Eastern Nile Technical Regional Office

ONE-SYSTEM INVENTORY

ANNEXE: BARO-SOBAT-WHITE NILE SUB-BASIN

June 2009

EASTERN NILE TECHNICAL REGIONAL OFFICE
ADDIS ABABA
ETHIOPIA

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Introduction to the One System Inventory

Eastern Nile Subsidiary Action Programme: The Eastern Nile Technical Regional Office (ENTRO) is an organization meant to plan and implement the ENSAP (Eastern Nile Subsidiary Action Program) in the three Eastern Nile Basin (ENB) countries of Egypt, Ethiopia and Sudan. ENSAP seeks to realize the NBI Shared Vision for the Eastern Nile region aimed at reducing poverty, foster economic growth and the reversal of environmental degradation.

One System Inventory: To support its multipurpose development objectives, ENTRO began an exercise in 2006 to create a One System Inventory (OSI) to support the planning of the Joint Multipurpose Program (JMP). The OSI was to be a regional knowledge base across the three EN countries, initially focused on three themes, water resources, socio-economic and environmental issues. This information was expected to be useful for decision-makers and senior program and project coordinators at ENTRO to write terms of reference for new studies in the Inception Phase of the JMP and to aid the literature survey of these studies.

OSI Development Process: The process of development of the OSI is as follows:

- ***National reports:*** National consultants were appointed in 2005 to collect information but found it quite difficult to access national information. They submitted their reports in 2006, comprising all the information they were able to gather till then.
- ***Thematic reports:*** These national reports were compiled into three thematic reports, each reporting on the situation in four transboundary sub-basins, namely, the Baro-Akobo-Sobat-White Nile Sub-basin, the Abbay-Blue Nile Sub-basin, the Tekeze-Setit-Atbara Sub-basin and the Main Nile Sub-basin.
- ***Trans-boundary sub-basin reports:*** In Septemebr 2007, these thematic reports were compiled by an international consultant into four multiple-theme reports, divided according to trans-boundary sub-basins, to present issues 'without national borders'.
- ***Regional Workshop:*** The four sub-basin reports were presented in a Regional Workshop in Addis Ababa in November 2007 and several comments were received by country teams that reviewed the reports. The atmosphere in this regional meeting was quite positive and country teams acknowledged the usefulness of the information-gathering and sharing exercise of the OSI.
- ***Revised Outputs:*** Summaries of the four sub-basin reports were prepared in early 2008 and sent along with the more detailed Annexes to the three country ENSAP Teams by mid 2008 to receive corrected versions of information that were found to be incorrect or out-dated in the review done during the Regional Workshop. A CD kit was also prepared to demonstrate the interactive presentation of key data tables and maps.
- ***Country meetings:*** Meetings were organized with the country ENSAP teams in May 2009 to review and update the information in the Summaries, Annexes and CD kit. These country meetings were extremely positive and there was considerable willingness among the three countries to share all available and up-to-date information. However, time was too short for them to do much beyond providing feedback that some OSI data and information was incorrect and needed to be updated.

Other Initiatives and Future Plans: The OSI was meant to be a small initiative to support the JMP. ENTRO subsequently initiated Eastern Nile Water Resources Planning Model (ENWRPM) Project, and began building an information database to feed and validate this model. Thereafter, the Nile Basin Initiative (NBI) initiated the Decision Support System (DSS) and a basin-wide information collection and model building exercise. Both used OSI information. It is expected that the OSI will be handed over to the ENWRPM Project.

QUICK OVERVIEW OF THE EASTERN NILE BASIN

The Eastern Nile Basin is constituted of three riparian countries along the eastern Nile namely Egypt, Ethiopia and Sudan. A very small portion of Eritrea is also included in the Nile system.

EGYPT: With a total area of 997,739 square kilometres, Egypt is located in the upper north portion of the Nile, occupying the entire lower course of the Eastern Nile Basin including its mouth at the Mediterranean Sea. Egypt is bounded on the north by the Mediterranean Sea, on the east by the Gaza strip, Israel and Red Sea, on the south by Sudan and on the west by Libya. The country has a maximum length of 1,105 kilometres from north to south, with a maximum width at its southern border, stretching east-west for some 1130 kilometres. Less than 10% of its area is identified to be cultivable, the bulk of its geographical area (more than 90%) being desert where life would hardly survive. With a total area of 69,722 square kilometres the Nile watershed in Egypt accounts only 7% of the country and 4% of the Eastern Nile Basin.

ETHIOPIA: Located in the horn of Africa, Ethiopia is bounded on the northeast by Eritrea and Djibouti, on the east & south east by Somalia, on the south west by Kenya and on the west and northwest by Sudan. With total geographical area of 1,133,380 square kilometres, the highland plateau of the country (above 1,800 masl) is the heart of the country covering some 60% of its total area. The Great Rift Valley splits the Ethiopian highland plateaus diagonally in the north-eastern and south-eastern directions. The north-eastern half is largely drained by the Nile river system. The plateaus are drained by 12 major river basins and are characterized by deep valleys and canyons cut by numerous rivers and streams. Ethiopia is the source of the Tekeze, Blue Nile and Baro-Akobo Sub basins, which are believed to be the major contributor of the Nile river system. The Abbay (the Blue Nile) takes the lion's share both in terms of area (18% of the total area of the country) and water resources potential (more than 50%). Including the upper courses of the Tekeze, Abbay and Baro-Akobo Sub-basins, the Nile watershed in Ethiopia accounts for about 32% of the total geographical area of the country and 22% of the Eastern Nile Basin.

SUDAN: Located in the north-eastern Africa Sudan is the largest land state in the continent (2,505,800 square kilometres). It is bounded on the north by Egypt, on the east by the Red Sea, Eritrea, and Ethiopia, on the south by Kenya, Uganda and the Democratic Republic of the Congo, and on the west by the Central African Republic, Chad, and Libya. The maximum stretch in Sudan is from north to south, with a total length of 2,250 kilometres, while its maximum east-west stretch is 1,730 kilometres. About 50% of Sudan is included in the Nile watershed, while 74% of the Eastern Nile Basin is located within Sudan.

SUB-BASINS: The Eastern Nile Basin can be divided into four major sub basins; the Baro-Akobo-Sobat-White Nile Sub-basin, the Abbay-Blue Nile Sub-basin, the Tekeze-Setit-Atbara Sub-basin and the Main Nile Sub-basin (see Table 1.1).

Table 1.1: Total Area of the Sub-basins

	Area (Square kilometers)	Mean Annual Inflow (billion cubic meters)	Proportion of Nile inflow at Aswan Dam (%)
Baro-Akobo-Sobat-White Nile	468,216	26	29%
Abbay-Blue Nile	311,548	51	57%
Tekeze-Setit-Atbara	219,570	12	13%
Main Nile	656,398	0%	0%

THIS ANNEXE contains information on the Baro-Akobo-Sobat-White Nile Sub basin and is part of the four annexes that support the summary OSI report prepared by ENTRO.

Figure 1.1: Baro-Sobat-White Nile sub-basin: Location Map

***Source*:** Sudan: ENTRO GIS data base: Ethiopia WBISPP GIS database

1. GENERAL CHARACTERISTICS

1.1. SUB-BASIN LOCATION AND AREA

Location: The Baro-Akobo-Sobat-White Nile (BASWN) Sub-basin is one of the four major sub-basins in the Eastern Nile Basin, and is located in the southernmost portion of the Eastern Nile Basin (see Figure 1.1). Geographically, the sub-basin extends from 150 47' 40" to the north down to 30 25' 52" in the south, and from 290 24' 43" to the west up to 360 18' 27" to the east and covers some 468,215 km^2 (CRA Watershed Trans-boundary Report, ENTRO 2007).

Area: The sub-basin has an area of 468,216 km^2, accounting for about 28.3% of the total area of Eastern Nile Basin. The Baro-Sobat-White Nile sub-basin covers 76,742 Km^2 in Ethiopia, which is about 16% of the sub-basin, while 391,474 km^2 or about 85% of the sub basin's total area is located in the Sudan (OSI Environment Summary Report, p. 1)

1.2. ADMINISTRATIVE UNITS

Most of the sub-basin area (84%) is in Sudan and only a small proportion (16%) is in Ethiopia. The sub-basin area in the Sudan is spread across ten states while that in Ethiopia cuts across four regional states (Table 1.1 and Figure 1.1).

Table 1.1: Baro-Sobat-White Nile Administrative States and their Areas

Country	State	Area (km^2)	% of sub-basin area
SUDAN		**391,474**	**84%**
	Upper Nile	77,339	17%
	Jongoli	74,207	16%
	South Kordufan	57,110	12%
	North Kordufan	53,419	11%
	East Equatoria	49,517	11%
	White Nile	40,438	9%
	Blue Nile	18,191	4%
	Sinnar	10,339	2%
	El Gezira	8,708	2%
	Khartoum	2,206	1%
ETHIOPIA		**76,742**	**16%**
	Gambela	32,235	7%
	Oromiya	25,996	6%
	SNNP Region	13,045	3%
	Beni-Shangul Gumuz	5,466	1%
Baro-Akobo-Sobat-White-Nile sub-basin		**468,216**	**100%**

Source: Sudan: ENTRO GIS data base: Ethiopia WBISPP GIS Database

1.3. TOPOGRAPHY

1.3.1. Altitude

Altitude in the sub basin ranges from above 3,000 masl to below 400 masl at Khartoum, the mouth of the sub-basin. The major portion of the sub-basin (67%) is at an altitude of less than 500 masl, with the remaining 33% falling in the range of 500 to above 2,000 masl. Around 23% is from 500 to 1,000 masl, 5% between 1000 and 1,500 masl, 4% between 1,500 and 2,000 masl and around 1.5% is above 2000 masl. The Sobat area which covers 20% of the sub basin at Malakal passes through a flat seasonally inundated flood plain with land slope less than 2%. Between the Malakal station and the junction with the Blue Nile at Khartoum, the White Nile drops only 13 metres over a reach of about 840 kilometres.

The Ethiopian part of the sub-basin comprises high plateaux elevations ranging from 1500 to 2000 m and mountains with peaks exceeding 2,500 meters The elevation decreases towards the Sudan reaching as low as 250m (OSI Environment Summary Report, p. 1). The upper course of the sub basin (largely the watershed east of the Ethio-Sudan border) ranges from above 3,000 masl (south western highland plateaus of Ethiopia around Bedele & Jimma) to below 500 masl as it descends down to the Gambella low-land flood plain. Upstream of the Gambella town, the highland plateau first drops in to an altitude of 1,000 masl where hilly and steeply dissected land topography starts dominating which separates the south-western highland plateaus of Ethiopia with the Gambella low-lying flood plain. In the further west direction towards the border the elevation drops to below 600 masl and in between the rivers in the watershed entered in to a vast low-lying savannah area. Approaching the border between Ethippia and Sudan the elevation of the watershed drops to below 500 masl, where the rivers in the watershed cross flat seasonally flooded area. At Khartoum, the mouth of the sub basin, altitude drops to below 400 masl.

1.3.2. Slope

According to the slope map produced from the DEM files, more than 88% of the sub basin has a slope of less than 5% indicating its tremendous potential for irrigated agriculture, although the predominantly black clay soil is a possible challenge in the low-lying area of the sub basin. This portion of the sub basin constitutes the low-lying area of the Gambella flood plain in Ethiopia, the Machar flood plain, the low-lying seasonally flood plains at the mouth of the Gillo, Akobo and Pibor watersheds including the major portion of the Sobat and White Nile watersheds in the further downstream reaches of the sub basin. The altitude of these seasonal flood plains is below 500 masl. About 6% of the sub basin has a gentle slope of 5 - 10%, while less than 2% of the area (in the highlands) has a land slope of more than 20% (ENTRO, 2007).

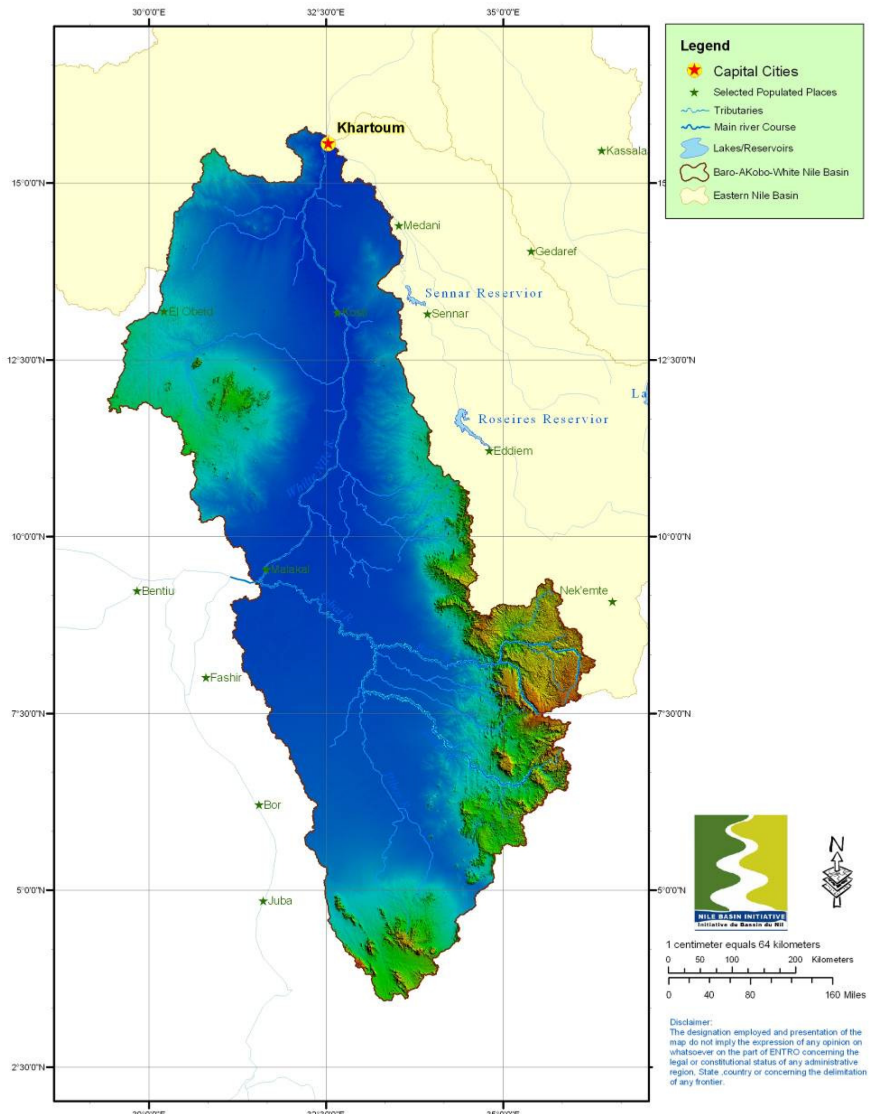
1.3.3. Relief and Landforms

Relief: The relief of the BASWN sub-basin is first discussed in three sections, while the major landforms in the sub-basin as a whole is discussed further below.

- ***Baro-Akobo***: In Ethiopia the Baro-Akobo Sub-basin can be divided into two major landscape units of roughly equal size, the western lowlands and the eastern highlands, separated by an escarpment and areas of severely dissected highlands. The Gambela catchments in the Ethiopian portion gently slope to almost flat plains that continue into the Sudan crossing the border. The plains are abruptly terminated in the east by a well defined, north-south escarpment. North of the salient the foot of the escarpment is less precise and forms a belt of lower altitude broken highlands in BeneShangul-Gumuz Revenue State. A similar area of broken highland terrain is found in the western part of SNNPR around Mizan Teferi and reaching out to Gurafarda, a highland outlier. Steep slopes clearly mirror the high relief, with the escarpment at the edge of the Ethiopian Highlands, the Imatong Mountains and associated hills and the Nuba Hills standing out. Less clear are the steep slopes of the hills on the Boma Plateau.
- ***Pibor-Sobat*:** The main relief features in the south of the Pibor-Sobat Sub-basin are a series of steep hills and mountains of basement complex rocks stretching north-eastwards along the Sudan-Uganda-Kenya border reaching up to 3,187 masl on Mount Kinyeti in the Imatong Mountains.
- ***White Nile*:** On the western side of the southern part of White Nile Sub-basin are the Nuba Mountains rising to about 1,500 masl. To the east are wide clay plains with the

Machar Marshes in the south. These plains terminate abruptly in the east against the Ethiopian Highlands. Further north the valley widens with low relief on both sides of the river with a very low watershed between the White and Blue Niles.

Figure 1.3: Relief Map of Baro-Sobat-White Nile Sub Basin



Source: SRTM 90m DEM Digital Elevation Database

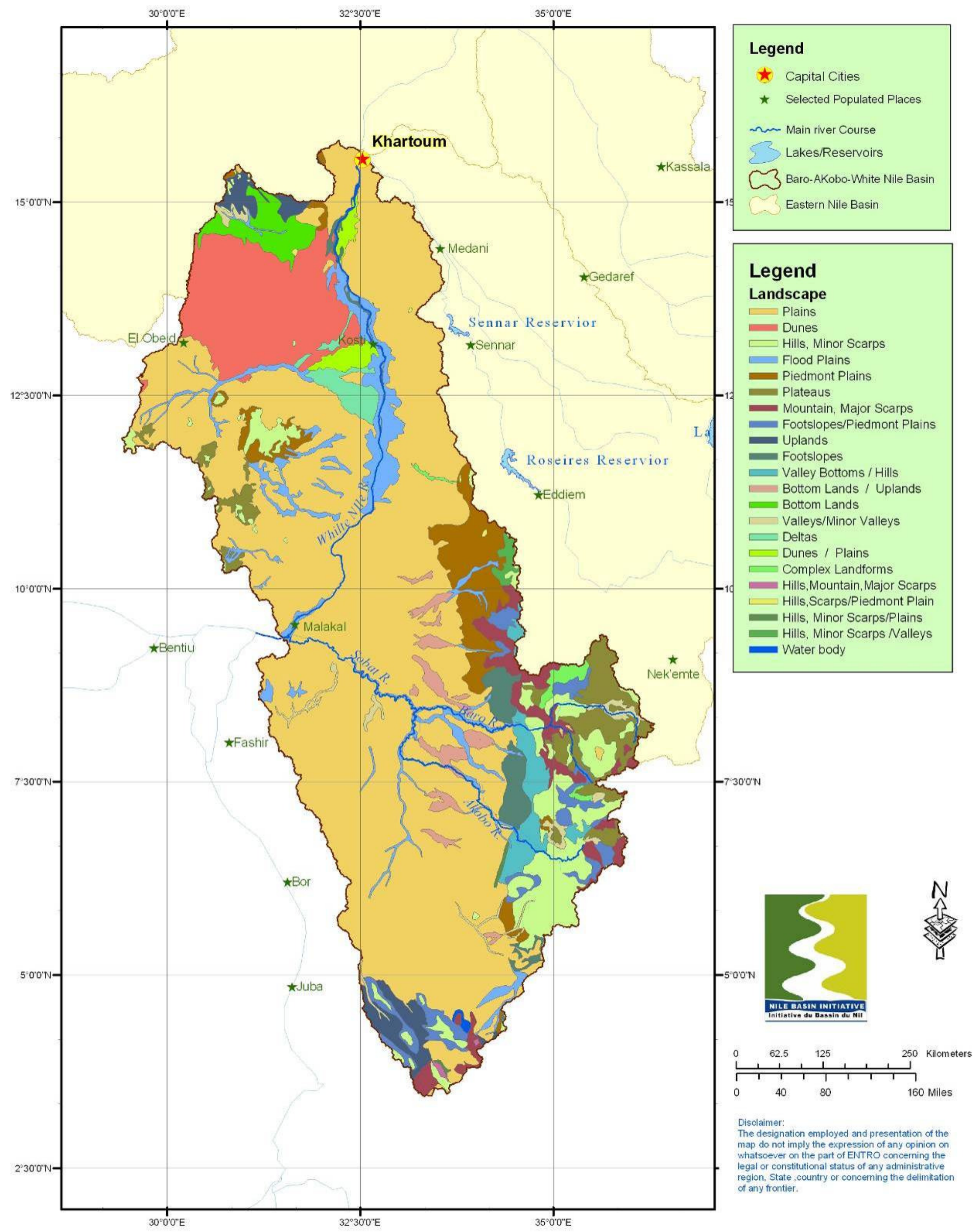
Major landforms: The sub-basin has plain areas with land slope of less than 3% in nearly 60% of area, while dunes (8%) and hills & major scarps (about 6%) are the next major land form. The flood plains and piedmont plains cover 5% and 4% respectively while mountains and major scarps largely located in the east of the sub basin covers only 2.4%. Other land forms in the sub-basin include plateaus (3.5%), valleys, deltas, dunes and water bodies.

Table 1.2: Major landforms of the Tekeze Sub-basin

Major Landform	% of Area
Plain areas (slope < 3%)	60%
Dunes	8%
Scarps	6%
Flood Plains	5.2%

Major Landform	% of Area
Piedmont Plains	4%
Plateaus	3.5%
Mountains and major scarps	2.4%
Others	10%

Figure 1.2: Terrain Map of Baro-Sobat-White Nile Sub Basin



Source: Sudan: ENTRO GIS data base: Ethiopia WBISPP GIS database

1.4. CLIMATE

1.4.1. Climate Types

The Baro, Gillo and large part of the Akobo watershed areas, located in the south-western highland plateaus of Ethiopia, are identified to have dominantly tropical climate with distinct dry winter classified as Tropical Climate-II with mean temperature of the coldest month is >18°C and the mean annual rainfall in the range of 680-1200 mm and the dry months are in winter (Baro-Akobo Master Plan studies, May 1997). Some portion of this area (some 10%) is identified to have tropical monsoon rainy climate with short dry season and some other parts (>5%) are identified to have warm temperate rainy climate with distinct dry season. The Pibor watershed starts in semi-arid south-eastern area of the Sudan land characterized with dry tropical type of climate. Alike the Sobat area, the WN watershed of the BASWN sub basin is also characterized with arid type of tropical climate.

1.4.2. Rainfall

Total and average rainfall: The sub-basin is particularly well-watered region of Ethiopia. Most of the upper sub-basin has an annual total rainfall over 1800 mm. Significant proportion of rain falling during the storms is lost by runoff and the occasional light rain fall out of season when soil and foliage are hot is lost by evaporation; so the effective average rainfall of 750 mm annually in the lowland rising to about 1,250 mm in the highlands (OSI Environment Summary Report, p. 1).

Mean annual rainfall in the sub basin varies from 2270 mm, in the upper courses of the Baro watershed to 120 mm in Khartoum, at the mouth of the sub basin.

Seasonal and spatial variation in rainfall: The spatial variation of the mean annual rainfall is considerable due to the great range of difference in elevation across the basin: Average annual precipitation is as low as 600 mm in the lowlands (less than 500 masl), while it reaches as high as 3,000 mm over the highlands (over 2,000 masl). Most of the upper basin has an annual total of more than 1,800 mm while Gore has an average annual total of over 2,200 mm. Seasonal and spatial variation of rainfall in the entire area of the sub basin is governed both with the movement of the Inter Tropical Convergence Zone (ITCZ), the sun and altitude. Moisture availability/scarcity is also correlated with altitude. High altitudes (at an average above 2000 masl and at some spots even exceeding 3000 masl) in the Baro and Gillo watersheds, are characterized with relatively high moisture and longer wet periods, that extends from April/May to October/November.

Rainy period: The rainy period is from May to October when 85% of the annual precipitation occurs with a single peak in July.

Wet and Dry Seasons: The entire sub basin is characterized with distinct dry and wet seasons. In the summer, as a result of the ITCZ movement towards the north direction (through the Blue Nile & Tekeze-Setite-Atbara sub basins), the westerly (winds prevailing from the Indian Ocean) warm moist winds get access to cover the entire watershed area of the sub basin. This brings the wet season to the entire upper course of the sub basin that extends from April/May to October/November. The Baro and Gillo watersheds are characterized with relatively high moisture and longer wet periods that extends from April/May to October/November. In the downstream reaches of these watersheds, where altitude is largely below 1000 masl, moisture is scarce with relatively shorter wet period limited to less than four months (May/June to September/October). Further in the downstream reach of the sub basin, beyond the Ethio-Sudan border, where the altitude is well below 500 masl the wet period is shortening to less than three months, with arid tropical climate dominating towards its mouth around Khartoum. Meteorological data at Pibor post, and Malakal stations would have been helpful to understand the climate better especially in the lower course of the sub basin. In the downstream reaches of these watersheds, before it enters the Gambella low-lying seasonally flooded plain, where altitude is largely below 1000 masl, moisture is scarce with relatively shorter wet period that is limited to less than four months (May/June to September/October). Further in the downstream reach of the sub basin, both in the Gambella low-lying flood plain and beyond the Ethio-Sudan border, where the altitude is well below 500 masl the wet period is shortening to less than three months, with arid tropical climate dominating towards its mouth around Khartoum.

Average rainfall greater than 100 mm occurs from May to October (a six months rainy season). Months with average rainfall greater than 200 mm are June, July, August and September. On average, November, December, January and February are dry months.

Maximum rainfall: The maximum rainfall over the southern portion of the Baro-Akobo river reaches as high as 300 mm in July and over the northern portion of region may reach 250 mm in July. In the northern part of the area, the rainfall amount exceeds 200 mm during June and July. Within Sudan the highest rainfall is found in the southwest and southeast of the Sub-basin where the mean annual rainfall exceeds 1,000 mm/yr. Over much of the Pibor-Sobat Sub-basin it varies between 750 and 1,000 mm/year. In the White Nile Sub-basin rainfall decreases northwards from 750 to 250 mm near the junction of the White and Blue Niles.

Dependable rainfall and growing seasons: Rainfall exhibits both seasonal and year-on-year variability. Variability increases form south to north.

- **Ethiopia:**
  - **Gambela Plain:** On the Gambela plain below 500 meters elevation only about six years in ten have a dependable rainfall of at least four months, which is sufficient to support good yields of most annual crops.
  - **Highlands:** Above about 1,000 masl the dependable growing season for annual crops is reliable and failures would occur in only about one year in twenty, and even longer than that above 2,000 masl. In an average season and better, a second rainfed crop should yield well during a dependable growing season of seven and more months in the Highlands.

Figure 1.4: Seasonal Rainfall Distribution at Masha Station (1980-96, 1998-2000)

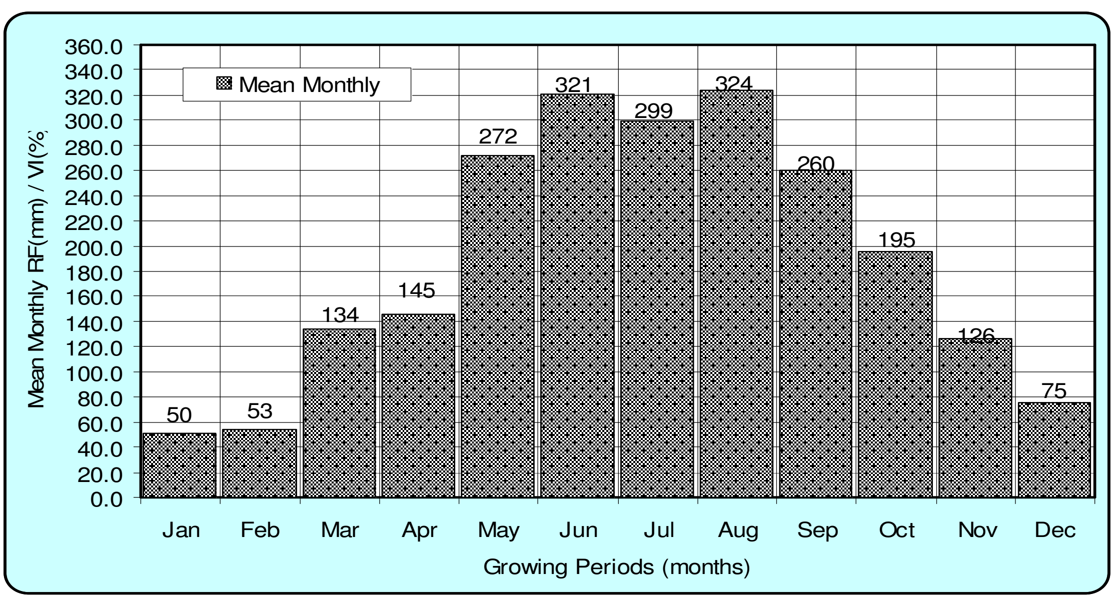


Figure 1.5: Seasonal Rainfall Distribution at Masha Station (1980-96, 1998-2000)

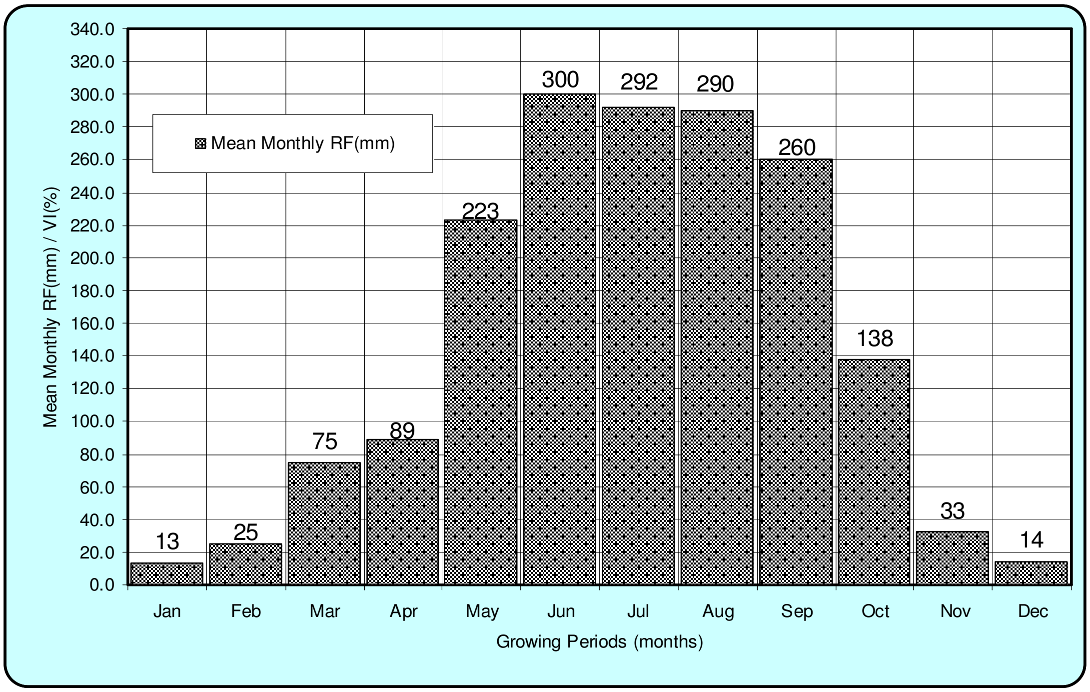
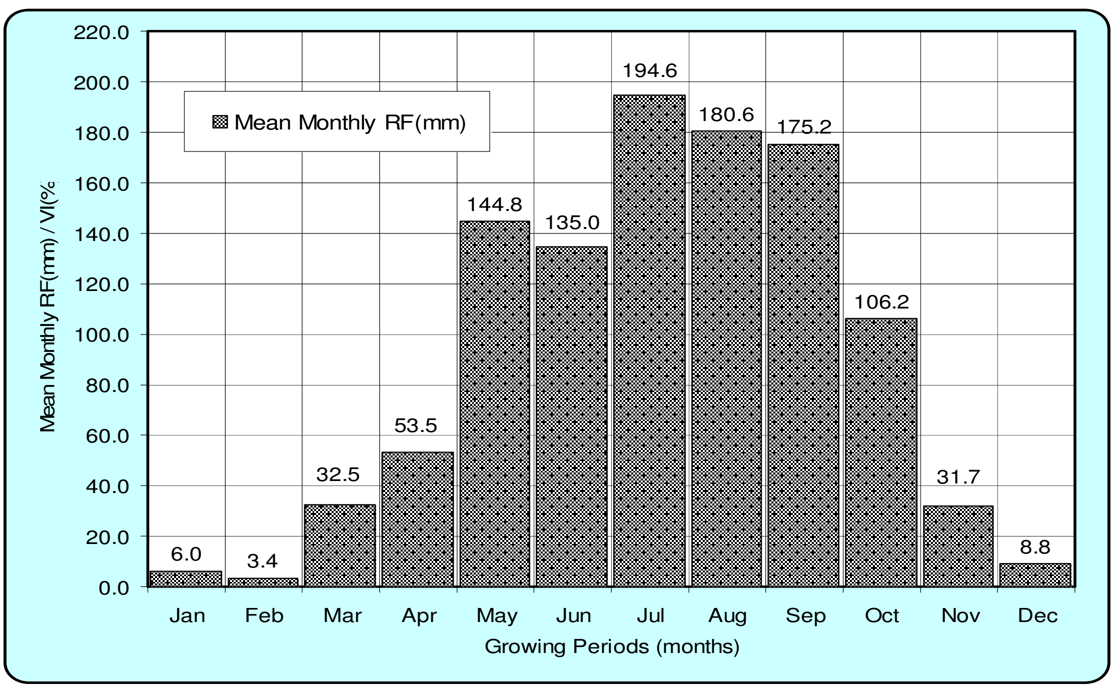


Figure 1.6: Seasonal Rainfall Distribution at Bedelle Station (1980-96, 1998-2000)



1.4.3. Temperature

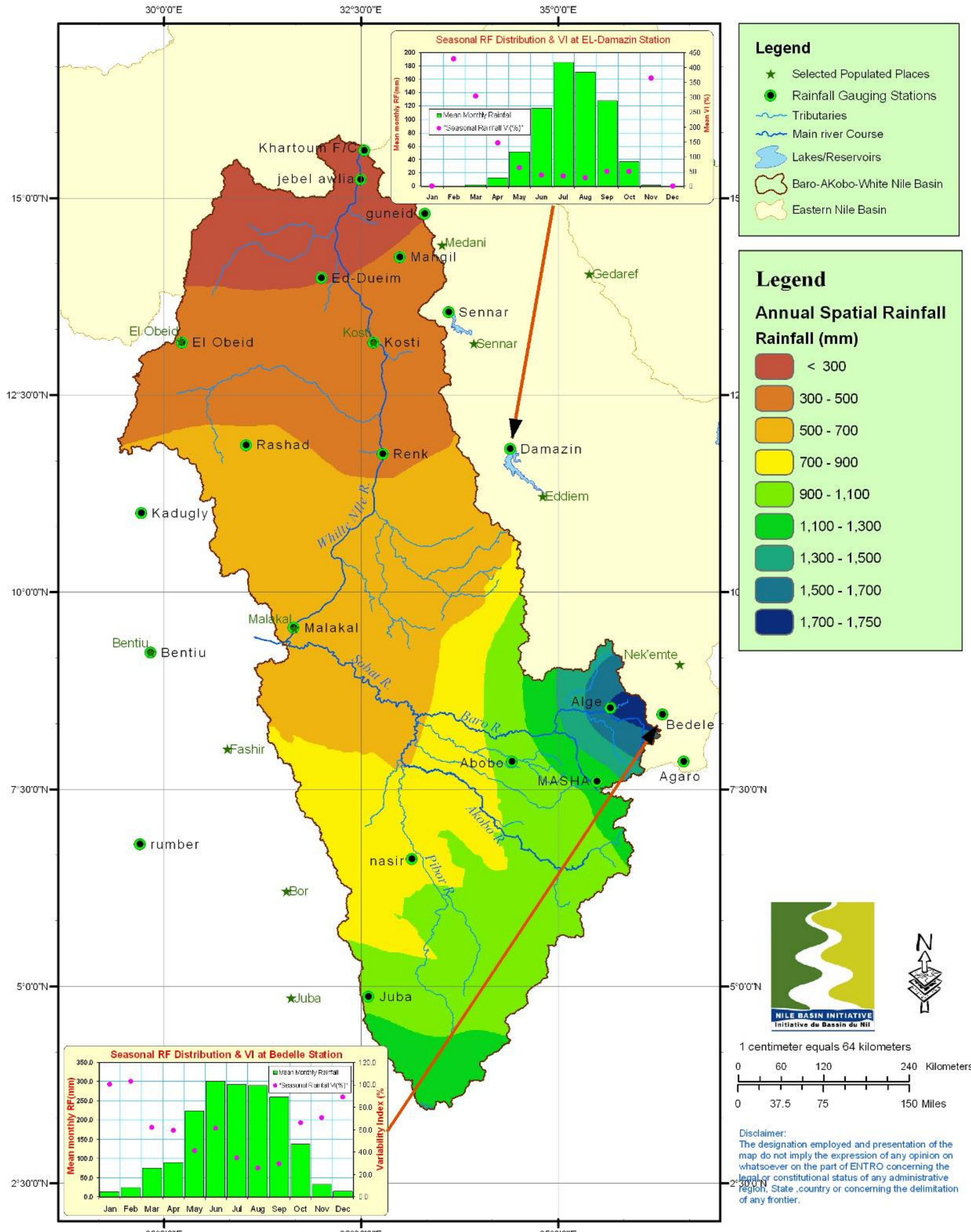
Baro-Akobo:

- **General:** Daytime temperature in lowlands is very stable over the year with mean maximum not falling below 30^{0}C even during the rainy season (OSI Environment Summary Report, p. 1). Climate in the eastern highland plateaus is sub-tropical with pleasant temperature rarely exceeding 20°C.
- **Maximum and minimum temperature:** The temperature range in the Baro–Akobo basin is from about 27.5°C below 500 meters elevation on the flood plain to about 17.5°C at 2,500 meters in the highlands. The range in mean maximum is 35 to 24 ^{0}C and mean minimum from 20 to 10^{0}C. Temperature is maximum in April and minimum in December. Maximum temperatures in the highlands rarely exceed 25°C, whereas in the lowlands they generally exceed 36°C during the hotter months of January to April. The mean minimum temperature values greater than 15.5°C occur from January to May while the mean minimum temperature values ranging from 14°C to 15.4°C occur from June to December.
- **Mean monthly maximum temperature:** Mean monthly maximum temperatures range from below 22°C in the highlands around Kombolcha (Wollega) to about 40°C, in the lowlands of Gambela around Akobo. The temperature peaks during February and March on the flood plain but high values extend in to April in the high lands. Below about 700m mean maximum values are in excess of 38^{0}C for two to three months. There are short periods of more than 40^{0}C, the critical value for anthesis of some crops, Notably Maize, but this does not coincide with the cropping season. Mean maximum temperatures greater than 30°C occur from February to April in the Lowlands while July and August have the mean maximum temperature values less than 25°C.
- **Mean annual daily temperature:** In the upper courses of the Baro watershed (average altitude above 2200 masl) mean annual daily temperature is at a range of 17°C to 19.5°C. In the Gillo and Akobo watersheds, where average altitude is below 1800 masl, temperature rises in the range of 21.5°C to 24°C.
- **Mean monthly minimum temperatures:** These generally range from 14 – 16°C in the highlands of Illubabor and western Wollega, but they sometimes drop to below 10°C in isolated locations of the highlands during November-February.

Pibor-Sobat:

- **Maximum and minimum temperatures:** In the Pibor watershed it ranges from 24.5°C to 26.5°C. In the Sobat and Malakal areas where altitude is below 500 masl, temperature ranges from 26.5°C, reaching to a range of 30.5°C at the mouth of the sub basin around Khartoum.
- **Mean annual temperature:** In the Pibor-Sobat sub-basin mean annual temperatures range from about 17°C in the southern mountains to 26°C at the Sobat-White Nile junction. In the White Nile valley temperatures are generally 25-27°C along the river but decrease with altitude in the Nuba mountains and towards the Ethiopian highlands.

Figure 1.7: Mean Annual Rainfall Spatial Distribution (Isohyets) map of the sub-basin



Source: ENTRO OSI Databse

Raw data source; Ethiopia: Ethiopian Ministry of water resources

Sudan: Metrological Authority of Sudan

1.4.4. Evaporation

Mean annual evaporation within the BASWN sub-basin varies from below 1000 mm in the highland plateaus of Ethiopia, to 6815 mm at Khartoum. Evaporation in the upper course of the Baro-Gillo watersheds ranges from 783 mm to 1200 mm. In the low-lying areas (<1000 masl) mean annual evaporation is in the range of 1200 mm to 2000 mm. In the upper course of Pibor and Akobo rivers (low lying areas in the land of Sudan) it ranges from 2000 mm to 3200 mm. Around Malakal station, where the Sude and Sobat make a confluence to form the White Nile, mean annual evaporation is in the range of 3200 mm to 4500 mm. At Khartoum, the mouth of WN, it is recorded to be 6815 mm and in the area it ranges from 6500 mm to 7500 mm. Fig 3.6 below demonstrates spatial variation of evaporation, along the course of the river flow (i.e vertical spatial variations), in the sub basin.

Average monthly maximum and minimum: The average monthly maximum evaporation occurs from February to May and the minimum from June to September.

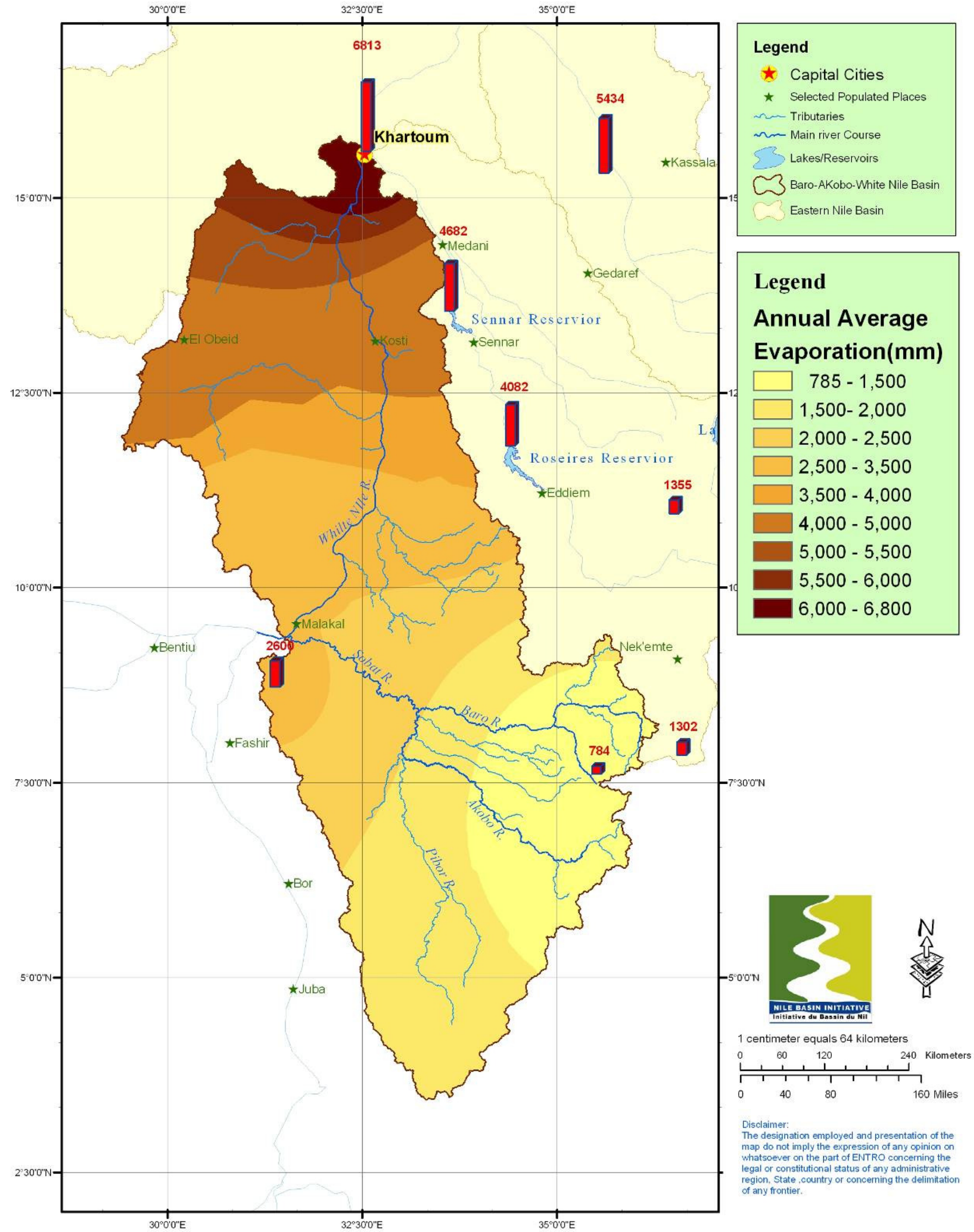
Evaporation losses in reservoirs: As a result evaporation loss at Jebel Awlia reservoir with a total storage capacity of 3.5 billion cubic metres is 2.12 billion cubic metres per year on average.

Potential evapotranspiration is lowest over the highlands and increases progressively towards and onto the Gambela lowlands. For example, Gore (2,130 masl) has a total evapotranspiration of 1,263 mm/yr while Jikawo (410 masl) has a total evapotranspiration of 1,545 mm/yr. In Sudan rates of 1,450 mm/yr occur in the southern mountains and increase northwards to 2,500 mm/yr at the junction of the White and Blue Niles.

1.5. HUMIDITY

Mean annual relative humidity: About 50% of the area has a mean annual relative humidity exceeding 55% indicating much proportion of the sub basin is relatively wet, despite the fact that low-lying areas (less than 500 masl) account for nearly 70% of the total sub basin area. This may be due to the presence of relatively good vegetation cover and less environmental degradation. Nearly 35% of the sub basin has a mean annual relative humidity ranging from 40% to 55%, while less than 20% of the sub basin has a relative humidity of less than 40%.

Figure 1.7: Mean Annual Rainfall Spatial Distribution (Isohyets) map of the sub-basin



Source: ENTRO OSI Databse
Raw data sources: Ethiopia: Ethiopian Ministry of Water Resources
Sudan: Metrological Authority of Sudan

2. SOCIO-ECONOMIC CHARACTERISTICS

2.1 DEMOGRAPHIC CHARACTERISTICS

2.1.1 Population estimates

- Sub-basin The Baro-Akobo-Sobat-White Nile basin has an estimated population of 12.4 million (7.3 in Ethiopia and 5.11 in Sudan) according to the CRA WSM Trans-boundary Sub-Basin Report and an estimated population of 15.1 million (10.0 in Ethiopia and 5.11 in Sudan) according to the OSI Socio-Economic Synthesis Report (p. 110). The total population of Ethiopia was estimated at 12.69 million in 2002, using the LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL) of the United States, which provides 2002 population estimates on a 1 km grid. This was clipped by the State and Regional State boundaries within the Sub-basin to provide population estimates within the Sub-basin by State/Regional state. National census estimates of the rural-urban distribution were used to provide estimates of total rural and urban populations (Table 2.1).

Table 2.1: Baro-Sobat-White Nile Sub-Basin: Population Estimates, 2002

State	Total Population	% of sub-basin Population
SUDAN	**9,889,241**	**78%**
Blue Nile	411,895	3%
East Equatoria	398,782	3%
El Gezira	1,131,140	9%
Jongoli	392,065	3%
Khartoum	2,148,190	17%
North Kordufan	1,366,520	11%
Sinnar	451,829	4%
South Kordufan	811,353	6%
Upper Nile	615,417	5%
White Nile	2,162,050	17%
ETHIOPIA	**2,801,137**	**22%**
Beni-Shangul-Gumuze Region	89,903	1%
Oromiya	1,816,430	14%
Gambela	338,233	3%
SNNP Region	556,571	4%
Sub-basin Total	**12,690,378**	

Sources: Ethiopia: CSA, 1999. Sudan: UN Population Fund & Sudan Central Bureau of Statistics (2002). Population densities: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory.

Note: These are not the full State populations as many states are "clipped" by sub-basin boundary.

2.1.2 Population growth rates

Population is expected to grow in the immediate future but to gradually slowdown on the Ethiopian side of the basin by 2015. Urban population growth rates are substantially larger than rural rates, but those in Sudan are generally higher than in Ethiopia (Table 2.3).

Table 2.3: Rural and Urban Growth Rates, Baro-Sobat-White Nile sub-basin

Country	State	Rural	Urban
SUDAN	**NORTH SUDAN**	**2.80**	**37.3**
	Khartoum	4.00	86.7
	El Gezira	3.00	22.4
	Sinnar	2.60	28.3
	Blue Nile	3.00	25.2
	North Kordofan	1.80	31.1
	South Kordofan	1.40	23.2
	White Nile	2.80	39.0
	SOUTH SUDAN	**1.80**	**19.6**
	Upper Nile	0.90	21.6
	Jonglei	n.d.	n.d.
	Equatoria	1.00	26.2
ETHIOPIA*	Beni-Shangul-Gumuze	2.43	16.9
	Oromiya	2.56	17.0
	Gambela	2.71	10.3
	SNNP	2.98	9.7

Source: Ethiopia: CSA (1999); Sudan: UN Population Fund, Sudan Central Bureau of Statistics (2002)
Note: These are not the full State populations as many states are "clipped" by sub-basin boundary.

2.1.3 Population Density

Population density is defined as the total number of people per square kilometer.

- Ethiopia: Population density in the BASWM sub-basin varies from 3 in the Gambella region to 127 in the SNNPRS region in Ethiopia (Table 2.1). The central part of the Ethiopian plateau has the highest density exceeding 122 in some parts, while densities are very low in the deep valleys and the escarpment and low in the lower Baro River basin.
- Sudan: Population density in the Sudanese part of the sub-basin varies from 974 in Khartoum state to only 5 in Jongli state (Table 2.1 and Figure 2.1). Densities are highest in Khartoum, El Gezira, White Nile States and along the main roads in Senner and North Kordofan States. Areas of medium population density include the Nuba Mountains in South Kordofan State, along the White Nile and along the Khor Machar in Upper Nile State, and along the main road from Kenya to Juba in the southern part of East Equatoria State. Elsewhere population densities are very low (Table 2.2 and Figure 2.1).

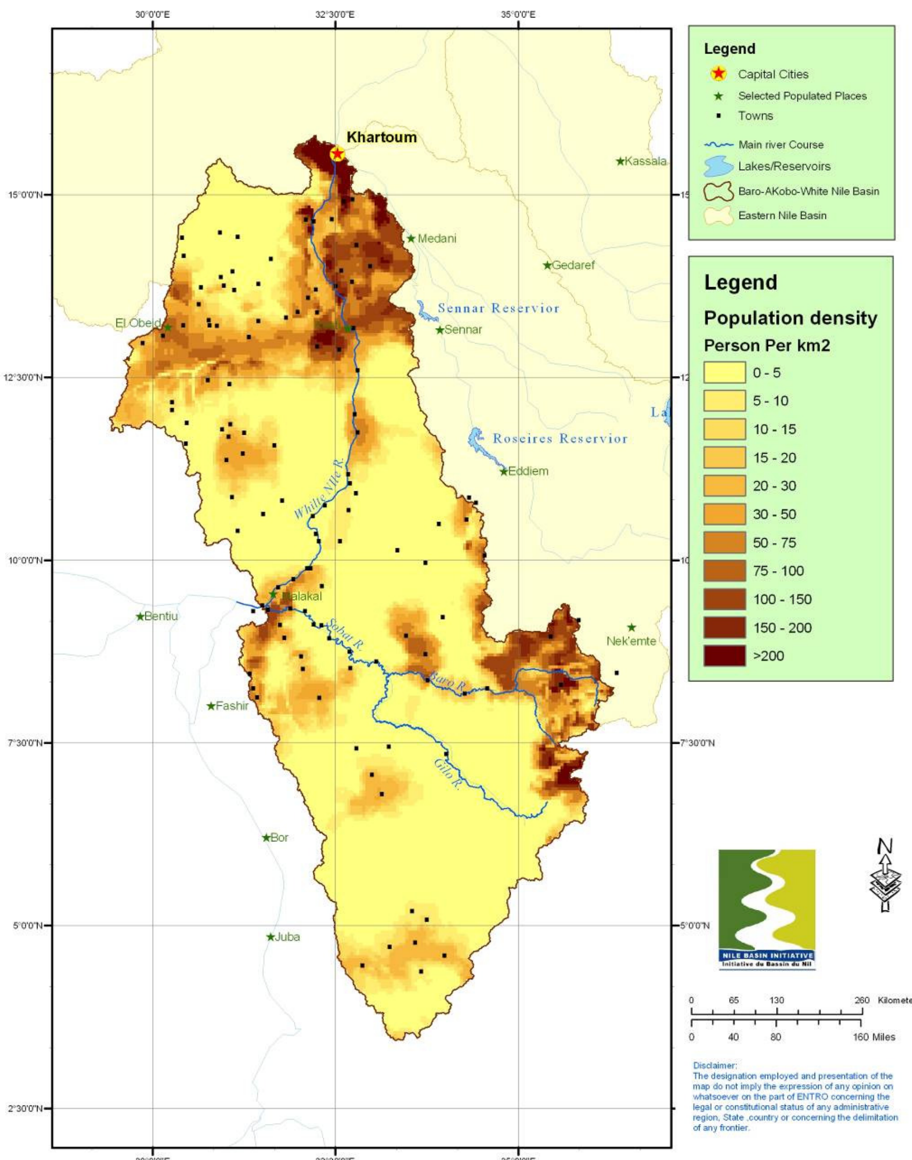
Table 2.1: Baro-Sobat-White Nile Sub-Basin: Population Estimates, 2002

Country	State	Population Density
SUDAN	Blue Nile	23
	East Equatoria	8
	El Gezira	130
	Jongoli	5
	Khartoum	974
	North Kordufan	26

Country	State	Population Density
	Sinnar	44
	South Kordufan	14
	Upper Nile	8
	White Nile	53
ETHIOPIA	Beni-Shangul-Gumuze Region	16
	Oromiya	70
	Gambela	10
	SNNP Region	43

Sources: Ethiopia: CSA, 1999. Sudan: UN Population Fund & Sudan Central Bureau of Statistics (2002). Population densities: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory.
Note: These are not the full State populations as many states are "clipped" by sub-basin boundary.

Figure: 2.1: BASWM Sub-basin: Population densities and distribution



Source: Ethiopia: CSA (1999); Sudan: UN Population Fund & Sudan Central Bureau of Statistics. (2002). LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory.

2.1.4 Rural-urban divide

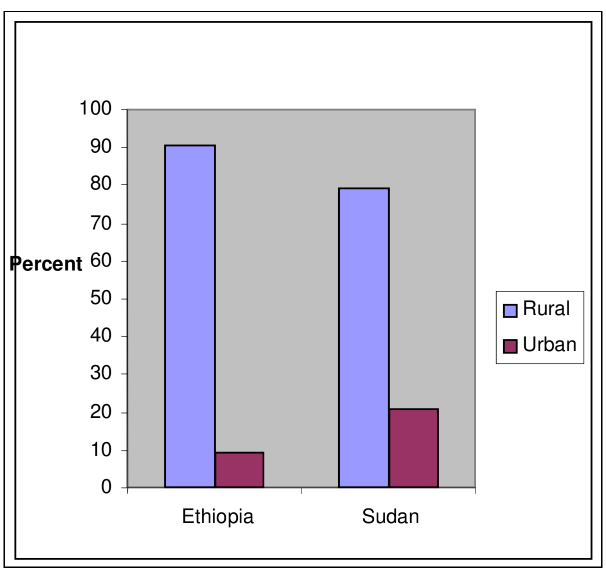
The overwhelming majority of the population, 91% in Ethiopia and 79% in Sudan, is rural (Figure 2.2). Excepting Khartoum rural rates are generally high between 61% in White Nile State in Sudan and 90% in the SNNP Regional State in Ethiopia (Table 2.3). This predominance of rural over urban partly reflects a lack of development opportunities.

Table 2.3: Baro-Sobat-White Nile Sub-Basin: Population Estimates, 2002

State	Population			Rural %
	Total	Rural	Urban	
SUDAN	**9,889,241**	**5,762,390**	**4,126,851**	
Blue Nile	411,895	308,097	103,798	75%
East Equatoria	398,782	294,301	104,481	74%
El Gezira	1,131,140	877,765	253,375	78%
Jongoli	392,065	307,379	84,686	78%
Khartoum	2,148,190	285,709	1,862,481	13%
North Kordufan	1,366,520	941,532	424,988	69%
Sinnar	451,829	323,961	127,868	72%
South Kordufan	811,353	622,308	189,045	77%
Upper Nile	615,417	482,487	132,930	78%
White Nile	2,162,050	1,318,851	843,200	61%
ETHIOPIA	**2,801,137**	**2,388,099**	**413,032**	
Beni-Shangul-Gumuze Region	89,903	74,711	15,192	83%
Oromiya	1,816,430	1,507,577	308,846	83%
Gambela	338,233	303,283	34,950	90%
SNNP Region	556,571	502,528	54,044	90%
Sub-basin Total	**12,690,378**	**8,150,489**	**4,539,883**	

Sources: Ethiopia: CSA, 1999. Sudan: UN Population Fund & Sudan Central Bureau of Statistics (2002). Population densities: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory.

Figure 2.2: Patterns of settlement in the Baro-Akobo-Sobat-White Nile Basin



Source: OSI Socio-economic Sysnthesis Report, p. 111

2.1.5 Sex ratios

- Sudan: There is a slight excess of males over females in South Sudan (i.e., 104 males per 100 females) and in North Sudan (100.4 males), and are strikingly higher in Khartoum (111), Equatoria (109) and Blue Nile (108), while there is an excess of females over males in North and South Kordofan and White Nile states in North Sudan (Table 2.5).

- Ethiopia: There is also a slight excess of males over females in Beni-Shangul-Gumuze region in Ethiopia (101.4 per 100 females).

Table 2.5: Sex ratios in BSWN sub-basin states

Country	State	Sex Ratio
SUDAN	North Sudan	100.4
	Khartoum	111.3
	El Gezira	96.8
	Sinnar	98.8
	Blue Nile	108.3
	North Kordofan	91.8
	South Kordofan	94.3
	White Nile	95.7
	South Sudan	104.4
	Upper Nile	101.7
	Jonglei	n.d.
	Equatoria	109.0
ETHIOPIA	BENI-SHANGUL-GUMUZE Region	101.4
	Oromiya	99.6
	Gambela	103.6
	SNNP Region	98.9

Source: Ethiopia: CSA (1999); Sudan: UN Population Fund, Sudan Central Bureau of Statistics (2002)

2.1.6 Population age groups

Around 40-45% of the population in all the states in the sub-basin is below the age of 15, while only a small proportion of around 4-5% are above 60 (Table 2.6).

Table 2.6: Population age groups in the BSWN sub-basin states

Country	State	Proportion below 15 years (%)	Proportion above 60 years (%)
SUDAN	**NORTH SUDAN**	**42.8**	**4.1**
	Khartoum	36.5	3.8
	El Gezira	42.5	4.4
	Sinnar	44.5	4.0
	Blue Nile	42.7	3.7
	North Kordofan	47.4	4.9
	South Kordofan	47.5	3.4
	White Nile	45.5	3.9
	SOUTH SUDAN	**43.5**	**2.9**
	Upper Nile	45.9	3.3
	Jonglei	n.d.	n.d.
	Equatoria	43.8	2.6
ETHIOPIA*	**BENI-SHANGUL-GUMUZE**	**44.5**	**4.7**

Country	State	Proportion below 15 years (%)	Proportion above 60 years (%)
	Region		
	Oromiya	45.0	5.5
	Gambela	41.1	2.5
	SNNP Region	**45.2**	**4.0**

Source: Ethiopia: CSA (1999); Sudan: UN Population Fund, Sudan Central Bureau of Statistics (2002)

- Sudan: The proportion of elderly (above 60) is strikingly low in South Sudan (2.9%).
- Ethiopia: The proportion fo the elderly (above 60) is also low in Gambella state.

2.1.7 Crude birth and death rates

The crude birth rates are around three times the crude death rates in all the states of the sub-basin, and are fairly similar across the states of Sudan and Ethiopia with the exception of Gambella, which has the lowest crude birth rates (Table 2.4).

Table 2.4: Crude birth and death rates, Baro-Sobat-White Nile Sub-basin

Country	State	Crude Birth Rate	Crude Death Rate
SUDAN	**NORTH SUDAN**	**37.8**	**11.0**
	Khartoum	33.7	8.8
	El Gezira	38.5	9.5
	Sinnar	39.9	10.9
	Blue Nile	38.5	12.3
	North Kordofan	40.1	12.2
	South Kordofan	39.3	124
	White Nile	40.4	10.0
	SOUTH SUDAN	**38.0**	**13.9**
	Upper Nile	38.5	16.2
	Jonglei	n.d.	n.d.
	Equatoria	33.8	11.6
ETHIOPIA*	**BENI-SHANGUL-GUMUZE Region**	**37.2**	**12.6**
	Oromiya	38.3	10.9
	Gambela	32.7	11.8
	SNNP Region	**38.6**	**11.4**

Source: Ethiopia: CSA (1999); Sudan: UN Population Fund, Sudan Central Bureau of Statistics (2002)
Note: These are not the full State populations as many states are "clipped" by sub-basin boundary.

2.1.8 Infant Mortality

- Sub-basin: Infant mortality rates are higher on the Sudanese side than on the Ethiopian side in general.
- Sudan: The rate in South Sudan is 177 per 1000 live births and higher than the North Sudan rate of 116 deaths. There are, however, regional variations and female deaths are generally lower than male deaths(Table 2.7).
- Ethiopia: The rates in both the Beni-Shangul-Gumuze and SNPP regions are considerably lower than in Sudan, although there are regional variations. There is, however, no gender-segregated data on infant mortality as in Sudan.

Table 2.7: Infant mortality, Baro-Sobat-White Nile sub-basin

Country	State	Deaths per 1000 live births		
		Male	Female	Total
SUDAN	**NORTH SUDAN**	**116**	**98**	
	Khartoum	98	85	
	El Gezira	101	76	
	Sinnar	121	109	
	Blue Nile	137	122	
	North Kordofan	125	106	
	South Kordofan	138	119	
	White Nile	109	100	
	SOUTH SUDAN	**152**	**130**	
	Upper Nile	100	92	
	Jonglei	n.d.	n.d.	
	Equatoria	177	156	
ETHIOPIA*	**BENI-SHANGUL-GUMUZE Region**			**104**
	Oromiya			86
	Gambela			68
	SNNP Region			**95**

Source: Ethiopia: CSA, 1999. Sudan: UN Population Fund & Sudan Central Bureau of Statistics, 2002.
Note: *Rural rate

2.1.9 Life Expectancy at Birth

- Sub-basin**:** Average life expectancy for the basin population ranges from 46 to 55 years for both males and females.

2.1.10 Ethnic groups

- Sudan: A substantial proportion of the population in the Blue Nile Sub-basin lives and works on large irrigation schemes and semi-mechanized farms or in service and processing industries related to these developments. Many in the past were pastoralists and agro-pastoralists but since lost their livestock and became sedentary.

- Ethiopia: Within Ethiopia in two of the three regions located within the sub-basin one ethnic group tends to be predominant (Table 2.2)

Table 2.2: Relative proportions of ethnic groups in Ethiopia

Region	Number of ethnic groups	Main ethnic groups	% to rural population
Amhara	55	Amhara	**91%**
		Agew	4%
Ben-Shangul-Gumuze	6	Jebelaw/Koma/Mao	**29%**
		Gumuz	**25%**
		Amhara	20%
		Oromo	12%
		Sinashi	7%
		Agew	3%
Oromiya	71	Oromo	**88.7%**
		Amhara	7%

2.2 ACCESS TO SOCIAL INFRASTRUCTURE

2.2.1 Literacy and education

- Sub-basin: Most of the population in the basin area has limited access to education. Primary net enrolment ratio is the number of children (7-12 years) currently attending primary school divided by the total number of children in that age group. Similarly, secondary net enrolment ratio is the proportion of children aged 13-18 attending secondary school (grade 7-12) divided by the total number of children in that age group. The literacy and primary school enrolment rates for the states/regional states in the sub-basin are shown in Table 2.10.

Table 2.10: Baro-Akobo-Sobat-White Nile Sub-basin: Literacy and Primary School Enrolment

State	Literacy Rates > 15 years			Population 6-13 years	Total Primary School enrolment	% enrolment
	Average	Male	Female			
SOUTH SUDAN	**52.6**	**65.4**	**39.3**	**1,037,964**	**120,682**	**11.6**
Khartoum	73.6	81.1	65.0	795,983	659,028	82.8
El Gezira	65.2	75.5	55.8	658,547	538,183	81.7
Sinnar	52.0	64.5	40.0	267,649	146,090	54.6
Blue Nile	31.3	41.8	20.4	143,305	48,914	34.1
North Kordofan	39.1	52.0	29.4	364,719	170,023	46.6
South Kordofan	44.4	56.2	34.4	290,819	100,663	34.6
White Nile	54.4	64.5	44.3	335,040	255,152	76.2
NORTH SUDAN	**54.5**	**66.6**	**42.4**	**5,455,266**	**3,187,705**	**58.4%**
Upper Nile	62.4	75.8	50.3	259,318	48,002	18.5
Jonglei						
Equatoria	47.4	60.6	34.3	292,646	42,728	14.6
ETHIOPIA*						
BENI-SHANGUL-GUMUZE Region	17.7	24.9	10.5	180,971	493,599	95%
Oromiya	22.4	29.3	15.6	2,240,471	3,600,777	64%
Gambela	29.3	38.6	19.5	1,098,511	335,222	76%
SNNP Region	24.4	33.9	15.2	609,321	207,169	85%
TOTAL				**4,129,274**	**4,636,767**	**89%**

Sources: Sudan: UN Population Fund & Sudan Central Bureau of Statistics (2002); Ethiopia: World Bank, 2004.

2.2.2 Water Supply

- Sudan: There is a wide variation in the nature of access to drinking water within the sub-basin. Urban Khartoum has the largest proportion of population using piped water (64%), followed by El Gezira (61%) and Sinnar (41%), White Nile, while this proportion is lowest in South Kordofan (2.6%) (Table 2.11). Khartoum, El Gezira and Sinner States have rates of piped water and deep wells well above those of Blue Nile, and North and South Kordofan State. Data for other South Sudan States are missing although the town of Malakal has 94 per cent of the population using rivers or canals, which may be indicative of the rates in Southern Sudan.

Table 2.11: Baro-Akobo-Sobat-White Nile Sub-basin: Access to Drinking Water

State	Main source of water							
	Piped into dwelling	Public tap	Deep Well/ pump	Dug Well/ bucket	River/ canal	Rain water	Others	Not Stated
SOUTH SUDAN								
Khartoum	59.8	3.5	29.5	2.4	0.2	1.6	2.9	--
El Gezira	47.2	14.1	16.6	6.6	12	0.2	3.3	--
Sinnar	30.2	11.3	32.4	0.6	8.1	9.3	7.6	0.4
Blue Nile	12.3	2.1	9.3	2.1	33.2	27.9	13	0
North Kordofan	16.3	5.3	20.5	25.4	2.2	13.2	17.1	--
South Kordofan	0.9	1.7	76.6	7.1	0.1	4.9	8.6	--
White Nile	23.1	5.5	10.3	12.4	28.5	7.7	11.8	0.8
NORTH SUDAN	**50.8**	**4.3**	**15.8**	**9.8**	**12.8**	**--**	**6.4**	**0.1**
Upper Nile								
Jonglei								
Equatoria								
Malakal	3.6	1.8		0.2	94.1		0.3	
ETHIOPIA*	**Tap**		**Protected well/ spring**	**Unprotected well/ spring**	**River, Lake, pond**			**Not Stated**
Beni-Shangul-Gumuze	12.5		5.7	0.1	63.1			18.6
Oromiya	11.2		11.2	34.2	43.1			0.3
Gambela	16.7		9.8	16.5	56.2			0.8
SNNP	7.6		11.2	30.5	50.1			0.2

Sources: Sudan: Sources: Sudan: UN Population Fund & Sudan Central Bureau of Statistics. (2002). Ethiopia: World Bank, 2004.

- Ethiopia: In the four Ethiopian states the proportion of population using taps ranges from 28% (Beni-Shangul-Gumuze) to 19% (SNNP). The proportion of population using rivers, lakes and ponds is also highest in the Ethiopian states. According to the 1994 second National CSA survey, only 24% of the housing units in Ethiopia used a safe source of water, 14% through piped (tap) water, 10% from protected and springs. The rest, 76% of the country's population used "unsafe" water, such as from unprotected springs and wells or directly from rivers. In 1994 over 40 million people had no access to safe drinking water and in 1998 the number had risen to 46 million people or 77% of the population (OSI Water Synthesis report, p. 160). The per cent population with access to drinking water facilities are shown in Table 2.12.

Table 2.12: Access to safe drinking water by region, % of population (2001)

Region	% of total population	% of Rural population	% of Urban population
Gambella	17.6	14	35
Ormiya	31.2	25	76
SNNPR	28.6	24	83
Beni-Shangul-Gumuze	20.3	18	43
Ethiopia	**30.9**	**23.1**	**74.4**

Source: National Water Development Report for Ethiopia (2004), quoted in the OSI Socio-economic Synthesis Report, p. 114.

2.2.3 Sanitation

- Sub-basin: The majority of states in Sudan reported around 40-45% of population without access to sanitation facilities, while the proportion was higher in North Kordofan, Beni-Shangul-Gumuze and Gambela (Table 2.13).

Table 2.13: Baro-Akobo-Sobat-White Nile Sub-basin: Access to Sanitation Facilities

State	Flush to Sewage System	Flush to septic tank	Traditional pit latrine	Soak pit	Others	Missing	No facilities
SUDAN							
Khartoum	1.1	11.2	73.8	0.9	3.1	0.4	9.5
El Gezira		4.2	51.7	2.1	1.7	0.2	40.0
Sinnar		2.7	46.6	5.3	2.1	0.7	42.7
Blue Nile		3.5	56.0	3.2	0.4	0.8	36.0
North Kordofan		2.9	31.4	1.9	1	0.1	62.6
South Kordofan		2.4	48.7	0.3	1.4	0.9	46.4
White Nile		4.8	45.7	3.7	2.2	0.5	43.2
NORTH SUDAN		7.7	69.2	1.6	1.6	--	19.9
Upper Nile							
Jonglei							
Equatoria							
Malakal		2.1	22.4	4.5	0.6	0.3	70.1
ETHIOPIA*	**Private Flush**	**Shared Flush**	**Private Pit**	**Shared Pit**		**Not stated**	**No facilities**
Beni-Shangul-Gumuze	2.2	3.9	30.3	0.3		1.7	61.6
Oromiya	1.8	1.4	33.4	22.4		1.1	39.9
Gambela	3.0	3.1	13.1	11.7		2.1	67.0
SNNP	1.2	0.9	38.1	22.8		1.2	36.0

Sources: Sudan: UN Population Fund & Sudan Central Bureau of Statistics, 2002; Ethiopia: World Bank, 2004.

- Ethiopia: The Sanitation Sector Strategy Paper of 1987 (WSSA) estimated that only 7% of the population is estimated to have access to sanitary latrines. In towns the coverage was 54%, in rural areas only 4% (National Water Development Report for Ethiopia, 2004). In the 1998 Welfare Monitoring Survey it was estimated that 92 % of the rural population is without latrines. Regarding the four basin states, some 86%, 77%, 90% and 91% of the rural population in Gambella, Beni-Shangul-Gumuze, Oromiya and SNNPR are without latrines.

2.2.4 Health

Government health posts and clinics

- Sub-basin: There are few health centers and hospitals in the Baro-Akobo Basin.

- Ethiopia: There are only 2 hospitals and 11 health centers in Beni-Shangul-Gumuze region for a population size of 424,432, according to the 1994 Housing and Population Census.

2.3 TRANSPORT AND COMMUNICATIONS

2.3.1 Roads

Number of roads

- Sub-basin: There are no major road linkages between Ethiopia and Sudan within the BASWN sub-basin. A dry weather track crosses the border at one point, Kurmuk, and there are two secondary roads: one in Sudan from Malakal and one in Ethiopia from Gambela town come very close and may meet at Jikauo on the north bank of the Baro River, which at this point forms the border. Secondary roads in Ethiopia touch or come very close to the border at Akobo and Dioma (Figure 2.4).
- Ethiopia: Within Ethiopia, the basin is traversed by a network of all-weather roads of some 1,058 km. The roads Addis – Gambela, Addis – Assisi, Jimma – Mizan Teferi, and Gore – Tepi are well maintained all-weather roads. The Gambela – Dembidolo road is also all-weather road, but in need of maintenance. There are numerous smaller roads or dry-weather road links, accessible only during the dry season. In general, the western part of the basin is the least served by roads. Further improvements to roads in the basin are expected to take place consistent with the priorities of the Road Sector Development Plan of the Ethiopian Road Authority.
- Sudan: Within Sudan there are three primary and three secondary roads. The three primary roads are: (1) Senner to Kosti and El Obeid; (2) Khartoum – Kosti and (3) Kenya border – Juba. The last road has been opened from the Kenya border as far as Torit. The Torit to Juba section remains impassable as at December 2005 (FAO/WFP, 2006). The road linking Juba to Malakal is still not operational. There are three secondary roads that may not be passable during the rainy season: (1) Ad Damazin - Paloich; (2) Rabak – Malakal and (3) Pocalla-Boma-Lokichoggio (Kenya). Other roads are generally in poor condition and on the clay plains often impassable during the rains.

Length and density of roads

- Ethiopia: Road density is low compared to many African countries.

Access to all-weather roads

- Ethiopia: The 2004 Welfare Monitoring Survey conducted by the Central Statistical Agency suggests that more than half of the sub-basin population does not have access to all-weather roads. This is especially true of Gambela region which is remote and isolated as most of the river and its tributaries flow through here. The absence/lack of all-weather roads is a major obstacle to efforts to promote basin-based development such as fishing and irrigation (Socio-economic Synthesis Report, p.113).

2.3.2 Railways

- Sub-basin: There is only one railway from Sennar to El Obeid.

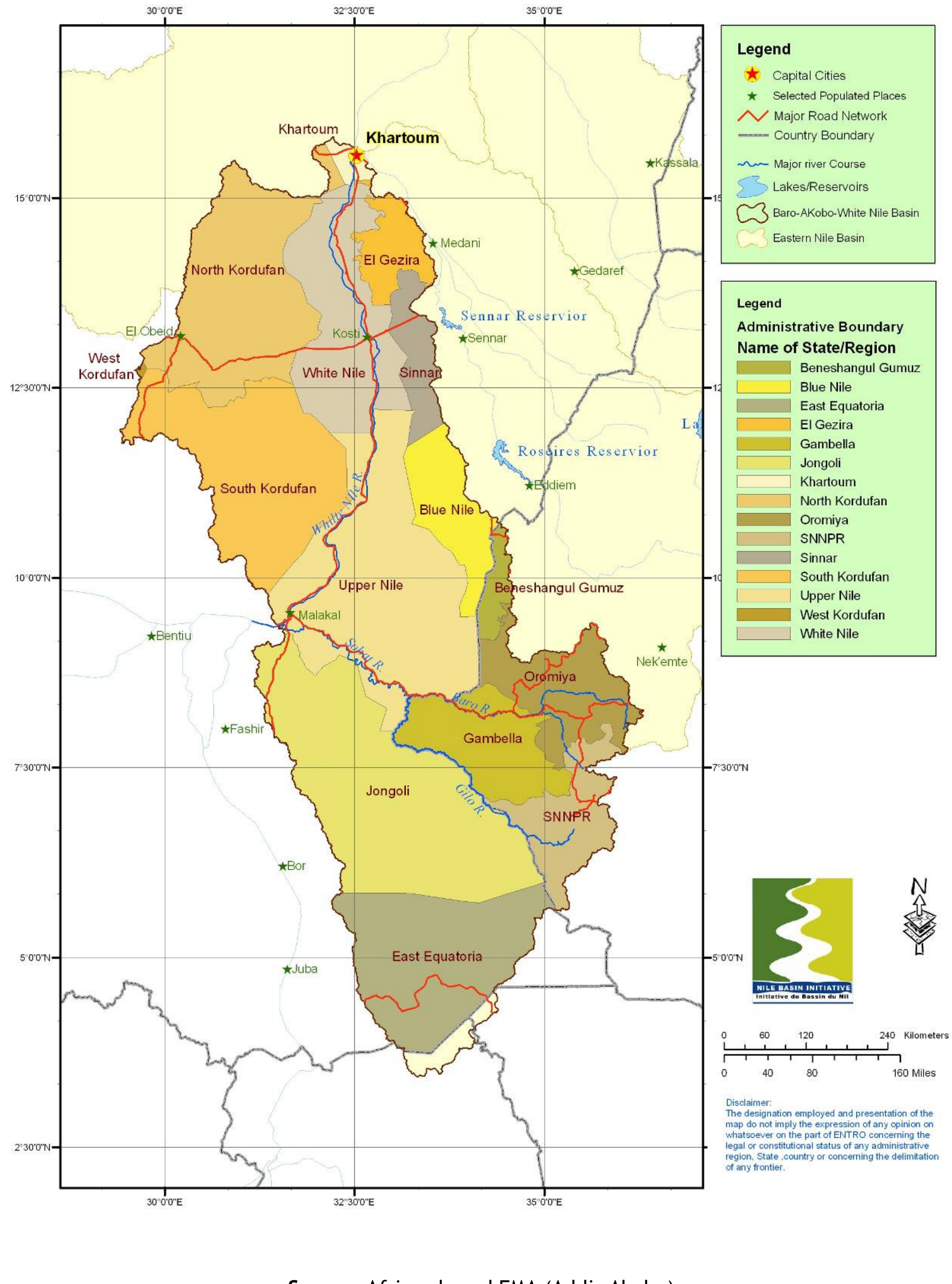
2.3.3 River Transport

- Sudan: River transport between Kosti-Alkali-Juba is now functioning and the number of barges increasing.

2.3.4 Air transport

- Ethiopia: There are six operational airports in the Baro-Akobo basin connected to Addis Ababa by schedule air services. Gambela is the largest and the only airport with paved runway and navigation aids. It handles about 5,000 passengers (arrivals and departures) per year, while the other five handle 15,000 between them.

Figure 2.4: Administrative map and road Network in the BASWN sub-basin



Source: Afriroads and EMA (Addis Ababa)

2.4 ECONOMIC ACTIVITIES

2.4.1 Activity rate

Activity rate is defined as the proportion of the total economically active (employed plus unemployed) population to the total working age population.

Sub-basin: Data from the Sudan part is not available but some data is available from the Ethiopian side of the sub basin.

Ethiopia: The sub-basin states have the following activity rates: SNNPRS (77%), Oromiyo (70%), Beni-shangul-Gumuze (70%), and Gambella (63%).

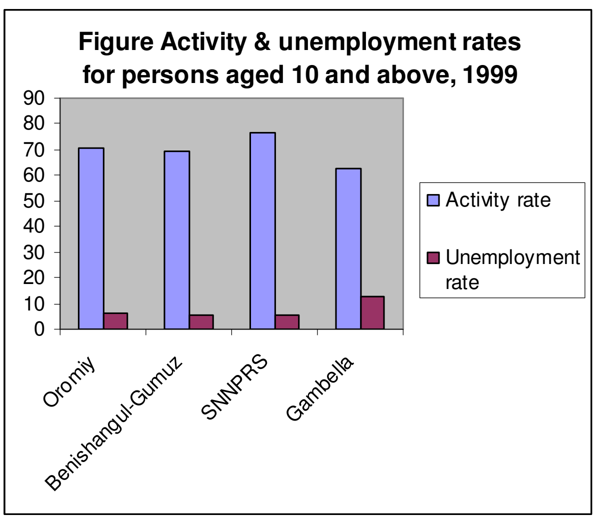
2.4.2 Unemployment rates

- **Sub-basin:** Data on unemployment rates is not available for the Sudan and only available for the four states in the Ethiopian side of the sub-basin.
- **Ethiopia:** Unemployment rates for the four states in the BASWN sub-basin ranges from 5-6% in Oromiya, Beni-Shangul-Gumuze and SNNPRS to 12.5% in Gambella (Table 2.14).

Table 2.14: Unemployment rates of Ethiopian states

State	Rate
Oromiya	6.1%
Beni-Shangul-Gumuze	5.2%
SNNPRS	5.5%
Gambella	12.5%

Figure 2.5: Activity & unemployment rates for persons aged 10 and above, 1999



Source: OSI Socio-economic Synthesis Report, p. 113

2.4.3 Livelihood patterns

Sub-basin

- **Cultivation:** Rain fed crop cultivation is the principal activity in most of the basin where adequate rainfall is available. The economy, largely based on traditional methods of plough cultivation and supplemented by the hoe in the lowlands, is subsistence oriented. Production is dominated by growing of crops (e.g. maize & sorghum) for local consumption. The lowland population practices some kind of shifting cultivation, mainly for growing sorghum. In semi-arid to arid conditions, pastoral livestock becomes predominant. Livestock as a source of livelihood is mainly important for the Sudanese side of the basin population where there exists a high concentration of cattle, sheep, and goats. Generally, it seems that combining crop and livestock production followed by 'crop only' farming and 'livestock only' production are main livelihood strategies undertaken by the basin population in that order. Farm employment (combining crop and livestock production) constitutes the primary source of occupation for the population. The communities along the basin (both in Ethiopia and Sudan) seems to have very limited experience in accessing cash income because of the remoteness and inaccessibility of the sub basin region from regional market centers and hence employment is concentrated in the production of primary commodities. There is very little use of the basin and its tributaries for irrigated agriculture (except some traditional methods of water diversion).

- **Farm employment:** Farm employment (combining crop and livestock production) constitutes the primary source of occupation for the population. The communities along the basin (both in Ethiopia and Sudan) seems to have very limited experience in accessing cash income because of the remoteness and inaccessibility of the sub basin region from regional market centers and hence employment is concentrated in the production of primary commodities.
- **Irrigated agriculture**: There is very little use of the basin and its tributaries for irrigation activities (except some traditional methods of water diversion).
- **Fishing:** Fishing is indispensable to the economy of the Baro-Akobo River, on the Ethiopian side (Hussein and Yared, 2003). Intensive fishing is done on perennial and seasonal swamp areas during the dry season, although it is currently mainly for subsistence in the main river channels and floodplain areas. The basin has high potential for flood plain aquaculture, although it currently lacks aquaculture technologies.
- **Ethiopia:** In rainy season rivers in their lower reaches over-flow their banks and inundate a considerable area. The rivers contribute to the fishery development and hence to the economy of the Gambela Regional State and country are indispensable. The fish fauna of these main rivers is similar. It is rich in fish diversity and so far identified 106 distinct types of fish species (Golubtsob, A.S., and Mina, M.V. 2003). During wet season rivers flooded a large area of land and created perennial and temporary water bodies and swamps. Intensive fishing activity is done on these perennial and seasonal swamp areas and ponds in dry season. The basin has a high potential for flood plain aquaclture, however it lacks efficient aquaculture technologies. Fishing in the area is mainly on a subsistence basis, both in the main river channels and floodplain areas. Virtually every Agnuak ethnic family that settled near along the course of rivers fishes for supplement their diet. A socio-economic appraisal of the capture fisheries in the basin is essential if the development potential of the basin is to be achieved (OSI Socio-economic Synthesis Report, p. 112).

2.5 AGRICULTURE AND PEOPLE

2.5.1 Major livelihood activities of ethnic groups

There are a number of groups of people who retain their original way of life, although now somewhat altered.

- **The Rufa'a al-Hoi** are an Arab speaking Muslim nomadic peoples with sheep, cattle and camels. The southern group, the Badiya used to move between the Yabus (in the dry season) and the Gezira/Managil schemes (in the wet season). As well as livestock production gum collection (from *A. seyal*) and sorghum cropping supplement livelihoods. In the past two decades and particularly after the 1984 drought, there has been an increasing number of Rufa'a al-Hoi people without livestock becoming sedentarized. Following the abolition of the Native Authorities many sedentary villages ran their own village councils and the power of the Rufa'a al-Hoi declined. The recent installation of the Federal structure has further weakened the power of the Rufa'a al-Hoi and so increased that of the sedentary people.
- **The Fulani** are in fact a mixture of many ethnic groups from West Africa who moved into the Funj in the mid 1940's, were expelled to western Sudan in 1954 but have since returned. They have the West African long horned cattle that are fast walkers but poor milkers. The Fulani follow the same transhumant patterns as the Rufa'a al-Hoi but at slightly different times usually leaving the dry season grazing area later. They are said to remain out of contact with government tax and veterinary agents, often moving at night.
- **The Nuba:** West of the White Nile are the Nuba group of peoples who live in the Nuba Mountains but who also cultivate on the plains. They make up 90 per cent of the population in the Nuba Mountains. They are in fact a group that have more than 50 languages and dialect clusters falling into 10 groups (Mohamed Suliman, 1999). They practice a range of productive activities including the mainstay of their economy crop production, as well as animal husbandry, hunting and foraging.
- **The Baggara** are an Arab speaking pastoral people, a large proportion of whom belong to the Hawazma group, their home area being west of the White Nile in and below the Nuba Mountains. They are said to have started to enter the mountains at the beginning of the 19^{th} century. They use the mountains, the clay plains west of the White Nile and cross over in the dry season and also graze to the north of the Machar Swamps. They only enter the southern Funj area in the dry season.
- **The Nilotes people:** Further south are the group of Nilotes peoples: the Nuer, Dinka, Shilluk, Anuak and the Murle. The Nuer, Dinka and Murle are pastoralists or more properly agro-pastoralists whilst the Shilluk and Anuak are mainly sedentary cultivators.
- **The Dinka** within the Sobat-White Nile Sub-basin occupy the area just to the east of the White Nile. They comprise four "tribes": the Ngok (to the south of the Sobat), the Dunjol, the Paloich and the Abialongto the north. The Nuer occupying the Sub-basin are found to the east of the Dinka and eastwards to the Gambella region of Ethiopia. They belong to the Eastern Jikaing and the Lau tribes: two of the 11 major grouping. The Lau occupy the area to the south of the Sobat whilst the Jikaing are to the north.
- **The Shilluk** occupy a narrow strip along the banks of the White Nile between the Sobat-White Nile confluence northwards to Kodok. Unlike the Nuer and Dinka the Shilluk are sedentary. Around the villages rainfed cultivation of sorghum, maize, groundnuts, beans and tobacco occurs. Unlike the Nuer and Dinka the Shilluk posses far fewer cattle and depend less on cattle products. Thus they are not obliged to migrate with the seasons. Additionally the intermediate and "toich" grasslands are close by the villages. Fishing is an extremely important component of their economy.
- **The Anuak** are also cultivators but have no cattle or small stock. They are found in Ethiopia and just to the south of the Gambella salient. They occupy the high levees

along the Sobat River and its eastern tributaries. They cultivate sorghum and maize on the flood retreat soils below the levee. Fishing is an important element of their livelihoods.

- **The Murle** occupy the Boma Plateau as far north as Pibor Post in Pibor Locality of Eastern Equatoria. They are divided into two groups: the plains Murle (Lotilla) and the Hills Murle (Ngalan) who occupy the Boma Plateau. The Plains Murle are essentially Agro-pastoralists. However, although cattle are their main source of livelihood they do cultivate some maize and sorghum. The Hill Murle are essentially agriculturalists with some cattle. The cultivate maize, sorghum, sesame, tobacco and coffee.
- **The Toposa** live in Kapoeta Locality of Eastern Equatoria, which experiences a lower rainfall than elsewhere in the Region. They are mainly pastoralists keeping cattle, camels, goats and sheep, but also cultivate some maize and sorghum.

2.5.2 Main Agricultural Land Use Systems

The main agricultural land use systems in the Baro-Akobo-Sobat-White Nile Sub-basin in Sudan and Ethiopia are relatively distinct except along the international border where the cultural affinities have given rise to very similar systems. Nevertheless, three broad systems can be identified: (i) rainfed cropping, (ii) irrigated cropping and (iii) extensive livestock production (with minor cropping). Differences in the scale of operations, tenure type and to a lesser extent cropping patterns give rise to a number of recognizable sub-categories (Table 2.15).

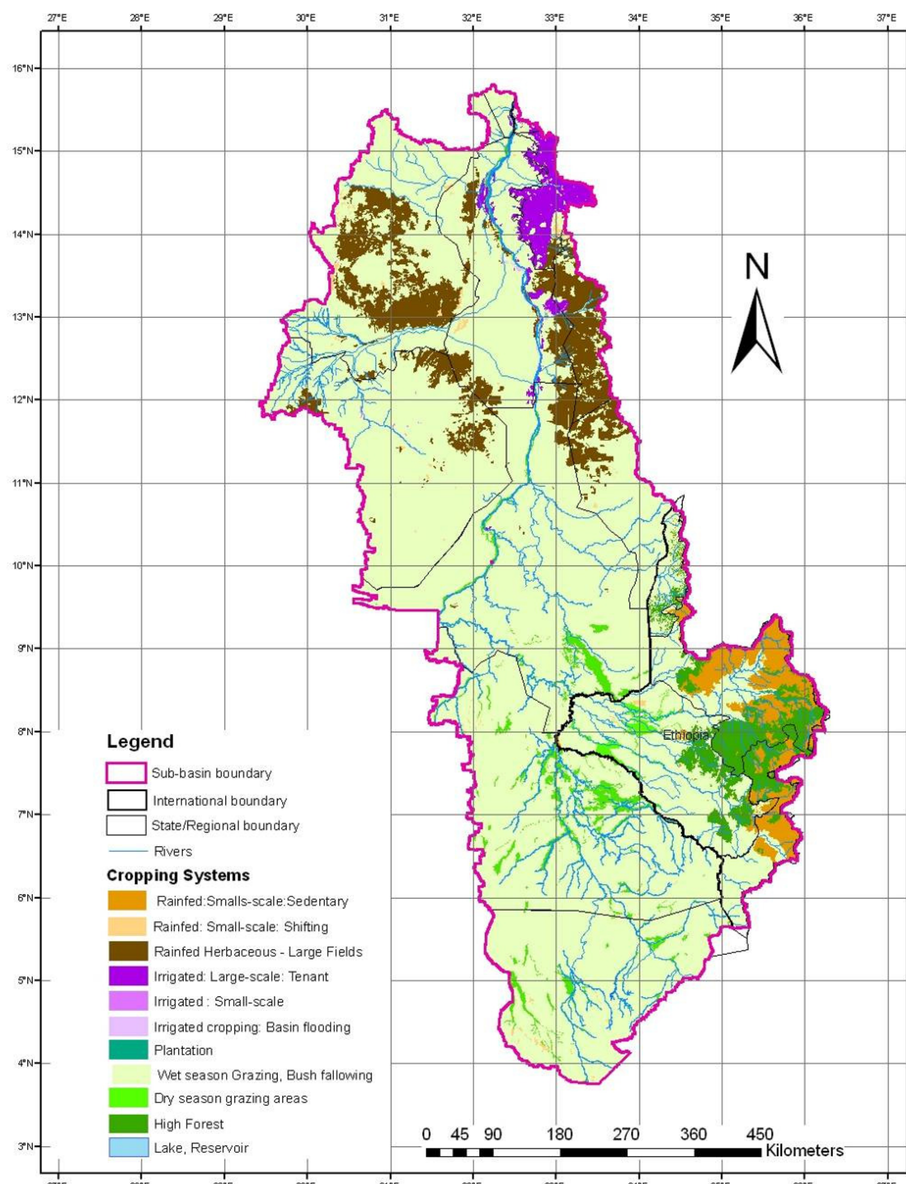
Table 2.15: Main Agricultural Systems in the Baro-Akobo-Sobat-White Nile Sub-basin

Main Category	Scale of operations	Tenure type	Main Components	Location
RAINFED CROPPING	Small-scale traditional; sedentary	State land: Individual and Communal use rights	Cropping (Cereals, pulses, oil seeds) Cropping (Enset, roots, cereals, pulses) Small Livestock holdings (Communal grazing, crop residues)	Ethiopia: Highlands
	Small-scale traditional; shifting	State land: Individual and Communal use rights	Cropping (cereals, pulses): No livestock holdings (Tsetse infestation)	Ethiopia & Sudan: Lowlands
	Small-scale: traditional: flood retreat	State land: Individual and Communal use rights	Cropping (cereals, pulses) Small Livestock holdings (Communal grazing	Ethiopia & Sudan: (Anuak, Shilluk)
	Large-scale: Semi-mechanized	State land: Medium-term Leases	Cropping (Sorghum, cotton, sesame)	Sudan: Lowlands
IRRIGATED CROPPING	Small schemes in valley bottoms: Small-scale operations (< 1.0 ha) Gravity: Controlled water-tables	State Land: Individual use rights: additional to rainfed land	Cropping (cereals, vegetables)	Ethiopian Highlands
	Small-scale:(<20 ha) Pump	Individual Freehold State land: Lease	Cropping: Sorghum, wheat, Alfalfa	White Nile
	Large scheme: small-scale operations (<40 feddans) Gravity	State land: Individual long-term leases	Cropping: Cotton, Sorghum, wheat Small-livestock holdings	Sudan: Gezira and Rahad Schemes
	Large scheme: large-scale operations	State land: Long lease	Cropping: Sugar	Sudan: Kenana Schemes
LIVESTOCK	Small-scale: Extensive Pastoral Transhumant	Communal use (grazing, water) rights	Cattle, small-ruminants	Sudan (Toposa)
	Small-scale: Extensive	State land:	Cattle, small-	Sudan (Nuer, Shilluk, Murle)

Main Category	Scale of operations	Tenure type	Main Components	Location
	Agro-pastoral Transhumant-sedentary	Communal use (grazing, water) rights	ruminants Small-scale cropping	

Rainfed cropping operates at the traditional small-scale and the large and semi-mechanized scale (Figure 2.6). The former is under individual use rights for cropping and communal use rights for grazing and fuelwood collection. Mixed cropping and livestock production are the main production components. In the Highlands cropping is sedentary whilst in the lowlands it incorporates bush fallowing and shifting cultivation.

Figure 2.6: Baro-Sobat-White Nile Sub-basin: Cropping Systems



Source: FAO Africover Sudan (2002) & WBISPP-MARD (2001 -2003)

In both the highland and lowland systems use of improved inputs (chemical fertilizer and seeds) is low. Conversely, the large-scale semi-mechanized systems are under state lease-hold tenure (25 years leases) and a number of cultural operations (ploughing, harrowing and seeding) are mechanized. Nevertheless, the use of improved inputs (fertilizer, seed) is minimal.

More details about each of these systems is given below (from WSM CRA, 2007).

Traditional Small-scale Rainfed Agriculture Systems

- **Highland traditional rain-fed system:** The Highland traditional rainfed systems can be divided into cereal based and enset-root based. The enset-root based system is represented by the Mocha (Sheka) people, living mainly in the highest parts of the Ethiopian Highlands, cultivating Enset as a co-staple crop with cereals and tubers. The system is based on two types of field: a permanent garden around the homestead and the open and rotating fields beyond. The garden crops include enset, root crops (yam, taro and sweet potato), pulses, vegetables, spices and coffee. The open field crops are mainly cereals: teff, maize and sorghum. The Highland cereal based systems are found in the Ethiopian Highlands, the Nuba Mountains and the Imatong Mountains. In the Ethiopian Highlands they are represented by sorghum-maize-coffee system. The dominant crops are maize and teff and some sorghum. Below 2,000 masl coffee is an important cash crop. Some root crops (sweet potato and Oromo potato) are grown in homestead gardens, occasionally with a small enset plot. Livestock include cattle, sheep and goats. Cattle are important for draught power, milk and as a store of wealth. Livestock feed supply comprises open grazing, crop residues and grass hay. Because open grazing is still available (although decreasing rapidly), cropping, livestock production and tree growing are not closely integrated.
- **The Nuba mountain systems:** West of the White Nile are the Nuba group of peoples who live in the Nuba Mountains but who also cultivate on the plains. They practice a range of productive activities including the mainstay of their economy crop production, as well as animal husbandry, hunting and foraging. Farmland is divided spatially and in terms of crop production into three units: the homestead, the hillside and the far farms. Homestead farms produce early maize, bulrush millet and finger millet and are the responsibility of the women. The terraced hillside farms are planted with later maturing grains. The far farms are located on the clay plains and are used for sorghum. The hillside and plain farms are under a form of shifting cultivation and bush fallowing. Whilst necessitating much labour, the spread of farms among three types tends to spread risk and harvesting times are different thus spreading scarce labour.
- **The Imatong mountain systems:** In the agricultural systems of the Boya, Lakuka and Dindinga peoples who inhabit the Imatong Mountains there are two cropping seasons (April-July, and September-December (Muchomba and Sharp, 2006). Crops in the first and second season include sorghum, cowpeas, groundnuts and sesame. Cassava is a crop that bridges the two seasons. Livestock are important but household assets have been severely depleted during the Civil War.
- **Lowlands and escarpment systems:** In the Lowlands and on the escarpment there are two main types of agricultural systems: (i) rainfed cropping based on bush fallowing and shifting cultivation practiced by the Berta, Komo, Mao and Meban peoples in the lowlands and the Majangir on the Escarpment and (ii) cropping based on rainfall and residual moisture (flood retreat) practiced by the Anuak along the Baro-Akobo and the Shilluk along the White Nile. In the shifting cultivation systems the main crops are sorghum, maize and beans. The Majangir people practice a sophisticated system of weed mulching and forest fallowing. The use of the weed mulch to suppress weed

growth extends the period of cultivation by some two to four years. Thus, the Majangir appear to have partially solved the problem of weed infestation, which is probably the cause of final abandonment of shifting cultivated fields elsewhere. Livestock holdings in this land use system are very low. Less than 7 per cent of households have cattle, but 47 per cent have goats. Most of the system lies within areas of high tsetse challenge, and are thus exposed to trypanosomiasis. Bee-keeping is a speciality of the Majangir.

- **River bank systems:** The Anuwak, Opo and Komo peoples cultivate the banks and levees of the Baro, Akobo and Sobat rivers rather than the woodlands on the interfluves. Two crops of maize and beans and one crop of sorghum are obtained. The average cropped area of each maize crop is 1-2 ha with 1 ha of long season sorghum. The first maize and bean crops are grown on the wetter soils where there is residual moisture. The second crop is grown during the rain season on the high and better-drained levee soils with the sorghum and bean crops. Because of the high tsetse challenge in the woodlands and lowland forests no livestock except chickens are kept. Fishing is an important source of food.
- **The Shilluk** occupy a narrow strip along the banks of the White Nile between the Sobat-White Nile confluence northwards to Kodok. Around the villages rainfed cultivation of sorghum, maize, groundnuts, beans and tobacco occurs. The Shilluk posses far fewer cattle and depend less on cattle products than the Baggara, Dinka and Nuer Agro-pastoralists. Thus they are not obliged to migrate with the seasons. Additionally, the intermediate and "toich" grasslands are close by the villages. Fishing is an extremely important component of their economy.

Large-scale Semi-Mechanized farms

The large-scale semi-mechanized systems are identical to those in the Abbay-Blue Nile Sub-basin. They are under state lease-hold tenure (25 years leases) and a number of cultural operations (ploughing, harrowing and seeding) are mechanized. Nevertheless, the use of improved inputs (fertilizer, seed) is minimal. Sorghum is the main crop with some sesame. In the Sub-basin rainfall is relatively higher and more reliable than in the Tekeze-Atbara and the Abbay-Blue Nile Sub-basins.

There are approximately 9.1 million feddans (3.8 million ha) of land covered by large-scale semi-mechanized farms. This figure will include land that may have been abandoned as it is almost impossible to distinguish this from fallow land or land with crop residues on the surface.

Small-scale Irrigated Cropping: Highland Valley Bottoms

Traditionally these wetlands have been avoided due to the presence of diseases such as typhus fever for humans and liverfluke for cattle. Limited wetland edge cultivation of maize is known to have been practiced in the area going back to the mid 19th century (McCann, 1995) but this expanded during the 20th century (Wood and Dixon, 2001). In some areas, where upslope erosion has been particularly severe, as in the Ghimbi to Nejo area, wetlands have become the major source of food accounting for up to 70% of the grain produced by these communities. More commonly this figure is around 10 to 20%, but the timing of these harvests, as the hungry season approaches, makes the wetland food particularly valuable.

In addition, to the drainage-based cultivation of wetlands in the northern and eastern parts of the upper Baro-Akobo sub-basin, there is also long established cultivation of *taro* (*Colocasia esculenta*) in wetlands in Bench Maji Zone around Mizan Teferi, and in Sheka Zone around Tepi. Traditionally this does not usually involve any water management as this crop is tolerant of flooding. However, water management is occurring in some places farmers because farmers have realized that yields can be increased in this manner with flooded areas extended and water availability improved before and after the rains.

Small-scale Pump Schemes: White Nile

Along the banks of the White Nile are a significant number of small-scale irrigators using a variety of irrigation methods. These are estimated to cover some 494,000 feddans (207,480 ha) (Knott & Hewett, 1994). Pumped irrigation straight from the river is common. Cereals and vegetables are the main crops grown by small-scale irrigators. Maize and sorghum are produced in summer and wheat in winter. Large areas of broad beans and vegetables are also grown under irrigation during the winter

Large Irrigation Schemes: Small-scale Operations

The two major schemes are the Gezira and Managil. Here some 60 percent of the land is owned by the State and 40 per cent compulsory leased by the State from the original freeholders (World Bank, 2000, Wallach, 2004). The Sudan Gezira Board (SGB) manages all land within the Scheme and leaseholders are not allowed to sub-lease. Tenancies are for 20 feddans (8 ha) and can be inherited and sub-divided to a maximum of one half. There are 114,000 tenancies but with half tenancies this may be as high as 120,000. Most tenants use hired labour. Cropping intensity is 70 per cent with a 5 course rotation (cotton. sorghum, groundnuts, wheat and fallow. Given the very low profitability of cropping, most tenants have taken up livestock production.

Large Scheme: Large-scale Production of Sugar Cane

This is the Kenana Sugar Scheme which is part State and part commercially financed. Water is pumped from the White Nile. It has some 146,000 feddans (61.320 ha) of irrigated land (Knott & Hewett, 1994) under sugar cane. The Mill has a crushing capacity of 17,000 tons/day over a 218 day cycle.

Agro-Pastoral Systems of Production

There are a number of groups of agro-pastoralists who practice various forms of transhumant herding across the Sub-basin.

- **White Nile valley:** In the northwest and northeast in the valley of the White Nile are groups that follow a north-south movement: moving northwards in the wet season and returning to their homelands at the end of the rains. In the south across the vast clay flood plains of the Baro and Pibor Rivers groups move between their villages on slightly higher ground in the wet season and follow the retreating floods in the dry season to take advantage of the fresh pastures on the residual moisture.
- **North Kordofan area:** In the far north-west in North Kordofan are the Zagawa, Kawahia and Kababish who move north in the wet season to take advantage of the annual grasses that flourish at this time, moving back again at the end of the rains. Their herds are mixed: cattle, sheep and camels. To the south of them, east of the Nuba Mountains and west of the White Nile are the Baggara who essentially cattle herders. During the dry season they move with their herds south and east across the White Nile to the north of the Machar Marshes returning to their home areas in the dry season.
- **East of the White Nile:** East of the White Nile are two groups: the Rufa'a al-Hoi and the Fulani who herd their livestock from their base to the north of the Machar Marshes in the dry season, moving north in the wet season to the Geizira-Mangil Scheme and the large-scale semi-mechanized farms to take advantage of the new pastures and to escape the scourge of biting flies in their home area. The Rufa’a al-Hoi are an Arab speaking Muslim nomadic peoples with sheep, cattle and a few camels. The Fulani are in fact a mixture of many ethnic groups from West Africa who have the West African long horned cattle that are fast walkers but poor milkers.

- These northern groups engage in the very substantial livestock and well established marketing system of Northern Sudan. This marketing system is involved in a substantial domestic market and well as the export market to Middle Eastern countries. Their livestock are sold at the most northerly points of their herding movements when they are in prime condition.
- **Southern pastoral systems:** The southern pastoral systems are practiced by the Dinka, Nuer, Murle and Toposa. They are primarily pastoral people but also practice a form of shifting cultivation growing millet, maize and occasionally cotton. In addition, fish is an important part of their diet. Settlements are located on higher ground. They are occupied during the rains from May to November. During the rains the cattle are close to the settlement. At the cessation of the rains the cattle are moved to extensive grass plains until about January when both grass and water are finished. Then with the crops harvested all the people and livestock move to the "*toich*" (seasonally flooded) grasslands along the rivers. Here the grazing and fishing is excellent. At the beginning of the rains in May women and children move back to the villages to clear the land for cultivation, whilst the cattle slowly follow.
- These groups engage in both the northern livestock marketing system and also a southern marketing system. The southern system caters for a relatively small domestic market centred on Juba, but export markets to the south in Kenya, Uganda and the Democratic Republic of Congo. There is also a substantial local market for breeding stock catering for young returning migrants establishing their own herds.

2.6 FORESTRY AND AGRO-FORESTRY

2.6.1 Forestry Contribution to the Economy

- **In Sudan:** Approximately 8.8 million m^3 of wood fuel and charcoal (per capita consumption of 1.4 m^3) are consumed forming about 80 per cent of the total energy consumption. An unknown quantity of charcoal is exported from the central parts of the Sub-basin to Khartoum.
- **Ethiopia:** The situation in Ethiopia is not dissimilar to that in Sudan. In Ethiopia in the Baro-Akobo Sub-basin some 7.95 million m^3/yr of fuelwood and charcoal (wood equivalent) are consumed as fuel forming about 65 per cent of domestic energy consumption.

2.6.2 Agro-forestry

- **Sudan: Gum Arabic**: Woodlands provide all building materials in rural areas. They constitute 33 per cent of the livestock feed as browse. They also provide a number of non-timber forest products the most important of which is Gum Arabic. In addition to these products the woodlands give a number of services which have no direct monetary values such as environmental protection, increase in crop production, conservation of soil fertility, biodiversity, protection of cultural heritage, forming habitat for wildlife and eco-tourism attraction.

  The Gum Arabic Belt (GAB) in the Baro-Sobat-White Nile Sub-basin comprises the major part of the low rainfall woodland savannah zone extending from the border with Ethiopia to North Kordofan on clay soils east of the White Nile and sandy soils to the west. There is a distinct difference between the clay and the sand provenances of *Acacia senegal* in terms of their water-use efficiency and gum yield (Raddad & Luukkanen, 2006). The clay provenances were distinctly superior to the sand provenances in all traits studied especially in their basal diameter and crown width. The clay provenances are adapted for fast growth rates and high biomass and gum productivity. Seasonal labourers from other parts of the country migrate to the Gum Arabic Belt (GAB) seeking employment and thus its production system supports and extends livelihood strategies. Currently, Gum Arabic production is unstable due to climatic factors and marketing policies, in particular the ban on private companies exporting unprocessed Gum Arabic. The floor prices paid by the government-owned Gum Arabic Corporation as a percent of export prices (f.o.b. Port Sudan) declined from 70 per cent in 1994 to only 21 per cent 2000/2001 (World Bank (2004). In 1990-1992 the government temporarily waived controls and the per cent of export price rocketed to 160 per cent! The gum Arabic plays an important role as major source of foreign exchange, accounting for 13.6 per cent of the annual export income excluding petroleum.

- **Ethiopia:** Agro-forestry takes the form of coffee growing under shade. Some on-farm Eucalyptus planting is taking place in the Kaficho-Shakiso Zone where the forest has largely been cleared. In other Highland areas considerable numbers of indigenous trees remain in and around cropland.Browse is of little importance in the Ethiopian Highland livestock systems. The official figures for timber production do not include timber and poles produced and used outside the official marketing structures, in particular, for domestic use in rural areas.

2.6.3 FISHERY

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

Upper basin (>800 masl)

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

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

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

Lower Baro Akobo Basin (<800masl)

- **Fish Species**: Studies carried out on Species by the Russian academy of Science as part of the overall Russian study (Selkhozpromexport, 1980) found 72 fish species in the lower basin. Nile perch (Lates niloticus) Nile tilapia (Oreochromis niloticus), Catsish (Clarias sp), Bargrus, barbus and Labeo species were important both in ecological and commercial terms.
- **Fishing**: Fishing in the region is mainly on a subsistence basis, both in the main river channels and many of the floodplain lakes. Virtually, every family that lives near water fishes to supplement its diet. Active fishing is carried out by men using spears, or modifications thereof, cones, various hook and line devices, traps made of reed, etc. In addition to subsistence fishermen, there are three fishing co-operatives at Pinudo (at Tata), Pinkew and Itang which were established by Lutheran World Federation and fish is bought from the co-operatives at 1.5 birr/Kg at Pinudo, 1.25 Birr/Kg at Pinkew and 1 Birr/Kg at Itang. Fishing is highly seasonal in the lower Baro-Akobo basin. Flooding between June and October prevents most fishermen from operating and thus the main fishing season is restricted to the drier periods between October and April. No direct estimates of present fishing efforts and production are available because catch and effort data are not collected.

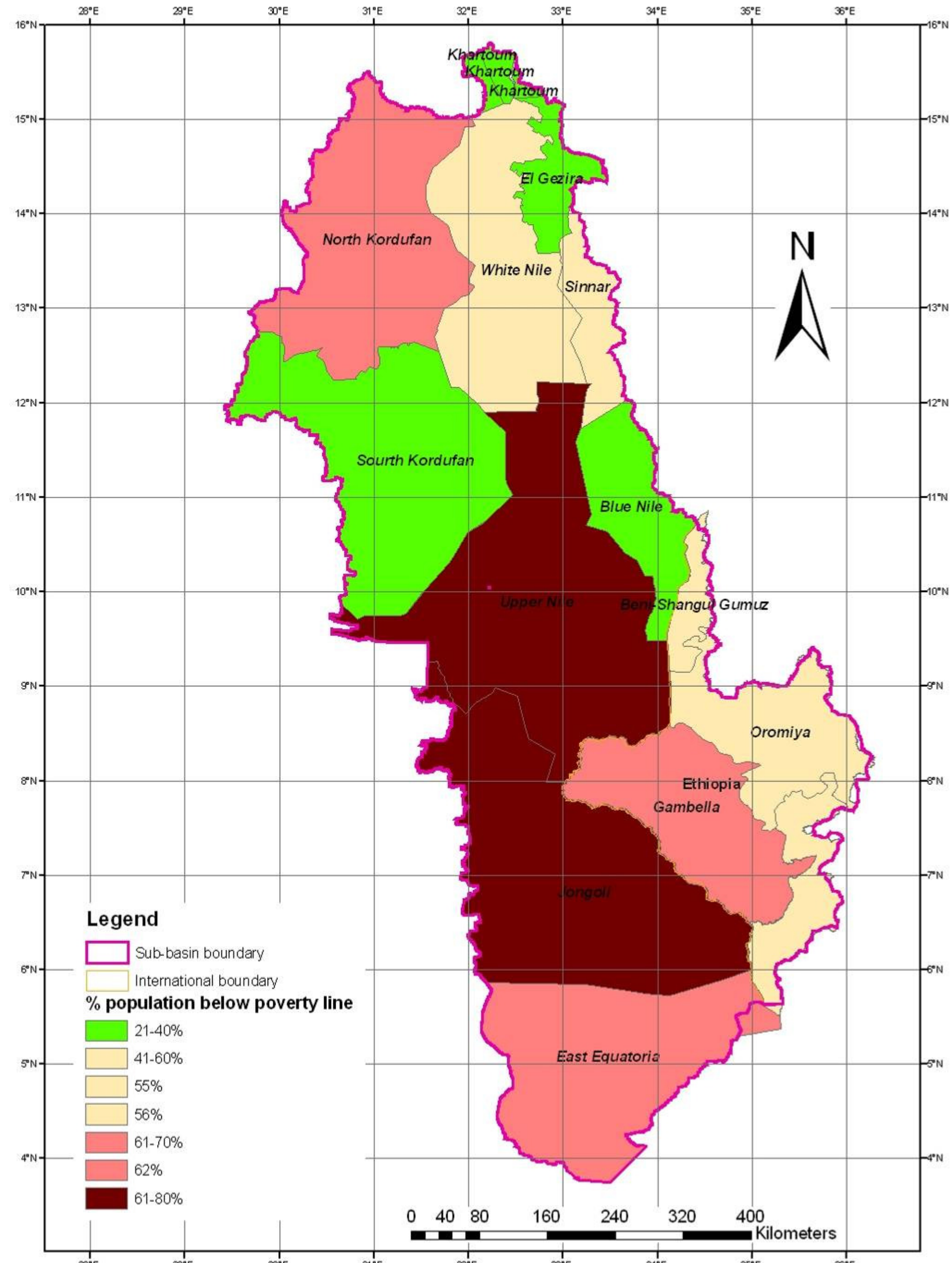
2.7 POVERTY PROFILE

2.7.1 Poverty measurements

Sub-basin: In the sub basin the scale of poverty ranges from 70% to 20% (Figure 2.3). The JAM (2005) defined the poverty rate in Sudan as the proportion below 40 per cent of an economic status index based on asset ownership. Unfortunately the index is not defined. The poverty line in Ethiopia is set using a basket of food items sufficient to provide 2,200 kcals per adult per day which, together with a non-food component, represents Ebirr 1,070 in 1995/96 prices. Clearly, the two measures used in Sudan and Egypt are not directly comparable. The published poverty rates in Ethiopia are lower than those in the Sudan. This has been noted in the Sudan Joint Assessment Mission (JAM) Report. It appears that the difference is likely to be more a question of difference in methodologies and definitions, than actual differences in poverty rates.

Poverty estimates in Sudan: High poverty rates are most prevalent in Southern Sudan and North Kordufan State. In the North Kordufan state it ranges from 61% to 70%. In the Khartoum state economic growth is observed to be better with an average poverty scale ranging from 21% to 40%.

Figure 2.3: Distribution of per cent of population below the official poverty line



Sources**:** Sudan (JAM, 2005), Ethiopia (FDRE-MOFED, 2002)**.**

Note**:** Sudan is total population while only rural for Ethiopia

Poverty estimates in Ethiopia: In Ethiopia, poverty ranges from 55 per cent in SNNP Region and Oromiya to 62 per cent in Gambela.

Trends in poverty in Ethiopia: In Ethiopia a comprehensive review of poverty was undertaken (FDRE-MOFED, 2002) as an input to the Country's Sustainable Development and Poverty Reduction Programme (SDPRP). Between 1995/96 and 1999/2000 in Ethiopia rural poverty rates declined by 4.2 per cent, although it increased in urban areas (by 11.1 per cent). In all Regional States, except Oromiya, rural rates had increased since 1995 as had all urban rates.

Trends in poverty in Sudan: The extent and dynamics of poverty in the Sudan since the 1990's has been examined by the Joint Assessment Mission (JAM, 2005). Despite the sustained growth since 1997 many experts believe that poverty has remained widespread and has actually increased. The gap between the "haves" and the "have nots" has increased. Thus whilst the traditional agricultural sector has shown a rebound in the past decade this is only to levels that prevailed before the massive droughts of the early 1980's.

2.7.2 Welfare and Poverty

Studies undertaken in the western part of the basin have shown that there is a wide spread poverty and vulnerability situation. For example, the Gumuz, one of the groups inhabiting the basin, are very poor, living a “hand to mouth” existence, and are “below the threshold” of peasants’ subsistence economy (Fekadu, 1988). In describing this widespread nature of poverty distribution, Dessalegn (1988) used an expression that “If there is equality in Begga [Gumuz] society, it is equality in destitution. The poverty situation may be worse among agro-pastoral communities of the basin whose livelihood depends on raising cattle and small-scale farming. Overall, the basin is one of the regions that suffers from paucity of socio-economic data on the welfare and poverty of the local population. This calls for a need to undertake basin-level socio-economic inventory focusing on the living condition of the basin population.

2.7.3 Food Aid as a Proxy Indicator of Poverty

One indicator of the poverty situation of the basin population is the level of food aid dependency in the region. According to the 2004 Welfare Monitoring survey, 22.8%, 36.3% and 26.9% of households respectively in the Benishangul-Gumuz, Oromiya and SNNP regions were suffering from food shortage over the last 12 months prior to the survey date. Unpublished data from DPPC (2000) also showed that 12.6% of rural population from Oromia, 29.9% from Gamblella, 14.0% from SNNP and 2.1% from Benishangul+ Gumuz regions were reported to require food aid.

3. NATURAL RESOURCES AND ENVIRONMENTAL ISSUES

GEOLOGY

The Baro-Akobo watersheds consist primarily of a high mountainous zone (2400 masl to 3000 masl) of tertiary basalt caped in places with quaternary volcanic rocks, in the general eastern uplands, the high plateaus sectors (1300 to 2400 masl) covered with basalts and granites, the strip of lowlands (800 masl to 1400 masl) staffed with crystalline basement complex rocks and the low-lying are (largely less than 500masl) formed and underlain by unconsolidated and undifferentiated Plio-Quaternary material (such as the Gambella alluvium) that grades westwards at less than 500 masl (WSM CRA, sub-basin report, 2007).

The surface and near surface geology of the high mountains zone (2,400 to 3,300 masl) is formed by weathered Tertiary basalts capped in places by resistant Quaternary volcanic rocks. West of the high mountainous area lies a high plateau ranging from about 1,300 to 2,400 masl, which is underlain by basalts and granites. Next in westward succession are the crystalline basement complex rocks that form the Masongo Ranges and vary in elevation from about 800 to 1,400 masl. The western-most geomorphic zone in the basin is occupied by the gradually westward slopping surface of the Gambela Plain. This plain is formed and underlain by unconsolidated and undifferentiated Plio-Quaternary sediments that grade westward from about 495 masl at Gambela to 400 masl at the Ethiopia – Sudan border (WSM CRA, sub-basin report, 2007).

Granites and gneisses of the basement Complex outcrop in the mountains and hills of the southern part of the Pibor-Sobat basin. North of these stretching all the way the Blue and White Nile junction are deep deposits of Quaternary and late tertiary Unconsolidated Sediments. To the west of the White Nile Basement Complex gneisses outcrop in the Nuba Mountains (WSM CRA, sub-basin report, 2007).

SOILS

Nearly 60% of the sub basin is covered with black colored vertisols. The low-lying area of Gambella, the entire watershed of the Sobat river and majority of the White Nile watershed downstream of Malakal are almost covered with black cracking vertisols, which poses considerable challenges in agricultural operations. Arenosols covers 10% of the sub basin. Nitosols, Luvosols, fluvisols etc with few proportions for each soil unit, covers the remaining part of the sub basin.

The predominant soils in the highlands are the Nitisols, which usually are deep with smaller areas of Leptosols (Table 3). Unconsolidated Sediments that cover all of the Lowlands in Ethiopia and Sudan are overlain by very extensive areas of Vertisols – deep black cracking clays (56 per cent of the area). Arenosols derived from wind blown sands are extensive in the north-western part of the sub-basin (10 per cent of the area). Locally Fluvisols occur on coarser textured recent alluvial sediments. A range of soil types occur over the southern Mountains and hills, including Lixisols, Nitisols and Leptosols. On their footslopes and across to the Boma Plateau in the south-east are Cambisols and Solonetz soils.

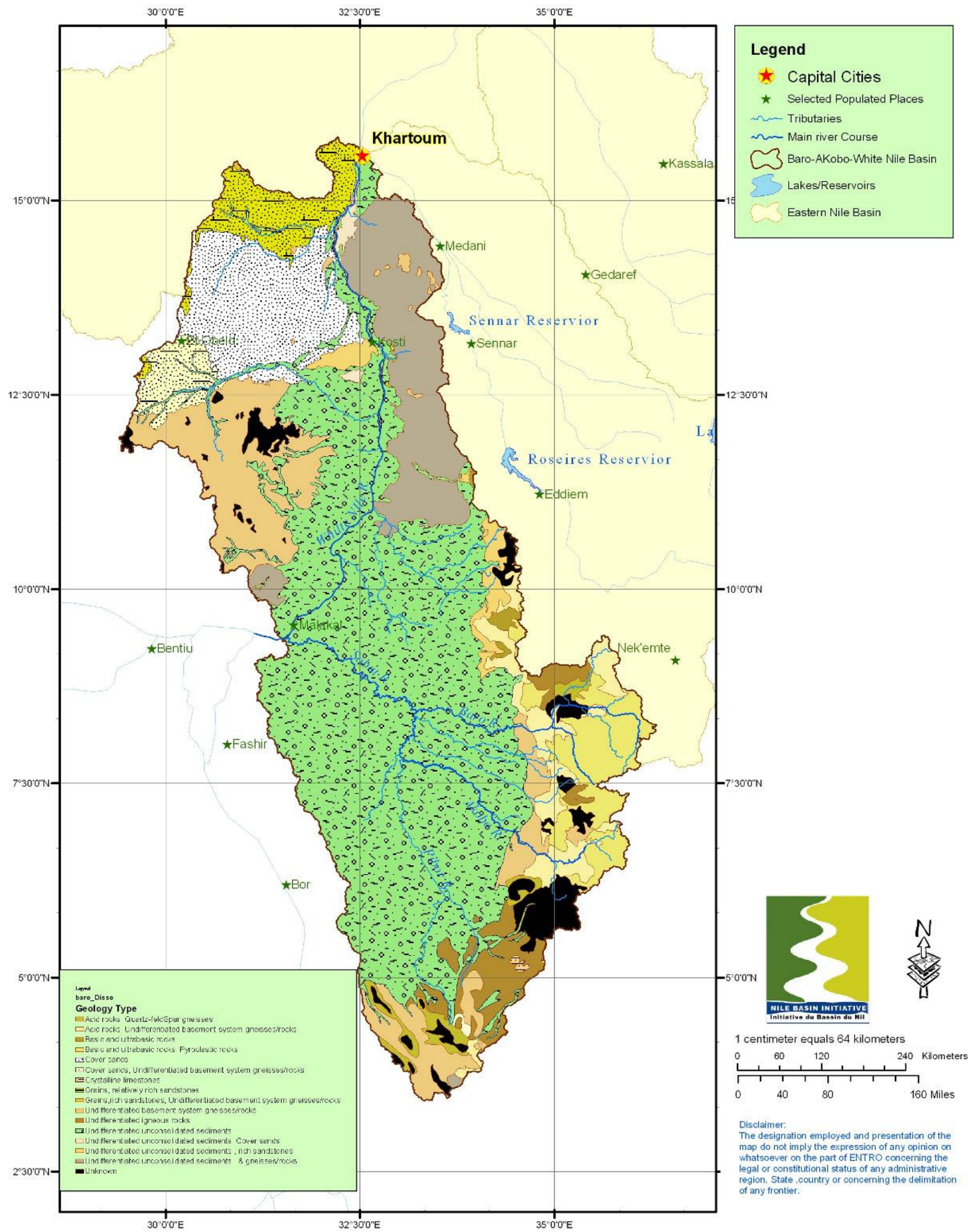
Deeper Luvisols and shallower Leptosols occur in the Nuba Mountains. Very coarse textured Arenosols overlay the Cover Sands that merge into Phaeozems and Leptosols over the Nubia Sandstones.

Table 3.1: Baro-Akobo-White Nile Sub-basin: Dominant Soil Types

Soil Type	Area (km^2)	% Area
Vertisols	262,785	56.1%
Arenosols	48,779	10.4%
Nitisols	41,657	8.9%
Luvisols	30,397	6.5%
Fluvisols	23,381	5.0%
Leptosols	20,554	4.4%
Cambisols	10,541	2.3%
Alisols	10,048	2.1%
Solonetz	9,757	2.1%
Lixisols	7,190	1.5%
Water	1,252	0.3%
Solonchaks	1,056	0.2%
Calcisols	710	0.2%
Phaeozems	109	0.0%
Total Area	**468,216**	**100%**

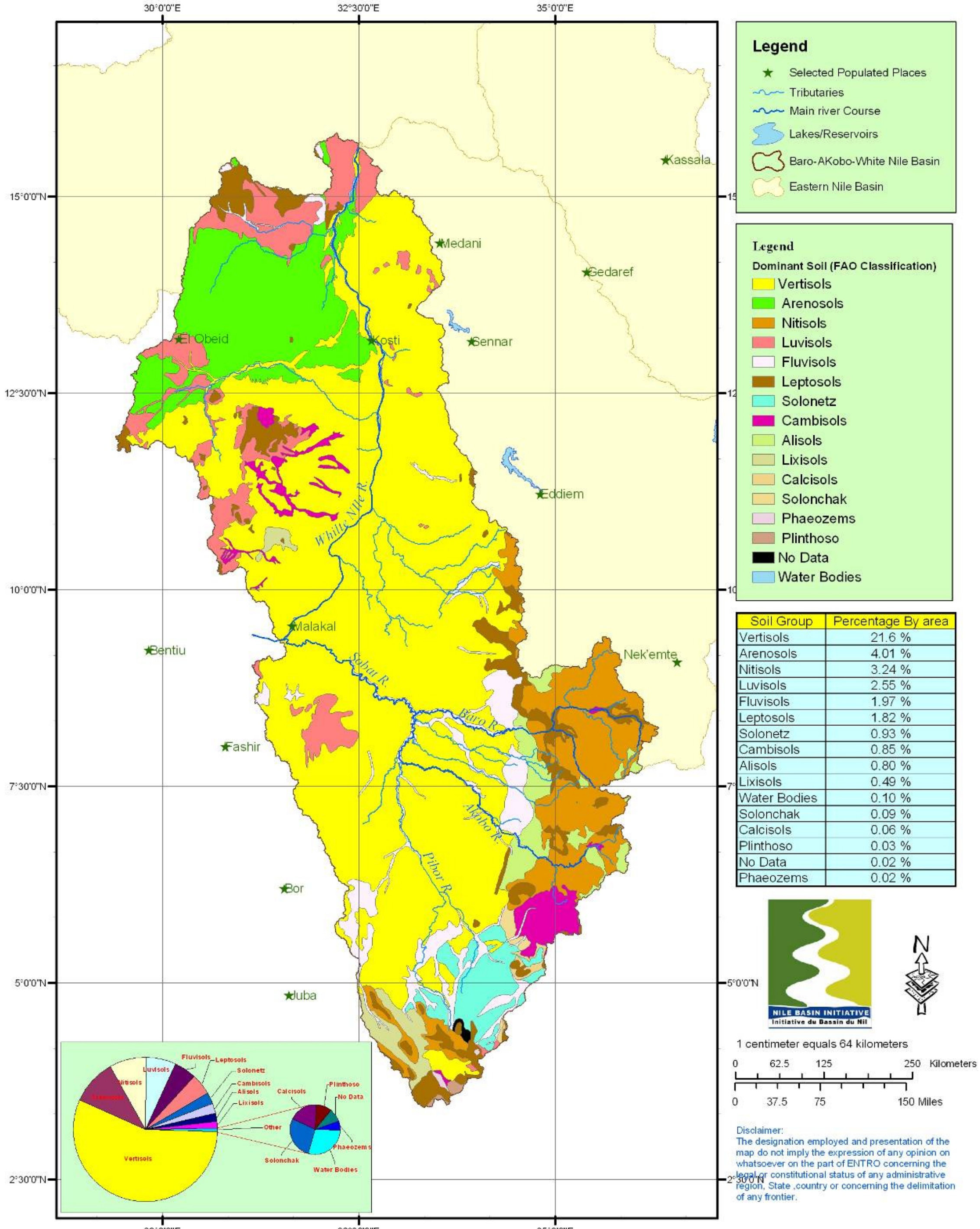
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

Figure 3.1: BASWM sub-basin: Geology



Source: FAO Classification

Figure 3.2: BASWM sub-basin: Dominant Soil Types



Source: FAO Classification

LAND USE LAND COVER

The dominant land cover is given in Table 3.2 and mapped in Figure 3.3.

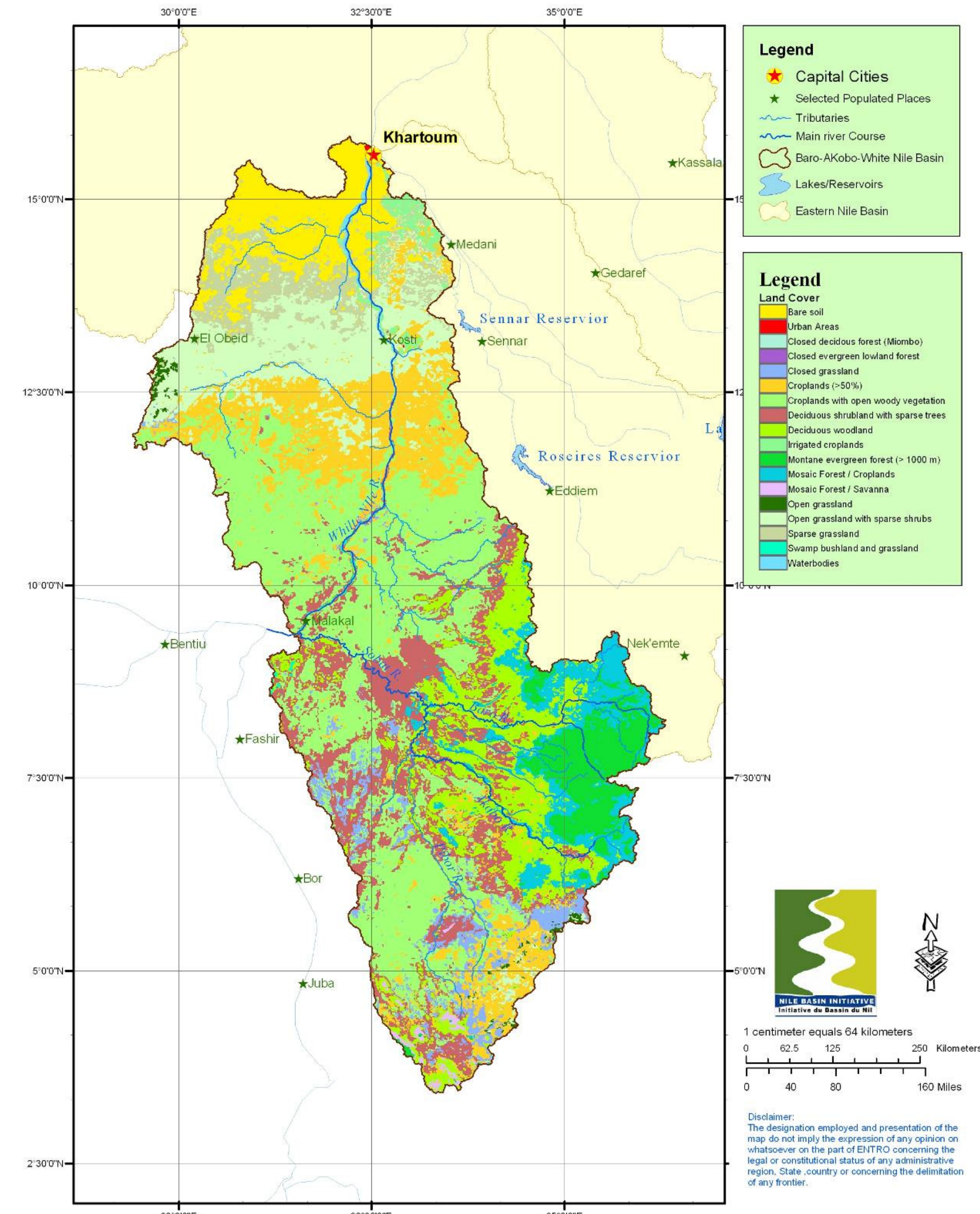
Table 3.2: Tekeze-Atbara Sub-basin: Dominant Land Cover

Landcover Type	Area (ha)	% Total
Grassland	136,075	29.1%
Open shrubland	108,993	23.3%
Open woodland	81,486	17.4%
Semi-mechanized Farms	38,187	8.2%
Seasonal swamp	28,974	6.2%
Rainfed crops: Sedentary	16,851	3.6%
Montane forest	14,412	3.1%
Bare land: Sand	14,131	3.0%
Irrigated crops	8,613	1.8%
Dense woodland	6,680	1.4%
Permanent swamp	5,032	1.1%
Lowland Forest	3,581	0.8%
Rainfed crops: Shifting	2,400	0.5%
Water	905	0.2%
Dense shrubland	865	0.2%
Urban	641	0.1%
Bare land: Rock	338	0.1%
Plantation	51	0.0%
Total	**468,216**	**100%**

Sub-basin: The land cover is dominated by grassland and open woodland and shrubland. Grassland, open shrub lands and open wood land with coverage of 30%, 23% and 17% respectively are the dominant land cover units in the sub basin (Table 4). The grass land predominantly covers the low-lying area of the sub basin. In the low-lying area of the Gambella seasonally flooded area and around the border a savannah of considerably large in size, which is perhaps believed to be the largest food chain in Ethiopia, is available. In this area the grass land and the open wood land units are intermingled together forming the savannah land in the system. Semi-mechanized farms cover some 38,187 km^2 and are fourth in terms of area coverage. The land use land cover map as prepared from Afri-cover indicates that cultivated land in the sub basin covers only 14%, indicating its high potential for future agricultural development works. Seasonal swamp area covers some 6.2% of the sub basin indicating the environmental importance of the extensive flooded lowland areas below 500 masl. Montane and Lowland High Forests cover 4 per cent of the sub-basin located almost entirely in the Baro-Akobo catchment. Wetlands cover over 7 per cent of the sub-basin, with the Machar wetland, as a permanent wetland, covering about 1% of the sub basin.

Ethiopia: The land cover in the Baro-Akobo area is shown in Table 3.3 below.

Figure 3.3: Tekeze-Atbara Sub-basin: Dominant Land Cover



Source: FAO Classification

Table 3.3: Distribution of land cover units of Baro-Akobo area

DADB	Legend	Hectares	%
BO	Open Woodland	110,981.94	1.46
C1	Cultivated Area (>60%)	139,5908.42	18.32
C2/FB3	Cultivated Area (<60%)	141,391.26	1.86
C2/GO	Cultivated Area (<60%)	154,93.95	0.20
C6	Perennial Crop	13,899.44	0.18
C6/FB3	Perennial Crop	25,713.33	0.34
C6/FP1	Perennial Crop	2,773.07	0.04
FB2	Disturbed Forest	336,292.17	4.41
FB3	Very Disturbed Forest	1,085,451.01	14.24
FB3/C6	Perennial Crop	136,488.10	1.79
FB3/GO	Very Disturbed Forest	10,501.11	0.14
FO/WO	Open Woodland	19,716.41	0.26
FR2	Disturbed Forest	90,875.98	1.19
SF	Perennial Crop	1861.92	0.02
WD	Dense Woodland	628,296.46	8.24
WD/WO	Dense Woodland	118,404.50	1.55
WO	Open Woodland	3,169,661.54	41.59
WO/GO	Open Woodland	256,885.08	3.37
WO/WD	Open Woodland	60,638.73	0.80
Total		7,621,234.432	100.00

Source: Ministry of Water Resources, Ethiopia

VEGETATION

Vegetative Types

The major vegetations in the sub basin are the forest type vegetations (which includes seven types of forest units (Aninegeria forest, Olea forest, Evergreen forest, Lowland Baphia forest, Tropical rain forest, Podocarpus forest & Riparian forests, *Afro-Alpine and Sub-Alpine Forests* the Highland and lowland bamboos, woodland type vegetations, seasonally river and rain flooded grass lands, the swamp vegetations and cultivated lands.

Sources of information

Information on the vegetation of the BASWM sub-basin can be obtained from a number of sources.

- **For Sudan** these include the Jonglei Investigation Team's study (JIT, 1954), that of the Southern Development Investigation Team (SDIT, 1955), Mann (1977), Obeid Mubarak et al., (1982), Mefit-Babtie (1983), Howell et al., (1988), Howell and Lock (1993), FAO (2005), and Bussmann (2006).
- **For Ethiopia** sources included Chaffey (1979), Friis (1993), WBISPP-MARD (2002), Wood and Abbott (2001) and EWLNRS-Bird Life International (1996).

Forest Types

- ***Aningeria Forests***: These forests lie between 1600 and 2000 m in the Ethiopian Highlands where the annual rainfall is about 1600-2400 mm. The species composition of this type is high due to its wide range of suitable climate conditions. Important species include Syzygium guineense, Ficus spp, Olea welwitschll, Prunus africana, Albizzia gummifera, Polyscias fulva, Morus mesozygia, Ekbergia capensis, Celtus gomphophylla, Cordia Africana, and Croton machrostachyus.

- ***Olea Forests***: These forests lie between 1,500 and 2,000 masl in both the Ethiopian Highlands and in the Imatong Mountains. Their preference for gentle slopes exposes them to disturbance and exploitation. They comprise a wide range of commercially desirable species: Olea welwitschii, Bosqueie phoberos, Apodytes dimidiate, Polysicias ferruginea, Olea hochstetteri, Cordia abysinnica and Syzygium guineense.
- ***Evergreen Forests***: These forests occur throughout the highland plateau. Remnants of the forests which once clothed Ethiopia's uplands, they are now made up of islands of trees whose under-storey has been removed to provide space for coffee; there is no forest regeneration. Nonetheless, the trees continue to provide a low intensity of habitat for birds and other life as well as some slight hydrological benefit.
- ***Lowland Baphia Forests***: Baphia forests often merge with riparian forest. It is an open Lowland forest type with associations with the Sudano-Guinea rainforest realm. It is found in the Gambela Lowlands. It contains such species as Zizyphus pubescens, Diospyrus mesipiliforms, Alstonia boonei, Celtis integrifolia, and Chlorophora excelsa. Woodland species, Albizzia schimeriana, Croton macrostachyus, and Combretum molle, also occur. Baphia forests are under threat from burning and fuel wood collection.
- ***Tropical rain forest***: This is confined to a few small and scattered localities in the south-western part of the Pibor Catchment. The Talanga, Lotti and Laboni forests are found at the base of the Imatong Mountains. In these forests, four stories can be distinguished in the vegetation: the canopy trees, which are 30–50 meters high with long, straight trunks, often buttressed at the base; the second-storey trees, from 15 to 30 meters high, usually not so straight, more copiously branched and with less tendency to form buttresses; the shrub layer, 4–6 meters high, often very dense, with numerous creepers and lianas, and the ground layer of herbs and grasses, usually sparse and often absent. The species occurring in rain forest are similar to those of the drier parts of the forests of West Africa. The most common species are Chrysophyllum albidum and Celtis zenkeri, with Holoptelea grandis in Azza forest. A number of valuable timber trees are found, including Khaya grandifoliola, Chlorophora excelsa, Entrandrophragma angolense and others.
- ***Podopcarpus Forest of the Imatong Mountains***: Between 1,500 and 2,600 masl, the climax vegetation is closed evergreen forest with Podocarpus milanjianus, Olea hochstetteri and Syzygium spp. dominant over a shrubby understorey. Regret of Acacia xiphocarpa occupies large areas of old cultivation sites. Between 2,600 and 3,000 masl Podocarpus milanjianus again forms the climax vegetation, but is less mixed with other species, apart from a little Olea hochstetteri. This zone includes large areas of mountain meadow dominated by the sedge Bulbostyles atrosanguineus. The bamboo Arundinaria alpina is also found. Much of the ground is wet or swampy because of the combination of high rainfall and low potential evapo-transpiration. Above 3,000 masl, ferns, Erica arborea and Myrica salicifolia are dominant and many species of herbs occur.
- *Riparian Forests*: Riparian forests extend throughout the plateau drainage pattern, dropping down to the flood plains. Like woodlands of the savannah and upland basin, riparian forests are under enormous pressure from local and refugee populations. Important species include Celtis kraussiana, Ficus sycamorus, Mimusops aethiopum, Tamarindus indica, Maytenus senegalensis, Kigelia aethiopum, Syzgium guinenses and Acacia spp.
- **The Afro-Alpine and Sub-Alpine Forests**: The Afro-Alpine and Sub-Alpine Forests lie above 3200 m where they comprise small trees, herbs, and suffrutecents. Little human activity occurs in the zone other than grazing and barley cultivation. Coniferous forest,

lying between 1800 and 2500m occur principally on steep lands, where gravity dispersion of seeds assists their regeneration (OSI Environment Summary Report, p. 3).

Bamboos

- ***Highland bamboo thicket (Arundaria alpine)*:** This occurs on gentle slopes above 2,400 masl in the high rainfall areas of both the Ethiopian Highlands and the Imatong Mountains. It is generally in pure stands or occasionally interspersed with trees.
- ***Lowland bamboo*** (Oxytenanthera abyssinicus): Within the Baro-Akobo catchment 127,400 ha of lowland bamboo are found in Assossa Zone of BS-G Region and extends into Sudan. It occurs in two main forms: in pure continuous stands with few or no trees or shrubs, and as clumps scattered with woodland and shrubland. In the dense pure stand bamboo area of Ambessa Chaka Forest, LusoConsult estimated an average of 8,124 live culms per hectare, weighing 19.53 tons per hectare. The density of culms in open "clumped bamboo/woodland-shrubland" is probably about 20 per cent of that in the dense pure stands.

Woodlands

- ***Mixed Deciduous Woodlands*:** These woodlands extend along the south-western and north-western edges of the plateau at about 1200 m altitude. Their species include Albizzia schimperiana, Croton macrostachyus, Euphorbia abyssinica, E. candelabrum, Grewia bicolour, Bersama abyssinica, and Acacia spp, among others.
- ***Acacia Seyal-Balanites Savanna*:** Above 570 mm to about 1,500 masl there is increasing dominance by A. seyal in association with Balanites aegyptiaca. A. senegal is retained for gum arabic harvesting whilst A. seyal is used for charcoal production. B. aegyptiaca is becoming increasing prevalent because it is fire resistant, does not produce good charcoal and is hard to cut.
- ***Acacia Thornland alternating with Grassland on Clays*:** Between the 360 mm and 570 mm isohyets on the heavy clays on either side of the White Nile grassland merges into A. mellifera thornland. Other tree species include A. nubica, C. decidua, Cadaba glandulosa, C. rotundifolia and Boscia senegalensis. The last three species often persist after A. mellifera has been cleared. Much of this vegetation has being cleared for small-scale sedentary and large-scale semi mechanised agriculture. Grass species include Cymbopogan nervantus, Sorghum purpereo-sericeum, Hypparhenia ruffa, Tetropogan cenchriformis and Cenchrus cilliaris. Sufficient grass dry matter is produced to provide material for annual burning.
- ***Acacia senegal Savanna and Combretum cordofanum Savanna on Sands*:** Between the 360 mm and 570 mm isohyets on the western side of the White Nile on the sandy Arenosols of the cover sands and stabilized sand dunes there occurs Acacia senegal Savanna. The former is most extension and tree species include Acacia senegal, A. tortilis and Indigofera oblongifolia. This area comprises the sandy Gum Arabic belt. The grass cover is represented by the genera Cenchris and Aristida. Occasionally the valuable the perennial grass Andropogun gayanus is found. The grasses tend to occur in pure stands of Hyparrhenia anthistirriodes or Cymbopogon nervatus with Sorghum spp. in the higher rainfall areas. These grasses become largely unpalatable to livestock during the dry season. There is abundant material for annual fires.
- ***Seasonally River-flooded Grasslands*:** These grasslands are flooded annually to varying depths and periods and form the toich, which yields dry season grazing essential to the Nuer and Dinka agro-pastoralists. Two main types can be distinguished: (a) Oryza longistaminata dominant, and (b) Echinochloa pyramidalis dominant (Howell, 1988).

- ***Oryza longistaminata Dominant Grassland***: The dominant species constitutes 80-90 per cent of the standing crop. Oryza does not flower or reach maximum production unless it has been deeply flooded for several months. It yield 1t/ha when not flooded to 7 tons/ha when deeply flooded for a long period. These grasslands are burnt each year early in the dry season. Although a perennial it can produce abundant seed. They provide high quality grazing for much of the year even into the dry season.
- ***Echinochloa pyramidalis Dominant Grassland***: These grasslands are further away from the river and thus flooded less frequently (although a tall variant grows close to the river). It occupies Vertisols with much gilgai micro-relief. The species produces growth even during the dry season and is thus a year-round pasture. Associated species include O. longistaminata, Sporobulus pyramidalis, Digitaria debilis and Echinochloa haploclada.

Grasslands

- ***Echinochloa haploclada Grassland***: Between the river-flooded and the rain-flooded grasslands there is often a strip of land with light textured soils and slightly elevated, which is used for settlement and cultivation. As livestock are concentrated here for long periods this grassland is heavily grazed. Nutritionally the grassland is of very high quality during the wet season but quality falls off during the dry season.
- ***Sprobolus pyramidalis Grassland***: This tussock-forming species is not widespread. It is characteristic of heavily grazed areas. It makes no growth during the dry season, is low in protein and during the dry season nutrient levels fall below those needed for maintenance. It is used to make string used in house construction.
- ***Hyperrhenia Rufa Grassland***: These grasslands occupy level ground out of reach of river-flooding but are inundated by rain for varying periods. In some northern areas Hyperrhenia may be replaced by Setaria incrassata. Although biomass attains 6-7 tons/ha at the end of the wet season, 90 per cent of this is stem and contains little of value to livestock. A high proportion of these grasslands are burnt each year. They are generally used at the beginning of the wet season and at the beginning of the dry season after burning. The grass provides a major source of thatching material.

Swamp vegetation

- ***Cyperus Papyrus Swamps***: These swamps form a fringe along water courses, pools and other water with deep and constant depth. The plants form a floating mat upon which other species – mainly climbers are found.
- ***Typha Domingensis Swamps***: These are most extensive away from the river channels. The vegetation is not floating but rooted into the substrate covered by very shallow water. There are few other plant species. This is probably the extensive swamp type in the Machar Marshes
- ***Vossia Cuspidata Swamps***: This vegetation is found next to flowing water. It has creeping, submerged or floating stolons. It is often associated with water hyacinth.

WETLANDS

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

According to the report on the 43 surveyed wetlands of Ethiopia six are located in the sub-basin, and are described in Table 3.4 below.

Table 3.4: Profiles of Wetlands in Baro-Akobo Basin

Name	Size (ha)	Type	Physical features	Uses	Threats	Ownership	Management Measures
Alwero Reservoir	2,210	Man Made	No rainfall and temperature data No Limnology Data	Water Supply Fishing Grazing Forest area	Deforestation Malaria and Fascioliasis are Common	State-Owned	No known conservation measures but found in good status
GININA	Not delineated	Seasonal Flood Plain	Belongs to the wet Kolla agro-ecological Zones near Gambela Town	Dry season Grazing Fire- wood collection Settlement	Mimosa Pigra, an invasive plant becoming a problem by preventing fishing, grazing and farming	State-Owned	No known conservation measures
Tata /Thata	185	Fresh water Lake	No temperature and rainfall data	Fishing Water supply Grazing Canoe transport Farming	Current Water hyacinth Siltation Potential Introduction of Alien species Malaria and Fascioliasis	Annuak People	Traditional management but facing pressure of refugees
Cheffie Gebo	Not delineated	Wooded Wetland	No Limnology Data No rainfall and temperature data	Forestry Pasture Religious functions Water supply Farming	Current Farming, Overgrazing and Siltation Potential Introduction of Alien species, expansion of drainage farming	Private Farmers Mechara and Sigsega Farmer Associations	Management measures to protect trees
Abol	Not delineated	Seasonal Flood Plain	No Limnology Data No rainfall and temperature data	Fishing (seasonal) Grazing	Current No threat Potential Introduction of Alien species Malaria and Fascioliasis and tse-tee flies	Farmers of Abol Kebele farmers	No management measures The site is naturally conserved

Source: Environmental Protection Authority, Government of Ethiopia

WILD LIFE

The Gambella national Park in the upper course of the Baro-Akobo-Sobat-WN sub basin has apparently received legal protection since 1974 and the region was at one time considered as one of the most important wildlife areas in Ethiopia. Its present status hardly warrants designations as protected area of any kind. Large area of the original park has been cleared and is being used for cultivation and/or grazing.

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

This portion of the sub basin was once identified as the place for abundant wildlife: At least 27 species of large mammals were recorded 25 years ago. Wildlife in the forests includes Colobus and Vervet Monkeys, Tree Squirrel, Lion, leopard, antelopes, buffalo, Elephant, Porcupine, Aardvark, Wart Hog and Forest Pig. Atwell (1996), has indicated that the basin has undergone severe hunting, civil unrest, and depletion of habitat in recent years that resulted in the reduction of its significant mammal population. Important change to the habitat have occurred, most notably the occupation of large part of Gambella National Park by a state farm and Abobo Dam, part of whose upper reservoir also extends in to the Abobo Gog protected area.

Most famously the wetlands-flooded grasslands are home to the White-eared Kob (*Kobus kob subspp. leucotis*) and to the Nile Lechwe (*Kobus megaceros*). The white eared kob undertake a massive migration of some 1,500 kms. Both listed by IUCN as threatened species. In addition the area is an important habitat for 100 mammal species and 400 avifaunal species.

LIVESTOCK

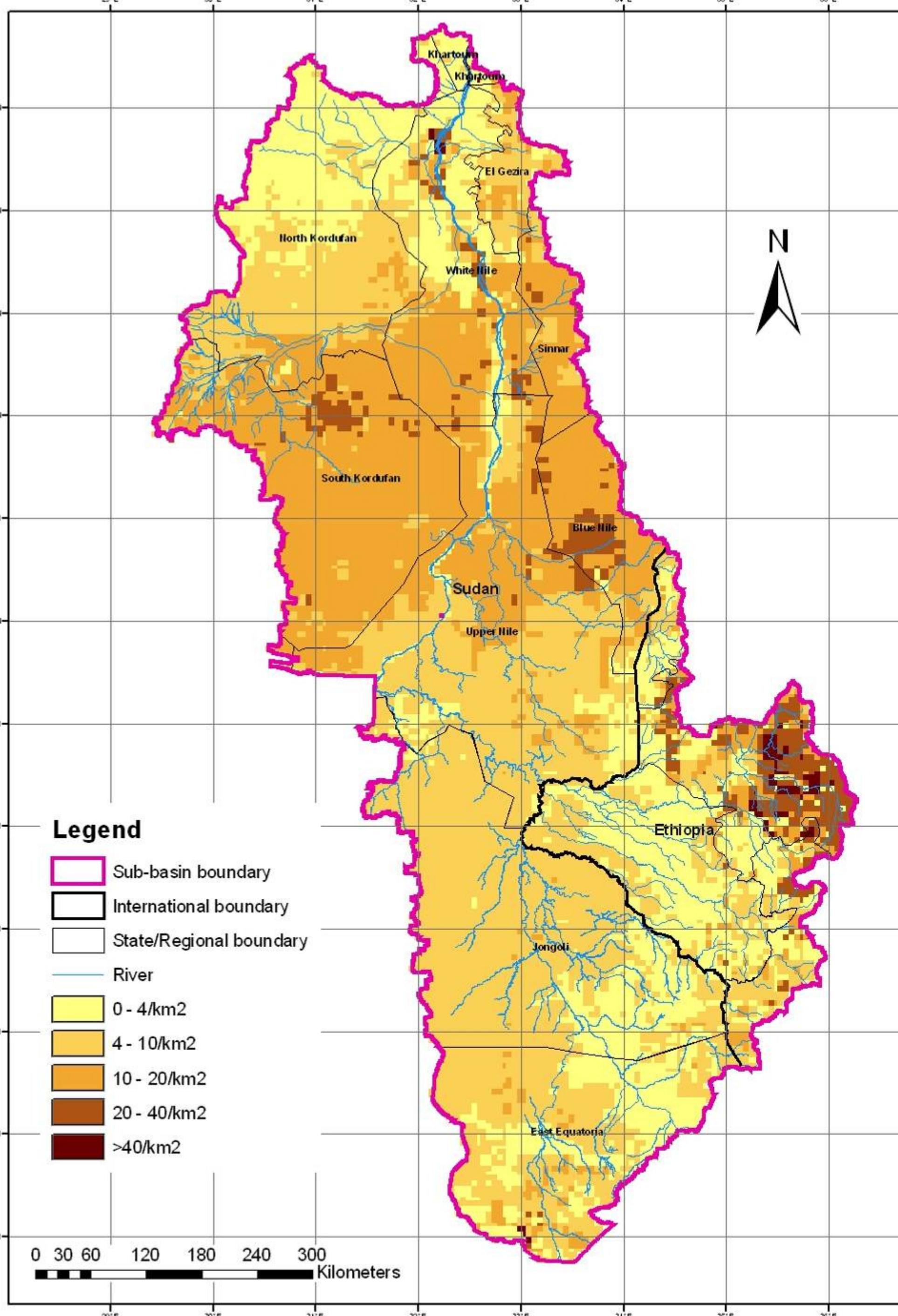
The Baro-Akobo basin contains about 1.2 million cattle, 0.4 million Sheep, 0.24 million goats, 0.09 million equines and 1.1 million chickens. Cattle are of primary importance, representing about 90% of the total livestock unit. They are used for draught, milk, capital reserve, and source of cash. Furthermore, they are used for cultural purposes such as status and serve as bride price during marriages.

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

Data from the FAO Livestock Atlas for Africa are used to derived Map 17 and 18 to show the distribution of cattle, sheep and goats. Cattle densities are high in the Ethiopian Highlands, the Nuba Mountains and in the area just to the north of the Machar marshes. There moderately high in the central area across the White Nile catchment, the area occupied by the groups that are engaged in the south-north grazing movements. The southern areas have relatively low densities, in particular the area of intermittent drainage across the Pibor catchment.

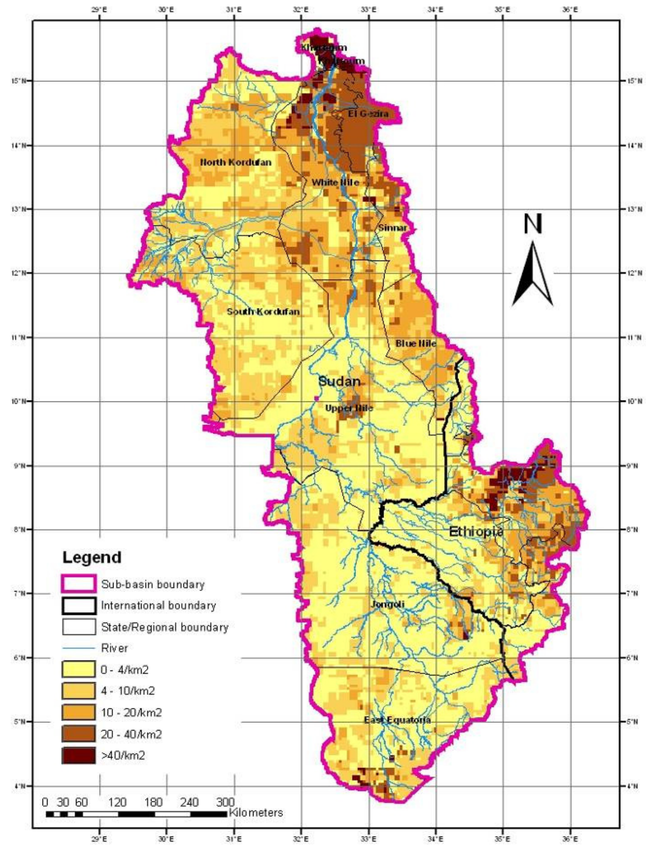
Overall densities of sheep are nearly everywhere higher than goats. Highest sheep densities are located in the Ethiopian Highlands, the Nuba Mountains and in and around the Gezira-Managil Irrigation Scheme. Moderate densities are found across the central part of the White Nile Valley. Goat densities are lowest over the Ethiopian Highlands and in North Kordofan with only moderate densities elsewhere.

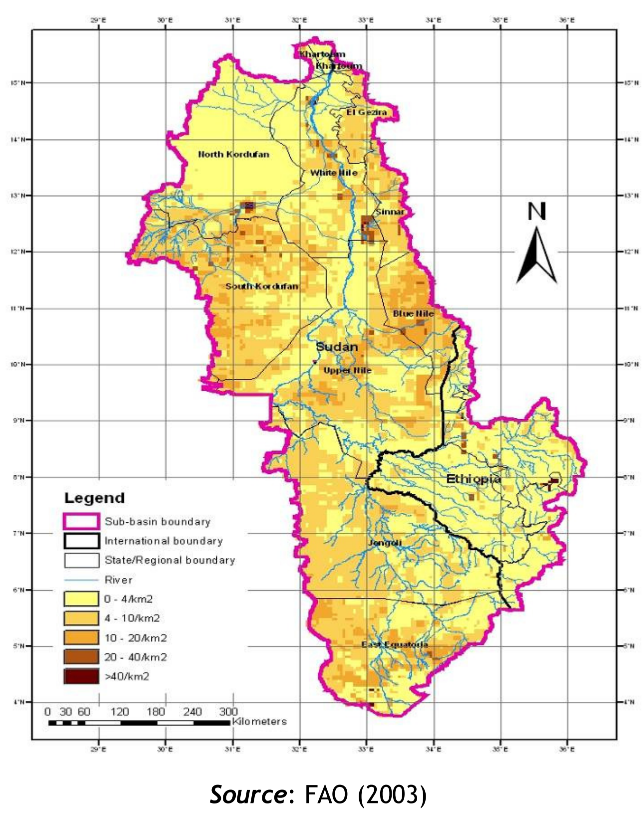
Figure 3.4: BASWM sub-basin: Cattle densities



Source: FAO (2003)

Figure 3.5: BASWM sub-basin: Sheep(top) and Goat(bottom) densities





Source: FAO (2003)

BIODIVERSITY

The sub-basin has an extremely wide range of species and habitat biodiversity. In terms of habitat two of the most important of the Lowland-Highland High Forests of the Ethiopian Highland and the Imatong Mountains, and the wetland-flooded grassland mosaic of the Ethiopian and Sudan Lowlands.

Ethiopia

The transect from the Gambela plains to the highest parts of the sub-basin contains in nearly one continuous a wide range of forest subtypes from the Guinea-Congolian forest through transitional sub-types to a numbers of the Afro-Montane sub-types identified by Friis (1992). The high forests are covered by 15 Regional Forest priority Areas (RFPAs), but only 6 of these have been demarcated on the ground. Further, many areas of the RFPAs are without forest cover, and there are some areas of forest outside the RFPA boundaries. Many of these sub-types have never been fully studied and may contain Guinea-Congolian species not yet recorded in Ethiopia. The forests are home to wild coffee and are an important genetic resource with a natural resistance to coffee berry disease. Tree ferns are known from only this part of Ethiopia and cover dense stands over large areas. Pure stands of Highland Bamboo (Arundaria alpina) also occur over substantial areas between 2,800 to 3,100 masl. These forests are recognized as being less rich in avifaunal diversity than the woodland-shrubland habitats, possibly because of their long isolation from the forests of Kenya and Uganda (EWNRS, 1996).

Sudan

The forest areas on the Imatong and adjoining Mountains also rise out of semi-arid plains and likewise exhibit marked altitudinal zoning (Bussman, 2006). In terms of avifaunal the forests contain some 62 of the 68 species of the Guinea-Congo Forest biome, some 33 of the 49 species of the Afrotropical Highlands Biome and 33 of the 49 species of the Somali-Masai Biome. The forests were gazetted as a forest reserve in 1952 but have lacked conservation status despite its special biodiversity importance (Makakis, 1998). No Management Plan has been prepared for the forests (FAO, 2005).

National Park Areas

There are two national parks in the sub-basin, the Gambela National Park in Ethiopia and the Boma National Park in Sudan. In addition there is the Kidepo Game Reserve, which adjoins the Kidepo National Park in Uganda.

- **The Gambella National Park:** The Baro-Akobo Sub-basin contains only one of Ethiopia's nine National/Regional Parks and three of the 17 Controlled Hunting Areas. The Gambella Regional Park is 506,100 ha in extent and is located between the Akobo and Ghilo rivers, east of the road between Gambella and Gog. The Park encompasses a wide range of habitats including wetlands, seasonally flooded grasslands and savanna grasslands and woodlands. It has not been gazetted and conservation resources in terms of staff and facilities are extremely meagre. Following the change of government in 1991 control of the Park passed to the Gambela Regional Administration. The area is visited by the White Eared Kob and elephant have visited the area in the past.
- **The Boma National Park** encompasses an area of some 2.28 million ha of the clay plains and a mosaic of wetlands, seasonally flooded grasslands and open wooded savanna grassland in the north-western part. The south-eastern part of the Park includes part of the Boma Plateau and the escarpment that separates the plateau from the plains. It was declared a National, Park in 1977 but has not been gazetted. Oil has been discovered in the Park in commercial quantities. The area is extremely

inaccessible, most particularly during the wet season. The main routes have been mined and minor routes un-maintained. The Park is now managed by the New Sudan Wildlife Organisation (NSWO) and a regional headquarters has been established at Boma town. There are 22 Staff including 5 Senior Staff but facilities and equipment are lacking (Morjan et al., 2001). A first study of the Park for nearly two decades was made in 2001 and preliminary wet season wildlife inventory and human livelihoods survey was made.

- **The Kidepo Game Reserve** is located in the upper Kidepo Valley and adjoins the Kidepo National park in Uganda and covers some 120,000 ha. It was declared a Game Reserve in 1975. No information is available on either the state of the Reserve or maps of its boundaries (Babiker A. Ibrahim, 2000).

MAJOR ENVIRONMENTAL ISSUES

Overview

Soil erosion, deforestation in the Ethiopian Highlands, lack of sustainable management of wetlands and low-lying flood plains, and wild life preservation and management are the key environmental issues related to water resources development in the sub basin.

Water quality

Water quality in the Baro-Akobo-Sobat-White Nile sub basin is not threatened.

Industrial and agricultural pollution

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

Water-related diseases

The major concern is malaria which is increasing, is difficult to control, has potential to infect a vary large population in epidemic outbreaks. The other water related diseases are Schistosomiasis, Typhoid, Diarrhea, Helminthiasis, Leshimaniasis, Onch ocerchiasis.

Soil Erosion

A key issue of soil degradation within the sub-basin is declining soil fertility, the immediate cause of which is soil nutrient "mining". Whilst some of the underlying causes may be nationally specific (e.g. land policy) the impact on the rural population of the Sub-basin is the same: declining livelihoods and increasing rates of poverty. For this reason it is considered a basin-wide issue. The locations of the various types and degrees of soil erosion and deposition, soil nutrient mining (Semi-mechanized Farms), wetlands and High Forest areas within the Baro-Sobat-White Nile Sub-basin are shown in Figure 3.6.

In Ethiopia, up to 400 tons of fertile soil/hectare is lost annually from lands devoid of vegetative cover as well as from lands where no soil conservation has been carried out. The soil lost annually is from the farmlands, which make up 13 % of the total area. This kind of erosion is common at altitudes between 1,700 and 2, 600 meters above sea level and where extensive farming activities are carried out.

In the Baro-Akobo sub basin, for example, soil loss due to runoff, loss of forest cover, etc., are increasing and the risk and consequences of soil erosion have been expanded. Soil loss due to removal of vegetation cover is an ever-present condition in the upland zones of the basin (Table 3.5).

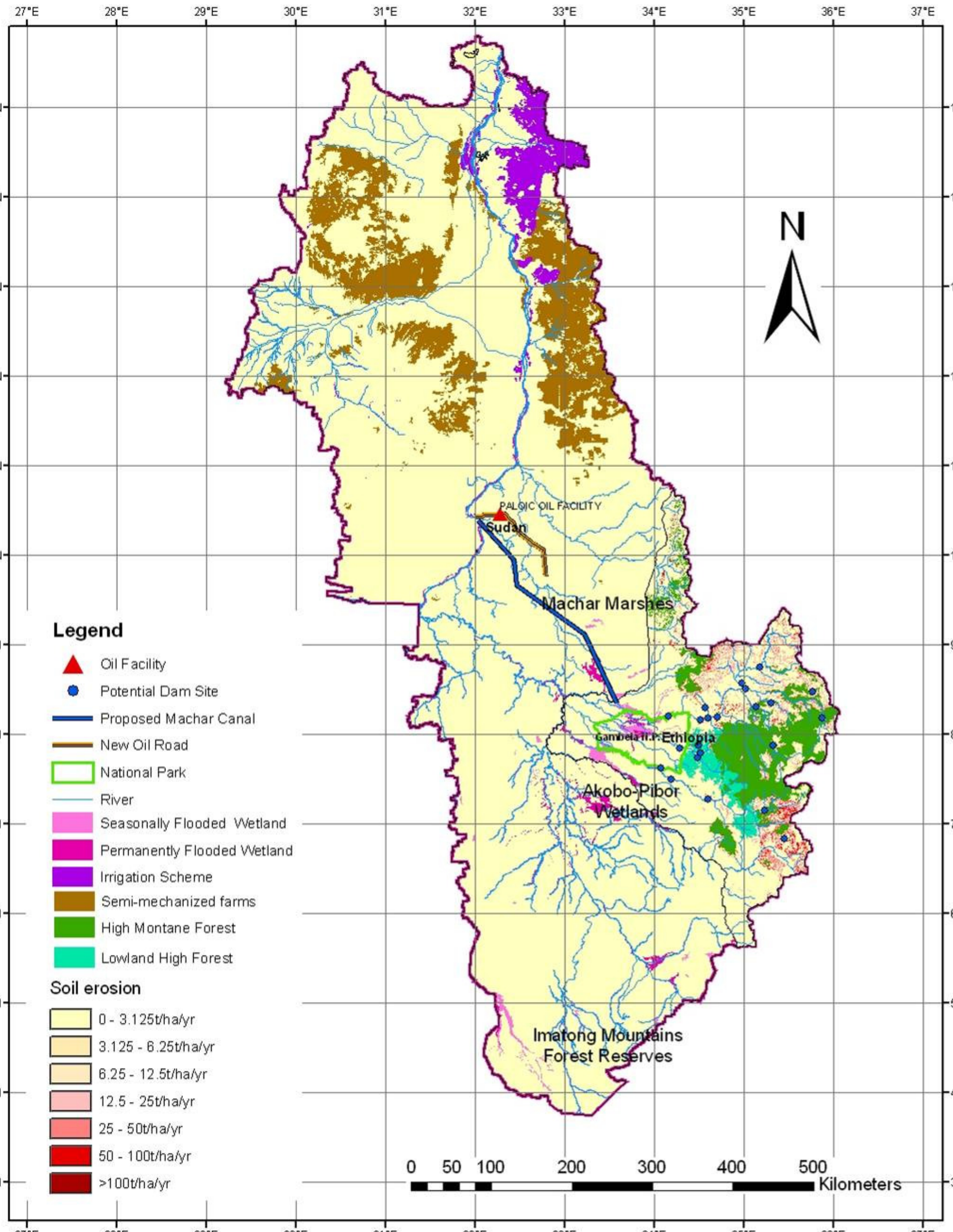
Table 3.5: Soil loss in the Baro-Akobo sub basin

Cover	Slope (%)	Runoff (%)	Soil Loss (T/Ha/Y^{-1})
Grass, percent	36	6.9	0.026
Grass, 20 percent	20	29	12
Forest	7	2.4	0.24
Cirrus + mulch	7	2.6	4.3
Citrus	7	9.2	18.9
Row crop + mulch	7	39	89.4
Fallow + Weed Grow	7	-	5.3

Source: Ministry of Water Resource (Ethiopia), quoted in OSI Environment Summary Report p. 64

- **Sheet erosion**: Most sheet erosion in the Sub-basin occurs in the Ethiopian Highlands. Some sheet erosion occurs within Sudan, mainly on and around the rock hills (*Jebels*), which have become devoid of vegetative cover. Most of this is deposited on the footslope and does not enter the drainage system. Some water induced soil movement also occurs on the flat clay plains, but given the poorly developed surface drainage system little sediment reaches the main rivers. However, given the steep slopes prevailing in parts of the Nuba and the Imatong Mountains and where the forest and woodland cover has been cleared for agriculture sheet erosion is likely to be taking place in these locations.
- **Gully erosion:** Little work has been done in Ethiopia on gully densities and erosion rates. In the Baro-Akobo gully erosion is local and mainly confined to inappropriately located culverts. In this high rainfall area natural vegetation quickly invades and helps stabilize gullies. The Ethiopian highlands of the Sub-basin are relatively free of gulley erosion given the good vegetative cover in this high rainfall environment. Locally some gully erosion can be observed, almost invariably due to the poor location of a road culvert, and along cattle tracks between villages and water sources. In Sudan gully erosion in the Nuba Mountains is more likely given the long period of settlement and the low vegetative cover.
- **River bank Erosion:** Given the relatively dense vegetative cover along the Baro, Akobo, Pibor, Sobat and White Nile Rivers, river bank erosion is not the problem that it is in the Blue Nile, Atbara and Main Nile Rivers. The slow current and almost flat banks of the White Nile could also be an additional factor.
- **Total soil eroded:** The 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. This is a much higher proportion than in either the Tekeze or Abay Sub-basins, a reflection of the much higher vegetative cover in the communal lands of this high rainfall area.
- **Impacts on agricultural production:** The current annual crop grain production for the Baro-Sobat-White Nile Sub-basin is 0.514 million tons. The annual loss due to soil erosion as a proportion of total production is 0.5 per cent in the Sub-basin. However, after 10 years this rises to 5 per cent and after 25 years to 13 per cent of annual crop production.

Figure 3.6: BASWN sub-basin: Actual and Potentials for Natural Resource Degradation.



Source: Watershed CRA Tekeze Atbara Setit report

Suspended Sediment in the river system

- **Sediment yields:** Sediment yields vary from 35 to 324t/km^2/yr with an average of 125t/km^2/yr. These rates are considerably lower than those of the Tekeze and Abay Sub-basins, reflecting the greater ground cover in this forested high rainfall regions. There is no significant difference between the sediment yields of small and large catchments. This would appear to indicate there is little or no storage of sediment within the Baro-Akobo river system within the Highlands, a factor normally attributed to declining sediment yields with increasing catchment areas. However, in this case, this is to be expected given the steep gradients in both tributary and main rivers. Given the relatively high sediment delivery ratios and very similar sediment yields it would appear that within the Highlands the river system is relatively efficient in delivering and removing eroded sediment from the landscape. The inference of this is that interventions to reduce in-field erosion are likely to have a relatively immediate impact on sediment loading in the river system.
- **Annual mean suspended sediment load:** With an estimated annual mean suspended sediment load in the Baro and Akobo Rivers of 8.15 million tons and an estimated 43.7 million tons of soil eroded, this gives an estimated sediment delivery ratio (SDR) for the whole Sub-basin of only 19 per cent, considerable less than the Tekeze (about 60 per cent) and the Abay (about 49 per cent). This is a clear reflection of the very substantial vegetation cover in the upper catchments of the Baro and Akobo Rivers. Thus some 81 per cent of soil eroded remains within the landscape.

Dam and Reservoir Siltation

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

- **Alwero Dam:** The only dam in the Baro-Akobo catchment is the Alwero Dam. It has a catchment of approximately 2,738 km^2. Using the average sediment yield estimate for the Baro-Akobo catchment (124t/km^2/yr) the annual suspended sediment load of the Alwero River would be approximately 341,155 tons/yr or 332,720 m^3/yr. Given that the catchment is heavily forested with little cultivation this is likely to be an overestimate. Assuming a sediment retention rate of 86 per cent this would result in an estimated accumulation of 284,616 m^3 of sediment per annum.
- **Baro 1 Dam:** The proposed Baro1 Dam on the Baro River has an estimated sediment inflow of 0.42 million tons/yr and a sediment retention rate of 98 per cent. Thus the dam would retain 0.41 million tons/yr and allow 0.1 million tons/yr to Baro 2 Dam below. Assuming the same sediment retention rate the Baro River below Baro 2 would have only 0.009 million tons/yr of suspended sediment. After 50 years it was estimated that 0.24 per cent of Baro 1 Dam's live storage would be depleted and that of Baro 2 would be 0.62 per cent.

Deforestation and Loss of Vegetative Cover in the Upper Baro-Akobo

The conversion of forest land to crop land and then grazing land has implications for hydrology. Although there is much debate at present about the role of forest land in affecting the volume of flow, due to evapotranspiration by trees, there are clear implications of forest loss upon the moderation of stream flow, especially the storage of water from the rainy season into the dry season. Hence, linked to the loss of forest are trends towards higher floods and lower dry season flows.

There is some evidence of this already occurring in the sub-basin, with the Sor hydro-power plant (near Metu) becoming more seasonal in its power generation and the Baro

River at Gambela having more frequent high floods which are affecting long-established villages and low flows which allow the river to be forded in the dry season. Further, as forest in the upper sub-basin is replaced by farm land sediment loads are reported to be increasing with their implications for dam development in the upper sub-basin and for river bed levels and channel overflow in the lower sub-basin.

Ethiopia

- **Loss of forest cover:** The dominant environmental change in the Baro-Akobo sub-basin is the loss of forest cover which is most marked in the southern and eastern part of the upper sub-basin where the main areas of forest remain (Map 23). The most recent analysis of forest clearance in the south-west highlands, both within the sub-basin and to the east, was made by Reusing (1999) using data from the WBISPP. He identified extensive thinning of the forest and the break-up of the major block of forest in the south-west due to clearance in particular salients, especially along newly constructed roads. His figures show that between 1971 and 1997 approximately 60% of the high forest showed signs of some negative human impact, with 17% having such severe impact that there was complete deforestation. In this period he identified a loss of approximately 4,940 sq km out of a total monitored are of 18,000 sq km (Reusing, 1999, pp.29-32).
- **Driving Forces**: The main cause of forest loss is agricultural clearance. This is driven by two main factors, the decline in yields on cultivated land with the subsequent abandonment of that land from cultivation, and rural population growth. These and other factors are outlined below:
  - ***Population Growth and Resettlement:*** Population growth is in the order of 2.8% in the rural areas of the upper sub-basin. This growth is mostly due to natural increase, but there has been a long history, when permitted, of spontaneous migration of people in search of land or economic opportunities associated with the coffee economy, as well as planned resettlement from famine affected areas.
  - ***Forest Land Alienation to State Farms and Investors:*** The process of forest land allocation for parastatal estate farming accelerated during the Derg government (1974-1991) as the road infrastructure in this area was improved. This saw the establishment of the 8,000 ha coffee estate at Bebeka, to the west of Mizan Teferi and the established of another state farm for coffee near Tepi covering around 5,000 ha. In the lower basin the state farm at Abobo was also established partly in woodland. Since the change of government in 1991, and the introduction of the free market, forest land has been allocated to investors on long leases for estate agriculture. This has mostly been done in SNNPRS where a rather favourable attitude to investors exists, compared to that in Oromiya where more stringent EIA procedures have been applied. The new estates are mostly in Sheka Zone, near Masha, along the road from Tepi to Gore, but also west of Mizan Teferi. In all cases the estates have been established in areas of high forest and experience shows that when options exist for using secondary / thinned forest within the allocated area, investors prefer the high forest.
  - ***Coffee Prices:*** A further irregular driver of forest clearance is the periodic fall in coffee prices and the subsequent decision by farmers to convert coffee forest, already thinned in terms of tree density, into farmland. The most recent experience of this was in the early years of the 21st century. The impact of low coffee prices is exacerbated by the impact of a long and complex trading chain which means that the village price for coffee is often only some 30% to 45% of the international price. Conversely, forest thinning for coffee increases during times when the coffee prices are strong relative to other crops.

- ***Sawmills and Forest Access:*** There is little legal logging going on today, although small-scale pit sawing remains. The major aspect of large-scale logging that was undertaken during the derg regime has been the way in which it opens up areas of forest for spontaneous agricultural settlement.
- ***Land Tenure and Land Registration:*** Where land tenure related issues have had an impact upon forest clearance is during the last two years (2004-2006) since the process of land registration has been publicized – but not implemented. Land registration rights will be given to individuals on the basis of the land they are using and so the rule has led to those with access to forest areas clearing it and undertaking minimal farming so that they can claim they are using this land. This seems to involve all elements of the community, rich and poor, as well as settlers.

Vegetation Loss in the Lowlands of the Baro-Akobo Catchment

- **Forest Loss**: Analysis by the WBISPP in the high forest areas of Dima, Godere, Gog, Akobo and Gambela weredas has estimated the rates of deforestation caused by expanding population (2.23% per annum) and its need for agricultural crop land. Annual destruction of the woody biomass from the high forest areas for agricultural expansion was estimated at about 4,287 ha per annum in 1995. This will increase exponentially and it is estimated that Gambela Regional State could lose 32% of its high forest resources between 1990 and 2020. Some 68 per cent of the loss will occur in Godere and Dima weredas. These weredas are also exhibiting the fastest rate of decrease of forest. The impact of forest loss is likely to be much less serious for soil erosion than in the escarpment zone due to the lower gradients. Nonetheless, there are serious biodiversity implications of the loss of this forest and the habitat it provides for wildlife.
- **Woodland Destruction:** The main threats to the lowland woodlands come from clearing for large scale irrigated agriculture, state farms and resettlement schemes, fuel wood collection around the large refugees camps, fuelwood collection for the towns, and the burning activities associated with hunting by the Anuak and Majangir. The impact of these fires on tree mortality of both the lowland forest and the Combretum-Terminalia woodland is not known but must be positive.

Deforestation and Desertification in the Khor Abu Habel of the White Nile Catchment

The Khor Abu Habel is one of the tributaries of the White Nile between Malakal and Khartoum on the western side of the River. This tributary drains the Nuba Mountains (Southern Kordofan) and parts of Northern Kordofan and White Nile States into the White Nile downstream of Tendelti town. Throughout these States desertification is accelerating and continued large increase in rural and urban population are likely to worst the situation in future. The exploitation of woodland resource round towns is leading to increase in soil erosion and sand dune encroachment. The rapidly growing demand for charcoal among urban population is leading to severe desertification in these areas.

The incidence of desertification is also resulting from fuel wood requirements, and in association with subsistence and commercial farming which is spreading throughout these sub-catchments. The impact of drought together with steadily increasing population pressure on arable land, has led subsistence farmers to move out of marginal or depleted lands to extend cultivation into forested areas. The encroachment of cultivation on these vulnerable lands has led to loss of biodiversity. This practice accelerated the soil erosion making the people of these areas even more vulnerable to future droughts which may result in environmental refugees and displaced Citizens. The droughts of the last decades have more severe impact on the land and the people of these areas than on those of the eastern side of White Nile (from comments of the Sudan Steering Committee).

Deforestation and Loss of Vegetative Cover in the Upper Pibor Catchment

The Africover project mapped some 88,000 ha of montane Podocarpus forest in the Imatong Mountains and nearby hill masses, with some 46,174 ha within the Pibor Catchment. The forests were gazetted as a forest reserve in 1952 but have lacked conservation status despite its special biodiversity importance (Markakis, 1998). During the 1970's the Reserve was exploited by the regional forestry department, the Taklanga Tea project and the Imatong Mountains Development Authority. There was a research station at Soba and the trend then was to replace indigenous species with Eucalyptus. No Management Plan has been prepared for the forests (FAO, 2005). A survey undertaken in 2005 using satellite imagery identified 12 plant communities primarily of mountain forest types (Prins & Friis, 2005). The Mountains hold 30 of the 33 bird species of the Afrotropical Highlands Biome and 62 of the 68 species of the Guinea-Congo Forests Biome (African Bird Club, accessed 2006). The current status of the forests is not clear. However, these forests are unique in Sudan and there is an urgent need to determine their status and afford them protection. With the expanding Eco-tourism industry, the Mountains could prove a significant attraction.

Wetland Loss in the Highlands

- **Trends:** Within the plateau area of the upper sub-basin there are many small permanent and semi-permanent wetlands, mostly occupied by *Cyperus latifolius*. These are mostly found in the upper reaches of the Sor, and Gabba rivers. These account for approximately 2% of the land area but they are becoming increasingly important as land pressures in the cleared area outside the forest increase. Management of wetlands for sustainable cultivation, when drainage is involved, is not easy and there has been extensive and, in some areas, complete, loss of wetlands in the southwest highlands of Ethiopia. The impacts of the loss of wetlands or their transformation for farming are considerable and are also distributed in different ways across the communities. Women and the poor are especially seriously affected when wetland cultivation leads to the loss of safe spring water for domestic use and the loss of plant materials for craft and domestic use. Similar losses are linked to wetland degradation, but in addition the typically richer cultivators loose out.
- **Driving Forces:** The main driving forces for upland wetland drainage cultivation are the following:
  - <u>Seasonal food shortages</u> caused by grain storage problems and the small areas of uplands cultivated due to guarding problems and shortages of plough oxen. Other constraints on upland farming have included the expansion of coffee land by landlords in the past. Hence a combination of environmental and socio-economic issues, as well as technical failings are driving wetland use.
  - <u>Market opportunities</u>: More recently and also more location specific, there has been a growing demand from urban areas for green maize, *tef* and vegetables which are grown in wetlands. Urban growth has been associated with the growth of the coffee-based economy and there has been some response by farmers close to urban centres to grow crops in response to these market opportunities.
  - <u>Land Tenure Change:</u> A key driving force which led to an expansion in wetland cultivation in the late 1970s was the land reform of 1975. This led to the equal redistribution of all types of farm land, including wetlands, but excluding forest land, amongst the households of each Peasant Association. In order to keep access to each type of land farmers had to show that they were using it and so wetland cultivation increased.
  - <u>Resettlement:</u> The resettlement after the 1984 famine also led to the increased use of wetlands in some areas of Illubabor where the integrated resettlement

approach was used. Local communities asked to host resettlers allocated them land which was not in use or not of prime quality, and in some cases this included wetlands. Settlers were also encouraged to cultivate wetlands for an early maize harvest as they did not have root crops which help local farmers fill the hungry season food gap.

- Menschen fur Menschen (MFM) Eco Programme**:** In the mid / late1980s, the NGO MFM developed a programme, in Illubabor, which sought to reduce the pressure for forest clearance by developing rural livelihoods in the areas outside the forest. One element in this was wetland drainage for vegetable cultivation. Although this element of the programme was closed by the late 1990s, it showed communities some of the possibilities, as well as some of the problems, that could be encountered in wetlands and provided a stimulus to further wetland drainage.
- Wetland Task Force: Since the early 1990s there has been Wetland Task Forces in the south-west highlands, including parts of the upper Baro-Akobo sub-basin. In years when food shortages are severe in other parts of the country, the Task Forces set communities targets for additional wetland drainage and cultivation and regularly visit communities to ensure these are achieved. In some cases they are also requiring farmers to extend the drainage period and undertake double cropping in the wetlands.

Loss of Biodiversity: Gambela Regional Park and Boma National Park

- **Gambela Regional Park:** The Park is not legally gazetted and no Management plan has been prepared. There are no visitor facilities. The two vehicles and Park stores were destroyed during the government change over in 1991. The Park contains the Akobo large-scale farm and Alwero Dam, and irrigation developments is currently underway in the centre of the Park. There is a critical problem of illegal hunting, with a large number of arms made available because of the Sudanese Civil War. The Phugnido Refugee Camp is located adjacent to the Park. The last major study of the area was made in 1986 by the Russian Institute of Evolutionary Morphology and Animal Ecology under the UNESCO Man and the Biosphere programme. (Sokolov, 1989) although a bird survey was undertaken in 1995-96 by the Ethiopian Wildlife and Natural History Society (EWNHS-Bird Life Int., 1996).
- **The Boma National Park:** The Park has been neglected as indeed has the area generally, partly due to its remoteness and in part to the fact that during the Civil War the area was contested between the government and the SPLA. Some five ethnic groups inhabit the park and its environs: the Murle (Boma plateau agriculturists), Murle (plains pastoralists), Jie, Anuak, Suri (Kichepo). The plains Murle, Suri and the Jie are predominantly pastoralists whilst the Anuak and plateau Murle are predominantly agriculturalists. The pastoralists used to have very large herds of cattle, sheep and goats but have lost substantial numbers during the conflict and now own 25 to 30 per cent of their previous holdings. In the wet season of 2001 a Team supported by USAID and in collaboration with the University of Missouri, USA, undertook a survey to assess the impact of conflict on the Boma National Park looking in particular at the status of food security livestock and wildlife (Deng, 2001). Generally the pastoralists saw internal tribal conflict as the major source of livelihood vulnerability the agriculturalists saw drought as the main external shock to their livelihoods. A major wildlife inventory was undertaken in 1980 (Fryxell, 1983) and provided a baseline for the 2001 study. With the exception of population estimates for Reedbuck, Ostrich and Eland populations the 2001 estimates suggest that there has been a massive decline in nearly all animal species. The most affected were the White-eared Kob and the Mongalla Gazelle. A summary is provided in table 17. The big increase in hunting has caused the migratory routes of White-eared Kob and Elephant to change over 20 years.

However, the vegetation survey revealed an increase in tree densities an indication of habitat improvement and stability.

Potential negative impacts on natural resources

These issues relate to potential rather than current negative impacts on the natural resources and the associated livelihoods of the peoples occupying these three catchments within the Baro-Akobo-Sobat-White Nile sub-basin. These catchments are in stark contrast to those in the other three Sub-basins in that much of its natural vegetation and environmental is intact. However, there are a number of ongoing negative impacts of development activities and a number of potential threats emerging to the natural resources and environment of the Sub-basin.

- **Returning refugees from the Civil war:** Much of the area has been affected by the 20 years of Civil War (on both sides of the international border) and its attendant destruction of physical and social infrastructure, and the breakdown in socio-cultural networks and relations. Considerable movements of people have taken place and only now are many of the displaced people beginning to return. The sub-basin is thus in a state of considerable human flux. The ceasefire and the CPA have already resulted in the return of 500,000 IDPs and refugees into the south and transitional area with limited or no resources. In a situation where even under normal conditions there is competition over natural resources, there is a danger of conflict flaring up if the delicate local ecology is disturbed (JAM, 2003, Catterson et al., 2003). As people return there will be a need to clear land for farming, which will involve considerable cutting of trees and burning. It will be important that as far as is possible that they do not occupy marginal land and that the most fertile of traditional crop areas are not alienated for agro-industrial schemes.
- **Proposed investments in water infrastructure:** There are long-standing plans to change the hydrology of the Bahr el Jebel and the Sobat Sub-basins. In the Bahr el Jebel Sub-basin the Jonglei Canal is proposed. The full implementation of this project will have important implications and impacts on the livelihood systems of the Sobat-White Nile Sub-basin. There are also long-standing plans to change the hydrology of the Sobat River with a diversion canal to collect spill from the Sobat that currently sustains the Machar Marshes and transmit this directly to the White Nile.
    - ***Dams in the Baro-Akobo catchment:*** A number of dams have been proposed in the Baro-Akobo catchment those designated Baro 1 and Baro 2 have been studied by the Baro Multi-Purpose Project Feasibility Study, which states that "it is not anticipated that the change in river flow will cause any significant changes in the ecology along the Baro, Sobat, White and Nain Nile." However it is estimated that there will be a reduction of flooding of about 410 km^2, a decrease of about 12 per cent. As this represents valuable dry season grazing for pastoralist groups that use the area during the dry season, this is not an "insignificant" impact. Also, any dams on the Akobo that would change the nature of the high peak flood flows would have a significant impact on the amount of spill into the extensive area of wetland of both seasonal and permanent swamps. This could have serious impacts on the ecology (e.g., migratory routes of the vast herds of white-eared kob, and the population of Nile Lechew) and thus the livelihoods of the Murle people who use this area for grazing. It is not known whether oil exploration is being conducted in this area.
    - ***Machar Marshes scheme:*** The annual benefits of this scheme to increase the flow of the White Nile and provide "new water" for downstream users have been seriously questioned by Sutcliffe and Parks (1999). The most recent study (using MODIS satellite data for 2001) undertaken for the JMP (Waterwatch, 2006) estimates a potential gain of only 0.96 km^3. Clearly the impact of this Scheme

would be considerable if it captured all the spill and inflow from the eastern Torrents. The Machar Marshes would effectively dry out apart from some localized flooding from rainfall (Howell & Lock, 1983). In addition the canal would cut across livestock trekking routes between dry and wet season pastures.

- **Oil extraction:** Both exploration (cutting of seismic traces, test drilling, access road construction) and drilling and extraction (road construction, new towns, pipelines, oil wells) have already had severe environmental and social impacts. There are two potential problems related to oil extraction and transport within the Machar Marshes. The first is that the oil is pumped together with water and the two have to be separated. At this point the water is heavily contaminated and must be treated before disposal. If this is not done effectively then severe pollution problems will occur. Given the importance of the marshes in terms of water supplies and fishing this would have a serious impact on the livelihoods of the local inhabitants. A second potential problem is the construction of all-weather roads without effective drainage and adequate culverts. In these cases the road acts as a dam and can cause serious flooding on the upstream side and lack of water on the downstream side. Given the very complex drainage systems within the Marshes any disruption in water flow can have very serious impacts on the distribution of the important "toich" grazing areas.

- **Water hyacinth infestation:** Water hyacinth (*Eichhornia crassipes*) appeared in the White Nile in 1957 in the area of the Sudd and has since spread north and southwards (Abdalla Abdelsalem Ahmed, 2006), in the Baro in Ethiopia about 1976 (EWNHS, 1996) and also in the Sobat system. The weed has a number of serious negative impacts. The presence of the weed in the river system leads to an increased loss of water from evapotranspiration. It also reduces the areas of open water available for fishing, which is an important livelihood strategy for the people of the Sub-basin. It also acts as impedance to river navigation along the White Nile a factor of considerable economic importance. Experiments in Sudan revealed that the water loss was 1.5 gm/cm^2 /day for water hyacinth covered water surface as compared to 0.85 gm/cm^2 /day for a free water surface (Dissogi, 1974). Computing the total loss from the 3,000 km^2, being the estimated infested area in the 1970s, the water loss in the infested area is 16.425 km^3 compared to 9.308 km^3 being lost from an equal free water surface. Obeid (1975) calculated the total loss due to the presence of water hyacinth as 7.12 km^3, which is one tenth of the average of the normal yield of the Nile based on (1912 – 1965) records. Current reports indicate that the water hyacinth problem is not as serious as it was in the seventies and eighties of the last century and consequently, the water loss would be less than the previous figures. Nevertheless, there would still be water lost due to the presence of water hyacinth in the White Nile stretches, and hence an updated investigation is required inasmuch as ecological and climatological changes might trigger a second, even more severe, episode of infestation.

4. HYDROLOGY AND WATER INFRASTRUCTURE

SURFACE HYDROLOGY

General description: The Tekeze-Atbara sub basin comprises two major catchments covering the Ethiopia northwestern highlands (Tekeze river basin) and the Sudanese southeastern lowlands (Atbara river basin). This sub basin, like the other sub basins of the Eastern Nile, originates from the Ethiopian highlands north of Lake Tana and flows westward into the Sudan joining the Nile as its last tributary at the town of Atbara. The Tekeze River basin includes the River Tekeze (610 km length and 68,751 sq. km basin area), the River Angereb (220 km length and 14750 sq. km basin area) and the River Goang (130 km length and 6500 sq. km basin area) (TBIDMPP, 1998; quoted by Hussein and Yared, 2003). (Source: OSI Socioeconomic synthesis report, pg.130)

Sub-basin area: The Tekeze-Atbara Sub-basin covers an area of 227,128 sqaure kilometres (including the Mereb-Gash basin). This sub-basin extends from the north-western Ethiopia to the lowlands of Sudan, meeting the Main Nile approximately 285 km downstream of Khartoum.

1.5.1. River system

The Baro and Gillo rivers start in the south-western highlands of Ethiopia fed by considerable number of small watersheds at an altitude of well above 2500 masl (the hilly upland areas of the "*Fitawrari*" Mekonen Plateau and the Masongo Range around Metu & Jimma). These two rivers are heading in a general south-west direction and terminate at the confluence point at an altitude of less than 500 masl. The gauging station for Baro River near Gambella is at an altitude of 480 masl.

Akobo River starts in the low-lying areas of the Ethiopian south-western highlands, bordering Ethiopia & Sudan in the north-west direction and forms a confluence with Pibor river before it forms a confluence with Baro and Gillo to finally form the Sobat river.

The Pibor River starts in the Sudan low land areas heading north-west directions before it joins the Akobo. The Machar swamp, fed by the flood spilled from the Baro river, is located at its lower course. The Machar is also fed by local streams sharing the same watershed divide with the Baro river in the north.

The main tributaries of the Sobat are the Baro, Gillo and Akobo that rise on the Ethiopian Plateau at some 3,300 masl. Below Gambela the Baro bifurcates into the Baro and the Adura which rejoin about 70 kms downstream. The Jikawo joins the Baro, but below this junction are a number of spills from the Baro into the Machar Marshes. Below the Pibor-Baro confluence the Sobat forms a defined channel through grassy plains with numerous back swamps. It joins the White Nile just above Malakal. The Bahr el Jebel and the Bahr el Zeraf strictly become the White Nile at their confluence at Lake No, although the Sobat junction is the point at which most hydrological measurements are made.

Below Malakal until its junction with the Blue Nile at Khartoum the White Nile falls about 13 meters over a distance of 840 kms. The inflows from tributaries are small and sporadic. The natural flow regime has been disturbed by the construction of the Jebel Aulia dam 40 kms above the confluence. Until the Malakal station, the sub basin flows in a general west direction and after Malakal, the White Nile flows in a general north direction to form a confluence with the Blue Nile at Khartoum and forms the Main Nile system beyond Khartoum.

The sub-basin is estimated to contribute about 26 billion m^3 of water every year to the Nile system at Khartoum.

River system: The Baro and Akobo Rivers rise in the Ethiopian Highlands between altitudes of 1,500 to 3,100 masl. The highlands are covered with dense montane forests although these are rapidly being cleared for small and large scale agriculture and settlement. The rivers pass through an escarpment zone in deep incised valleys before they debouch onto the Gambela Lowlands. Here they pass through wide grassy and swamp plains before reaching the Pibor River and becoming the Sobat River. (Source – OSI Water Synthesis Report Pg 28)

The Sobat River rises in the far southeast as the Pibor River on the highlands actually inside Uganda on Mount Moruogole (2,750 masl) although the water from these headstreams only reaches the Pibor in years of very high rainfall. The Pibor joins the Akobo and Baro along the Sudan-Ethiopian border. From the Pibor-Baro junction the river becomes the Sobat. Just before joining the Sobat the Baro has a flood spillway (the Khor Machar) into the Machar Marshes. The water from the Machar Marshes, together with that from khors coming off the Ethiopian Highlands, occasionally reaches the White Nile via the Khor Adar.

The White Nile emerges from the Sudd swamps at Lake No and is joined by the Sobat just above Malakal. Then it flows north in a shallow valley between the Juba Mountains to the west and the Ethiopian Highlands and then the White Nile-Blue Nile divide to the east.

Table 4.1: Main Rivers of Tekeze sub basin

River Basin	Major River	Major Tributary River
Tekeze	Tekeze	Zamra, Tserare, Gheba and Worie, Insia and Zarema
Angereb	Angereb	Kaza
Goang	Goang	Gendua

***Source**: Ministry of Water Resources (Ethiopia)*

Influencing areas: The Tekeze sub basin consists of three main influencing areas: (1) Tekeze up to Humera, which is an area of 63,376 km^2 (of which 4,070 km^2 in Eritrea); (2) Angereb up to Abderafi, an area of 13,327 km^2 and (3) Goang up to Metema, which is an area of 6,694km^2.

Drainage: Drainage in to Sudan is 3,113 km^2, of which 90 km^2 in Eritrea. The total area is 86,510 km^2 and 82,350 km^2 without Eritrea. Compared with the drainage network in Ethiopia, the Sudanese portion of the Tekeze-Atbara Watershed is characterized by a very low density of watercourses except in the south-west along the Blue Nile watershed where there are numerous intermittent *khor* channels.

River flows at boundaries: Estimated river flows at the boundaries are given in Table 4.2

Table 4.2: Estimated river flows at national boundaries

Tekeze (Humera)	5,875	Million cubic metres
Angereb (Abderafi)	1,454	Million cubic metres
Goang (Meterna)	862	Million cubic metres
Total	**8,191**	**Million cubic metres**

***Source*: ??????**

Watersheds: The sub-basin can be divided into nine major catchments. Because of the very flat gradients over most of the Sub-basin division into lower order catchments is virtually impossible with the current digital terrain models. Thus in Sudan the USGS/EROS gtopo30 HYDRO1k data set published by UNEP/DEWA/Grid was not used and instead a visual interpretation of the DTM and the drainage patterns was made in order to define the major catchments of the Sub-basin (Table 4.1). Despite its much larger catchment the

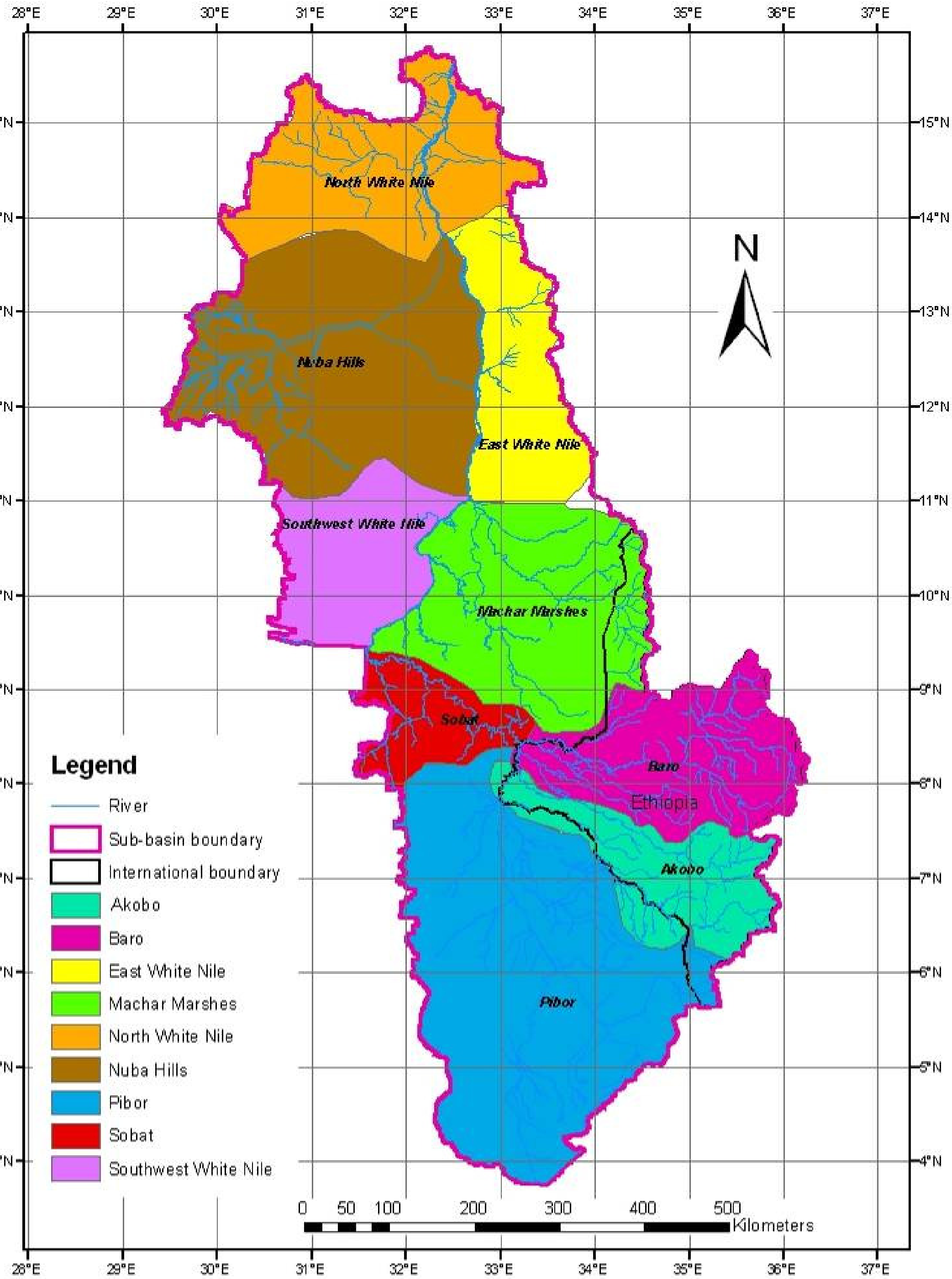
Pibor -with Akobo and Gillo - only supply about 25 percent of the Sobat flow, whilst the Baro supplies 75 per cent even after spill to the Machar Marshes.

Table 4.3.Baro-Akobo-Sobat-White Nile Sub-basin: Major Catchments

Major Catchments	Area (square kilometres)	% of total Sub-basin area
Pibor	110,873	24%
Nuba Hills	85,293	18%
Machar Marshes	61,682	13%
North White Nile	49,608	11%
Baro	43,838	9%
East White Nile	33,955	7%
Akobo	31,979	7%
Southwest White Nile	31,903	7%
Sobat	19,085	4%
SUB-BASIN	**468,216**	**100%**

Source: Basin boundaries: Ethiopia MWR (Addis Ababa) and Sudan: Visual interpretation.

Figure 4.1: Baro-Akobo-Sobat-White Nile Sub-basin: Drainage Network and Catchments



***Source*:** ENTRO OSI database derived from SRTM DEM 90m

The Baro-Akobo Catchment

The major rivers within the Baro-Akobo basin are Baro and its tributaries (Birbir, Geba, Sor), Alwero, Gillo with its tributaries (Gecheb, Bitun, Beg) and Akobo with its tributary Kashu. The general direction of the rivers is from the east to the west. Streams with steep gradients originate in the eastern highlands (about 2,000 – 3,500 masl) where rainfall is high and debauch onto western plains (Gambela plain around 500 masl) that have relatively low rainfall and moderate to low river gradients, which ultimately join Sobat River which is a tributary of the White Nile.

The Akobo appears to spill across to the Pibor through an extensive area of wetland at its junction with the Akula River, although this fact does not appear in any reports from Ethiopia or Sudan. Just above the Jakawu junction the Baro bi-furcates into the Baro to the north and the Adura to the south. They rejoin below the junction with the Khor Machar. The Baro both overflows and spills along the Khor Machar into the Machar marshes.

The Pibor-Sobat System

The hydrology of the Pibor-Sobat system is complex and still imperfectly understood. A hydrological distinction may be made between the Pibor Catchment, the Baro-Akobo Catchment almost entirely in Ethiopia and the Sobat-Machar Marches. Here only the Pibor Catchment and the Sobat-Machar Marshes Catchment are considered.

Pibor Catchment

Four patterns of streams have been recognized in the Pibor Catchment that occur successively northwards in approximately west-east zones (Jonglei Investigation Team, 1954). The first zone is the area of rapid runoff where streams branch off the Basement Complex Hills and Mountains. Flows are seasonal and highly variable, sediment loads are high and gradients very steep. Below these streams on the foot-slopes is the second zone where gradients rapidly decrease and coarse sediment is deposited forming well defined valley floodplains.

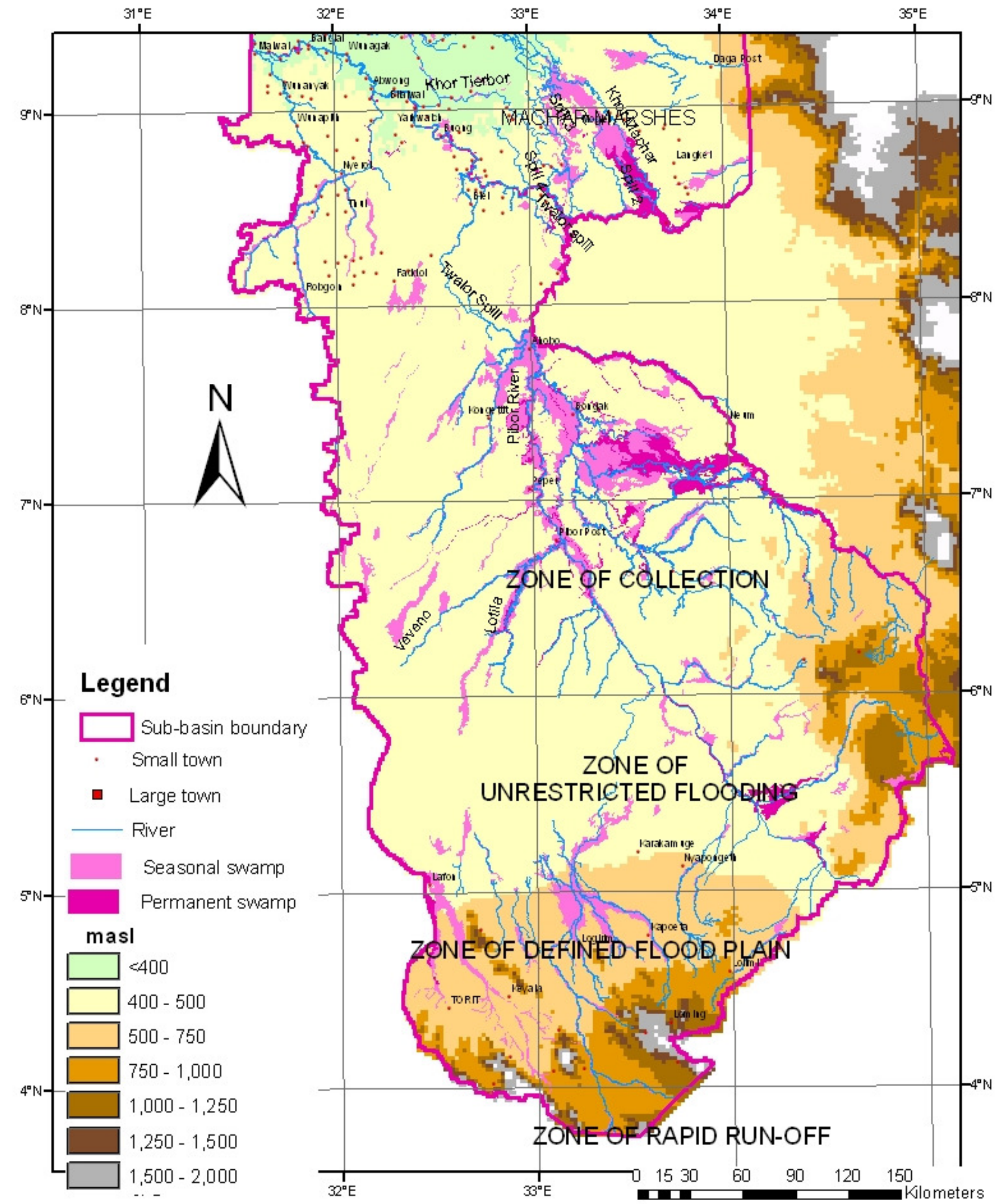
The third zone comprises the very flat impermeable clay plains with high grasses. The streams spill out into inter-connected channels, eventually defined channels disappear. In the wet season rainfall combined with water from the streams forms a "creeping flow" of water up to a meter deep that moves slowly across the plains often into the dry season. Most water is lost through evaporation.

Finally, in the fourth zone, defined but wide channels begin to form again as water collects the creeping flow. Alluvial banks begin to form and well defined rivers such as the Pibor, Akobo, Baro and the Sobat can now be recognized. Here rivers may braid into two or more channels during the high floods. Occasion spillways occur where water during the high flood spills out of the main river. Some water spills onto the wide floodplains eventually to return to the main river as the flood subsides. Some water flows across low watersheds into other channels.

It is in this Zone that there is an area of wetlands even more extensive than those of the Machar Marshes, where a spill appears to occur between the Akobo and the Pibor Rivers to the northeast of Pibor Post.

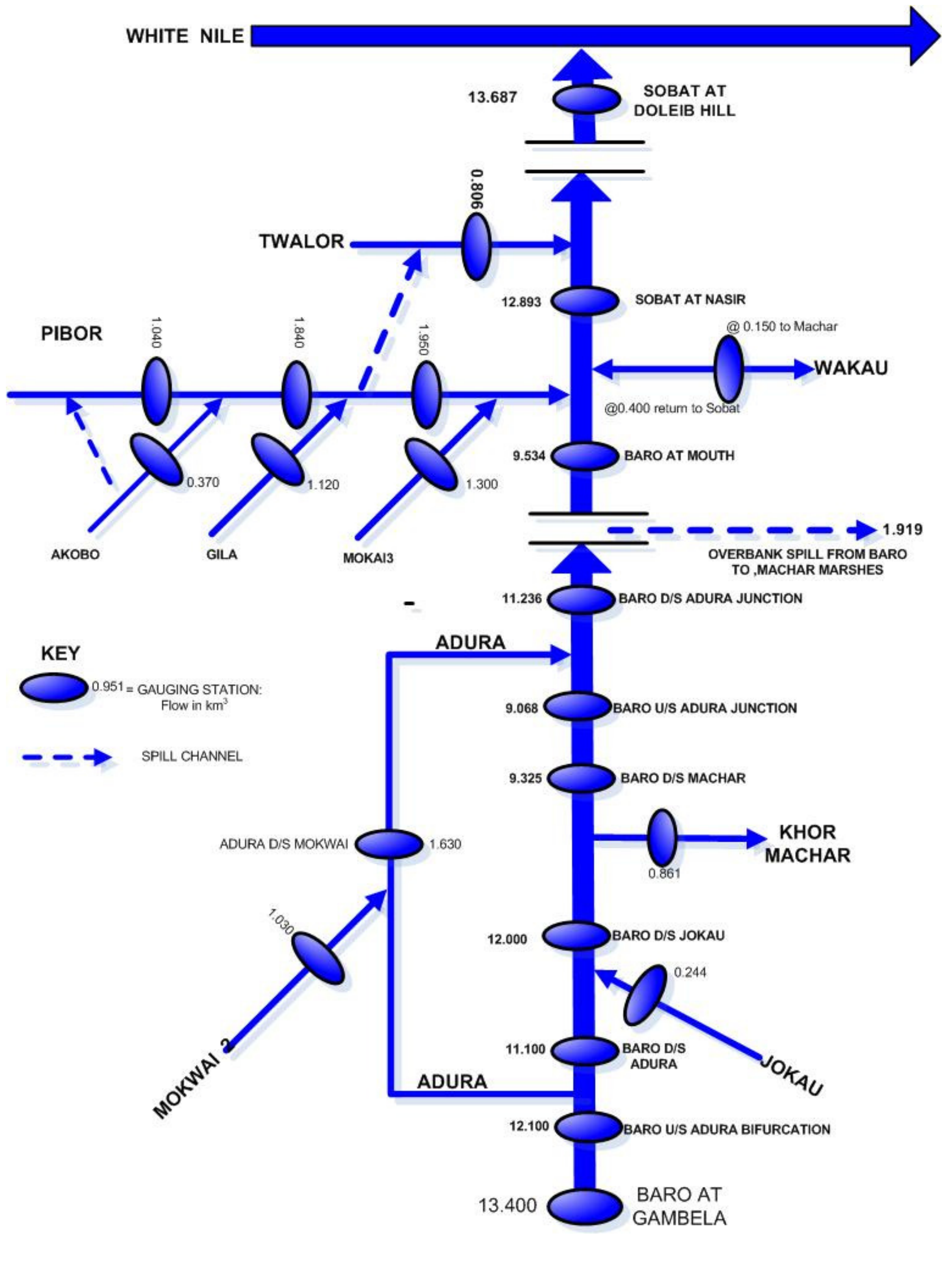
Three main "collector" streams: the Viveno, Lotila and Kengen join at Pibor Post to form the Pibor River. Downstream the Pibor is joined on the west by the Geni and from the Ethiopian Highlands by the Akobo. Further downstream the Pibor is joined successively by the Gillo, Mokai and Baro from Ethiopia. At Baro-Pibor confluence the river becomes the Sobat. During high flows just below the Akobo confluence the Pibor spills westwards to the Twalor (Nyanding) a south bank tributary of the Sobat (see figure 4.3).

Figure 4.2: Sudan: Pibor-Sobat Sub-basin: Hydrology



Source: Landsat TM 36-05 & Howell et al (1983)

Figure 4.3: The Pibor-Sobat Catchments: the hydrology of the Sobat and its tributaries (Source: Sutcliffe & Parks, 1999).

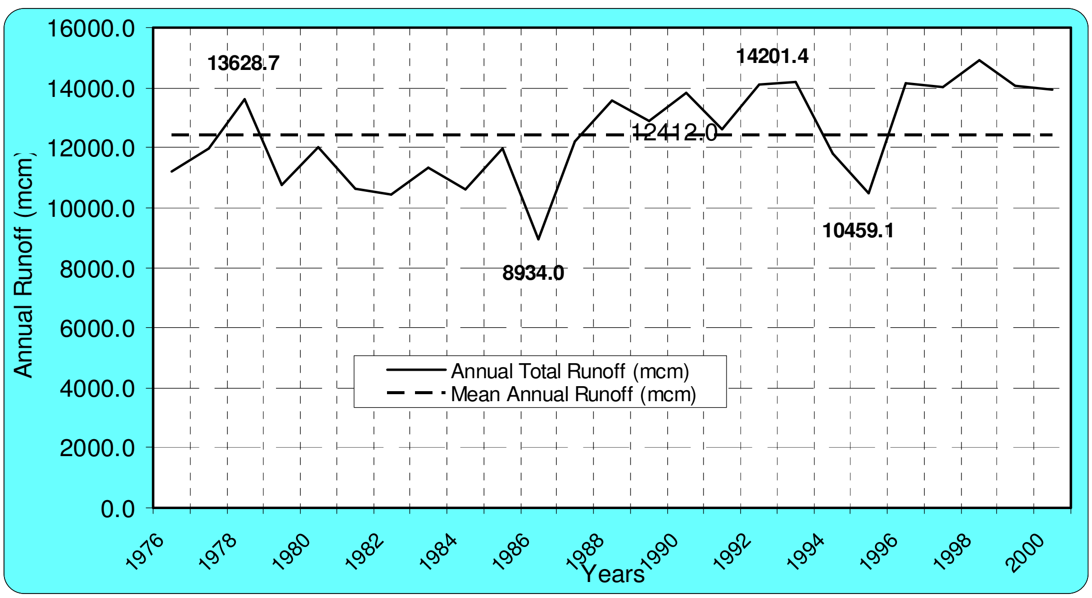


Source:ENTRO database

RUNOFF

- **Location:** The Baro watershed is largely drained by Geba, Sor, Gumaro, Birber, Ofa in its northern portion and the upper Baro river in its southern portion. All these rivers form a confluence upstream of the Gambella town then after to form the Baro River which flows in the general west direction in to the Sudanese land to Sobat River to form the White Nile watershed system. At the confluence, the Baro and its tributaries form 41400km^2 (OSI Water Synthesis Report, p. 21). It shares the same watershed divide with Gillo and the BN in its southern and northern portions respectively.
- **Data:** The data are from the Baro-Akobo Master Plan Studies (May 1997), which used monthly runoff data for the period 1976 to 2000 from the gauge near Gambella for Baro river to estimate some basic statistical features of the runoff from the Baro watershed.
- **Mean Annual Runoff:** The mean annual runoff is estimated to be 12.412 bcm with an effective runoff of 415 mm that indicates a runoff coefficient of 30%. In the upper course of the Baro watershed, effective runoff is estimated to be 750 mm with mean weighted annual rainfall averaged at 1800 mm, indicating that the runoff coefficient is more than 40%. Nearly 85% of this mean annual runoff happens in the wet (May – November) season (Figure 4.4).

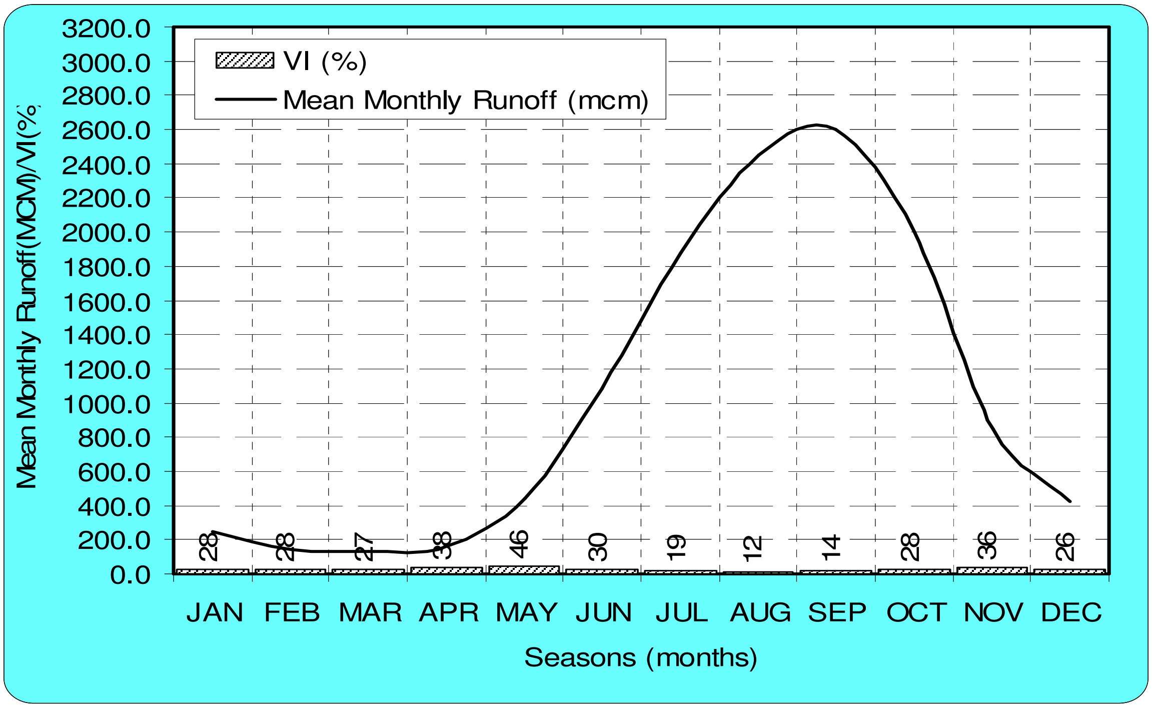
Figure 4.4: Annual Runoff Series of Baro River near Gambella



***Source**: Ethiopian ministry of water resources Baro-Akobo Master Plan Studies (1997).*

- **Hydrological variability:** The hydrologic variability for the annual series is 12.8%. The hydrologic variability for seasonal series ranges from 46% (May) to 12% (August). Mean seasonal variability for the wet period (May to November) is computed to be 24% and for the dry season it is estimated to be 26%. Annual runoff for years from 1979 to 1988 is below average and thereafter, for most of the events, it is above average (Figure 4.5).

Figure 4.5: Seasonal Distribution & Variability of Runoff at Baro River near Gambella

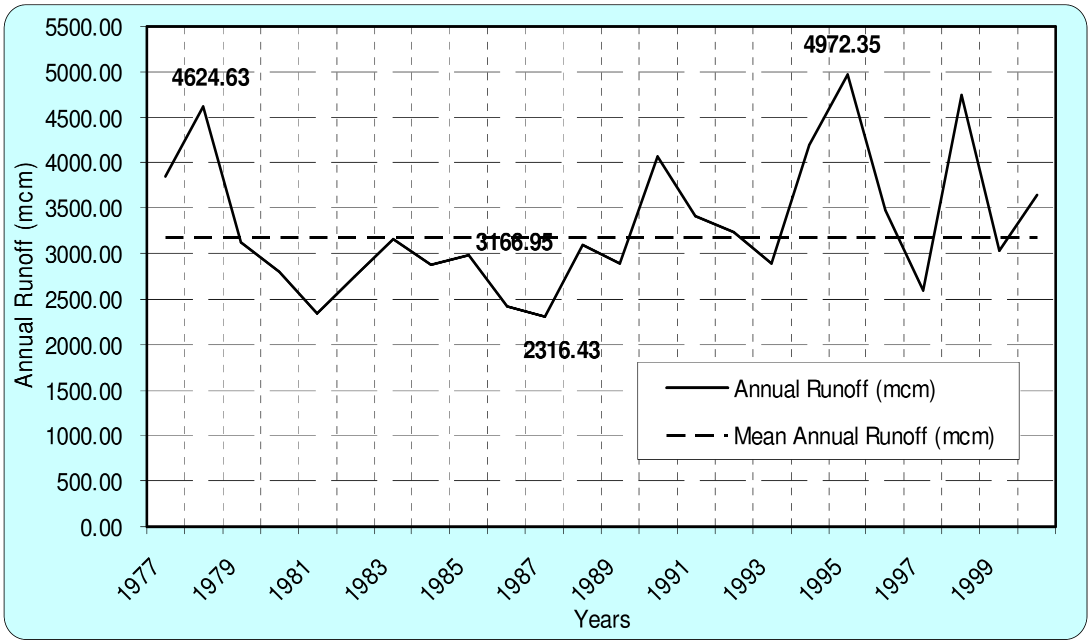


Source*: Ethiopian ministry of water resources Baro-Akobo Master Plan Studies (1997).*

Gillo river

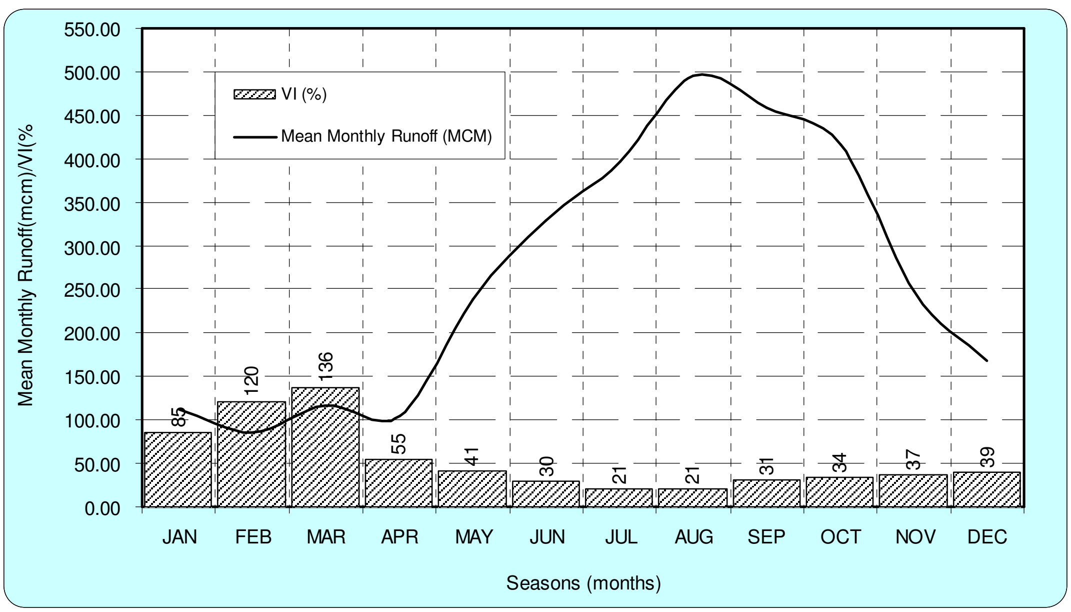
- **Location:** The Gillo River is the second largest contributor of the Sobat watershed system. Its watershed at the Ethio-Sudan border is estimated as 12,815km^2 (Baro-Akobo Master Plan Studies, May, 1997, quoted in OSI Water Synthesis Report, p. 21).
- **Data:** The data are from the Baro-Akobo Master Plan Studies (1997), which used monthly runoff data for the period 1977 to 2000 from the gauge near Pugnido to estimate some basic statistical features of the runoff from the watershed.
- **Mean Annual Runoff:** Mean annual effective runoff is estimated at 315 mm indicating a runoff coefficient of 25% with mean weighted annual rainfall of 1300 mm over the watershed. The mean annual runoff at the gauging station near Pugnido is recorded as 3.2 billion cubic meters, out of which about 80% falls in the wet (May to November) season (see Figure 3.4).
- **Hydrological variability:** The hydrologic variability for the annual series is estimated to be 22%, which is more than the watershed in the Baro River. The hydrologic variability for seasonal series is also much more pronounced in this watershed and is estimated to be around 50% (April) to 21% (August). The mean hydrologic variability in the wet season is 31% and for the dry season it is 85%. The annual runoff from 1980 to 1990 is below average, but is higher than average thereafter. This is similar to the situation in the Baro watershed where the period from 1980 to 1990 was drier than average (Figure 4.6).

Figure 4.6: Annual Runoff Series for Gillo River near Pugnido



***Source**: Ethiopian ministry of water resources Baro-Akobo Master Plan Studies (1997).*

Figure 4.7: Seasonal distribution & variability of runoff, Gillo River near Pugnudo



***Source**: Ethiopian ministry of water resources Baro-Akobo Master Plan Studies (1997).*

Akobo river

- **Location:** The river has two major watersheds, the upper Akobo (draining the Ethiopian land, with estimated watershed area of 6036 km^2) and the lower Akobo (largely draining the Sudanese land with estimated watershed area of 7,209 km^2) (Baro-Akobo Master Plan Studies, May 1997). The river flows in a north-west general direction bordering Ethiopia and Sudan before it forms a confluence with Pibor river, then after forms a confluence with Gillo and Baro to form the Sobat river and the White Nile system in the further downstream reach of the sub basin.

- **Data:** Runoff data are from Sutcliffe & Parks (1999) and the Baro-Akobo Master Plan Studies (1997).
- **Mean annual flow:** Sutcliffe and Parks estimate the mean annual flow from Akobo river at its confluence with Pibor river for the period 1929 - 1944 to be 0.37 billion cubic meters.
- **Mean annual runoff:** The Baro-Akobo Master Plan Studies estimate the mean annual runoff from this watershed to be 3.9 bcm. Overall, this watershed yields mean annual effective rainfall of 295 mm.
- **Hydrological variability:** There is no data on hydrological variability.

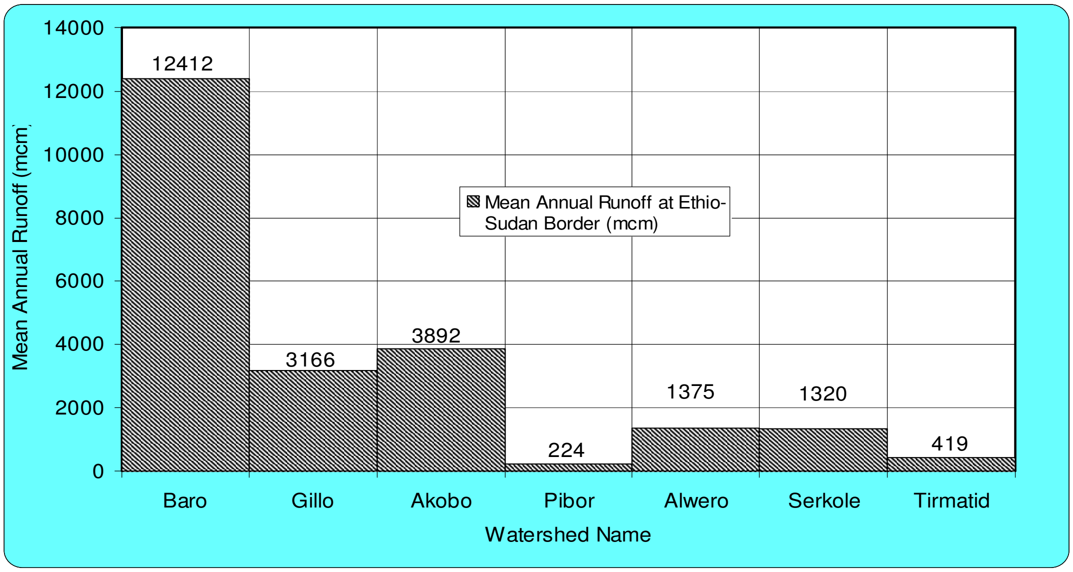
Pibor river

- **Pibor River:** This river drains a wide area of relatively low land plains extending to the mountains of southeast Sudan and few parts of the north east of Uganda. It flows in north-west general direction to form its first confluence with Akobo river and then with Gillo and Baro rivers to form the Sobat river. It also drains a wide area of the plains east of the Bahr el Jebel, from which there is little runoff in most years but considerable flows in some years. Pibor River has an estimated total watershed area of 1435km^2 (OSI Water Synthesis Report, p. 31). At the confluence, the Pibor and its tributaries form 109,000km^2 (Sutcliffe & Parks, Feb 1999, quoted inOSI Water Synthesis Report p. 31). Its flow disappears into a swamp about 5^{o}N (Sutcliffe & Parks, 1999).
- **Data:** Runoff data is from Sutcliffe & Parks (1999) and the Baro-Akobo Master Plan Studies (1997).
- **Mean annual flow**: Sutcliffe and Parks estimate the mean annual flow from the Pibor river upstream at its confluence with the Akobo river for the period 1929 - 1944 to be 1.04 billion cubic meters.
- **Mean annual runoff:** The Baro-Akobo Master Plan Studies estimate the mean annual runoff from this watershed to be 0.224 billion cubic meters.
- **Hydrological variability:** There is no data on hydrological variability.

Sobat river

- **Location:** The Sobat watershed is drained by four major tributaries, Baro, Gillo, Akobo and Pibor, and other three small watersheds, namely, Alewero, Serkole, and Tirmatid. At the Ethio-Sudan border the total watershed is estimated to be 76000km^2 (OSI Water Synthesis Report, p. 31). The area of the Sobat watershed at Malakal is estimated to be in the range of 175,804km^2 (Baro-Akobo Master Plan studies (May 1997) & The Hydrology of the Nile, Sutcliffe & Parks, Feb 1999) to 186,275 km^2 (Sudan National OSI Report Water Resources Theme, May 2006). Together with the Sude, it is one of the major constituents of the White Nile system.
- **Data:** The data are from the Baro-Akobo Master Plan Studies (1997).
- **Mean annual runoff:** The mean annual runoff is estimated to be 23.24 billion cubic meters. This yields a mean annual weighted effective rainfall of 305mm. The mean annual runoff from Alewero, Serkole & Tirmatid rivers at the Ethio-Sudan border is estimated to be 1.375, 1.32 and 0.419 billion cubic meters, respectively. The mean annual runoff contributions to the Sobat watershed at the Ethio-Sudan border is given below (Figure 4.8).

Figure 4.8: Mean Annual Runoff Contributions in the Sobat Watershed at the Ethio-Sudan Border



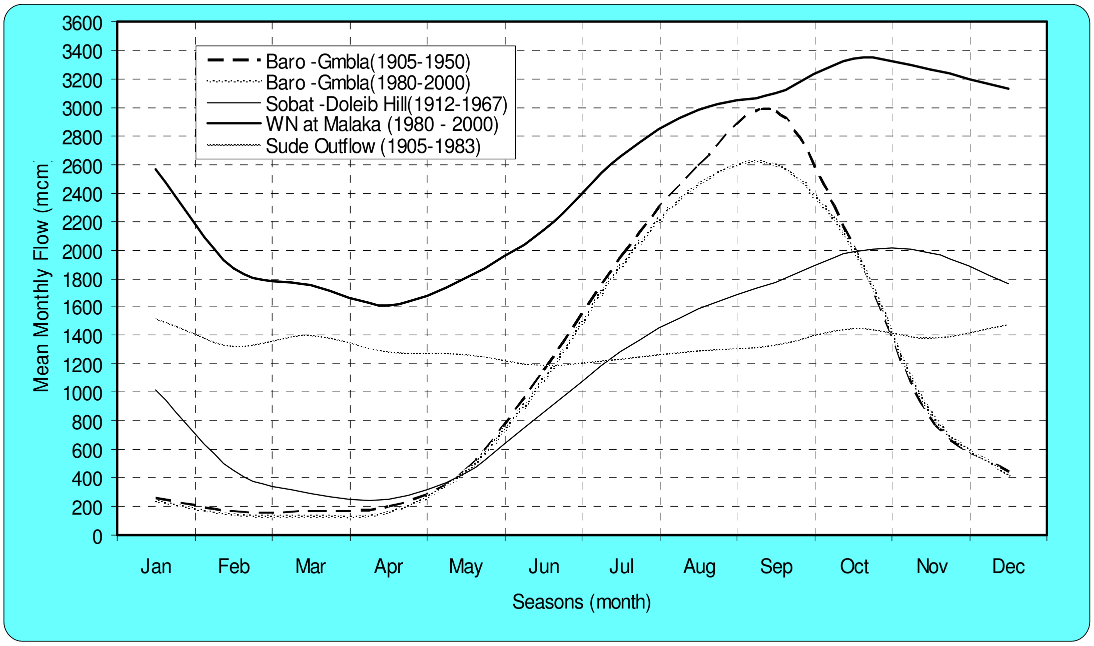
Source: After the Baro-Akobo Master Plan Studies (1997).

- **Mean annual inflow:** At its mouth, the mean annual inflow is estimated to be 13.5 billion cubic meters, and hence its contribution to the White Nile system is almost 50%. The mean annual inflow from the Sude outflow is 16 billion cubic metres. With an estimated watershed area of 186,275 km^2 for the Sobat at its mouth, the mean annual weighted effective rainfall is estimated at 75 mm.
- **Hydrological variability:** There are no estimates of hydrological variability unlike in the case of the Baro and Gillo. As a result of the routing effect of the Sude wetland, the Sude inflow to the White Nile system is observed to be regulated, and hence said to contribute nearly all of the base flow for the White Nile system (Sutcliffe & Parks, 1999). The seasonal element manifested in the White Nile system is therefore deduced to be contributed by the Sobat river, which it turn, acquires it from the hydrologic variability and seasonality of the inflows from the Ethiopian highlands(Figure 4.9).

Machar Marshes

- **Location:** The Machar wetland is located north of the Baro river upstream of its confluence with the Pibor river in the Sudan. The Machar wetland is hydraulically connected to the Baro river during high stage flows (spillage through the banks of the Baro river) from its south and to the ephemeral torrents originated from the foothills of the western highlands of Ethiopia from its east side. It is also hydraulically connected to the Whie Nile system through an extended grass field channel named as Khor Adar. Below the bifurcation with Adura (a branch channel in the left bank of the Baro river before its confluence with Pibor) the Baro river receives inflow from the Jakao river at its right bank and loses water through spillage over its right bank and through the Khor Machar channel towards the Machar wet land.
- **Data:** The water balance of the Machar swamp has been studied by a series of investigators since Hurst (1950), including the Jonglei Investigation Team (JIT, 1955), MIT (El-Hemry & Eagleson, 1980), Sutcliffe and Parks (1999) and most recently by Waterwatch (2006) for the JMP Scoping Study. Except for the Waterwatch study these have been summarized by Sutcliffe and Parks (1999)

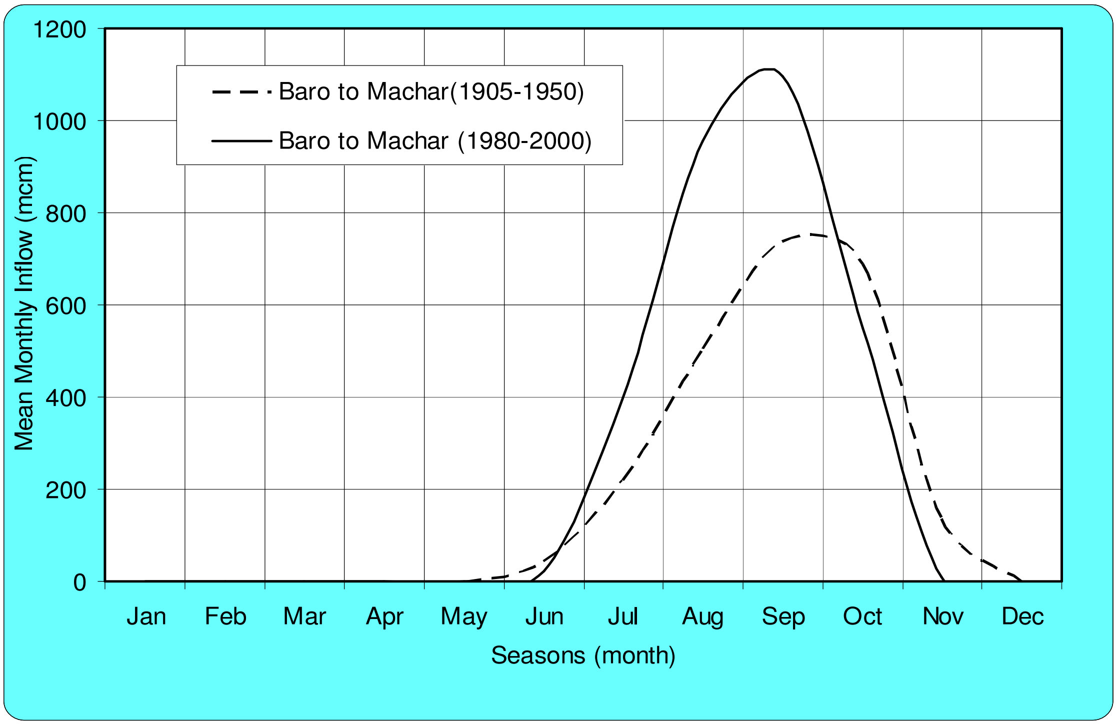
Figure 4.9: Seasonal Distribution of Mean Monthly Flow for Baro at Gambella, Sud Outflow & White Nile at Malakal & Sobat at Doleib Hill



- **Marsh area**: The Machar Marshes are the least known of the southern Sudan wetlands. There is neither direct ground evidence for the distribution of permanent and seasonal swamp nor direct evidence of the swamp and grassland vegetation types. The JIT study estimated an annually flooded area (swamp and grassland) of between 6,000 and 20,000 km^2. The area was mapped by El-Hemry and Eagleson (1980) using Landsat imagery. They estimated the area of permanent swamp as 8,700 km^2 (of which 60 percent was grass and forest). The area has also been mapped by the FAO Africover Project. Their survey mapped 967 km^2 of permanently flooded swamp and 1,947 km^2 of seasonally flooded swamp – a total of 2,913 km^2 of flooded land. They also map 5,392 km^2 of grassland with no trees or shrubs. It is possible that part of these grasslands could also be seasonally flooded.
- Sutcliffe and Parks (1999) using a water balance model estimated the area of inundated land as varying between 1,500 and 6,000 km^2 over a 5 year period (1950-55). An examination of a December 1986 thermal infra red image suggested an approximate "evaporating" or flooded area of 3,000 km^2, close to the Africover figure.
- Thus the area of "seasonally" flooded vegetation that is actually mapped depends very much on the year the satellite imagery was taken. In a high rainfall year more flooded vegetation will be mapped than in a dry year. Also it important to note that interpreting vegetation (particularly seasonally flooded land) using satellite imagery in this area is extremely difficult as many areas are burnt. (Because of the problems of cloud cover satellite imagery is only available for the dry season.)
- In conclusion, it is possible that the area of permanent Papyrus, Phragmites and Typha swamp may be relatively small and given the extreme variability of permanent water levels the area of Papyrus and Vossia swamp (which prefers constant and deep water) may be very small indeed. Given the variability of the spilling and seasonality of rainfall the area of seasonally flooded land can vary widely from year-to-year. Thus, the Machar Marshes are very different from those of the Sudd in terms of the small area of permanent swamp and the extremely variable area of seasonal swamp.

- **Drainage through the marshes**: The drainage pattern within the area has been mapped by this Project using 2005 Landsat imagery (Figure 3.8). The general pattern accords with that of the JIT survey (JIT, 1954). Water passes through the swamps by three main routes. Firstly, water from the eastern Baro passes through the Khor Machar and other spills that join to form the Khor Adar, which eventually joins the White Nile. This khor has a channel some 100 m wide and 2.5 m deep separated by alluvial banks from a flood plain 800 m wide. However, the channel is normally choked with grass, and except in extraordinary high rainfall years little water reaches the White Nile. The average outflow is estimated at 0.150 km^3.
- Secondly, water from the eastern torrents (the Tombak, Yabus, Daga and other small streams) link up on the Khor Daga that in turn links up with the Khor Adar.
- Thirdly, there is a tributary of the Khor Machar that flows parallel to the Sobat becoming the Khor Tiebor that in turn becomes the Khor Wol. The Khor Wol eventually joins the White Nile at Kodok. The average outflow of the Khor Wol is 0.100 km^3 although exceptionally it can reach 1.0 km^3.
- **Water balance of the marshes:** There are four components of the water balance: (i) northward spills from the Baro, (ii) the eastern khors from the Ethiopian escarpment, (iii) rainfall over the marshes, and (iv) evaporation/evapotranspiration. The Waterwatch Study focussed only on the balance between rainfall and evaporation and used a different method to estimate the loss by evaporation of the two inflow components.
- **Inflows into the Marshes: Spills from the Baro:** Spills from the Baro occur to both sides of the river during the flood peak when flows exceed 1.5 km^3 between July and October, with spills from the upper Baro earlier than those from the lower Baro. Total spill as estimated by the JIT Study varies between 1.0 to 6.0 km^3 with a mean spill of 3.60 km^3. Approximately 2.82 km^3 (including the Khor Machar) flows north to the Machar Marshes through the Khor Machar, Khor Wakau, other spill channels and by over-bank flooding. Some 0.4 km^3 returns to the Sobat via the Khor Wakau on the receding flood. The MIT Study made an estimate of 3.54 km^3 but included spill during low flows of the Baro-Sobat. If these are excluded their estimate is 2.873 km^3. Sutcliffe and Parks using the 1950-55 (years with below average rainfall) flow data estimated northward spill as 2.328 km^3.
- Assuming similar channel size exists in the same reach (which is unlikely as there will be channel size reduction due to silt deposition at the river bed) the spillage from Baro river for similar reach for years 1980 to 2000 is averaged to be 3.03 bcm with the annual spillage ranging from 1.1bcm to 4.6 bcm. However, it can be inferred, from practice, that spillage in these recent periods is expected to be more than 3.03 bcm due to the fact that the channel capacity of Baro river in the then mentioned reach must have been reduced due to silt deposition, which intern aggravates spillage. Based on the above conclusions of the JIT, the inflow to the Machar wetland from the spillage of Baro river (for years 1980 – 2000) is estimated to be more than 2.374 bcm (OSI Water Report for Ethiopia, 2007). Figure 4.10 presents the comparison of the Machar inflow from the Baro spillage for two periods (1905 – 1950 and 1980 – 2000) at different periods.

Figure 4.10: Mean Monthly Inflows from Baro to Machar Marshes (1905-55 & 1980-2000)



- **Inflows into the Marshes: Eastern Torrents:** The JIT also investigated the runoff entering the Machar marshes from the 'eastern torrents', a term they coined to describe inflows that originate on the Ethiopia Escarpment and drain an area of approximately 10,300 km². The two main khors are the Yabus and Daga and by erecting measuring structures on the Yabus at Yabus Bridge and on the Daga at Daga Post, they estimated their total drainage area to be 5000 km^2. Accordingly, the mean annual inflow to the Machar wetland from the eastern torrents is estimated to be 1.744 billion cubic meters, based on the gauged values and applying a runoff coefficient of 15% for the un-gauged part of the watershed ((Sutcliffe & Parks, 1999).
- **Water balance components:** The JIT (1954) summarized the water balance components of the Machar wetland (Table 4.4).

Table 4.4: Machar Marshes Water Balance

Million cubic metres

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Spill from Baro towards Machar (1905 - 1955)												
0	0	0	0	0	44	218	504	738	689	135	0	2328
Spill from Baro River (1980 - 2000)												
0.0	0.0	0.0	0.0	0.0	22.2	396.6	954.9	1096.3	551.1	11.4	0.0	3032
Inflow of Yabus at Yabus Bridge (1950 - 1955)												
9.88	4.7	3.39	3.15	8.59	17.7	30.1	88.7	118	108	42.8	19.6	455
Inflow of Daga at Daga Post (1950 - 1954)												
1.78	1.24	0.31	1.04	5.85	16.4	48.1	113	93.8	91.5	36.3	10.9	421
Total Estimated inflows from east Torrents to the Machar Swamp (1950-1955)												
23	12	7	8	29	68	156	401	423	398	158	61	1744
Average Rainfall over the Machar Watershed (1905- - 1955, mm)												
0	2	3	31	109	126	179	241	139	77	26	0	933

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Evaporation (mm)												
217	190	202	186	183	159	140	140	150	177	189	217	2150

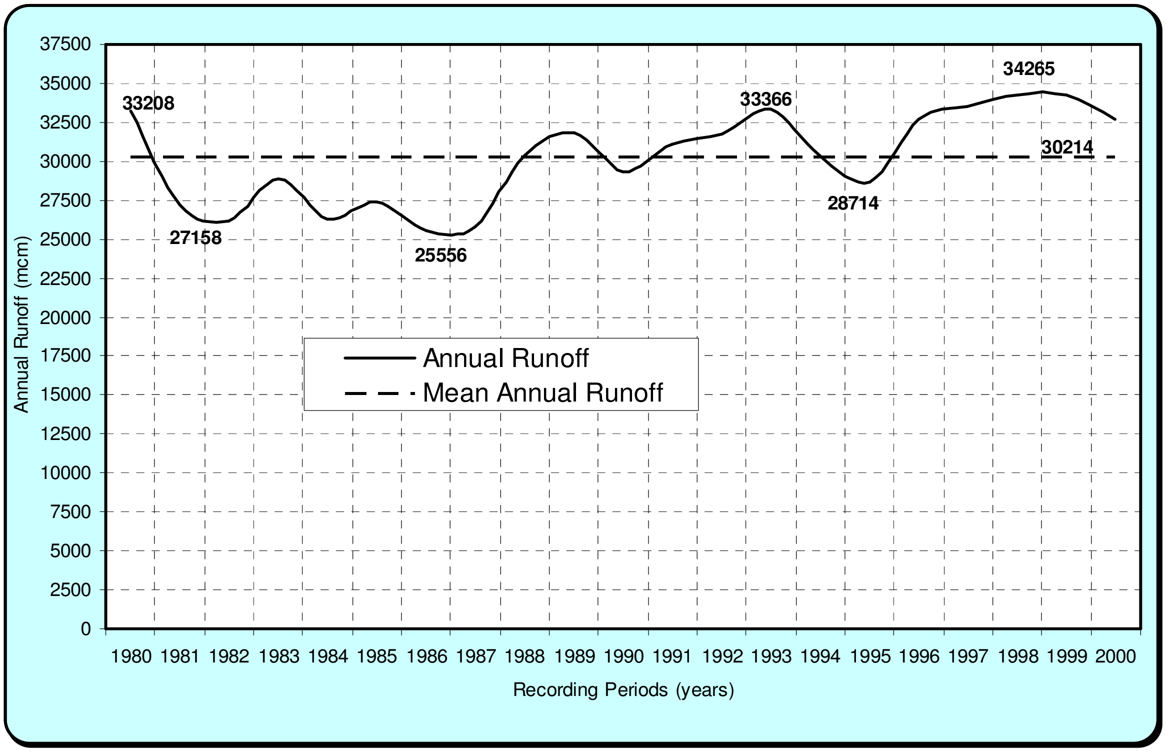
Source: MIT (El-Hemry & Eagleson, 1980)

- **Mean annual runoff:** Based on the mean annual rainfall and a gauged runoff coefficient of 15 per cent, total mean annual runoff was estimated by the JIT to be 1.744 km^3. The MIT study estimated total runoff from the Eastern Torrents to be 4.2 km^3 and a further runoff from the clay plains of 1.41 km^3. Sutcliffe and Parks (1997) consider these to be severely over-estimated and used the JIT estimate.
- **Direct annual rainfall:** The JIT study estimated that direct annual rainfall on the Marshes was 800 mm giving a total annual supply of 15 km^3 (over an area of 20,000 km^2). The MIT Study used a mean annual rainfall of 933 mm over an area of 8,700 km^2 giving an annual supply of 8.12 km^3. Sutcliffe and Parks estimated the average annual rainfall 1950-1955 to be 933 mm over a mean flooded area of 3,350 km^2 giving an annual supply of 3.125 km^3. Waterwatch estimated the annual rainfall for the year 2001 using the Tropical Rainfall Measuring Mission (TRMM) satellite sensor as 784 mm.
- **Mean annual losses:** Losses from the area include (i) drainage to the White Nile, and (ii) evaporation. Drainage to the White Nile is through Khors Adar and Wol. Mean annual loss through the Ada was estimated to be 0.150 and that through the Wol at 0.100 km^3.
- **Annual evaporation rate:** The MIT used an annual open water evaporation rate of 1,340 mm/yr whilst Sutcliffe and Parks estimated the annual evaporation rate to be 2,150 mm. No allowance for soil re-charge was made as it was assumed the soil moisture had already been recharged when the khors and spills begin to flow. The Waterwatch study estimated annual evaporation as 972 mm using the SEBAL energy balance model on MODIS Satellite 1 km data. Map 7 in this report indicates annual evaporation rates over the Machar Marshes as between 1,666– 1,900 mm. There are clearly considerable differences between these estimates.

White Nile

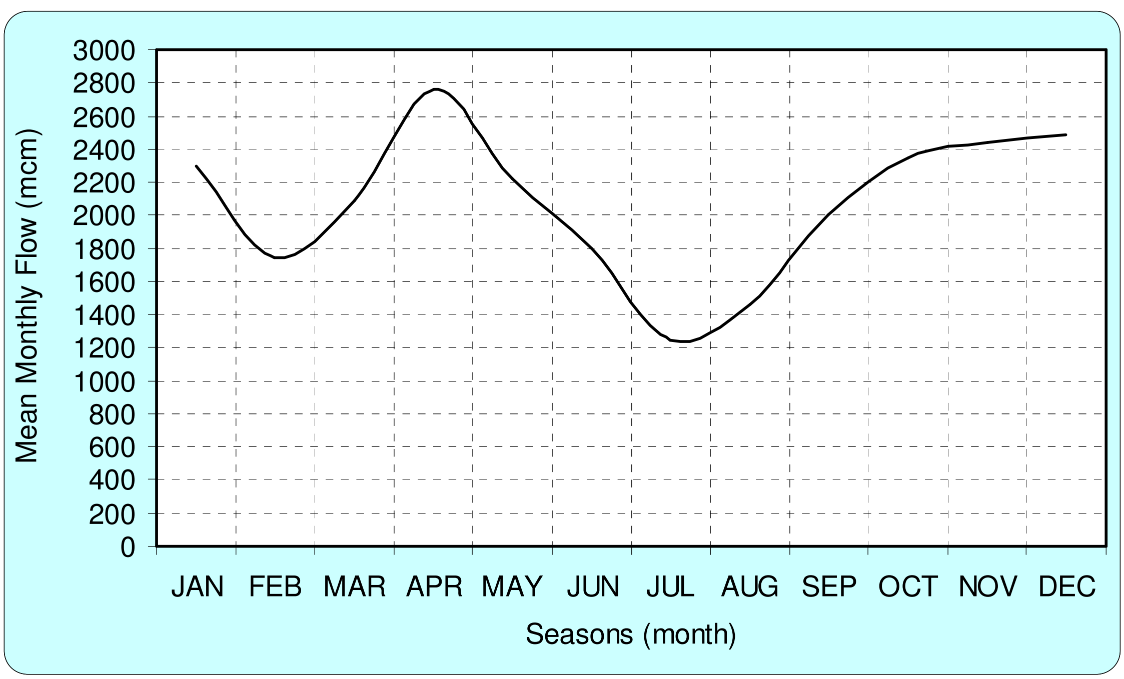
- **Location**: The White Nile system starting from the Malakal station is formed from the Sobat river, flowing from the general east and south-east directions (Baro, Gillo & Pibor being major constituents) and the outflow of the Sude flowing from the general south direction and the latter being hydraulically connected to the great East African Lakes through the Bahr El Jebel basin in its further south upper course and to the Bahr El Ghazal basin in the western direction
- **Inflows:** The flow from this huge watershed has been recorded at Malakal, a town where the eastern and southern sub basins of the WN system make a confluence, located in the entrance (upstream reach) of the White Nile system and at Jebel Aulia located at the mouth of the White Nile system. Monthly runoff record from 1980 to 2000 both at Malakal and Jebel Aulia has been made available for the synthesis from? The mean annual runoff entering the White Nile system at Malakal is recorded to be 30.214 bcm (1980-2000) and the mean annual outflow (1980 – 2000) at Jebel Aulia at the mouth of the White Nile System is recorded to be 26.0 bcm.

Figure 4.11: Seasonal Distributions of Inflows Entering the White Nile River at Malakal (1980-2000)



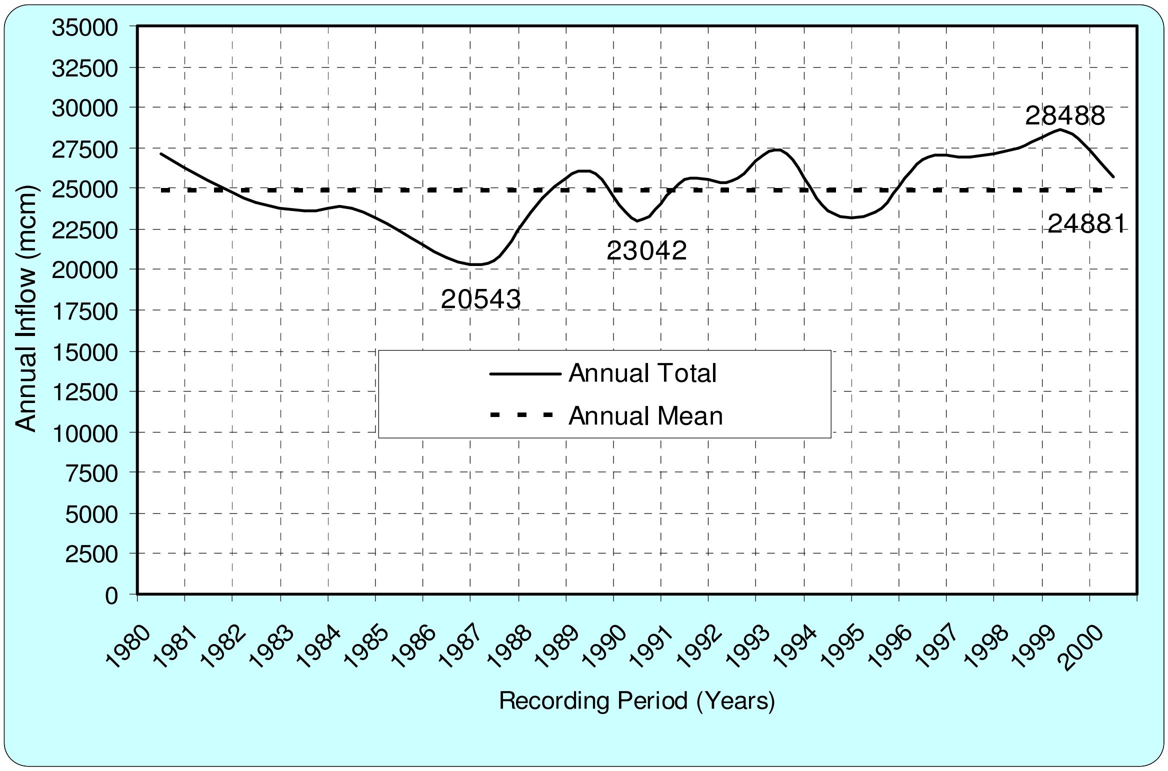
Source:OSI synthesis report on water related issues
[Raw data source: Sudan Ministry of Irrigation and water]

Figure 4.12: Annual Runoff Series of WN at Malakal



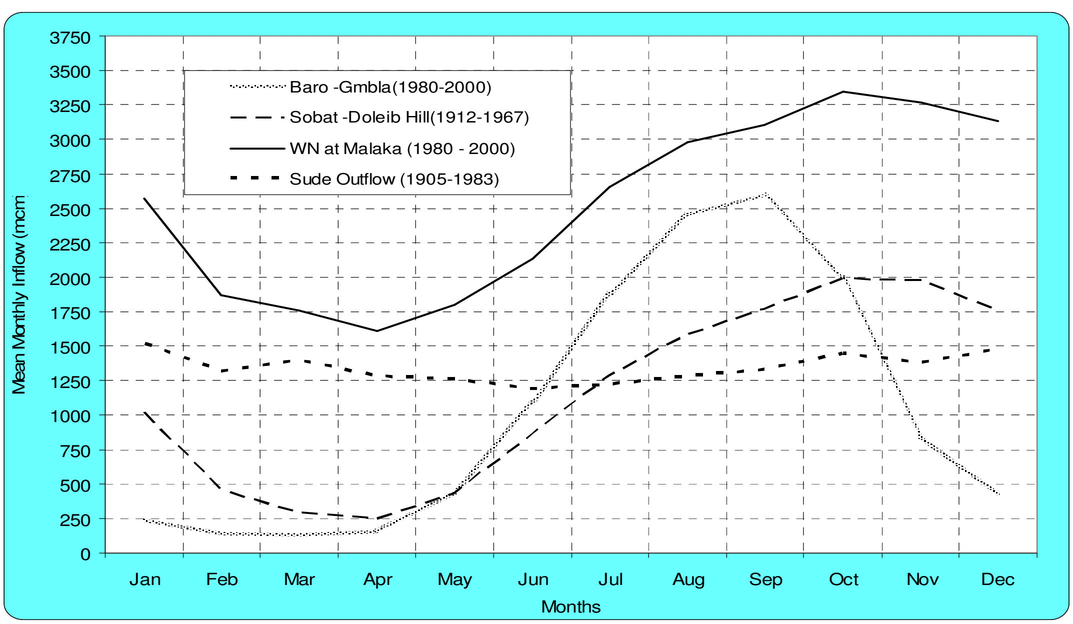
Source:OSI synthesis report on water related issues
[Raw data source: Sudan Ministry of Irrigation and water]

Figure 4.13: Seasonal Inflow Distribution of WN System at Jebel Aulia Station (1980-2000)



Source:OSI synthesis report on water related issues
[Raw data source: Sudan Ministry of Irrigation and water]

Figure 1.14: Annual Flow series of WN System at Jebel Aulia



Source:OSI synthesis report on water related issues
[Raw data source: Sudan Ministry of Irrigation and water]

The runoff at Malakal starts peaking in June and recedes in January getting at its minimum in April (fig 3.18 above). This seasonal distribution is different as compare to the inflows coming from the Ethiopian highlands. This could be factored due to the presence of the flood plain/wetlands u/s of the Sobat confluence, such as Machar and the vast seasonally flooded low land plains, from the eastern watershed side and the presence of the Sude flood plain/wetland u/s of Malakal from the basins in the southern direction. These flood plains have considerable routing effect on the inflows and could widen the base of the inflow hydrograph, which has resulted delays for peaks and a relatively smooth & mild slope in the rising limp of the hydrograph. At Malakal, the flow starts peaking in May/June get its maximum in October and gets into its recession limp up to February, seemingly it is flowing as a base flow starting at the end of February and through the months March, and April. The inflow from the Ethiopian highlands, on the other hand, starts peaking in April/May get in to the rising limp of the hydrograph until July/August, reaching its maximum inflow in August/September and are in the recession limp until the end of November. The flow distribution at Gambella and Malakal reveals that the peak is delayed at an average by 1.5 to 2 months due to the routing effect of the spills largely from the Baro and the Pibor rivers. This delay is also detected at Jebel Aulia station. The flow at Sobat Dolleib hill and WN at Malakal are observed to have similar seasonal distribution pattern.

Mean annual outflows: Between Sobat Mouth and its junction with the Blue Nile, the White Nile falls about 13 m in 840 kms. The inflows from tributaries are low and sporadic. The natural regime has been affected by the Jebel Aulia dam that was constructed in 1934-37. The average (1905 – 1983) annual outflow from the Sudd is 16.091 km^3.

- **Seasonal variation:** There is little seasonal variation with mean monthly flows varying from 1.188 km^3 in June to 1.515 km^3 in January. It is the Sobat inflow that provides some seasonality to the White Nile flow.
- **Mean annual flow:** The mean (1905-83) annual flow of the Sobat at Doleib Hill is 13.530 km^3, with a mean monthly variation of 0.273 km^3 in March to 1.992 km^3 in October. The Sobat flood is attenuated by the spill both to the Machar Marshes and to the southern plains.
- **Annual flow reductions:** Between Malakal and Mogren (Khartoum) the White Nile mean (1961-95) annual flow reduces from 32.85 km^3 to 28.13 km^3 (a mean reduction of 4.72 km^3) due to abstraction and evaporation. However, these reductions have been increasing from a low reduction of about 3.0 km^3 in 1978 to about 6.00 km^3 in 1995 (Sutcliffe & Parks, 1999: fig. 8.4), although the rise is not explained· A part of this increase would be due to the start-up of the Kenana Sugar Scheme in the late 1970's.
- **Evaporation losses:** A Waterwatch Study for the ENSAP JMP on the evaporation from the Jebel Aulia Dam estimated the (2001) evaporation to be 1.766 km^3 although Abdel A. Ahamed (2006) reported evaporation losses from the reservoir 2.5 km^3. The Waterwatch study estimated gross evaporation loss from the Kenana Sugar Scheme as 0.612 km^3.

Runoff in the sub-basin

- **Overview**: The highest runoff rates occur over the Ethiopian Highlands and the western escarpment (Figure 4.16). Very low runoff rates are recorded from the southern clay plains, the north-eastern clay plains and the cover sands of North Kordofan State. Intermediate rates are found to the west of the Ethiopian Escarpment and the northern parts of the Pibor Catchment.

Table 4.5: Summary of surface water resources

Name of basin	Catchment area (km^2)	Mean annual runoff (MAR) km^3/yr
Baro Masha	1,653	1.792
Baro 1 site	2,333	2.356
Baro- Kella	4,937	3.473
Baro Gambela	23,461	12.230
Baro: Itang	24,636	10.710
Baro: Jikawo	26,940	11.174
Baro: Border in Ethiopia	30,004	
Baro: Border in Sudan	8,396	
Baro: Total	**38,400**	**9.500**
Akobo-Pibor: in Ethiopia	45,906	
Akobo-Pibor: in Sudan	39,994	
Akobo-Pibor: Total	**85,900**	**3.100**

Source: Feasibility Study of the Baro Multipurpose Project: Volume 1-table 14.2.

- **Loss of runoff:** Available data suggests a major loss of runoff in the sub basin, largely through evaporation losses in the flood plain, and partly through seepage, as the soil is mostly of high clay content, and partly through reduction in rainfall along the low-lying flood plain (about 88%) of the sub basin. This is seen in the data presented above: The weighted mean annual runoff in the upper course of the sub basin (eastern watersheds in the Ethiopian Highlands) is estimated to be 750 mm with a weighted runoff coefficient of more than 40%, but descending down to the Gambella low-lying flood plain (for instance at Gambella), the weighted mean annual runoff is reduced to 415 mm with a runoff coefficient of 30%. Further, at the Ethio-Sudan border the effective rainfall is reduced to 300 mm and at Malakal, the weighted mean annual effective rainfall is even below 75 mm, with a runoff coefficient of 7% at weighted mean annual rainfall of 1057 mm.

- **Regulation strategies:** Upstream regulation works would undoubtedly save much of the runoff lost in the flood plains and in the lower course of the sub basin. Also upstream regulation works would help to capture high runoff before it joins the low-lying flood plains and would substantially help in the flood management works of the Gambella low-lying flood plains and the Machar wetland, available in the system in its further downstream reaches.

Water balance of the sub-basin

- **Mean Annual Inflows: Baro Upstream of Gambella:** The mean annual contribution of the Baro river u/s of Gambella is 12.412 bcm (1980-2000) and constitutes about 40% of the balance of the WN system at Malakal. According to the investigation made by JIT, in 1955 (Sutcliffe & Parks, Feb 1999), this inflow was averaged at 13.4 bcm (1905-1955). In its lower course b/n Gambella and its mouth or the confluence with Sobat the flow spills over the extended wide low-lying flood plain taking place on both sides of the river bank, with large proportions spilling through the right (north) bank to the Machar wetland (Hurst, 1950 & JIT investigations, 1954). In this reach mean annual spillage is estimated to be above 3.03 bcm (1980-2000). As per to JIT investigations this spillage is estimated to be 3.6 bcm (1905-1955). Large proportion of this spillage (more than 2.374 bcm (1980-2000) enters the Machar swamp through the Khol Machar channel and some portion is returned back to directly the Baro system through the Adura channel and to the Pibor river and the Sobat system through the Mokwai and other small flood plain channels.
- **Mean annual inflows: Baro:** The mean annual inflow upstream of the Adura junction is averaged at 9.068 bcm (1905 – 1955) which is less than the mean annual inflow at Gambella, indicating spillage losses in the system. Mean annual inflow of Baro downstream of the Adura junction is recorded to be 11.236 bcm (1905-1955, JIT, 1954), which indicates that some of the spilled water might have met the Baro system through the Adura and some other channels at their junction with the Baro river. At its mouth mean annual inflow is recorded to be 9.534 bcm (1905 – 1955) indicating the loss due to spillage again through the Baro itself.
- **Mean annual inflow: Sobat**: Mean annual inflow in the Sobat system downstream of the Sobat mouth is recorded to be 12.893 bcm (1905-1955) indicating gains from the Pibor river and also the return of some of the spillages through the Mokwai channel.
- **Mean annual inflows: Gillo**: The mean annual inflow from the Gillo river to the Pibor river at Pugnido is recorded as 3.2 bcm (1977- 2000). The mean annual inflow of Gillo river at its confluence with Pibor is, however, averaged at 1.12 bcm (1905 – 1955, JIT Investigations, 1954).
- **Mean annual inflow: Pibor:** The inflow from Pibor river upstream of the Akobo confluence is estimated as 0.224 bcm (Baro-Akobo master plan studies, May 1997) and this inflow is averaged at 1.04 bcm (1905-1955, JIT investigations, 1954). The contribution from Akobo river is estimated to be 3.879 bcm (Baro-Akobo Master Plan Studies, May 1997) and at its confluence with the Pibor this inflow was reported by the JIT investigation (1954) to be 0.37 bcm (1905-1955). From similar sources the inflow to

Pibor from Mokwai is averaged at 1.3bcm. However, the inflow of Pibor river upstream of its confluence with the Mokwai is recorded at 1.95 bcm indicating the possibility of spillage from the Pibor river upstream of its confluence with the Mokwai. Some of this spillage joins the Sobat system in its further downstream reach. This is probably demonstrated by an increased mean annual inflow record, 13.687 bcm (1905-1955), at the Doleib hill located u/s of the Malakal station.

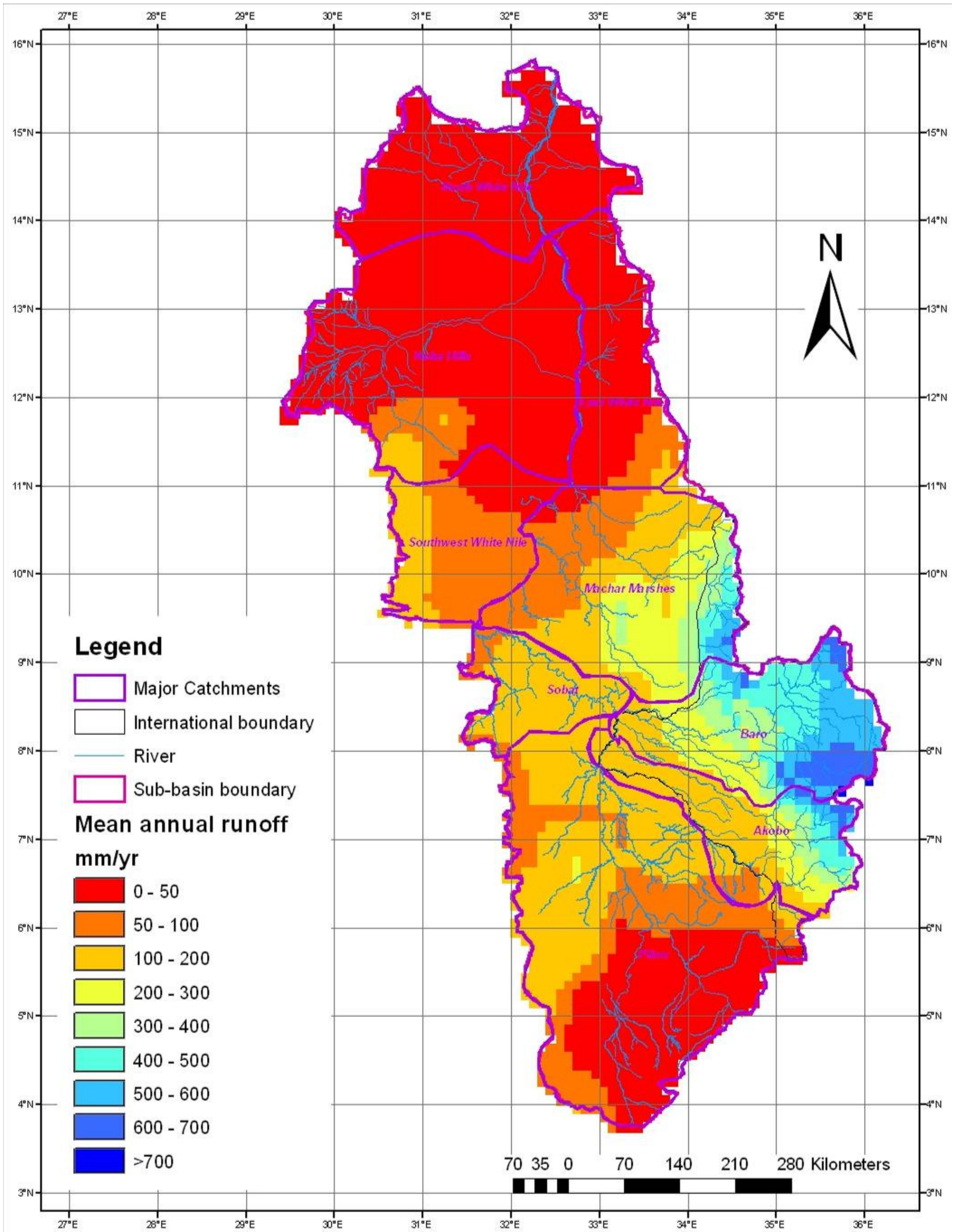
- **Mean Annual inflow: Sude**: At Malakal, mean annual inflow from the Sude is estimated as 16.813 bcm and together with the Sobat system, producing a mean annual inflow of 30.50 bcm to the WN system.
- **Mean Annual Inflows: White Nile System:** At Jebel Aulia station, the mouth of White Nile, the mean annual inflow of the White Nile system is averaged at 26 bcm (1980-2000), the difference could be attributed to (i) evaporation losses at the Jebel Aulia reservoir and from the flood plains between Malakal & the Jebel Aulia reservoir, and (ii) the consumptive use of irrigation projects (Kenana and Assalaya sugar schemes with 63531 ha and 16613 ha, with gross irrigation water requirements of 0.642 bcm and 0.125 bcm respectively) , which all together are estimated at 4.5 bcm. Evaporation loss from Jebel Aulia reservoir is averaged at 2.12 bcm (Sudan OSI water Component Report, May 2006). The White Nile system at Khartoum is thus believed to contribute about 30% of the Nile inflow at Aswan. The White Nile system at Malakal contributes 36% of the inflow at Aswan; the reduction in its contribution (less by 6%) at Khartoum is attributed to the evaporation losses and abstractions for irrigation requirement made for the reach between Malakal and Jebel Aulia. At Malakal the Sobat and the Sude contributes 16% and 20% of the Nile inflow at Aswan dam respectively. Schematic presentation for the indicative water balance of the sub basin is presented in Figure 3.23 below.
- **Peak flows:** The peak flows of the major rivers closely match the rainy season, with peak discharge occurring during September.
- **Summary of surface water resources:** The mean annual runoff for the different catchments in the sub-basin are given in Table 4.6 below.

Table 4.6: Summary of surface water resources

Name of basin	Catchment area (km^2)	Mean annual runoff (MAR) km^3/yr
Baro Masha	1,653	1.792
Baro 1 site	2,333	2.356
Baro- Kella	4,937	3.473
Baro Gambela	23,461	12.230
Baro: Itang	24,636	10.710
Baro: Jikawo	26,940	11.174
Baro: Border in Ethiopia	30,004	
Baro: Border in Sudan	8,396	
Baro: Total	**38,400**	**9.500**
Akobo-Pibor: in Ethiopia	45,906	
Akobo-Pibor: in Sudan	39,994	
Akobo-Pibor: Total	**85,900**	**3.100**

Source: Feasibility Study of the Baro Multipurpose Project: Volume 1-table 14.2.

Figure 4.16: Baro-Sobat-White Nile Sub-Basin: Mean Annual Runoff (mm/yr)



Source: USGS/gtopo30/HYDRO30

Groundwater

Quantitative estimates of groundwater in the Sudan are rather approximate and considerable efforts are needed to arrive at more accurate figures.

The Baro-Akobo Catchment has two basic types of aquifers (MWR: Baro-Akobo Master Plan, 2001). One is associated with fracture and crush zones in the Basement Complex rocks and the other in the Pliocene to Quaternary alluvium, an unconsolidated sedimentary porous medium. Basement Complex aquifers characteristics vary with the degree of fracturing and area continuity that exists in otherwise impermeable bodies of metamorphic and/or igneous rock. Rock type and mode of emplacement usually have little relationship to Basement Complex permeability. The available information indicates production rates to be generally less than one litre per second (1 lt/s).

The alluvium constituting the aquifers in the Baro and Pibor Plains is usually fine sand to silt. Water yields from wells constructed in these aquifers range from about 0.01 – 1.01 litres per second. Static water levels of wells in these aquifers usually vary from ground surface to about 7.0 meters below ground surface.

In areas of the Unconsolidated Sediments that stretch from the Sobat Basin and then down the Main Nile and across to the Blue Nile the hydro-geological system comprises two aquifers: an upper and a lower (Farah et al., 1997). The upper aquifer includes mainly the Upper Gezira Formation and the upper part of the Lower Gezira formation in the area between the Blue and White Nile. The lower aquifer is developed mainly in the deeper Nubian Sandstones. The water storage in the lower aquifer is some eight times that of the upper aquifer. Except for a few isolated localities water quality is free from impurities for drinking and irrigation requirements.

West of the White Nile in the south Basement Complex rock outcrop to form the Nuba Mountains and are likely to be similar to the basement Complex aquifers in the Blue Nile and Atbara Sub-basins. There the presence of groundwater varies with the degree of fracturing and is limited to deep cracks in otherwise impermeable bodies of metamorphic and/or igneous rock. North of the Basement Complex rocks cover sands initially overly the Nubian Sandstone aquifer until its outcrops in the north-western part of the Sub-basin. Everywhere groundwater depths are 241 to 310 meters. Estimated water yield of the Umm Ruaba Basin is 1.7 cubic kilometres and that from the Nahud Basin 0.1 cubic kilometres (MEPD-HCENR, 2003).

DAMS AND RESERVOIRS

Alewero reservoir in the upper course of the Baro watershed in Ethiopia, and the Jebel Aulia reservoir at the mouth of the White Nile in the Sudan are the two dams/reservoirs existing in the sub basin.

Existing Dams and Reservoirs

Alewero Reservoir

- ***Reservoir Features***: This reservoir is located in the upper course of the Baro watershed, at Alewero River, in Ethiopia. The reservoir was initially built for irrigation purposes and currently its operation is not active.
- ***Reservoir Sedimentation***: Since no specific data is available for the specific reservoir it is difficult to infer the situation directly. However, during the master plan study of the Baro-Akobo basin in Ethiopia (Baro-Akobo Basin Master Plan Studies, May 1997), sediment data record available for six sub watersheds (Keto, Gumero, Ouwa, Sor, Gecheh and Begwuha) were used to estimate annual sediment load in the system. The measurements from these stations were used to establish sediment rating curves (Table 4.7). The estimate has used a synthetic duration curve as it was difficult to

effect an integration techniques in its strict sense, due to the absence of daily flow duration curves for these stations. According to this estimate, the mean annual sediment yield (table 4.7) is observed to be in the range of 35 t/km^2 per year (Gumero river 106 km^2, mean annual flow of 2.05 m^3/s) to 324 t/km^2 per year (Keto river, 1006 km^2 & mean annual flow of 17.6 m^3/s). According to the same source this sediment load is equivalent to mean annual loss of 3 mm depth of soil from the agricultural land in the upper course of the sub basin.

Table 4.7: Average Annual Sediment Yield in the Upper Course of the Sub Basin

River/Sub Watershed	Drainage Area (km^2)	Mean Annual Flow (m^3/s)	Sediment Rating Curve Equation	Annual Sediment Load (t/yr/km^2)
Keto	1006	17.60	$Qs = 0.01010q^{0.974}$	324
Gumero	106	2.05	$Qs = 0.00372q^{0.720}$	35
Ouwa	288	5.80	$Qs = 0.00089q^{1.419}$	284
Sor	1620	53.60	$Qs = 0.00130q^{1.189}$	124
Gecheh	79	1.90	$Qs = 0.00056q^{1.220}$	63
Begwuha	125	3.30	$Qs = 0.0011q^{1.145}$	85

Source: ????

Notes: Qs = Daily Sediment Load (MT/day per km^2); and q (the discharge module) = (daily flow/mean annual flow)

- ***Uses of reservoir water***: The reservoir is used for both irrigation and hydropower.
  - Irrigation: The existing Alewero reservoir was initially planned to command 10,400 hectares of agricultural area, but this potential is not fully developed and there is no data regarding the current level of irrigated agriculture development from this reservoir.
  - Hydro-power*:* According to the Baro-Akobo Integrated Master Plan Project that at 60% project efficiency the hydro-module is estimated at 13,106 cubic metres per hectare per year.
- ***Impacts of sedimentation:*** This magnitude obviously poses a considerable threat both for reservoir life and agricultural production, as land degradation due to soil loss from agricultural land affects food production and hence food security.

Jebel Aulia Reservoir

- **Reservoir Features:** - This reservoir is located at the mouth of the White Nile. It was built in 1937 with a storage capacity of 3.5 billion cubic metres. Mean annual evaporation from the reservoir is averaged at 2.12 billion cubic metres. No seasonal distribution is available. In between the Malakal and the reservoir there is a wetland which is flooded seasonally and mean annual evaporation loss is averaged at 2 billion cubic metres (Sudan OSI water component report, May 2006). Other important features of the reservoir (water surface area, time series for reservoir levels, catchments area, etc) are not provided in the Sudanese OSI water component report.
- **Reservoir Sedimentation:** After being in the operation for nearly seven decades, reservoir sedimentation is not yet a threat for the Jebel Aulia reservoir. It still maintains its original designed storage capacity (Sudan OSI water Component report, May 2006). The presence of the flat land in the lower courses of the Baro river (Gambella low-lying plain) and the Pibor tributaries (Akobo, Gillo & Alewero), the entire watershed of the Sobat river & the Machar wet land in the eastern portion of the sub basin and the presence of the Sude in the south portion, are serving as a filter for any sediment load coming from the highland portions of the sub basin. And this is the reason why the Jebel Aulia reservoir is not threatened by sediment load, unlike

other reservoirs like the Sennar (60% storage capacity lost), Roseires (35% storage capacity lost) and El-Girba (57% storage capacity lost) in the Blue Nile and Tekeze-Setit-Atbara sub basins.

- ***Uses of Reservoir water***: The reservoir is used for both irrigation and hydropower.
  - Irrigation: Upstream of the Jebel Aulia reservoir, pump abstractions for irrigation is currently underway for both large and small-scale agricultural development on both government and private land. The current irrigated agriculture practice constitutes public and private pump abstractions at small scale level (an average plot size of less than 50 ha). The Assalaya and Kenana sugar schemes with a total command area of 80,144 ha (16,613 ha and 63,531 hectares respectively) are the two state owned large scale irrigated farms in the system. These two large scale farms are largely meant for sugar cane production. With a total command area of around 300 hectares (seven small scale schemes with a total area of 700 feddans, as reported in the Sudan OSI water component report), small scale level irrigated farms are also under operation in this lower course of the sub basin. Moisture stress in this lower course of the sub basin is considerably high as observed through the prevalence of high computations for irrigation water.
  - Hydropower: At 60% project efficiency (Sudan OSI report, May 2006) the hydro-module is estimated at 10,125 cubic metres per year per year with mean annual abstraction of about 820 million cubic metres, including abstractions for small scale projects. The hydro module appears to be under estimated as compared to the hydro module in the upstream course Alewero project.).
- **Evaporation loss:** The Jebel Aulia reservoir with a total storage capacity of 3.5 billion cubic metres has an evaporation loss of 2.12 billion cubic metres per year on average.

Potential Water Infrastructure Identified

- **Dams and reservoirs:** Several dams and reservoirs have been identified in the upper course of the sub basin. Integrated Master Plan Studies were conducted in 1997 by the Ethiopian Government for the Baro-Akobo basin, which identified 14 dams and reservoirs, five for irrigated agriculture development, one for multi-purpose development and eight for hydropower development purposes. A schematic of these reservoirs is presented in Figure 3.24 below and salient features are presented in Tables 4.8 and 4.9.
- **Irrigation Projects:** Irrigation projects have been planned in both Ethiopia and Sudan.

Table 4.8 Identified Reservoirs and/or Dams for Irrigation Purpose in the Baro-Akobo-Sobat-White Nile Sub Basin

DAM NAME	ITANG LARE	DUMBONG	CHIRU	GAMBELLA	GILLO-2	GILLO-1
Catchments Area (km^2)	24420	1100	733	22740	9640	7570
Mean Annual Flow (m^3/s)	390	7.8	5.5	372	92.3	74.1
Dam type	Earth fill	Rollcrete	Earth fill	Rock fill	Earth fill	Rock fill
Dam Height (m)	11	48	37	50	36	107
Crest Level (masl)	436	518	517	490	478	612
Normal Max Operating Level (masl)	431.6	513.5	512	485	472	606.6
Normal Min. Operating Level (masl)	428.5	506	504	482	460	578.6
Active Storage(mcm);	157.9	93.3	132.5	214	1427.6	2341
Dead Storage(mcm);	88.6	66.2	115.1	1239	564.1	874
Reservoir Surface Area (km^2);	71	13.9	21.8	74.5	150.7	116.8

DAM NAME	ITANG LARE	DUMBONG	CHIRU	GAMBELLA	GILLO-2	GILLO-1
Spillway Design Flood (m^3/s);	1397	600	100	1740	665	1065
Gates	None	None	None	None	None	3-7 m * 6 high
Max.Flood Level (masl);	434	515.5	514	487	475	609
Irrigation Outlet Capacity (m^3/s);	100 max each bank	20	18	200	61 (RB) 35(LB)	200
Gates	8-5 m * 5m high	2-5m * 2.5m high	2-5 m * 2.5 m high	8-5 m *5 m high	8-5m *2.5m high	2-1 m * 3.5 m high

Table 4.9 Identified Reservoirs and/or Dams for Hydropower Purpose in the Baro-Akobo-Sobat-White Nile Sub Basin

DAM NAME	Baro	Geba-A	Birbir-A	Gumero	Birbir-R	Sor
Catchments Area (km^2)	1620	1086	3579	443	6840	1770
Mean Annual Flow (m^3/s)	49.9	35.9	57.9	8.7	105.9	53.7
Dam type	Earthen	Earthen	Earthen	Rock	Rock	Earthen
Dam Height (m)	45	45	56	33	190	66
Crest Level (masl)	1725	2175	1436	1613	1163	1544
Normal Max Operating Level (masl)	1720	2170	1430	1608.5	1158	1539
Normal Min. Operating Level (masl)	1710	2160	1410	1600	1056	1513
Active Storage(mcm);	483	550	827	160	2490	184
Dead Storage(mcm);	117	315	273	140	180	59
Reservoir Surface Area (km^2);	78.5	65.8	65.7	30.9	57.5	13.6
Spillway Design Flood (m^3/s);	460	270	340	60	726	672
Gates	Ungated	Ungated	Ungate	Ungate	3-6m*4mhigh	3-6m*5.5mhigh
Max.Flood Level (masl);	1722	2172	1433	1610	1160	1541
Irrigation Outlet Capacity (m^3/s);	55.2	48.3	89	12.8	360	200
Gates	1-2m*2m	1-2m*2m	1-2m*2	1-.8m*.8m	2-1.83m*3.66m	2-1.8m*2.8

Table 4.9 Cont'd			
DAM NAME	**GILLO-1**	**Thams**	**Gaba-R**
Catchments Area (km^2)	7570	20970	6220
Mean Annual Flow (m^3/s)	74.1	329	143.1
Dam type	Rock fill	Rock fill	Rock fill
Dam Height (m)	107	270	240
Crest Level (masl)	612	765	1120
Normal Max Operating Level (masl)	606.6	760	1115
Normal Min. Operating Level (masl)	578.6	705	1083
Active Storage(mcm);	2341	4807	1365
Dead Storage(mcm);	874	5543	2535
Reservoir Surface Area (km^2);	116.8	105	53.1
Spillway Design Flood (m^3/s);	1065	1365	920

Gates	3-7m*6high	3-6.75m*8high	3-8*6m high
Max. Flood Level (masl);	609	762	1117
Irrigation Outlet Capacity (m^3/s);	200	1200	400
Gates	2-1M*3.5high	4-1.83m*3.66high	2-1.5m*3.5mhigh

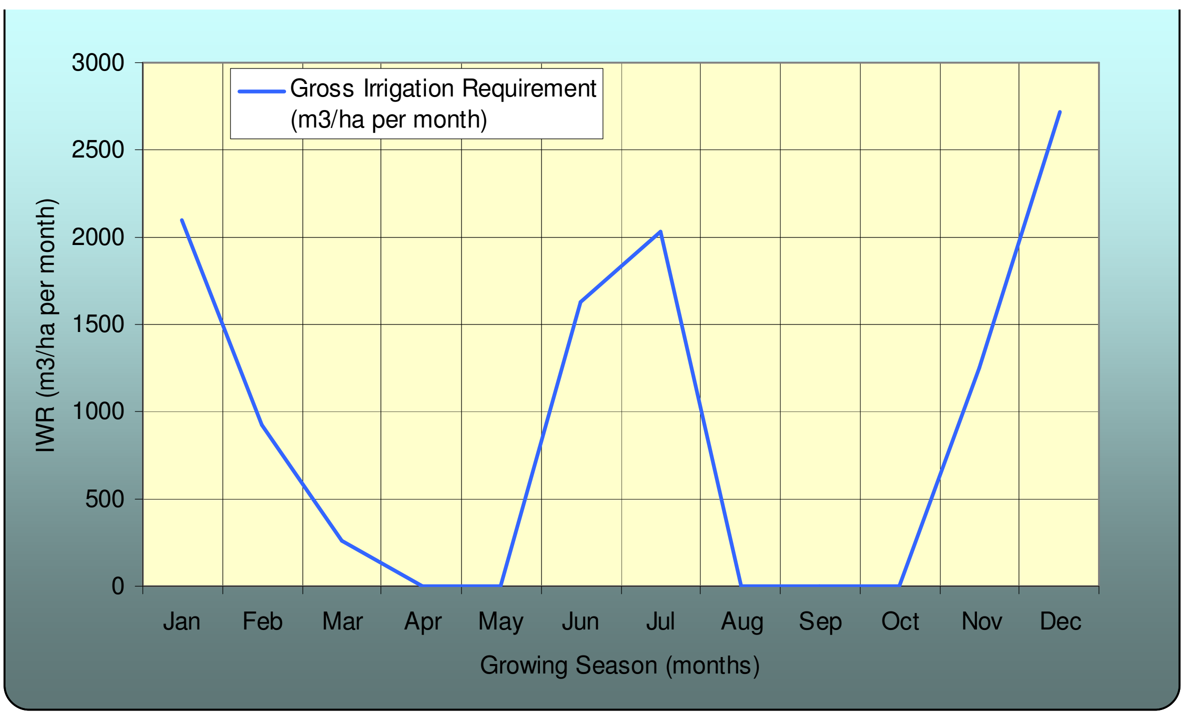
Ethiopia

Six reservoirs with a total gross command area of 631,000 ha are identified in the upper course of the sub basin. The net command area is estimated at 480,000 ha. The Baro (250,000 ha), Alewero (34,000 ha) and Gillo (196,000 ha) are the three sub watersheds used as a source of irrigation water (storage) in the system.

The proposed cropping pattern in the Baro-Akobo watershed in Ethiopia is designed to have a cropping intensity of 100% for the dry season and 66% for the wet season that constitutes an annual cropping intensity of 166%. Dry season crops constitute; Cotton (25%), Maize (40%), Sorghum (19%), Soya Bean (10%), Groundnuts (5%) and Green Manure (fodder, 1%). Wet season cropping constitute, cotton, maize and groundnuts each 15%, Sorghum and Soya Bean each 10% and green manure 1%.

At 60% project efficiency the hydro module for the upper course of the sub basin is estimated at 13106m^3/ha per year, which is on the higher side as compared to the current practice (10125m^3/ha per year in the Jebel Aulia irrigation practices) in the lower course of the sub basin. This might be attributed to the use of seasonal peak requirements while master planning is exercised at a planning stage. Seasonal distribution of the demand is presented in fig 3.27 below.

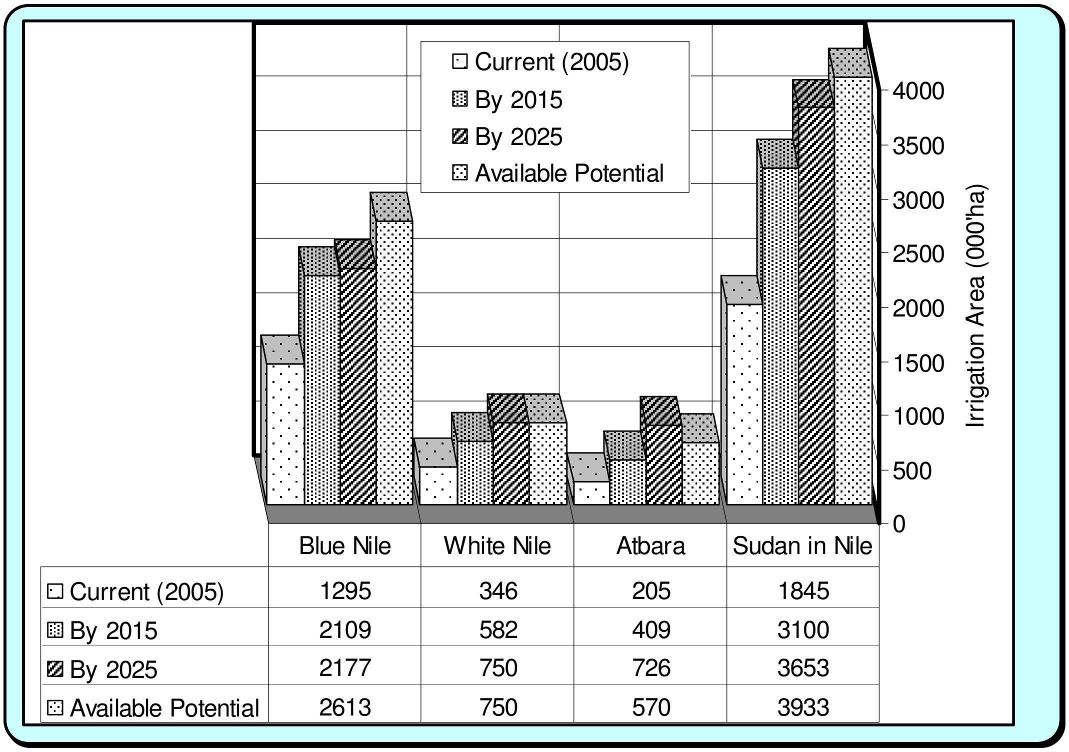
Figure 4.17: Irrigation Demand Distribution at 60% Project efficiency



Sudan

In Sudan the master plan study reveals that the current irrigated area 346000 ha will be expanded to 582000 ha by the year 2015 and to 750,000 ha by the year 2025 (Sudan OSI Water Component Report, May 2006). From the same resources the total expansions in Sudan by the year 2025 is estimated at 3.93 million hectare from the current 1.84 million hectare, which raises the current abstraction of Sudan in the Nile system, from 20 to 40 bcm (Sudan OSI Water Component Report, May 2006).

Figure 4.18: Sudan Current & Potential Expansion of Irrigated Area by Sub Basin



HYDROPOWER AND TRANSMISSION

Installed Capacity

Hydropower projects were identified to constitute three categories/scales; large (>150 MW), medium (>50 MW) and small (>5 MW) projects (table 4.10). In the upper course of the sub basin, eight large projects (2375 MW), six medium projects (395 MW) and three small projects (55 MW) were identified as feasible for the first screening stage.

Table 4.10: Salient Features of Identified Hydropower Projects

Large Projects (> 150 MW)		Medium Projects (> 50 MW)	
Project	**Installed Capacity (MW)**	**Project**	**Installed Capacity (MW)**
Bonga/Baro	372	Gillo-1	72
Tams	519	Sor-A	80
Gambella	258	Sese	30
Geba-R	180	Beko	100
Birbir-R	304	Gumaro	62
Baro-A	270	Kashu	50
Geba-A	180	Small Projects (> 5MW)	
Birbir-A	290	Gillo-3	14.4
		Sor-R	16
		Sako-Guda	25

Proposed Interconnections and Transmission Lines

Interconnections with the Ethiopian ICS: In the Baro-Akobo master plan studies it is proposed that the large and medium scale hydropower plants after commissioning will be connected to the existing national grid system (fig 3.29)

Interconnection with the Sudan: Studies into the interconnection of the power system of Ethiopia and the Sudan were undertaken by IVO International in the mid 1980's and again in the mid 1990's. These studies indicate that the interconnections could be justified on the basis of exchange of surplus energy b/n the two systems rather than firm energy exchange as hydropower will continue to play important role in the Ethiopian expanding system, there will be periodic surplus of energy by the time the envisaged hydropower plants are commissioned.

The route of the interconnection recommended by IVO extends from Debre Markos to Roseires dam, a distance of about 430 km (fig 3.30). Another promising route examined by IVO was from Ghedo via Ghimbi to Roseires over a distance of 617 km and it is found to be more promising if the envisaged large hydropower plants in the upper course of the sub basin (Baro-Akobo basin of Ethiopia) are realized. The interconnection proposed by IVO is a single circuit 345 KV line with 315mm^2 aluminum conductors.

WATER SUPPLY PROJECTS

According to the Baro-Akobo master plan studies in Ethiopia (TAMs-ULG, 1997) four level development plans: immediate (1997 – 2000), Short term (2001 – 2015), Medium term (2016 – 2030), and long term (2031-2035) segregated in main towns, small towns and rural populations have been proposed. The investment plan averaged for the master plan period is intended to be implemented at a rate of USD 1.8 million for main towns, USD 0.6 million for small towns and USD 2.8 million for rural populations. This master plan development assumes that by the end of the master plan period populations in main and small towns fully and 59% of the rural populations in the basin states will be accessed to safe water supply facilities. Information regarding the Sudanese part of the sub basin is not made available.

5. ANNOTATED BIBLIOGRAPHY

INTRODUCTION

The purpose of this list is to provide an overview of some of the sources of social, hydrological and environmental data for the Tekeze-Atbara sub-basin of the Eastern Nile. These data sources have been used for a wide array of purposes by a wide array of government, private and university entities. Thus the use of any secondary material should be approached from a user-beware perspective. While some of the works have been consulted in the preparation of this inventory on the socio-economic theme, the list is not exhaustive and there no doubt exists sources that have not been included. However the list does include some of the most recent references on the Ethiopian side of the 'sub-basin population. Reference materials on the on the Sudanese portion of the sub-basin is very scanty and future research should be able to fill the existing gap.

Most of the references listed here can be accessed from government, private and university institutions of the respective sub-basin countries, namely Ethiopia, and Sudan. Some data sets (national population census reports) can be available in soft copies or a few are on-line resources. Users are advised to contact the relevant/ affiliate institutions where the data is likely to be stored or housed. The listed references are organized into the following categories: institution/regulatory regimes, population characteristics, occupation and employment, social and physical infrastructure. Each category is preceded by a brief description of the nature of information contained under the listed annotated bibliographies.

REGULATORY REGIMES GOVERNING NATURAL RESOURCES

The works listed below cover information on different land tenure regimes and also recent attempts to reform land tenure regimes.

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POPULATION CHARACTERISTICS

The following sources provide information on population size and distribution by age and sex at regional levels classified by rural and urban place of residence, total population of urban and rural areas (by Awrajas, weredas and kebele or Peasant Associations) actual and projected distribution of population size by age, sex and place of residence. These reports also contain sex ratios by five-year age groups for urban and rural areas at regional level for the year 1984 and by different religious groups. These reports also contain number of deaths by sex and age group, crude death rates, age specific death rates by sex and urban and rural place of residence at regional level for the year 1984. Abridged life table, children dead and surviving, estimates of infant and childhood mortality levels along with implied life expectancy derived using different methods are also provided in the reports.

The reports also contain population size and distribution by age and sex at regional, zonal, wereda and kebelel levels classifies by rural and urban place of residence for the year 1994. The reports indicate actual and projected population size on the basis of the census enumeration. These reports also contain sex ratios by five-year age groups and place of residence at regional level for the year 1999. The reports also provide projected population size for each of the years during 1995 to 2030 for total population classified by sex and place of residence. Projected population by five-year age group is also provided for 1995 to 2000 every year, but every five years then after.

Some of the reports contain numerical and percentage distribution of major ethnic groups (10,000 population or more) and religion affiliations by age, sex and place of residence at regional, zonal and wereda levels **and some of the towns with large population size.** The reports also contain level **of migration by sex and place of residence,** stream of in- and out- migration rates by place of residence and sex. It also presents forms of migration by sex and place of origin for the year 1984. Information, however, is available at the then administrative region level.

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EMPLOYMENT, OCCUPATION AND LIVELIHOODS

These reports contain the distribution of working age population by economic participation status and activity rates, unemployed population and unemployment rates by age group and sex at regional level and **major urban centers.** The reports also present numerical and percentage distribution of employed and unemployed persons and reasons for not engaging in the labor force by sex and place of residence at regional levels and some of the major urban towns for the year 1984. The reports also contain employment status, occupation and industrial characteristics of the employed people by educational level; and the age as well sex characteristics of the unemployed population.

The reports also contain major occupational and industrial distribution of the economically active population in Ethiopia including skilled and unskilled labour in agriculture, livestock, hunting and fishing, as well as jobs taken as primary activity by sex, age group and place of residence at regional level for the year1994. The reports also contain minor occupational and industrial distribution of the economically active population by sex and place of residence at regional level.

Also some of the reports contain the type of holding (mixed, crop only and livestock only) of agricultural holders by sex and place of residence at regional, zonal and wereda level for the year 2001/01. The reports also show working status and reasons for not working among the population in the agricultural households by sex and place of residence. They also show employment status and type of working by sex and place of residence regional, zonal and wereda level

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SOCIAL AND PHYSICAL INFRASTRUCTURE

These reports contain level of literacy and school attendance status distribution, gross and net enrolment rates by sex and place of residence at regional and zonal levels for the year 1994. The reports also contain the distribution of those currently attending school by age, sex, grade and place of residence and also show school progression at regional level by sex and place of residence. Age-sex specific enrolment rates as well as gross and net enrolment rates are also given by place of residence at regional level for the year 1984. The reports also show percentage distribution of population by literacy status, and highest grade completed across sex and place of residence at regional and zonal levels.

The reports also provide the total number of hospitals, health centers, and clinics; as well as total number of medical personnel at regional level. The reports also contain distribution of households according to distance to the nearest health facilities (health post, clinic, health center, hospital and pre/post natal care), use of health facilities and reason for not using health facilities by place of residence at regional level for the year 2004. Distribution of households according to level of access to source of drinking water, toilet facility and method of waste disposal in rural areas at regional level and some selected urban centers for the year 1996 is also provided in the reports. Besides, limited data is available on access to roads, credit and markets infrastructure as well as extension services

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DEVELOPMENT PROJECTS

Most of the works listed below provide information on recent government and non-government efforts to introduce development programs in and around the sub-basin areas and cover issues of resettlement, villagization, extension program, irrigation projects, household food security. Most of the works are research reports and academic papers produced in the form of theses or dissertations.

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