	NBI	129 260	8.34	33.21	1929-1933, 1945-1963, 1973-1977	

Flow Gauging Station	Source	Catchment Area (km^2)	Lat	Long	Record Period (Unpatched)	Analysis Period
Sobat at mouth into White Nile (at Hillet Doleib)	NBE	207 308	9.36	31.59	1905-1983	1905-1983
Sobat at Nasir	NBE	170 991	8.61	33.06	1929-1963, 1968-1972, 1978-1981	1929-1963, 1968-1972
Sor at Metu	EMP	1 712	8.30	35.60	1967-1993	1967-2006
	EMWIE		8.30	35.60	1985-2006	
Twalor at mouth into Sobat	NBI	1 346	8.55	32.96	1934-1939, 1941-1962, 1970	1945-1950

Sources: NBRP: Nile Basin Research Programme; NBE: Nile Basin Encyclopaedia; EMP: Ethiopian Master Plan Studies; NBI: Nile Basin Initiative; NP: Baro 1 and 2 Feasibility Studies (Norplan, 2006); EMWIE: Ethiopian Ministry of Water, Irrigation and Energy

Flow data quality control

Data quality checks were conducted on the flow records at the selected stations including tests for stationarity, an assessment of the period of data availability and the extent of data gaps, and correlation analyses.

Stationarity

Cumulative flow graphs (single mass plots) were used to evaluate the stationarity and extent of missing data of the flow records.

Baro at Masha is missing a significant amount of data over its record period. Geba at Suppi is missing a significant amount of data between 1991 and 1995, and the gradient of the cumulative flow plot changes at 2001. The flow at Gambela is stationary, however, there is a gap in the flow record between 1958 and 1967. The record at Baro at its mouth into Sobat contains several gaps, however there is a complete record between 1929 and 1933 which is stationary.

The record at Gilo at its mouth into Pibor contains missing years, however, the period from 1929 to 1933 is complete and stationary. The cumulative flow plot for Agwei at its mouth into Pibor shows that the record is not stationary and contains missing data, which suggests that this gauge should be excluded from this study.

The record at Pibor at its mouth into the Sobat, as well as Pibor d/s of Gilo mouth, has a complete and stationary record from 1929 to 1933. Pibor Post, Pibor d/s of Akobo mouth, Pibor u/s of Akobo mouth, Pibor u/s of Gilo mouth, contain missing data and are not stationary records.

The gauge at Sobat at Nasir gives a good quality, stationary flow record between 1929 and 1963. Similarly, the gauge at Sobat at Hillet Doleib provides a good record from 1919 to 1963.

The gauges at Fullus at its mouth into Sobat and Nyanding at its mouth into Sobat contain missing data, and do not have stationary flow. The gauge at Twalor at its mouth into Sobat also contains missing data and is non-stationary for most of its record, however, there are a few years of good, stationary flow data between 1945 and 1950.

Missing data

The gauge on the Baro River at Gambela is the most complete of all the stream flow gauges and has a long record from 1904 to 2009 with a few years of missing data between 1958 and 1967 and some missing data after 2007.

In the upper Baro catchment, there are flow records at four gauges on the Baro, Birbir and Geba rivers (between 1986 and 2005, with missing data) and at one gauge on the Sor River (1966 to 2005). The Baro at Masha gauge has missing peak flow as well as missing low flow data. The Baro at Kella gauge has only one year of flow data. The Geba at Suppi gauge has missing data, with only a few years of complete records. The flow record on the Birbir River at Yubdo is mostly complete. The Sor at Metu has an almost complete record from 1967 to 2006.

The gauge at Baro at its mouth into the Sobat provides five years of complete flow data between 1929 and 1933, while the remainder of the record period has missing base flow readings in the dry months.

The Alwero River at Abobo has a record from 1976 to 1990. However, it is characterised by missing data.

The gauge on the Pibor River, at Pibor Post has significant missing data during its short record period of 1928 to 1933. The gauge at Pibor mouth into the Sobat gives four full years of flow data from 1929 to 1932, with some additional flow peaks measured in 1933. The other gauges along the Pibor River (upstream and downstream of the Gilo, Akobo and Mokwai mouths) give fairly complete flow records between 1929 and 1933, however, many of the years are missing base flow records in the dry months.

The gauge at Khor Gilo mouth into the Pibor gives a complete record between 1931 and 1933, with the remainder of the dataset missing base flows in the dry months. Similarly, the gauge at Agwei mouth into the Pibor gives base flow values for 1935, but is missing base flows for the remainder of the record period.

The Nyanding at its mouth into Sobat and Twalor at its mouth into Sobat gauges are characterised by missing data. While the gauges record peak flows for over 20 years, there are no complete years (mostly missing base flow values). Khor Fullus only has six years of data, however, 1930 and 1933 give a full year of flow data.

The stations on the Sobat River downstream of the Baro-Pibor junction at Nasir (1929 to 1963) and Hillet Doleib (1905 to 1983) have long flow records with almost no missing data.

Correlation analysis

Upper Baro sub-basin

The flow records at gauges in the upper Baro sub-catchments were expected to be more or less similar as these gauged catchments are similar in size and location. On this premise, the flows for Birbir at Yubdo, Geba at Suppi, Sor at Metu, Baro at Masha and Baro at Kella were compared for an overlapping time period (see Figure A.1). The catchment areas for Birbir at Yubdo, Sor at Metu and Baro at Masha are comparable at 1858, 1712 and 1729 km^2 respectively. The gauges at Baro at Kella and Geba at Suppi measure flow from larger catchments of 4737 and 3735 km^2 respectively. The plot in Figure A.1 highlights inconsistencies in the Masha data with regard to apparent missing peaks, while wet season flows at Yubdo appear to be too low compared to the peak flows of the surrounding sub-catchments of similar size.

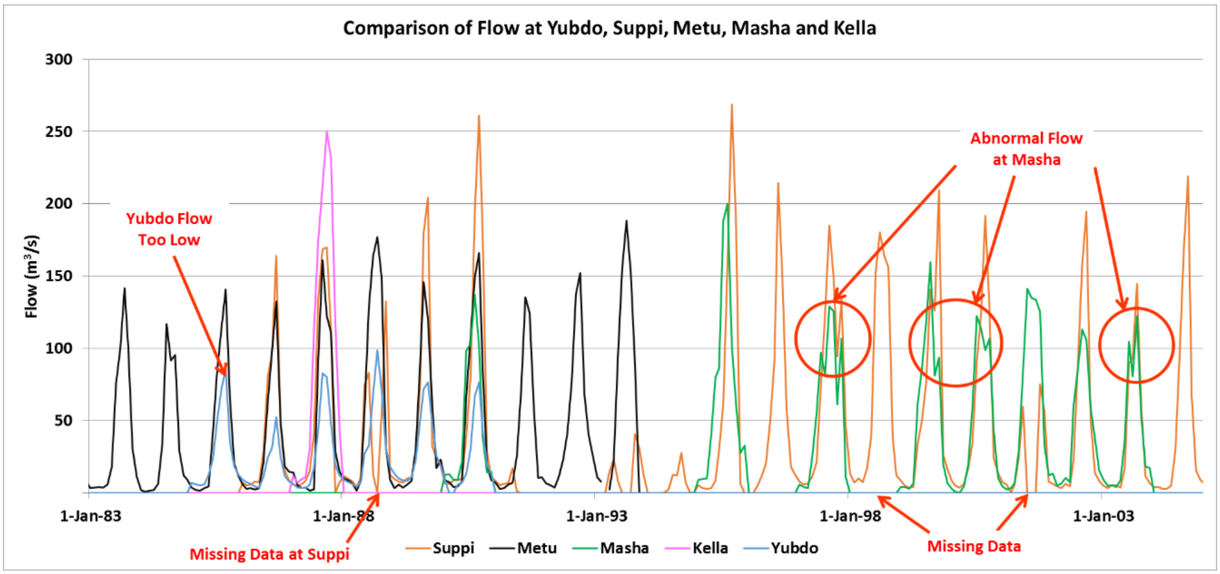


Figure A.1: Comparison of flow records at Suppi, Metu, Masha, Kella and Yubdo

The unit runoff was calculated for each of the upper Baro sub-catchments and plotted against the corresponding Mean Annual Precipitation values for each catchment, as shown in Figure A.2. The unit runoff for Birbir at Yubdo appears too low compared to similar sub-catchments.

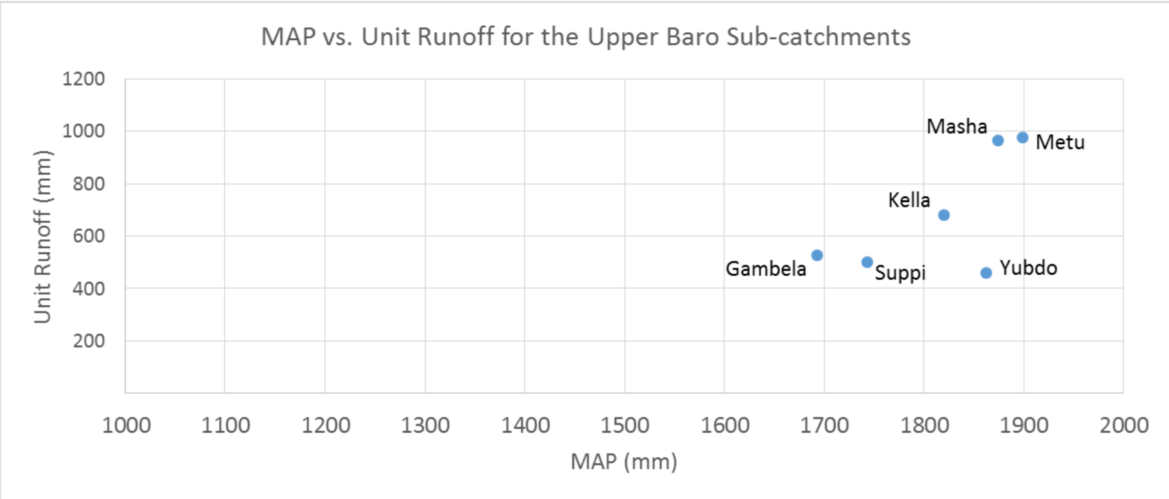


Figure A.2: Comparison of MAP and unit runoff for the upper Baro sub-catchments

Lower Baro River

The flow records at Gambela and Itang were expected to be similar as Itang is located directly downstream of Gambela. A comparison plot of these two records is shown in Figure A.3. The flow records show good agreement for the overlapping record period, with the exception of two or three apparent anomalies as indicated.

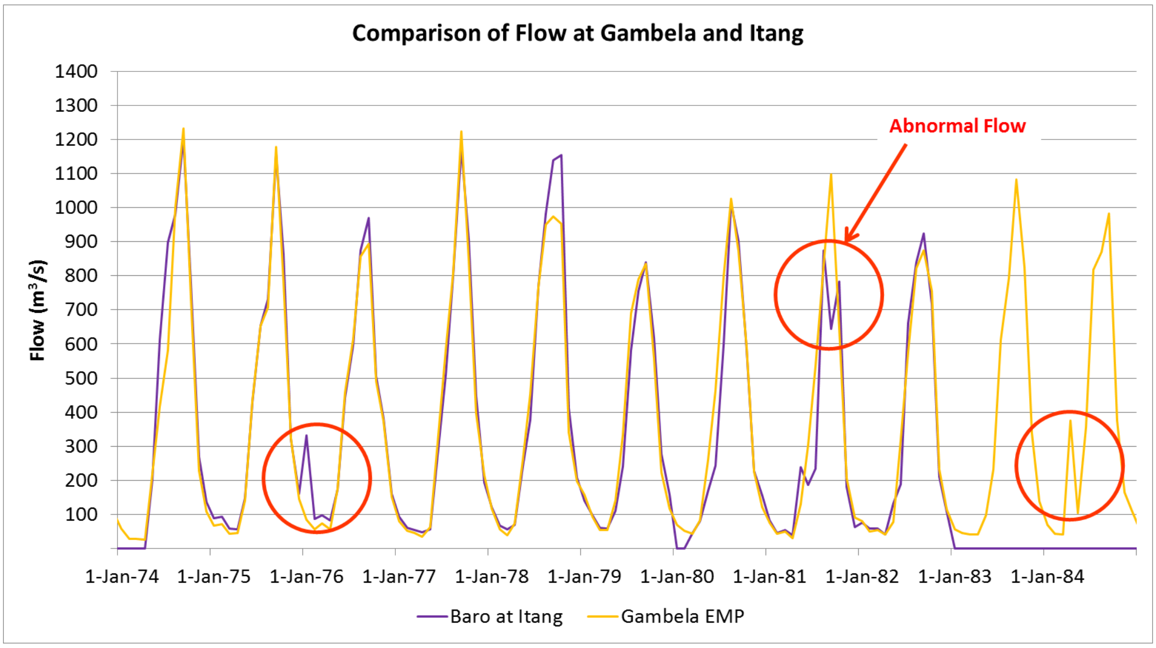


Figure A.3: Comparison of flow records at Gambela and Itang

Lower Sobat

The flow records at Nasir and Hillet Doleib on the Sobat were expected to be similar as most of the flow at Hillet Doleib comes from the contribution from Nasir. The Sobat tributaries (Twalor, Nyanding, Beguyang and Fullus Rivers) also contribute to the total flow recorded at Hillet Doleib, and water may be spilled from the Sobat upstream of Nyanding to the Wal River. A comparison plot of Hillet Doleib and Nasir is shown in Figure A.4. The flow records show good agreement for the overlapping record period. The flow record at Nasir has missing values from 1964 onwards. The plot also highlights possible missing peak flows at Hillet Doleib where the shape of the hydrograph appears abnormal. The years which indicate greater flow peaks at Hillet Doleib could be due to high flows from the Sobat tributaries.

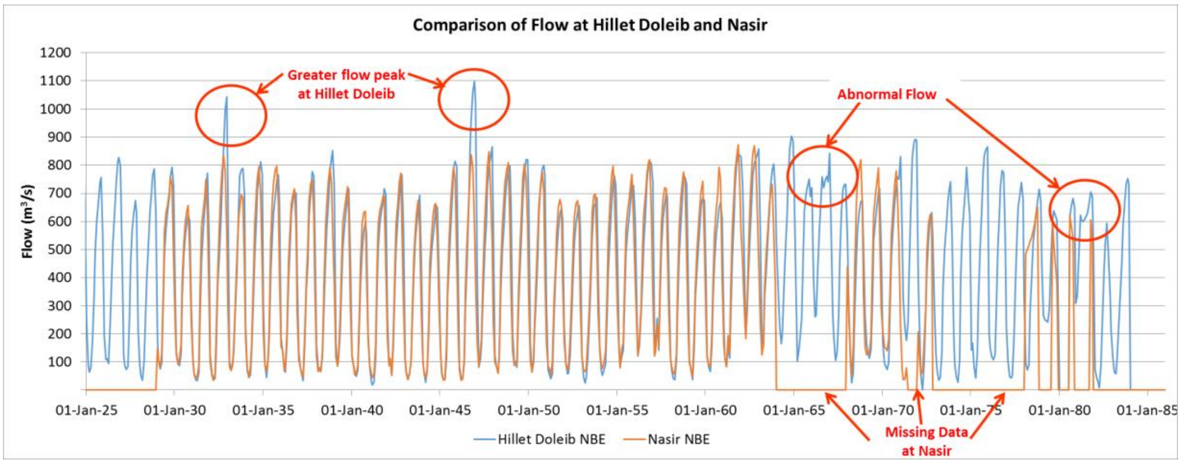


Figure A.4: Comparison of flow records at Nasir and Hillet Doleib

Lower Pibor

The flow records at key gauging stations along the Pibor River were plotted for an overlapping period and compared, as shown in Figure A.5. The flows downstream of the Akobo mouth and the flows upstream of the Gilo mouth show a good match, as expected. The flows upstream of the Akobo mouth are lower than the flows downstream of the Akobo mouth, and the two flow records have similar shaped hydrographs, as expected. The flow record at Pibor Post is short and contains missing data for the later years.

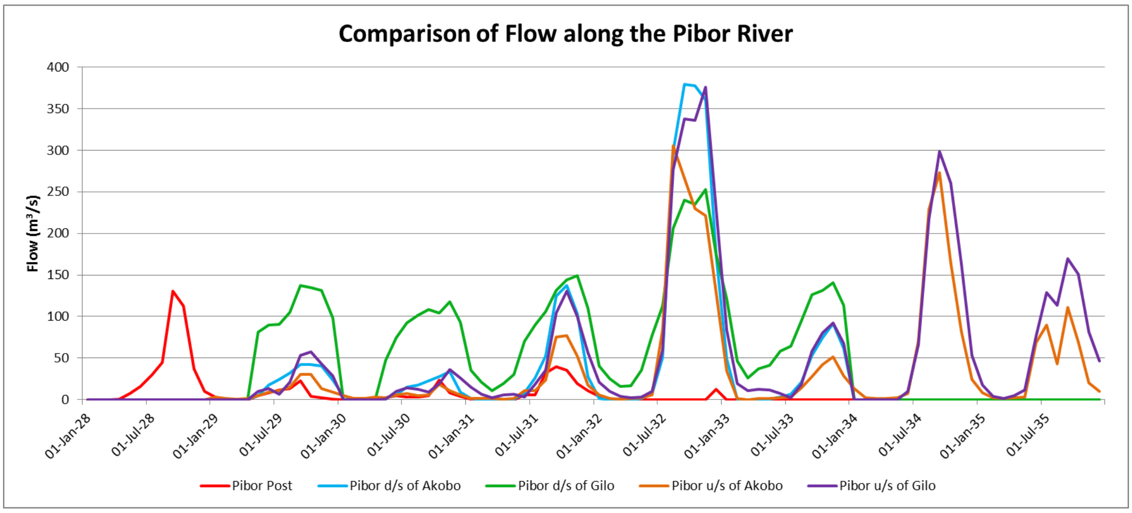
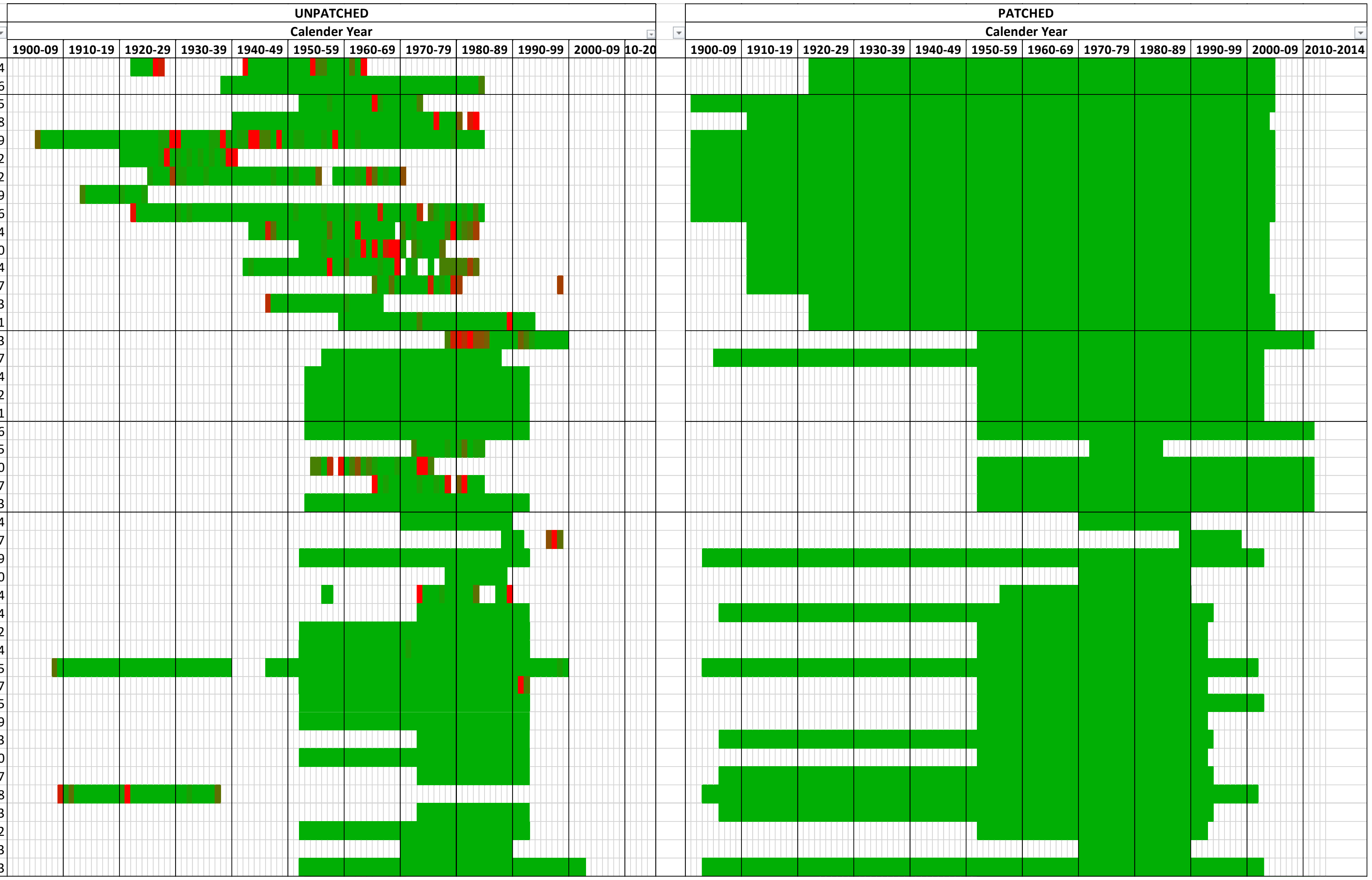


Figure A.5: Comparison of flow records along the Pibor River

A.2: Rainfall Data

Rainfall Data Chronogram

RAINFALL STATION NAME	GROUPING	SOURCE	PATCHED MAP
1224Nagi_Shot	01. Upstream of Pibor Post	DST	1094
1937Kapoeta	01. Upstream of Pibor Post	FAO	766
1220Mongalla	02. Adjacent to Upstream of Pibor Post	DST	895
1490Agoro	02. Adjacent to Upstream of Pibor Post	GHCN	918
1580Bor	02. Adjacent to Upstream of Pibor Post	NBE	889
2123Malek	02. Adjacent to Upstream of Pibor Post	NBE	862
2439Terakeka	02. Adjacent to Upstream of Pibor Post	NBE	922
2447Tombe	02. Adjacent to Upstream of Pibor Post	NBE	849
2454Torit	02. Adjacent to Upstream of Pibor Post	NBE	1016
2584Orom	02. Adjacent to Upstream of Pibor Post	MWE	944
2585Karenga	02. Adjacent to Upstream of Pibor Post	MWE	970
2586Naam	02. Adjacent to Upstream of Pibor Post	MWE	994
2588Madi_Opei	02. Adjacent to Upstream of Pibor Post	MWE	977
2591Kaabong	02. Adjacent to Upstream of Pibor Post	MWE	723
3312Lokichokio	02. Adjacent to Upstream of Pibor Post	NBRP	501
730Mizan_Teferi	03. Abobo, Gilo, Akobo Headwaters	DST	2293
1448Abobo	03. Abobo, Gilo, Akobo Headwaters	EMP	1137
2180Mizan_Teferi_School	03. Abobo, Gilo, Akobo Headwaters	EMP	2164
2438Tepi	03. Abobo, Gilo, Akobo Headwaters	EMP	1592
2535Yeki	03. Abobo, Gilo, Akobo Headwaters	EMP	1581
1577Bonga	04. Adjacent to Abobo, Gilo, Akobo Headwaters	EMP	1786
1797Gojeb	04. Adjacent to Abobo, Gilo, Akobo Headwaters	GHCN	1285
2112Maji	04. Adjacent to Abobo, Gilo, Akobo Headwaters	GHCN	1650
2376Shebe	04. Adjacent to Abobo, Gilo, Akobo Headwaters	GHCN	1587
2525Wush-Wush	04. Adjacent to Abobo, Gilo, Akobo Headwaters	EMP	1803
1496Alem_Teferi_School	05. Upstream of Gambela	EMP	1634
1498Alge	05. Upstream of Gambela	FAO	1037
1610Bure	05. Upstream of Gambela	EMP	1279
1642Chanka	05. Upstream of Gambela	EMP	1480
1676Dembi_Dollo	05. Upstream of Gambela	GHCN	544
1677Dembi_Dolo	05. Upstream of Gambela	EMP	1234
1691Dongoro	05. Upstream of Gambela	EMP	2122
1791Gimbi_HS	05. Upstream of Gambela	EMP	1844
1806Gore	05. Upstream of Gambela	GHCN	2115
1847Hurumu	05. Upstream of Gambela	EMP	2037
2141Masha	05. Upstream of Gambela	EMP	2395
2172Metu_Hospital	05. Upstream of Gambela	EMP	1839
2191Mugi	05. Upstream of Gambela	EMP	1723
2267Nolekaba	05. Upstream of Gambela	EMP	1960
2324Rob_Gebeya	05. Upstream of Gambela	EMP	1417
2352Saiyo	05. Upstream of Gambela	NBE	1258
2377Shebele	05. Upstream of Gambela	EMP	1513
2530Yayu	05. Upstream of Gambela	EMP	1602
2539Youbdo	05. Upstream of Gambela	EMP	1583
3611Gore	05. Upstream of Gambela	NBRP	2163



1488Agaro	06. Adjacent to Upstream of Gambela	GHCN	1657
1507Anger_Gutin	06. Adjacent to Upstream of Gambela	GHCN	1380
1508Anger_Gutin	06. Adjacent to Upstream of Gambela	EMP	1559
1512Arjo	06. Adjacent to Upstream of Gambela	EMP	2138
1560Bedele	06. Adjacent to Upstream of Gambela	FAO	1386
1649Chora_Kumbabe	06. Adjacent to Upstream of Gambela	EMP	1765
1781Getema	06. Adjacent to Upstream of Gambela	EMP	1412
1837Henna	06. Adjacent to Upstream of Gambela	EMP	1963
1867Jarso	06. Adjacent to Upstream of Gambela	EMP	1735
2163Mendi	06. Adjacent to Upstream of Gambela	EMP	1608
3233Nekemtewelega	06. Adjacent to Upstream of Gambela	NBRP	2009
3238Sibusirewellega	06. Adjacent to Upstream of Gambela	NBRP	1363
3673Nedjo	06. Adjacent to Upstream of Gambela	NBRP	1634
1192Gambela	07. Lowlands Upstream of Nasir	DST	1238
1198Pibor	07. Lowlands Upstream of Nasir	DST	889
1494Akobo	07. Lowlands Upstream of Nasir	NBE	938
1764Gambela	07. Lowlands Upstream of Nasir	FAO	1231
1766Gambella	07. Lowlands Upstream of Nasir	EMP	1262
1864Itang	07. Lowlands Upstream of Nasir	EMP	883
1874Jikawo	07. Lowlands Upstream of Nasir	EMP	798
2290Pakwo	07. Lowlands Upstream of Nasir	EMP	1037
2291Pakwo	07. Lowlands Upstream of Nasir	GHCN	1047
2294Pibor_Post	07. Lowlands Upstream of Nasir	NBE	914
3542Ganbella	07. Lowlands Upstream of Nasir	NBRP	1059
1197Nasir	08. Lowlands Upstream of Hillet Doleib	DST	765
1462Abwong	08. Lowlands Upstream of Hillet Doleib	NBE	754
1839Hillet_Doleib	08. Lowlands Upstream of Hillet Doleib	NBE	802
2242Nasser	08. Lowlands Upstream of Hillet Doleib	NBE	778
1193Kodok	09. Adjacent to Lowlands Upstream of Hillet Dolei	DST	758
1194Malakal	09. Adjacent to Lowlands Upstream of Hillet Dolei	DST	754
1195Malakal_MofA	09. Adjacent to Lowlands Upstream of Hillet Dolei	DST	798
1196Malakal_Town	09. Adjacent to Lowlands Upstream of Hillet Dolei	DST	804
1207Shambe	09. Adjacent to Lowlands Upstream of Hillet Dolei	DST	708
2118Malakal_Aero	09. Adjacent to Lowlands Upstream of Hillet Dolei	GHCN	778
2162Melut	09. Adjacent to Lowlands Upstream of Hillet Dolei	NBE	629
2432Taufikia	09. Adjacent to Lowlands Upstream of Hillet Dolei	NBE	733
2448Tonga	09. Adjacent to Lowlands Upstream of Hillet Dolei	NBE	868
2546Zeraf_Cut	09. Adjacent to Lowlands Upstream of Hillet Dolei	NBE	572
3441Malakal	09. Adjacent to Lowlands Upstream of Hillet Dolei	NBRP	778
1177J_Maiak	10. Machar Marshes	DST	716
1178El-Kurmuk	10. Machar Marshes	DST	922
1201Yabus_Bridge	10. Machar Marshes	DST	927
1261J_Dinduro	10. Machar Marshes	DST	485
1523Asosa	10. Machar Marshes	EMP	1155
1562Begi_School	10. Machar Marshes	EMP	1387
1641Chali	10. Machar Marshes	GHCN	744
1705El_Keili	10. Machar Marshes	NBE	843
2005Kiltukara	10. Machar Marshes	EMP	1596
2060Kurmuk	10. Machar Marshes	NBE	936
2061Kurumuk	10. Machar Marshes	EMP	831
Gore	11. Daily	GHCN	2115
Jimma	11. Daily	GHCN	1512
Juba	11. Daily	GHCN	938
Malkal	11. Daily	GHCN	754
RFE1.0 Decadal	12. Satellite Rainfall		
RFE1.0 Daily	12. Satellite Rainfall		
RFE2.0 Daily	12. Satellite Rainfall		
SimCLIM monthly	12. Satellite Rainfall		
SMHI	12. Satellite Rainfall		
CRU	12. Satellite Rainfall		

PATCHED RAINFALL STATIONS IN THE VICINITY OF THE BARO-AKOBO-SOBAT BASIN

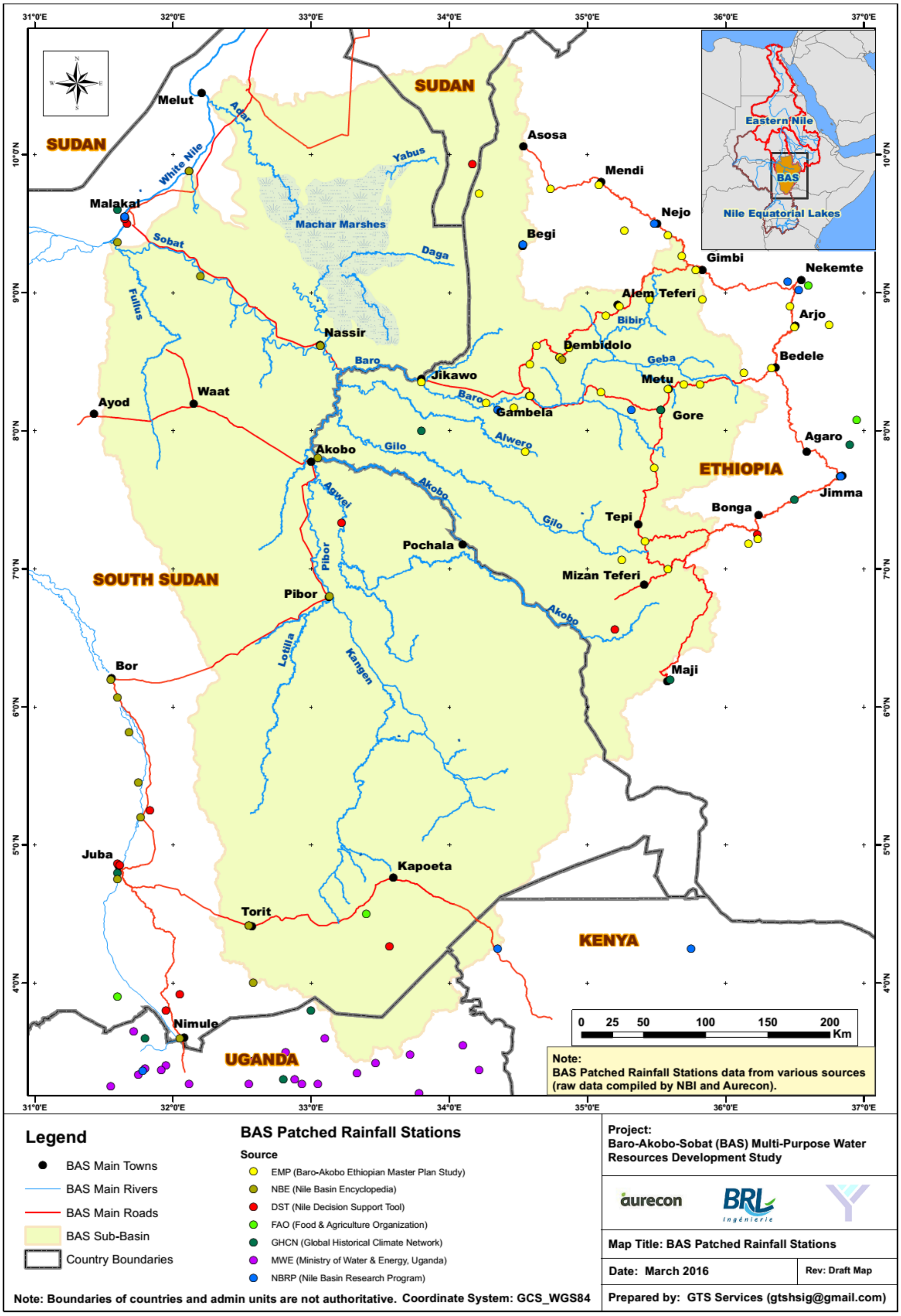
ID	Station Name	Lat	Long	Source[1]	Start Date	End Date	Accuracy[2]
1	Gojeb	7.250	36.230	DST	3/31/1972	3/31/1994	1
2	Mizan Teferi	6.560	35.200	DST	1/31/1978	12/31/1999	3
3	GAMBELA	8.250	34.583	DST	8/31/2005	12/31/1980	2
4	KODOK	9.883	32.117	DST	1/31/2003	7/31/1978	3
5	MALAKAL	9.550	31.650	DST	1/31/1940	9/30/2000	2
6	MALAKAL (M. OF A.)	9.500	31.667	DST	7/31/1950	12/31/1999	2
7	MALAKAL TOWN	9.533	31.650	DST	1/31/2015	12/31/1939	3
8	NASIR	8.617	33.067	DST	6/30/2022	9/30/1973	2
9	PIBOR	7.333	33.222	DST	12/31/2013	11/30/1976	2
10	YABUS BRIDGE	9.933	34.167	DST	1/31/1952	12/31/1978	3
11	JUBA	4.867	31.600	DST	1/31/1949	9/30/2000	3
12	JUBA TOWN	4.850	31.617	DST	6/30/2024	12/31/1949	4
13	LOA	3.800	31.950	DST	1/31/1945	12/31/1963	2
14	MONGALLA	5.250	31.833	DST	1/31/1952	9/30/1973	3
15	NAGI SHOT	4.267	33.567	DST	1/31/2022	11/30/1963	3
16	OPARI	3.917	32.050	DST	1/31/2029	4/30/1973	2
17	TORIT	4.417	32.550	DST	1/31/2023	12/31/1984	3
18	Abobo	7.850	34.550	EMP	1/31/1956	12/31/1987	2
19	Abwong	9.117	32.200	NBE	1/31/2019	12/31/1964	2
20	AGARO	7.900	36.900	GHCN	4/30/1953	10/31/1970	3
21	AGORO	3.800	33.000	GHCN	1/31/1940	7/31/1984	2
22	Akobo	7.800	33.050	NBE	1/31/1938	12/31/1978	2
23	Alem Teferi School	8.900	35.233	EMP	1/31/1970	12/31/1989	1
24	ANGER GUTIN	9.400	36.400	GHCN	5/31/1972	12/31/1984	3
25	Anger Gutin	9.367	36.367	EMP	1/31/1972	12/31/1992	3
26	Arjo	8.750	36.500	EMP	1/31/1954	12/31/1992	1
27	Bambessi	9.750	34.733	EMP	1/31/1955	12/31/1997	2
28	Bedele	8.450	36.333	EMP	1/31/1952	12/31/1992	1
29	Begi School	9.350	34.533	EMP	1/31/1961	12/31/1988	2
30	Bonga	7.217	36.233	EMP	1/31/1953	12/31/1992	1
31	Bor	6.200	31.550	NBE	6/30/2005	12/31/1992	2
32	Bure	8.283	35.100	EMP	1/31/1952	12/31/1992	2
33	Chanka	8.833	35.133	EMP	1/31/1978	12/31/1988	1
34	Chora Kumbabe	8.417	36.133	EMP	1/31/1952	12/31/1992	1
35	Dembi Dolo	8.533	34.800	EMP	1/31/1973	12/31/1992	3
36	Dongoro	9.267	35.683	EMP	1/31/1952	12/31/2000	2
37	GAMBELA	8.250	34.580	FAO	8/31/2005	11/30/1993	2
38	Gambella	8.250	34.583	EMP	8/31/2005	12/31/1993	2
39	Getema	8.900	36.467	EMP	1/31/1955	12/31/1988	1
40	Gimbi H S	9.167	35.783	EMP	1/31/1952	12/31/2003	2
41	GORE	8.150	35.530	GHCN	5/31/2008	5/31/2004	2
42	HARO	9.900	36.500	GHCN	4/30/1970	12/31/1984	3

ID	Station Name	Lat	Long	Source[1]	Start Date	End Date	Accuracy[2]
43	Henna	9.417	35.583	EMP	1/31/1952	12/31/1992	2
44	Hillet Doleib	9.367	31.600	NBE	5/31/2003	5/31/1945	3
45	Hurumu	8.333	35.700	EMP	1/31/1952	12/31/1992	1
46	Itang	8.200	34.267	EMP	1/31/1956	12/31/1989	2
47	Jarso	9.450	35.267	EMP	1/31/1952	12/31/1992	2
48	Jikawo	8.350	33.800	EMP	1/31/1973	12/31/1989	2
49	JIMMA	7.670	36.830	FAO	6/30/1952	12/31/1998	2
50	JIMMA	7.670	36.830	GHCN	6/30/1952	10/31/2011	1
51	JUBA	4.800	31.600	GHCN	1/31/2001	12/31/2004	2
52	KAJO-KAJI	3.900	31.600	FAO	1/31/2016	12/31/1982	1
53	KAPOETA	4.500	33.400	FAO	1/31/1938	8/31/1985	2
54	Kiltukara	9.717	34.217	EMP	1/31/1955	12/31/1992	3
55	KITGUM V.T.C	3.300	32.800	GHCN	1/31/2014	12/31/1995	1
56	Kodok	9.883	32.117	NBE	8/31/2000	2/29/1980	3
57	LEKEMTI	9.050	36.600	FAO	1/31/1971	12/31/1998	2
58	Lerua Mission (Palataka)	4.000	32.583	NBE	2/28/2027	3/31/1938	4
59	LIMUGENET	8.080	36.950	FAO	1/31/1969	12/31/1991	3
60	MAJI	6.200	35.600	GHCN	4/30/1954	9/30/1975	3
61	MALAKAL (AERO)	9.600	31.600	GHCN	1/31/2009	5/31/2004	2
62	Malek	6.067	31.600	NBE	12/31/2019	2/29/1940	3
63	Masha	7.733	35.483	EMP	1/31/1952	12/31/1992	2
64	Mendi	9.783	35.083	EMP	1/31/1955	12/31/2000	2
65	Metu Hospital	8.300	35.583	EMP	1/31/1952	12/31/1992	1
66	Mizan Teferi School	7.000	35.583	EMP	1/31/1953	12/31/1992	2
67	Mongalla	5.200	31.767	NBE	4/30/2003	8/31/1939	2
68	MOYO	3.600	31.800	GHCN	1/31/1939	7/31/1980	3
69	Mugi	8.617	34.633	EMP	1/31/1973	12/31/1992	3
70	Nasser	8.617	33.067	NBE	6/30/2022	3/31/1981	2
71	Nimule	3.600	32.050	NBE	1/31/2004	12/31/1965	2
72	Nolekaba	8.950	35.833	EMP	1/31/1952	12/31/1992	2
73	Pakwo	8.167	34.467	EMP	1/31/1956	12/31/1989	2
74	PAKWO	8.000	33.800	GHCN	6/30/1956	5/31/1984	3
75	Pibor Post	6.800	33.133	NBE	9/30/2013	11/30/1976	1
76	Rejaf	4.750	31.600	NBE	1/31/2014	8/31/1939	2
77	Rob Gebeya	8.600	34.867	EMP	1/31/1973	12/31/1992	3
78	Saiyo	8.517	34.817	NBE	10/31/2009	8/31/1937	2
79	SHEBE	7.500	36.500	GHCN	3/31/1965	12/31/1984	3
80	Shebele	8.483	34.583	EMP	1/31/1973	12/31/1992	3
81	Tepi	7.200	35.417	EMP	1/31/1953	12/31/1992	2
82	Terakeka	5.450	31.750	NBE	1/31/2025	12/31/1972	3
83	Tombe	5.817	31.683	NBE	1/31/2013	11/30/2024	3
84	Torit	4.417	32.550	NBE	11/30/2022	12/31/1992	2
85	Wama	8.767	36.750	EMP	1/31/1975	12/31/1987	2
86	Wush-Wush	7.183	36.167	EMP	1/31/1953	12/31/1992	1
87	Yayu	8.333	35.817	EMP	1/31/1952	12/31/1992	1

ID	Station Name	Lat	Long	Source[1]	Start Date	End Date	Accuracy[2]
88	Yeki	7.067	35.250	EMP	1/31/1953	12/31/1992	2
89	Youbdo	8.950	35.450	EMP	1/31/1970	12/31/1989	1
90	Adjumani Dispensary	3.383	31.800	MWE	1/31/1942	11/30/2002	4
91	Moyo Boma	3.650	31.717	MWE	1/31/1938	12/31/1998	3
92	Obongi Dispensary	3.250	31.550	MWE	6/30/1939	2/28/1979	2
93	Zaipi Dispensary	3.400	31.950	MWE	1/31/1942	6/30/1980	2
94	Pakelli Dispensary	3.367	31.917	MWE	1/31/1943	6/30/1980	3
95	Adjumani Prisons Farm	3.333	31.750	MWE	10/31/1968	2/28/1982	3
96	Kitgum Centre VT	3.300	32.883	MWE	4/30/2014	9/30/2003	1
97	Atiak Dispensary.	3.267	32.117	MWE	1/31/1942	5/31/1977	2
98	Palabek Divisional Hqs	3.433	32.583	MWE	6/30/1939	2/28/1981	1
99	Padibe	3.500	32.817	MWE	1/31/1942	12/31/1983	1
100	Patiko	3.017	32.317	MWE	1/31/1965	1/31/1985	3
101	Aringa Valley Coffee	3.267	32.933	MWE	7/31/1967	4/30/1983	3
102	Acholi Ranch	3.267	32.550	MWE	7/31/1970	8/31/1985	3
103	Kitgum Matidi	3.267	33.050	MWE	2/28/1943	12/31/1982	2
104	Kalongo Hospital	3.050	33.367	MWE	1/31/1956	12/31/1981	3
105	Paimol	3.067	33.417	MWE	1/31/1942	4/30/1980	2
106	Orom	3.417	33.467	MWE	1/31/1943	5/31/1983	1
107	Karenga	3.483	33.717	MWE	1/31/1952	11/30/1977	2
108	Naam	3.350	33.333	MWE	1/31/1942	9/30/1983	1
109	Madi Opei	3.600	33.100	MWE	5/31/1965	9/30/1998	3
110	Kacheri	3.200	33.783	MWE	3/31/1964	12/31/1991	3
111	Kaabong	3.550	34.100	MWE	9/30/1946	12/31/1966	3
112	Kotido	3.017	34.100	MWE	2/28/1947	10/31/2003	2
113	Loyoro [County Dodoth]	3.367	34.217	MWE	4/30/1947	11/30/1963	3
114	JIMMA	7.667	36.833	NBRP	6/30/1952	12/31/2002	2
115	NEKEMTEWELEGA	9.080	36.450	NBRP	6/30/1952	12/31/2002	1
116	SIBUSIREWELLEGA	9.020	36.530	NBRP	3/31/1954	12/31/1999	1
117	LODWAR	3.117	35.617	NBRP	1/31/1950	12/31/2004	3
118	LOKICHOKIO	4.250	34.350	NBRP	1/31/1959	12/31/1993	3
119	LOKITAUNG	4.250	35.750	NBRP	1/31/1957	11/30/1993	3
120	MALAKAL	9.550	31.650	NBRP	1/31/1950	8/31/2001	2
121	ADJUMANI	3.367	31.783	NBRP	1/31/1961	12/31/2000	3
122	GANBELLA	8.150	34.350	NBRP	11/30/1956	4/30/1999	4
123	BEGIE	9.350	34.533	NBRP	2/28/1967	12/31/2003	2
124	GORE	8.150	35.320	NBRP	1/31/1952	8/31/2002	2
125	NEDJO	9.500	35.483	NBRP	1/31/1952	12/31/2003	1

(1) **Sources:** DST: NB-DSS Work Package 2 stage 2; GHCN: Global Historical Climate Network; NBRP: Nile Basin Research Programme; MWE: Ministry of Water and Energy Uganda; NBE: Nile Basin Encyclopedia; FAO: Food and Agricultural Organisation; EMP: Ethiopian Master Plan Studies.

(2) **Patching correlation Accuracy** 1 – Excellent; 2 – Good; 3 – Acceptable; 4 – Non-compliant


SUDAN
SUDAN
SOUTH SUDAN
ETHIOPIA
KENYA
UGANDA
Melut
Malakal
Nassir
Jikawo
Gambela
Akobo
Waat
Ayod
Pochala
Pibor
Bor
Juba
Torit
Kapoeta
Nimule
Asosa
Mendi
Nejo
Begi
Gimbi
Nekemte
Alem Teferi
Arjo
Dembidolo
Bedele
Metu
Gore
Agaro
Jimma
Bonga
Tepi
Mizan Teferi
Maji
White Nile
Adar
Yabus
Machar Marshes
Daga
Sobat
Fullus
Baro
Bibir
Geba
Alwero
Gilo
Akobo
Agwei
Pibor
Lotilla
Kangen
Eastern Nile
BAS
Nile Equatorial Lakes
0 25 50 100 150 200 Km
Note:
BAS Patched Rainfall Stations data from various sources (raw data compiled by NBI and Aurecon).
Legend
BAS Main Towns
BAS Main Rivers
BAS Main Roads
BAS Sub-Basin
Country Boundaries
BAS Patched Rainfall Stations
Source
EMP (Baro-Akobo Ethiopian Master Plan Study)
NBE (Nile Basin Encyclopedia)
DST (Nile Decision Support Tool)
FAO (Food & Agriculture Organization)
GHCN (Global Historical Climate Network)
MWE (Ministry of Water & Energy, Uganda)
NBRP (Nile Basin Research Program)
Note: Boundaries of countries and admin units are not authoritative. Coordinate System: GCS_WGS84
Project:
Baro-Akobo-Sobat (BAS) Multi-Purpose Water Resources Development Study
aurecon
BRL ingénierie
Map Title: BAS Patched Rainfall Stations
Date: March 2016
Rev: Draft Map
Prepared by: GTS Services (gtshsig@gmail.com)

A.3: EVAPORATION DATA

AVERAGE MONTHLY EVAPORATION VALUES AT AVAILABLE STATIONS

Station Name	Source	Type	Record Period	Lat	Long	Average Monthly Evaporation (mm)												MAE (mm)
						Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Abobo	EMP	Penman	1956-1987*	7.51	34.33	119	132	161	153	129	114	108	114	117	123	114	116	1500
Bedelle	EMP	Penman	1985-1998*	8.27	36.20	124	137	143	139	141	141	117	96	100	116	136	140	1530
Gambella	EMP	Penman	1906-1993*	8.15	34.35	136	140	176	161	130	113	107	113	116	124	120	125	1561
Pokwo	EMP	Penman	1956-1989*	8.10	34.28	127	138	172	162	134	113	109	107	118	127	118	123	1548
Gore	EMP	Penman	1952-2002*	8.09	35.32	145	130	152	138	121	97	96	97	103	125	125	131	1460
Jikawo	EMP	Penman	1973-1989*	8.21	33.48	112	109	149	152	115	88	88	97	110	108	107	99	1334
Metu	EMP	Penman	1952-1992*	8.20	35.35	116	133	156	159	123	102	93	98	101	121	108	111	1421
Mizan	EMP	Penman	1953-1992*	7.00	35.35	114	118	134	130	123	109	100	103	107	118	110	109	1375
Wush	EMP	Penman	1953-1992*	7.11	36.10	111	116	134	131	126	111	100	103	107	119	107	108	1373
Anger	EMP	Penman	1954-1992*	9.22	36.22	110	121	143	150	127	109	100	103	103	116	104	105	1391
Arjo	EMP	Penman	1954-1992*	8.45	36.30	106	114	138	131	119	100	89	94	100	112	105	105	1313
Bambessi	EMP	Penman	1955-1992*	9.45	34.44	128	145	169	161	122	99	91	92	93	98	101	121	1420
Dembi	EMP	Penman	1973-1992*	8.32	34.48	111	119	139	135	112	97	91	95	98	115	102	108	1322
Gimbi	EMP	Penman	1952-1992*	9.10	35.47	118	131	152	154	124	102	93	96	100	112	114	115	1411
Kurmuk	EMP	Penman	1961-1988*	10.26	34.28	163	181	205	199	151	125	114	118	116	127	130	152	1781
Mendi	EMP	Penman	1955-1992*	9.47	35.05	116	131	144	144	125	104	99	92	95	109	99	107	1365
Nedjo	EMP	Penman	1952-2003*	9.30	35.29	106	130	142	141	122	101	96	91	93	108	98	106	1334
Dongoro	EMP	Penman	1952-1992*	9.16	35.41	117	128	150	151	114	93	84	87	92	102	103	106	1327
Wama	EMP	Penman	1975-1987*	8.46	36.45	116	126	162	145	133	112	91	95	101	114	111	110	1416
Bonga	EMP	Penman	1953-1992*	7.13	36.14	114	118	131	127	119	106	99	101	104	114	112	109	1354
Gambela	FAO	Penman-Monteith	1985-1986	8.25	34.58	-	-	-	-	144	117	119	109	126	139	131	143	-
Burre	FAO	Penman-Monteith	1989-1991	8.27	35.08	155	130	165	142	122	101	101	101	113	155	142	146	1570
Gore	FAO	Penman-Monteith	1982-1991	8.17	35.55	120	121	138	135	116	92	96	95	102	128	110	113	1365
Alge	FAO	Penman-Monteith	1990-1991	8.53	35.67	147	132	-	135	133	104	103	-	-	130	136	153	-
Nejo	FAO	Penman-Monteith	1989-1990	9.50	35.48	217	-	-	243	156	172	150	107	124	175	216	251	-
Bedele	FAO	Penman-Monteith	1986-1991	8.45	36.38	-	120	136	129	126	116	97	102	105	130	128	115	-
Gambela	Shahin, 1985	Open Water	1950-1957	8.25	34.58	205	216	248	180	109	75	65	65	66	87	108	155	1578
Akobo	Shahin, 1985	Open Water	1950-1957	7.78	33.02	270	277	285	222	136	135	102	74	60	81	117	202	1961
Gore	Norplan, 2006	Open Water	1974-2003	8.15	35.53	112	116	134	128	111	88	81	85	91	102	100	103	1251
Baro-1	Norplan, 2006	Open Water	1974-2004	8.07	35.33	116	120	138	132	115	91	84	87	94	106	104	106	1293
Baro-2	Norplan, 2006	Open Water	1974-2005	8.15	8.15	119	123	142	135	118	93	86	90	96	108	106	109	1325
Genji	Norplan, 2006	Open Water	1974-2006	8.12	35.22	120	125	144	137	120	95	87	91	98	110	108	110	1345
Malakal	FAO Calculator	Penman-Monteith	1951-2005	9.53	31.65	186	190	229	186	152	144	133	121	120	149	174	180	1965
Torit	FAO Calculator	Penman-Monteith	1951-2005	4.42	32.55	180	179	198	150	105	99	105	105	99	112	123	158	1614
Pibor Post	FAO Calculator	Penman-Monteith	1951-2005	6.80	33.13	195	193	220	168	127	120	124	121	111	124	144	180	1827

*Record period estimated based on corresponding rainfall station record period

A.4: MODEL SUB-CATCHMENTS

DETAILED INFORMATION OF THE MODELLED SUB-CATCHMENTS

Sub-catchment	Catchment Area (km2)	MAP (mm)	Rainfall stations used for catchment rainfall file (monthly)	Rainfall stations used for catchment rainfall file (daily)	MAE (mm)	Evaporation stations used for catchment monthly evaporation	NAM parameters used	MAR (million m3/a)	Runoff Coefficient
Hillet Doleib	3,015	769	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,916	Malakal (FAO calculator)	Alwero	41	0.018
Residual Pibor Post	10,975	886	1937Kapoeta, 3312Lokichokio, 2112Maji, 2294Pibor_Post	Pibor Post	1,731	Pibor Post (FAO calculator)	Alwero	99	0.010
Nasir	348	788	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,738	Malakal (FAO calculator)	Alwero	9	0.033
Baro at Burebeiy	1,203	825	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,673	Gambella (Observed)	Alwero	2	0.002
Baro at Itang	221	1,013	2191Mugi, 2377Shebele, 1192Gambela, 1764Gambela	Gore	1,550	Gambella (Observed)	u/s Gambella	13	0.058
Baro at Gambella	2,269	1,363	2191Mugi, 2377Shebele, 1192Gambela, 1764Gambela	Gore	1,484	Gambella (Observed)	u/s Gambella	630	0.204
Baro at Kella	1,016	1,611	1610Bure, 3611Gore	Gore	1,445	Metu (Observed)	u/s Gambella	455	0.278
Birbir at Yubdo	1,858	1,863	1691Dongoro, 1791Gimbi_HS, 2267Nolekaba, 2539Youbdo, 1837Henna, 3673Nedjo	Gore	1,389	Dongoro (Observed)	u/s Gambella	1,431	0.413
Geba at Suppi	2,154	1,750	1806Gore, 1847Hurumu, 2530Yayu, 1649Chora_Kumbabe	Gore	1,358	Arjo (Observed)	u/s Gambella	1,235	0.328
Sor at Metu	1,712	1,899	1806Gore, 2172Metu_Hospital, 2530Yayu	Gore	1,375	Arjo (Observed)	u/s Gambella	1,179	0.363
Baro at Masha	1,729	1,875	2438Tepi, 1806Gore, 3611Gore	Gore	1,385	Arjo (Observed)	u/s Gambella	1,159	0.357
Alwero at Abobo	710	1,311	1764Gambela, 2290Pakwo, 2291Pakwo, 2141Masha	Gore	1,491	Metu (Observed)	Alwero	157	0.169
Piyor	1,814	907	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,687	Gambella (Observed)	Alwero	34	0.021
Torit	822	967	1490Agoro, 2454Torit	Torit	1,609	Torit (FAO calculator)	Alwero	27	0.034
Upper Daga	3,124	1,401	1562Begi_School, 2005Kiltukara	Gore	1,501	Bambessi (Observed)	Machar Torrents	394	0.090
Proposed Abobo Dam	1,071	1,333	1764Gambela, 2290Pakwo, 2291Pakwo, 2141Masha	Gore	1,486	Metu (Observed)	Alwero	253	0.177
Birbir A	1,634	1,733	1691Dongoro, 1791Gimbi_HS, 2267Nolekaba, 2539Youbdo, 1837Henna, 3673Nedjo	Gore	1,393	Dongoro (Observed)	u/s Gambella	1,081	0.382
Birbir R	3,377	1,556	1496Alem_Teferi_School, 1610Bure, 1642Chanka, 2324Rob_Gebeya	Gore	1,403	Metu (Observed)	u/s Gambella	1,482	0.282
Geba 1	977	1,731	1806Gore, 1847Hurumu, 2530Yayu, 1649Chora_Kumbabe	Gore	1,356	Arjo (Observed)	u/s Gambella	582	0.344
Geba 2	550	1,750	1806Gore, 1847Hurumu, 2530Yayu, 1649Chora_Kumbabe	Gore	1,356	Arjo (Observed)	u/s Gambella	315	0.327
Sor	152	1,865	1806Gore, 2172Metu_Hospital, 2530Yayu	Gore	1,393	Arjo (Observed)	u/s Gambella	99	0.349
Geba R	1,053	1,783	1806Gore, 1847Hurumu, 2530Yayu, 1649Chora_Kumbabe	Gore	1,405	Arjo (Observed)	u/s Gambella	615	0.328
Gumero	424	2,040	1610Bure, 3611Gore	Gore	1,409	Metu (Observed)	u/s Gambella	345	0.398
Baro 1	492	2,022	1610Bure, 3611Gore	Gore	1,409	Metu (Observed)	u/s Gambella	393	0.395
Baro 2	115	2,085	1610Bure, 3611Gore	Gore	1,424	Metu (Observed)	u/s Gambella	97	0.406
Genji	1,385	1,816	1610Bure, 3611Gore	Gore	1,417	Metu (Observed)	u/s Gambella	861	0.342
Tams	2,590	1,466	1610Bure, 3611Gore	Gore	1,444	Metu (Observed)	u/s Gambella	890	0.234
Kashu	456	2,032	1448Abobo, 2535Yeki, 2112Maji	Gore	1,373	Mizan (Observed)	u/s Gambella	376	0.406
Itang	930	1,227	2191Mugi, 2377Shebele, 1192Gambela, 1764Gambela	Gore	1,522	Gambella (Observed)	u/s Gambella	156	0.137
Dumbong	1,079	1,441	1764Gambela, 2290Pakwo, 2291Pakwo, 2141Masha	Gore	1,463	Metu (Observed)	Alwero	343	0.221
Gilo 1	7,408	1,703	1448Abobo, 2180Mizan_Teferi, 2438Tepi, 2535Yeki	Gore	1,427	Mizan (Observed)	u/s Gambella	3,294	0.261
Gilo 2	1,912	1,226	1448Abobo, 2180Mizan_Teferi, 2438Tepi, 2535Yeki	Gore	1,427	Mizan (Observed)	u/s Gambella	200	0.085
Jakau	2,337	1,391	2191Mugi, 2377Shebele, 1192Gambela, 1764Gambela	Gore	1,488	Gambella (Observed)	u/s Gambella	663	0.204

Sub-catchment	Catchment Area (km2)	MAP (mm)	Rainfall stations used for catchment rainfall file (monthly)	Rainfall stations used for catchment rainfall file (daily)	MAE (mm)	Evaporation stations used for catchment monthly evaporation	NAM parameters used	MAR (million m3/a)	Runoff Coefficient
Baro Flood Dam	2,798	1,024	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Gore	1,557	Gambella (Observed)	Alwero	177	0.062
d/s Gilo Flood Dam	1,867	959	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,698	Gambella (Observed)	Alwero	9	0.005
Akobo Flood Dam	3,882	1,094	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,609	Gambella (Observed)	Alwero	326	0.077
Akobo/Aculla	1,737	1,331	1448Abobo, 2535Yeki, 2112Maji	Gore	1,533	Mizan (Observed)	Alwero	233	0.101
u/s Gilo Flood Dam	746	1,047	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,593	Gambella (Observed)	Alwero	54	0.069
Alwero 2	1,611	1,043	1764Gambela, 2290Pakwo, 2291Pakwo, 2141Masha	Gore	1,554	Metu (Observed)	Alwero	67	0.040
Agwei Flood Dam	13,727	1,037	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,701	Gambella (Observed)	Alwero	273	0.019
Upper Akobo	14,281	1,546	1448Abobo, 2535Yeki, 2112Maji	Gore	1,481	Mizan (Observed)	u/s Gambella	4,698	0.213
Upper Yabus	6,321	1,219	1177J_Maiak, 1178El-Kurmuk, 1201Yabus_Bridge, 1523Asosa, 1641Chali, 2005Kiltukara, 2060Kurmuk, 2061Kurumuk	Gore	1,605	Kurmuk (Observed)	Machar Torrents	334	0.043
Upper Kenamuke	1,982	1,098	1937Kapoeta, 3312Lokichokio, 2112Maji, 2294Pibor_Post	Pibor Post	1,609	Pibor Post (FAO calculator)	Alwero	133	0.061
Kobowen	18,758	1,006	1937Kapoeta, 3312Lokichokio, 2112Maji, 2294Pibor_Post	Pibor Post	1,560	Pibor Post (FAO calculator)	Alwero	823	0.044
Lower Kenamuke	5,412	816	1937Kapoeta, 3312Lokichokio, 2112Maji, 2294Pibor_Post	Pibor Post	1,646	Pibor Post (FAO calculator)	Alwero	31	0.007
Upper Domongo	8,712	934	1937Kapoeta, 3312Lokichokio, 2112Maji, 2294Pibor_Post	Torit	1,585	Torit (FAO calculator)	Alwero	201	0.025
Veveno/Lotilla	24,765	896	1220Mongalla, 2439Terakeka, 2447Tombe, 2454Torit, 2294Pibor_Post	Pibor Post	1,712	Pibor Post (FAO calculator)	Alwero	267	0.012
Lower Akobo	2,431	974	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,695	Gambella (Observed)	Alwero	76	0.032
Pignudo	104	1,167	1448Abobo, 2180Mizan_Teferi, 2438Tepi, 2535Yeki	Gore	1,563	Mizan (Observed)	Alwero	7	0.058
Alwero 1	2,076	1,071	1764Gambela, 2290Pakwo, 2291Pakwo, 2141Masha	Gore	1,566	Metu (Observed)	Alwero	155	0.070
Lower Alwero	1,026	930	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Gore	1,632	Gambella (Observed)	Alwero	15	0.016
Wal	5,403	762	1197Nasir, 1462Abwong, 1193Kodok, 2162Melut	Malakal	1,839	Malakal (FAO calculator)	Alwero	124	0.030
Twalor	1,346	849	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,769	Malakal (FAO calculator)	Alwero	50	0.044
Nyanding	7,197	865	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,831	Malakal (FAO calculator)	Alwero	254	0.041
Sobat u/s Nyanding	1,099	789	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,778	Malakal (FAO calculator)	Alwero	12	0.014
Sobat u/s Beguyang	3,576	783	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,837	Malakal (FAO calculator)	Alwero	68	0.024
Beguyang	2,592	806	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,862	Malakal (FAO calculator)	Alwero	56	0.027
Fullus	17,492	844	1494Akobo, 1197Nasir, 1462Abwong, 1839Hillet_Doleib, 2242Nasser, 1195Malakal_MofA, 1207Shambe	Malakal	1,894	Malakal (FAO calculator)	Alwero	462	0.031
Machar Marshes	29,362	897	1197Nasir, 1462Abwong, 1193Kodok, 2162Melut	Malakal	1,732	Malakal (FAO calculator)	Alwero	2,021	0.077
Into Lower Pibor	5,126	894	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,846	Gambella (Observed)	Alwero	48	0.010
Upper Pibor	4,113	903	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,821	Gambella (Observed)	Alwero	46	0.012
Lower Pibor	957	798	1198Pibor, 1494Akobo, 1864Itang, 1874Jikawo, 2291Pakwo, 2294Pibor_Post, 3542Ganbella	Pibor Post	1,705	Gambella (Observed)	Alwero	1	0.001

A.5: FLOODPLAINS, WETLANDS AND MARSHES

SOURCES OF INFORMATION

The following sources were used to conceptualise and model the floodplains of the BAS Basin, and are discussed in more detail below:

- GIEMS - Global Inundation Extent from Multi-satellites Dataset (Prigent et al., 2007; Fluet-Chouinard et al., 2015; Miolane et al., in print)
- GLWD - Global Lakes and Wetlands Database (Lehner and Doll, 2004).
- TTI spatial mapping of wetlands and marshes in the BAS Basin (Baro-Akobo-Sobat Multipurpose Water Resources Development Project: Scoping Report: Annex2, Dec 2015)
- The Hydrology of the Nile (Sutcliffe and Parks, 1999)
- Baro-Akobo basin master plan study of water and land resources of the Gambela Plain (Selkhozpromexport, 1990)
- 2012 Field Report on visit to Machar Marshes
- Baro-Akobo-Sobat Wetlands Knowledge Base Consultancy (Ssebuliba, 2012)
- A Directory of African Wetlands (Hughes and Hughes, 1992)

GIEMS

The Global Inundation Extent from Multi-Satellites (GIEMS) is a monthly-mean water surface extent derived at a low spatial resolution of 0.25°equal-area grid for the period between 1993 and 2007. The derivation included combining satellite observations in the visible, near-infrared, and passive/active microwaves. It expresses the fractional inundation within each 773 km^2 grid box (resolution at the equator) attributed to lakes, rivers, wetlands and irrigated agriculture.

GIEMS-D15 was derived from the GIEMS data at a pixel size of 15 arc-seconds. The downscaling procedure predicted the location of surface water cover with an inundation probability map that was generated by bagged decision trees using globally available topographic and hydrographic information from the SRTM-derived HydroSHEDS database and trained on the wetland extent of the GLC2000 global land cover map. GIEMS-D15 represents three states of land surface inundation extents: mean annual minimum, mean annual maximum, and long-term maximum (the largest surface water area of any global map to date).

The GIEMS data was also downscaled to a 3 arc second (90 m) dataset (GIEMS-D3) using topographical information from the HydroSHED database and a new floodability index procedure. The resulting GIEMS-D3 database is the only long-term (1993-2007), dynamic (monthly time-scale), and high spatial resolution inundation database that is available at the global scale.

GLWD

The Global Lakes and Wetlands Database (GLWD) represents a comprehensive dataset of global surface water area, including small and large lakes, reservoirs, smaller water bodies, rivers, and a good representation of the maximum global wetland extent. GLWD is a static database.

<u>TTI</u>

Using landsat and radar images, TTI prepared an inundation map for the study basin.

<u>The Hydrology of the Nile (Sutcliffe and Parks, 1999)</u>

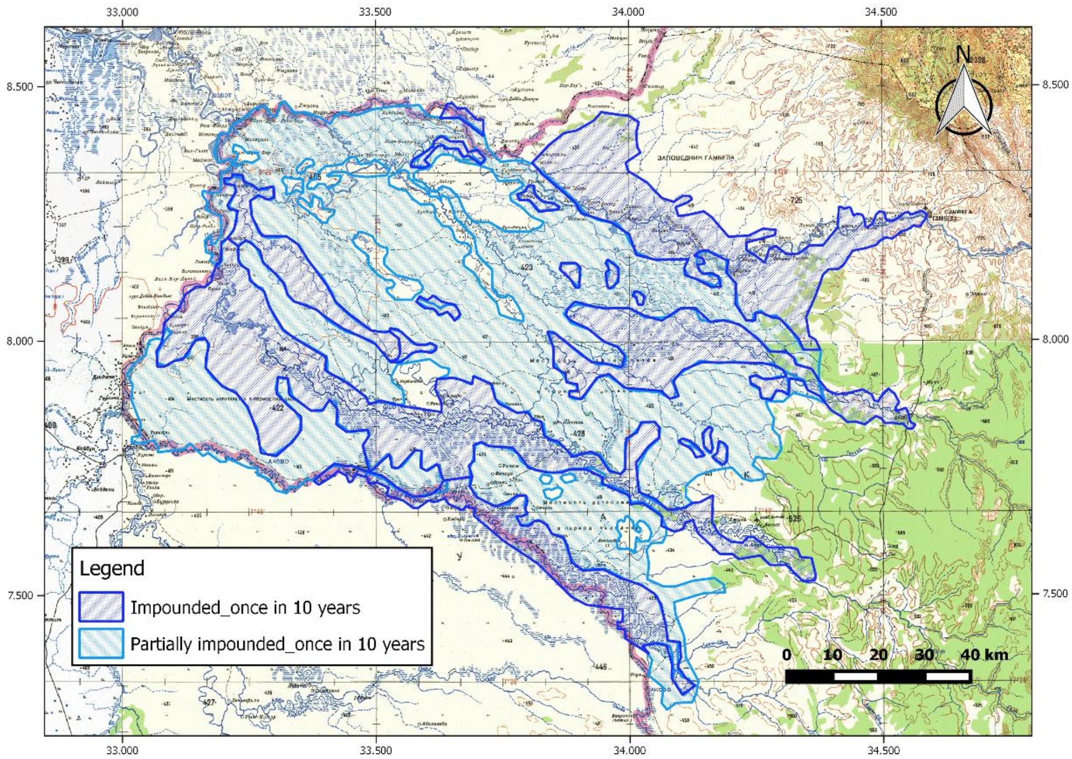
Sutcliffe and Parks (1999) reported that the streamflow in the Baro River below the Machar Marshes does not exceed 1.5 km^3 per month (560 m^3/s), even though the inflow upstream of the Marshes at Gambella exceeds that value. Hurst (1950) estimated that 78% of the lost water is diverted into the Machar Marshes, and the remaining 22% spills over to the left bank.

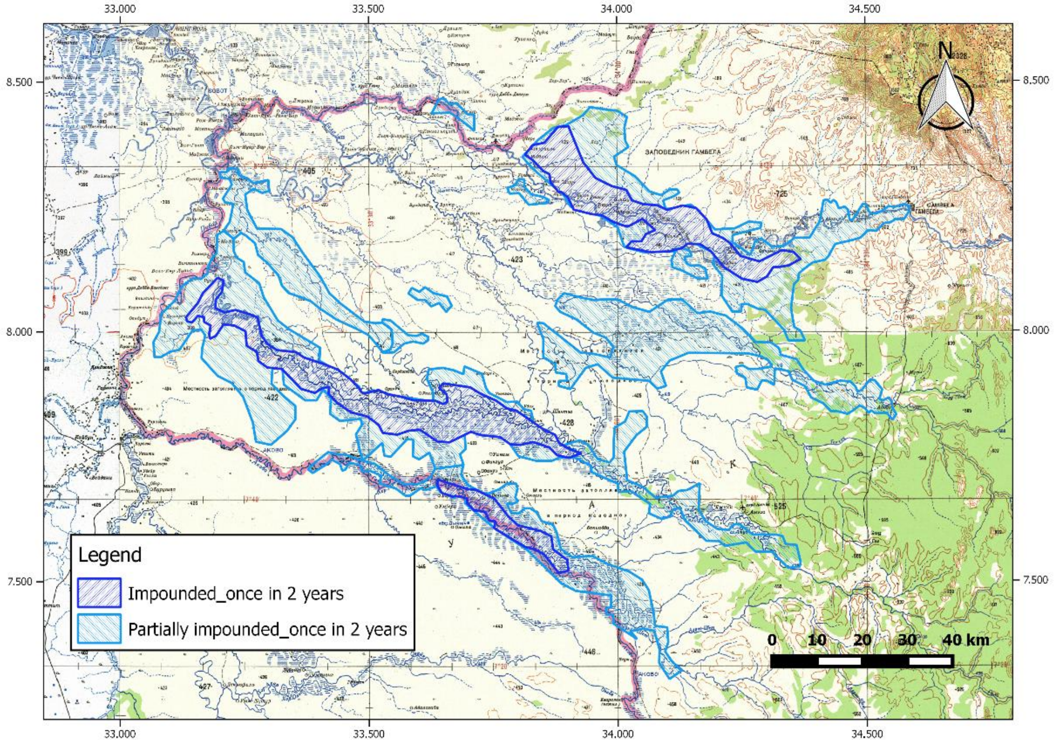
<u>Baro-Akobo basin master plan study of water and land resources of the Gambela Plain (Selkhozpromexport, 1990)</u>

A study by Selkhozpromexport (1990) reported on the flooding of areas along the Baro, Alwero, Gilo and Akobo Rivers due to limited conveyance capacities as follows:

- Baro River: 860 – 1000 m3/s
- Gilo River: 150 – 300 m^3/s
- Alwero River: 60 - 70 m^3/s.

These capacity ranges were used in the model in order to simulate spills when the river capacities were exceeded. Selkhozpromexport (1990) also reported on the 1988 flood at Gambella and presented maps of inundated areas for one in 10 year and one in 2 year floods – these were digitised for this project, as shown below.





2012 Field Report on visit to Machar Marshes

This report describes a field mission to the Baro River at the locations of major spills to the Machar and provides information about the locations and elevations of spill channels

Baro-Akobo-Sobat Wetlands Knowledge Base Consultancy (Ssebuliba, 2012)

This report provided useful information on the river system and wetlands in the basin.

A Directory of African Wetlands (Hughes and Hughes, 1992)

This report provides very useful information regarding the location and extent of wetlands in the study area, including the Pibor catchment. It also describes the main rivers draining into and out of the wetlands.

Modelling of Bifurcation Nodes

The links and spills between the main river channels were modelled using bifurcation nodes. The bifurcation node rules (spill rules) used were determined using the available information on channel capacities and wetland extents, as well as an iterative process to obtain accurate simulated flows at validation points. The spill rules are described below:

- Baro spill to Machar: the flow threshold assumed for the Lower Baro after which spill to Adura Junction occurs is 510 m³/s; 78% of the flow in the Adura Junction spills to Machar.
- Baro spill to Alwero: the Baro does not spill up to 940 m³/s, after which it breaks its banks and spills 60 m³/s to the Alwero.
- Gilo spill to Alwero: The Gilo River has a capacity of 250 m³/s, after which it spills surplus flow to the Alwero.

- Pibor spill to Twalor: The Lower Pibor has a capacity of 250 m^3/s, after which it spills surplus flow to the Twalor.

- Upper Akobo to Agwei: The Upper Akobo spills a maximum of 200 m^3/s into the Lower Akobo, and the surplus spills into the Agwei.

- Akobo spill to Gilo: The Lower Akobo River has a capacity of 25 m^3/s, after which it spills surplus flow to the Gilo.

- Sobat spill to Wal: The Sobat River has a capacity of 1 400 m^3/s, after which it spills surplus flow to the Wal.

Modelling of Wetlands

In order to accommodate lags, evaporation and infiltration losses and attenuation in the wetlands, marshes and floodplains, dummy dams were introduced and modelled as rule-curve reservoirs to represent storage in these areas. Coarse storage-elevation-area relationships for the wetlands were estimated based on historical inundation extents from satellite images, previous study reports and various global inundation datasets. Historical observed inundation areas during specific flood events were used to refine the assumptions regarding channel capacities, spill locations and spill volumes.

Wetlands are modelled as one single reservoir for individual wetlands/marshes and as several reservoirs for the more complex wetland areas. The level-area-volume relationships for the major floodplains, wetlands and marshes in the basin are given below.

1. Gambella Plains (modelled as six dummy dams, namely Lower Baro, Baro, Gilo, Pibor, Alwero and Lower Alwero):

Lower Baro

Level (m)	Area (km^2)	Volume (million m^3)
0	0	0
2	50	50
4	75	100
5	90	250
8.5	100	550
9.9	500	999
10	1000	1000

Baro

Level (m)	Area (km^2)	Volume (million m^3)
0	0	0
2	405	384
4	994	1436

Gilo

Level (m)	Area (km²)	Volume (million m³)
0	0	0
1	3000	1500
2	3300	4650
3	3300	7950

Pibor

Level (m)	Area (km²)	Volume (million m³)
0	0	0
2	150	150
8	573	800
10	2768	1000

Alwero

Level (m)	Area (km²)	Volume (million m³)
0	0	0
1	414	207
2	798	813
3	798	1611

Lower Alwero

Level (m)	Area (km²)	Volume (million m³)
0	0	0
1	360	180
2	1798	1259
3	1798	3057

2. Machar Marshes (modelled as one dummy dam):

Machar Marshes

Level (m)	Area (km²)	Volume (million m³)
0	0	0
3	8000	12000
10	8000	68000

3. Gwom Wetland (modelled as one dummy dam):

Agwei

Level (m)	Area (km^2)	Volume (million m^3)
0	0	0
1	2000	1000
2	4000	4000

4. Sobat Wetlands (modelled as three dummy dams, namely Sobat. Nyanding and Fullus):

Sobat

Level (m)	Area (km^2)	Volume (million m^3)
0	0	0
1	1200	600
2	1350	1875
3	1500	3300

Nyanding

Level (m)	Area (km^2)	Volume (million m^3)
0	0	0
1	1923	962
2	1923	2885

Fullus

Level (m)	Area (km^2)	Volume (million m^3)
0	0	0
1	4353	2177
2	4353	6530
3	4353	10883

Annex 7: Detailed climate change projections

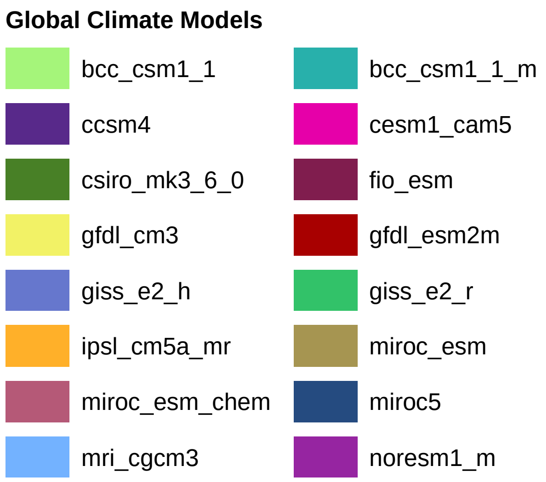
SOURCE OF INFORMATION

Data from the "Climate Change Knowledge Portal" of the World Bank, available online on *http://sdwebx.worldbank.org/climateportal/* were used to study climate change projections in the BAS.

This portal was created to disseminate existing information regarding climate change in a user friendly manner and thus inform decision makers. The website uses a vast collection of models to outline projected future changes of temperature and precipitation across the globe and for major river basins. The collection analyzed is a representative subset of the full CMIP5[54] distribution (Taylor et al. 2012) used by the Intergovernmental Panel on Climate Change (IPCC) in the 5th Assessment Report released in 2009.

Climate change projections are presented as changes in 20-year period of time (2040-2059) relative to a reference period 1986-2005. The different models used in the Climate Change Knowledge Portal are presented in **Erreur ! Source du renvoi introuvable.**.

Figure 11-46: Global climate models used in the Climate Change Knowledge Portal



54 CMIP5 is "the fifth iteration of a globally coordinated experiment collection which reflects different possible futures of distinct emissions, landuse change, and associated atmospheric radiative forcing."(Metadata of the Climate change knowledge portal)

PROJECTIONS IN THE BAS

On the portal, the location for which the information is required can be easily chosen. In order to cover the various climatic areas of the BAS, four areas were selected : Ethiopian highlands, South Sudan highlands, Ethiopian lowlands, South Sudan lowlands.

Some key results are presented hereafter for a medium SRES emission scenario (RCP4.5):

- Projected change of the mean monthly temperature – projection from 2040 to 2055 compared to the reference period 1986-2005.
- Projected change in mean monthly Rainfall - projection from 2040 to 2055 compared to the reference period 1986-2005.

The different colours represent the 16 models that were used and which are presented in figure above.

Figure 11-47: Projected change in temperature from 2040 to 2059

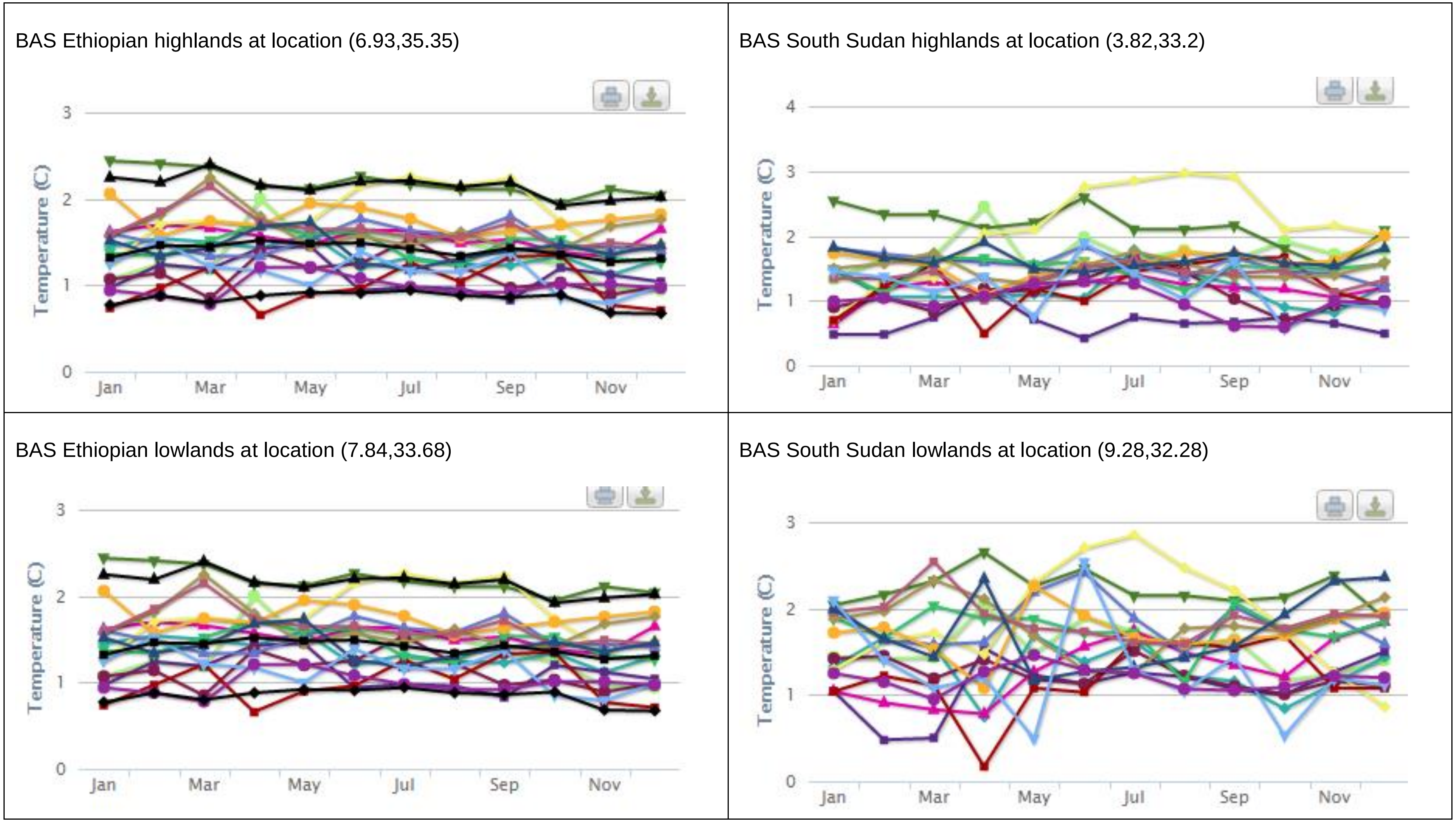
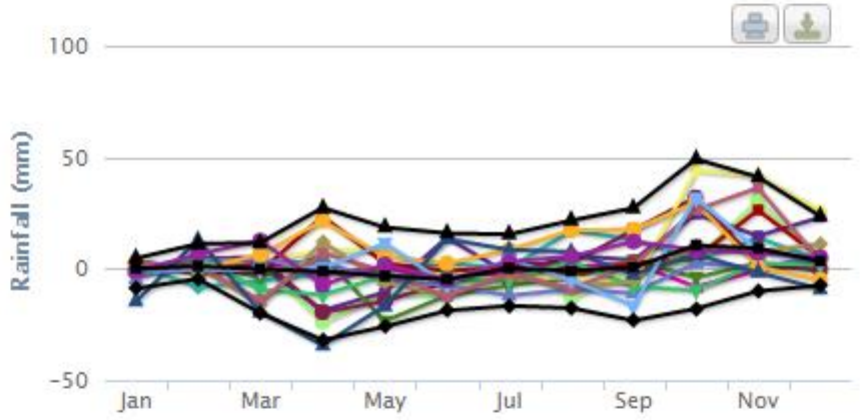
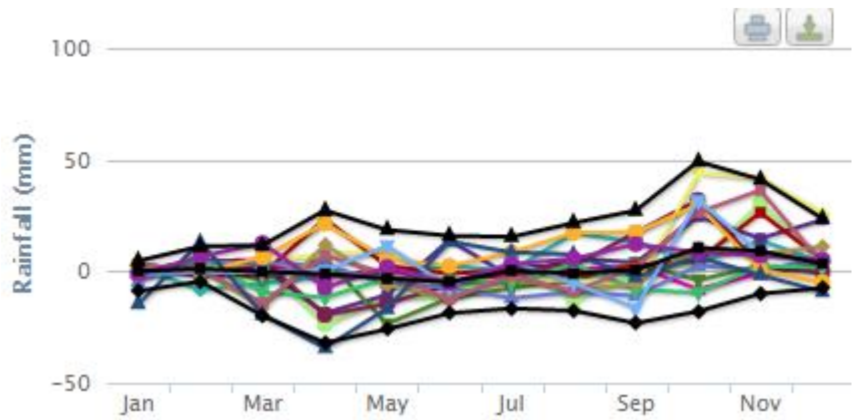


Figure 11-48: Projected change in rainfall from 2040 to 2059

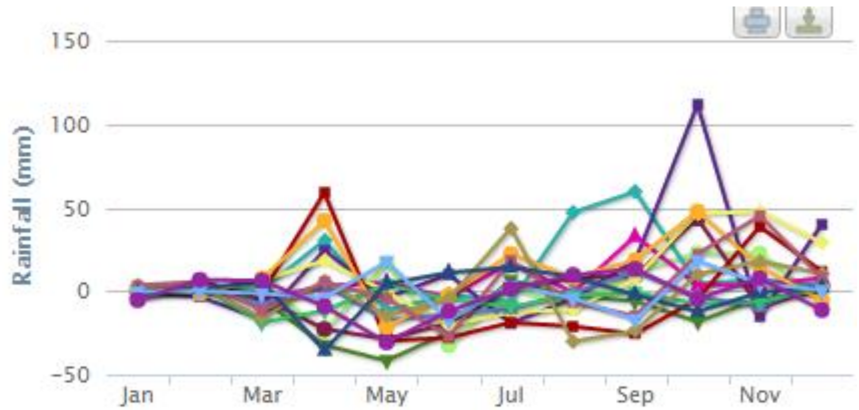
BAS Ethiopian highlands at location (6.93,35.35)



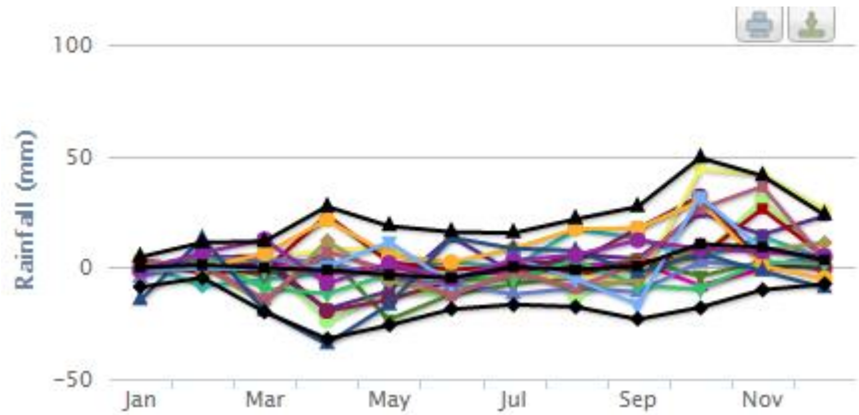
BAS South Sudan highlands at location (3.82,33.2)



BAS Ethiopian lowlands at location (7.84,33.68)



BAS South Sudan lowlands at location (9.28,32.28)



Annex 8: Case studies of social impacts of developments on access to water

INTRODUCTION

Since the team's access to the study area has been limited due to security concerns, case studies of actual situations with similar characteristics in the same or nearby areas will be used to illustrate possible factors that are likely to influence the outcomes of the developments in the scenarios, especially hydropower and irrigation. The cases presented are empirical in the sense that they are based on actual evidence from individuals and groups affected by recent activities in similar situations in nearby locations. In presenting the cases an effort has been made to include the perspectives of people actually affected by developments.

The case studies to be presented are as follows:

1. The Gibe III dam and hydropower project in western SNNPR, Ethiopia
2. Social Impacts of Agricultural Investment Projects in western Ethiopia
3. Land investment in South Sudan
4. Sugar Plantation in Equatoria, South Sudan
5. Al Ain National Wildlife, Boma National Park, South Sudan

These cases can also serve as a proxy ground-truthing and as useful information for the planners and implementers of future water-related developments in the BAS basin.

NB: The presentation of the following case studies is adapted in part from the following sources:

- Understanding Land Investment Deals in Africa, Oakland Institute, 2013 and Gurtang Trust; http://www.gurtong.net
- Understanding Land investment Deals in Africa, Country report: South Sudan, Oakland Institute, 2011..

CASE STUDY 1: GIBE III DAM AND HYDROPOWER PROJECT – WESTERN SNNPR, ETHIOPIA

Construction of the now completed Gibe III dam as it appeared in 2012

The Gibe III hydroelectric dam was completed in 2016. Along with the yet to be built Gibe IV and V dams, this will be the second in a cascade of four dams and one powerhouse (Gibe II). Gibe III will make large-scale irrigation in the Lower Omo basin possible by controlling the flow of the Omo River. Contracts for the export of electricity to Kenya and a loan from the World Bank to construct transmission lines to Addis Ababa have been negotiated.

Without the dam, the annual floods would damage much of the planned downstream irrigation infrastructure and the low flows in the dry season would be too low for irrigated agriculture. In the impact assessments for the dam, it was said that an artificial flood released annually from the reservoir would compensate the downstream population for the loss of the natural flood; this is the main feature of the downstream mitigation plan. But the subsequent development of large-scale irrigation infrastructure for commercial plantations downstream has made the controlled flooding a moot point.

Plans for large-scale sugar cane and other plantations in the Lower Omo River have been accompanied by a resettlement program for the local pastoral and agro-pastoral people. To acquire land for large-scale commercial plantations, the people living in the area must first be resettled. Once cleared, state-run plantations and private plantations leased by Indian, Italian, and Malaysian, companies and Ethiopian firms, as well as US-based Ethiopian diaspora-owned plantations move into these areas to grow crops such as oil palm, sugar cane, bio fuels, oil seed, grain, and cotton.

Current plans by the state-run Ethiopian Sugar Corporation (ESC) plantations will impact the people of the Lower Omo, especially the 170,000 people from ten ethnic groups who live along or near the Omo River: Dizi, Suri, Bodi, Kwegu, Mursi, Mugudji, Karo, Nyangatom, Murle, and Dassanach. More than 200 kilometers (125 miles) of irrigation canals are planned and an earthen dam to divert water to the plantations was built. This has reduced the annual floods that people along the river depend on for flood recession agriculture, and has inundated the perennial cultivation areas of the Bodi and Kwegu people upstream. Central to Bodi and Mursi concerns is their ability to maintain cattle herds. However, the Government has indicated that for legal reasons it will not issue titles for the communal ownership of land.

In 2011 it was announced that the government would take over 150,000 hectares (580 sq. miles) of land for sugarcane plantations and sugar mills. According to the plan, almost all the land of the Nyangatom, as well as large parts of the land used by the Bodi, Kwegu, Mursi, Karo and Mugudji, will become commercial plantations. In addition, another 200,000 hectares (770 sq. miles) will be leased to other foreign and Ethiopian private farms. This will require that the indigenous agro-pastoralists be moved to resettlement sites on the plateau away from the river.

It is reported that the ESC had planned to acquire about a third of the Omo National Park for cultivation of sugar cane and another 33,000 hectares (125 sq. miles) from the neighboring Mago National Park to establish the Mago commercial farm. Part of a newly gazetted area of the Omo National Park, an important breeding ground for wildlife, has been designated for sugar cane, which has contributed to creating disagreements between the regional and federal government. However, it was later reported that these plans had been changed to exclude lands in the national parks.

When completed, the sugar plantation and the estimated 500,000+ workforce, expected to come mainly from the highlands, will have a significant impact on the livelihoods and way of life of the indigenous people, which seems likely to significantly increase the risk of conflicts between these two groups.

In the Bodi villages, the arrival of the sugar plantation and government-assisted construction projects appears to be seen with hostility. Respondents were generally suspicious, associating resettlement with a broader set of problems including traffic accidents on new roads; police confiscation of unlicensed AK47s; and hyenas and lions driven into their villages as forest is cleared for the sugar plantation. In this context minor events and poor communications can easily trigger conflicts.

The rapid pace with which it is proposed to implement villagisation and the sugar cane plantations will significantly accelerate the social and cultural change, as the Bodi and Mursi are increasingly exposed to external influences. This will be likely destabilize agro-pastoralist and semi-nomadic communities. The culture and way of life of groups such as the Mursi and Bodi are likely to be fundamentally and irreversibly transformed.

Case Study 2: Social Impacts of Agricultural Investment Projects in western Ethiopia

Following are actual statements from individuals from various groups affected by agricultural investment projects in the Gambella and Oromiya regions in western Ethiopia.

Anuak Farmer - Gambella, Ethiopia

Our land is fertile and has access to water. So the land was leased to a national investor. So, I was told I had to move and tell the other people to accept. I said that the villagization program will bring hardships to our land. Our livelihood depends on our fertile fields and access to nearby forests.

Last year, the program moved closer. We had to move, so the people built tukuls. The promises of food and other social services made by the government were not fulfilled on time. So people went back to their former farms. Money promised for schools and clinics did not come. No medicine is provided in the clinics. The government receives funds from donors, but it is not transferred to the communities.

This is not just for agriculture. Minerals and gold are being mined and exported. We have no power to resist. We were promised tractors to help us cultivate. But we did not get the tractors.

Under the new villagization program, the new land provided is too small. It is not enough for the family and does not compare to the large farms we had before. In the lands where our farms were before, we had many fruit trees—banana, mango and others. It is hard to plant again in a new place and wait a long time until they mature and start to produce.

South Omo Pastoralist

In Hammer, a woreda in South Omo, there are 38 kebeles. Of those, 10 kebeles have been targeted for resettlement (sefara). The plan was to move 10 kebeles 78 km away from where we were. It was a failure. Now no one lives where they were moved to. Grinding stones were left behind—empty villages remain.

The experience of moving people from their own land to the Bodi's land provides lessons. There is now conflict between the Bodi and Konso people. The Hammer refused to go there. If they went, there would be the same conflicts, like the conflict between the Nyongtham and the Mursi in Sala Mago. The Hammer only use water and pasture for their cattle, not for cultivation.

There was no open consultation between the community and the government. If there was a common agreement based on joint consultations, perhaps the community might accept. But the government dictated what to do. Most people who are living there are pastoralists using the land for grazing. The government wanted to start a sugar plantation. There is already one in Sala Mago. They also came to the Dassanech, and then went to Hammer.

We are afraid that the highlanders will come and take over our pasture land. What will we do? The government says we can keep two to three cattle, but this is not enough. Our life is based on cattle, and we cannot change our way of life overnight. I keep livestock—cows, oxen, sheep, and goats.

Recently, the government provided land to investors from Addis Ababa in the areas the Hammer used for grazing cattle. When the local administrators gave the land, they asked for more and then expanded, blocking the access of the Hammer to water. The land was given to an investor to develop and help you. The reason given is "we are here to change you, we will send your boys to school to help change you".

The investors take land in the Omo Valley. They clear all land, choose the best place where trees are, leaving the area open. They say it is for development, but they are clearing the forests. I wonder how to reconcile development with forest destruction.

The PCDP [the Pastoral Community Development Program] asked locals to put lactating lambs and cattle in fenced enclosures. But there was no grass. When we asked "why do you cut down forests when there is no grass?" you are told that you will be rejected from the group.

Pastoralists live hard lives with meager resources. They fight over resources. I remember traditional leaders went to Kenya and visited the Maasai. One was convinced by the people who brought him to accept what the government says. Government then says the leader accepted, so everyone should accept. This is a big problem for us. How can we keep access to our land and water?

Government Employee - Gambella

The Saudi Star issue is the issue of land. Before talking about land investment, there has to be talk of who will use the land. Today, customary land laws are not consulted or respected by the government. In Anuak culture, all land is owned by the chieftain. No land is free. Traditionally, land owners in Ethiopia are the protectors of community rights. The mother of my father and her relatives had lots of land. So they used customary land laws to give land use rights to others.

When the government started resettlement or villagization in Gambella, they ignored customary land rights and land use practices. Today, resettlement and villagization are related to land investment. Lack of consultation, lands are given to the investors. This is a new phenomenon in Gambella.

I was born in Gambella. Almost five years ago, Karuturi came. The village is in the poorest part of Gambella Region. Behind our huts were forests that provided fruit, medicines, and oil. The shea tree has fruit that is good for oil and/or eating. When Karuturi came, we lost the benefit from the forest because they took the land beside the village and cleared all the land.

The first time they came, they made relations with federal authorities, then regional. We were told “We are coming to live with you. We have agreed with the federal and regional authorities and they gave us land.” We said, “This land is useful for us—for our homes, our cultivation. How can you take this?”

Disagreement erupted between the two sides. Regional authorities came to tell us that we must accept the plan. The community asked again, what are we going to do for resources like trees and grass for houses, etc.? They told us that Karuturi will only use the demarcated area, not all of our land.

But when they started, they cleared the whole area because there were no signs for demarcation. The community complained to regional authorities. The vice president of the region came to the village and explained to us that now this land has been given to Karuturi. They paid much money to the regional government.

Before Karuturi, people used the cultivated area near River Baro on both sides. If there was a flood, the people went to the forest. After Karuturi arrived, only the riverbank is left. There is no way out when there is a flood.

Karuturi give jobs to locals and also to highlanders. In 2014, highlanders earned about 3,000 birr per month (about $149). The locals—the Karuturi staff call the locals “non-people” who earned 1,000 birr per month (approximately $50).

At Karuturi, the work is hard and the salaries low. People begin work at 8 am and go on until late with only a one-hour break. My friend works there. Sometimes they pay salaries a month late. People have complained and asked to increase the salary. But there is no change.

At the school, the children have left. Karuturi recruits under 18-year-olds to work in their fields.

Today [in 2014], Karuturi is still there, but there are money problems between Karuturi and the villagers because they do not support the villages. They told us “Now we will do more things— build schools, provide health care, and more, and what you ask for.” It has been five years, but nothing is done that was promised.

Karuturi made a nursery for biofuels for palm oil. They cleared an area of land near the village, but did not move the seedlings from the nursery. Instead, they planted maize, which they sell to the Ethiopian market. But our people cannot buy it. We cannot buy 1 kg (2.2 lbs) or 100 kg (220 lbs) of maize because Karuturi only sells to wholesalers who come from the highlands.

After they collect the harvest, instead of letting the villagers collect what remains, they burn it. Their farms are protected by the authorities.

The cattle go there, but are not allowed to graze. The cattle would still graze, so they used chemicals on the crops. Over 20 cattle (cows, oxen, goat, and sheep) have died.

A cattle owner complained, but the regional authorities say Karuturi is within its rights.know our cattle will die, but we have no alternative.

Now many other investors come, foreign as well as from the highlands. We have no information on them, but, as the investors increase, our problems increase. They take away our land and forests that we have depended upon for generations.

Case Study 3: Land investment in South Sudan

Legal and regulatory uncertainty encourages certain types of investment. Opportunistic companies are able to take advantage of the unclear procedures for land allocation to secure favorable deals with power brokers at the local level. This is a potential source of conflict, both directly between project proponents and affected communities, and among affected communities themselves when they are forced to compete with neighboring communities over dwindling resources.

There are at least three reasons why the assumption that land is abundant must be scrutinized. First, there are land uses in South Sudan that are not immediately apparent to the casual observer. Many communities practice shifting cultivation, and an area that looks like natural forest may actually be a field that is left fallow for a number of years, sometimes up to a decade or more,

There are at least three reasons why the assumption that land is abundant must be scrutinized. First, there are land uses in South Sudan that are not immediately apparent to the casual observer. Many communities practice shifting cultivation, and an area that looks like natural forest may actually be a field that is left fallow for a number of years, sometimes up to a decade or more, until it is ready to be planted again. South Sudan also has one of the largest populations of pastoralists in the world, and rural communities may designate seemingly unoccupied areas for seasonal use by people and livestock. There are even some grazing lands that pastoralist communities use only in times of great hardship, such as during famine or drought. If communities are denied access to these resources, it could have far-reaching impacts on food security and livelihoods for local populations.

Second, aside from the question of non-apparent land uses, one must distinguish between land use and land ownership. South Sudan is home to some 65 ethnic groups whose territories span the entire region. There is no terra nullius, or no man's land, in South Sudan. The RSS has put in place a land administration system whereby communities defined mainly in terms of tribal and sub-tribal affiliation own all land that is held under customary land tenure. This applies to virtually all of the rural land in South Sudan. The government's land holdings are limited to a handful of national parks, wildlife reserves, forest reserves, and pre-war agro-industrial complexes. Therefore, even if there is land in South Sudan that is unused or underused, in the majority of cases that land still belongs to a community and the community's ownership rights must be respected under South Sudan law.

Finally, given the complexity of displacement and migration patterns in South Sudan, it is often difficult to determine which areas of the country are populated. Many communities were displaced from their ancestral homelands during the war and now, in the postwar period, expect to return to their homes to rebuild their lives. In other situations, displaced communities may choose to permanently settle in their new locations. Without a firm understanding of local histories and the movement of local populations over time, it is difficult to determine the importance of specific areas to host communities and whether they are in fact abandoned or merely left temporarily vacant.

Case Study 4: Sugar Plantation in Equatoria, South Sudan

A Ugandan conglomerate called the Madhvani Group has entered into a preliminary agreement with the RSS to revitalize a defunct government-owned sugar plantation and processing facility in Mangala Payam in Central Equatoria State. The plantation would cover 10,000 ha of prime riverfront property along the Nile, about 70 kilometers north of Juba. According to the paramount chief in Mangala, the community has not been involved in any of the investment negotiations or decisions.

The Madhvani Group, owned by Ugandans of Indian descent, is among the largest companies in Uganda, at one time accounting for 10% of the country's gross domestic product (GDP). It operates across a wide variety of sectors, from agriculture and agro-processing to media and information technology. The company owns sugar plantations in several East African countries, including Rwanda and Uganda.

There are a number of potential adverse impacts associated with this investment. First, a large population resides in the project area and would have to be relocated to make the land available for the company. The community has experienced high levels of insecurity in recent years, and if they were permanently displaced from the land leased by the company, it would further undermine livelihoods that have already been severely affected by conflict-related displacement.

Second, the plantation is adjacent to Bandingilo National Park, and there are concerns that it would affect the migratory routes of wildlife in the area. Third, there is an ongoing border dispute between Juba and Terekeka county administrations that centres on the land where the plantation is located. The border dispute arose during the elections in 2010 and has since become heavily politicized.

There is a question about the legitimacy of the government's ownership claims. In the government's view, land owned by the northern government prior to the CPA passed to the GoSS when it assumed power. However, there is a growing body of law maintaining that customary claims can only be extinguished through procedures that comply with standards of due process, such as registering community land under freehold title or expropriation with fair compensation and for a public purpose. When the Sudan government passed the Unregistered Land Act in 1970, decreeing all unregistered land to be government property, it did not compensate communities.

Therefore, since the original expropriation was not lawful, according to the argument, the GoSS's claims to these lands are not valid. The issue is further complicated in Mangala by the fact that the government expropriated the land in the mid-1970s and was only making active use of the property for a few years before the war reached Mangala in 1985. The community reoccupied the land during the war and continues to reside there until the present day, making the government's claim all the more tenuous.

Case Study 5: Al Ain National Wildlife in Boma National Park, South Sudan

In July 2008, Al Ain National Wildlife, a United Arab Emirates (UAE) company, entered into a 30-year agreement with the GoSS Ministry of Wildlife to develop and manage a 1.68 million ha tourism project in Boma National Park, Jonglei State. Although the company's rights are not exclusive, they plan to relocate a large number of people—possibly as many as 15,000—from the project area. Al Ain began operations in 2009 and by August 2011, the company had constructed its project facilities, including guest accommodations, offices and a large airstrip near a village called Maruwa. According to officials at the Ministry of Wildlife, the company planned to begin receiving guests in December 2011.

Lack of Prior Consultation

Boma is among the least developed areas in South Sudan. The road infrastructure in the area is severely underdeveloped, and during the rainy season, travel over land to and from Boma is virtually impossible. Boma is also among the most ethnically diverse regions in South Sudan. The communities residing in the area include people from the Murle, Jie, Kachipo, and Anyuak ethnic groups. According to a local resident:

"Up to now you can't even see a road. You can't access telephone networks. There are no good schools, there's no water. That is because we don't have a voice in the government. We can't really say what the government is going to do. Even the governor of the state does not come here. We have no way of taking a message to them. I would tell the governor that you must always have equal distribution of resources in the State."

The marginalization of groups residing in Boma is also evident in the manner in which they were not consulted in the negotiations of the investment agreement with Al Ain. The Al Ain agreement was brokered at the highest levels of government in South Sudan. After the president's return from a trip to UAE in which he met with representatives of Al Ain, the office of the president reportedly instructed the Ministry of Wildlife to sign the investment agreement with the company. According to residents in affected communities, the government did not consult with them during the negotiations, contrary to the spirit of the interim constitution of Southern Sudan, which states: "All lands traditionally and historically held or used by local communities or their members shall be defined, held, managed, and protected by law in Southern Sudan."

Respecting Social Obligations

According to a local government official, since signing the agreement, Al Ain has held just one meeting with local leaders in Boma. In that meeting, company representatives pledged to provide affected communities with a variety of development projects and services, including educational and health services, boreholes, housing and road infrastructure, and three strategically placed airstrips. The company also promised to build “model villages” at locations outside of the project area in order to encourage communities to resettle outside of the park. However, none of these obligations were formalized in a written agreement with the affected communities.

Displacement

According to local officials, Al Ain, together with officials in the Ministry of Wildlife, have requested that the people living in the area around its project facilities relocate to another part of the park, about four hours away by car. The local officials estimate that 10,000 to 15,000 people reside in the area and would be affected.

The community has expressed security concerns about the proposed move. The residents of Maruwa are mostly pastoralists from the Murle ethnic group. The proposed location is adjacent to Murle and Jie pastoralist communities and would make the Maruwa community more susceptible to cattle rustling and inter-ethnic conflicts. Also, the company has not yet delivered on its promise of providing infrastructure and services in the new location, and the community is reluctant to move until the company carries out these developments.

In July 2011 the Ministry of Wildlife repeated its request for the community to relocate from Maruwa. When the local chief refused, he was reportedly told that if the community does not move voluntarily, then they will be forcibly evicted. Negotiations are still ongoing between the Murle leaders and the government. However, according to a local resident, the Murle leaders have sided with the government and it is highly likely that the community will be forced to move from the area.

The implications of such relocation of people is significant; not only is the risk for conflict greatly increased due to competition over land and resources between the relocated community and the communities already living in the area, but the chances of conflict between the Murle people, Al Ain Wildlife, and the South Sudan government are also increased.