Nile Basin Initiative

Nile Technical Regional Office (ENTRO)
Nile Basin Initiative Trust Fund / IDA

Eastern Nile Watershed Management Project

Cooperative Regional Assessment (CRA) for Watershed Management

TRANSBOUNDARY ANALYSIS
FINAL COUNTRY REPORT
SUDAN




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CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ACT	African Country Almanac
AHD	Aswan High Dam
CBD	Convention on Biological Diversity
CPA	Comprehensive peave Agreement
CRA	Cooperative Regional Assessment
DFID	Department for International Development
ECC	Environmental Compliance Certificate
EIA	Enviopnmental Imapct Assessment
ENSAP	Eastern Nile Subsidiary Action Programme
FAO	Food and Agricultural Organization
FNC	Forest National Corporation
GEF	Global Environmental Fund
GAIL	Gross Annual Immediate Loss
GDCL	Gross Discounted Cumulative Loss
GDFL	Gross Discounted Future Loss
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GIS	Geographic Information System
GOS	Government of Sudan
HCENR	Higher Council for Environment and Natural Resources
IDEN	Integrated Development of the Eastern Nile
IFPRI	International Food Policy Research Institute
IGADD	Inter Governmental Agency for Drought and Desertification
IIED	International Institute for Environment and Development
ILO	International Labour Office
IRR	Internal Rate of Return
IUCN	International Union for the Conservation of Nature
ITCZ	Inter Tropical Convergence Zone
IWMI	International Water Management Institute
JAM	Joint Assessment Mission
JMP	Joint Multipurpose Programme
Km	Kilometre
Km2	Square kilometre
MEA	Multilateral Environmental Agreement
MoA	Ministry of Agriculture
MEPD	Ministry of Enviroment and Physical Development
MIWR	Ministry of Irrigation and Water Resources
MCM	Million Cubic Meters
MW	Mega Watt
NBI	Nile basin initiative
NCS	National Comprehensive Strategy
NWP	National Water Policy
PERSGA	Strategic Action Plan for the Red Sea and Gulf of Aden

PRSP	Poverty Reduction Strategy Project
SIDA	Swedish International development Agency
SLM	Sustainable Land Management
SWC	Soil and Water Conservation
t	ton
UNDP	United Nations development Programme
UNFCCC	United National Framework Convestion on Climatic Change
USAID	United States Agency for International Development
USLE	Universal Soil Loss Equation
WB	World Bank
WM	Watershed Management

EXECUTIVE SUMMARY

1. Scope of the report:

The Eastern Nile Basin in the Sudan comprises the Sobat, Blue Nile, Atbara and Main Nile river systems. The area and population of each basin and total area within Sudan are as follows:

Sub-basin	Area (km2)	% area	Population	Population %	Density p.p.km2
Sobat/White Nile	390,860	32.7%	10,917,495	48.9%	27.9
Blue Nile	112,465	9.4%	7,400,324	33.2%	65.8
Atbara	109,208	9.1%	61,892	0.3%	0.6
Main Nile	582,368	48.7%	3,928,696	17.6%	6.7
TOTAL	**1,194,901**		**22,308,407**		**18.67**

The Transboundary Analysis component comprises an integrated, cross-border analysis of the watershed system in order to identify the main watershed characteristics and watershed challenges in each of the Sub-basins, and to opportunities and benefits of cooperation in watershed management. The analysis is being undertaken in five stages:

- National level analysis for the agreed Sub-basins;

This is the subject of this report. This will be followed by

- A Regional Workshop to assure interaction between the national level activities and foster a regional understanding of common issues;
- Consolidation of the three national level analyses into a system-wide analysis of issues and opportunities to improve livelihoods;
- Identification of additional benefits of cooperation in watershed management by identifying potential additional cross-border positive and negative impacts of watershed related interventions;
- Distillation from the system-wide analysis the greatest system-wide opportunities for high impact cooperative watershed management.

This report contains the results of the National level analysis for the Eastern Nile Basin within Sudan. It comprises:

(i) a review of successful experiences of interventions to address watershed interventions (with a specific view of approaches aiming at improved livelihoods);

(ii) stakeholder consultations in selected relevant locations;

(iii) a detailed problem and solution analysis for each watershed for current trends in land degradation;

(iv) policy and institutional issues conducive as well as hindering successful interventions on the national level; and

(v) an outline of long-term capacity building and monitoring needs to evaluate successes/impacts of interventions on the watershed.

2. Understanding of the Biophysical and Socio-economic Aspects of the three Sub-basins:

The Report then provides a detailed description of the biophysical and socio-economic aspects of the four Sub-basins. It first provides an overview of the agricultural and forestry sectors and provides some details of production and marketing systems.

3. Summary of the Proximate Problem Analysis:

Sedimentation: Heavy sedimentation is reducing the storage capacity of the Roseires, Sennar and Kashm El Girba Dams and the irrigation and drainage canals of the irrigation schemes. Other impacts include increased costs of water purification, damage to pumps, aggradation of the river bed causing accelerated meandering and river bank erosion.

Natural Resource Competition, Conflict and Rangeland Degradation: under increasing population pressure and massive expansion of the large scale mechanized farms there is increasing competition and conflict between natural resource managers: shifting cultivators, pastoralists/agro-pastoralists and mechanized farm owners. The loss of rangelands to mechanized farms has resulted in severe detrimental impacts on pastoralist livelihoods and livelihood strategies.

Soil Degradation: all forms of soil degradation are prevalent (Mekki Abdul Latif, 2005). Soil nutrient mining is occurring on the large mechanized farms because of continuous cultivation and the lack of fallowing. Salinization is occurring on a number of the irrigation schemes with poor drainage. Soil erosion occurs on areas with steeper slopes. Gullying is very common along the Atbara and Dinder rivers.

Drifting Sands and Moving Sand Dunes: In the Main Nile and Atbara Sub-basins drifting sand and moving sand dunes are covering valuable irrigated areas and burying villages. In the gash Delta drifting sand is choking irrigation channels.

Water pollution: Some 600 agro-chemicals, many of which are hazardous to humans and livestock, are used on irrigated farms and much of the residue is washed into drains and eventually to the Blue Nile.

Pressures of Protected Areas: The Dinder National Park is under increasing pressure from surrounding population with the demand for grazing, fuelwood, timber and more recently from the impacts of oil exploration.

4. Summary of the Underlying Causes of Natural resource Degradation:

The proximate causes of land degradation are reasonably well known. An understanding of the underlying causes is still imperfectly understood, notwithstanding the impressive amount of research work undertaken over the past decade. There results of research to-date may be briefly summarized as:

- The profitability of land management technologies is very important, though not the only factor influencing adoption or non-adoption.

- **Underlying Poverty**: Available evidence suggests that about 71-80 percent of the population in the north and 90 percent in the south are living below the poverty line. The majority of the poor live in the traditional rainfed farming areas. Distribution of benefits from agricultural growth during the last decade has favoured those with access to capital and land.

- Climatic risk is also a very important consideration, especially in the semi-arid areas with respect to rainfed cultivation.

- In the context of imperfect markets and institutions the suitability and feasibility of land management interventions in different locations and farmer circumstances are very context dependant making generalisations difficult. The numerous potential factors include: agro-ecological conditions; nature of the technology; land tenure relations; household endowments of natural, human, social and financial assets.

- The massive expansion of the semi-mechanized farm sector has had negative environmental and social impacts. Many pastoralist groups have lost extensive areas of grazing, putting intense pressure on remaining resources.

- The Malthusian argument of the negative impacts caused increasing population pressure may still be operating because of inefficient markets, lack of extension and research support. These are enabling factors for Boserup argument for population induced agricultural intensification.

- Lack of proper coordination between different sectors dealing with the natural resources.

- Lack of harmony between the different sectoral policies and legislations in the area of natural resources management and utilization.

5. Review of Lessons learnt:

There is substantial evidence that active participation by communities in development and conservation activities leads to success and sustainability. Local level participatory land use planning also contributes to success and sustainability. There is an urgent need for a strategic land use plans at the State and perhaps the national levels. Linked to this is an urgent need to reform the land tenure policy. Transparency combined with participation has improved access to land in the Gash Delta.

6. Interventions

A number of technical and supporting interventions are presented for each of the main natural resource degradation problems.

7. Long-term Capacity and Monitoring Needs:

The report concludes with a number of areas where capacity building is required.

The need for long-term and consistent monitoring of landuse/landcover and of sediment monitoring at all levels and scales is stressed.

1. BACKGROUND

1.1 Introduction

The Eastern Nile Basin Watershed Management Cooperative Regional Assessment (CRA) is in support of the Eastern Nile Subsidiary Action Programme (ENSAP). ENSAP, which includes Egypt, Ethiopia and the Sudan, seeks to initiate a regional, integrated, multi-purpose programme through a first set of investments. The first project under this initiative, referred to as The Integrated Development of the Eastern Nile (IDEN) comprises seven components:

- Eastern Nile Planning Model,
- Baro-Akobo Multi-purpose Water Resources Development,
- Flood Preparedness and Early Warning,
- Ethiopia-Sudan Transmission Interconnection,
- Eastern Nile Power Trade Investment
- Irrigation and Drainage
- Watershed Management

The results of the analyses of the sectoral CRA's will be brought together in the design and decisions in a joint multi purpose programme (JMP) of interventions. The general elements of a CRA are (i) institutional strengthening, (ii) a participatory process for building trust and confidence, and (iii) to gain a transboundary understanding the watershed system from a basin wide perspective.

The results of the Watershed Management CRA will provide valuable input to the JMP planning. The CRA will highlight some of the major issues relevant to the JMP, identify transboundary benefits and develop long term cooperative arrangements for monitoring land use change, sediment loads and impacts on livelihoods.

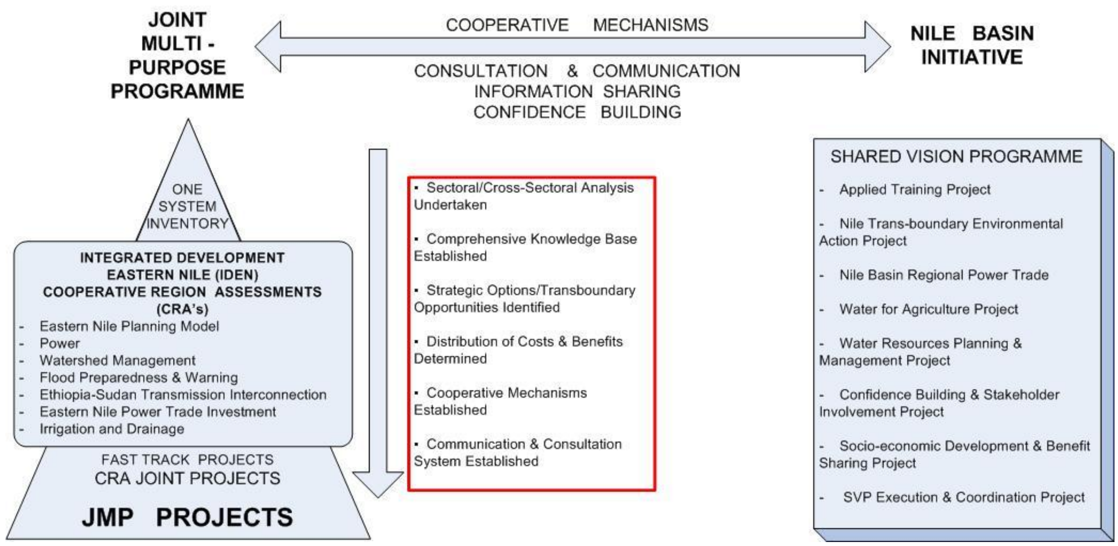


Figure 1. Relationships among and processes of the IDEN CRA's, the Joint Multi-purpose Programme and the Nile Basin Initiative's Shared Vision programme

1.2 Primary Objectives of the Watershed Management CRA

The primary objects of the Watershed Management CRA are to develop a sustainable framework for catchment management in order to:

- Improve the living conditions of all peoples in the three sub-basins
- Create alternative livelihoods
- Achieve food security
- Alleviate poverty
- Enhance agricultural productivity
- Protect the environment
- Reduce land degradation, sediment transport and siltation.
- Prepare for sustainable development orientated investments.

1.3 The Scope and Elements of Sustainable Watershed Management

1.3.1 Watersheds and River Basins

River basins, watersheds and sub watersheds and their hydrological processes operate in systemic way within a nested hierarchy but often in complex spatial and temporal patterns. For example, the linkages (or coupling) between vegetation cover, soil erosion (or soil conservation) and sediment yield at the micro-watershed level and the sediment load and sedimentation downstream at the macro-watershed level often do not have simple linear relationships. There is no well defined terminology for basins/watersheds. It is generally based on area although given the potential for extreme variability in hydrological factors, this is of necessity rather arbitrary.

Table 1. Watershed Management Units and Hydrological Characteristics

Management Unit	Typical area (km2)	Example	Degree of coupling
Micro-watershed	0.1 -5km^2	Typical watershed adopted by MERET interventions (Ethiopia)	Very strong
Sub-watershed	5 – 25km^2	An assemblage of micro-watersheds	Strong
Watershed	25 -1,000km^2	Guder	Moderate
Sub-basin	1,000 – 10,000km2	Lake Tana	Weak
Basin	10,000 – 250,000km2	Abay-Blue Nile	Very weak

After World Bank (2005)

In micro and sub-watersheds there is a strong coupling between the catchment area and the channel. Vegetation and land management practices closely control the runoff and the export of water, sediment and dissolved load into the stream channel. There is also a close coupling between groundwater and the river. In medium to large basins coupling between the catchment and the river is weak. The dominant process in basin of this size is transfer of material through the channel network and there is often temporary storage of sediment. Thus, the channel acts as a conveyor belt intermittently moving pulses of sediment during flood events. There is additional sediment from stream bank erosion and drifting sand.

1.3.2 Approach Adopted to the Eastern Nile Watershed Management CRA

> *" In view of the multi-sectoral nature of the problem (land degradation, fuelwood demands, population pressures, illiteracy, lack of alternative sustainable livelihoods, etc.) a comprehensive and integrated approach is required, as traditional watershed management actions, in this case, would treat the symptoms, as opposed to address the root causes which lead to the spiral of degradation and poverty.*

> *The preparation of an integrated watershed program in the Eastern Nile region will require a holistic approach and interaction between national level and regional studies through a Cooperative Regional Assessment (CRA)."*

(Terms of reference: Cooperative Regional Assessment in Support of the Eastern Nile Watershed Management Project.)

Clearly, the approach to be adopted in developing a framework for watershed management for the Eastern Nile Basin needs to be very broad in order to address a wide-range of objectives based on stakeholder perspectives across multiple levels and countries. The objectives to be addressed go beyond developing and conserving land, water and vegetation in the four sub-basins in the three countries. They include but are not limited to:

- Improving the management of land and water, their interactions and externalities;
- Linking upstream and downstream areas, and integrating environmental concerns with economic and social goals;
- supporting rural livelihoods by linking interventions in other "non-watershed" sectors (e.g. health in pond development, training in non-farm employment activities);
- addressing equity and gender concerns in the distribution of costs and benefits of watershed interventions (e.g. positive and negative externalities at various levels);
- identifying opportunities for incremental benefits accruing to cross-border coordinated interventions, including those being developed for the other IDEN CRA's and the Joint Multi-purpose programme (JMP);
- identifying global benefits (e.g. conservation of tropical forests, biodiversity and carbon sequestration) that accrue from national and regional level interventions.

At the same time it will be important to maintain a "Watershed Perspective". This is necessary to avoid a lack of focus on the unique upstream-downstream characteristics of watersheds and river basins. Maintaining such a perspective will avoid the danger of the analysis failing to develop a "system-wide" understanding of the basin-wide issues and thus the identification of transboundary opportunities to improve livelihoods and achieve poverty reduction. Finally, a Watershed perspective will enable the identification of basin-wide synergies from cooperative transboundary interventions.

Another essential element of the Watershed Management CRA approach that distinguishes it from many Watershed Management approaches is the "Regional Process": i.e. building capacity, trust and confidence among riparian stakeholders. This will be made operational through a continuous process of regional stakeholder consultation.

FAO[1] (2006) has undertaken a review of lessons learnt from decades of Watershed Management Programmes and outlined a new approach to watershed management that is emerging from the "Integrated Watershed Management" approach that has served the past two decades. The review of lessons learnt identified a fundamental dilemma about integrated watershed management programmes and sustainable development processes:

- Should watershed management programmes incorporate sustainable development objectives by providing benefits and services that are not directly related to natural resource management? or
- Should they be embedded in broader sustainable development processes, by ensuring that sustainable development considers land and water issues?

The first option referred to as "programme-led" integrated watershed management has prevailed often because of insufficient coverage by line agencies. Embedded watershed management focuses on those aspects of sustainable livelihoods that are directly linked to natural capital assets. Other elements that are relevant to sustainable development – off-farm livelihood diversification, education, health, etc – are less relevant to watershed management programmes. Partnerships between watershed management programmes and other institutions working on livelihood, poverty alleviation, land reform, education, and health issues make it easier to address environmental and social issues effectively.

The new approach termed "Embedded Watershed Management" differs in a number of important ways from the previous approach. These are outlined in Box 1.

[1] Undertaken in collaboration with the European Observatory of Mountain Forests, International Centre for Integrated Mountain Development, Red Latinoamericana de Cooperacion Tecnica en Manejo de Cuenncas Hidrograficas and the World Agroforestry centre.

Box 1. Comparison between (programme led) Integrated and Embedded Watershed Management

Integrated Watershed Management	Embedded Watershed Management
Environment and Social issues are strictly related and cannot be addressed separately.	Most watershed problems are related to socio-economic issues, but there is always scope for measures and actions that specifically address environmental issues.
Watershed management programmes should have a sustainable development mandate and aim at both natural resource and sustainable livelihood goals.	The mandate and goals of watershed management programmes should focus on natural resource management **FOR** sustainable livelihoods and development.
Integrated programmes to address environmental and livelihoods issues comprehensively should be developed.	Sectoral programme focusing on watershed natural capital assets should be developed. Issues that are not related to natural resource capital should be addressed in collaboration with other programmes or institutions.

Along with integration, "participation" has been another essential attribute of watershed management practice for more than 20 years. However, it now clear that beneficiaries (people, communities) are not the only important actors in participatory watershed management. Collaboration between watershed management programmes and stakeholders (including downstream interest groups and countries) at many levels is now seen as essential. This shift is linked to the administrative decentralisation process that many countries have adopted in past decade. The differences between the two approaches are set out in box 2.

Box 2. Comparison between Participatory and Collaborative Watershed Management

Participatory Watershed Management	Collaborative Watershed Management
Focuses on communities and people and targets grassroots social actors: households and small communities.	Focuses on civil society and targets a variety of social and institutional actors, including local governments, line agencies, enterprises as well as technical experts and policy makers.
Based on assumption that sound natural resource management is a public concern shared by all social actors.	Based on the recognition that stakeholders have particular – sometimes contrasting – interests in natural resources, which need to be accommodated.
Seeks (claims) to make decisions through bottom-up process, by which grassroots aspirations are progressively refined and turned operational action.	In decision-making, seeks to merge stakeholders aspirations and interests with technical experts recommendations and policy guidelines through a continual two-way (bottom-up and top-down) negotiation process.
Centred on watershed management with local government assisting.	Centred on local governance process, with the watershed management programme acting as facilitator and supporter.
Aimed at creating a consensus, presuming that conflict can be solved through dialogue and participation.	Aimed at managing social conflicts over natural resources, based on awareness that dialogue and participation can mitigate conflicts but not solve them structurally.

Most government and donor funded watershed management programmes follow a clearly defined project logical framework specifying what has to be achieved and how. Objectives, outputs and activities are defined during identification and formulation stage, often based on limited information. This planning approach is not compatible with the new approach to watershed management, which requires greater flexibility in programme design.

Strategic watershed planning needs to take into account different temporal and spatial scales and accept a degree of uncertainty. It can be implemented at scales ranging from small upland watershed to entire trans-boundary river basins. Whilst small-scale projects have the advantage of face-to-face interaction with stakeholders they have limited impact at the watershed or river basin level. The design and operation of local programmes must consider upstream-downstream linkages and a methodology for multi-level watershed, sub-watershed and micro-watershed planning needs to be developed. Scaling-up of successful local experience is critical for the new generation of watershed management programmes.

1.4 Purpose and Scope of the Transboundary Analysis Country Report

The Transboundary Analysis component comprises an integrated, cross-border analysis of the watershed system in order to identify the main watershed characteristics and watershed challenges in each of the Sub-basins, and to opportunities and benefits of cooperation in watershed management. The analysis is to be undertaken in five stages:

- National level analysis for the agreed Sub-basins;
- Regional Workshop to assure interaction between the national level activities and foster a regional understanding of common issues;
- Consolidate the three national level analyses into a system-wide analysis of issues and opportunities to improve livelihoods;
- Identify additional benefits of cooperation in watershed management by identifying potential additional cross-border positive and negative impacts of watershed related interventions;
- Distill from the system-wide analysis the greatest system-wide opportunities for high impact cooperative watershed management.

The analysis at the national level includes:

(vi) a review of successful experiences of interventions to address watershed interventions (with a specific view of approaches aiming at improved livelihoods);

(vii) stakeholder consultations in selected relevant locations;

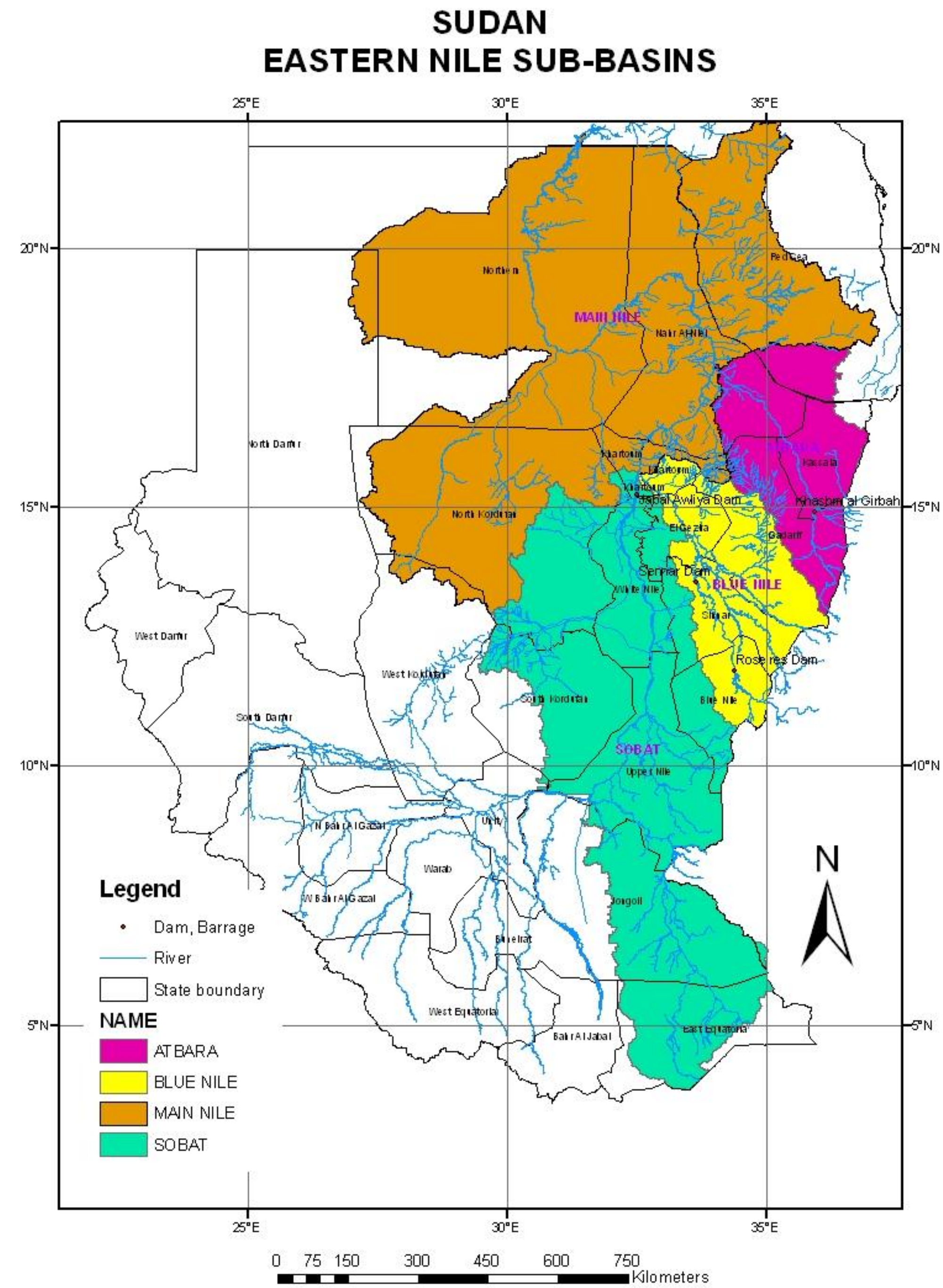
(viii) a detailed problem and solution analysis for each watershed for current trends in land degradation;

(ix) policy and institutional issues conducive as well as hindering successful interventions on the national level; and

(x) outline long-term capacity building and monitoring needs to evaluate successes/impacts of interventions on the watershed on local livelihoods, agricultural output and sedimentation control.

National reports are to be assembled based on the points outlined above. The Country report will then be consolidated into four Sub-basin Reports as follows: (i) Baro-Sobat-White Nile, (ii) Abay-Blue Nile, (iii) Tekeze-Atbara, and (iv) Main Nile to the Aswan High Dam.

1.5 Overview of Situation and Issues in Eastern Nile Basin in the Sudan



Map 1. Eastern Nile Basin: with the Tekeze-Atbara, Abay/Blue Nile, Baro-Akobo-Sobat and the Main Nile Sub-basins.

The CRA focuses on four Sub-basins: the Abay/Blue Nile, Tekezi/Atbara, the Baro-Akobo-Sobat and the main Nile from Khartoum to the Aswan High Dam (Map 1)

The area and population of each Sub-basin within the Sudan are shown in table 2.

Table 2. East Nile Basin – Sudan: Area, Population and Population Densities by Sub-basin.

Sub-basin	Area (km2)	% area	Population	Population %	Density p.p.km2
Sobat/White Nile	390,860	32.7%	10,917,495	48.9%	27.9
Blue Nile	112,465	9.4%	7,400,324	33.2%	65.8
Atbara	109,208	9.1%	61,892	0.3%	0.6
Main Nile	582,368	48.7%	3,928,696	17.6%	6.7
TOTAL	**1,194,901**		**22,308,407**		**18.67**

Population Source: ORNL (2003).

There are clear differences in terms of area and population among the Sub-basins. The Atbara Sub-basin is smallest in terms of area, population and population density. The Main Nile Sub-basin comprises nearly half the area of the ENB but with only 17.6 percent of its population. The Sobat-White Nile Basin contains nearly half the population but the highest population density is within the Blue Nile Sub-basin.

Rainfall varies from almost zero in the north to about 1,500 mm in the south occurring mainly between July and September. Actual amounts vary considerable between and within seasons. On the wide flat plains in the main river valleys are dark cracking clays (Vertisols) derived from colluvial/alluvial sediments with locally sand covered areas. Away from the plains towards the east and west are lighter textured soils derived from Basement Complex rocks and Nubian Sandstones.

There is a wide range of agro-ecological zones from desert along the northern border through semi desert scrub around the confluence of the Blue and White Niles. Further south is semi-arid grassland on clays merging into Acacia thornland alternating with grassland. In the higher rainfall areas this merges into *Acacia-Balanites* savanna woodland alternating with grasslands. In many parts of the Pibor-Sobat Sub-basin are areas of seasonal and permanent swamps.

The traditional agricultural systems are shifting (bush fallowing) although in a number of areas shortage of land is leading to more continuous cultivation. Crops include dura, okra, legumes and some oil crops. Cultivation continues until soil looses its fertility or weed growth exceeds labour capacity to clear. The land is left for 12 – 15 years before re-cultivation. In the system, which is prevalent in the south, 12 -15 year old grass or scrub is cleared and then burnt to kill any weeds.

To the north of the Blue Nile in the Butana Plains the area is also used by a number of transhumant pastoralists and agro-pastoralists. South of the Gezira-Managil scheme the area is also used by transhumant pastoralists, dominant among whom are the Rufa'a al-Hoi, the Fulani and Baggara. Further south are the Nuer and Dinka agro-pastoralists who utilize the vast grassland plains.

Large irrigated schemes cover some 4.5 million feddans (1.9 million ha) and are dominated by the Gezira-Managil scheme totaling about 2.1 million feddans (880,000 ha). This and the New Halfa scheme on the Atbara are gravity schemes whereas most others are pump schemes. Principal crops are cotton, what, groundnuts and sorghum.

In the Butana Plains and the clay plains south of the Gezira scheme are large areas of mechanized rainfed farming. These are mainly cultivated to sorghum, groundnuts and sesame.

There are a number of key issues:

Sedimentation: Heavy sedimentation is reducing the storage capacity of the Roseires, Sennar and Kashm El Girba Dams and the irrigation and drainage canals of the irrigation schemes(NBI-TEAP, 2005). Other impacts include increased costs of water purification, damage to pumps, aggradation of the river bed causing accelerated meandering and river bank erosion.

Natural Resource Competition, Conflict and Rangeland Degradation: under increasing population pressure and massive expansion of the large scale mechanized farms there is increasing competition and conflict between natural resource managers: shifting cultivators, pastoralists/agro-pastoralists and mechanized farm owners. The loss of rangelands to mechanized farms has resulted in severe detrimental impacts on pastoralist livelihoods and livelihood strategies.

Soil Degradation: all forms of soil degradation are prevalent (Mekki Abdul Latif, 2005). Soil nutrient mining is occurring on the large mechanized farms because of continuous cultivation and the lack of fallowing. Salinization is occurring on a number of the irrigation schemes with poor drainage. Soil erosion occurs on areas with steeper slopes. Gullying is very common along the Atbara and Dinder rivers.

Water pollution: Some 600 agro-chemicals, many of which are hazardous to humans and livestock, are used on irrigated farms and much of the residue is washed into drains and eventually to the Blue Nile.

Underlying Poverty: Available evidence suggests that about 71-80 percent of the population is living below the poverty line (JAM Report, 2005). The majority of the poor live in the traditional rainfed farming areas. Distribution of benefits from agricultural growth during the last decade has favoured those with access to capital and land. Traditional agriculture shares 56 percent of agricultural GDP and 70 percent of the population; mechanized farming contributes 7 percent of agricultural GDP but only has 0.7 percent of the population. Irrigated agriculture contributes 22 percent of agricultural GDP and only has 12 percent of the population.

Pressures of Protected Areas: The Dinder National Park is under increasing pressure from surrounding population with the demand for grazing, fuelwood, timber and more recently from the impacts of oil exploration.

Pressures on Wetlands: Considerable pressures are being exerted on wetlands in Blue Nile and the Sobat-White Nile Sub-basins from encroachment of large and small cultivation, grazing, road construction and the activities associated with oil exploration and extraction.

Deforestation: Large areas of Acacia and Balanites woodlands have been lost to the expansion of large-scale rainfed and irrigated agriculture. This loss has been exacerbated by unsustainable harvesting for fuelwood and charcoal production. In the southern grass plains uncontrolled fires cause high mortalities amongst young seedlings and trees.

Weak Enforcement of Environmental and other Laws: Environmental laws with respect to Environmental Impact assessments for major developments are weakly enforced. The illegal and uncontrolled expansion of semi-mechanized has caused large areas of woodland to be destroyed.

Poor Institutional Coordination and Policy Harmonization: There is poor institutional coordination and harmonization of policies, particularly at lower levels of government where capacity is weak.

Inequitable Land Policy: The 1970 land legislation where unregistered land – even where it was being used by rural communities – was formally assumed by the state, coupled with its inequitable allocation without consideration of the environmental, social and economic impacts has been one the root causes of conflict within Sudan.

2. NATIONAL SETTING - SUDAN

2.1 Bio-physical and Socio-economic Setting

Sudan covers an area of approximately 2.5 million km2 and in 2002 an estimated population of 31.3 million with an annual growth rate (1998-2003) of 2.6 percent. The projected 2025 population is 49.6 million. The total, rural % and growth rates by region are shown in table 3.

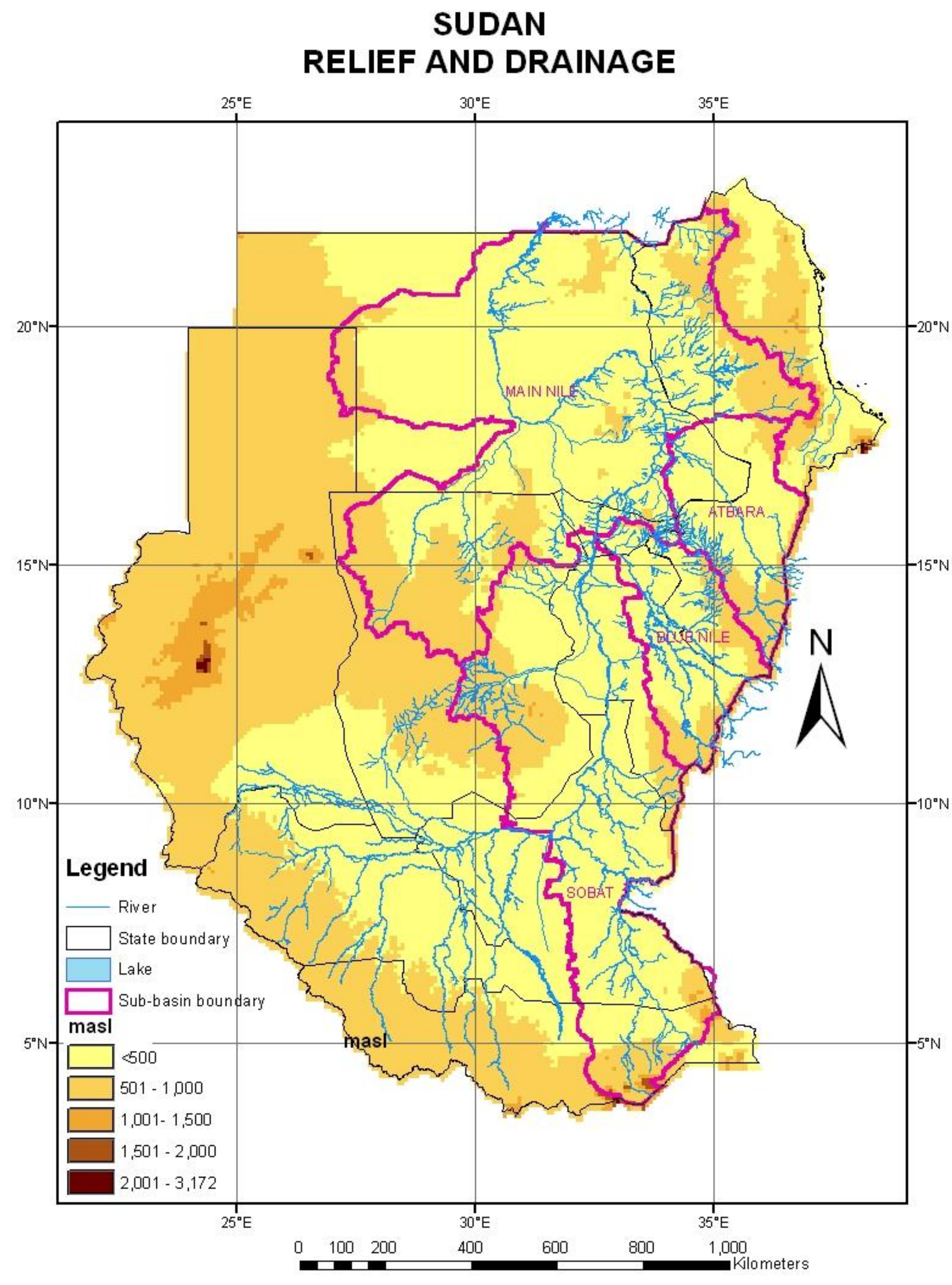
Table 3. Sudan: Total population, Rural % and growth rates by Region (2002)

REGION	TOTAL POP ('000) 2002	RURAL %	TOTAL GROWTH RATE
Eastern	3,360.5	57%	2.25%
Northern	1,392.5	75%	1.85%
Khartoum	5,301.3	14%	4.04%
Central	6,278.7	70%	2.80%
Kordofan	3,512.0	74%	1.50%
Darfur	6,212.6	82%	3.01%
N. Sudan	26,057.0	60%	2.58%
S.Sudan	5,283.3	79%	1.61%
SUDAN	31,340.0	65%	2.64%

Source: Y.A.Mohamed (2005)

Overall population density is 12.4 p.p.km2 but this masks considerable variations. Population tends to concentrate along the streams and rivers and other water sources.

The relief and drainage of Sudan are shown in Map 2.



Map 2. Sudan: Relief and Drainage.
Source: Shuttle Radar Terrain Mission (SRTM 90) digital terrain model.

Land under 500 masl occupies the central White and Main Nile valleys as very gently sloping plains. Higher land is found along the eastern edge as outliers of the Ethiopian Highlands together with the Red Sea Hills. The southern and southwestern edges of the basin form the Congo-Nile watershed. The Jebel Marra forms the Nile-Lake Chad watershed along the western border. Locally hills and mountains rise above 1,500 masl (e.g. the Imatong Mountains being the country's highest point at 3,224 masl).

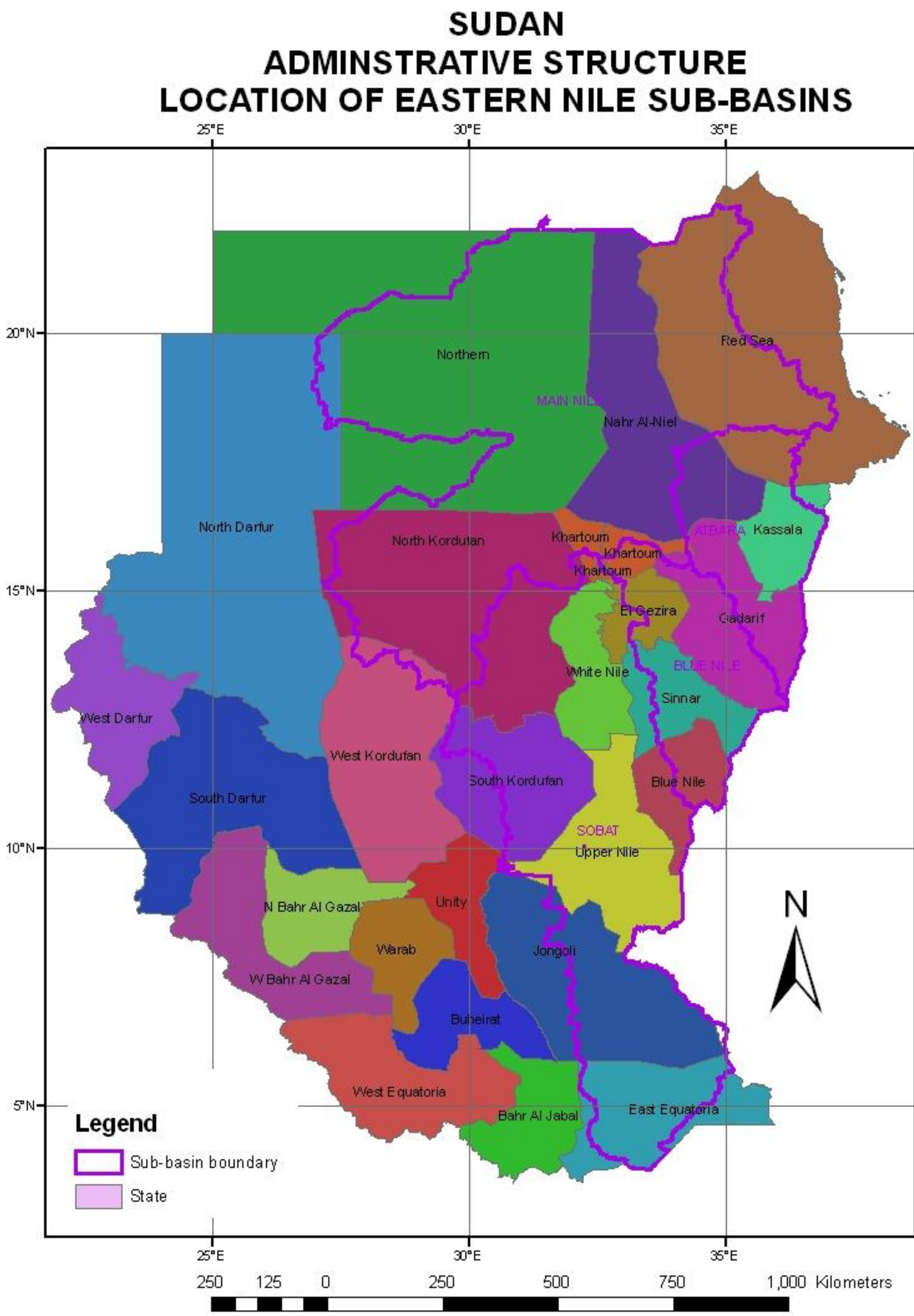
The Bahr el Jebel enters Sudan from Uganda with the Bahr el Ghazal forming on the northern slopes of the Congo-Nile Divide. They join at Lake No to be known as the White Nile. They both lose much water through evaporation in the Sudd. Just above Malakal the Sobat River, which rises in the southwestern Ethiopian Highlands, joins the White Nile. At Khartoum the White Nile is joined by the Blue Nile, which rises in the Central and Northern Ethiopian Highlands. Thence known as the Main Nile it is finally joined by its last tributary the Atbara, which also rises in the northern Ethiopian Highlands. There are many seasonal wadis and khors, which flow intermittently during the rain season. Locally they are of considerable importance in small-scale irrigation, water harvesting and human and livestock water supplies.

The country encompasses three major ecological zones: desert, semi-desert and savanna. Annual rainfall varies from less than 25 mm in the north to 1,500 mm in the south. Rains are erratic and variable, increasingly so in the north. Rains fall in a single season and are closely related to movements of the inter-tropical convergence zone (ITCZ).

Soils in the Sudan are commonly classified into four groups: (i) thin desert soils consisting of loose sand over bare rock in the north, (ii) fixed or shifting aeolean sands in the north and central parts, (ii) clay soil derived from old and recent alluvium over large areas of the central and eastern parts, and (iv) lateritic soils on the ironstone plateau in the southwestern part of the country.

Natural vegetation closely follows the rainfall patterns with local edaphic variations related to soil moisture conditions. Successively from the north are desert, semi-desert, woodland savanna on clay, woodland savanna on sands, high rainfall woodland and swamps. Large areas of the central woodlands on clay have been cleared for semi-mechanized farming and other areas of woodland are under severe pressure from traditional farming, and fuelwood and charcoal production for both urban and rural household consumption.

2.2 Administrative Structure



Map 3. Sudan: Adminstrative Structure with Eastern Nile Sub-Basin Boundaries.
Source:: ENTRO GIS data base:

In the past five years Sudan has embnarkled a policy of administrartive decentralization. According to the Local Government Act of 2003, the Sudan has been divided into 26 States, some 16 located in the north and 10 in the south (Map 3). Each State is divided into anumber of Localities (Mahaliyat). The aim of decentralization is to improve the delivery of basic social services and address the severe spatial disparitries in access to education, health, water, agricultural extension and other government services.

Decentralization and concommitant capacity building will be undertakenn over two pahses: Phase I (2005 – 2007) and Phase II (2008 – 2011). Priorities in the local government will be:

- Enhancing managment capacity by empowering suitable structures to lead reform;
- A broad consultation on organizational structures;
- Developing a comprehensive strategy for institutional arranbgement, polices and guidleines for public services and training;
- Improving systems and practices of local publicprivate partnerships in service delivery;
- Support to Locality development planning;
- Improving Locality information systems;
- Establishing Locality monitoring systems;
- Promoting civil society participation in planning and organization of governmenbt activities;
- Mobilizing local revenue generation for State and Local Government.

2.3 National and Regional Policy Framework

2.3.1 The National Comprehensive Strategy (NCS) (1992-2002)

Sudan's main objectives and priorities for sustainable development were spelt out in the National Comprehensive Strategy (NCS) which provided policy directions to all economic and social sectors. The NCS incorporates the country's environmental strategy, which states clearly that environmental issues must be embodied in all development projects. Within the NCS, the government manages the economy through a series of three years rolling plans and annual budget processes. The NCS has also served as a key reference document and basis for sectoral policies and measures.

A main weakness of the NCS is the lack of coherence as it was a result of work of different sectoral teams without emphasis on horizontal and vertical integration

2.3.2 Comprehensive Peace Agreement CPA

The Comprehensive Peace Agreement (CPA), signed between GoS and SPLMA on 9 January 2005, represents a remarkable event in the history of Sudan and is a major opportunity for restoring peace and the social contract between the state and society in the country.

The CPA provides for a socially informed land tenure policy and legislation as it accords specific reference to ownership of land and natural resource. It calls for competency in land administration, provides for incorporation of customary laws and practices and establishes an independent Land Commission for the purposes of arbitration, rights of claims in respect to land, land compensation and the possibility of recommending land reform policies.

The CPA is expected to have many implication (institutional and administrative) - e.g. the establishment of a Land Commission for the south parallel to existing central institutions responsible for land and natural resources management.

However, there is the question of the existing sectoral environmental legislation. Should that legislation remain federal as it is currently stands, or should it be amended and passed down to the states in accordance with the obligations given to them by the federal structure? (NBSAP,2002)

There is now a counterpart ministry of Environment and Wildlife in Southern Sudan and it is expected that the post CPA developments will witness greater decentralization on all levels. This will necessitate the initiation of a dialogue on developments in the sub-basins in Sudan as a basic requirement for sustainable development in the sub-region. Of special concern also are issues related to conflict resolution, internally displaced refugees, good governance, and the rights of the socially, economically and politically marginalized groups in post conflict Sudan

2.3.3 The Joint Assessment Mission (JAM) (2005)

The JAM Reports are the most recent documents which are guiding the economic development in post peace period in Sudan. The reports have developed the policy guide lines and interventions in eight clusters, including the economic policy cluster. The issue of environment has been classified as one of the cross-cutting issues. The report identified many environmental challenges Sudan is facing and need to be addressed during the short and medium term to enable the country make an equitable and sustainable development in the foreseen future.

The JAM report has stated that the foremost challenge is to minimize the negative environmental impacts that returning refugees and Internally Displaced Populations (IDPs) may pose on the natural resources base through increased deforestation and destructive agricultural practices

2.3.4 Poverty Reduction Strategy (2000)

Under the coordination and leadership of the Ministry of Finance and National Economy, Sudan is also in the process of formulating a national poverty reduction strategy. This strategy is expected part of the country's long-term strategic plan and seeks to involve all groups of Sudanese society.

The preliminary draft of the PRSP was prepared in January 2004 with participation and contribution of a number of highly qualified national experts,. The PRSP is considered to be the main available document of the government of the Sudan for poverty reduction. It covers the sixteen States of North Sudan for the period 2005-2007.

PRSP main objectives are:

- Maintain Economic Stability.
- Ensure Political Stability
- Social Stability.
- Environmental integrity
- Improve standards of living
- Assist in the flow of financial resources.

2.3.5 Environment Protection Act 2001

In 2001, the Higher Council for Environment and Natural Resources (HCENR) initiated the development of environmental regulations under the Environment Protection Act which was issued through a presidential decree. It established guidelines and requirements for environmental impact assessments and environmental conservation frameworks.

The Environmental Protection Policy (2001) requires that any new projects that are deemed to have an impact on the environment conduct an Environmental Impact Assessment (EIA). This must be done in order to obtain an Environmental Compliance Certificate (ECC) from the HCENR through the receipt of an Initial Environmental Impact Assessment (IEA) Report. This report should contain a Mitigation Plan or a description of the mitigation measures to be implemented to reduce the environmental impacts of the proposed project.

The EIA report is normally made available for viewing and comment by interested and affected parties prior to the HCENR giving the go ahead with the project. This legislation represents a major step in coordinating national developmental projects on an environmentally sustainable basis

2.3.6 National Water Policy (2001) - Draft

Through a process of consultations with stakeholders, a Draft National Water Policy was prepared. The policy builds on experiences of a wide range of experts and institutions involved in water sector. The draft policy document assesses the water situation in the country, existing policies and legislation and then provides the main policy principles and statements. These policy principles are considered under water resources, water utilization, water and environment, international issues, socio-economic issues, disaster management and institutions and capacity building. It also recommends development of strategic plan for the water sector.

The objectives of the NWP are to:

- Review and adapt water policy to meet changing circumstances within the country;
- Ensure that the water resources of Sudan are properly managed, protected and efficiently utilized for the benefit of all;
- Provide the basis for the on-going development of water related regulations and legislation, and
- Strengthen and clarify the functions and responsibilities of water related institutions in both the public and private sectors in Sudan

Part 3 of the Water Policy (2001) addresses issues related to water and environment. It examines at policy as it affects the environment and related matters such as pollution and catchments degradation.

2.3.7 National strategies in response to Multilateral Environmental Agreements (MEAs)

(i) Agenda 21 Project - Sudan

In response to Agenda 21 (Rio Earth Summit 1992) a project was implemented in Sudan to build the capacity needed to meet the challenges of the Twenty First Century. The project helped to build capacities of government institutions, the private sector and non-governmental organizations to implement sustainable development projects. The project played an important catalytic role in promoting community level environmental protection. The project succeeded in building the capacities of Two State Environmental Councils and in the preparation of Environmental Action Plans for 4 States. This provided the basis for a ground level identification of a National Agenda 21 and initiated the formulation of a National Sustainable Development Strategy.

(ii) National Biodiversity Strategy and Action Plan (NBSAP)

In 1995, the Sudan government has become party to the Convention on Biological Diversity (CBD). The Government developed with GEF support and technical assistance from World Conservation Union (IUCN) its first National Biodiversity Strategy and Action Plan in May 2000 and its first Country Study on Biological Diversity in April 2001. The NBSAP outlines strategies, priorities and actions for biodiversity conservation and protection of natural ecosystems

(iii) National implementation Strategy for the UN Framework Convention on Climate Change

In 1992, the government of Sudan signed the United Nations Framework Convention on Climate Change (UNFCCC), and ratification took place in 1993. An enabling activity for climate change funded by GEF/UNDP was implemented by the HCENR. The project conducted many activities including training, a Greenhouse Gas inventory, a vulnerability and adaptation assessment and mitigation analysis and an intensive awareness program. As part of complying with its commitments to the Climate Change Convention, Sudan completed its National Communication under the UNFCCC in February 2003.

To fill the gaps and short comings of the vulnerability and adaptation assessment to climate change a three-year project is being implemented as part of the "Global Assessment of Impacts of and Adaptation to Climate Change (AIACC)" through GEF/UNEP. This project aims at enhancing the scientific and technical information, assessing the impact of climate change and designing cost-effective response measures needed to formulate national policy options.

(iv) National Action Plan (NAP) to Combat Desertification

In November 1995 Sudan ratified the United Nations Convention to Combat Desertification (UNCCD). The National Drought and Desertification Control Unit (NDDCU) has been designated as the national focal point to the UNCCD. The NDDCU identified the States that are affected by the desertification process. As part of its commitments under this convention, a National Action Programme (NAP) has been prepared in April 2002.

The challenges which face the implementation of NAP in Sudan include lack of a coherent national land use plan, dependence of household energy on forests products, expansion of mechanized rain fed agriculture and the civil war.

(v) Other International Environmental Obligations

Sudan is also involved in key GEF funded regional initiatives under the international waters operational programmes and is an active player in all these initiatives. These include the Kijani Initiative, the project for the Protection of Key "Bottleneck" Sites for Soaring Migratory Birds in the Rift Valley and Red Sea Flyway, the Nile Transboundary Environmental Action Project, the Strategic Action Programme for the Red Sea and Gulf of Aden (PERSGA) and the project for the Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies.

2.4 Institutional Framework

2.4.1 National Institutions:

(i) Higher Council for Environment and Natural Resources (HCENR)

In recognition of the importance of environmental protection for the sustainable development of Sudan, as well as for the fulfillment of the various United Nations global environmental commitments, the government in 1992 established the Higher Council for Environment and Natural Resources (HCENR) as the central government organ co-ordinating efforts for sustainable development, use of natural resources and environmental protection. The Council includes a number of relevant ministries and places special emphasis on addressing degradation, resource depletion, and chronic pollution. A parliamentary committee on environment and natural resources was also established in 1992.

In 1995, the Government also created the Ministry of Environment and Tourism, now Ministry of Environment and Physical Development (MOEPD) to oversee overall environmental management and integrate environmental protection into national development strategies.

The mandate of the HCENR as stated in the Environment Protection Act 2001 includes inter alia:

- Formulation of general policies for Natural Resources, inventories and development to ensure the appropriate management of the resources and their conservation and sustainable use,

- Develop in co-operation with other government authorities strategies to encourage environmentally sound and sustainable activities; and

- Initiate measures for the co-ordination and enforcement of environmental protection legislation.

The HCENR is chaired by the Minister of the Environment and Physical Development. The HCENR discharges its functions by a General Secretariat with the following mandate:

- Draft general policies for Natural Resources Inventories and Development to ensure the appropriate management of the resources and their conservation and sustainable use.

- Environment conservation in coordination with the appropriate authorities in the States.

- Coordinate the work of the Council Branches and all efforts in natural resources inventories and conservation and efforts for the sustainable development of the resources, monitor changes in the natural resources;

- Specify areas subjected to depletion, desertification and pollution and decide on priorities for surveys and studies on natural resources.

- Make long-term plans for rational and balanced use of the natural resources and environment conservation and follow-up the execution of the plan with appropriate authorities.

- Periodically review legislation related to the natural resources and the environment, make sure that Laws are effective and introduce any necessary amendments to improve the Laws.

- Establishment of branches in the different States to help the Council in performing its responsibilities.

- Encourage support and coordinate scientific research in all fields of the environment and natural resources.

- Formulate a federal plan for environmental awareness and rational use of the natural resources and try to incorporate environmental education in school curricula.

The HCENR is Sudan's outlet to the international environmental arena. It acts as the technical focal point for most of the environmental the conventions emerged from the Earth Summit in Rio de Janeiro (1992) namely: Convention on Biological Diversity (CBD) and the United Nations Framework Convention on

Climate Change (UNFCCC). In addition it is a party to the Convention on Persistent Organic Pollutants (POPs).

The cross-cutting nature of the environmental issues, which spread over different disciplines, has guided the HCENR to form steering and technical committees so as to bring all the concerned stakeholders together, and playing its coordinative role.

(ii) Other Government Institutions

In addition to the HCENR, other government ministries have significant roles and responsibilities in the areas of natural resource management, land use planning, and socio-economic development, including :

- Ministry of Agriculture and Forests;
- Ministry of Irrigation and Water Resources;
- Ministry of Finance
- Ministry of Technology and Scientific Research;
- Ministry of Industry and Commerce;
- Ministry of Energy and Mining
- National Council for Strategic Planning
- Ministry of Health;
- National Meteorological Authority
- Ministry of Culture and Information; and
- The General Directorate of Public Corporation for Investment

The **Ministry of Agriculture and Forests** is responsible for agricultural development and natural resources planning and policies, and the National Drought and Desertification Control Unit (NDDCU) in this Ministry has been designated as the national focal point (NFP) to the UNCCD.

In 1989 the **Forest National Corporation** (FNC) replaced the old Forest Administration (that was established in 1902) to be responsible for the protection and management of forest resources in the country. The FNC is a semi-autonomous corporate body that is attached to the Ministry of Agriculture and Forests. It has a Board of Directors constituted by the Council of Ministers and 10 representatives from related institutions. As such, the FNC is entrusted with the role of protection and conservation of forest resources.

The **Ministry of National Industry** is responsible for formulating industrial policies, strategies and programmes that fall within overall national objectives. The Ministry can orient the activities of many industrial activities that are directly related to the Biodiversity, Climate Change and Desertification issues, as the industrial sector is an important user of natural resources.

The **Ministry of Irrigation and Water Resources** is responsible for setting national water resources policies, strategies and plans, development of water resources to meet the needs, monitoring of ground water basins, and forging cooperation between the Nile basin countries. It also, contributes to the environmentally sound socio-economic development such as in big irrigated agriculture schemes.

The Wildlife Conservation General Administration (WCGA) was established in 1902 by the colonial authorities. The WCGA was part of the Game and Fisheries Department of the Ministry of Animal Resources. Today, it is administratively accountable to the Ministry of Interior while technically it is accountable to the Ministry of Environment and Tourism. It is entrusted with the conservation of wildlife in the Sudan. Wildlife includes also ecosystems and habitats where species are living. WCGA is also entrusted with the task of establishment and management of protected areas in Sudan. Among its main responsibilities are:

- Sustainable management and utilization of wildlife resources in the country.
- Origination of hunting (issuing licenses and setting by limits).
- Cropping of wildlife, trade in wildlife parts and live animals.
- Establishment of zoological gardens for wildlife public education.
- Control of wildlife damaging problems.
- Management of marine national parks and protected areas.

WCGA is the focal point for CITES (Convention on International Trade in Threatened and Endangered Species (includes botanical or animal species.) as well as for RAMSAR Convention for the protection of wetland.

The **Wildlife Research Center (WRC)** is a part of the Animal Resources Research Corporation. There are no official links between the WCGA and WRC. Research recommendations are not implemented, and the WCGA major approach to wildlife conservation is policing and licensing with no efforts in the area of involving the people in participatory wildlife management or applying scientific wildlife management practices (NBSAP, 2001). The WCGA lacks official link with the Fisheries Administration, Fisheries Research which is also under the Ministry of Animal Resource.

The Institute **of Environmental Studies (IES), University of Khartoum** was formally established in 1979. Although in fact it was created in 1972 following United Nations Conference on Human Environment in 1972 and the subsequent call by the Arab League Educational Cultural and Scientific Organization, (ALECSO) that universities should respond to environmental problems and challenges. Since then, he IES (the first in Africa and the Middle East) has pursued a program that blends a) post-graduate education in environmental studies b) short-term training in natural resources c) research and consultancies in project design, environmental impact assessment and education.

IES executes projects funded by international organization e.g. i) Dry Land Husbandry project (OSSREA & EPOS) i) Environment Impact Assessment projects (UNEP, UNICEF,US-AID,CPECC UNSO) and iii) Acted as coordinators between Research Institutions and NGOs (Ford Foundation).Project proposals are coordinated through the IES pertaining to the field of coastal zone , arid lands, wetlands meteorology and urban planning. IES qualifies teaching assistants and lecturers to obtain M.Sc. and PhD degrees in environmental sciences.

(iii) Non-Government and Civil Society Institutions

Several national NGOs in Sudan have formed a network called the Network Committee for Combating Desertification (NCCD), NDDCU and NCCD worked in close collaboration throughout the NAP process. Organized forms of NGOs have become well known after 1975 (Mohamed, 1999). Many registered NGOs are actively working on different fields of the environment and rural development. Also there are some networks for coordination between NGOs e.g. the NGOs National Coordination Committee on Desertification (NCCD). The following are some examples of Sudanese NGOs working on environment-related work.

The Sudanese **Environmental Conservation Society (SECS)** is considered to be the most active NGO in promotion of environmental awareness and lobbying for better environmental policies and actions. It does so by initiating and supporting small projects with grassroots involvement designed to improve living conditions and well being. Examples of these projects include tree planting, waste management and awareness-raising. SECS have more than 80 branches distributed all over Sudan, with more than 6000 members. The main objectives of SECS include:

- Conservation of the environment and mitigation of any action that may lead to environmental degradation.
- Dissemination of environmental awareness.
- Cooperation with the government in law enforcement for environmental conservation.
- Strengthening the links with the local, national, regional and international institutions endeavoring to conserve the environment.
- Encouraging scientific research and studies aiming at the conservation of the environment, in addition to writing of the natural history of the Sudan. (El Nour *et al* ., 2001)

The Sudanese Social Forestry Society (SSFS) is a charitable NGO with dedicated memberships who believe in social and multiple benefits of the forest. SSFS seeks promotion of concepts and practices of people involvement and social forestry in Sudan. The main objectives of SSFS are:

- To promote the concept and practices of social forestry, through networking and linkages between social forestry and extension units in Sudan.
- Enhance the standards of awareness of the community participation in social forestry.
- Encourage the scientific applied research in social forestry and promote the output of the same among the interested persons.
- Assist in the fund raising and appropriate resource funding of the social forestry projects.
- Facilitate and forward the technical consultancies in the field of social forestry projects.
- Cooperate with the concerned bodies, for the development of social forestry.
- Collect, authenticate and publish information regarding the social forestry activities.
- Establish advanced relation with international and national network.
- Preserve the natural forests as a natural heritage.

The Environmentalist **Society** is one of the active national NGO's in the field of environment. It aims at promoting environmental awareness and capacity building in environment related fields. All graduates from the Institutes of Environmental Studies are by default members in this society and could volunteer to provide services and contribute to environmental assessments and training programs whenever, it is required.

(iv) Traditional Institutions

These include traditional structures (local Administration, community leaders and other community-based organizations (CBOs). Traditional leaders are generally elected from the same families and thus, the holding is semi-hereditary one. These systems play important roles at the local community level. Their responsibilities include:

- Land allocation and settlement of conflicts;
- protection of the common natural resources;
- organization of usage of natural resources;
- construction of fire lines;

- keeping order of security and organization of foreign tribes presence in their areas, assigning nomadic routes;
- organization of communal public activities e.g. pest and bush fire control and settlement of tribal disputes

They have well identified roles in relation to resource conservation and management. According to Elnour the system of traditional management was supported by equity of use right and social customs governing common property resources. This flexibility facilitated resource conservation particularly under the dry conditions. Additionally, they play an important role in conflict resolution based on the indigenous mediation (*Judiyya*) system. The "*Judiyya*" is established tradition in Sudan and can be initiated by a member of the local administration or a religious leader (Fagir) or a group consisting of representatives of all of them. They all represent mediating roles with the ultimate objective of reaching a consensus and peaceful settlement to their conflicts.

3. AGRICULTURAL AND PASTORAL SYSTEMS

3.1 Role of Agriculture in the Economy

Despite years of modernization, Sudan is still predominantly agrarian in cultural and economic outlooks. The majority of the population is rural and engaged in primary activities based on crop farming, agro-pastoralism and pastoralism. A rapid process of transformation is, however, taking place with increasing proportion of the population moving out of the primary sector and making their way towards urban settlements where they are absorbed by the formal economic sector.

Sudan is basically dependent upon agriculture. Accordingly, the agricultural sector employs the bulk of the labor force. The structure of the agricultural sector comprises crops (51%), livestock (38%) and forestry (10%). Agriculture in Sudan is subdivided into irrigated and rain-fed production as well as modern and traditional systems.

Until recently the bulk of Sudanese exports (90 percent) originated from the agricultural sector. The major export commodities include cotton, Gum Arabic, oil seeds and livestock. The bulk of Sudan's exports are directed towards the European Economic Community (EEC) and the Arab countries. More recently the Sudan has benefited from investment in oil production, which is expected to reduce the country's import bill and improve the availability of foreign exchange for development financing. The economic system in the Sudan is moving towards free enterprise market economy. This drive is initiated and enhanced by the governmental policy measures of liberalization and privatization.

Sudan is well endowed with natural resources in terms of agricultural potential and minerals. Currently and in the foreseeable future the country will remain highly dependant on agriculture and oil. Agriculture is the mainstay of the economy contributing about 37 percent of GDP and 15 percent of the exports and provides the livelihood of about 70 percent of the population (Sudan Central Bureau of Statistics, 2005). The agricultural contribution to GDP has declined during the last 5 years whilst the oil sector has developed from almost nil to more than 11 percent of the GDP over the same period. Presently oil and petroleum products account for 81 percent of exports and 40 percent of the public revenue. Neither the agricultural nor the oil potentials are being fully exploited, both affected among other things by the climatic conditions and poor management. At present the industrial sector contributes about 9 percent of GDP and is primarily based on agro-processing, oil refining, sugar and textile production.

Since 1997 Sudan has implemented a comprehensive macro-economic program monitored by the IMF. According to the official reports of the Ministry of Finance the national economy has shown rates of growth in the order of 5-8%. However major constraints to growth remain, of which the most important are: the unstable and insecure environment for utilization of the natural resources, low capacity of the infrastructures, the civil war and a low-skilled work force.

3.2 Socio-Cultural Factors Affecting Resource Use:

The cultural and socio-economic factors affecting resource use can be classified into two broad categories relating to the household economy. These include both internal and external factors.

3.2.1 Internal Factors:

Agricultural resource users in the country, as classified in the previous sections include: farmers practicing irrigated agriculture, mechanized rain-fed farmers, traditional farmers and pastoralists. Each may be influenced by a set of internal factors that affect the farming operations and consequently, the resource use.

Most of those involved in irrigated agriculture are tenants and their farming operations, are decided in many cases by the scheme management. Thus, decisions regarding crops to be grown are not taken by the farmer. However, the tenants, in spite of the scheme management’s concern for cash crops involve themselves in food production as part of the rotation. Along the Blue and main Niles, there is a significant number of smallholder irrigators using pump from river, wells and basin-flood irrigation. Mechanized schemes are mainly operated by rich merchants who are concerned with profit maximization. The lease system common to mechanized farming schemes does not provide an incentive for sustainable land management leading to a widespread move from mechanized farming.

In the traditional farming sector the household economy is basically oriented towards subsistence production based on shifting cultivation and livestock rearing. A fundamental goal is food security. The climatic factor plays a very important role in such strategy. Through accumulated knowledge the traditional farmers have perfected local warning systems that affected their economic behavior. Flexibility is the strategy guiding many management decisions. To achieve livelihood security farmers attempt to increase productivity of existing land, occupy unutilized land, develop external linkages and maximize family herds. Flexibility also allows the household to adjust quickly to changes during the production cycle, such as market conditions and environmental circumstances. These are achieved through crop diversification or planting quick maturing crops in response to a late start to the rains. This feature is very common in Western Sudan (Yagoub Mohamed, 1982).

3.2.2. External Factors:

External factors have different impacts on the different resource users in the Sudan. Individual households are part of a large community and hence, the most important aspect to be considered here is how the community organizes access to resources including land. Here, the tribal heritage and subsequent interventions by the different government set limits that influence strategies pursued.

There are four main land tenure systems:

- Private ownership in areas along the Nile;
- Government land with community rights organized by customary rules;
- Government lands with no community rights;
- Government Leases.

Each type of land tenure has far reaching implications on resource use. In the areas along the Nile where private ownership is recognized, there is some concern for proper land management. The lease system is dominant in rain fed mechanized agriculture. This has created a tendency towards mining the soil rather than conservation. The most widespread land tenure system is customary tenure. In such areas, unclaimed land is free for all as common land. Land degradation and desertification in many parts of the country resulted from such practices and the mismanagement of the common lands.

The development of rural markets facilitated the exchange of commodities and livestock between the different groups occupying different environments. These developments influenced both cultivators and livestock raisers. Commodity prices have led towards more involvement in cash cropping, which influenced the production strategies of many traditional farmers. Awareness of market opportunities promoted an increase in areas under groundnuts, sesame, and other cash crops. Favorable prices offered to Gum Arabic are directly reflected in attempts to improve *Acacia senegal* gardens. In irrigated agriculture, there is also strong tendency to integrate livestock in the rotation in such schemes like El Rahad where most of the farmers are of nomadic background.

Decisions regarding resource use are also influenced by services offered by the government in form of extension, credit, veterinary services and pricing policies. These support services may affect the adoption of a particular land use practice which may in some cases, if not properly managed, lead to land degradation, due to the absence of clear land use policy.

3.3 Main Farming Systems

Agriculture in Sudan is classified under five main farming) systems: (i) Large scale irrigated schemes, (ii) small-scale irrigated farms, (iii) large scale semi-mechanized farms (> 1500 fed.), (iv) small scale sedentary farms (< 1500 fed.) and (v) pastoral and agro-pastoral systems. Also, these farming systems are classified according to the type of irrigation to: Irrigated Schemes and Rain fed Farming- systems which includes: semi-mechanized schemes, traditional rain-fed systems, agro-pastoral and pastoral systems. Rain fall is the limiting factor for rainfed cultivation north of the 300 mm isohyte.

3.3.1 Large scale Irrigated Cropping

(i) Structure

The irrigated sub-sector is an important component of the Sudanese agricultural sector. Although, the irrigated area only represents 20% of the cultivated area, yet it contributes more than 50% of the total value of the agricultural production of the whole country. Some important cash crops such as wheat, sugarcane and cotton are only produced in irrigated schemes. The irrigated sub-sector, directly or indirectly, provides employment for more than 80% of the population.

Until the turn of last century, the traditional irrigation methods used in the Sudan were basin irrigation along the bank of the main Nile and the Blue Nile, flush irrigation in the Gash and Baraka rivers. Water lifting for irrigation before then, was confined to water- wheel (sagia) and Shadoof. Modern irrigation was introduced by the construction of the first pump on the river Nile in the Al Zeidab Scheme (1906), to be followed by Taiba experimental farm (1912) in the Gezira Region. Gravity irrigation had begun in 1925 in the Gezira Scheme after the completion of Sennar Dam. The irrigated area was increasing rapidly, particularly during the fifties, sixties and seventies of the last century, as the result of the construction of the Managil Extension, Halfa Algadida and Rahad project, consecutively.

Nowadays, the cultivated area is about 4.2 million feddans consuming an annual average of 14.0 km3 of water, which makes Sudan with the largest irrigated area in Sub-Saharan Africa.

(ii) Dams:

Limited Water resources from the river Nile and its tributaries would certainly lead to scarcity during this century due to increased water use and needs. The 1959 Nile Waters Agreement shows that the Sudan share is 18.5 km3. measured at Aswan High Dam which is equivalent to 20.5 km3. at Sennar Dam. The irrigated schemes were situated along the Nile and its tributaries. Due to the seasonality of the Nile waters and rainwater variability, it is a necessity to establish storing reservoirs to guarantee stable productivity and cultivating various crops. Four dams were constructed on the Nile and its tributaries for irrigation, power generation and other purposes. Table 4 below shows the location, year of commission and the capacity of each dam.

Table 4. Existing Dams* in the Sudan, (Source: MIWR 2006)

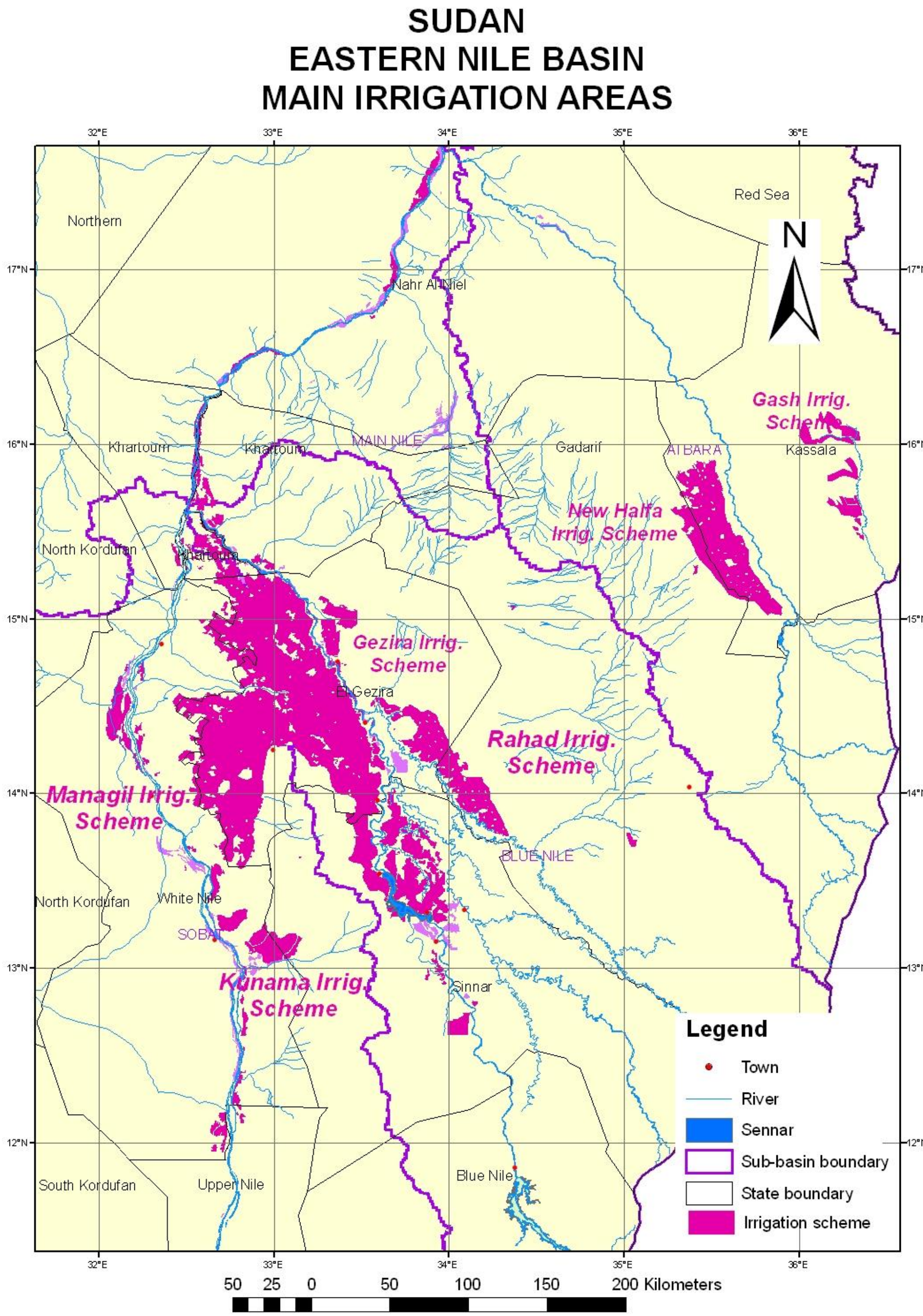
Name	Location	Year of Commission	Capacity (10^9 m^3)	
			Design	Present
Sennar	Blue Nile *	1925	0.93	**0.37**
Jebel Aulia	White Nile	1937	3.50	**3.50**
Khashm El Girba	Atbara River*	1964	1.30	**0.60**
Roseires	**Blue Nile***	**1966**	**3.35**	**2.20**

* Originating from the Ethiopian plateau.
* Merowe dam is under construction now.

From the table above, it is evident that all dams build across rivers originating from the Ethiopian plateau suffer from a reduction in the storing capacity due to sediment deposition in their reservoirs.

(iii) Irrigation Schemes (Map 4)

The availability of irrigation water, suitability of land topography and the soil type led to the concentration of the major irrigation development in a limited area of the country. Nearly 90% of these developments to took place in the so called Central Clay Plain (CCP) of the eastern side of the central Sudan. The annual average rainfall in these plains ranges from about 170 mm in the north to 550 mm in the south. Almost all this amount of rainfall occurs during three months from July to September making supplementary irrigation necessary for secured crop production and diversification.



Map 4. Sudan – Eastern Nile Basin: Main Irrigation Schemes
Source: Sudan FAO Africover, 2003

Various methods of irrigation had been known through time, yet modern irrigation was introduced in Al Zeidab scheme in the beginning of last century as stated before, to be followed by Taiba experimental project and lastly by the Gezira scheme as a real addition to modern irrigation.

After Independence in 1956 the irrigated area increased considerably from 0.8 to 4.2 million feddans. Sudan established new schemes at New Halfa, Es Suki, Abu Naama, Rahad, sugar Schemes and food security projects in the North. Tables 5 and 6 below show the different national schemes in the Sudan and their irrigated areas. Most of these irrigated areas are located in the Blue Nile and Atbara Sub-Basins.

Table 5. Largest Sudanese Irrigated Schemes

Irrigated Scheme	Site (State)	Date of Operation	Area (10^3 feddans)
Gezira & Managil	Gezira & Sennar	1925	**2100**
Rahed	Gezira & Gedaref	1979	**300**
New Halfa	Kassala	1964	**450**
Es Suki	Sennar	1971	**90**
Al Guneid*	Gezira	1961	**38**
North-West Sennar*	Gezira & Sennar	1974	**50**
Kenana *	White Nile	1976	**86**
Asalaya *	**White Nile**	**1977**	**36**

* Sugar schemes
1.0 feddan = 0.42 ha
* Source: Ministry of Irrigation and Water Resources (MIWR).

Table 6. Irrigated Areas in the Sudan

No.	Water Source	Method of Irrigation	Area (10^3 feddans)
01	Blue Nile	Gravity	**2100**
02	Blue Nile	Pumps	**540**
03	Blue Nile	Pumps	**90**
04	White Nile	Pumps	**475**
05	White Nile	Pumps	**174**
06	Atbara River	Gravity	**400**
07	Atbara River	Bumps	**90**
08	Main Nile	Basin	**80**
09	Main Nile	Pumps	**210**
10	Gash & Baraka	Flush	**120**
	Total:		**4279**

Historically, large-scale Nile-based irrigation has been one of the pillars of Sudan's strategy for agricultural development. There are between 4 and 5 million feddans of land suitable for irrigation within the Eastern Nile Basin located in the Northern, Gaderif, Kassala, Khartoum, Gezira, Sennar, Blue Nile, White Nile and Upper Nile States. The Gezira irrigation scheme, established in 1925, accounts for almost half of that area, with a gravity-fed command area of 2.1 million feddan (about 882.000 hectares). Three other schemes along the Nile (Rahad, Suki, and New Halfa) have a total command area of 1 million feddan (420.000 hectares). These four irrigation schemes are owned and managed by the central government and are significant in three respects:

- They are highly capital-intensive, requiring regular maintenance.
- They produce a considerable volume of commodities for domestic consumption and export;
- All schemes have been subsidized by the federal government because of low productivity and excessive costs.

Initially, the schemes performed efficiently when they were managed as private entities with the government retaining a share of ownership. Gezira's performance deteriorated after it was taken over by the government. Since then, all schemes have been subsidized by the federal government because of low productivity and excessive costs.

The social and economic infrastructure associated with large-scale irrigation has accentuated the substantial geographical disparities associated with the unequal natural resource endowment among states. For example, about 21 percent of total agricultural GDP is produced in the Nile State (irrigated wheat farming). Gezira State alone produces more than 50 percent of irrigated agricultural output, including 90 percent of the nation's cotton and almost half of its wheat.

3.3.2 Small-scale Irrigated Cropping

Along the banks of the Blue Nile, White Nile and Main Nile are a significant number of small-scale irrigators using a variety of irrigation methods. Pumped irrigation straight from the river is common. Along the Main Nile basin irrigation is common where the topographic conditions of the flood plain allow flood water to enter basins under controlled conditions. Away from the Main Nile but generally within about 15 km irrigators use the shallow groundwater to be found in this zone. Cereals, vegetables and Date palm are the main crops grown by small-scale irrigators.

Maize and sorghum are produced in summer and wheat in winter. Here sorghum is produced as a cash crop the preferred staple being wheat. Large areas of broad beans and vegetables are also grown under irrigation during the winter, and a considerable area of alfalfa produced with up to ten cuts per year. Dates are an important source of income but in recent years infestation by green scale insects has significantly reduced yields and killed a large number of trees. Control measures have been identified but are costly.

3.3.3 Large scale Semi Mechanized Cropping (Map 5)

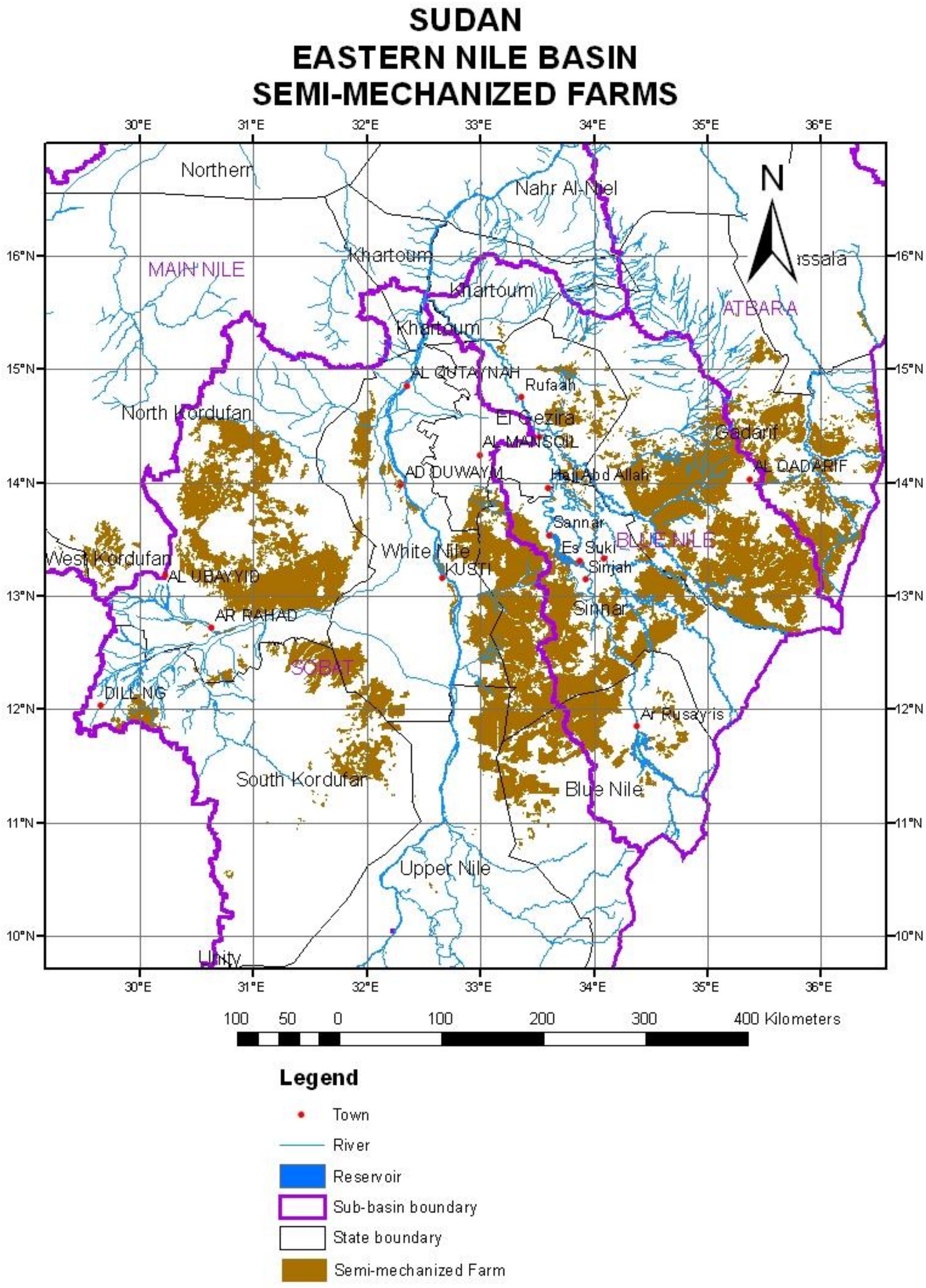
(i) Background

This farming system developed under the auspices of the government as mechanized crop production schemes in 1945 on generally alkaline clays and loams, which are not suitable for cultivation by hand or by oxen. While farms of about 1,000 feddan were initially based on share cropping with the government, this was not successful. In 1953 the farms were transformed into government leasehold. The area under this system of management increased rapidly and by the beginning of the 1970s was estimated to have reached 2 million feddan. It has spread to about 14 million feddan in the states of El Gedaref, Blue Nile, Upper Nile, White Nile, Sennar, and Southern Kordofan (Nuba Mountains). Semi-mechanized farm are now usually well over 1000 feddan as a result of amalgamations of leases and family partnerships. The government also allocated large tracts of land (between 50,000 and 1 million feddan) to Sudanese and foreign investors (mainly from the Gulf countries). Land preparation, seeding, and most threshing on these farms are mechanized, whereas weeding, harvesting, and some threshing are done by seasonal labor.

Land is leased by the State to individual investors whereby each individual is allotted “a farm”. These schemes are managed by both private and government sectors. Sometimes, rotation of dura, sesame and fallow with or without cotton are practiced, but often a piece of land is cropped with dura until the land loses its fertility and then abandoned completely.

The mechanized rainfed farming sector is criticized as being a major cause of environmental deterioration. To understand the role it played and to assess its impact a brief background is necessary.

The Mechanized Farming Corporation (M.F.C.) was established in 1968 (Act No. 14) to act as a main agency for the promotion of large scale rainfed agriculture.



Map 5. Sudan – Eastern Nile Basin: Distribution of Semi-Mechanized Farms

Source: Sudan FAO Africover 2003

In 1975, the M.F.C. came under a new Act which defined the responsibilities of the corporation as follows:

- Survey, allocate, demarcate and distribute schemes to farmers.
- Assist the private investors and direct their attention to the best agricultural techniques.
- Promo to agricultural research.
- Provide credit to farmers on reasonable terms.
- Operate state farms.
- Provide social services.

The emphasis over the past thirty years has been primarily on survey, demarcation and distribution of schemes as well as on the running of state farms. There had been very little activity in other aspects of responsibilities.

Since the introduction of mechanization more emphasis was given to horizontal expansion rather than to vertical expansion. For example, in the years from 1950 to 1952 the total area under mechanized rainfed farming in Gedarif state was 34,124 feddans. At present the area exceeds 3 million feddans, half of which is un-demarcated or unauthorized by the M.F.C. so, there is expansion without any control by concerned technical agencies i.e. M.F.C. or Land use department.

A general evaluation of these schemes indicates that there are many shortcomings in the planning of these schemes. They are often connected without site selection, or consideration of nomadic rights, stock routes and wildlife sanctuaries. The development of mechanized farming and its spread without proper control or appropriate environmental measures led to negative impacts on the environment and resulted in serious deterioration in the grazing resources, forest resources and soil fertility.

(ii) Impacts of mechanized rainfed farming:

The original advantages of a semi-mechanized farm sector were seen to be:

- Employment generation,
- Contributing to expanded food supply for domestic consumption and for export.
- Have a low demand for public services and support compared with peasant agriculture or large irrigation schemes.
- Mobilizes private investment.

In many ways these advantages have been realized. The SMF's provide employment opportunities that help to expand livelihood strategies for many rural families: particularly for agro-pastoral and pastoral families who have lost livestock assets as a result of drought. From the 1960's until the late 1980's the SMF's made an increasing contribution to the national food supply, although since the early 1990's this has begun to decline. Finally, by mobilizing private capital they made few demands on government resources.

However, the mechanized rainfed farms have had negative impacts on the resource base, environment and livelihood of the people. This can be seen in:

- Overgrazed areas and indications of soil erosion.
- Deforested areas for mechanized crop production results in gully erosion, degradation of soil structure, texture and fertility and hence a decrease in yields.
- Pressure on the grazing areas of pastoralists and exclusion of agro-pastoralists and traditional farmers from some of their traditional land
- Decreasing area of Gum Arabic trees.

3.3.4 Small-scale Sedentary Agriculture

Several systems of rainfed agriculture are found, such as shifting cultivation in the savanna woodlands and (terus) cultivation in the arid parts. These are described below.

Rainfed traditional farming. The traditional rainfed farming system includes nomadic, transhumance (moving with livestock and growing short-maturity subsistence crops), and sedentary agriculture which also includes a significant number of livestock. This system is found to some extent in every State. It is most prevalent in the three Kordofan states and the three Darfur states. Livestock provide an important capital asset and are a risk management tool for pastoralists and farmers in times of drought. The sedentary small farmers typically have 10 to 15 feddan on which they produce food crops as well as cash crops such as karkade, sesame, and water melon seeds. The total cropped area in this system is estimated at 18 million feddan.

Production from the rainfed traditional farming is very low and many hazards are encountered such as drought and/or water logging, plant diseases, pests….etc. these, in addition to bad management-practices are responsible for the poor yield attained.

3.3.4 Pastoral and Agro-pastoral Systems

(i) Introduction.

In 1998 livestock production comprised 40 percent of agricultural GDP. The livestock sector is rich and diversified and includes live animals for export, meat, hides and skins. Production increased significantly in the 1990's mainly because of the rapid expansion of the sheep export market in the Gulf countries. To a large extent livestock production is integrated into the traditional agricultural sector, although livestock on the large scale irrigation schemes are becoming an important component of that system.

"Pastoral" and "agro-pastoral" production systems are here defined as those systems where the livestock production component for subsistence and sale exceeds that of crop production. Many "pastoral" production systems are rarely totally reliant on livestock production and will include a crop production component although this may be very small and/or infrequent.

(ii) Changing Pastoral /Agro-pastoral production Systems

Since the drought of the early 1980's many households in what were predominantly "pastoral" ethnic groups have adopted livelihood strategies that include crop production, milk production for sale, wage labour and other non-agricultural activities. Many households no longer rely on livestock production as their main source of subsistence and are effectively sedentarised cultivators. Over the past two decades many households have and are still making the transition from pastoralism to agro-pastoralism to sedentarised crop cultivation and vice versa as household and external conditions change.

These changes in household production systems are the result of the massive losses in household and community livestock assets during the drought of the early 1980's exacerbated by the increasingly loss of wet season grazing areas and water resources from the big expansion of large-scale semi-mechanized farms during the 1980's and 90's.

Omer A. Egemi (2002) describes the emergence of two herding systems on the west Butana Plain from a previous mainly pastoral system that crashed during the drought. These are contract herding and village herding. Village herding is practised by former pastoralists who have lost most of their livestock during the drought. Their livestock holding are confined to sheep and goats. Crop cultivation is highly precarious and located in depressions and the major khors on share cropped land owned by the Gaalian people along the Nile. Seasonal migration for wage labour along the Nile Pump schemes is a major livelihood strategy. Contract herding is the dominant form. Herds comprise cattle, sheep and goats and comprise 80 percent or more of the livestock in the western Butana Plains.

The animals are owned by farmers along the Nile, traders, and government officials. The herders are former pastoralists who have lost all their livestock during the drought through mortality or by having to sell the livestock assets to the riverine farmers.

Morton (1988) describes a similar decline in pastoralism among the Lahawin people who occupy the area in the upper Atbara and Setit valleys in Kassala Province. Here again the 1980's drought exacerbated by loss of the grazing land to semi-mechanized farming has left many former pastoral families with few or no livestock. Many have settled on the New Halfa Irrigation Scheme and others now practice sedentary agriculture along the Atbara and Setit rivers and engage in migratory wage labour. Mohamed A.M. Salih (1988) recounts a similar story of the decimation of livestock assets (mainly camels) of pastoralists occupying western parts of River Nile and the western parts of Northern Kordofan Provinces during the drought and the settlement of many former pastoralists in the suburbs of Omdurman who now engage in milk production and non-livestock activities. Finally there are detailed accounts by Abdel G.M. Ahmed of the loss of livestock assets due to drought and exacerbated by loss of grazing lands to the expansion of semi-mechanized agriculture of the Rufa'a al-Hoi, the Ingessena and the Fulani (Fellata) who grazed the lands between the two Niles. By 2000 some 80 percent of the northern group of Rufa'a al-Hoi and 20 percent of the southern group had become sedentarized crop farmers.

On a more positive note the Rashaida people living in the same area as the Lahawin (Kassala province) had already diversified before into trade, labour migration and mechanized agriculture and thus were able to survive the drought. In addition, they escape the shortage of grazing land by lorry transport of livestock between grazing locations. Haug (2002) Recounts the story of the Hawaweer pastoralists who dispersed almost totally from their home area, mainly along the Wadi Al Muggaadam, to refugee camps in Omdurman, or as migrant labourers in Sudan and the Gulf Countries. With the cessation of the drought and an improvement in environmental conditions many have returned to their homeland and rebuilt their livelihoods.

Morton and Meadows (2000) Have proposed that by adopting a "sustainable livelihoods" (SL) approach to pastoral development the various "coping" and "adaptive" strategies adopted (e.g. migratory wage labour, trading, etc.) by pastoralists in the face of risks and shocks can be incorporated into supportive interventions. Viewing livestock not only as "natural capital" but also as 'financial and social capital" more effectively informs potential intervention programmes for restocking, savings, education and livelihoods diversification.

(iii) The Pastoral/Agro-pastoral Production Systems

These are mainly confined to the Butana north of the Blue Nile and similar rangeland areas to the south. The Butana has been described as the best rangeland for camels and sheep. This was largely due to the occurrence of good grazing fodder. However, these areas have been heavily grazed and have almost lost some of its valuable plant species such as *Belpharis spp.* Butana is considered as a marginal for rainfed cultivation, although it is sporadically practiced there using *terus* water harvesting structures or on low-lying water receiving sites.

The main household livelihood assets are the livestock herds, grazing and browsing resources (wet and dry season areas), water resources (wet and dry season areas), land for crop cultivation (rainfed or irrigated), gum trees for harvesting and family and community labour. Social assets included accumulated group knowledge of natural resources and their distribution and mutual coping and assistance mechanisms.

There is a complicated system of division of labour depending on the particular composition of the livestock assets and in turn the herd splitting strategies. These include division of cattle holdings into wet (i.e. in milk) and dry herds. Milking animals tend to be kept close to the permanent camp or moved slowly behind the dry herd when trekking. As camels and goats can go for longer periods than sheep or cattle they are often herded separately and at greater distances from the main camps. In terms of labour division men undertake herding, cultivation and gum tapping, whilst women and children undertake domestic work, herding goats or sheep for milk and tending calves and cows in milk.

Overall herd composition differs between the more arid north and the wetter south, with camels and goats predominating in the north and west and cattle and sheep in the south and east. Specific productions systems have developed over the years in specific areas as results of natural agro-ecological conditions including droughts, socio-cultural factors, economic factors and changing accessibility to grazing and water resources.

3.4 Crop Yields and Productivity:

Trends in crop yields vary considerably among the major farming systems. Data in Table 7 for the growing season 2005/06 show that sorghum yields (kg/fed) was 778, 211 and 279 for Irrigated schemes, mechanical rainfed and traditional rainfed systems, respectively.

The same trend is clear for other crops. In addition, the absolute yield levels are generally low by international standards. Table 8 shows that the average yields (kg/fed) for irrigated seed cotton and wheat are 86% and 90% of the international yield averages. However, it is 16% for corn, 56% for sorghum, 21% for cereals (total), 47% for groundnuts, 32% for sesame, and 39% for onion.

In the irrigation schemes there have been some improvements (based on hybrid varieties) in farmer yields for wheat (mainly in Northern state) and sorghum, but the yield levels achieved are still considerably less than research yields (Table 9). Average cotton yields in the major irrigated areas were no better at the end of the 1990s than they are now (2006). Yields in the Gezira Scheme are well below potential and research levels performance in major cotton-producing countries (despite difficulties inherent in making such comparisons). Yields of irrigated cotton in the Sudan in the 1990s (at that time the country's main cash export crop), were equivalent to only 47 percent of Egypt's average yield and 53 percent of the average in China.

If one examines yield of rainfed sorghum (the most important food crop in Sudan), the trend has remained stagnant or has declined[2] during the last decade. The trends in Table 10 reveal the decline in yields and minimal differences between average sorghum yields in the fertile semi-mechanized areas and the less fertile traditional farming areas during 1996-2006. The reasons need to be explored but they almost certainly include (i) a reduction in fertility in areas that have been continually cropped for decades in the semi-mechanized areas without fallow and no conservation practices; ii) the well-documented expansion of sorghum cultivation into marginal areas (both semi-mechanized and traditional) where the probability of substantial destruction of soil structure, soil erosion, and hence low yields is close to 100 percent; and (iii) in the traditional rainfed sub-sector, particularly, the low yields reflect a serious lack of support services such as research, extension, high yielding varieties, certified seeds, pest and weed control, fluctuation of rain fall and credit for smallholders.

[2] * Between 1977/1978 and 2000/2001 the average yields in semi-mechanized and traditional areas declined by 2 percent and 1.1 percent per annum, respectively.

Table 7. Average crop yields (kg/feddan) and area planted (000 feddan) for 2005/06 as compared to 2003/04, 2004/05 and (1996/7 -2000/01 average).

Year / Crop	1996/97-2000/01			2003/04			2004/05			2005/06			Sudan			
	Irrigat.*	McR	TrR	Irrigat.	McR	TrR	Irrigat.	McR	TrR	Irrigat.	McR	TrR	96-01	02/03	04/05	05/06
A.Yield (kg/fed)																
	802	211	201	740	240	246	873	196	215	778	211	279	249	269	265	274
Sorghum	229	179	116	135	168	114	150	124	71	400	147	121	119	122	74	124
Millet	875	-	385	977	-	500	958	-	500	980	-	500	861	971	953	976
Wheat	314	-	-	789	-	-	806	-	-	436	-	-	314	789	806	436
Corn	1000	86	55	-	89	86	-	87	64	-	86	95	75	105	76	92
Sesame	864	-	231	1026	-	251	1046	-	151	1100	-	273	287	311	227	389
Groundnuts	273	189	-	625	137	-	684	285	-	684	333	-	208	538	480	611
Sunflower	-	-									-		-	-	167	250
Guar													481	609	655	610
Cotton:	390	-	-	695	-	-	694	-	-	697	-	-	-			
Egyptian	581	-	-	431	-	-	656	-	-	629	-	-	-			
Ackala	-	481	-	-	364	-	-	88	-	-	105	-	-			
American																
B. Area (000fed)																
Sorghum	1020	9337	5755	1017	10608	8324	949	8209	6124	1105	11607	7741	16112	19949	15282	20453
Millet	9	181	8843	18	572	19734	11	169	6816	16	537	7449	9033	10324	6996	8002
Wheat	454	-	15	426	-	6	403	-	4	427	-	6	469	432	407	433
Corn	199	-	-	205	-	-	36	-	-	277	-	-	199	205	36	277
Sesame	3	3118	2018	-	2498	1921	-	2426	2111	-	2781	2530	5164	4419	4537	5311
Groundnuts	318	-	3653	217	-	3540	203	-	2806	208	-	1407	3971	3757	3009	1615
Sunflower	12	40	-	8	7	-	19	9	-	70	17	-	52	15	28	87
Guar	-	-													18	10
Cotton:													502	455	536	474
Egyptian	111	-	-	300	-	-	258	-	-	192	-	-				
Ackala	340	-	-	131	-	-	258	-	-	237	-	-				
American	-	51	-	-	24	-	-	20	-	-	-	45				

***** Irrigat.= Irrigated, McR= Mechanized Rainfed, TrR= Traditional Rainfed.

Source: Ministry of Agriculture, Khartoum, Sudan. April 2006.

Table 8. Average Yield (kg/ha) of Main Crops in Sudan as Compared to World and African Averages, 2003.

Crop	World	Africa	Sudan
Seed Cotton (irrigated)	1744	947	1500
%	100	54.30	86.01
Wheat (irrigated)	2665	2029	2420
%	100	76.13	90.80
Cron	4472	1605	750
%	100	35.89	16.77
Sorghum	1301	876	733
%	100	67.33	56.34
Rice* (Paddy)	3837	1865	3400
%	100	48.60	88.61
Total Cereals	3078	1257	648
%	100	40.84	21.05
Groundnuts	1347	856	632
%	100	64	47
Sesame	448	331	144
%	100	74	32
Sugar cane	65293	56747	84615
%	100	86.91	129.59
Onion (dry)	17451	14461	6860
%	100	82.87	39.31

***** Limited areas (5000 ha).
Source: FAO Production Yearbook, Vol. 57 (2003).

Table 9. Comparison of Potential, Research and Farmer Yields for Major Crops in Sudan

Type of Crop	Yields		
	Potential Yields	**Research Yields**	**Farmer Yields**
Cotton	(Kantar seed cotton per feddan)		
Extra Long (Barakat)	16	12	4.5
Long (Shambat)	18	14	5.0
Medium (Acala)	22	18	5.5
	(tons per feddan)		
Wheat	2.5	2.0	0.6
Sorghum	2.5(open) / 3.0(hybrid)	2.3(open) / 2.7(hybrid)	0.8
Groundnuts	2.8	2.0	1.2
Onions	16	12	0.8

Source: Agricultural Research Corporation
Note: 1 Kantar = 315 Ibs seed cotton; 1 feddan = 1.038 acres = 0.42 hectares
Potential yield= The genetic yield potential under optimal growing conditions
Research yield= Yield under a standard set of practices and research management
Farmer yield= The average yield on farmers/tenants' fields

Although international yield comparisons are fraught with difficulties because of different circumstances such as policies and technologies, the differences between Sudan and some benchmark countries are unlikely to be entirely the result of lack of comparability. For example, average yield of rainfed sorghum in Sudan are typically only about 56 percent of the world average, and only. 25 percent of average yields for some countries. Destructive land management, low yields, and inadequate support services are not new issues in discussions about Sudanese rainfed agriculture. They need to be urgently addressed at the highest level of government[3] because of the importance of rainfed agriculture to the long-term economic growth of Sudan and the welfare of millions who derive their livelihood from the rainfed areas.

Fertilizers and chemicals not a major factor in rainfed crop production. There are no chemical fertilizers produced in Sudan, although there is now obviously some potential for nitrogen fertilizer production from local oil deposits. Most fertilizer is used in irrigated areas (for cotton and other crops). Fertilizers have been applied on a pilot basis by some large companies in the semi-mechanized rainfed sector for sorghum, sunflower, and short staple (*acala*) cotton production on a trial basis. Insecticides and pesticides are applied mostly on irrigated cotton, but as a result of integrated pest management (IPM) the number of applications of insecticides has declined substantially. For example, it was common practice in the Gezira Scheme to apply 10 aerial sprayings per season in the 1980s whereas now the number is 2-3. This has had substantial beneficial effects for the environment and has reduced costs, as was mentioned by the Gezira scheme management officials. However, now there is a wide-spread use of herbicides to control weed in semi-mechanized rainfed schemes such as AGADi. This is due to the adoption of zero-tillage, which may have negative impacts in the long-term.

3.5 Causes of Low Agricultural productivity

3.5.1 Overview

As mentioned before, production from the rainfed traditional farming is very low and many hazards are encountered such as drought and/or water logging, plant diseases, pests…etc. These, in addition to bad management practices are responsible for the poor yields attained. The same trend is true for the mechanized rainfed farming system, which affects soil structure, texture and fertility and leads to low crop yields. The irrigated farming systems are constrained by many management, technical, economical and institutional problems that all reduce crop yields (table 10).

[3] The "Strategy for National Development of Agriculture-Horizon 2015" (draft), noted the increased resource degradation as one of the three major constraints to agricultural development and food security in Sudan. The recommended policy action is to maintain environmentally sound practices in semi-mechanized farming areas. This is probably not a strong enough recommendation to address the problems.

Table 10. Some factors affecting crop production under farmer conditions:

Crops	Sowing date	Variety	Plant density	Land preparation	Fertilizers	Weeds	Insects and diseases	Irrigation*
Sorghum	+	+++	++	+	++	+++	+	+
Cotton	++	+	+	+	++	++	+++	+++
Groundnut	+++	+	+++	++	-	+++	+	++
Wheat**	+++	+	+	+++	+++	++	+	+++
Vegetables	+++	++	+	++	++	++	++	++
Maize	+	+++	+	+	++	++	++	+
Sesame	+	+	+	-	-	++	+	+
Sunflower	+	+++	+	+	+	+	+	+
Sugar cane	+	+	+	++	++	+++	++	++

+++ Very strong; **++** strong; **+** moderate; -week; ***** rainfed farming influenced by amount and distribution of rain; ****** wheat production is highly influenced by prevailing temp and cold duration in winter time (growing season).
Source: Agricultural Research Corporation, Wad Madeni, Sudan (2006).

In addition, the irrigated schemes do not integrate animal-raising in their farming system. Agronomic practices affecting crop production and crop yields under farmer conditions were summarized by the Agricultural Research. Corporation (ARC). The table shows that common causes are:

Sowing data: has a very strong effect (+++) on groundnut, wheat and vegetable yields, and a strong effect (++) on cotton.

Variety: has very strong effect (+++) on sorghum, corn (maize) and sunflower, and strong effect (++) on vegetables,

Plant density: has a very strong effect on groundnuts and strong effect on sorghum.

Land preparation: has a very strong effect on wheat and strong effect on groundnut, vegetables and sugar cane.

Fertilizers: has strong positive effect on wheat and strong effect on sorghum, cotton, vegetables, corn (maize) and sugarcane.

Weeds: have a strong negative effect on sorghum, groundnut, and sugar cane and strong effect on cotton, wheat, vegetables, maize, and sesame.

Insects and diseases: have a very strong negative effect on cotton, and strong negative effect on vegetables, maize and sugar cane.

Irrigation: has a very strong effect on cotton and wheat and strong effect on groundnut, vegetables and sugar cane.

These eight factors are negatively influencing crop yields due to mismanagement and improper implementation of the technological recommendations. Also, lack of technology transfer and agricultural extension services increases yield reduction. Yield decrease is proportional to each factor as well as the cumulative effect of two or more factors and their combination or interaction.

3.5.2 Irrigated Agriculture:

The Gezira Scheme is chosen as an example for irrigated agriculture (World Bank, Report No. 20398-su, 2000). Another example of the irrigated agricultural schemes is Al-Rahad scheme (RAS). Both Gezira and RAS are giving low crop yields. The New Halfa irrigation scheme is no better than the other schemes. The cropped area as well as crop yields have declined progressively over the years as follows:

The Gezira Scheme (GS): was established in 1925. In 1959-63 the original Gezira Scheme was extended to include the Managil area. The combined Gezira/ Managil Scheme now covers a command area about 2.1 million feddan (about 882,000 hectares) under gravity irrigation, (Estimates of the total potential cultivable area under irrigation in Sudan within the Nile Basin is probably between four and five million feddan). However, the GS operates at a low level of technical and economic efficiency. Designed for a cropping intensity of 0.75 the achieved cropping intensity is usually no more than 0.50 which is very low by any international standard. The Scheme has been plagued over many years by serious water management and distribution problems, as well as low yields, costly pest control for cotton, inadequate financing and marketing arrangements for most crops, inefficient agricultural processing, disillusioned farmers, and low cost recovery for irrigation water deliveries. Main features of GS are:

Crop rotation: in GS is “five course” crop rotation sequence as follows:
Cotton – Sorghum – Groundnuts – Wheat – Fallow.

Cropping Calendar: only one crop is grown per year on a given area and the typical timing of harvesting and planting of each crop is shown in Table 11.

Table 11. Cropping Calendar for Major Crops in the Gezira Scheme

Crop	Planting	Harvesting
Acala - Cotton	July	December/January
Barakat - Cotton	August	January/March
Sorghum	June/July	October/November
Groundnuts	May/June	October/November
Wheat	November	March

In recent years, sorghum has been the main crop in terms of area in the Gezira Scheme with an average of 35 percent of total area planted, followed by wheat (25-30 percent)but trending sharply downward, cotton (under 25 percent) and groundnuts (about 20 percent). Sorghum has occupied the largest area because of its role as both a fodder and a subsistence grain crop.

Factors that depress yields of all crops in the GS are: i) lack of funding for labor for crop management and harvesting, ii) Lack of access to adequate finance and no formal financial intermediation, iii) Shortage of Irrigation Water. For all crops, the number of actual irrigations used by farmers is less than recommended (see Table 12). The lower number of irrigations is the result of the declining efficiency in water delivery infrastructure. Less frequent irrigation reduces yields. iv) improper land preparation, v) inadequate application of fertilizers and pesticides, vi) marketing, transportation, processing and payment problems, vii) high production costs, viii) Another important effect on yields relating to water supply is the "head to tail effect."

Table 12. Actual and Recommended Number of Irrigations by Crop

Crop	Actual	Recommended
Cotton	10-12	16
Wheat	6	8
Groundnuts	5	8
Sorghum	5	8

Source: Socio-Economic Unit- Sudan Gezira Board, 1999

The head to tail effect refers to the gradually diminishing supply of water as it travels to plots that are further away from the source. These plots are said to be at the tail of the irrigation flow. Farmers at tail ends have lower yields and, therefore, lower incomes. As Table 13 below shows, the head to tail problem is acute in the GS resulting in about 50 percent reduction in yield for cotton and typically about 30 percent loss for other crops. Another feature of this table is the substantial difference between the yields in the two systems. This may suggest the possibility of lower incomes in Managil although the areas of tenancies there are smaller.

Table 13. Yield Effect on Crops Because of Distance from Water Source

Crop	Gezira Main		Managil	
	Head	Tail	Head	Tail
Cotton (kantars seed cotton/feddan)	5.14	2.99	4.48	2.20
Wheat (tons/feddan)	0.57	0.39	0.41	0.30
Groundnut (tons/feddan)	0.40	0.31	0.45	0.27
Sorghum (tons/feddan)	0.51	0.35	0.47	0.39

Source: "Socio-Economic Impacts of Irrigation Water Shortages at the Tail ends of the Gezira Scheme Canalization System, " The Sudan Board, Planning and Socio-Economic Research, (supported by a Ford Foundation technical assistance grant), November 1995.

Table 14 shows the priority problems cited by farmers in the field interviews during the WB mission for the GS in November 1999.

Table 14. Farmers' Problems-Type and Frequency.

Problem faced by farmers	Total	Percent
Insufficient labor cash advance from SGB	11	20.0
Shortage/timing of irrigation water	9	16.4
Inadequate/late land preparation	9	16.4
Delayed payments for cotton crops	4	7.3
Inadequate pest control	4	7.3
Cleaning of Abu Ishreen	4	7.3
Inadequate health problems - malaria, bilharzias	3	5.5
Water charges too high	2	3.6
Cost of spraying too high	2	3.6
Low returns	2	3.6
SGB should market production and protect prices	2	3.6
Improved varieties not available	1	1.8
Silting problems in canals	1	1.8
High taxes	1	1.8
Total	**55**	**100.0**

Source: WB Report, 2000.

3.5.3 Agro-Pastoral Sedentary Cultivation

This is practiced in the marginal rainfed areas such as the Butana area, which was considered as the best rangeland for grazing and the growing of good grazing fodder. The cultivation is sporadically practiced through (*terus*) or on low-lying water receiving sites. Crop yields mainly "Dura" are hindered by the same constraints as in traditional cultivation as described below.

3.5.4 Traditional rainfed farming systems

The Traditional Sector produces mainly millet, groundnuts, sesame, Gum Arabic and to some extent, grain sorghum, vegetables and fodder in rotation in small holdings from 8-10 ha depending on family labour, using hand tools.

Production is very low and many natural hazards are encountered, i.e. drought and/or water logging, bio and environmental stresses, etc. In addition, poor management practices, low technology transfer and inadequate agricultural services, low ratio of extension agents/farmer, lack of adapted varieties and insufficient certified seed are responsible for low yields attained.

3.5.5 Mechanized rainfed farming:

Out of the approximately 84 million ha (200 million fed) of cultivable land in the Sudan, the rainfed agriculture occupies about 15 million ha, (36 million fed) of which 9 million ha (22 million fed) are in the traditional agriculture sector while 6 million ha (14 million fed) are in the mechanized agriculture sector.

The Mechanized Sector produces grain sorghum, sesame and to some extent, sunflower, millet and short staple cotton as a mono-cropping system, in large holdings from 210-8000 ha by individual farmers, government and companies using machinery in most of the agricultural operations.

Productivity is very low compared to what could be expected due to two main factors (i) variability of rainfall in time and space, and (ii) lack of adoption of the recommended cultural practices which would increase the productivity per unit area. Instead, the tendency of the farmers is to cultivate more land in order to attain the same yield: thus subjecting the area to land degradation and desertification.

Beside land degradation and desertification, many other factors are causing yield reduction including: technical, economical, institutional, and absence of endorsed social, political and legislative measures. The mechanized rainfed sector is criticized as being a major cause of environmental deterioration leading to negative impacts on grazing resources, forest area, soil fertility and crop production.

Mechanized farming depends upon horizontal expansion rather than to vertical expansion without any control by the Mechanized Farming Corporation (MFC) or the Land use Department. This in turn negatively affects grazing areas and tree cover. The importance of tree cover is clear in areas prone to flooding and erosion, e.g. Showak in Gedarif state. Negligence of conservation measures such as shelter belts between farms and around natural drains results in gully erosion.

Mechanized rainfed farming uses poor agricultural practices and mono-cropping which contribute to low yields. Soil structure, texture and fertility are negatively affected. All soil physical and chemical properties are changed, and formation of compaction layers in the top-soil and hardpan in the sub- soil occurs and lead to decrease in crop yields. In addition, crust formation due to continuous disking to the same depth is responsible for reduced infiltration and increased run-off, and then to crop failure. Also, inadequate soil and water conservation measures, and negligence of shelter belts, crop rotation and integrated crop management aggravate the problem of low yields.

Other factors leading to low yields in the MR farming system are:

- Lack of clear environmental policy.
- Lack of land use planning at the regional and national levels. There is no Land use Master Plan in Sudan.
- Inefficiency of the institutional control of MR farming.
- Ignorance of integrating animal resources in the cropping systems.
- Continuous cropping and mono cropping and harmful weed infestation.
- Ploughing at a shallow depth (5 cm) results in more resistance to root penetration, water infiltration and disturbing the soil /water balance.
- Lack of technical know-how and do-how.
- Inadequate rainfall in amount and distribution.

- High cost of production.
- Lack of extension services.
- Inadequate research activities and site-specific recommendations.
- Mismanagement agricultural practices.
- Negligence of proper soil and water conservation.

The response of farmers to some of these factors was studied by Atta El Moula (1985) and the results were as follows:

Table 15. The perceived factors of degradation in the vegetative cover due to Mechanized Rainfed Farming.

Causes of vegetative cover degradation	% of respondent
1. expansion of cultivation	74
2. commercial production of fuelwood and charcoal	57
3. increased number of human and livestock population	50
4. impact of pastoralists	39
5. others	29

Note: The respondents mentioned more than one
Source: Field work data, 1984 by Atta El Moula.

Table 16. Reasons behind not following recommended shelter-belts in the mechanized schemes

Reasons	% of respondent
1. trees will compete with crops for water	40
2. trees attract birds	32
3. trees hinder mechanized operations	46
4. trees will reduce areas that can be used for crops	30
5. others	15

Note: The respondents mentioned more than one answer.
Source: Field work data, 1984 by Atta El Moula.

Table 17. Reasons behind abandoning schemes in Gedarif State and the % of respondent to each reason

Reasons	% of respondent
1. loss of soil fertility	42
2. run off	22
3. location of schemes adjacent to nomadic routes	10
4. remoteness of the scheme	8
5. problems of drinking water	6
6. others	12
Total	100

Source: Field work data, 1984 by Atta El Moula.

Table 18. Reasons for drop in yields of crops

Reasons	% of respondent
1. inadequate rainfall	90

2. bad management practices	30
3. prevalence of pests and diseases	32
4. shortage of fuel and spare parts	28
5. shortage of drinking water	11
6. shortage of labour	8

Note: respondents mentioned more than one answer.
Source: Field work data. 1984 by Atta El Moula.

Table 19. Disposal of crop residues in mechanized schemes

Methods of disposal	% of respondent To each method
1. burning	**32%**
2. allow animals to graze	**33%**
3. cut and packed	**27%**
4. mulching	**5%**
5. others	**3%**
Total	**100%**

Source: Field work data, 1984 by Atta El Moula

Most if not all of the above mentioned causes by Atta El Moula (1985) still exist in all Mechanized rainfed schemes, as was noticed by the consultant team during May 2006.

3.6 Markets

3.6.1 Crop marketing:

(i) Macro Level

During the 1990's the government removed many of the crop price and marketing controls it had instituted in the decade previously. The power of the large Commodity Boards was considerably reduced. Heavy marketing charges and State agricultural taxes were also largely removed. The result was immediate with agricultural growth of 10.8 percent in the 1990's compared with only 0.8 percent in the 1980's. Uncertainty as to the government's intents on whether to restrict sorghum exports also contributed to a decline in the area planted to sorghum on the semi-mechanized farms.

(ii) Micro level

For most of the export crops, markets are in the hands of private traders who operate through primary (village); secondary (Locality) and main "terminal" markets (State). The government can still intervene in the sorghum market by restricting exports or through its influence on cropping patterns (through cheap credit) on the large irrigation schemes.

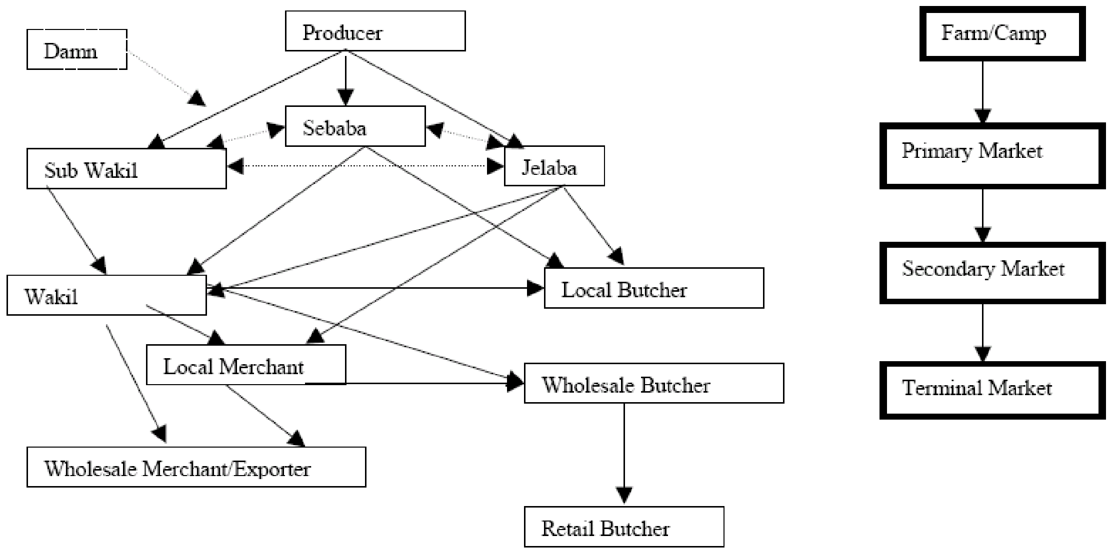
The export of Gum Arabic is still controlled by the Gum Arabic Corporation but local marketing and processing is possible. In Blue Nile State Gum producers and processors collaborate.

3.6.2 Livestock Marketing:

The livestock marketing structure is long established and is based on primary markets at the village level, secondary markets at the provincial level and five terminal markets. The largest terminal market is in Omdurman, which also has three other smaller terminal markets for domestic consumption. Terminal markets are also located at Kosti and El Gedarif.

The main livestock migratory movements are north-south in the dry season and south-north in the rain season, which brings livestock owners closer to the main markets in the wet season. The livestock marketing system is highly broker dominated (Yacob Aklilu, 2002). The brokers buy livestock from the villages and on-sell to brokers in the secondary markets who in turn sell to brokers in the terminal markets. Agents organize the trekking of animals up the marketing chain.

Figure 2. The Livestock Marketing Chain in Sudan.



The seasonality in livestock purchasing has led to the practice of feedlots around major markets. Most livestock are purchased “on trust” with payments being made some time after the original purchase with the producer being paid last. Marketing margins are extremely high because of the long distances travelled, costs of trekking, watering, feeding and numerous taxes. In July 2002 the average price at the primary market was one-eighth of the f.o.b. price.

3.7 Forestry

3.7.1 Administration and Legislation

The forestry service in Sudan started at the very beginning of the colonial era in 1902. Since then it has passed through a series of administrative changes. The forest law of 1932 (Central and Provincial Forests Ordinances) gave the Forests Department full charge over natural forests ,central forest reserves and the provincial forest reserves on behalf of the provincial authorities . In 1974 The Popular Local Rule gave the provinces and local councils full authority over the forest resource.

In view of the deterioration which took place in the forest resource the Sudan Government invited the World Bank to review the forestry situation in the country. In 1985 the Forests Administration was recentralized and in 1986 the 1932 Forest Policy was revised and approved. In April 1989 a Forest National Corporation (FNC) bill and Forests Bill were passed. The last forests and renewable natural resources law was passed in November 2002.

The general policy of the corporation aims at extending the reserved forest area to reach a national goal of 20 % of the country's area, increase the afforested area in and outside the reserved areas and raise the popular awareness of the importance of forests in the conservation of the environment and economic development. The corporation also encourages the reservation of community and private forests; local community participation in government forests management and protection is also among the highly rated objectives of the corporation.

The first law protecting natural forests and reserved areas against illicit felling and grazing and controlling the transport and trading of forest products was issued and enacted during the colonial era in 1932. The second forest act was passed by the last Constitutional Assembly in April 1989. This law had stronger punitive articles on illegal actions and reflected the concept of the role of civil society organizations and private sector in forestry. The last forest law was passed in November 2002. The new law incorporated new articles on range and pasture in view of the creation of a new corporation involving all other renewable natural resources.

In 2003 the Forests National Corporation, with technical and financial support, started a technical cooperative revision of forests policy legislation and institutional reorganization. A final legal report in January 2006 proposed amendments to Sudan's legislative framework on forestry, forests and renewable natural resources.

In addition to the Forestry Act local orders and ministerial orders are issued to protect some endangered tree species like *Balanites aegyptiaca* and *Borassus aethiopum* or regulation of other activities related to forestry such as those issued by the federal minister of Agriculture and Forests prohibiting the approval of new mechanized farming projects and putting heavy restrictions on the clearance of already approved projects.

3.7.2 Overview of the Contribution of Forestry to the Economy:

Agriculture and forestry are the main occupations in Sudan. Before the export of oil they constituted the bulk of the country's exports in the form of cotton, gum Arabic, sesame and ground-nuts. Non-wood forest products include henna, senna pods and tamarind.

Locally 43 million m^3 of wood fuel is consumed forming about 80 percent of the total energy consumption and thus saving a considerable amount of foreign exchange. The World Bank reported that more than 1.7 million people are engaged in forest related activities (IDA, 1986). Forests also provide all building materials in rural areas. They constitute 33 % of the national livestock feed as browse. In addition to these products the forests 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 contribution of forestry sector to the GDP according MEF is around 3.3% for 1999, but taking into account the outputs collected/consumed by local communities the forestry sector's contribution to the national economy is around 12% of the national GDP (Forest Products Consumption Survey, 1995).

3.7.3 Forests Reserves

The table below shows the number of forest reserved areas and areas under reservation to date.

Table 20. Total Number of Forest Reserves and Areas of Forest Land and Protected Forest by State

State	Number of areas reserved	Forest land Area (feddans)	Protected Forest Area (feddans)
Blue Nile	198	2,155,135	556,057
Gaderef	165	1,425,970	917,458
Gezira	101	396,0111	278,332
Kassala	38	436,635	26,684
Khartoum	70	79,923	24,173
North Darfur	51	148,062	16,993
North Kordofan	88	976,915	357,442

Northern	6	10,800	2,340
Red Sea	85	45,980	25,171
Nile	116	176,536	32,093
Sinner	266	1,182,495	497,109
South Darfur	51	4,248,300	3,505,701
South Kordofan	219	3,617,556	691,782
White Nile	248	2,087,736	1,370,137
	1702	**20,552,154**	**8,301,472**

(1 feddan is 0.42ha)
Source FNC

The Forest Reserves are for production and protection purposes. The production forests are mainly those in the Blue Nile and Rahad River basins while others play productive and protective roles. The number of forests reserved in the three sub-basins totals about half the number of forest reserves in the country. Riverine forests and irrigated forests, found mainly in the Gezira State, are managed under a clear felling system on a sustainable basis for the production of fuel wood and saw logs to supply the government and a small number of private sawmills. Irrigated eucalypts plantations also produce construction poles. Other natural reserved forests are not yet managed for production though some of them can be put under management plans for the production of wood and non-wood products.

Other areas covered by forests but not under reservation, generally termed natural, are the main source of forest goods and services. They supply more than 89% of the national consumption of fuel wood and other products. As such they are the main revenue source for the FNC[4] constituting more than 50percent of total FNC income. This revenue comprises royalties collected on forest products from outside forest reserves in accordance to the Royalty Order of 1939. These products come mostly from clearing of leased or registered land for agriculture or other purposes. The philosophy behind this is that royalties on forest products outside forest reserves should be higher (in accordance to the Royalty Order of 1939). Until 1994 the industrial sector used only 6.8 percent of the total wood consumption (FNC, 1995).

The Government encourages people to obtain wood for sawmilling and furniture-making from the Forest Reserves (natural forests) as regeneration is more guaranteed than in un-reserved forests. Ministerial Orders have recently been issued to restrict approval of new agricultural schemes and clearance of the already approved ones as a measure to control deforestation.

Afforestation activities are very limited compared to the demand on forest products. In 2004 some 30,369 feddans of different tree species were planted and sown by FNC and 87.1 km of shelter belts were planted by communities.

[4] Study on Forest Valuation and Investment in Sustainable Management in Sudan, 2003.

3.7.4 Non–timber Forest products

(i) Gum Arabic

One of the most important non-timber forest products is Gum Arabic. The gum Arabic is the exudates of *Acacia senegal* known as gum hashab and *Acacia seyal* known as "gum talh". Gum Arabic is used in food, beverages and pharmaceutical industries. Formerly the gum was exported after manual cleaning and grading but recently mechanized cleaning has been introduced.

The Gum Arabic Belt (GAB) comprises the major part of the low rainfall woodland savannah zone extending from the Western to the Eastern boundaries of Sudan on both sand and clay soils. There is a distinct difference between the clay and the sand provenances of *Acacia senegal* in terms of their water-sue efficiency and gum yield (Amin Raddad & Olavi 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.

There are a number of direct (production) and indirect (environmental) benefits accruing to gum production (Barbier, 1990). In terms of direct benefits the trees provides fodder for cattle, sheep, goats and camels. Older trees (i.e. 15 years or more) that no longer produce good quality gum are often cut for fuelwood and for charcoal production. In terms of indirect benefits the deep tap root and its extensive lateral root system means that it assists in reducing soil erosion and water runoff and for stabilizing soils. Because of its leguminous characteristics the tree fixes nitrogen, which encourages grass growth for grazing by livestock. The trees can act as wind breaks and can assist in the stabilization of shifting sand and moving dunes.

Seasonal laborers 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 percent in 1994 to only 21 percent 2000/2001 (World Bank, 2003). In 1990-1992 the government temporarily waived controls and the percent of export price rocketed to 160 percent!

Table 21 shows production figures of gum Arabic for the years 1991-1999.

Table 21. Sudan Gum Arabic Production (Metric tons) 1991-1999

Season	Gum Hashab	Gum Talh	Total
1991	11,466	595	12061
1992	7,152	177	7329
1993	9,955	1455	11410

1994	22,409	11049	33458
1995	39,303	9455	48758
1996	30,291	1434	31725
1997	17,746	13	17759
1998	12,479	4639	17118
1999	**21,165**	**6679**	**27944**

Source: Study on Forest Valuation and Investment in Sustainable Forest Management in Sudan

The gum Arabic plays an important role as major source of foreign exchange, accounting for 13.6 percent of the annual export income excluding petroleum.

Table 22 shows the value of gum Arabic exports.

Table 22. Sudan Gum Arabic Export Value

Year	Hashab (ton)	Talh (ton)	Total	Value US $
1997	15,576	6,972	22,548	26,142,275
1998	16,108	4,882	20,990	20,248,079
1999	15,019	4,909	19,928	19,151,825
2000	21,258	2,821	29,079	24,73,8042
2001	18,953	1,370	20,323	21,368,189

Source: Study on Forest Valuation and Investment in SFM in Sudan

The declining supply of gum as shown in table 20 above will encourage users to shift to other substitutes or other sources of supply if the current trend continues.

(ii) Other Products

Fodder: Sudan forests constitute 33% of the total feed requirement of the national herd (FOSA, 2001) estimated at 128 million heads. Research results showed that browse species (Fodder trees and shrubs) especially leguminous species, are important components of the natural range lands upon which livestock and wildlife depend during dry season. Most species are *Cepholocton cordofanum* (Umgutni), *Fedherbia albida* (Haraz), *Dichrostachys cinera* (Kadad) and *Acacia* species.

NWFPs of export and internal trade value: Despite the importance of these products for the economy and the people they are largely neglected by the decision makers. Though little quantitative data was available about the production of these products tables 23 and 24 below show the volume of production and the internal and export trade of some of these products. From the tables it can be seen that the NWFPs contribute to the GDP more than the woody products.

Table 23. Exports of Gum Arabic and Other Non-wood Forest Products

NWFP	1995		1997		1999	
	Volume of export MT	Export value (000 US $)	Volume Of export MT	Export Value (000 US $)	Volume Of Export MT	Export Value (000 US $
Gum Arabic	8081	60338	22445	25704	26220	19236
Hibiscus Roselle	3768	4459	17669	15999	4947	3576
Acacia nilotica pods	NA	NA	6.0	NA	685	400
Other natural gums	NA	NA	1054	827	32	NA
Senna pods	385	137	1846	725	951	365
Henna leaves	123	66	16	16	445	441
Tanning material	430	430	1051	694	828	760

Table 24. Sudan Production and Value of Internal Trade in NWFP

Product	Local unit	Total production	Value (000 SD)	Percentage Of Total value
Aradaib (Tamarind)	Sack	305590	13586.4	35.2
Dom (Hyphanae palm)	Sack	28000	576.3	1.55
Garad (Acacia nilotica pods)	Sack	20380	146.5	0.4
Gonglaiz(Adansonia fruit)	Sack of (dehusked) fruits	137475	7281.3	18.9
Gudaim(Grewia fruit)	Kontar	2805	823.0	2.1
Henna (Lawsonia leaves)	Kontar	65000	4225.0	10.9
Laloub(Balanites fruit)	Sack	111753	2871.0	7.4
Loban	Kontar	37522	2326.4	6.0
Nabag(Ziziphus fruit)	Sack	111140	3607.6	9.3
Saaf (Hyphanae fronds)	Tarid	121986	2919.1	7.6
Senna	Kontar	20000	2400.0	0.6
Total				100

3.7.5 Forestry and the Environment Protection Services

(i) Agricultural Services of Forests and Trees

Forests provide a restorative service to agriculture clearly seen in shifting cultivation replenishing degraded land, recycling nutrients and rehabilitating soil structure. Wind breaks are another important service in specific situations.

Another important service they provide is grazing and browsing. UNSO (1991) estimated that in many Sudano-Sahalian countries 30 to 40 percent of livestock depend on forests and woodlands for all of their grazing and fodder.

(ii) Water and Watershed protection:

The drainage system of Sudan is mainly of the streams and rivers running from the Ethiopian and Eritrean high lands in the east, those coming from the water divide line which forms the boundary of Sudan with Central African Republic and the Democratic Republic of Congo and the Bahr el Jebel River originating from the great lakes region. In addition to the Nile system watershed areas are found in the mountain ecosystem of Sudan like the Nuba mountains, from which flow a number of small streams forming important catchments basins like Wadi Al Galla and Khor Abu Habil, the Imatong Massif in Southern Sudan, Arkawit high lands in the east, Ingasena hills in Southern Blue Nile and Jebel Marra in Dar fur in Western Sudan.

Forests contribute to the watershed quality by stabilizing soils and reducing sedimentation and flood peaks and replenishing ground water. Forests in different environmental ecosystems of Sudan contribute to watershed protection. In low rainfall savannah in the Dinder National park the riverine forests and woodlands play a big role in regulating the drainage system. During the past two decades felling of trees and repeated fires caused the decrease of the amount of river discharge and the deterioration of the swamps which were originally created by the meandering nature of the river. These swamps are of very vital importance to the wild life of the park.

(iii) Carbon sequestration:

Sudan under UNCCC as identified a set of appropriate options to sequester carbon in non-energy sectors. One of the important environmental roles of forests is the provision of carbon sinks. Carbon density in forests increased annually due to natural regeneration and accumulation in vegetation. However the rate of increase depends on a number of factors such as species, density, and precipitation and rotation period. Opportunities in the agriculture, forestry and range land sectors had been reviewed and demonstrated the potential for augmenting national carbon sinks for GHG (Green House Gas) emissions and contribute to sustainable development priorities. The study indicated that there is a substantial increase in the amount of carbon sequestered and stored in Sudan.

(iv) Conservation of the Biological Diversity:

Sudan harbors diverse biological resources which constitute an important national wealth and heritage. Forests provide protection for various genetic resources of plants and animals. There are some 535 tree species in Sudan 25 of which are exotic. It was reported that there 184 species of shrubs including 33 exotics. Special areas with a wealth of special rare vegetation species are found in the Red Sea Coast and the bowl forests which are a relic of African tropical rain forests in the South West Equatorial region. It was reported that there are many gaps of knowledge in this field and much work needs to be done. Following the present state of environmental degradation loss in biological diversity is being experienced at an alarming rate.

(v) Protection of Natural and Cultural Heritage:

a) Conservation of Wild life Ecosystems:

Forests are the natural habitat for a wide spectrum of wild animals thus contributing for their biological diversity. Sudan was one of the first African countries that have adopted a Wild life Protection Act following the London Convention (1933) for the conservation of African flora and fauna. Protected areas as National Parks with highest degree of protection, game reserves with limited use of resources permitted and sanctuaries for the protection of special species were established. So far 25 protected areas have been declared most of which in the savannah wood land ecological zone. In response to the present day realities with increasing demands of local communities to forest products and wild life resources the system of biosphere reserves as a new concept involving local communities in sustaining reserves, has been adopted.

Sudan has proposed eight natural heritage and cultural heritage sites. These include Dinder National Park, Jebel Marra, Sanganaeb Marine National Park, Wadi Hawar National Park, Arkaweit, Imatong, Porbotok Protected Area and Boma Park. They contain important natural habitats for conservation of biological diversity and threatened species of outstanding universal value to science.

Recently in 2004 the Institute of Sudanese Civilization in collaboration with FNC reserved Naq'a and Masawarat Cultural Reserve, under Forests Law, including historic monuments of the old Meroe civilization with the view of protecting them by protecting their environment.

(b) Ecotourism and Recreation:

All game reserves and some forested areas have high potential to serve the development of ecotourism. Insufficient infrastructure is a big constraint. Ecotourism in forests in Sudan is still a very small component of the world's huge Travel and Tourism Industry, but at local level ecotourism in forests and parks is recently gaining significant interest. Tourists, mainly Arabs, come for sport hunting in Butana plains and River Nile State.

Though many people are optimistic about the revenues of oil being a blessing on forestry and improvement of the natural resources in general there is a general concern about the environmental dangers that are naturally attendant with the development of the industry itself. The exploration process can destroy the ground cover of trees, shrubs and other vegetation. Another concern is pollution of water sources in the vicinity of oil fields and possible hazards to coastal environment at the export points.

3.8 Fisheries

3.8.1 Fisheries Resources

The potential for freshwater fish production from rivers, reservoirs and hafirs is estimated by the MLS to be about 150,000 tons (including 60,000 tons from southern Sudan). Actual production has increased slightly from 45,000 tons in 1997 to 53,000 tons in 2001. However, actual production data from the south is difficult to obtain given the remoteness of the fishing areas. From the Blue Nile the majority of the fish are sun-dried whilst 70 percent of the White Nile catches are consumed fresh. "Tilapia" is the predominant catch, followed by Labeo, Synodontis and Lates (FAO (2000).

The inland fisheries are based on the Nile River and its tributaries, contributing over 90% of the estimated production potential of the country. The Sudd swamps in the south and the man-made lakes on the White Nile (Gebel Aulia Reservoir), the Blue Nile (Roseires and Sennar Reservoirs), Atbara River (Khashm El Girba Reservoir) and the Main River Nile (Lake Nubia) represent the major fishing localities with respect to fish resource magnitude and exploitation thrust. The Sudd region harbours an estimated fish potential of 75 000 tons/year with a productivity of 110 kg/ha. However, the civil war disturbances, the dense cover of aquatic macrophytes and the rudimentary fishing gear and techniques had a negative impact on fish production, which did not exceed 30 000 tons annually (43%).

The Gebel Aulia Reservoir has a fish potential of 15 000 tons/year and a current production of 13 000 tons/year (86.7%). Roseires Reservoir has a potential of 1 700 tons/year and fish landings of 1 500 tons/year (88.2%). Sennar Reservoir has an estimated fish capacity of 1 100 tons/year and an actual fish yield of 1 000 tons/year (91%). Lake Nubia's potential is 5 100 tons/year, but is able to produce only 1 000 tons of fish annually (19.6%).

Production from other Nile River localities has been estimated at 4 000 tons/year.

The artisan craftsmen from different ethnic groups carry out fishing activities in the inland waters. They are generally characterized by their low socio-economic profile and fishing capacity. The majority of the fishing craft used by the Nilotic and Falata tribes are dugout canoes maneuvered by bamboo staves. Arab tribes use oar-propelled or motor-driven wooden and steel boats. The predominant fishing gear includes active and passive gillnets, seine nets, trammel nets, long lines, hook and line, cast nets and baskets.

Over 100 fish species have been reported to prevail in the inland waters with different degrees of occurrence in the various localities. The commercially important fish are *Lates niloticus*, *Bagrus bayad*, *B. docmac*, (first class), *Oreochromis niloticus*, *Labeo spp*, *Barbus binny*, *Mormyrus spp*, *Distichodus spp* (second class), *Hydrocyon spp* and *Alestes spp* (for wet salting).

Although the inland fisheries are largely artisan in nature, a steady increase in market-oriented activities has occurred in recent years; particularly in the White Nile and Lake Nubia.

Aquaculture in the Sudan dates back to the early 1990s with respect to mariculture and to 1953 for freshwater culture. Considerable research emphasis has been devoted to the development of oyster cultivation as an activity, in order to reduce stress on the natural oyster population, thereby furthering consistent and steady production and improving the socio-economic status of the rural population. This prolonged research has culminated in the verification and adoption of sound and viable alternative culture technologies that have paved the way for the expansion of oyster family farms along the coast, as well as encouraging large investment enterprises to back artificial pearl production.

Freshwater *fish culture is primarily based on the pond culture of the indigenous species Oreochromis niloticus. Other local species such as Lates nilotius, Labio* spp and *Clarias lazira* have been experimented with, but have not as yet been released to farmers. Exotic species have been introduced for experimental culture in combination with Oreochromis niloticus (e.g. common carp), or for use as biological control agents for the eradication of aquatic weeds that infest the irrigation canals of large agricultural structures (grass carp). Freshwater fish culture has not as yet developed into a vertically-integrated economic activity, despite the fact that the prerequisites for it are available. Several state and private sector farms were established around the capital, Khartoum and other towns in various states. The current recorded production of these farms has not exceeded 1 000 tons/year.

3.8.2 Utilization of the catch

Finfish is marketed and consumed fresh (63%), sun-dried (28%) or wet salted (9%). The fresh fish is transported from distant fishing grounds to consumption areas in the capital, Khartoum and other towns, either chilled or refrigerated. Sun-dried fish is mostly marketed in rain-fed and mechanized agricultural structures. Wet salted fish (mainly *Hydrocyon spp*, *Alestes spp* and *Mugil spp*) is intended for both local consumption and export.

Shells of the mother-of-pearl oyster *Pinctada margaritifera* and the gastropod *Trochus dentatus* are exported to some European countries. Other mollusc shells are harvested and sold locally as a source of calcium for poultry feed or as souvenirs.

Fish by catch as well as discards are utilized on a small scale for fishmeal production.

3.8.3 Demand

According to estimates for the year 2000, the per caput supply of fish is 1.64 kg/year. This figure is not likely to substantially increase, in view of the population growth rate which is currently estimated at 2.84% per annum. A possible avenue for increasing fish production is through the expansion of aquaculture and the increase of productivity per hectare.

3.8.4 Status of the Fishing Industry

The contribution of fisheries to the Sudan GDP is presently marginal. The per caput supply is only 1.64 kg /year, which is mostly obtained by capture fish landings. The aquaculture industry is not developed as yet. Because of their basic characteristics, the Sudan inland capture fisheries are of a small-scale and semi-industrial nature. If properly managed, these types of fisheries would be qualified to satisfy subsistence and provide a good margin for large investments, particularly in the areas of freshwater fishing, mariculture and off-shore capture fisheries and their related facilities and supplies. The magnitude and trend of fish resource utilization and the level of development of the fisheries sector is handicapped by as number of problems and constraints. Some of these are mentioned below:

- The civil war disturbances in southern Sudan have jeopardized government plans for the proper utilization of the huge fish resources and for community development.
- Certain other important fishing grounds are either suffering from over-fishing or are virtually untapped.
- No attention has been paid to the development of rainwater bodies (totaling 1,775 hafirs) within the savanna belt in west, central and

eastern Sudan, which would augment fish production and form a basis for rural community development.

- Aquaculture is only playing a marginal role, despite the availability of its basic prerequisites.
- The low finfish production has coincided with high post-harvest losses resulting from improper handling at sea and during distribution.
- Insufficient infrastructure facilities and institutional capacities.

3.8.5 Institutional Arrangements

(i) Administration

According to the Sudan federal government system, there are structural arrangements for fisheries administration at the federal and state levels. The Fisheries Administration within the Federal Ministry of Animal Resources is the central fisheries authority entrusted with planning, policy formulation, training and the overall supervision of the fisheries sector. This Administration is answerable to the Undersecretary of the Ministry. It consists of three main divisions, namely, capture fisheries, aquaculture and conservation. This Administration currently has 78 staff members, 34 of whom are technical personnel.

At the state level, fisheries administration structures are under the umbrella of the Director General of Agriculture, who is answerable to the Minister of Agriculture of that state. There are currently 12 fisheries administration structures endowed with fisheries resources out the 26 federal states of the Sudan.

(ii) Research

Applied research and transfer of technology is the mandatory responsibility of the Fisheries Research Centre, Animal Resources Research Corporation of the Ministry of Science and Technology. The Fisheries Research Centre functions through six research stations located in different parts of the country. These include the Aquaculture Station (in Khartoum), the White Nile Station (Kosti), the Lake Nubia Station (Wadi Halfa), the Red Sea Station (Port Sudan), the Roseires Station (El Damazin) and the Khashm El Girba Station (Halfa El Gadieda). The staff of the Fisheries Research Centre consists of 79 members, of whom 24 are technical staff.

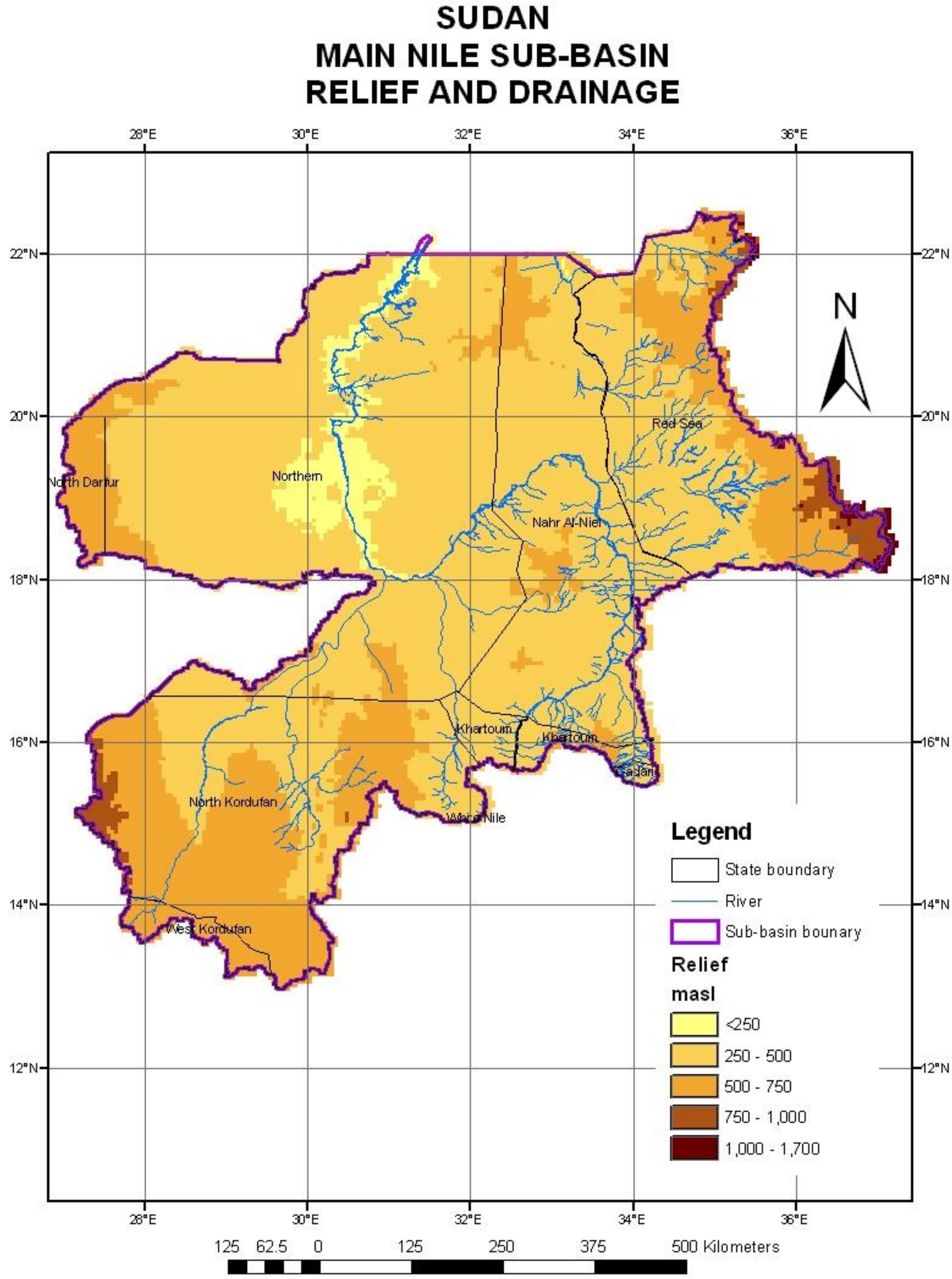
(iii) Training

The Fisheries Training Institute delivers short-term training targeting fisheries officers, private fish farmers and fishermen. Local and foreign universities provide training leading to undergraduate and postgraduate degrees.

4. MAIN NILE - BIOPHYSICAL AND SOCIO-ECONOMIC SITUATION

4.1 Bio-physical Characteristics

4.1.1 Location and Physiography



Map 6. Sudan – Main Nile: Relief and Drainage
Source: Shuttle Radar Terrain Mission (SRTM 90) digital terrain model.

The Main Nile lies within a broad gently sloping basin extending some 582,368 km2 or 48.7 percent of the Eastern Nile Basin within the Sudan. To the east are the Red Sea rises gently towards the Darfur plateau. A large wadi – the Wadi el Milk intermittently drains this area but fails to reach the Nile. The main feature is large loop made by the Nile River when it suddenly turns southwest-wards as far as Abu Dom before resuming its northerly course.

4.1.2 Climate

(i) Rainfall

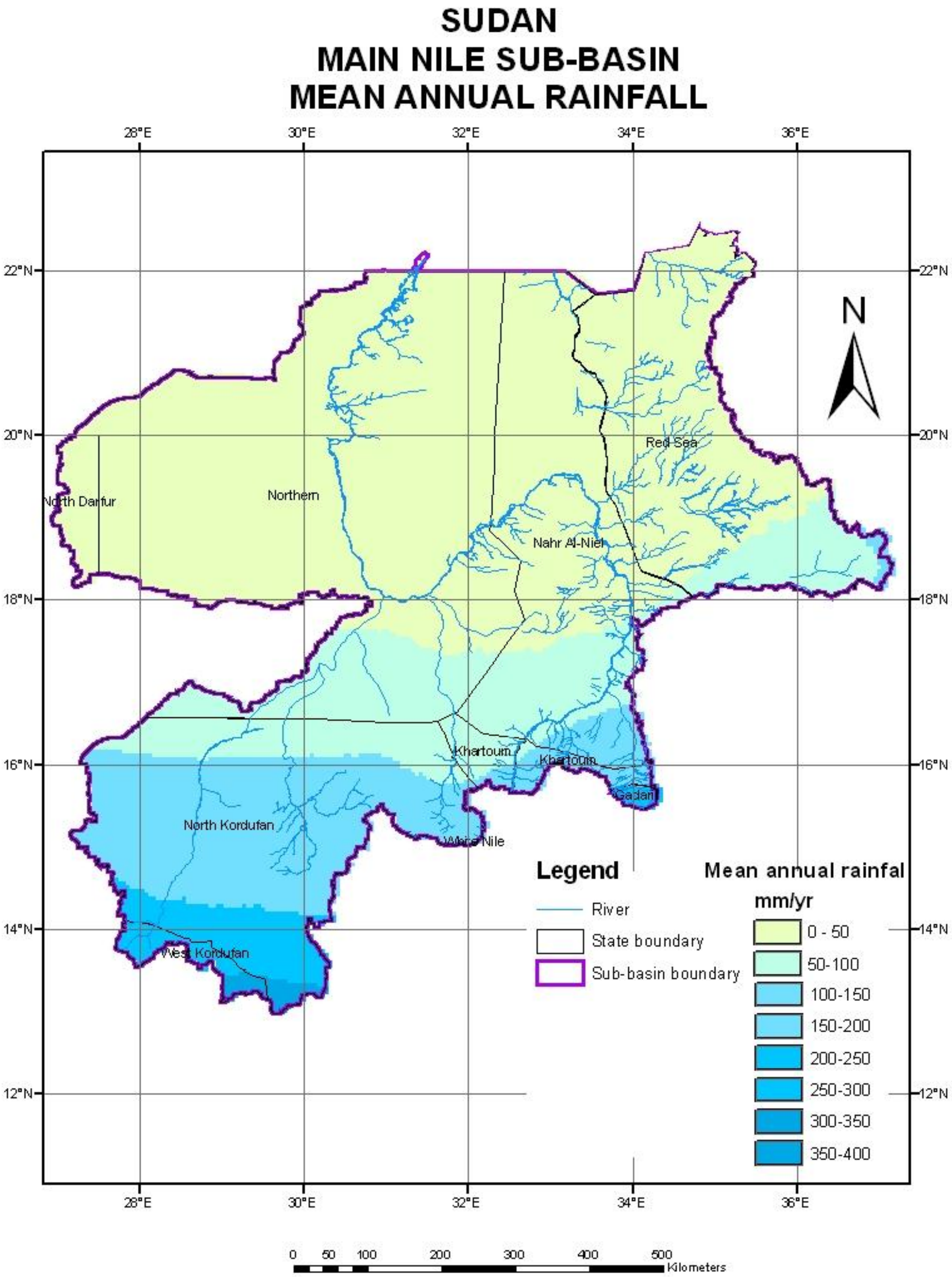
Annual rainfall isohyets generally run southwest to northeast, ranging from less than 25 mm in the north to 400 mm (UNDP/World Bank, 1988). Rain falls mainly between July and September in a single season. Two broad rainfall belts are recognized:

(i) from < 25 mm near the border with Egypt to 150 mm near Khartoum, rains are erratic with a coefficient of variation (CV) as high as 100 percent;

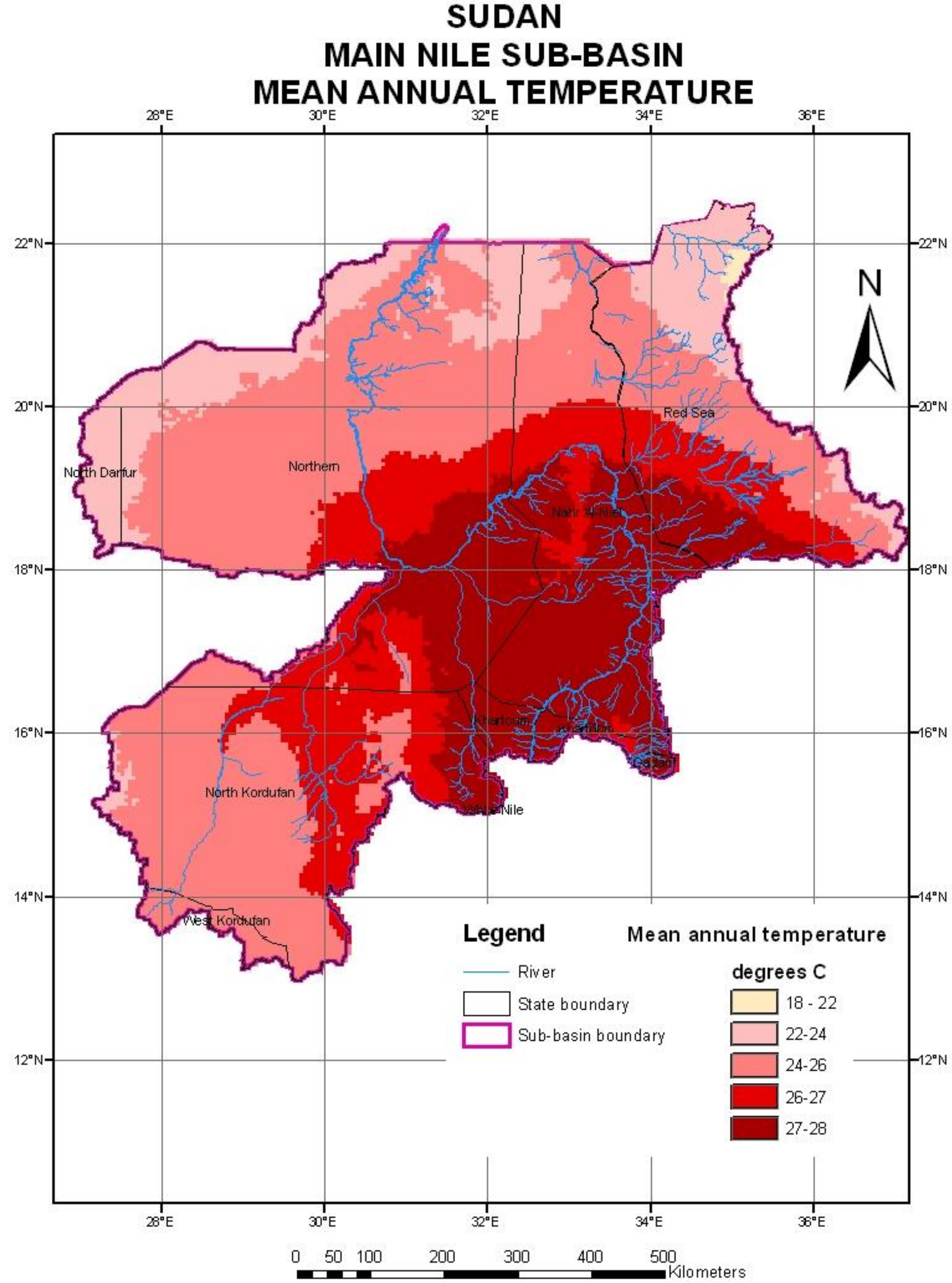
(ii) from 150 mm to 400 mm, rains are variable with CV's as high as 30 percent;

(ii) Temperature

Daily minimum and maximum temperatures in January are 14°C and 33°C and those in May are 24° and 44°C respectively. Highest mean annual temperatures occur in the eastern clay plains, rather than the north where minimum temperatures bring down the mean (Map 9). Daily evaporation rates range from 12 mm in August, the month a maximum cloud cover, to 21 mm in May (Obeid Mubarak, 1982).

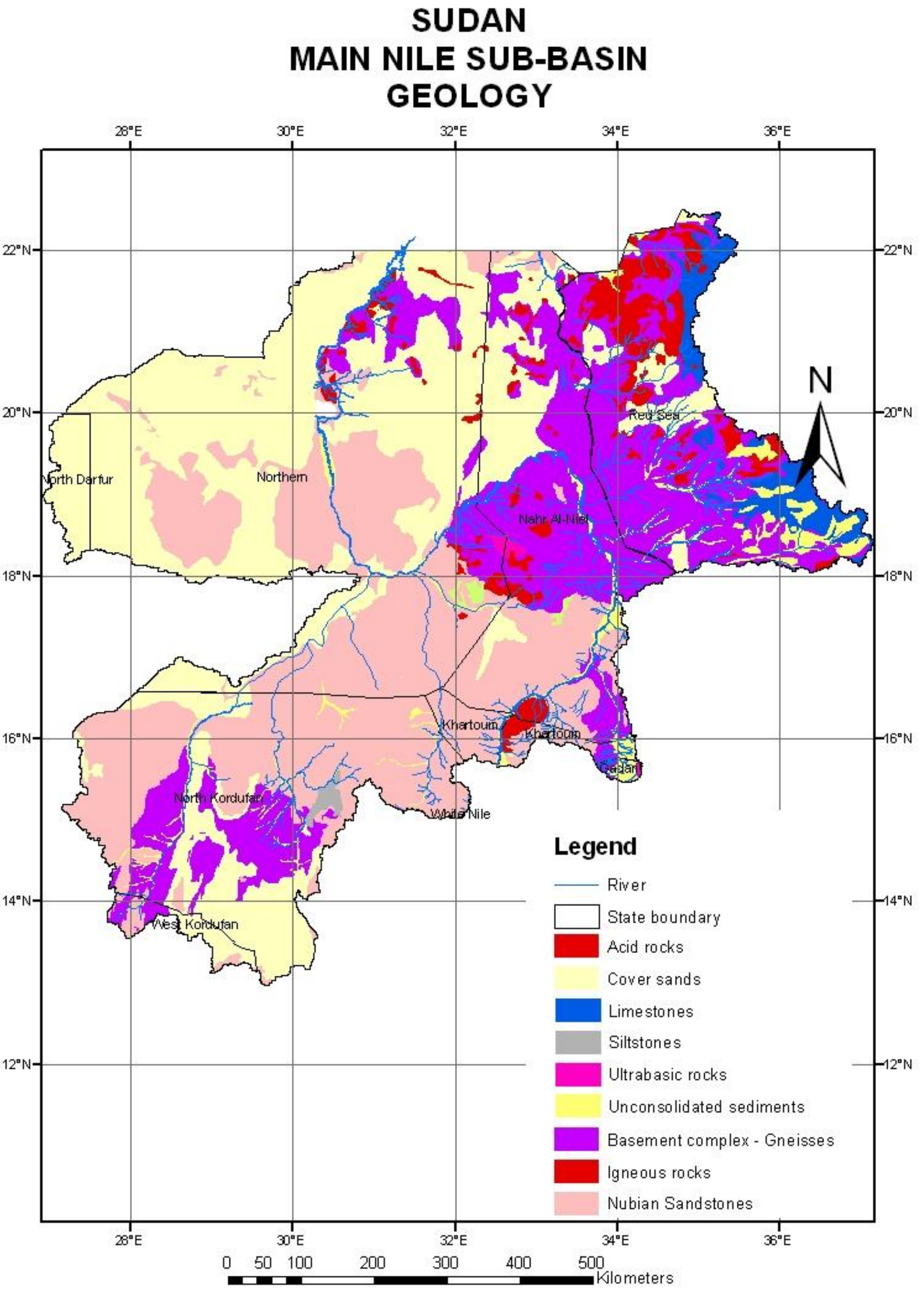


Map 7. Sudan – Main Nile: Mean Annual Rainfall (mm)
Source: ENTRO GIS Database



Map 8. **Sudan – Main Nile: Mean annual temperatures.**
Source: ENTRO GIS Database

4.1.3 Geology and Landscape (Map 10)



Map 9. Sudan – Main Nile: Geology

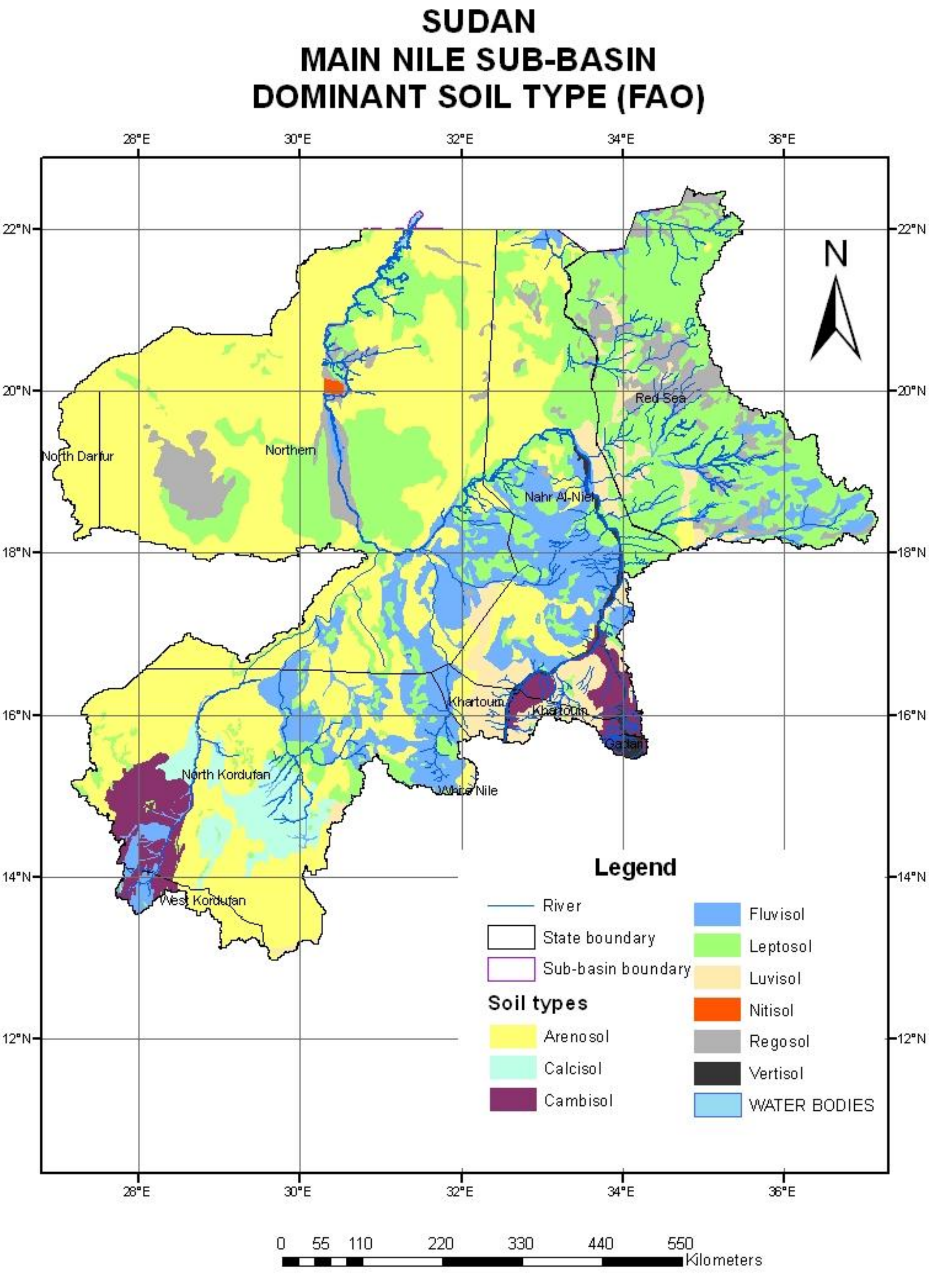
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

The main underlying geological formations within the Main Nile Sub-basin include the older Basement Complex rocks, the Nubian Sandstones, Tertiary unconsolidated sediments and Recent superficial wind blown sands. The Basement Complex comprises gneisses, schists, marbles and intrusive granites and basic rocks. The Nubian Sandstones overly unconformably the Basement Complex rocks and comprise mainly sandstones, siltstones and conglomerates. This formation forms the main groundwater basins in Sudan. The Recent deposits include the Nile alluvium, sand dunes and the black clays of the flood plains.

Relief in the north-eastern part of the Basin comprises hills and ridges of the Red Sea Hills rising to 2,700 masl. West of the hills are extensive plains lying between 300 and 500 masl, interrupted by isolated ridges and hills where the underlying Basement Complex rocks break through the overlying unconsolidated sediments.

4.1.4 Soils

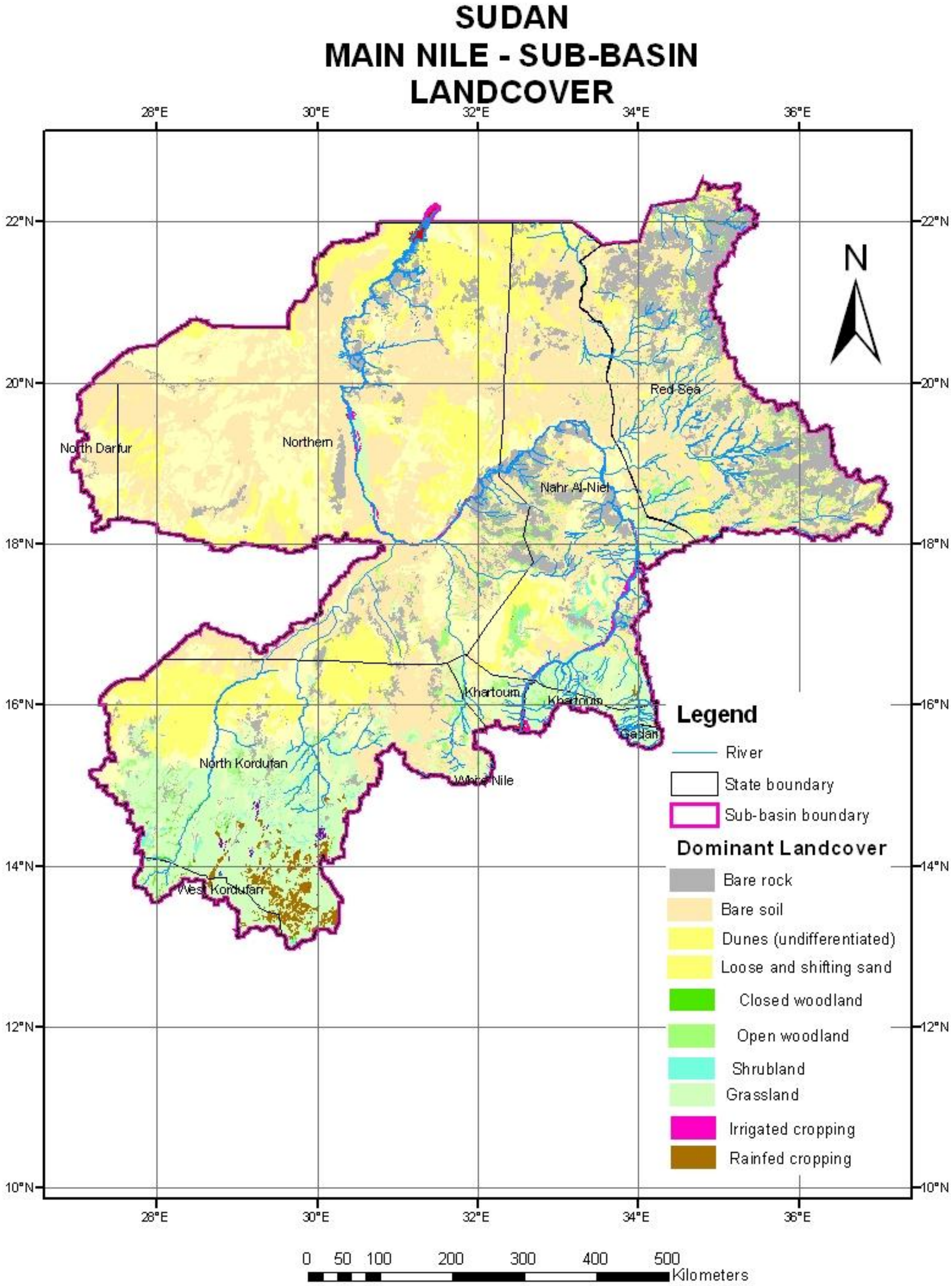
In the northeast on the hills and ridges of the Basement Complex rocks are shallow, stony and light textured Regosols, Leptosols and Phaeozems of low fertility. These soils are highly erodible. Across the northern part of the Sub-basin Arenosols are widespread and are derived from unconsolidated sediments and textures are very sandy. Soils are deep but excessively well drained. These soils are extremely susceptible to wind erosion. Where rock is near the surface these grade into shallow and stony Leptosols. Along the Nile River is a narrow band of Vertisols and Fluvisols.



Map 10. Sudan – Main Nile: Dominant Soil Types (FAO Classification)

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

4.1.5 Natural Vegetation and Habitats



Map 11. Sudan – Main Nile Sub-basin: Landcover
Source: Africover, 2002.

The patterns of natural vegetation closely follow those of mean annual rainfall, although locally edaphic conditions can provide a stronger influence. However, the biotic factors (grazing, cutting, burning and cultivation) are now of almost equal importance to the physical environment in determining the exact composition of vegetation communities.

(i) Desert

North of the 75 mm isohyet generally desert or semi-desert conditions prevail with little or vegetation except along wadis with a high watertable. Occasional years of very good rainfall can transform areas of desert into valuable grazing areas known as "*gizzu"*.

(ii) Semi-desert Scrub

Between the 75 and about 250mm isohyets "Semi-desert Scrub" is the most prevalent vegetation type, and comprises a varying mixture of grasses and herbs, generally with a variable scatter of shrubs up to 4 meters high interspersed with bare earth.

On sandy soils to the west of the Main Nile tree species include *Leptadenia pyrotechnica*, *A. Senegal* and *A. tortilis* subsp. *spirocarpa* and *raddiana*. On the clay plains there are a number of plant communities associated with specific habitat characteristics related to local topography and eroded, runoff and run-on sites. The most common tree species that have a wide "sociological tolerance" include (Obeid Mubarak, 1982): *Acacia tortilis* subsp. *tortilis* and *raddiana*, *A. nubica*, and *Caparis decidua. A. nubia* and *Calotropis procera* are common in the vicinity of villages and are indicators of overgrazing. Along the inundated areas of the Blue Nile *A. nilotica*, *A. albida* and *A.seyal* are common. *A. nilotica* is also found at the outlets to wadis which pour into the Nile and which receive flood water.

Grasses are mainly annuals. Heavy grazing and low rainfall ensures that there is insufficient dry matter for annual fires. In years of low rainfall and heavy grazing there can be an almost complete failure of annual plant growth. On very sandy soils *Panicum turgidum* is likely to be the dominant grass. This is an excellent grass for stabilizing sand dunes as well providing adequate browse. *Aristida spp.* are usually dominant on stabilized sands and on the shallow light textured surface materials, with *Schoenefeldia gracilis* dominating on the clay soils. Other ephemeral grass species include *Sporobulus cordofanus*, *Dactyloctenium aegyptium*, *Eragrostis cilianensis* and *Tragus berteronianus*.

Comparison of floristic composition from past studies with recent annual field observations of the Khartoum State range department have revealed no drastic change in floristic composition. However, a change in the species density could be observed. There are indications of movement or shift to the south for all subdivisions in this ecological zone. This shift is understandable and could be attributed to recent changes in rainfall, drought and man activities. The tree layer, and specially that of *Maerua crassifolia and Commiphora africana*, is the most affected due to browsing, over cutting and effects of drought.

4.1.6 Water Resources

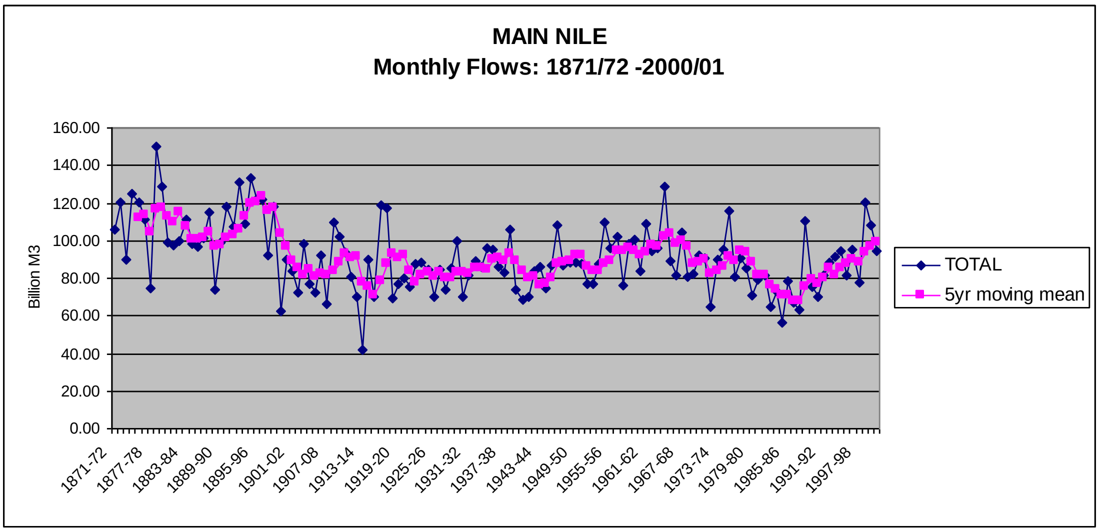
(i) Surface water Resources

The average annual flow of the White Nile at Khartoum is approximately 26 km^3. The Main Nile from the confluence of the Blue and White Niles flows 1,500 kms from Khartoum to Lake Nubia. The river flows through a series of cataracts with a total drop of 250m. The seasonal flow pattern exhibits the combined characteristics of the two main tributaries with the seasonal pattern of the Blue Nile superimposed on the regular pattern of the White Nile.

There are a number of ephemeral streams (wadis and khors) that flow during the rain season. The more important of these include the Gash on the east bank and the El Milk on the west bank.

The total annual flow at the border with Egypt has historically been taken (before any significant abstraction) as 84 km^3 (1905-1959). However, there are considerable year-on-year as well as periodic variations (fig.3).

Figure 3. Main Nile: Monthly Discharges and 5 year moving mean. 1871/72 -2000/01



From 1871 to 1896 saw a period of high flows, a period that saw high lake levels across East Africa. Between 1901 and 1975 annual discharges averaged around 87 km^3. The decade from 1976 to 1987 saw a series of very low flows – average annual flow about 76 km^3, since when flows have increased again.

The average annual suspended sediment entering Lake Nubia is estimated to be 120 million tons of which 72 percent is from the Blue Nile, 25 percent from the Atbara and only 3 percent from the White Nile.

In order to eliminate the current electricity deficit the Government of Sudan is currently constructing the 60 meter high Merowe Dam some 400 kms north of Khartoum at the Fourth Cataract. The reservoir will submerge the fourth cataract of the Nile and form a 200 km long artificial lake. With a surface area of 800 km^2, the lake will inundate 55 km^2 of irrigated land and 11 km^2 of farmland used for flood recession agriculture. The project includes an irrigation component but there are still uncertainties as to whether it will be implemented. The dam will have an installed capacity of 1,250MW, three times Sudan's current capacity. The dam will have an active storage capacity of 8.3 km^3. Fitted with deep sluices these could be used to operate the dam at a relatively low level during the period of highest sediment concentration. Whilst reducing power output it would reduce sedimentation within the dam.

Exactly how much sediment will be retained by the dam is a matter of some controversy. Three studies are available: (i) by Lahmeyer International (Lahmeyer International, 2001), the supervising consultants, (ii) a study by MIT (Paris,A, T.Yamana and S.Young, 2004) and (iii) by the EAWAG, Switzerland (Teodoru, Wuest & Werhli, 2006).

The Lahmeyer study estimates that some 30 percent of the annual mean sediment load of 120 million tons will be retained within the reservoir behind the dam.

The EAWAG study disputes this and claims some 90 percent of the annual sediment load will be retained behind the dam. This study also uses an estimated mean annual sediment load of 143 million tons. The study estimated that the reservoir would fill completely in approximately 150 years.

The MIT study estimates a trapping percent of 84 percent of which 65 percent will rest in the dead storage and 35 percent in the live storage. It used a mean annual sediment load of 128 million tons but notes that this can vary from 50 to 228 million tons. The MIT study looked at the changes in trapping efficiency as the reservoir capacity decreased. It also assumed that the dam would be operated to allow at least 40 percent of the sediment to pass through the sluices in July-August with a net retention rate of 60 percent. It looked at six scenarios of varying flow rates and sediment loads to determine the economic life. Assuming 60 percent retention and a suspended load of 128 millions tons it estimated the economic life of the dam as 105 years.

(ii) Ground Water Resources

Four categories of ground water basins have been recognized based on the geological formations:

(i) fractured/weathered basement complex aquifers

(ii) Nubian sandstone basins
(iii) Detrital Quaternary-Tertiary Basins
(iv) Recent Alluvium Basins.

Basement complex rocks only have a limited ground water yield but are especially important in the rainfed farming areas where reliable water supplies are a major constraint to agricultural development.

The Nubian sedimentary formation forms the most extensive and largest ground water basin in Sudan. Although recharge from rainfall is limited an annual amount of 1,074 million m^3 is received from the Nile River system. The quality is good to excellent with salinity values rarely exceeding 600 mg per litre.

The Quaternary-Tertiary aquifers are located in a steep sided rifted basin in the Blue Nile Rift in Sennar State. The total annual recharge is estimated at 160 million m3. Water quality is variable with local highly salinized zones.

The alluvial basins are located along most seasonal streams and are recharged from rainfall and season flows. Water quality is generally good. Along the Gash and other streams shallow hand dug wells are used to irrigate small plots of vegetables.

4.2 Socio-economic Situation

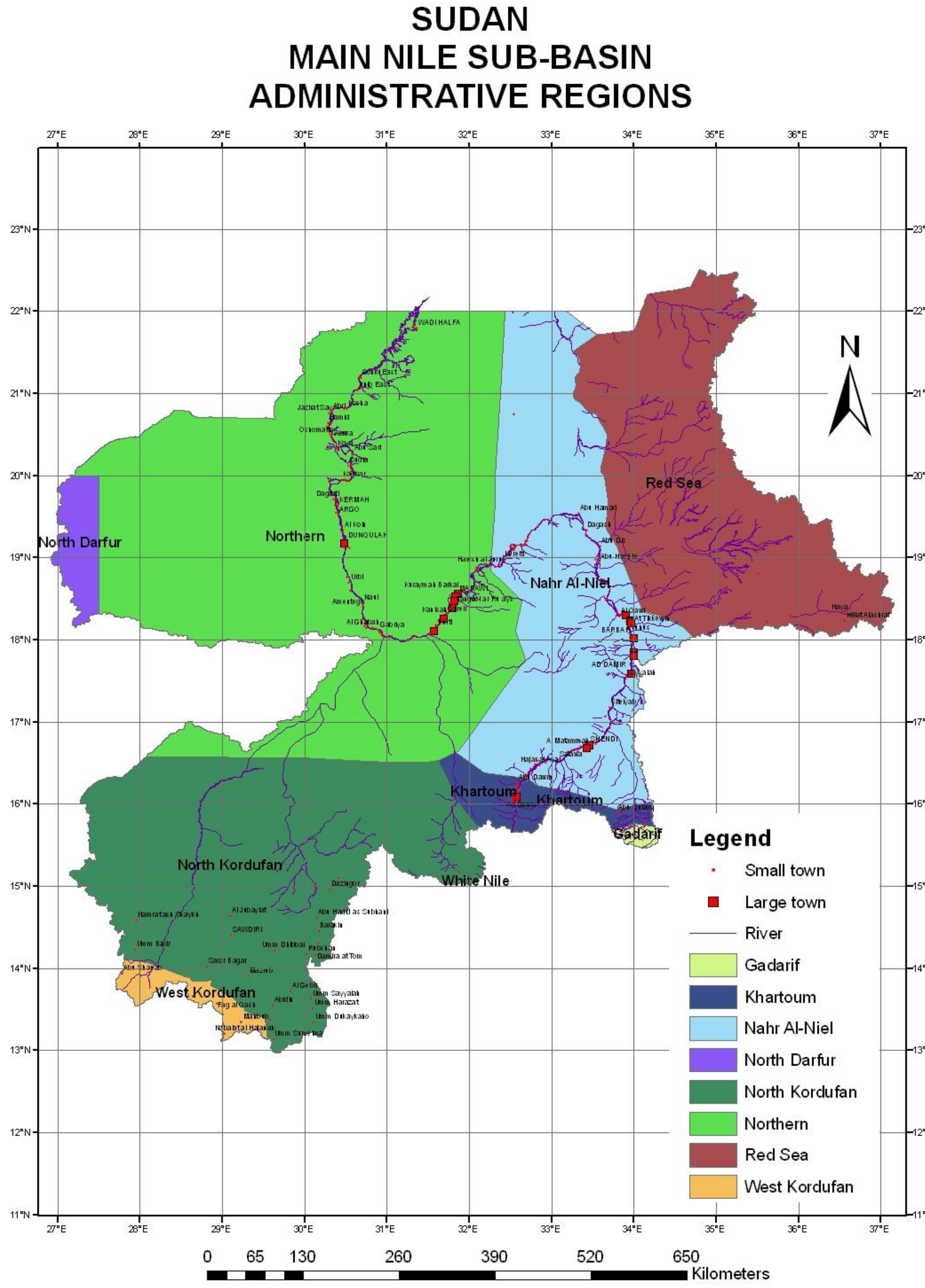
4.2.1 Administration

The Main Nile Sub-basin encompasses 8 Administrative Regions as follows:

Table 25. Administrative Regions within the Main Nile Sub-basin with area (km2)

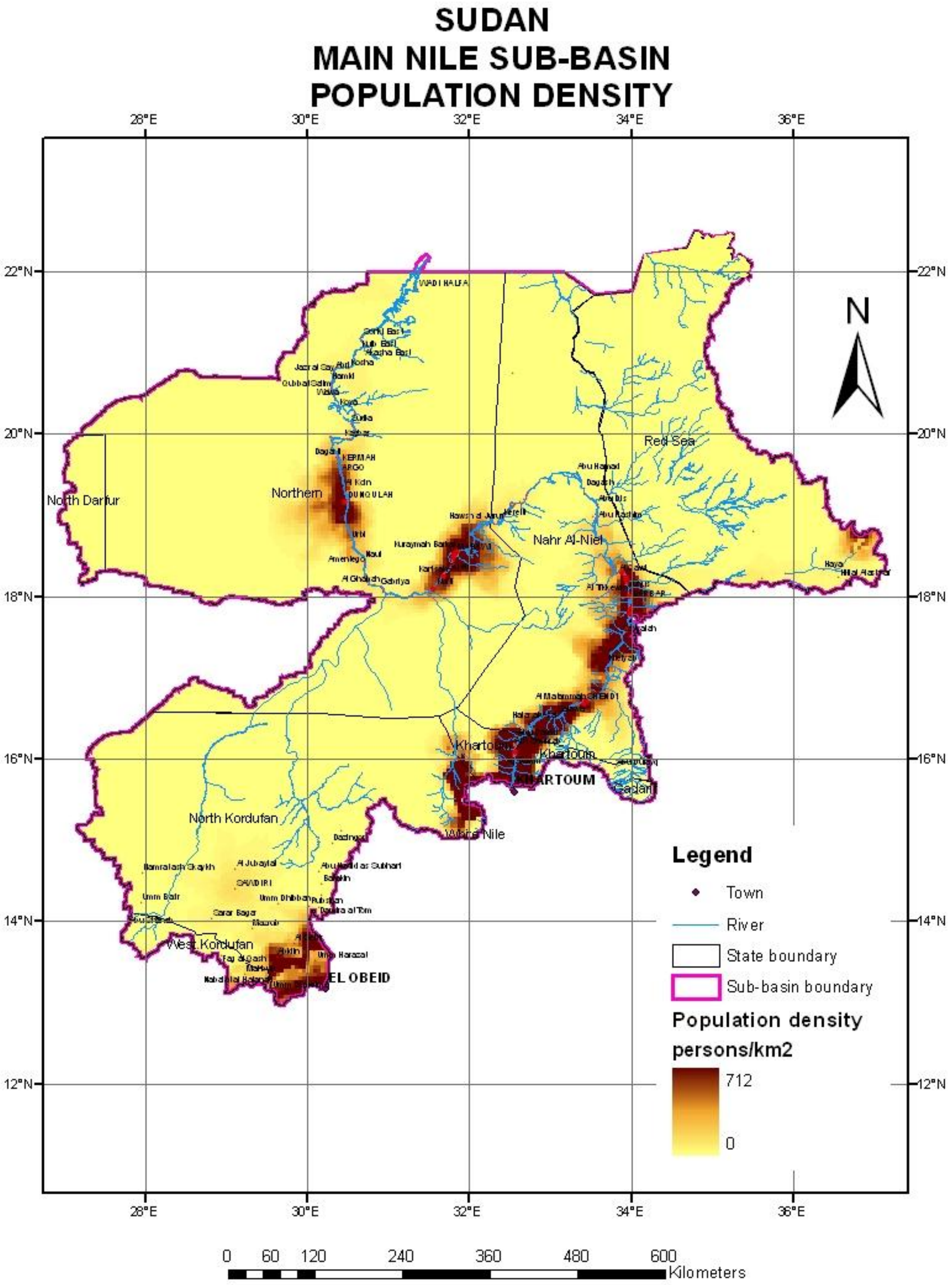
Region	Area (km2)	% of Sub-basin
North Dafur	9,788	**1%**
North Kordafan	139,636	**21%**
West Kordafan	7,220	**1%**
Northern	259,180	**39%**
Khartoum	13,663	**2%**
Nile	118,500	**18%**
Gaderif	1,654	**0.3%**
Red Sea	111,236	**17%**
SUB-BASIN	**660,877**	

The main Regions in terms of area are North Kordafan, Northern, Nile and Red Sea.



Map 12. Sudan – Main Nile: Administrative States.
Source: ENTRO GIS Database

4.2.2 Population



Map 13. Sudan – Main Nile Sub-basin: Population density (persons/km2)

Source: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL)

(i) Population Numbers

The population of the States contained mainly within the Main Nile Basin are as follows:

Table 26. Population of States within the Main Nile Sub-basin.

Northern	1,179,399
Nile	701,256
Red Sea	2,048,041
TOTAL	**3,928,696**

(ii) Population Distribution

Population densities are shown in Map 13. The main areas of high population density are along the Main Nile north of Khartoum and the areas around Kassala, Karima, Dongola and El Obeid. Elsewhere densities are less than 40 persons per km^2. It is estimated that in 1995 some 58 percent of Sudan's population lived within 300 kms of Khartoum (Abu Sin, 1995).

4.2.3 Demographic and Livelihood Characteristics

(i) Demographic Characteristics

Population growth rates are low, between 0.52 and 1.9percent per annum (table 27). There is high youth emigration, particularly to Khartoum and the Gulf countries. The sex ratios of less than 100 probably reflect under-reporting of females. It is not clear why Red Sea State should be so high. North Kordofan has above average (for Northern Sudan States) crude birth and death rates and also infant mortality rates.

Table 27. Main Nile Sub-basin: Administrative States - Demographic Characteristics

State	Gth rate %	Urban %	% <15yrs	% >60yrs	Sex ratio M/F	Crude birth rate	Crude death rate	Infant mort. male*	**Infant mort. female ***
Northern	1.70	15.2	39.7	5.9	94.7	37.8	11	116	**98**
Nile	1.90	33.7	41.0	5.3	97.6	34.0	10.8	108	**90**
Red Sea	0.52	60.5	38.5	4.3	116.1	34.7	9.7	95	**88**
North Kordofan	1.60	31.1	47.4	4.3	91.8	40.1	12.2	125	**106**
NORTH SUDAN	**2.8**	**37.3**	**42.8**	**4.1**	**100.4**	**37.8**	**11.0**	**116**	**98**

* per 1000 live births

Source: UN Population Fund & Sudan Central Bureau of Statistics. (2002).

(ii) Literacy and Education

The literacy and primary school enrollment rates for the four States are shown in table 28.

Table 28. Main Nile Sub-basin: Administrative States – Literacy and Primary School Enrollment Rates

State	Literacy >15yrs % Average	Literacy >15yrs % Male	Literacy > 15yrs % Female	Pop. 6-13yrs	Total Primary school enroll.	% enroll.
Northern	65.2	75.0	56.6	114,040	100,336	88.0
Nile	64.5	73.6	56.5	186,851	147,477	78.9
Red Sea	47.9	54.5	40.1	154,210	69,290	44.9
North Kordofan	39.1	52.0	29.4	364,719	170,023	46.6
NORTH SUDAN	**54.5**	**66.6**	**42.4**	**6,493,230**	**3,308,387**	**51.0**

Sources: UN Population Fund & Sudan Central Bureau of Statistics. (2002).

There are very clear differences in literacy and primary School enrollment rates between Northern and Nile States and Red Sea and North Kordofan States, with the former considerably above the Northern Sudan average. Female rates are below those of males, with Red Sea State well below the average for the Northern States.

(iii) Water and Sanitation

The percent population with access to drinking water and sanitation facilities is shown in table 29.

Table 29. Main Nile Sub-basin: Administrative States – (a) Percent Population Access to Drinking Water, (b) Sanitation Facilities

(a) Drinking Water by Source

State	Main source of water							
	Piped into dwelling	Public tap	Deep Well/pump	Dug Well/ bucket	River/canal	Rainwater	Others	Missing
Northern	50.8	4.3	15.8	9.8	12.8	--	6.4	0.1
Nile	42.3	3.7	12.2	13.5	24.7	--	3.4	0.2
Red Sea	25.6	18.3	28.3	25.8	1.5	--	0.5	--
North Kordofan	16.3	5.3	20.5	25.4	2.2	13.2	17.1	--
NORTH SUDAN	**50.8**	**4.3**	**15.8**	**9.8**	**12.8**	**--**	**6.4**	**0.1**

(b) Sanitation facility by type

State	Flush to Sewage System	Flush to septic tank	Traditional pit latrine	Soak away pit	Others	Missing	No facilities
Northern	--	7.7	69.2	1.6	1.6	--	19.9
Nile	--	12.3	72.6	0.7	0.7	0.1	13.5
Red Sea	--	20.9	26.1	4.2	0.7	0.2	47.9
North Kordofan	--	2.9	31.4	1.9	1	0.1	62.6
NORTH SUDAN	--	7.7	69.2	1.6	1.6	--	19.9

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

A similar distinction between Northern and Nile States and Red Sea and North Kordofan States is apparent with respect to water and sanitation facilities. The two former States are well above the national average with respect to piped water and sanitation facilities.

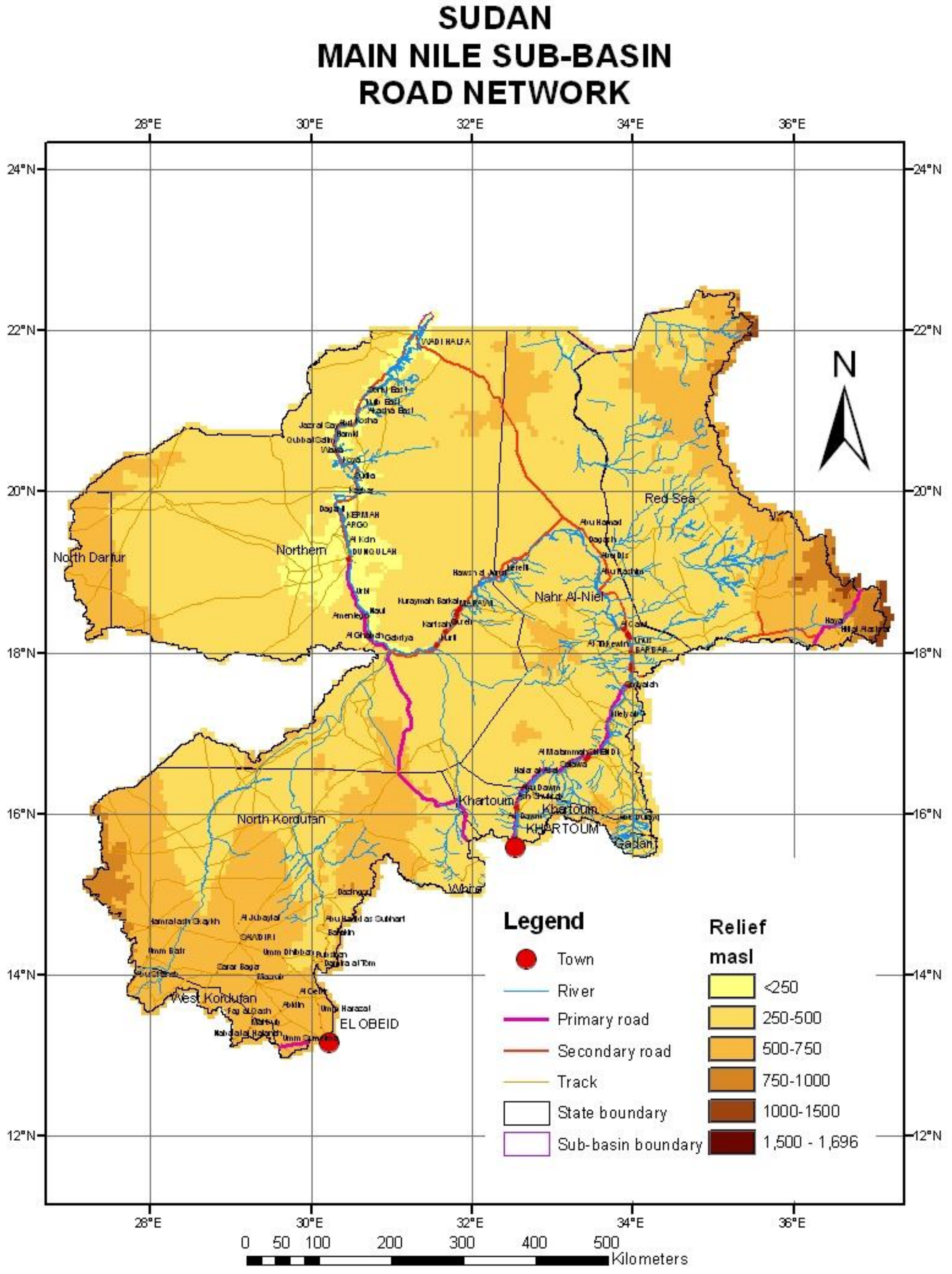
4.2.4 Socio-cultural Aspects of population

There is considerable socio-cultural diversity among the population of the Main Nile Sub-basin mirroring that of the whole of the Sudan. The following description is a brief summary of a complex picture and lists only the larger socio-cultural groups.

The main groups are Nubians, Danagla, Bedirya and Rekabia. Along both banks of the Nile itself are the Gaa'lian people who have inherited the rights to use their land and being closest to water were able to survive the devastating drought of 1983/84. Also living both sides of the river are the Shaigia, Kawahla, Kababish and Hassaniya peoples, mainly pastoralists but who also cultivate sorghum along the wadis. As with all the pastoral/agro-pastoral groups wage labour is a major feature of livelihood strategies. Living mainly along the Wadi Muqadam and more recently along the Nile below Korti are the Hawaweer people. Their livelihoods too were devastated by the 1983/84 drought but many have returned and rebuilt their livelihoods (Haug, 2000).

4.3 Transport Infrastructure

4.3.1 Transport Infrastructure



Map 14. Sudan – Main Nile: Road Network
Source: Afriroads, 2001.

Over much of the Basin road network is very poor given the vast expanse of desert. Within the Main Nile Sub-basin there are two primary (asphalt) and four all-weather secondary roads:

(a) Primary Roads

Khartoum-Atbara (312 kms) – Atbara - -Haiya (under construction)
Khartoum- Abu Dom (386 kms) Abu Dom -Dongola (under construction)

(b) Secondary Roads

Atbara-Wadi Halfa (613 kms)

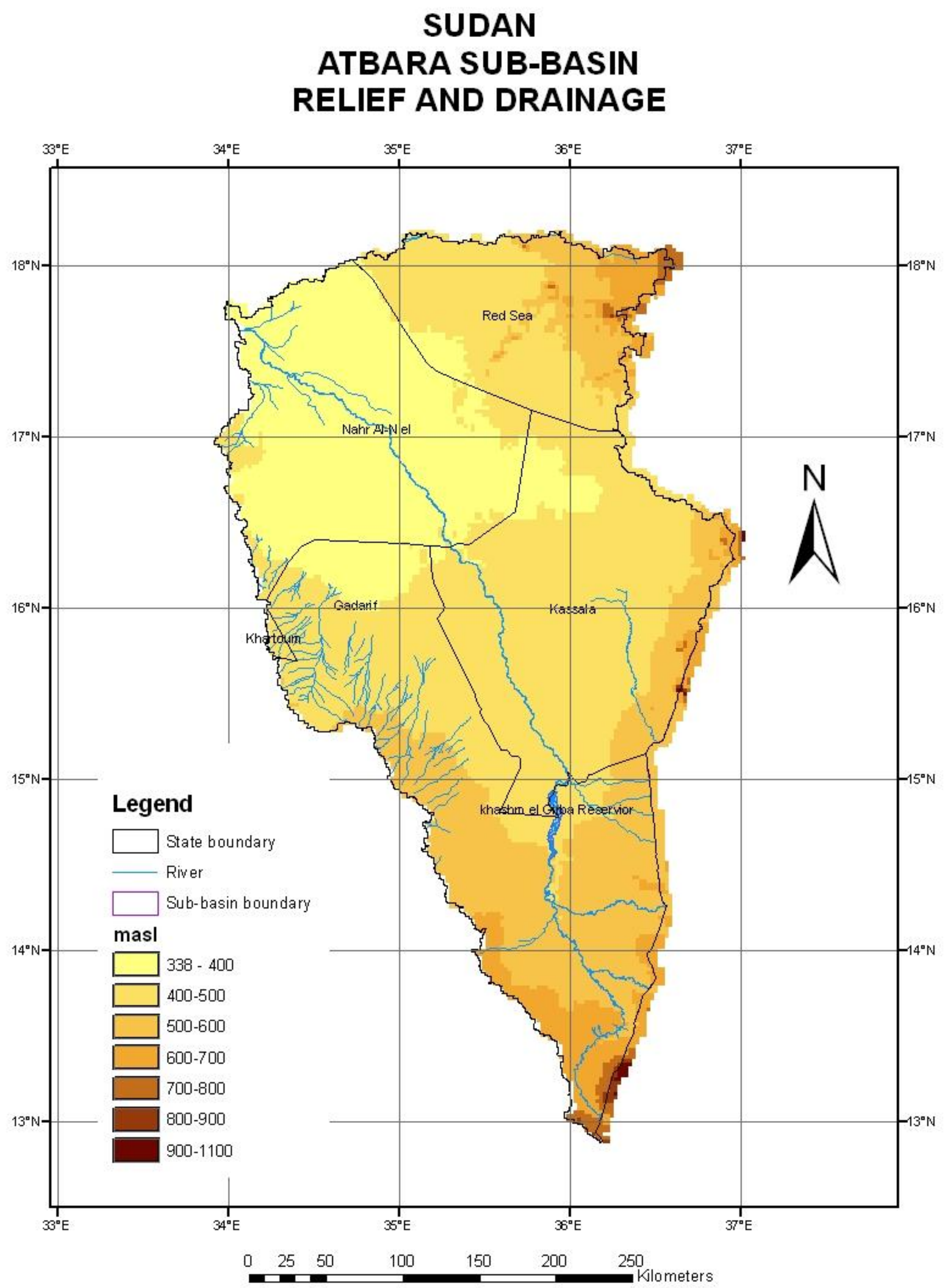
Other roads are generally in poor condition and on the clay plains often impassable during the rains.

There is one rail line: Wadi Halfa-Khartoum.

5. ATBARA SUB-BASIN – BIOPHYSICAL AND SOCIO-ECONOMIC SITUATION

5.1 Biophysical Characteristics

5.1.1 Location and Physiography

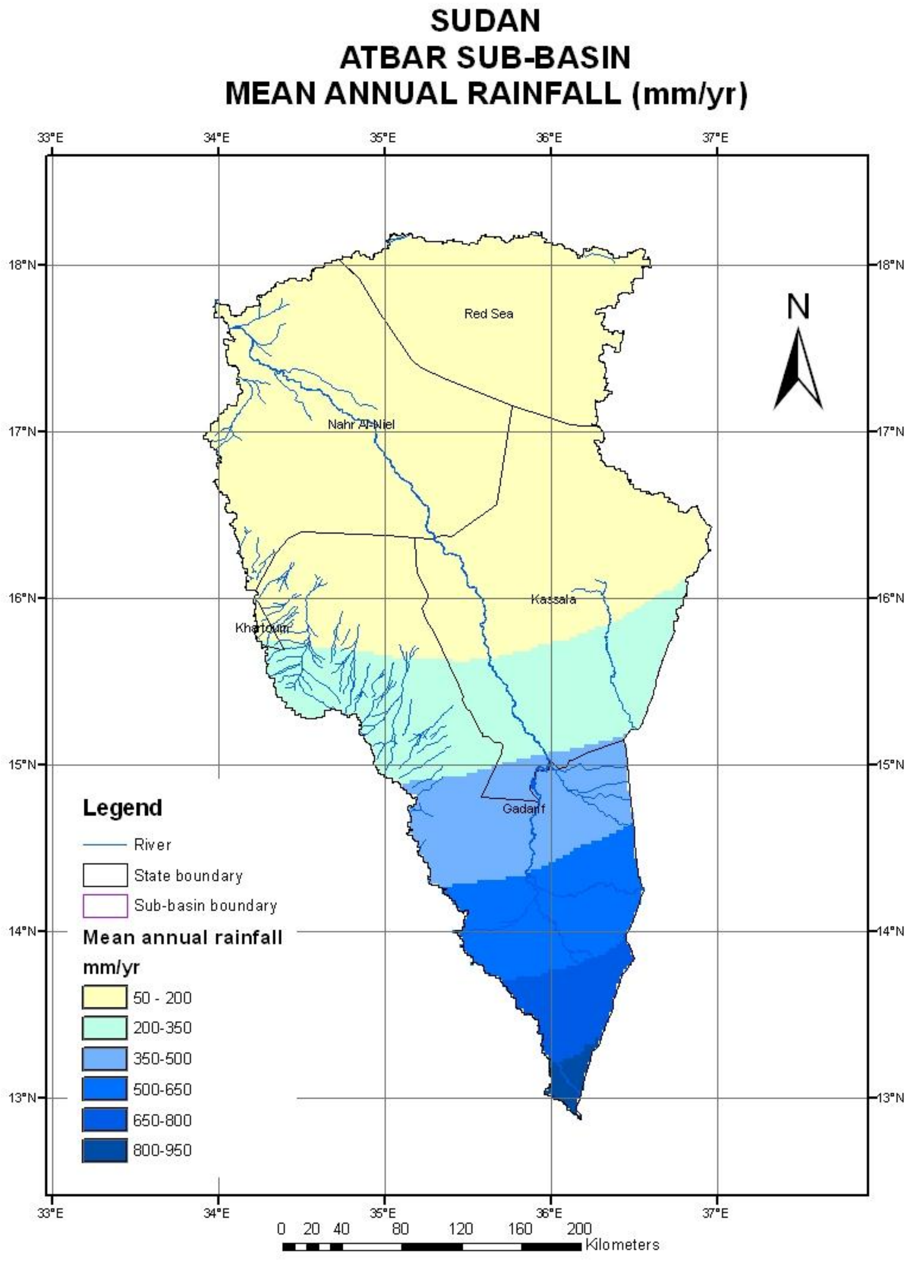


Map 15. Sudan – Atbara Sub-Basin: Relief and Drainage.
Source: Shuttle Radar Terrain Mission (SRTM 90) digital terrain model.

The Atbara Sub-basin occupies a wide valley with the edge of the Ethiopian Highlands at its upper edge. To the north are the western slopes of the Red Sea Hills. To the south is the low watershed between the Atbara and the Blue Nile occupied by the Butana Plains. The Gash River enters Sudan to the north of the Atbara loosing its water in the Gash Delta. A number of intermittent khori channels flow from the Blue Nile-Atbara watershed rarely if ever reaching the Atbara River.

5.1.2 Climate

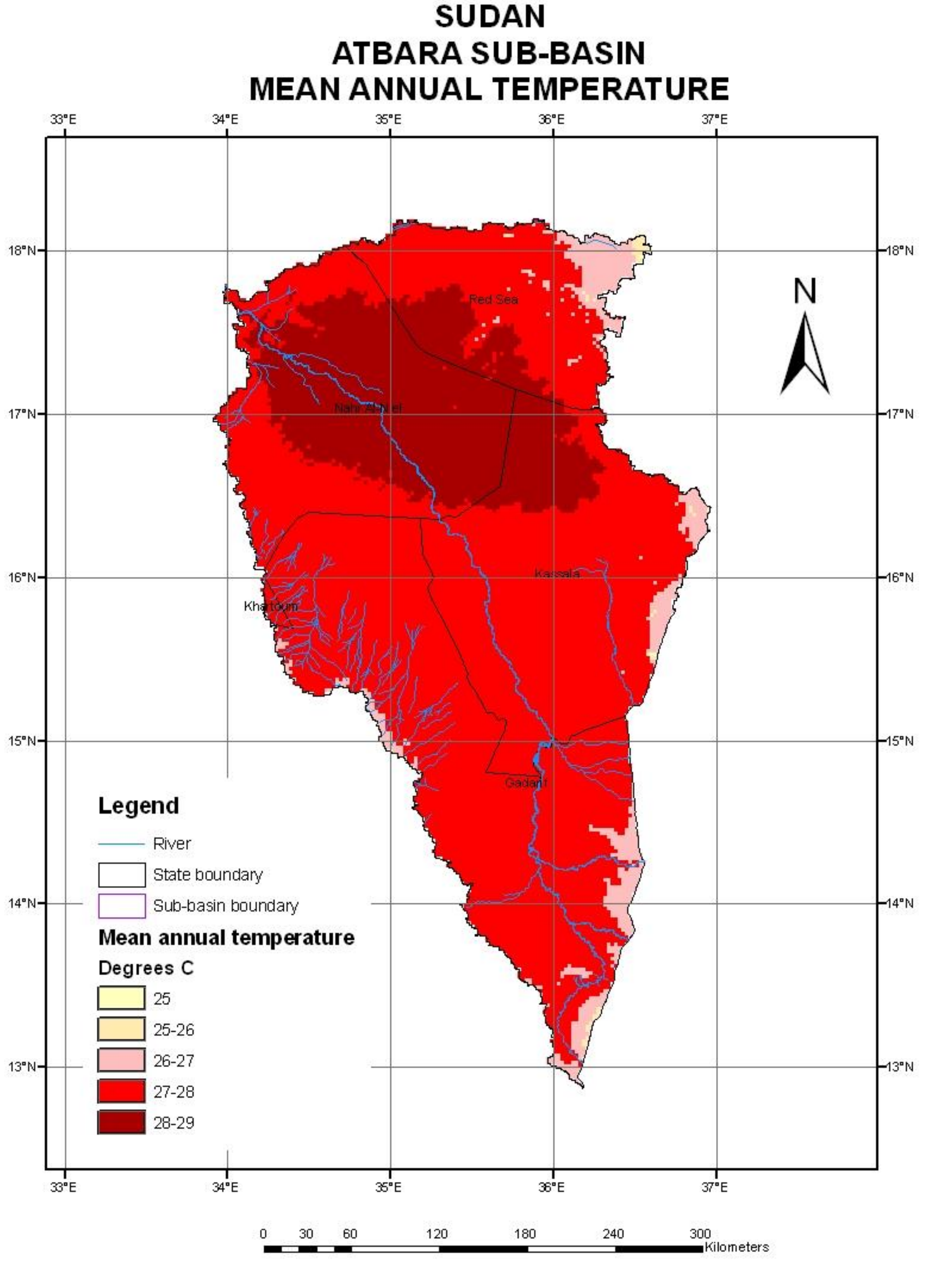
(i) Rainfall (Map 16)



Map 16. Sudan – Atbara Sub-basin: Mean annual rainfall.
Source: ENTRO GIS Database

The rainfall isohyets trend in an east-north-east to west-south-west direction, with rainfall decreasing northwestwards from where the river leaves Ethiopia. Rainfall ranges from about 800 mm/yr at the border to less than 50 mm/yr at the junction with the Main Nile with a coefficient of variation (CV) as high as 100 percent.

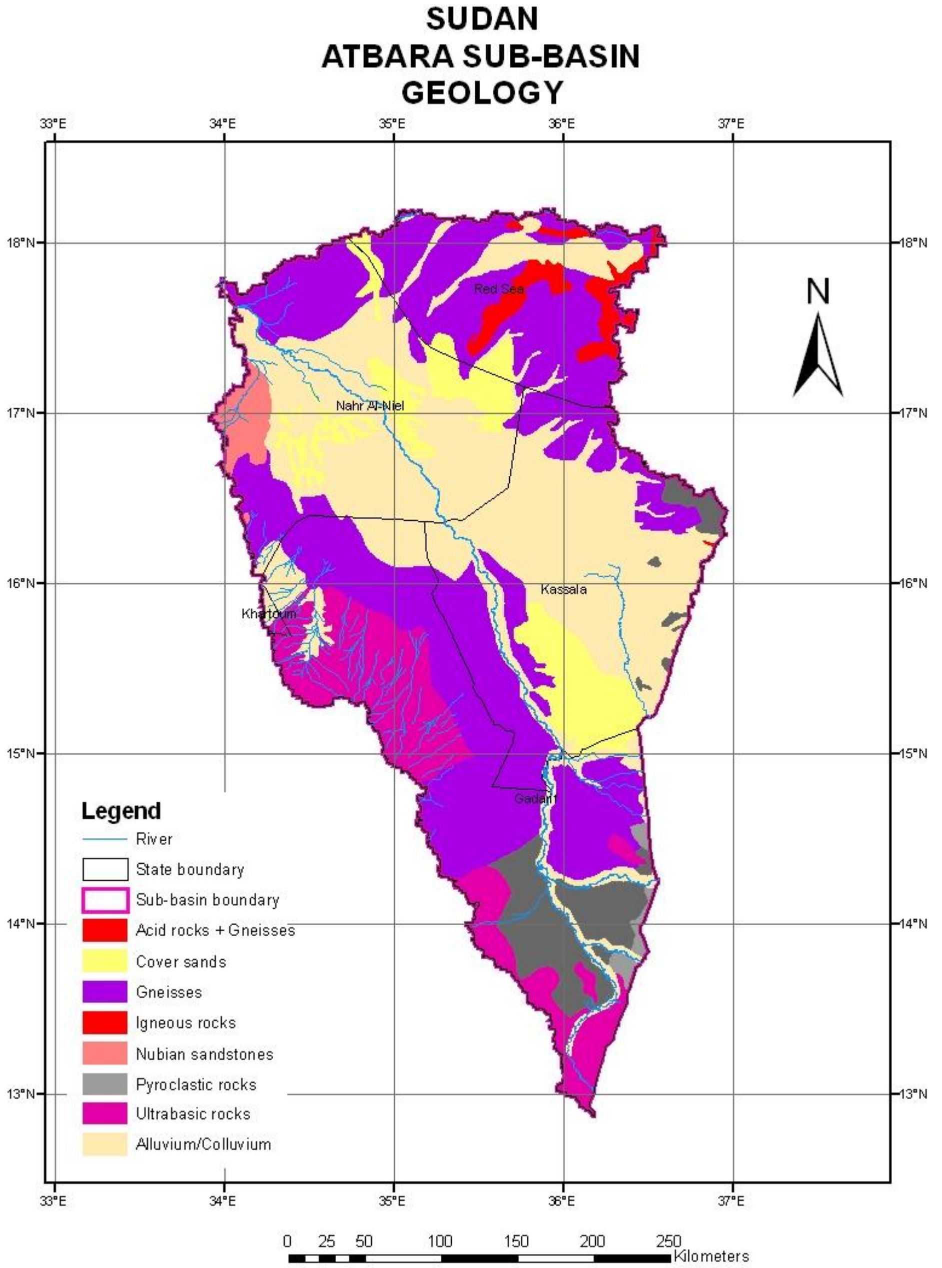
(ii) Temperature (Map 17)



Map 17. Sudan – Atbara Basin: Mean annual temperature.
Source: ENTRO GIS Database

Daily minimum and maximum temperatures in January are 14°C and 33°C and those in May are 24° and 44°C respectively. Highest mean annual temperatures occur in the eastern clay plains, rather than the north where minimum temperatures bring down the mean (Map 18). Daily evaporation rates range from 12 mm in August, the month a maximum cloud cover, to 21 mm in May.

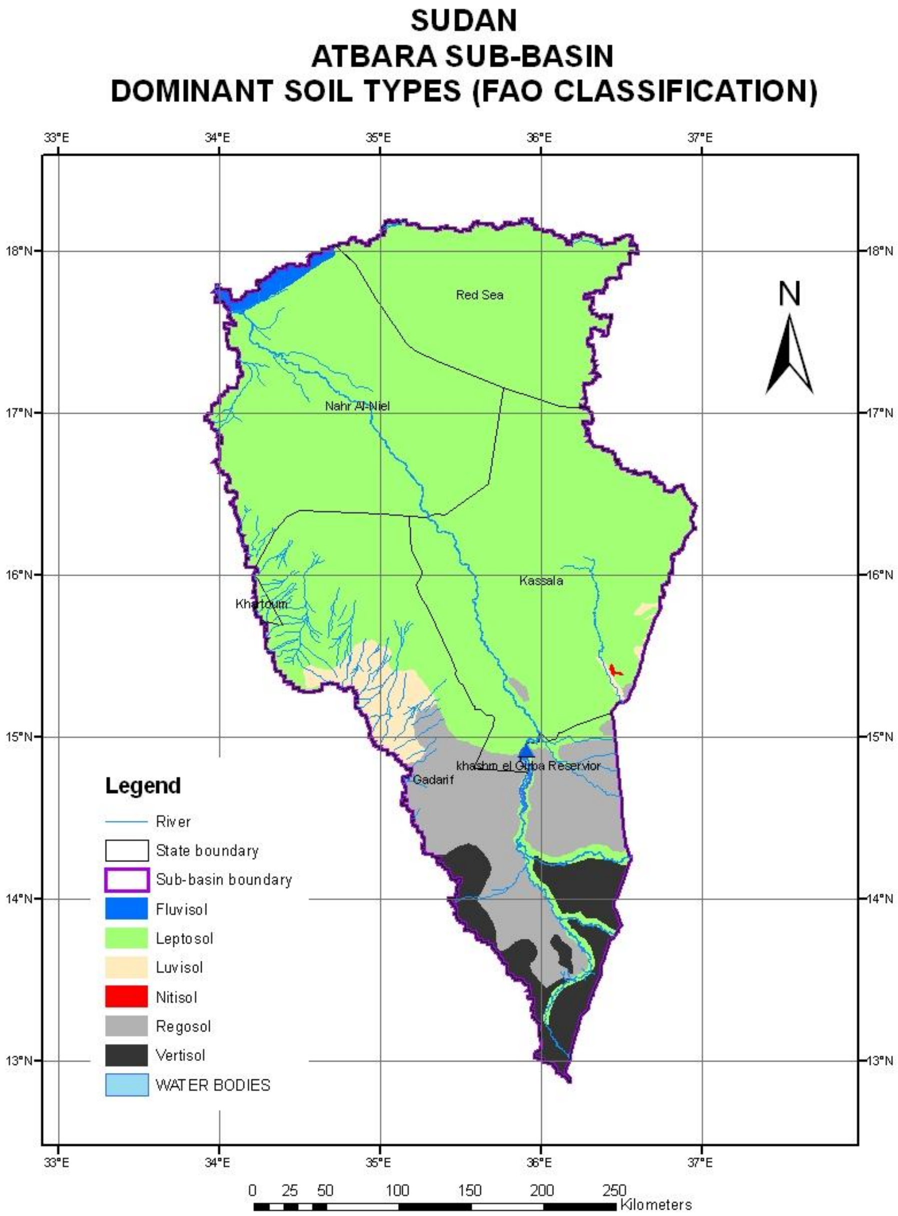
5.1.3 Geology (Map 18)



Map 18. Sudan – Atbara Sub-basin: Geology
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

The main underlying geological formations within the Main Nile Sub-basin include the older Basement Complex rocks, the Nubian Sandstones, Tertiary unconsolidated sediments and Recent superficial wind blown sands. The Located down the centre of the Sub-basin are deposits of alluvium and colluvium and form the black clays of the flood plains. In places these are overlain with cover sands. The basement Complex comprises gneisses, schists, marbles and intrusive granites and basic rocks. The Nubian Sandstones are located in the northwest corner and overly unconformably the Basement Complex rocks and comprise mainly sandstones, siltstones and conglomerates.

5.1.4 Soils (Map 19)



Map 19. Sudan – Atbara Sub-basin: Dominant Soil Types (FAO Classification)

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

Leptosols cover a large part of the Sub-basin. South of the Leptosols are Regosols. At the southern end on the interfluves between the Setit and Atbara rivers are Vertisols. These are black heavy cracking clays.

5.1.5 Landcover and Vegetation

(i) Desert

North of the 75 mm isohyet generally desert or semi-desert conditions prevail with little or vegetation except along wadis with a high watertable. Occasional years of very good rainfall can transform areas of desert into valuable grazing areas known as "*gizzu"*.

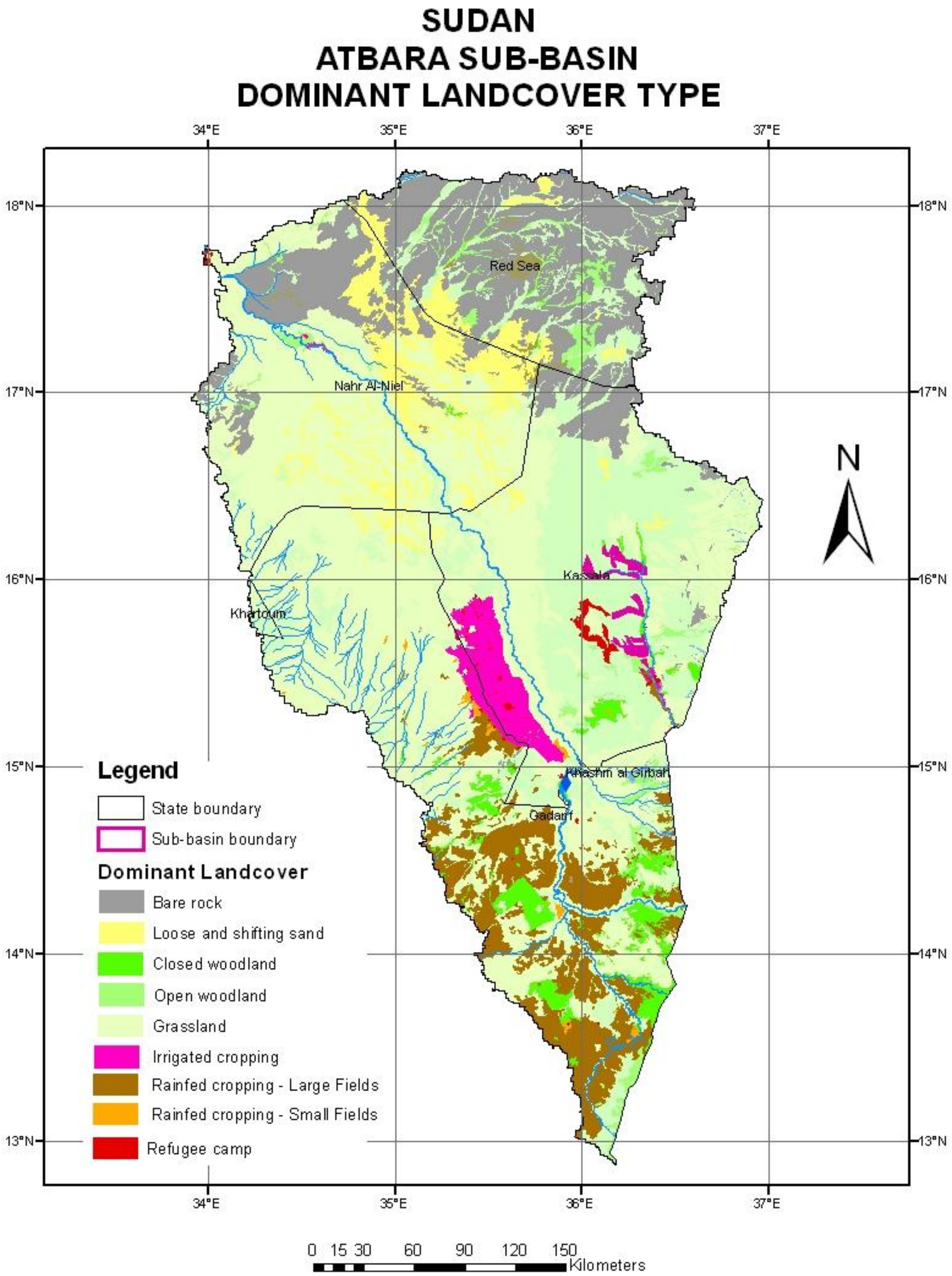
(ii) Semi-desert Scrub

Between the 75 and about 250 mm isohyets "Semi-desert Scrub" is the most prevalent vegetation type, and comprises a varying mixture of grasses and herbs, generally with a variable scatter of shrubs up to 4 meters high interspersed with bare earth.

On sandy soils tree species include *Leptadenia pyrotechnica*, *A. Senegal* and *A. tortilis* subsp. *spirocarpa* and *raddiana*. On the clay plains there are a number of plant communities associated with specific habitat characteristics related to local topography and eroded, runoff and run-on sites. The most common tree species that have a wide "sociological tolerance" include[5]: *Acacia tortilis* subsp. *tortilis* and *raddiana*, *A. nubica*, and *Caparis decidua. A. nubia* and *Calotropis procera* are common in the vicinity of villages and are indicators of overgrazing. Along the inundated areas of the Blue Nile *A. nilotica*, *A. albida* and *A.seyal* are common. *A. nilotica* is also found at the outlets to wadis which pour into the Nile and which receive flood water.

Grasses are mainly annuals. Heavy grazing and low rainfall ensures that there is insufficient dry matter for annual fires. In years of low rainfall and heavy grazing there can be an almost complete failure of annual plant growth. On very sandy soils *Panicum turgidum* is likely to be the dominant grass. This is an excellent grass for stabilizing sand dunes as well providing adequate browse. *Aristida spp.* are usually dominant on stabilized sands and on the shallow light textured surface materials, with *Schoenefeldia gracilis* dominating on the clay soils. Other ephemeral grass species include *Sporobulus cordofanus*, *Dactyloctenium aegyptium*, *Eragrostis cilianensis* and *Tragus berteronianus*.

[5] M.Obeid Mubarak (1982) op.cite (f.n.3)



Map 20. Sudan – Atbara Sub-basin: Landcover
Source: Sudan FAO Africover, 2003

South-eastwards from the 250 mm to the 360 mm isohyet the vegetation type becomes "Semi-desert Grassland". Much of this vegetation is now covered by the Gezira and Managil Irrigation Schemes.

Along the Atbara banks on eroded soils *A. nilotica* and *A. seyal* are found on the lower parts of the floodplain, whilst at higher levels *A. tortilis* subsp. *raddiana* is the dominant tree species. Along the banks of wadis and khors *C. decidua* and *A. nubica* occur either as pure or mixed stands.

On the heavy alkaline clay soils the natural vegetation is grassland without trees or shrubs. With increasing rainfall *A. mellifera* thornland gradually appears. Grass species are much the same as on the Semi-desert Scrub communities, mainly *Aristide spp*. and *S. gracilis*.

On sandy soils to the north tree species include *Acacia senegal* and *Combretum glutinosum*. Much of the dune areas are dominated by pure stands of *A. senegal* grown for gum production under a long term gum acacia-cultivation cycle.

(iv) Acacia Thornland alternating with Grassland

Between the 360 mm and 570 mm isohyets on the heavy clays 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 is 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.

(v) Acacia seyal-Balanites Savanna Woodland

Above 570mm to the border with Ethiopia 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* becomes increasing prevalent because it is fire resistant, does not produce good charcoal and is hard to cut.

In the northern parts of the Gash Delta there are an estimated 30,000 feddans of natural Acacia-Balanites Woodland grown under natural irrigation from water that has escaped from breaks in the irrigation canals. To the south is a further 10,000 fedans of similar woodland locally known as "*balag*", a term formerly used to describe natural flooded woodland.

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.

(vi) Cultivation

New Halfa Irrigation Scheme: Below the Kashm el Girba dam is the New Halfa irrigation scheme totally some 447,000 feddans (190,000 ha). The scheme was set up partly to resettle 7,000 Halfawi families who had been displaced by the rising waters of Lake Nasser/Nubia. In addition there were 20,000 local families. In 1970/71 the area under crops was 330,000 feddans but by 1982 had reduced to 145,000 feddans due to problems of siltation and loss of irrigation storage in the Kashm el Girba dam. Many families ion the scheme retain a stake in pastoralism beyond the scheme.

Flood Irrigation Schemes: Around Kassala in the Gash Delta is a large but variable area of flash flood irrigation. The floods average 88 days (Kirkby, 2001). Water is diverted into canals and so to large level areas known as "misgas". On the northern end of the Eastern Gash a different tyre of irrigation is found using pumped well water, mainly for vegetables and fruit trees. Originally small in number, they have increased substantially, and now use motorised pumps. Originally the scheme produced cotton, but now sorghum dominates with castor, sunflower and ground nuts. Vegetables are an increasingly important crop on the four large commercial farms in the northern delta.

Many of the Hadendowa and Rashaida are still pastoralists or agro-pastoralist and in the wet season graze their animals north and west of the delta.

There is a similar area of flood irrigation to the northeast in the Tokar Delta, but this scheme does not have the canals of the Gash Delta.

Semi-Mechanized farms: Above the dam are extensive areas of semi-mechanized rainfed farms that stretch over into the Blue Nile Sub-basin. The area within the Atbara Sub-basin is 2.00 million feddans. However, a proportion of this has been abandoned. The main crops grown are sorghum and sesame. An ILO/UNHCR Study (1984) estimated that 70 percent was outside demarcated schemes. The lease-holders are predominantly merchants from Gederif, Khartoum and the north, but also include some wealthy pastoralists, particularly from the Shukriya and Dubania tribes.

Small-holder Farms: Close to the Atbara and scattered elsewhere are areas of smallholder rainfed cultivation. These are generally less than 10 feddans in size. They cover approximately 0.079 million feddans within the Atbara Sub-basin. Many are Lahawin pastoralists who lost the livestock in the droughts of the 1980's or felt that they had better claim land before other groups (e.g. the Falleta) did so (Morton, 1988).

(vii) Refugee camp

Most refugees have now returned to Ethiopia, although the vegetation around the camp is now beginning to recover.

5.1.6 Water Resources

(i) Surface Water

The Atbara River contributes about 12.7% of the total discharge of the Main Nile and follows much the same seasonal pattern as the Blue Nile except that its discharge reduces to very low flows and sometimes to zero flow for almost four months of the year. The average discharge at Kashm el Girba station (1986-2000) was 11.45 km^3; that for the Kubur Station (1981-1999) on the Upper Atbara (i.e. above the Setit-Tekezi and Upper Atbara confluence) 7.42 km^3; and that for the Tekezi at Humera (1981-1984) 5.01 km3. There is a distinct difference in the amount of runoff between the Upper Atbara and the Tekezi. This is shown in Table 30, which indicates the area of catchment, total discharge and the runoff per km^2.

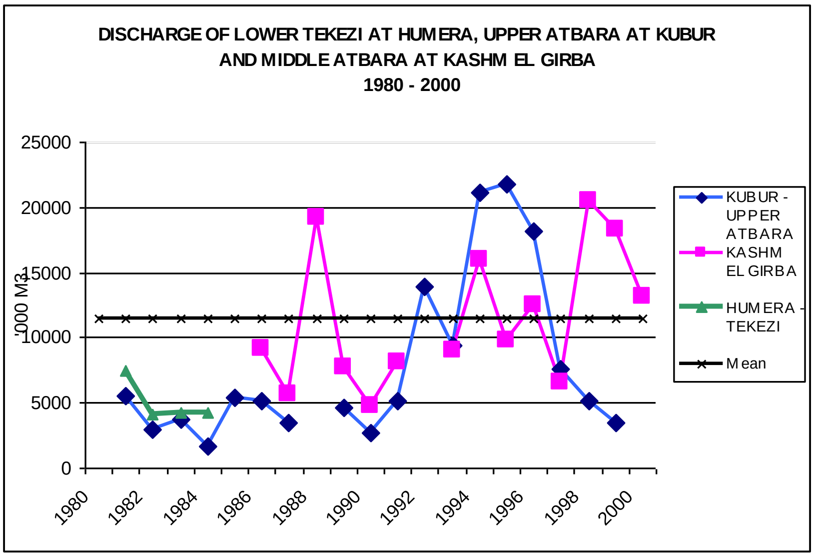
Table 30. Tekezi-Atbara Sub-basin: Area (km2), Discharge ('000 Mm3) and Runoff/km2 for the Tekezi and Upper Atbara Catchments (using 1981 – 1984 data)

Catchment	Area (km2)	Discharge ('000 Mm3)	Runoff Mm3/km2
Upper Atbara (Ethiopia)	21,933	3,442.7	**0.157**
Tekezi (Ethiopia)	63,967	5009.0	**0.078**

This clearly indicates a higher run-off per unit area in the Upper Atbara catchment compared with the Setit-Tekeze Catchment. The total runoff is 52,834 m^3 of water per km^2 per annum, compared with 169,612 m^3/km^2/yr for the Blue Nile, 28 833 m^3/km^2/yr for Baro-Akobo-Sobat. Most of Tekezi-Atbara water comes from Ethiopia, even though 50 % of the sub-basin is located in Sudan. This high proportion of water coming from the highlands is related to the rainfall pattern.

There is considerable year-on-year variation about the mean as can be seen in figure 4, which shows annual discharges. The highest discharge of 20,468 Mm3 occurred in 1997 and the lowest of 4,778 Mm3 in 1990. The station for Kashm el Girba is located below the dam and discharge may be affected by the water release regime of the dam. Thus in 1993 to 1995 discharges on the Upper Atbara appear to be higher than the main Atbara (i.e. Atbara + Tekezi).

Figure 4. Annual discharge of the Middle Atbara (Kashm el Girba), Upper Atbara (Kubur), and the Tekeze (Humera) – 1980 -2000.



Source: Abdelsalem Ahmed (2006) and Ethiopian MWRI.

The area of the Gash-Mereb catchment is about 31,000 km^2. The Gash rises as the Mereb River and in its upper reaches forms the border between Ethiopia and Eritrea. On debouching onto the plains near Kassala the river forms an inland delta where the water is used for flood irrigation, tree irrigation. The remaining surface flow is totally lost through evaporation and deep percolation, never to reach the Nile. The mean annual discharge is 680 million m^3, although it can range between 140 and 1,260 million m^3.

In addition to the main rivers there are a large number of ephemeral khors, which although contributing little or nothing to the main rivers are of considerable local importance. Much of the water is collected by water harvesting into hafirs for domestic and livestock watering and in *teras* for crop cultivation.

(ii) Groundwater

In the Lowlands a quantitative assessment of groundwater in the Showak area (Ibrahim & Giddo, 1992) give a storage capacity of the upper Nubian aquifer as 840 million m^3 and the safe yield is estimated at 8.4 million m^3. In the second major aquifer located in the Neogene-Recent Deposits ("Unconsolidated Sediments" in Map 4) 1 km away from the banks of the Setit and Atbara Rivers the storage capacity is estimated at 222 million m^3 and the safe yield 11.2 million m^3.

5.2 Socio-economic Characteristics

5.2.1 Administration

The Atbara Sub-basin encompasses 8 Administrative States and their areas are shown in table 31.

Table 31. Atbara Sub-basin: Administrative States and their areas (km2)

State	Area (km2)	**% of Sub-basin**
Khartoum	341	**0.3%**
Nile	30,751	**23.4%**
Gadaref	45,269	**34.5%**
Red Sea	19,055	**14.5%**
Kassala	35,854	**27.3%**
SUB-BASIN	**131,270**	

The main Regions in terms of area are Nile, Gaderif, Red Sea and Kassala (Map 21).

Map 21. Sudan – Atbara Sub-basin: Administrative regions
Source: ENTRO GIS Database.

5.2.2 Population

(i) Population Numbers

The population within the Sub-basin of the States contained mainly within the Atbara Sub-Basin are as follows:

Kassala	24,755
Gaderif	24,306
Nile	9,295
Red Sea	3,537
TOTAL	**61,892**

(ii) Population Distribution

In the south areas of high population density are related to the New Halfa Irrigation scheme and to the main Khartoum-Port Sudan Road. In the north an area of high population density is located to the east of Atbara town.

5.2.3 Demographic and Livelihood Characteristics

(i) Demographic Characteristics

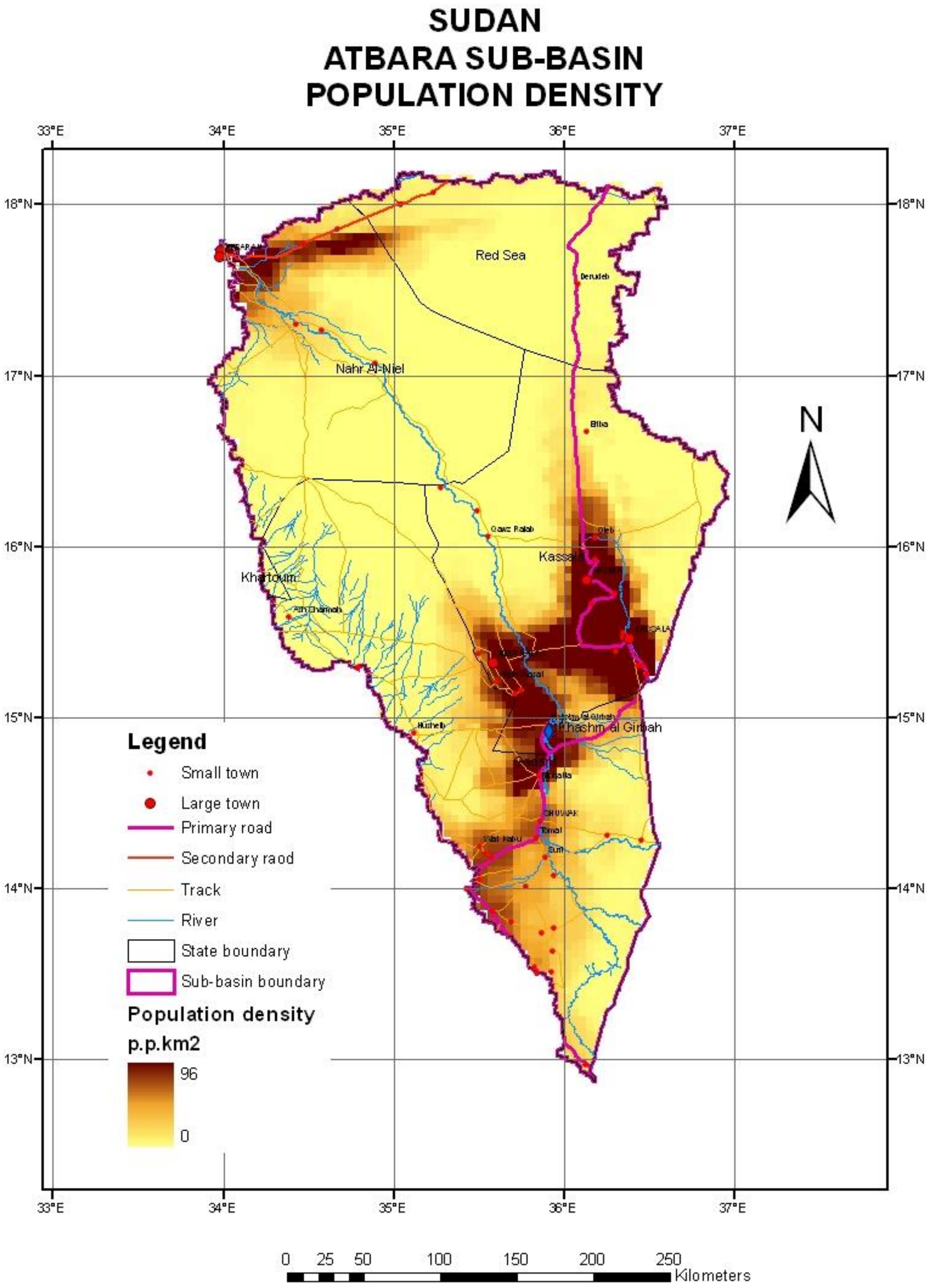
Except for Red Sea State, population growth rates are average to high, between 1.9 to 3.4 percent per annum (table 33). The high urban percent for Red Sea State is because of the dis-proportionate influence of the city of Port Sudan, which is outside the Nile Basin. Gederef State has the highest growth, birth and death rates of the four States.

Table 32. Atbara Sub-basin: Administrative States - Demographic Characteristics

State	Gth rate %	Urban %	% <15yrs	% >60yrs	Sex ratio M/F	Crude birth rate	Crude death rate	Infant mort. male*	**Infant mort. female ***
Kassala	2.50	34.6	41.8	4.2	98.2	37.8	10.5	107	**96**
Gaderif	3.40	28.9	43.1	3.7	105.3	40.3	11.7	135	**122**
Nile	1.90	33.7	41.0	5.3	97.6	34.0	10.8	108	**90**
Red Sea	0.52	60.5	38.5	4.3	116.1	34.7	9.7	95	**88**
NORTH SUDAN	**2.80**	**37.3**	**42.8**	**4.1**	**100.4**	**37.8**	**11.0**	**116**	**98**

* per 1000 live births

Source: UN Population Fund & Sudan Central Bureau of Statistics. (2002).



Map 22. Sudan – Atbara Sub-basin: Population density
LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL)

(ii) Literacy and Education

The literacy and primary school enrollment rates for the four States are shown in table 33.

Table 33. Atbara Sub-basin: Administrative States – Literacy and Primary School Enrollment Rates

State	Literacy >15yrs % Average	Literacy >15yrs % Male	Literacy > 15yrs % Female	Pop. 6-13yrs	Total Primary school enrol.	% enroll.
Kassala	44.7	52.9	35.8	274,713	103,131	37.5
Gaderif	55.6	72.9	38.4	311,547	142,313	45.7
Nile	65.2	75.0	56.6	186,851	147,477	78.9
Red Sea	47.9	54.5	40.1	154,210	69,290	44.9
NORTH SUDAN	**54.5**	**66.6**	**42.4**	**6,493,230**	**3,308,387**	**51.0**

Source: UN Population Fund & Sudan Central Bureau of Statistics. (2002).

There are significant differences in literacy and primary School enrollment rates between Nile State and the others, with the former considerably above the Sudan national average. In all sates female literacy rates are below those for males.

(iii) Water and Sanitation

The percent population with access to drinking water and sanitation facilities are shown in table 34.

Table 34. Atbara Sub-basin: Administrative States – (a) Percent Population Access to Drinking Water, (b) Sanitation Facilities

(a) Drinking Water by Source

	Main source of water							
State	Piped into dwelling	Public tap	Deep Well/pump	Dug Well/ bucket	River/canal	Rainwater	Others	Missing
Kassala	22.6	16	21	6.4	23.1	1.5	8.7	0.8
Gaderif	12.6	18.8	27.7	13.9	13.8	9.4	3.6	0.2
Nile	42.3	3.7	12.2	13.5	24.7	--	3.4	0.2
Red Sea	25.6	18.3	28.3	25.8	1.5	--	0.5	--
NORTH SUDAN	**50.8**	**4.3**	**15.8**	**9.8**	**12.8**	**--**	**6.4**	**0.1**

Source: UN Population Fund & Sudan Central Bureau of Statistics. (2002).

(b) Sanitation facility by type

State	Flush to Sewage System	Flush to septic tank	Traditional pit latrine	Soak away pit	Others	Missing	No facilities
Kassala	--	11.6	34.3	1.2	0.3	0.5	52.0
Gaderif	--	5	31.7	3.1	0	0	60.1
Nile	--	12.3	72.6	0.7	0.7	0.1	13.5

Red Sea	--	20.9	26.1	4.2	0.7	0.2	47.9
NORTH SUDAN	**--**	**7.7**	**69.2**	**1.6**	**1.6**	**--**	**19.9**

Source: UN Population Fund & Sudan Central Bureau of Statistics. (2002).

A similar distinction between Nile State and the others is apparent with respect to water and sanitation facilities. The former State is well above the national average with respect to piped water and sanitation facilities.

5.2.5 Socio-cultural Aspects of the Population

Beyond the Nile River on the Butana Plain to the foothills around Kassala are a number of pastoral/agro-pastoral groups keeping livestock and cultivation sorghum along wadis and in water harvesting structures. The main pastoral groups are the Shukriyya, Dubania, Bawadra and the Lahawin (Morton, 1988). More recent arrivals into the area include West Africans (*Feletas*), Beni Amer (from Eritrea) and Rashaida (from Saudi Arabia). These groups have been badly affected by the substantial development of large areas of Rainfed Semi-mechanized Farms that have taken over large areas of grazing lands.

Around the Gash Delta major ethnic group is the Hadandowa (the largest sub-group of the Beja). The Hadandowa come from the Gash Delta and have been there the longest. Another group is the Rashaida who are the descendants of a group who arrived from the Arabian Peninsula in the 1820's. Until the 1980's they had no title to land on the Gash Delta but have now started to farm on land made available to them. A small group of Sudanese Arabs also live in the Gash delta and have farmed there since the 19^{th} century. Fellata hold some 15 percent of the tenancies on the Gash Delta and in addition some 5,000 share crop land owned by Hadandowa.

5.3 Transport Infrastructure

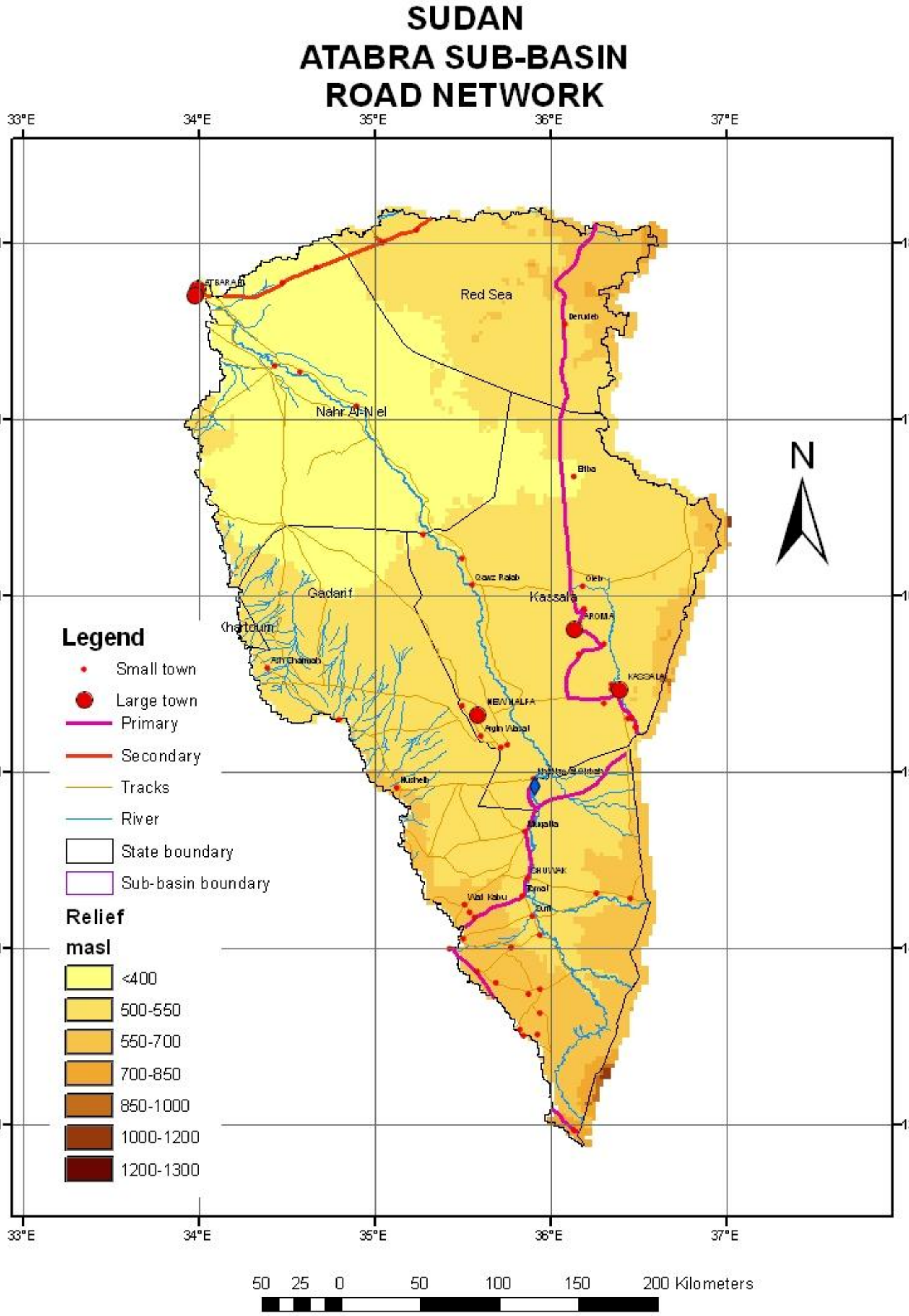
Within the Atbara Sub-basin there is one primary (asphalt) and four all-weather secondary roads:

(a) Primary Roads

Khartoum- Port Sudan
Atbara - -Haiya (under construction)

(b) Secondary Roads

Other roads are generally in poor condition and on the clay plains often impassable during the rains.



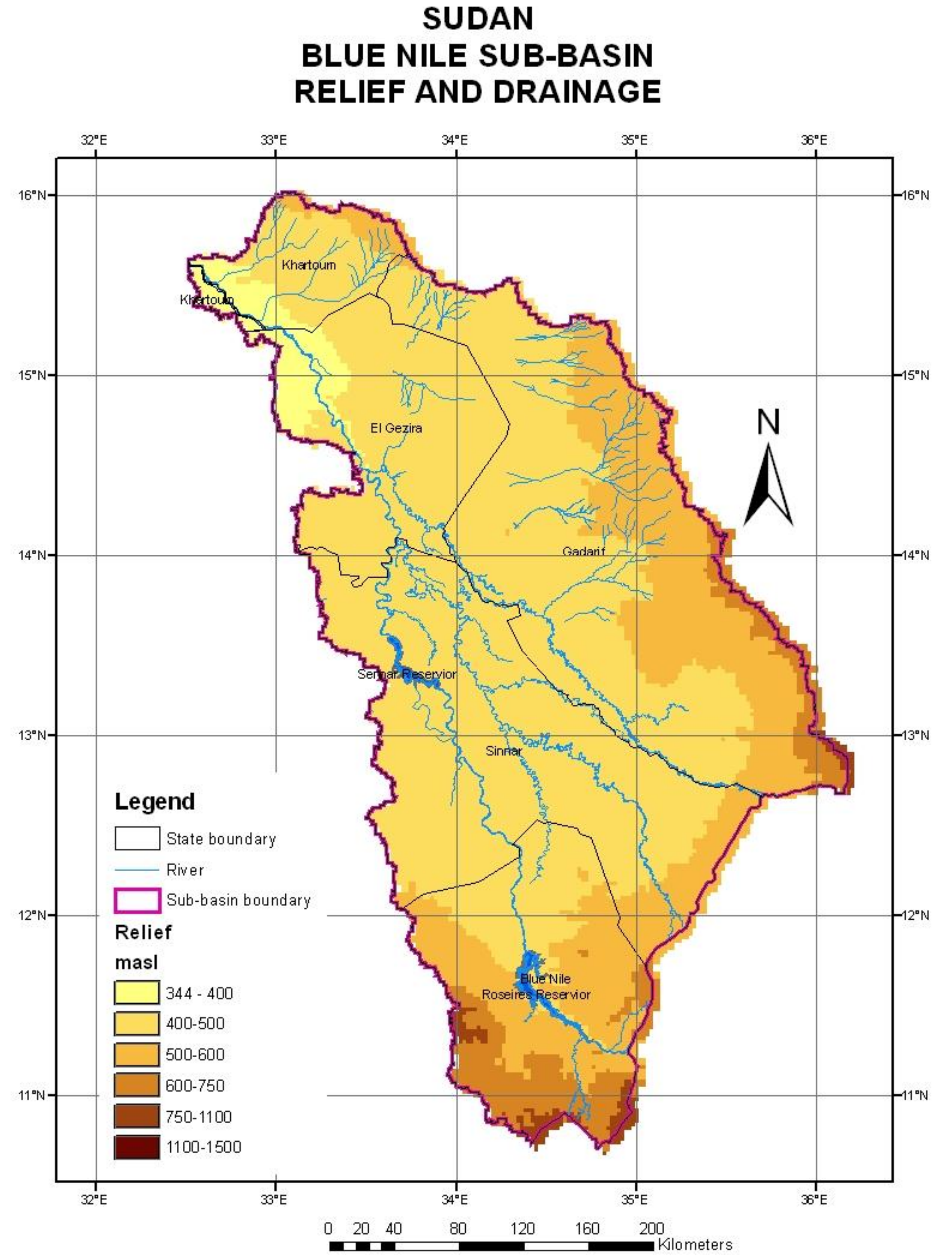
Map 23. Sudan – Atbara Sub-Basin: Road Network

Source: Afriroads

6. BLUE NILE SUB-BASIN – BIOPHYSICAL AND SOCIO-ECONOMIC SITUATION

6.1 Biophysical Characteristics

6.1.1 Location and Physiography (Map 24)



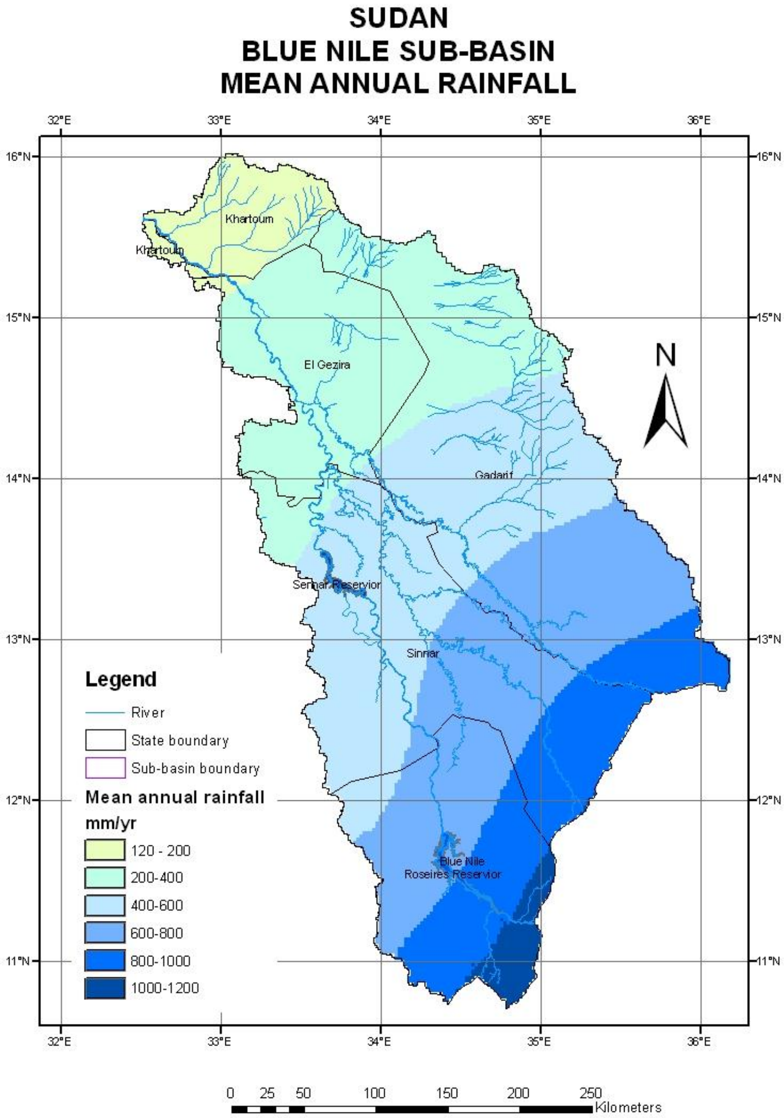
Map 24. Sudan – Blue Nile Sub-basin: Relief and Drainage.
Source: Shuttle Radar Terrain Mission (SRTM 90) digital terrain model.

As the Blue Nile enters the Sudan from Ethiopia it is confined in an incised channel. Before reaching the Roseires dam it flows onto wide area of colluvial and alluvial deposits. The basin comprises a very shallow valley between two interfluves of very low relief, the northern interfluve being of higher relief than that to the south.

In addition to the Blue Nile the Dinder and the Rahad rivers flow out of Ethiopia and join the Blue Nile below Sennar. A number of intermittent khories flow off the northern interfluve.

6.1.2 Climate

(i) Rainfall



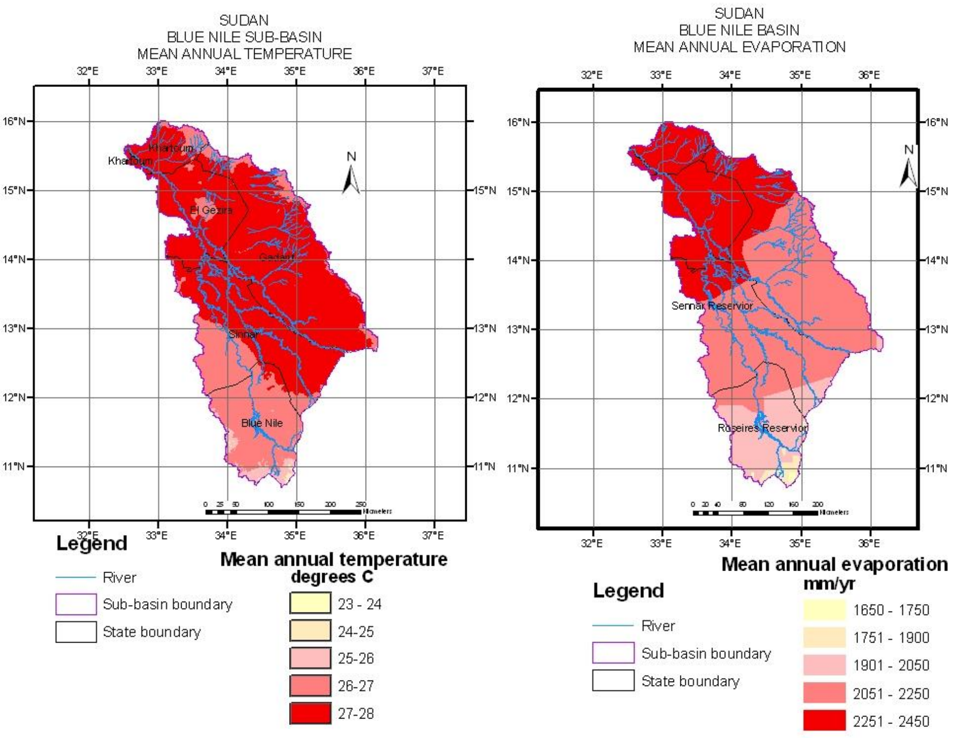
Map 25. Sudan – Blue Nile Sub-basin: Mean Annual Rainfall (mm/yr)
Source: ENTRO GIS Database

Rainfall in the Blue Nile Sub-basin exhibits a greater range than the Atbara or Main Nile Sub-basins, ranging from 120 mm at Khartoum to over 1,000 mm/yr at the border with Ethiopia. The isohyets trend more strongly northeast-southwest than in the Atbara basin. The rainfall coefficient of variability reduces from 80 percent in the north to 30 percent in the south.

(iii) Temperature and Evaporation

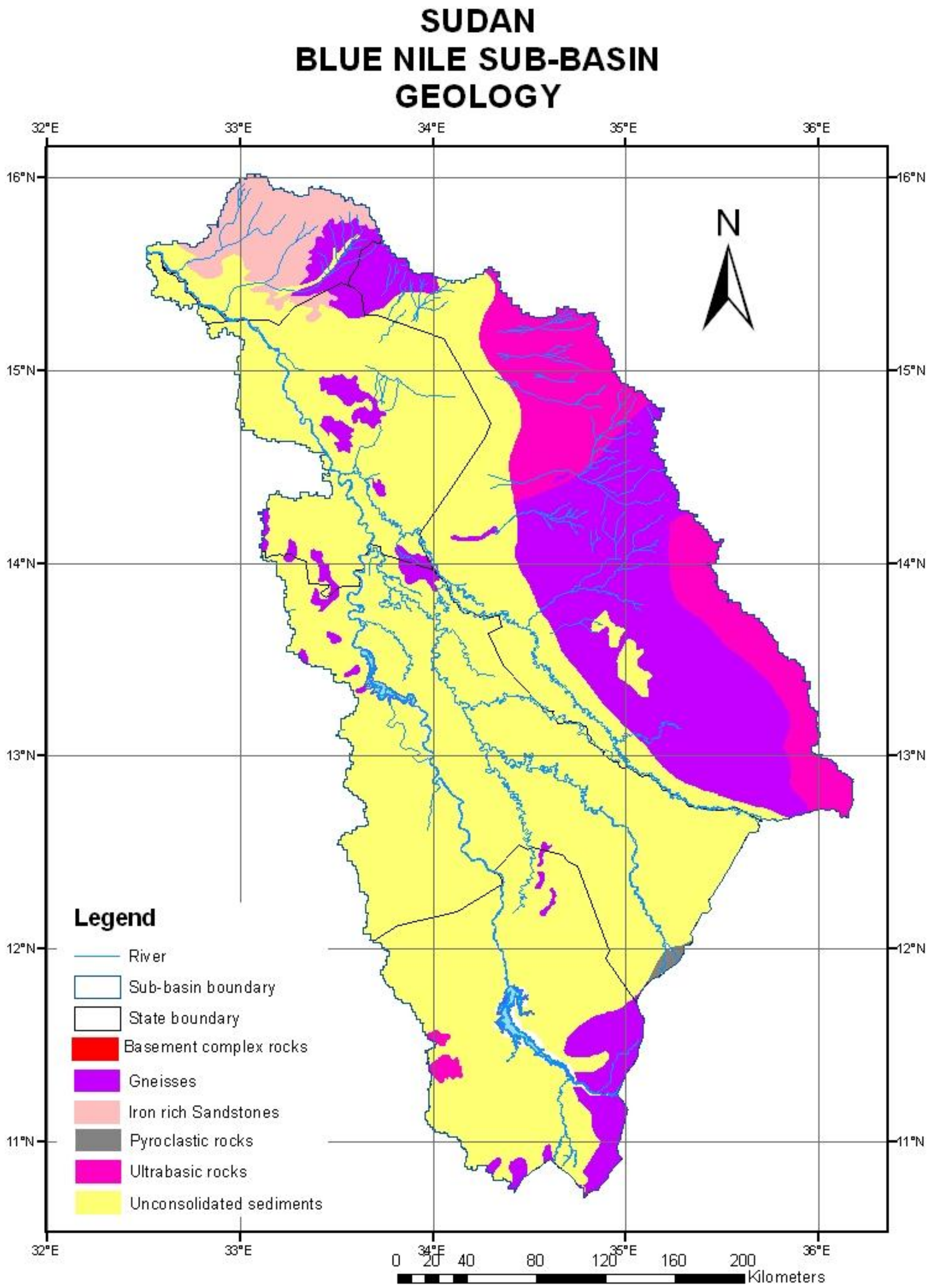
Daily minimum and maximum temperatures in January are 14°C and 33°C and those in May are 24° and 44°C respectively. The mean annual temperature over the northern two-thirds of the Sub-basin is 28°C falling to 25°C at the border with Ethiopia.

Evaporation follows more the rainfall pattern (in reverse) decreasing from northwest to southeast from 2,450 mm per annum at Khartoum to 1,650 mm per annum at the border with Ethiopia.



Map 26. Sudan - Blue Nile Sub-basin: Mean Annual temperature and Evaporation (mm/yr)
Source: ENTRO GIS Database

6.1.3 Geology

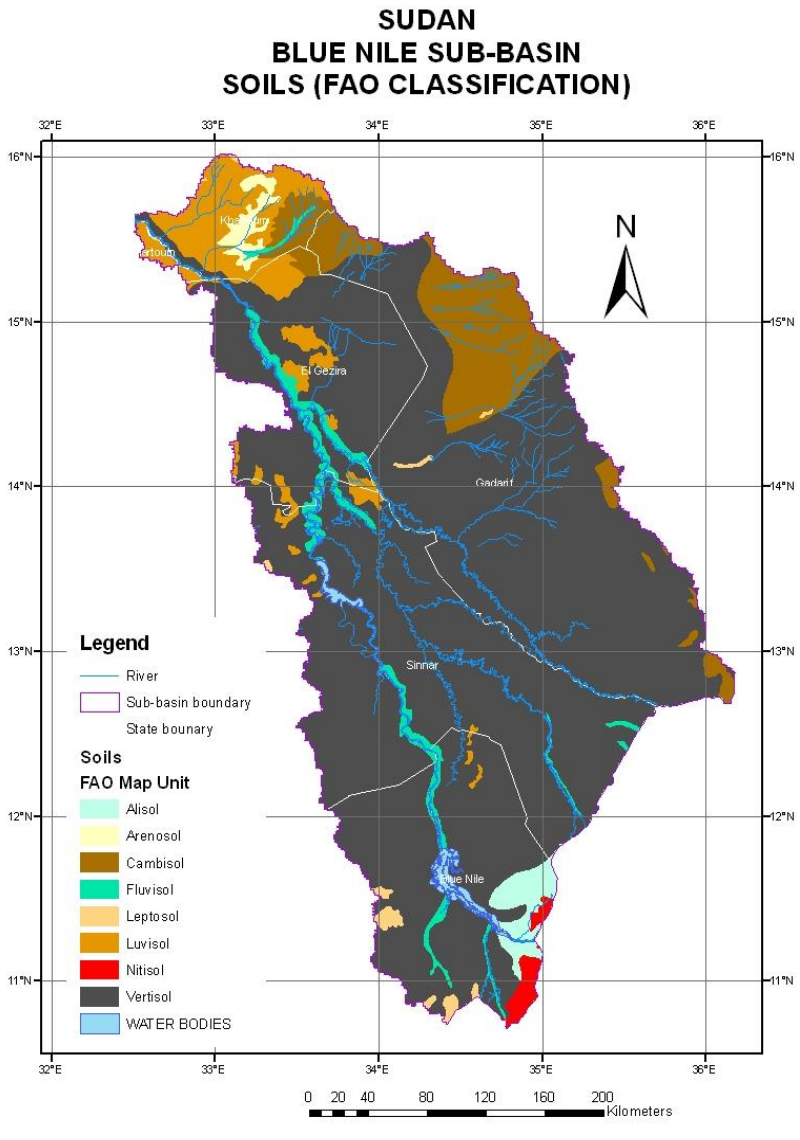


Map 27. Sudan – Blue Nile Sub-basin: Geology.
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

The Blue Nile Sub-basin is mainly underlain by the Gezira Quaternary and Recent alluvial sediments carried by the Blue Nile, which rest unconformeably on the Nubian Sandstones (Ismail Elboushi & Yassin Salam, 1983) There are three main members: Upper Clay, Lower Sandy and the Mungata sandy Clay.

The Nubian Sandstones outcrop in the north near Khartoum where it consists of conglomerates, sandstones and mudstones. The watershed between the Blue Nile and the Atbara to the north is underlain by Basement Complex gneisses, schists and granites. Mixed in these rocks are Greenschists, a meta-volcanic of basaltic origin.

6.1.5 Soils



Map 28. Sudan – Blue Nile Sub-basin: Dominant Soil Types (FAO Classification).
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

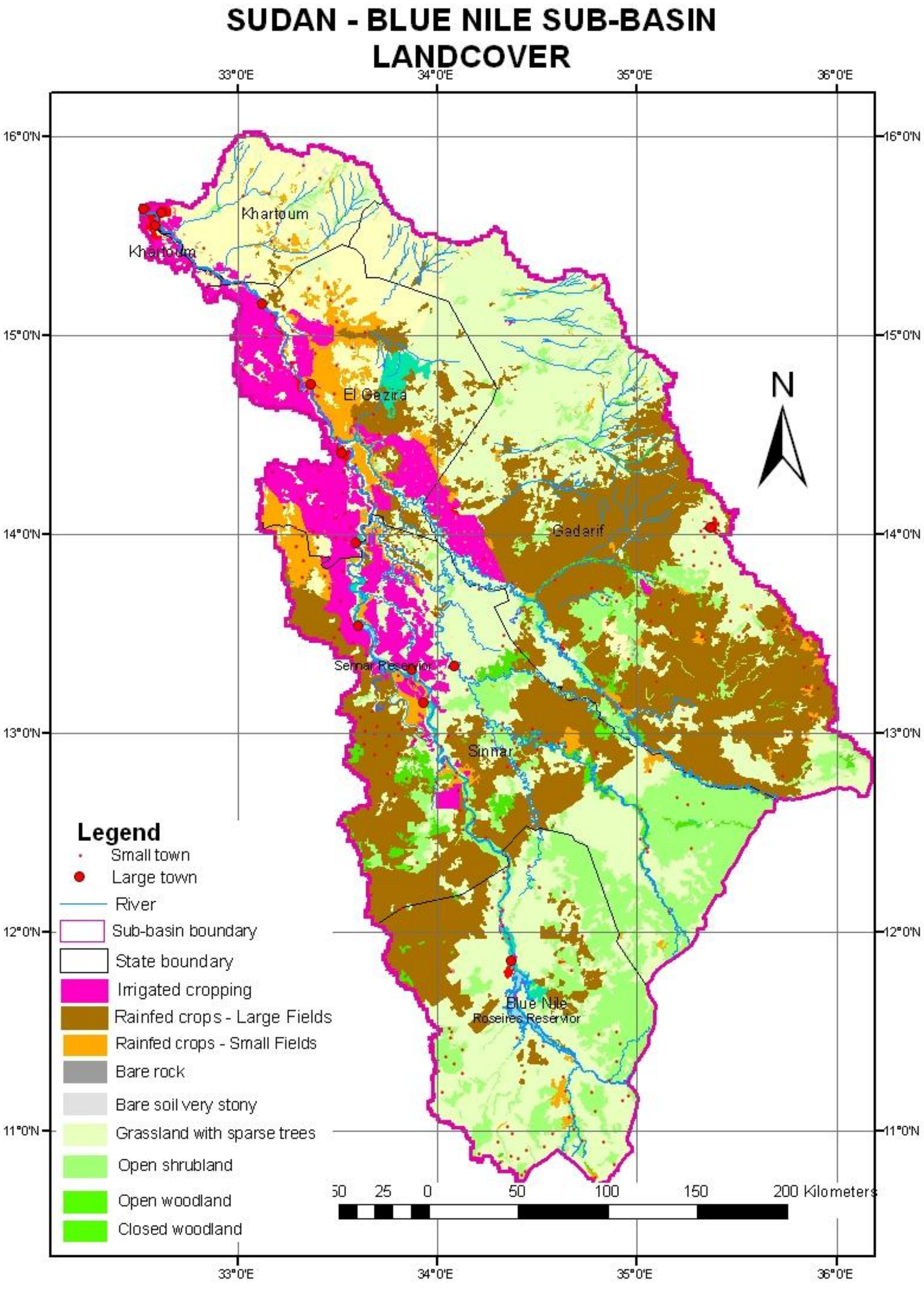
Vertisols occupy most of the Blue Nile Sub-basin. They are very deep with a relatively low watertable, comprising clay to sandy clay textures for 3 to 4 meters or more and underlain by sand or gravel. They are alkaline, very poorly drained and difficult to work when wet. Whilst some of these soils have been irrigated for 70 years or more and there is no evidence of salts rising or accumulating (Gun, 1983). Although apparently uniform they exhibit subtle differences in colour and self-mulching properties of the surface horizons. Surface colours are dark grey-brown except in the long shallow, closed depressions where dark-grey colours are associated with seasonal waterlogging. Mean sodium and salt contents are 12 percent and 0.14 percent.

To the north of the Butana Plains are Cambisols often with vertic characteristics. These are of lower fertility than Vertisols but slightly better drained and thus easier to work. In the northeast on the hills and ridges of the Basement Complex rocks are shallow, stony and light textured Leptosols and Phaeozems of low fertility. These soils are highly erodible. In the northwest Arenosols are derived from unconsolidated sediments and textures are very sandy. Soils are deep but excessively well drained. These soils are extremely susceptible to wind erosions.

6.1.6 Landcover and Vegetation

Of all the Sub-basins, the Blue Nile Sub-basin has experienced the greatest removal of the original vegetation, first from the large scale development of irrigation, and latterly from the large expansion of semi-mechanized farms.

The patterns of natural vegetation closely follow those of mean annual rainfall, although locally edaphic conditions can provide a stronger influence. However, the biotic factors (grazing, cutting, burning and cultivation) are now of almost equal importance to the physical environment in determining the exact composition of vegetation communities.



Map 29. Sudan – Blue Nile Sub-basin: Dominant Land Cover
Source: Sudan FAO Africover, 2003

(i) Acacia Thornland alternating with Grassland

Between the 360 mm and 570 mm isohyets on the heavy clays 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 is 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.

(ii) Acacia seyal-Balanites Savanna

Above 570 mm to the border with Ethiopia 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* becomes increasing prevalent because it is fire resistant, does not produce good charcoal and is hard to cut.

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.

(iii) Riverine Woodland

Pure stands of riverine woodland – “*sunt*” – are increasingly under pressure. The first trees to colonize a newly formed river bank are *Salix subserrata* and *Tamarix nilotica*. As the bank builds up xerophytic species such as *Ziziphus spina-christi* become established. On the lower terrace *A. nilotica* establishes itself, with *A. seyal* on the higher ground.

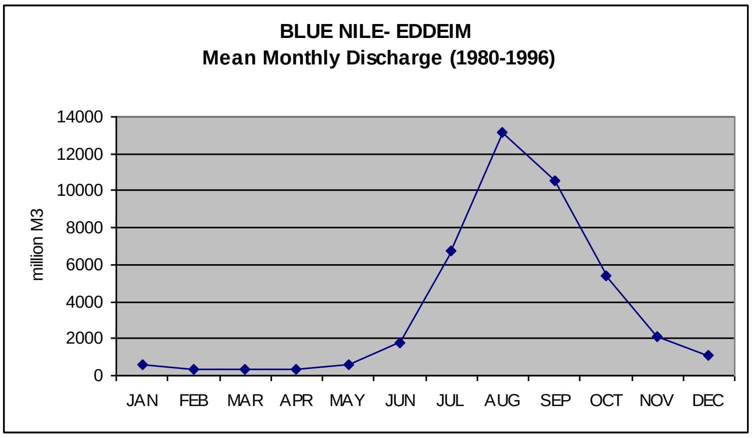
6.1.6 Water resources

(i) Surface Water

The Blue Nile and its two tributaries the Dinder and Rahad rise in the Ethiopian Highlands. The Blue Nile drops 120m between the Ethiopian border and Khartoum. The annual average outflow from Lake Tana is 4 km3, less than 10 percent of the flow at Roseires. There is little or no flow from the Rahad and Dinder during the dry season. Mean (1920-2000) annual discharge at the border is approximately 50 billion m3, with an addition 4 billion m3 coming from the Rahad and Dinder.

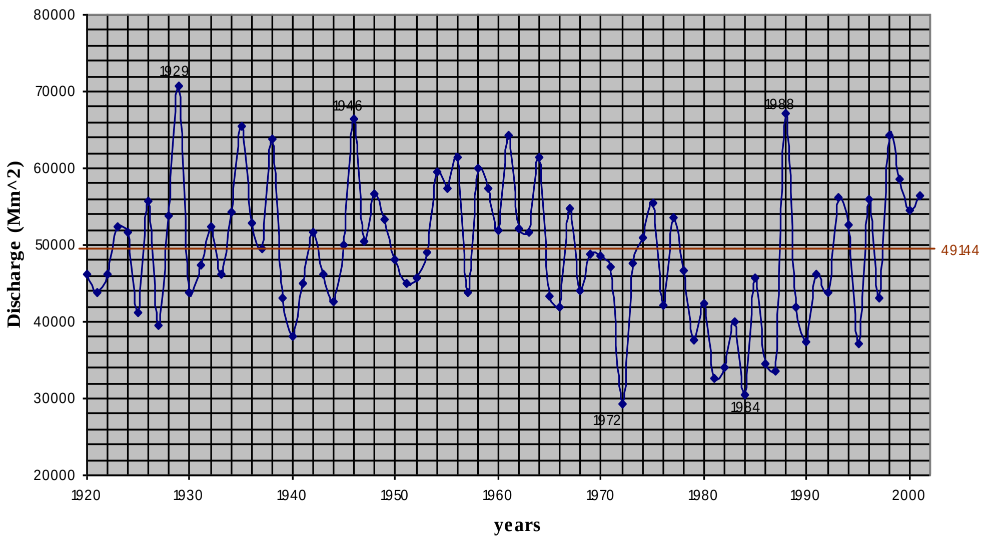
There are considerable seasonal variations in flow. The monthly low flow of the Blue Nile is 302 million m3/month in February and the peak flow 1,3151 million m3/month in August. In contrast to the White Nile the flow is highly seasonal being concentrated between July and October (figure 5).

Figure 5. Sudan – Blue Nile Sub-basin: Mean monthly discharge of Blue Nile at Eddeim – 1980-1996 (million m3)



Similarly, there are considerable variations in annual discharge. The annual discharge for the Blue Nile from 1920 to 2001 is shown in figure 6.

Figure 6. Sudan – Blue Nile Sub-basin: Blue Nile Hydrograph 1920-2001 (million M3)



Between 1920–1960 the annual discharge appeared to have oscillated around the mean. From 1960 to 1984 there appears to have been a general decrease in discharge until 1985. Thereafter discharges have gradually increased.

(ii) Groundwater Resources

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, the upper part of the Lower Gezira formation in the area between the Blue and White Nile, and the upper part of the Lower Omdurman Formation to the north of the Blue 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.

6.2 Socio-economic Characteristics

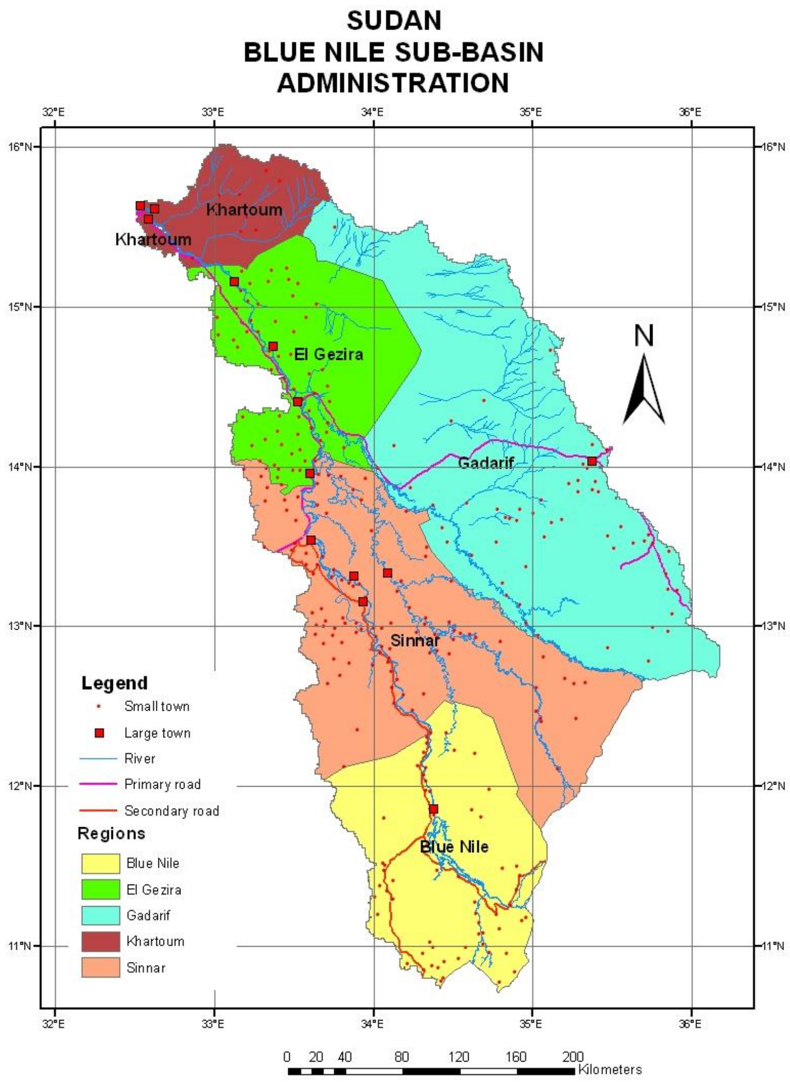
6.2.1 Administration

The Blue Sub-basin encompasses 5 Administrative Regions as shown in table 35.

Table 35. Blue Nile Sub-basin: Administrative States and their areas (km2)

Region	Area (km2)	**% of Sub-basin**
Blue Nile	20,208	**17%**
El Gezira	16,420	**14%**
Khartoum	7,111	**6%**
Gadaref	41,136	**35%**
Sennar	31,698	**27%**
SUB-BASIN	**116,573**	

The main Regions in terms of area are Blue Nile, El Gezira, Gaderif, Sennar and Khartoum (Map 30).



Map 30. Sudan – Blue Nile Sub-basin: Administrative Regions
Source: ENTRO GIS Database

6.2.2 Population

(i) Population Numbers

The population of the States contained mainly within the Blue Nile Sub-Basin is as follows:

Gederef	1,151,050
Khartoum State	2,105,800
Gezira	1,919,580
Sennar	1,091,640
Blue Nile State	338,291
Total	**6,606,361**

Sources: UN Population Fund & Sudan Central Bureau of Statistics. (2002)

(ii) Population Distribution (Map 31)

The main population concentrated is along the west side of the Blue Nile from Khartoum to El Damson. This is related to the Gezira irrigation scheme and the towns along the main road that service the scheme. Smaller concentrations are seen along the Sennar to El Kaferif road, and up the Dinder Valley. The latter are related to the Rahad Irrigation Scheme.

6.2.3 Demographic and Livelihood Characteristics

(i) Demographic Characteristics

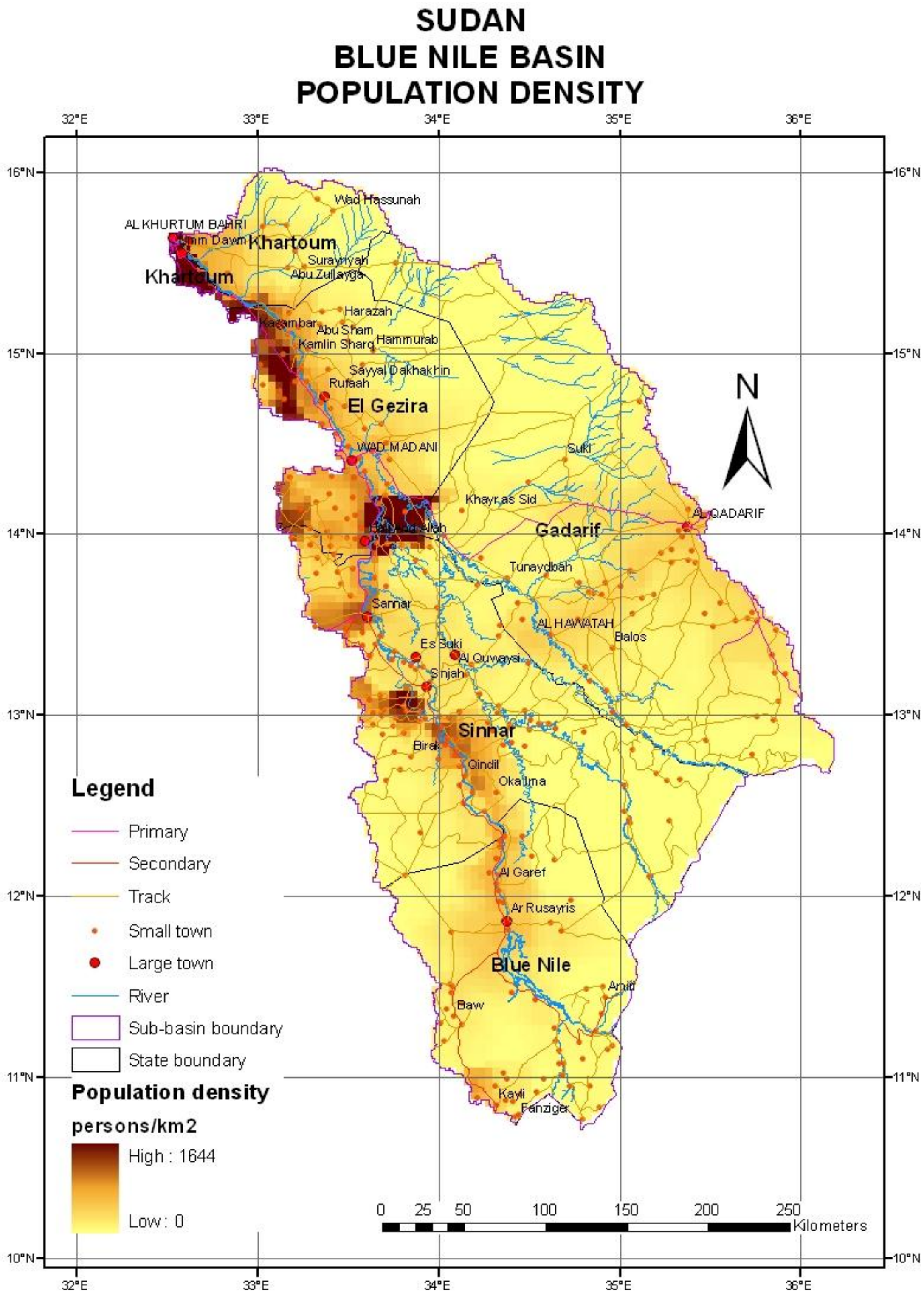
The demographic characteristics of States within the Blue Nile Sub-basin are similar and much closer to the average of the Northern States than the Main or Atbara Sub-basins. Khartoum is noticeable because of its lower birth, death and infant mortality rates and, of course its high urban percent.

Table 36. Blue Nile Sub-basin: Administrative States - Demographic Characteristics

State	Gth rate %	Urban %	% <15yrs	% >60yrs	Sex ratio M/F	Crude birth rate	Crude death rate	Infant mort. male*	**Infant mort. female***
Blue Nile	3.00	25.2	42.7	3.7	108.3	38.5	12.3	137	**122**
Gadaref	3.40	28.9	43.1	3.7	105.3	40.3	11.7	135	**122**
Khartoum	4.00	86.7	36.5	3.8	111.3	33.7	8.8	98	**85**
El Gezira	3.00	22.4	42.5	4.4	96.8	38.5	9.5	101	**76**
Sennar	2.60	28.3	44.5	4.0	98.8	39.9	10.9	121	**109**
NORTH SUDAN	**2.80**	**37.3**	**42.8**	**4.1**	**100.4**	**37.8**	**11.0**	**116**	**98**

* per 1000 live births

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



Map31. Sudan – Blue Nile Sub-basin: Population Density (persons/km2)

Sources: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL)

(ii) Literacy and Education

The literacy and primary school enrollment rates for the four States are shown in table 37.

Table 37. Blue Nile Sub-basin: Administrative States – Literacy and Primary School Enrollment Rates

State	Literacy >15yrs % Average	Literacy >15yrs % Male	Literacy > 15yrs % Female	Pop. 6-13yrs	Total Primary school enroll.	% enroll.
Blue Nile	31.3	41.8	20.4	143,305	48,914	34.1
Gaderif	55.6	72.9	38.4	311,547	142,313	45.7
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	64.5	40.0	267,649	146,090	54.6
NORTH SUDAN	**54.5**	**66.6**	**42.4**	**6,493,230**	**3,308,387**	**51.0**

Sources: UN Population Fund & Sudan Central Bureau of Statistics. (2002)

There are significant differences in literacy and primary School enrollment rates between Khartoum and El Gezira States and Blue Nile and Senner States. The former considerably above the Sudan national average. Gezira's literacy rate is significantly below the average for Northern Sudan. In all states female literacy rates are below those for males, although for Khartoum and El Gezira they are above the average for Northern Sudan.

(iii) Water and Sanitation

The percent population with access to drinking water and sanitation facilities are shown in table 38.

Table 38. Atbara Sub-basin: Administrative States – (a) Percent Population Access to Drinking Water, (b) Sanitation Facilities

(a) Drinking Water by Source

	Main source of water							
State	Piped into dwelling	Public tap	Deep Well/pump	Dug Well/ bucket	River/canal	Rainwater	Others	Missing
Blue Nile	12.3	2.1	9.3	2.1	33.2	27.9	13	0
Gaderif	12.6	18.8	27.7	13.9	13.8	9.4	3.6	0.2
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
NORTH SUDAN	**50.8**	**4.3**	**15.8**	**9.8**	**12.8**	**--**	**6.4**	**0.1**

Sources: UN Population Fund & Sudan Central Bureau of Statistics. (2002)

(b) Sanitation facility by type

State	Flush to Sewage System	Flush to septic tank	Traditional pit latrine	Soak away pit	Others	Missing	No facilities
Blue Nile	--	3.5	56.0	3.2	0.4	0.8	36.0
Gaderif	--	5.0	31.7	3.1	0	0	60.1
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
NORTH SUDAN	**--**	**7.7**	**69.2**	**1.6**	**1.6**	**--**	**19.9**

Sources: UN Population Fund & Sudan Central Bureau of Statistics. (2002)

In terms of water supply Khartoum and El Gezira States are well above the Northern States' average for piped water, whilst Blue Nile State is particularly deficient. With respect to sanitation facilities Khartoum is well above the average and Gederef State well below.

6.2.4 Socio-cultural Aspects of the Population

A substantial proportion of the population in the Blue Nile Sub-basin live and work on the large irrigation schemes and semi-mechanized farms or in service and processing industries related to these developments. Many in the past followed pastoralist and agro-pastoralist livelihoods, but who for one reason or other lost their livestock and became sedentarized.

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 people with sheep, cattle and camels and are divided into two groups: the northern Badiya located on the Blue Nile (dry season) and who move north towards the Dinder River (wet season); and the southern Badiya who 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 have 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 Kenana are also Arab speaking pastoralists who move between the Blue Nile northwards beyond the Dinder River. They come into contact with the northern Badiya group of Rufa'a el-Hoi along the Blue Nile.
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 Baggara are an Arab speaking pastoral people from west of the White Nile who 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, their home area being west of the White Nile.

The Ingessana is a name given to the people living in the Ingessana Hills with a distinctive language and culture. They are predominantly agriculturalists cultivating the foothills. Cattle, goats and camels are socially and economically important. Livestock are kept in the hills during the wet season and move either south-eastwards to the Machar Marches and the Yabus, and to the east to the Blue Nile and the border with Ethiopia. They maintain a spirit of cooperation with the Rufa'a al-Hoi and many Ingessana work as herders for them. As well as the Ingessana there are a number of smaller groups who practice sedentary agriculture. These include the Berta, Gumuz and Burun, and along the Blue Nile many peoples from western and northern Sudan who arrived after the Mahdist rule.

6.3 Transport Infrastructure

Within the Blue Nile Sub-basin there is two primary (asphalt) and one all-weather secondary roads.

(a) Primary Roads

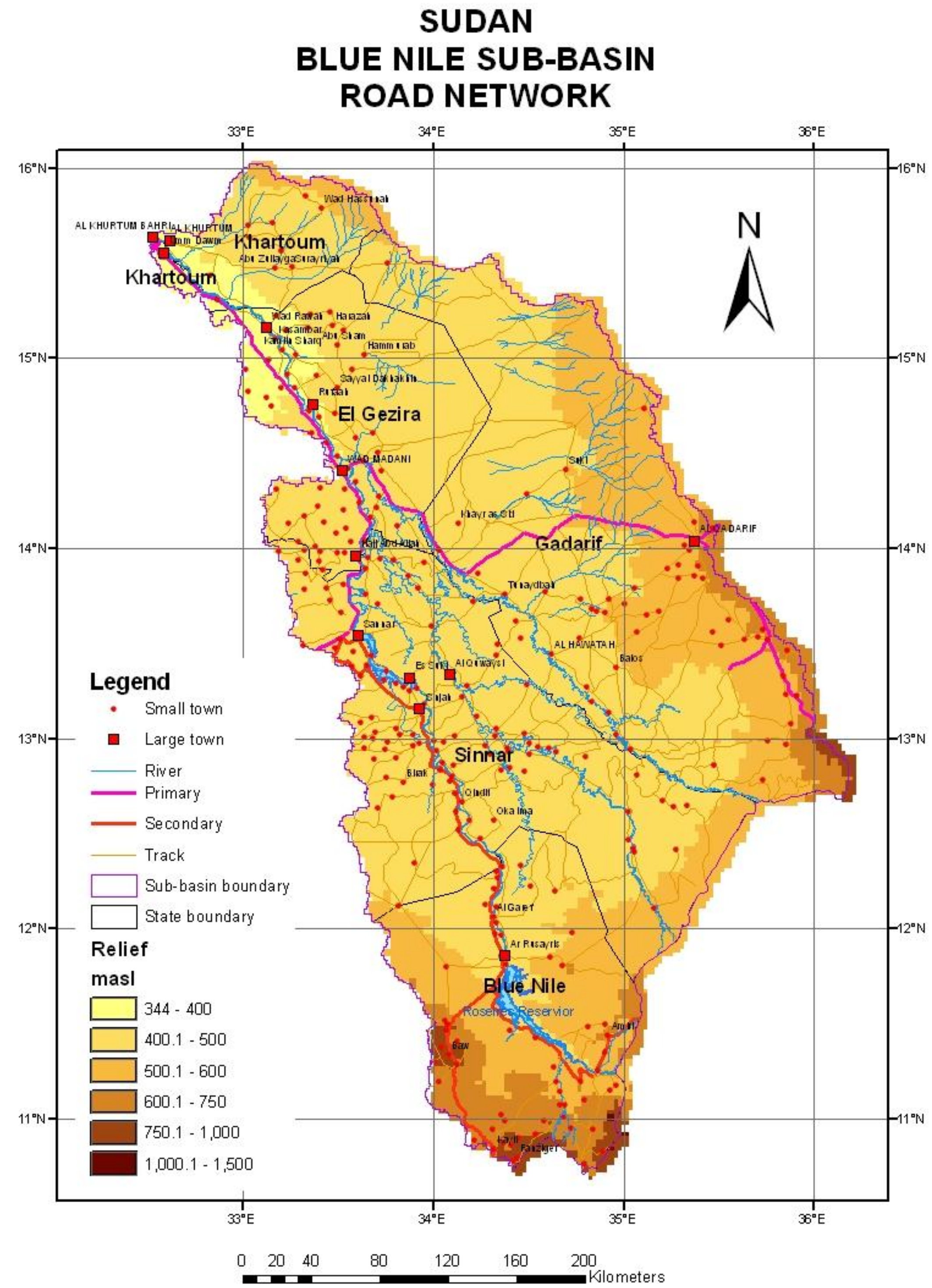
Khartoum- Wad Medani (187 kms) – El Gederif (187 kms)
Wad Medani - Sennar (50kms) – Damazin (278 kms)

(b) Secondary Roads

El Gederif – Metema (159 kms)

Other roads are generally in poor condition and on the clay plains often impassable during the rains.

There is one rail network: Khartoum – Sennar - Gederif

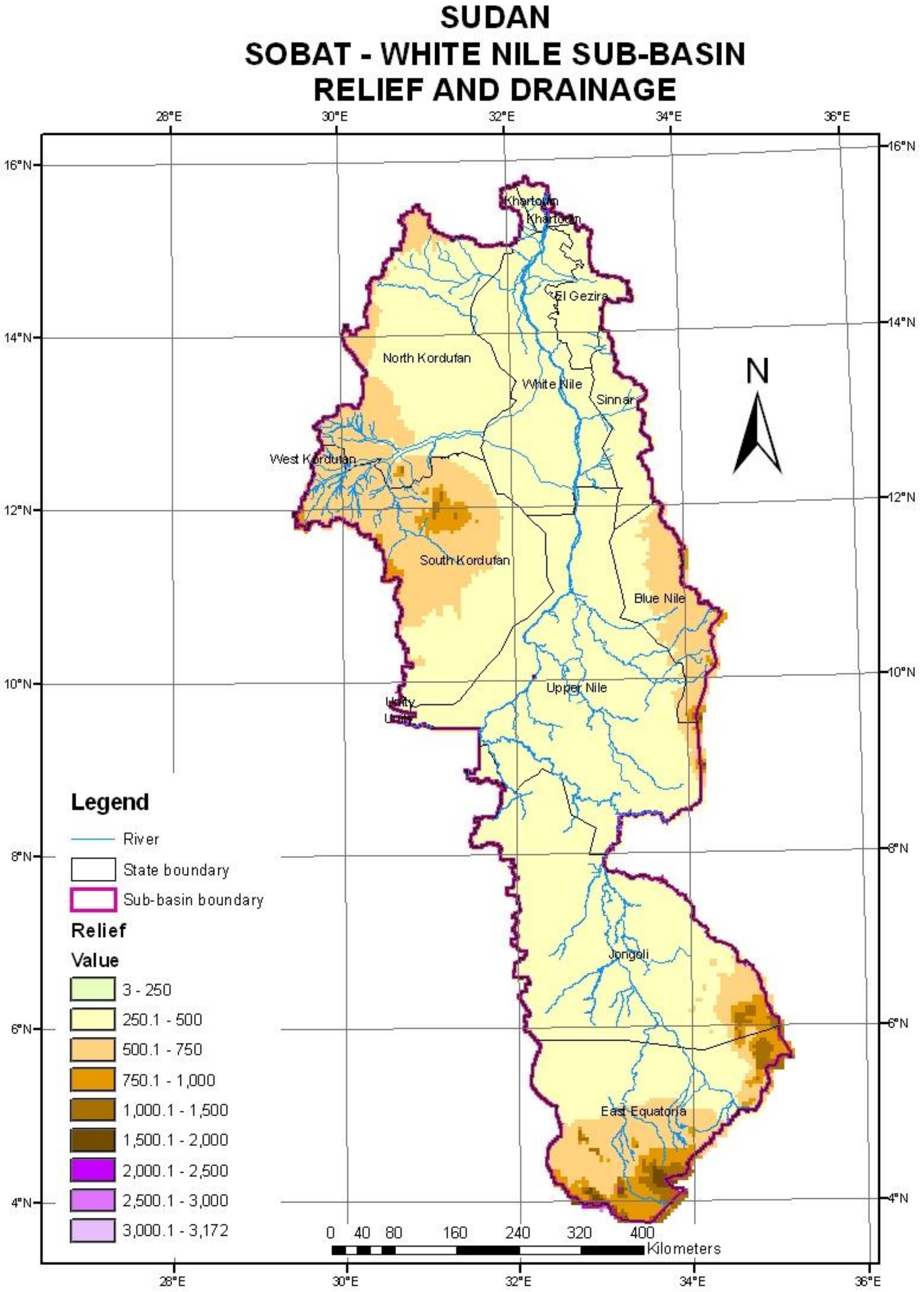


Map 32. **Sudan – Blue Nile Sub-basin: Road network**
Source: Afriroads

7. THE SOBAT-WHITE NILE SUB-BASIN – BIOPHYSICAL AND SOCIO-ECONOMIC SITUATION

7.1 Bio-Physical Characteristics

7.1.1 Location and Physiography



Map 33. Sudan – Sobat Sub-basin: Relief and Drainage

Source: Shuttle Radar Terrain Mission (SRTM 90) digital terrain model.

The Sobat-White Nile Sub-basin covers nearly 49 percent of the area of the eastern Nile Basin in Sudan, some 390,861 km^2. It stretches 1,350 kms from north to south.

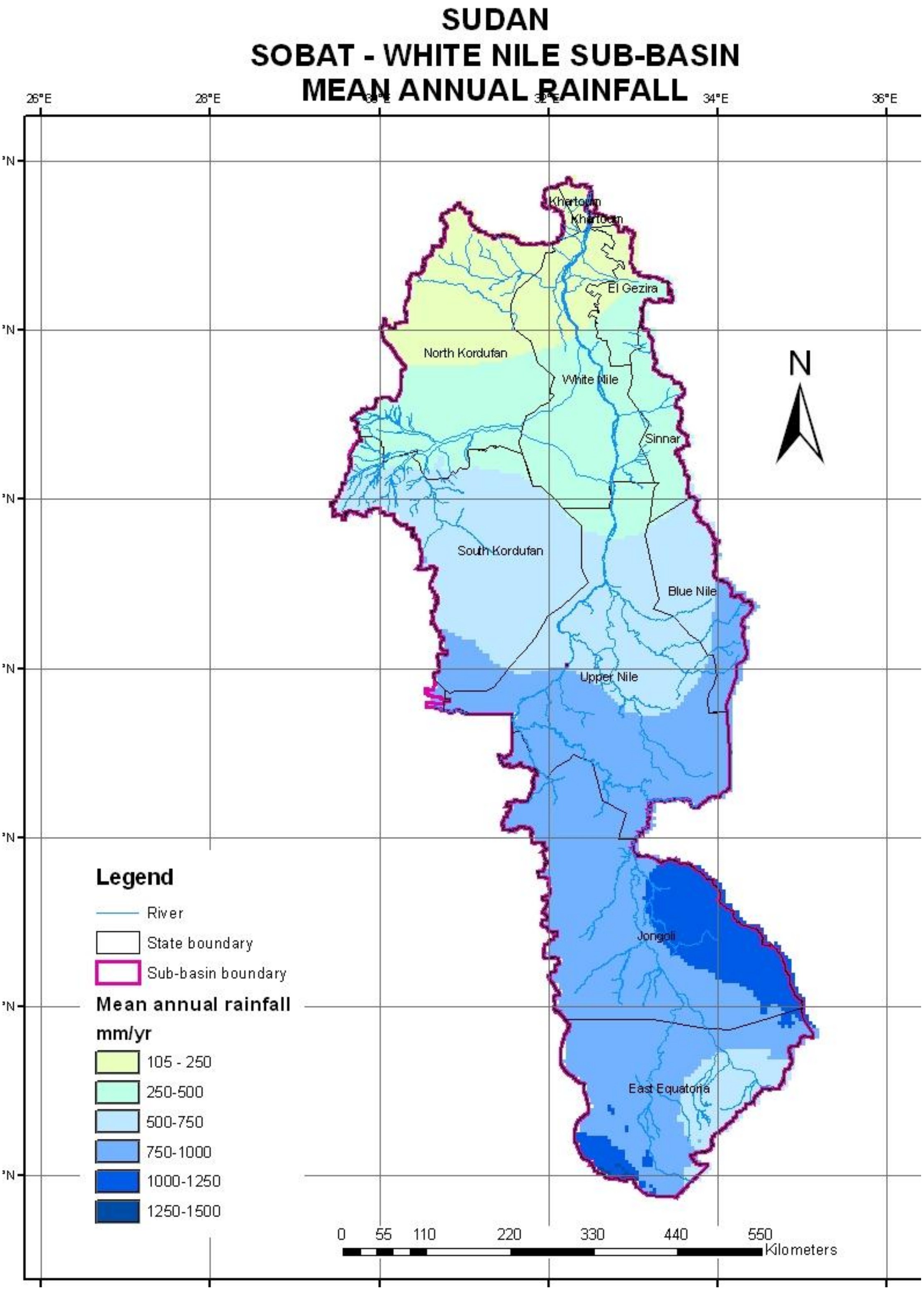
The main relief features in the south of the Pibor-Sobat Sub-basin are a series of steep hills and mountains of basement complex rocks stretching northeastwards along the Sudan-Uganda-Kenya border reaching up to 3,187 masl on Mount Kinyeti in the Imatong Mountains. Around these is a foothill zone of lower angle slopes that merge into very flat clay plains that stretch northwards to the Sobat River. These plains have slopes between 10 and 12 cms per km. The watershed between the Sobat and the Omo-Lake Turkana basin to the east is very low. In the recent geological past water flowed from Lake Turkana into the Nile basin.

On the western side of the southern part of White Nile Sub-basin are the Nuba Mountains rising to about 1,500masl. 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.

7.1.2 Climate

(i) Rainfall and Evaporation

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/yr. In the White Nile Sub-basin rainfall decreases northwards from 750 to 250 mm near the junction of the White and Blue Niles. However, everywhere rainfall exhibits both seasonal and year-on-year variability. Variability increases form south to north.

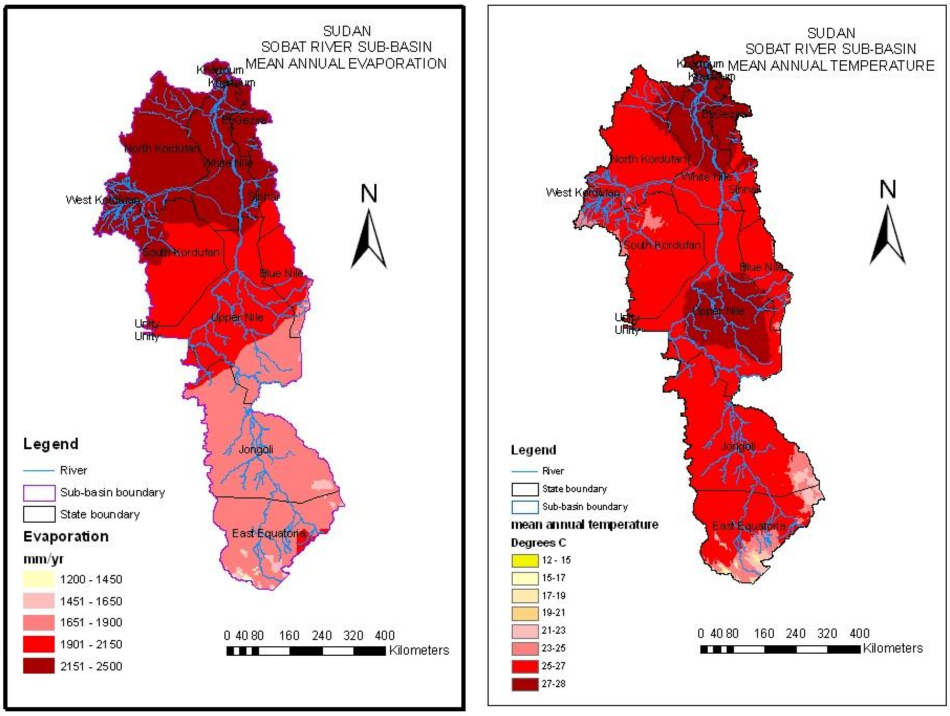


Map 34. Sudan – Sobat Sub-basin: Mean Annual rainfall (mm/yr)
Source: ENTRO GIS Database

(ii) Temperature and Evaporation

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.

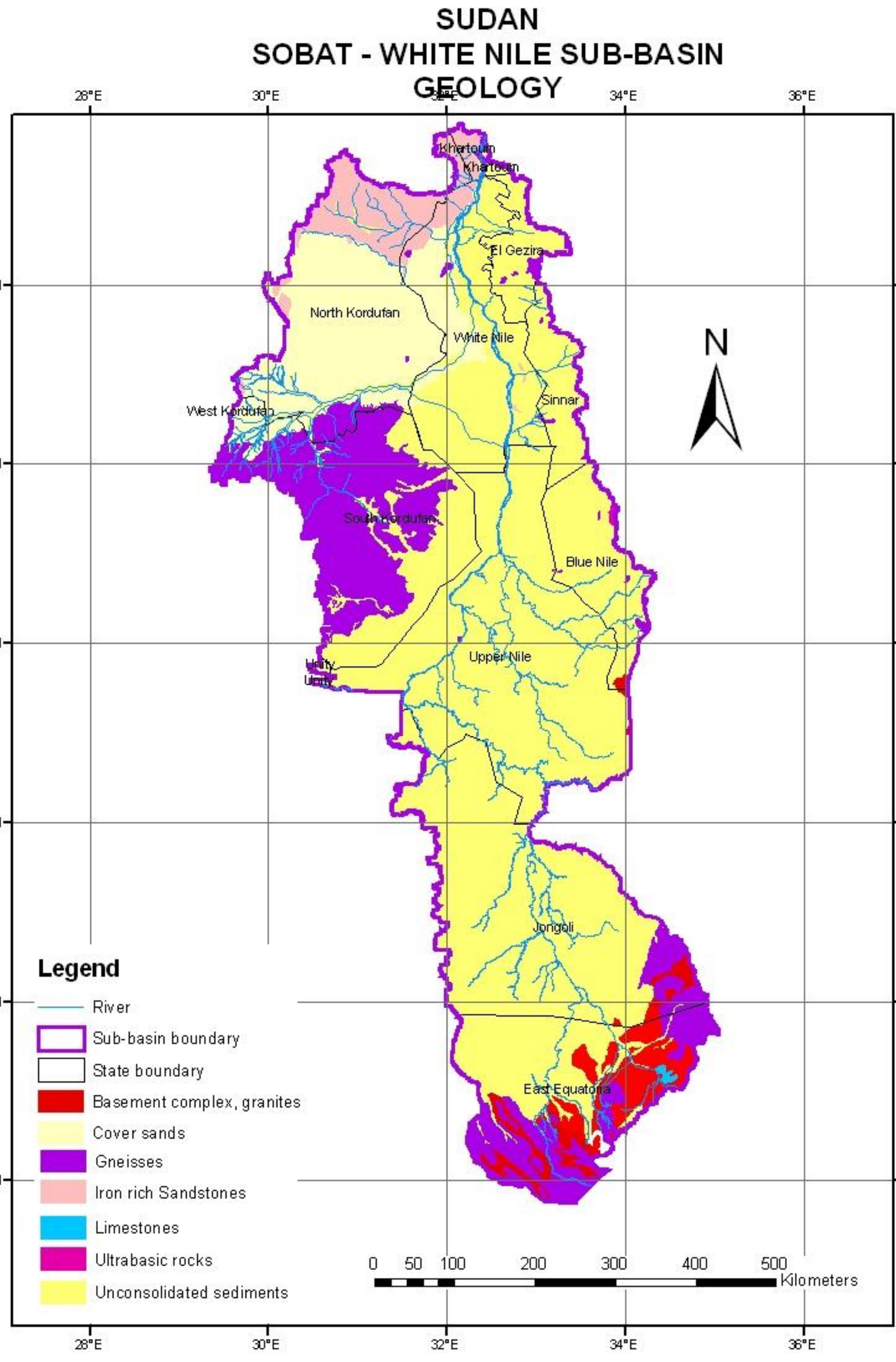
The patterns of mean annual evaporation follow closely those of temperature. Rates of 1450 mm/yr occur in the southern mountains and increase northwards to 2,500 mm/yr at the junction of the White and Blue Niles.



Map 35. Sudan – Sobat Sub-basin: Mean Annual Temperature (° C) and Evaporation (mm/yr)

Source: ENTRO GIS Database

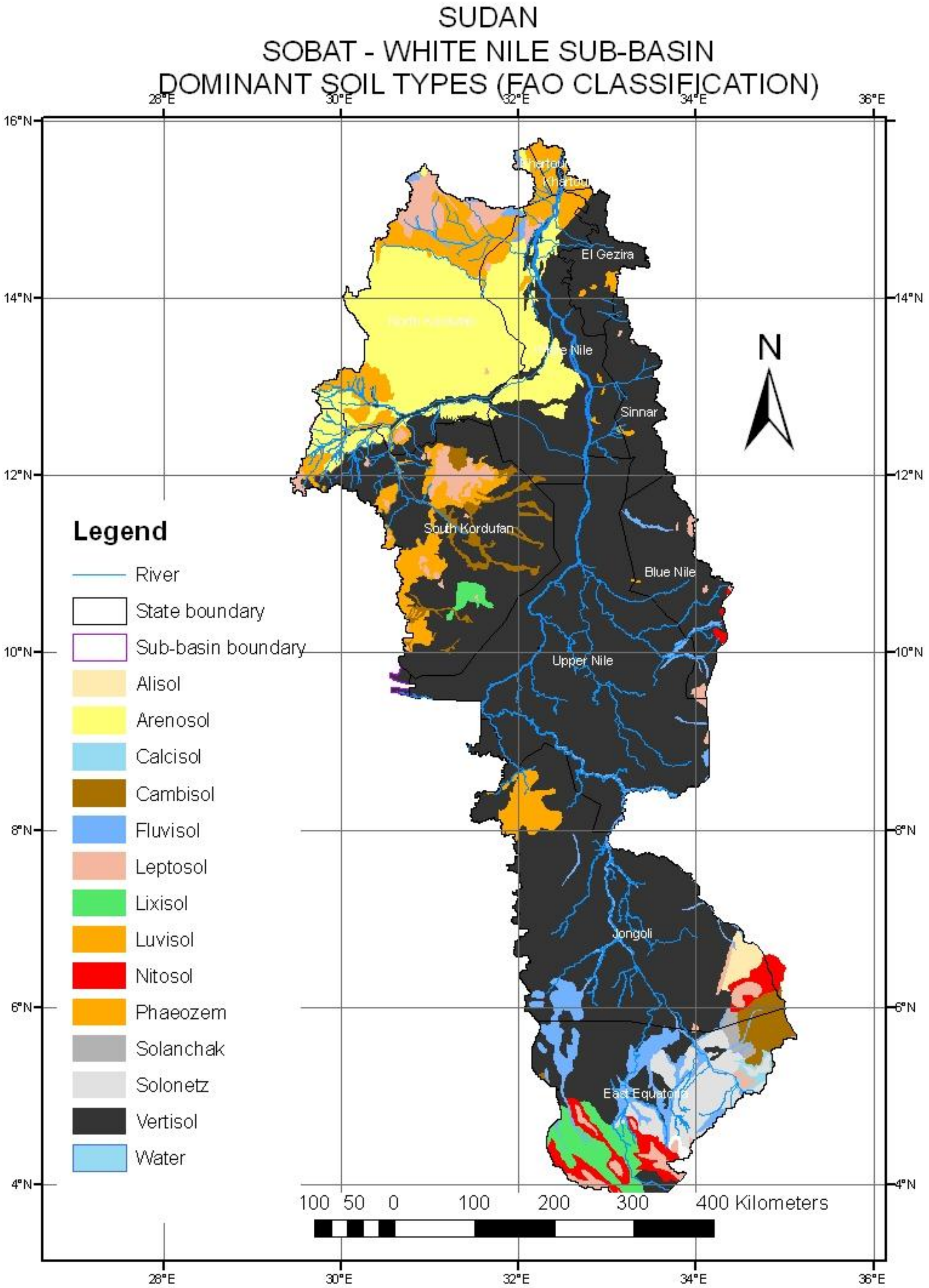
7.1.3 Geology



Map 36. Sudan – Sobat Sub-basin: Geology.
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

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. North of the gneisses is a large expanse of cover sands. Finally north of the cover sands the Nubian sandstones outcrop just to the south of Khartoum.

7.1.4 Soils



Map 37. Sudan – Sobat Sub-basin: Dominant Soil Types (FAO Classification)
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

The pattern of dominant soils follow to a large extent that of geology. The Unconsolidated Sediments are overlain by very extensive areas of Vertisols – deep black cracking clays. 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 in the southwest and Cambisols and Solonetz soils in the southeast.

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

7.1.5 Vegetation and Landcover

(i) Acacia Thornland alternating with Grassland on Clays

Between the 360 mm and 570mm 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.

(ii) *Acacia senegal* Savanna and *Combretum cordofanum* Savanna on Sands

Between the 360 mm and 570mm 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 (Mustafa Baasher, 1995). 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.

(iii) Acacia seyal-Balanites Savanna

Above 570mm to the border with Ethiopia 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.

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.

(iv) 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 et al., 1988).

(a) *Oryza longistaminata* Dominant Grassland:

The dominant species constitutes 80-90 percent of the standing crop. Oryza does not flower or reach maximum production unless it has been deeply flooded for several months. It yield 1 ton/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.

(b) *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*.

(v) Seasonally Rain-flooded Grasslands

Three types are recognized: (a) *Echinoochloa haploclada* grassland, (b) *Sporobolus pyramidalis* grassland, and (c) *Hyperhennia rufa* grassland.

(a) *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.

(b) *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.

(c) *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 percent 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.

(vi) Swamp vegetation

Three types of swamp vegetation are distinguished: (a) *Cyperus papyrus* swamp, (b) *Typha domingensis* swamp, and (c) *Vosia cuspidata* swamp.

(a) *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.

(b) *Typha domingensis* Swamps:

These are most extensive away from the river channels. It is most likely that 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

(c) *Vosia cuspidata* Swamps:

This vegetation is found next to flowing water and forms floating mats over the water. It is often associated with water hyacinth.

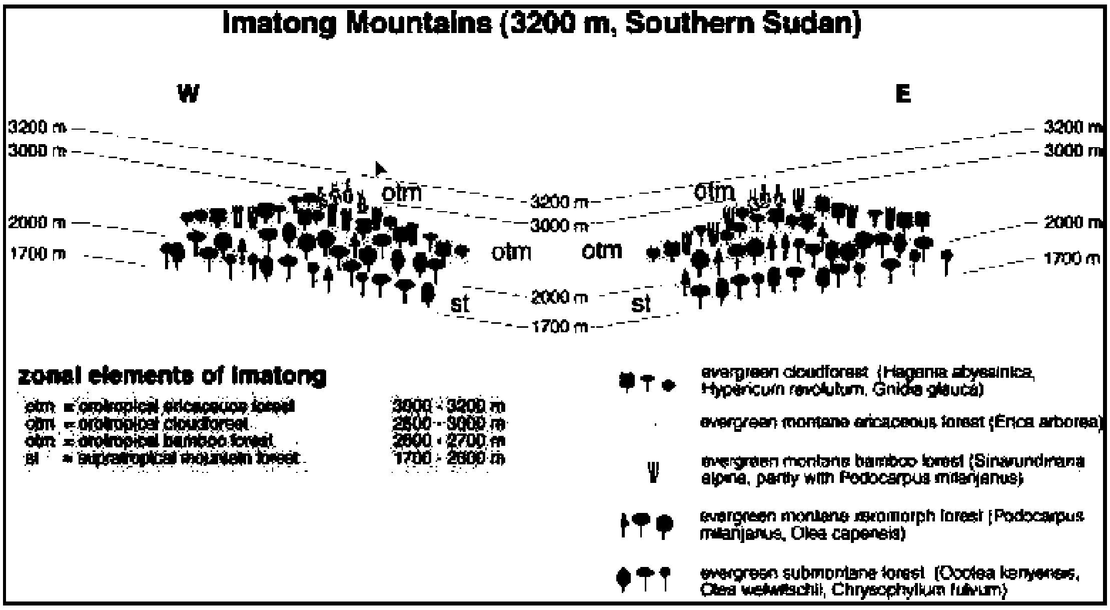
(vii) Montane Forest

This vegetation type is found on the mountain and hills of southern Eastern Equatoria State. In the Imatong and Dongotona Mountains and the Didinga Hills are some 88,000 ha of closed Montane forest[6], with some 46,174 ha within the Sobat-White Nile Sub-basin. The forest is distributed amongst the three mountain areas as follows:

Imatong	39,394 ha
Dongotona	2,139 ha
Didinga	4,641 ha

Given the very sharp climatic gradient the mountains are characterized by clear vegetation zonation (Bussmann, 2006). (figure10). The foot zone receives about 800 mm, whilst at 1,900 masl some 2,200 mm has been recorded.

Figure 7. Sudan – Sobat-White Nile Sub-basin. vegetation Zoning on the Imatong Mountains.



[6] Data from Africover Land cover map.

Three broad types have been described (FAO (2005).

Tropical rain forest is confined to a few small and scattered localities. 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 zenker*i, with *Holoptelea grandis* in Azza forest. A number of valuable timber trees are found, including *Khaya grandifoliola*, *Chlorophora excelsa, Entrandrophragma angolens*e and others.

The Montane vegetation of the Imatong and Dongotona ranges: the highest range reaches an altitude of 3,187masl. The lower slopes of these mountains, below about 1,500masl, have in wetter areas a vegetation similar to that of the derived woodland savanna, but with fewer species, while in drier areas they are similar to that of low rainfall woodland savanna, especially on rocky hill slopes, with an abundance of *Boswellia papyrifera* and *Terminalia brownii*. 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. Regrowth 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. Many species of herbs occur.

Montane vegetation of the Didinga range: The highest point, 2,963 masl, is Mount Lotuke at the south end. The summit carries a vegetation similar to that of the Imatong Mountains, with *Podocarpus milanjianus* mixed forest. Below this zone there is, however, a belt with a few relic trees of *Juniperus procera*, probably the remnants of a forest now destroyed by fire. At the north end of the Didinga mountains is a high plateau, in which trees of *Podocarpus milanjianus* occur in dense thickets of *Olea chrysophylla*, *Soutia myrtina* and other species. Dense forest of *Podocarpus* and *Albizia maranguensis* is confined to valleys.

(vii) Cultivated land

The five main cultivation types are (a) Rainfed Semi-mechanized farms, (b) Large Irrigated Farms, (c) Small irrigated farms, (d) Small rainfed traditional farms, and (e) Small Flood retreat Farms.

(a) Rainfed Semi-mechanized farms

There is 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.

(b) Large Irrigated Farms/Schemes

These include part of the Gezira-Managil scheme and the Kunana Sugar Estate and cover some 2.1 million feddans (0.9 million ha).

(c) Small Irrigated Farms

These are generally small pump schemes along the White Nile and cover some 54,409 feddans (22.852 ha).

(d) Rainfed Small farms

These include both sedentary and shifting cultivation farms where the latter can be distinguished on the satellite image. They cover some 0.48 million feddans (0.20 million ha).

(e) Small Flood Retreat Farms

These small farms are found along the White Nile and cover some 110.119 feddans (46,250 ha).

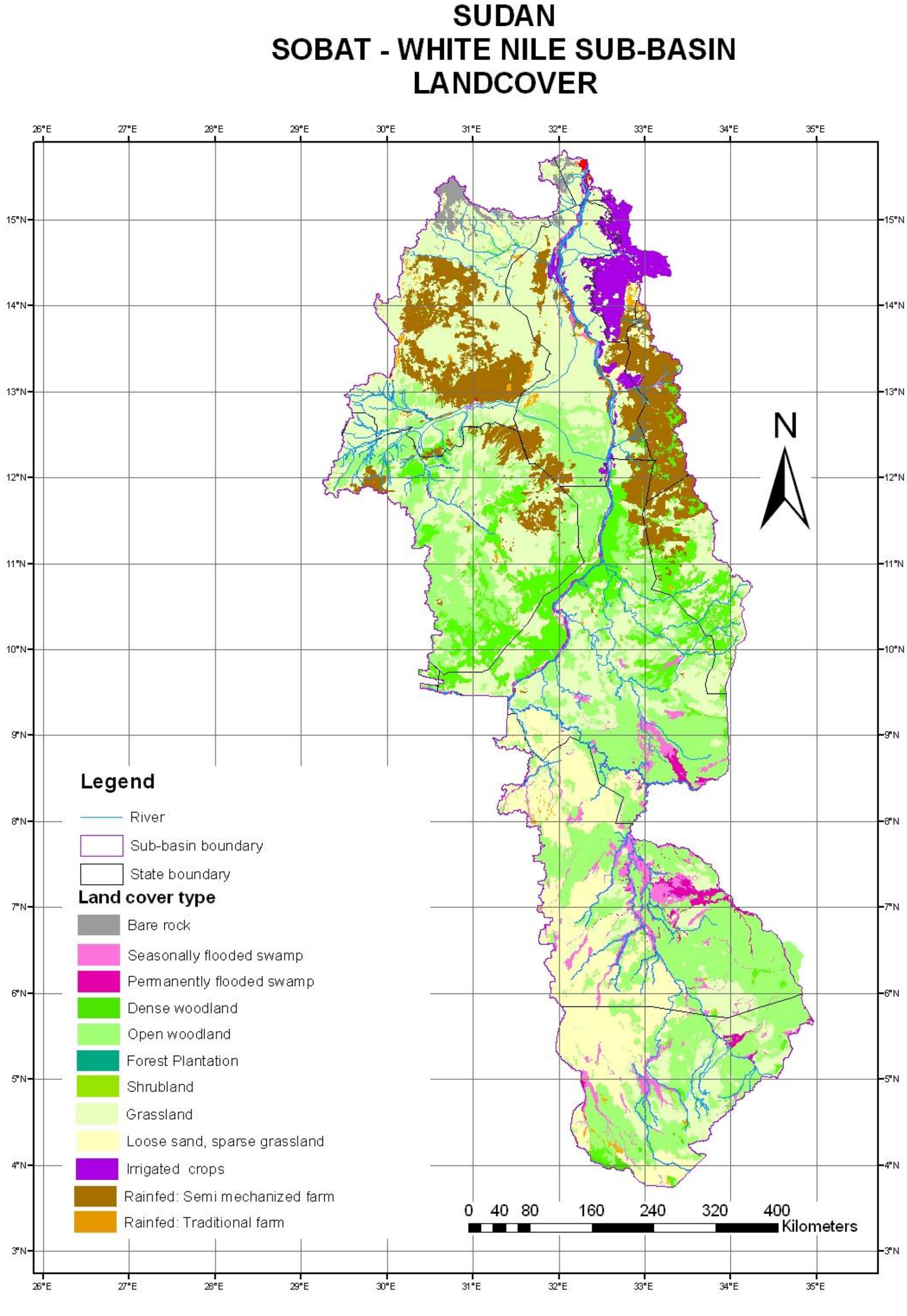
(vii) Summary of land cover Statistics

A summary of the area and percentage of total area of the major land cover types is presented in table 39.

Table 39. Sudan – Sobat-White Nile Sub-basin: Area (feddans and hectares) and percent of Total Area of the Main Landcover Types

Landcover Type	Area (feddans)	Area (ha)	Area (%)
Grassland	31,473,693	13,218,951	33.8%
Open shrubland	27,658,805	11,616,698	29.7%
Open woodland	16,447,105	6,907,784	17.7%
Rainfed: large scale	9,092,685	3,818,928	9.8%
Seasonal swamp	2,987,676	1,254,824	3.2%
Irrigated: Large scale	2,147,283	901,859	2.3%
Permanent swamp	1,280,738	537,910	1.4%
Bare soil, sand	761,738	319,930	0.8%
Rainfed: Small scale	483,982	203,273	0.5%
Water	215,484	90,503	0.2%
Settlement, Built-up	149,661	62,858	0.2%
Dense woodland	118,145	49,621	0.1%
Cropping: Flood retreat	110,119	46,250	0.1%
Rock	63,956	26,862	0.1%
Irrigated: Small scale	54,409	22,852	0.1%
Plantation	12,143	5,100	0.0%
Dense shrubland	4,421	1,857	0.0%
TOTAL	**93,062,043**	**39,086,058**	

Nearly 80 percent of the basin is covered by grassland or open woodland and shrubland. Permanent and seasonal swamps cover a significant 4.3 million feddans (1.8 million ha) or 4.6 percent of the total area.



Map 38. Sudan – Sobat Sub-basin: Dominant Landcover Types.
Source: Sudan FAO Africover, 2003

7.1.6 Water resources

(i) Overview

The Sobat and White Nile Sub-basins are in fact separate basins. The White Nile basin covers some 174,968 km2 and that of the Sobat (including the Machar Marshes) some 215,892 km2.

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.

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 Afdar.

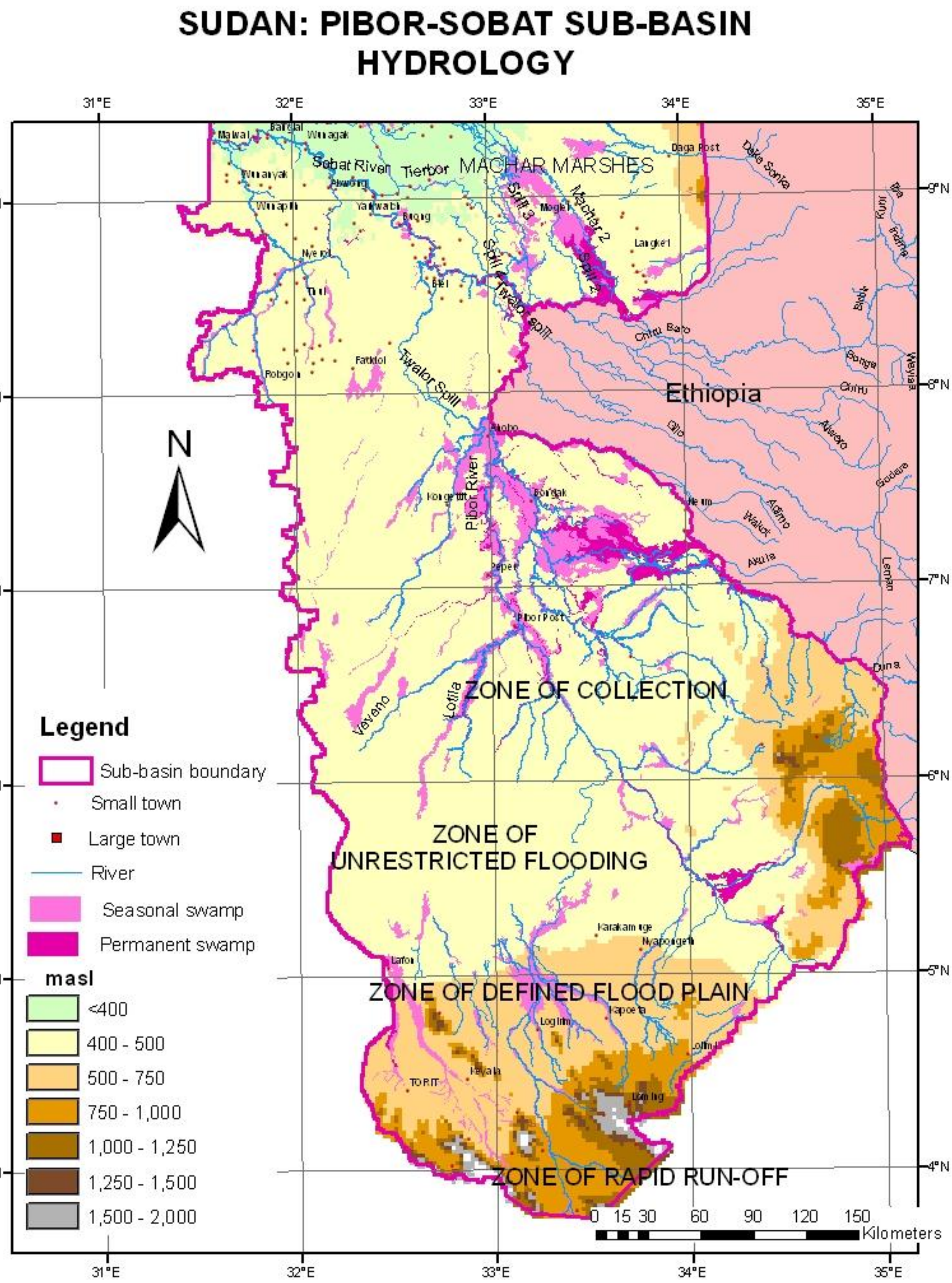
(ii) The Pibor-Baro-Sobat System

The hydrology of the Pibor-Baro-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.[7]

(a) 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 stream debouch 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 gradients rapidly decrease and coarse sediment is deposited forming well defined valley floodplains.

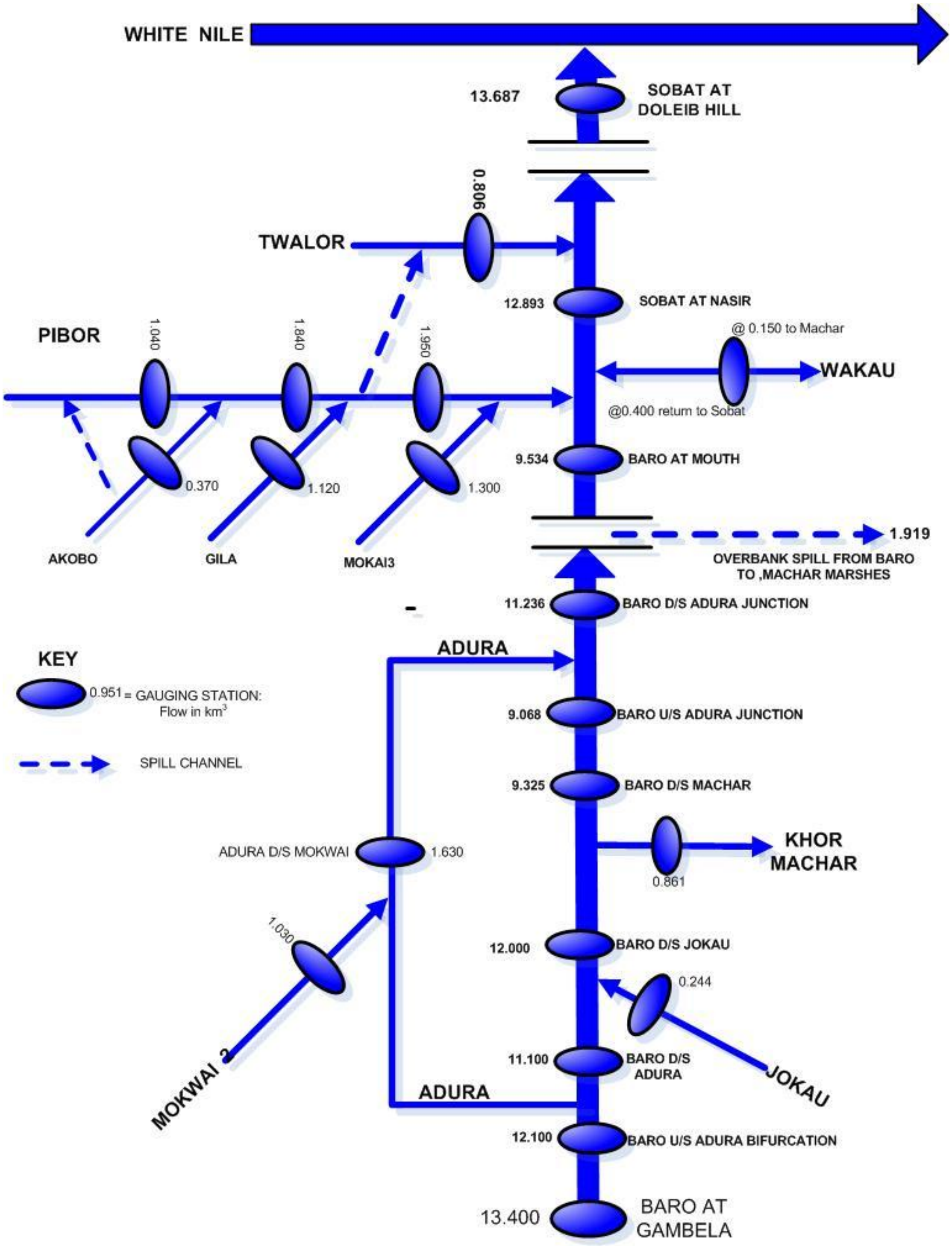
[7] The full Sub-basin is analysed in the Transboundary Sub-basin Analysis.



Map 39. **Sudan: Pibor-Sobat Sub-basin: Hydrology**
Source: Howell et al., 1983

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 upto a meter deep that moves slowly across the plains often into the dry season. Most water is lost through evaporation.

Figure 8. Sudan – Pibor-Sobat Sub-basin: the hydrology of the Sobat and its tributaries (Source: Sutcliffe and Parks, 1999).



Finally, 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 Gilo, 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 8).

(b) The Machar Marshes

<u>Permanent and Seasonal Swamp:</u>

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 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 km2 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 km2 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 Vosia 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 Machar Marshes

The drainage pattern within the area has been mapped by this Project using 2005 Landsat imagery (Map 40). The general pattern accords with that of the JIT survey of 1955.

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 800m 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 Machar Marshes:

A number of studies including Hurst (1950), JIT (1955), MIT (El-Hemry & Eagleson, 1980) and Sutcliffe and Parks (1999) and most recently by Waterwatch (2006) for the JMP Scoping Study have been undertaken on their water balance. Except for the Waterwatch study these have been summarized by Sutcliffe and Parks (1999). 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.

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 km3 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.

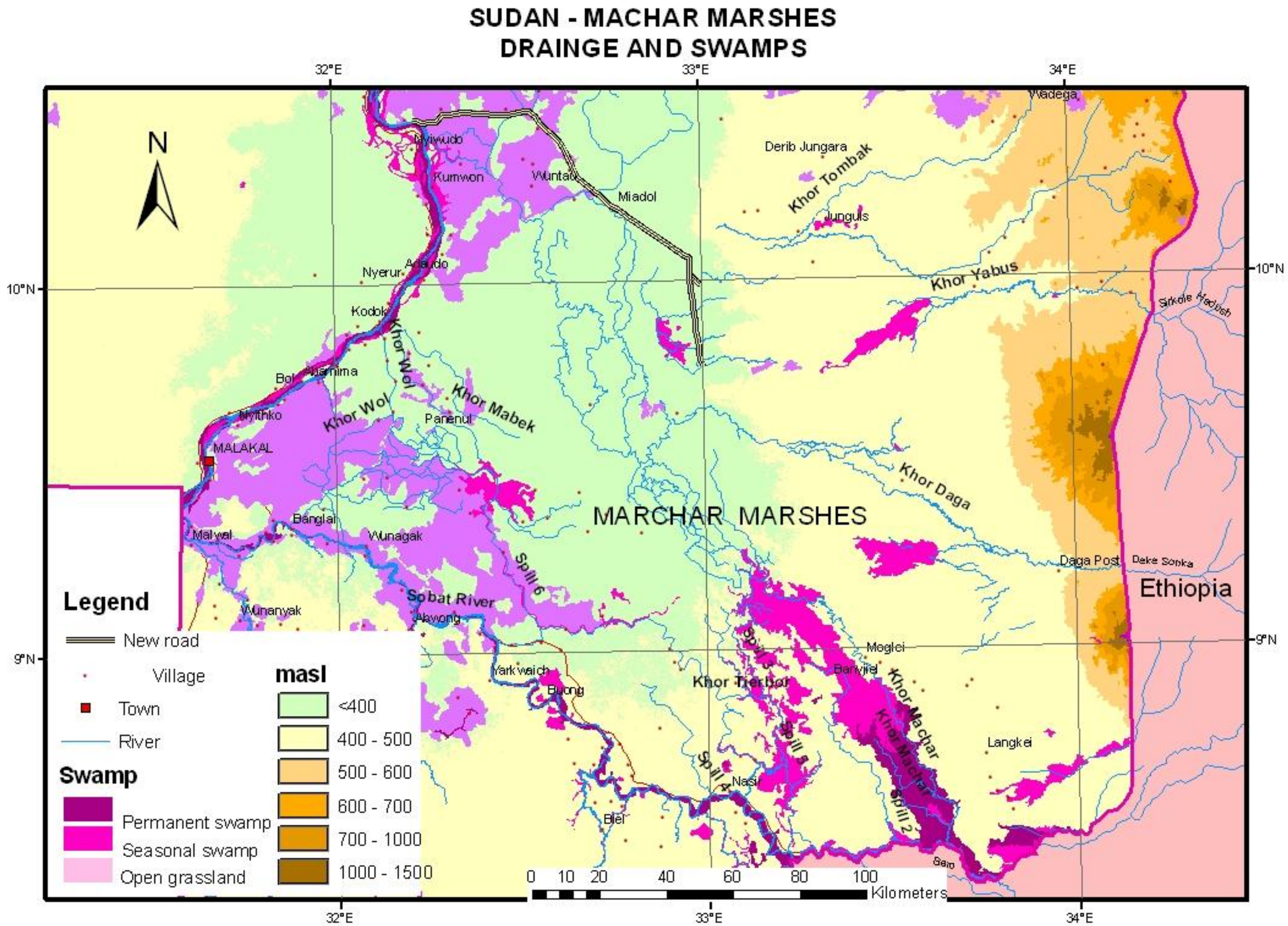
The "Eastern Torrents"[8] originate on the Ethiopia Escarpment and drain an area of approximately 10,300 km2. The two main khors are the Yabus and Daga. Based on the mean annual rainfall and a gauged runoff coefficient of 15 percent, total mean annual runoff was estimated by the JIT to be 1.744 km^3. The MIT study estimated total runoff from the Eastern Torrents 4.2 km3 and a further runoff from the clay plains of 1.41 km3. Sutcliffe and Parks consider these to be severely over-estimated and used the JIT estimate.

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 km2 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 km2 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.

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 km3.

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.

[8] Terminology used by the Jonglei Investigation Team.



Map 40. Sudan: Sobat-White Nile Sub-basin: Machar Marshes – Drainage and Swamps (Source Africover & CRA Interpretation)

(iii) White Nile

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. 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. 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 km3 in October. The Sobat flood is attenuated by the spill both to the Machar Marshes and to the southern plains.

Between Malakal and Mogren (Khartoum) the White Nile mean (1905-83) annual flow reduces from 29.636 km^3 to 26.026 km^3 (a mean reduction of 3.61 km^3) due to abstraction and evaporation. However, these reductions have been increasing in recent years to about 6.00 km^3. [9]

7.2 Socio-economic Characteristics

7.2.1 Administration

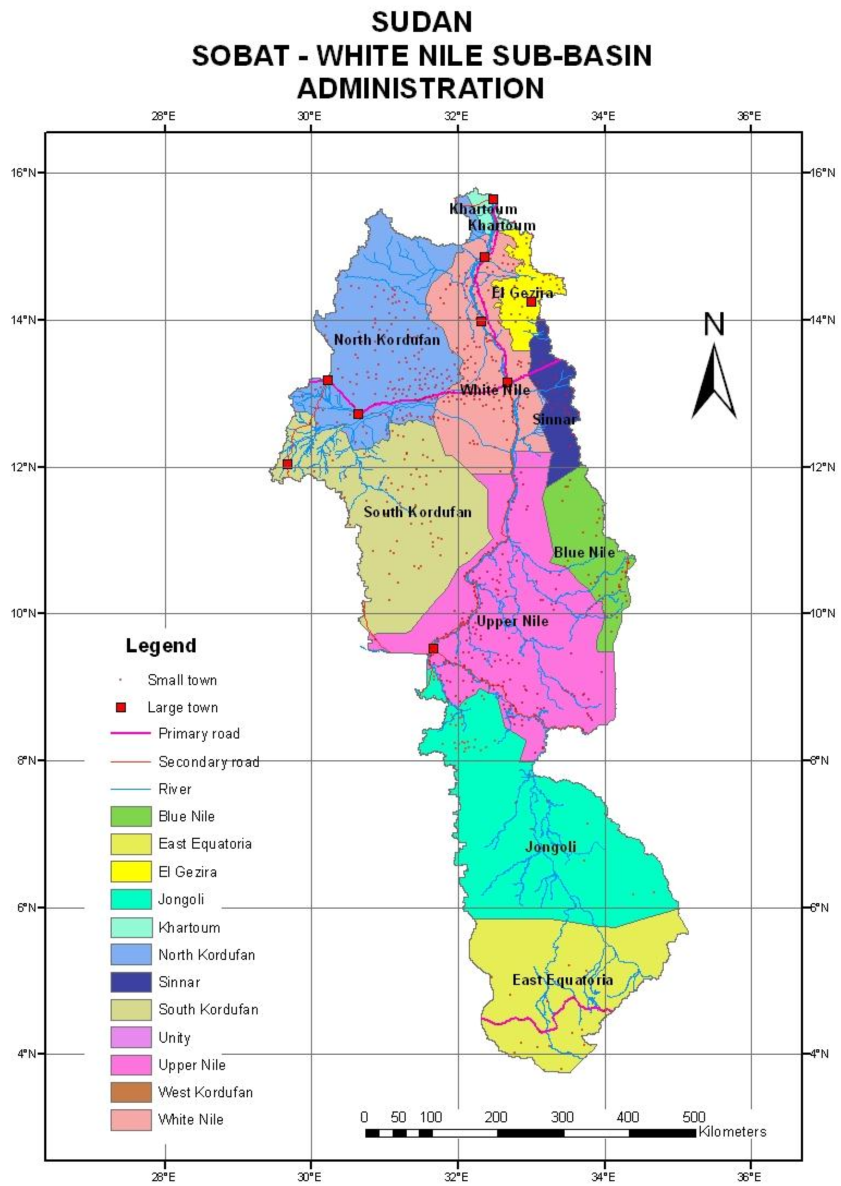
The Sub-basin encompasses 10 States. Their areas are indicated in table 40.

Table 40. Sobat-White Nile Sub-basin: Administrative States and their areas (km2)

Region	Area (km2)	% of Sub-basin
Upper Nile	76,442	**19.8%**
Jonglie	72,529	**18.8%**
South Kordufan	56,438	**14.6%**
North Kordufan	52,791	**13.7%**
East Equatoria	48,934	**12.7%**
White Nile	39,962	**10.3%**
Blue Nile	17,977	**4.7%**
Sinnar	10,218	**2.6%**
El Gezira	8,606	**2.2%**
Khartoum	2,180	**0.6%**
Unity	477	**0.1%**
TOTAL	**386,554**	

Source: ENTRO GIS Database

[9] Figure 8.4 in Sutcliffe and Parks (1999) op.cite

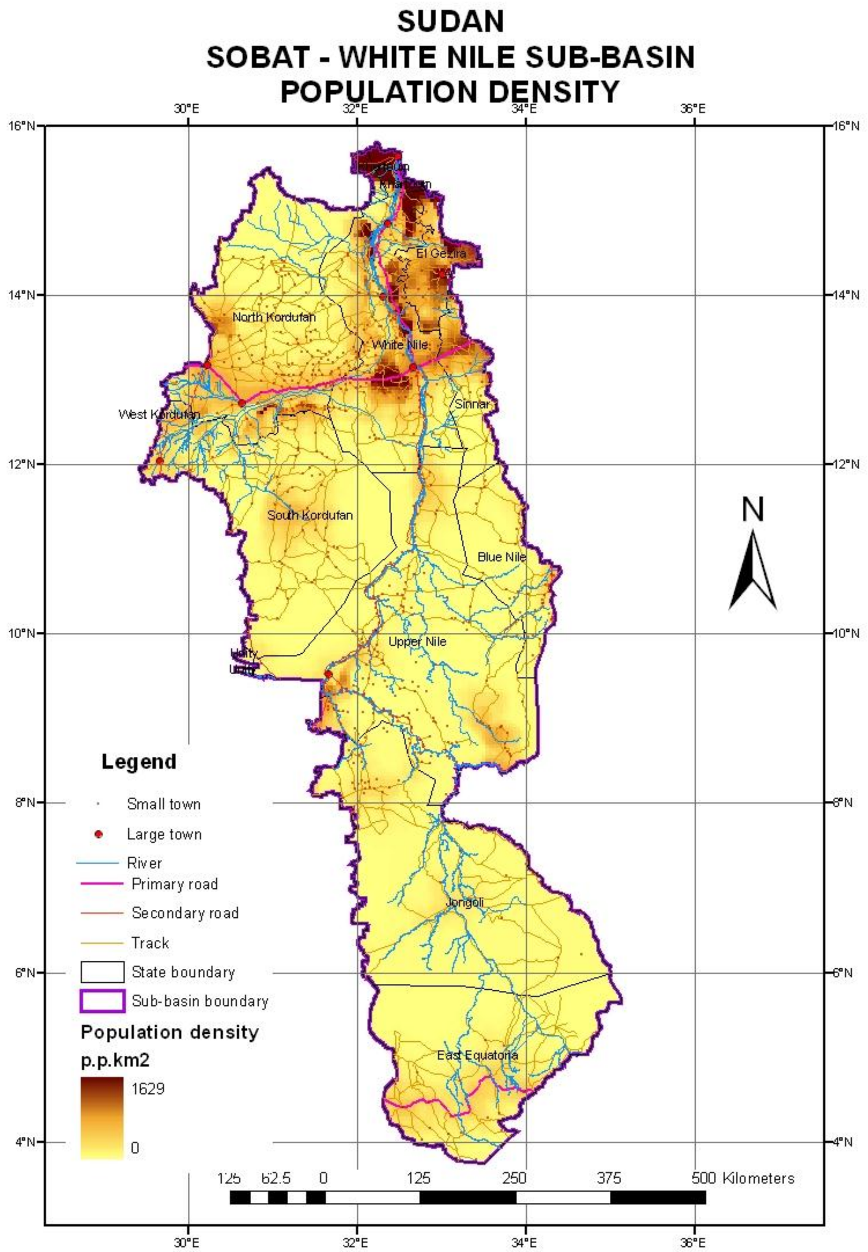


Map 41. Sudan – Sobat Sub-basin: Administrative States.
Source: ENTRO GIS Database

The main Regions in terms of area are Upper Nile and Jonglei followed by South and North Kordofan, East Equatoria and White Nile (Map 39).

7.2.2 Population Distribution

The highest population densities are found in Khartoum, El Gezira, White Nile States and along the main road 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.



Map 42. Sudan – Sobat Sub-basin: Population Density (persons/km2)

Sources: Population densities: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL)

7.2.3 Demographic and Livelihood Characteristics

(i) Demographic Characteristics

The demographic characteristics of States within the Sobat-White Nile are shown in table 41. Growth rates exhibit considerable variation, from 0.9 percent in Upper Nile State to 4.0 percent in Khartoum. The differences are related in some cases to different rates of in and out migration rather to differences in natural growth. Nevertheless the low growth rate in Equatoria is clearly related to the very high infant mortality rates there.

Table 41. Sobat-White Nile Sub-basin: Administrative States - Demographic Characteristics

State	Gth rate %	Urban %	% <15yrs	% >60yrs	Sex ratio M/F	Crude birth rate	Crude death rate	Infant mort. male*	Infant mort. female *
Khartoum	4.00	86.7	36.5	3.8	111.3	33.7	8.8	98	**85**
El Gezira	3.00	22.4	42.5	4.4	96.8	38.5	9.5	101	**76**
Sinnar	2.60	28.3	44.5	4.0	98.8	39.9	10.9	121	**109**
Blue Nile	3.00	25.2	42.7	3.7	108.3	38.5	12.3	137	**122**
North Kordofan	1.80	31.1	47.4	4.9	91.8	40.1	12.2	125	**106**
South Kordofan	1.40	23.2	47.5	3.4	94.3	39.3	124	138	**119**
White Nile	2.80	39.0	45.5	3.9	95.7	40.4	10.0	109	**100**
NORTH SUDAN	**2.80**	**37.3**	**42.8**	**4.1**	**100.4**	**37.8**	**11.0**	**116**	**98**
Upper Nile	0.90	21.6	45.9	3.3	101.7	38.5	16.2	100	**92**
Jonglei	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**n.d.**
Equatoria	1.00	26.2	43.8	2.6	109.0	33.8	11.6	177	**156**
SOUTH SUDAN	**1.80**	**19.6**	**43.5**	**2.9**	**104.4**	**38.0**	**13.9**	**152**	**130**

* per 1000 live births

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

(ii) Literacy and Education

The literacy and primary school enrollment rates for the ten States are shown in table 42.

Table 42. Sobat-White Nile Sub-basin: Administrative States – Literacy and Primary School Enrollment Rates

State	Literacy >15yrs % Average	Literacy >15yrs % Male	Literacy > 15yrs % Female	Pop. 6-13yrs	Total Primary school enroll.	% enroll.
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
SOUTH SUDAN	**52.6**	**65.4**	**39.3**	**1,037,964**	**120,682**	**11.6**

Source: Literacy: UNPF,Sudan. Enrollment: Min. of Educ., Khartoum.

The differences in literacy rate between north and south are no significant, although male rates are consistently above the female rates. There are significant differences in Primary School enrollment rates between Northern and Southern Sudan with the former considerably above the latter.

(iii) Water and Sanitation

The percent population with access to drinking water and sanitation facilities are shown in table 43.

Table 43. Sobat-White Nile Sub-basin: Administrative States – (a) Percent Population Access to Drinking Water, (b) Sanitation Facilities

(a) Drinking Water by Source

State	Main source of water							
	Piped into dwelling	Public tap	Deep Well/pump	Dug Well/ bucket	River/canal	Rainwater	Others	Missing
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**	

Source: UNICEF, Multiple Indicators Cluster survey, 2000, and Safe Motherhood Survey, 1999

In the north the range of sources varies considerably among the States. Khartoum has the highest proportion of dwelling with a piped supply followed by the well developed El Gezira and Senner States. In South Kordofan deep wells are the most prevalent source of supply. No data is available for Southern Sudan except for the town of Malakal where 94 percent of the population get their water from the river. Most population in the south are located along streams and rivers so the rural picture is likely to be very similar.

(b) Sanitation facility by type

State	Flush to Sewage System	Flush to septic tank	Traditional pit latrine	Soak away pit	Others	Missing	No facilities
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**

Sources: UN Population Fund & Sudan Central Bureau of Statistics. (2002).

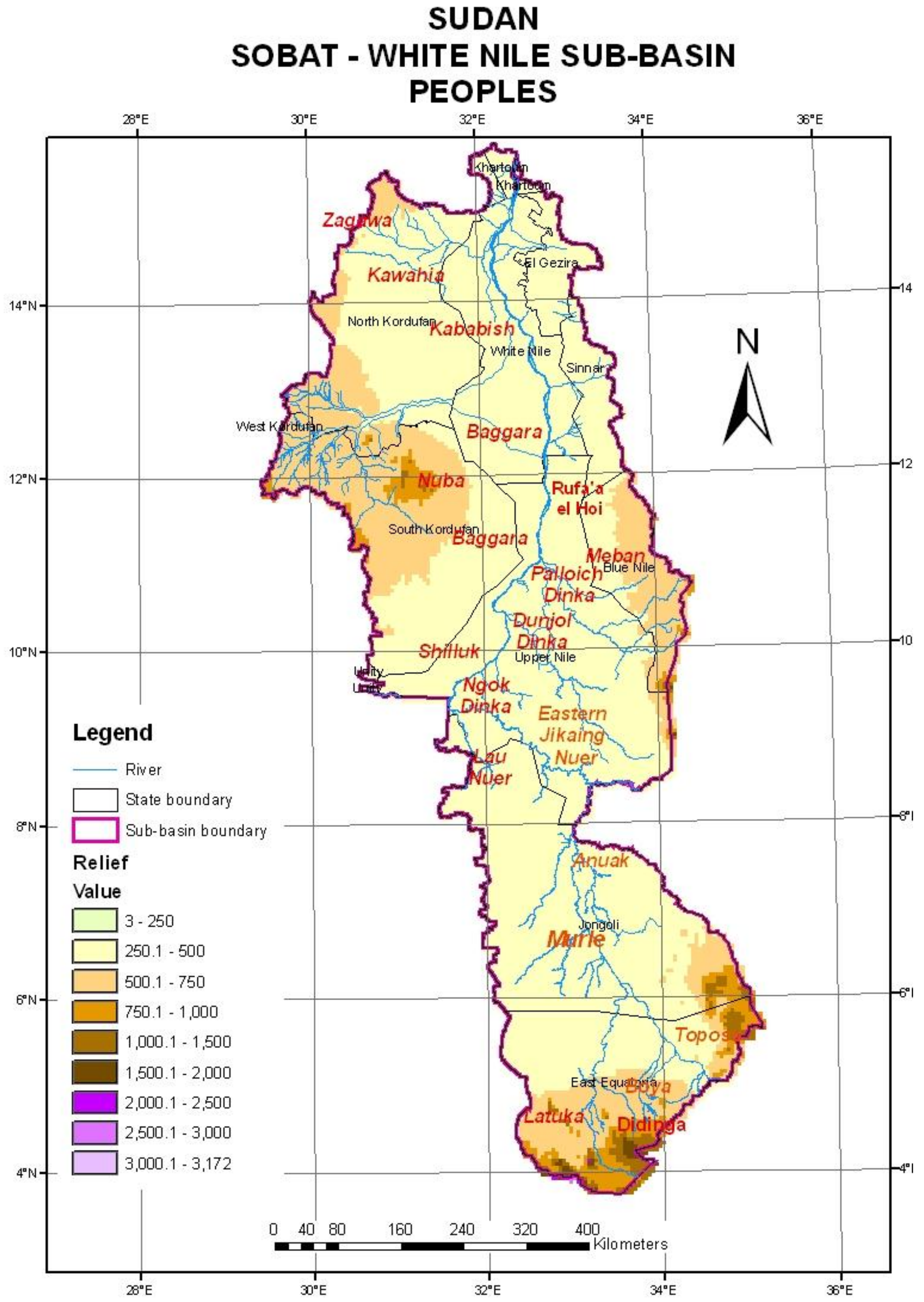
The Northern Sudan with respect to sanitation facilities Khartoum is well above the average and Blue and White States well below. No data except for Malakal are available for Southern Sudan. Given the very low rates of provision in this town the rates in other small towns and rural areas are likely to be much worse.

7.2.4 Socio-cultural Aspects of the Population

A substantial proportion of the population in the northern part of the White Nile Sub-basin live and work on the large irrigation schemes and semi-mechanized farms or in service and processing industries related to these developments. Many in the past followed pastoralist and agro-pastoralist livelihoods, but who for one reason or other lost their livestock and became sedentarized.

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.



Map 43. **Sudan – Sobat Sub-basin: Peoples**

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 percent 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 farm family is the basic unit. 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 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 Ingessana is a name given to the people living in the Ingessana Hills with a distinctive language and culture. They are predominantly agriculturalists cultivating the foothills. Cattle, goats and camels are socially and economically important. Livestock are kept in the hills during the wet season and move either south-eastwards to the Machar Marches and the Yabus, and to the east to the Blue Nile and the border with Ethiopia. They maintain a spirit of cooperation with the Rufa'a al-Hoi and many Ingessana work as herders for them. As well as the Ingessana, there are a number of smaller (Pre-Nilotes) Grotanelli, 1966) groups who practice sedentary agriculture. These include the Berta, Gumuz, Mao, Burun, and Maban who live along the border with Ethiopia.

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.

Both 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.

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.

7.3 Transport Infrastructure

Within the Sobat-White Nile Sub-basin there are three primary and three secondary roads.

(a) Primary Roads

The three primary roads are:

Senner to Kosti and El Obeid
Khartoum – Kosti

Kenya border – Juba: This road has been opened from the Kenya border as far as Torit. The Torit to Juba section remains impassable (December 2005) (FAO/WFP, 2006). The road linking Juba to Malakal is still not operational.

(b) Secondary Roads

There are three secondary roads that may not be passable during the rainy season:

Ad Damazin - Paloich
Rabak – Malakal
Pocalla-Boma-Lokichoggio (Kenya)

Other roads are generally in poor condition and on the clay plains often impassable during the rains.

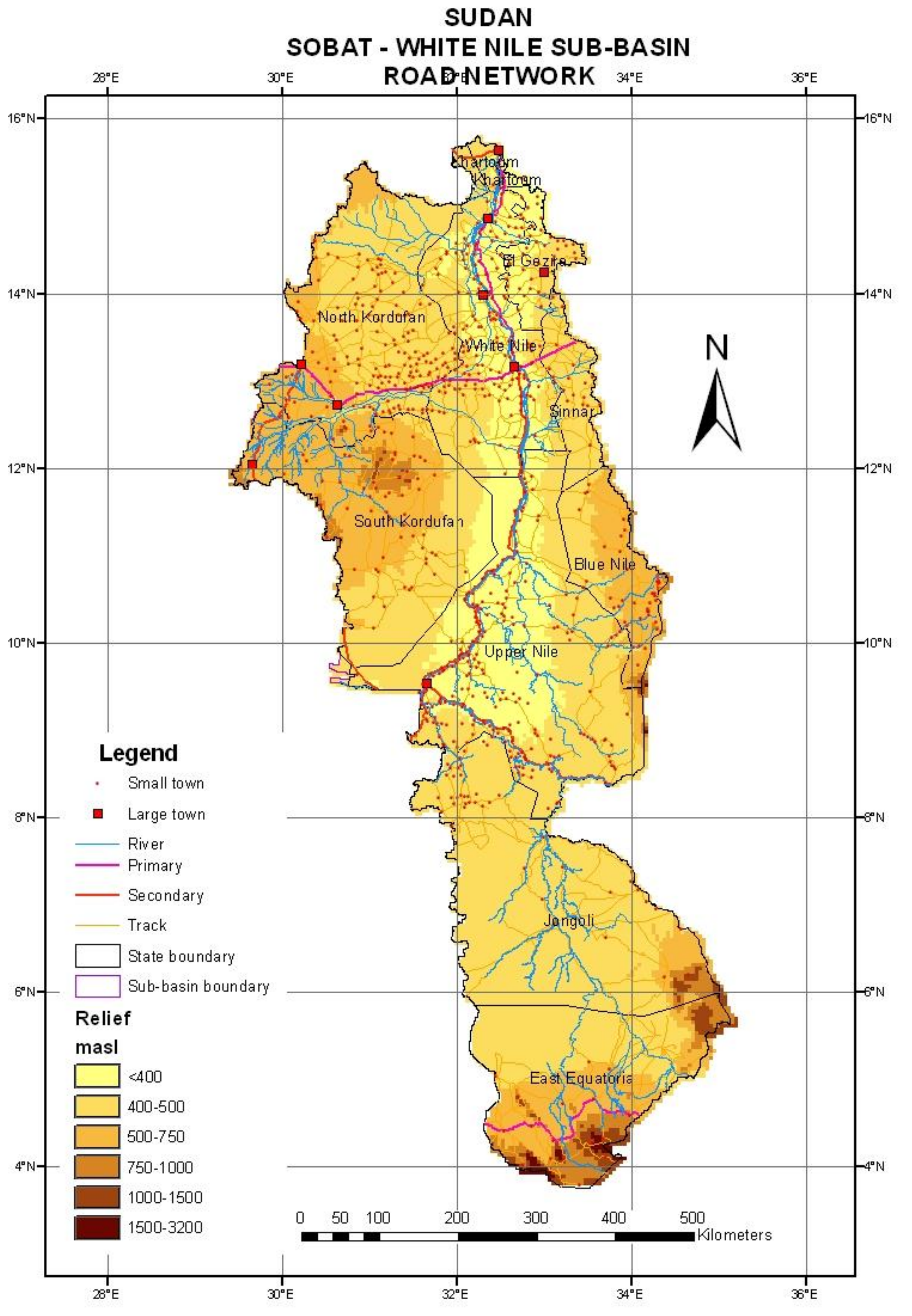
(c) Railway

There is one railway:

Sennar – El Obeid

(d) River Transport

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



Map 44. **Sudan – Sobat Sub-basin: Road Network.**
Source: Afriroads

8. PROBLEM ANALYSIS OF NATURAL RESOURCE DEGRADATION

8.1 A Framework for Analysis

8.1.1 Introduction

In the Sudan 80 percent of the people directly depend on their natural environmental for their livelihoods and survival, and agriculture constitutes nearly 40 percent of the GDP. This report has numerated some the main types of natural resource degradation, their extent and impacts. Whilst many of the proximate causes of resource degradation are well known the underlying causes are often less obvious and difficult to discern.

Some of these such as poverty and population pressure may at first seem obvious but recent research into these factors has revealed that the linkages between one or more factors and continuing resource degradation are far from clear. For example, in Ethiopia after nearly ten years of detailed research into the underlying causes of resource degradation by many natural, social and economic scientists the picture that has emerged is often mixed and contradictory. In many cases the underlying causes that are identified are very specific in time, place and situation.

The land and water use systems in the four sub basins are highly varied and reflect not only the natural resource base, but also the complex social, cultural and economic characteristics of the land users and the economic, institutional and policy environment in which they operate. Land use systems have their own dynamics responding to endogenous and exogenous factors that have impacts on user livelihoods and the properties of natural resources and environmental services.

This analysis seeks to establish any causal linkages between land use systems and trends in these properties and services at the National Level. The subsequent Transboundary Analysis at the Sub-basin level will view the Eastern Nile Basin as a hydraulic system and will try to identify and where possible quantify the upstream and down stream impacts of current resource use and management systems.

8.1.2 The Framework

The International Food Policy Research Institute (IFPRI) has over the past decade developed an appropriate framework for analyzing the dynamics of change of the complex web of factors[10] (fig. 9). Pressure or “shift” variables

[10] Scherr, S.J. et al (1996) “Policies for Sustainable Development in Fragile lands: Methodological Overview”. IFPRI, Washington DC.

(e.g. changes in population/migration, markets and market prices, land tenure institutions) will induce changes in baseline conditions such as natural resource endowments of households and communities, household assets, market integration and local institutions (e.g. property rights).

These shifts can in turn induce responses at the community and household level. Of particular importance and of relevance to the present analysis are the community and household decisions with regard to investments (or non investments) in agriculture, soil conservation, and small-scale irrigation. Other responses could include changes in natural resource management systems (e.g. livestock exclusion zones, rangeland management systems). These responses in turn can have positive or negative impacts on agricultural productivity, the condition of natural resources (soil fertility, forage production) and on human welfare (health, livelihoods). At each of these stages negative or positive feed back mechanisms may operate. The public policy environment (e.g. agricultural research programmes, resettlement policies, land access policies) and interventions (e.g. in infrastructural development) can influence this temporal process at various levels.

8.2 Pressure-Shift Factors: The Underlying Causes of Natural Resource Degradation

8.2.1 Poverty

(i) Patterns and Extent

The extent and dynamics of poverty in the Sudan since the 1990's has been examined by the Joint Assessment Mission - JAM (2005). It is estimated that about 60 to 70 percent of the population in the North is living below US$1 a day, whilst estimates in the south put the proportion at 90 percent. 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.

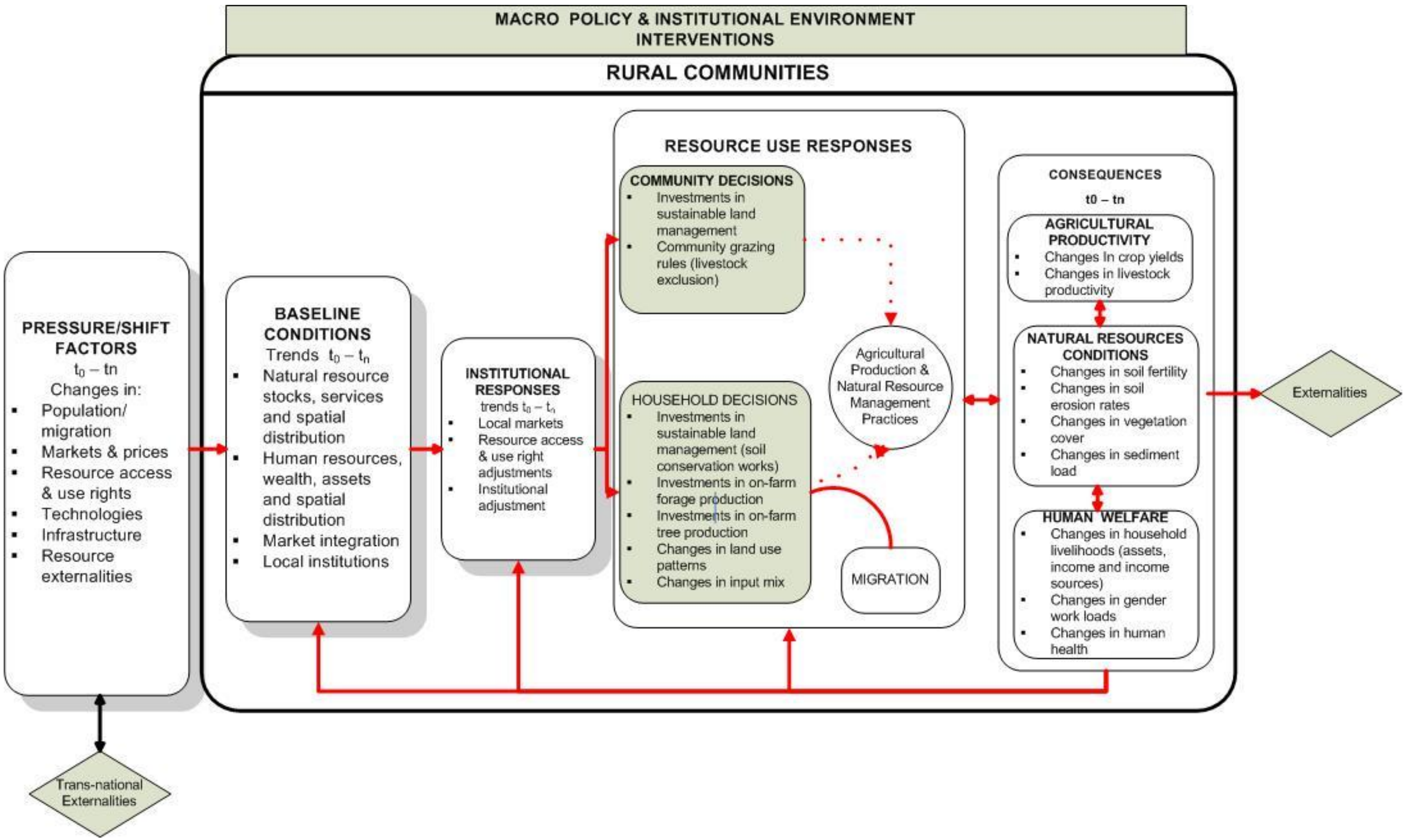
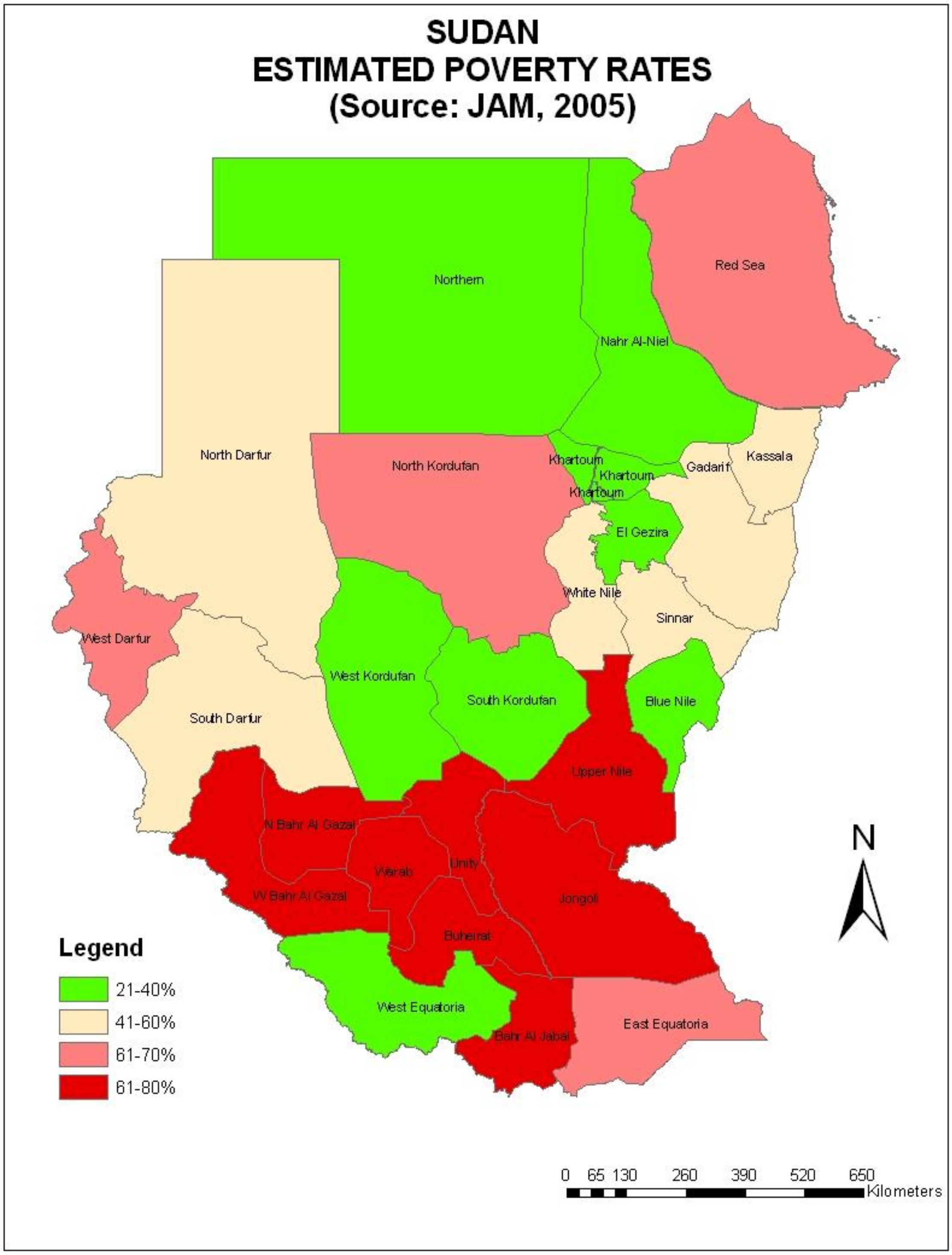


Figure 9. Framework of Analysis for Natural Resource Degradation in the Sudan.

Map 45 shows the distribution of poverty by State.



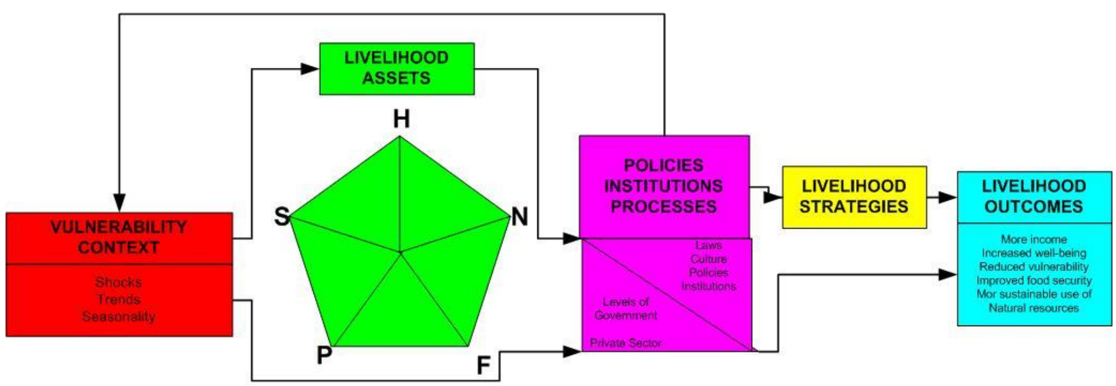
Map 45. Sudan: Distribution of Poverty by State (JAM, 2005)

(ii) Poverty Natural Resource Degradation Nexus

The "poverty-natural resource nexus is where livelihood activities of households and the communities to which they belong, and the natural resource based interact. These are represented by the two boxes in figure 9 as "household decisions" and "community decisions".

At this detailed level of the household the “Sustainable Livelihoods Framework” (DIFID (2001) has become a common diagnostic tool in development planning and interventions (figure 10). The Framework promotes poverty eradication, protection and better management of the environment and places emphasis on people rather than resources. “Livelihood” comprises the household’s assets (social, human, natural, physical and financial capital), their livelihood outcomes (or objectives) and the livelihood strategies they adopt in attempting to achieve these. These occur within a “Vulnerability Context”, i.e. the shocks, trends and seasonality of conditions that affect assets, strategies and thus outcomes. Finally “Transforming Structures and Processes” include the policy and institutional framework that affects and is affected by assets, strategies and outcomes.

Figure 10. A Framework for Household and Community Livelihoods Analysis in a Poverty-Natural Resources Context.



KEY:
H = Human Capital
S = Social Capital
N = Natural Capital
P = Physical Capital
F = Financial Capital

It will be seen that there are similarities between the IFPRI and the DIFID frameworks and in fact the detailed livelihoods framework “nests” within the household and community boxes of the IFPRI framework.

(iii) Total Loss of Livelihood Assets

The distribution of high rates of poverty in the South is clearly related to the negative impact the war has had on the reduction and in many cases total loss of household and community livelihood assets (capital, family labour, and secure access to land). The households and communities here are extremely vulnerable to natural and human induced sudden, seasonal and long-term changes in their natural environment and breakdowns in the social and economic networks that sustained them in the past.

Given these high rates of poverty there will need to be a substantial government support in providing rural infrastructure, establishing a climate for efficient markets and providing support to agriculture in terms of credit, extension and research. Communities themselves will need to respond to the expect influx of returning IDP's and refugees returning to their homeland. This will require very strong community level institutions that can equitably allocate access rights to the community's natural resources.

(iv) A Secure Livelihoods Asset Base and Low Vulnerability

The low rates of poverty from El Gezira to Northern State are a reflection of the assured access to generally low risk irrigated cropland along the Blue and Main Nile. An assured and low-risk production environment clearly reduces the incidence of poverty. It enables households to build up assets that reduce their vulnerability to sudden changes in circumstances.

In these areas land is generally held in freeholds and perceptions of tenure insecurity are low. Where leaseholds prevail the general secure natural asset base, the availability of physical (pumps, irrigation water) and financial (seasonal credit) assets creates an environment for secure and sustainable livelihoods and low vulnerability.

(v) A High Risk Environment and the Alienation of Natural Resource Assets

Elsewhere rural households land resource assets are generally rainfed cropland where rainfall amounts and variability present a high risk environment. Here, the opposite conditions prevail, where it is not possible to buildup household assets, and there are many cases where these have actually declined through land degradation (e.g. kerib land) or alienation of assets (e.g. to the large semi-mechanized farms).

Where livestock are the main livelihood capital assets these too depend on the same high risk environment as well as dwindling rangeland resources in the face of expansion of large semi-mechanized farms. The coping mechanisms that communities and groups have developed over millennia to deal with and recover from natural calamities have been insufficient in the face of insecurity and alienation of basic natural resources. Livestock assets provide a buffer in times of need. Where access to water and forage has becoming limiting for the reason set out above vulnerability to shocks and hazards such rainfall variability and drought becomes more acute.

In Sudan decisions to adopt sustainable land management technologies depend on households' asset endowments (human capital). This is particularly of relevance in areas of shifting cultivation and the need for labour for frequent clearing to access land of better fertility as well as for weeding. It is also true for pastoral families because of their need for herding different animal types (camels, cattle, sheep and goats) in different places and times. In efforts to maintain livelihoods some household members have had to leave the farm in order to seek wage employment. This has led to a reduction in households' human capital and the lack of labour for cultivation and herding.

8.2.2 Population Pressure

Currently there are two basic hypotheses regarding the relationship between population growth and land degradation. The "neo-Malthusian" hypothesis predicts that agricultural production is unable to keep pace with population growth leading to falling agricultural production per capita, and increasing negative impacts on natural resources including land, water, forests and biodiversity.

More recently, a more optimistic perspective has developed following from the work by Ester Boserup (Boserup, 1965) and others. This perspective emphasizes the responses of households and communities to population pressures that include a reduction in fallow periods, intensified use of labour and land, development of labour-intensive technologies and institutional changes. However, more recent evidence suggests that more specific conditions seem to be needed to get a Boserupian scenario to operate. These have been identified in the Machakos study as secure tenure, efficient markets, cash crops, supporting social organization and proven SWC measures.

The chapter on agriculture in the eastern Nile Basin of Sudan has identified a number of constraints to sustainably increasing agricultural production. These include poor management practices, inefficient markets, low technology transfer and inadequate agricultural services, low ratio of extension agents/farmer, lack of adapted varieties and insufficient certified seed are responsible for low yields attained. The issue of land tenure is expanded on in section 9.5 below. Thus, it is apparent that in many areas there are a number of constraints to farmers breaking out of neo-Malthusian trap and that there will be a continuing negative impact of population pressure.

8.2.3 Environmental Policy and Institutional Issues

Despite the active role played by Secretariat of the HCENR, which is the focal point for all environmentally related conventions, the HCENR has not been able to perform all its mandated tasks. This is mainly due to the following constraints:

- Most of the state's councils have not been established and this has resulted in weak representation of the HCENR at the state level.

- The council members (ministers of relevant institutions) have never met since the establishment of the HCENR. This reflects the low priority and commitments of the governments towards environmental issues in Sudan. This situation could be explained by the fact that that the country has been weighed down by long years of war and many urgent pressures and that politicians could not allocate the necessary time or resources to cater for environment.

However, this situation is expected to change now after the CPA and the need to follow and adopt a sustainable course of development.

At the field level it was reported that there a lack of horizontal and vertical coordination between and among responsible agencies, organizations and ministries.

8.2.4 Poor Local Governance in securing Access to Land and Water: an Example from the Gash Delta

The problems that are facing the Gash Delta irrigation Scheme are an example of how it is often a combination of many factors that underlie the causes of the poverty-environment nexus in the Sudan. Whilst not all factors are present everywhere many are, and the case study of the Gash Delta highlights the complexity and difficulty of disentangling root causes of poverty and environmental degradation, as well as the lack of a simple solution tom these causes.

In the Gash Delta as elsewhere in Sudan the level of rural poverty is closely related to the strength of agricultural production and productivity. Here the total cultivated area has decreased by over 50 percent over the past 20 years and the total cultivated area per tenant has declined from 7 to less than one feddan. Managerial, institutional and policy factors are the root causes of this process of impoverishment (IFAD (2004).

Chief among these factors has been the lack of an agreed approach and a plan for the development of the area resulting in:

- an ad hoc use of current resources and investments;
- unpredictable local and extra local resource allocations, including inequitable patronage systems;
- lack of transparency in the management of the Gash area resources and investments and the diversion of the surpluses extracted from the area away from re-investment in the area;
- erratic support services;
- frequent exemption from non-payment of services charges, such as water rates; and
- weakening of traditional solidarity and social support mechanisms.

The fragile and harsh agro-ecology and the cumulative degradation of natural resources further aggravate the situation.

The specific problems facing the people of the Gash delta have identified as:

- a decrease in the area cultivated by households, combined with a decrease in the average herd size per household;
- income derived from agriculture is not sufficient for food security;
- coping mechanisms put in place to address the deterioration of the total land cultivated have used a system that keeps poor households poor and enable the better off to accumulate land; and
- the management of the scheme is fragmented and under constant non-compliance with both formal and informal land access rules.

These problems derive from:

- a weak, fragmented and nepotistic management;
- poor technical competence over many years;

- loss of the cash-crop and income generation base of the scheme, with growing expenditure on scheme management and social services (water, health and education)
- insecurity of access to land which acts as a disincentive to invest in sustainable land development for better flood control;
- unclear level of water fees that do not reflect the cost recovery of operation and management of the scheme;
- low state and federal fund transfers when compare to those budgeted;
- climatic variability and civil unrest, which results in a constant flux of people seeking refuge in the Gash Delta. This in turn puts pressure on the production base, the social infra-structure and traditional coping and support mechanisms.

8.2.5 Land tenure and Resource Conflict

Issues of land tenure here include insecurity of tenure, ability to use land as collateral and transferability of property rights and the impacts these have on land investment or factor (land, labour or capital) allocation. This is a complex subject in Sudan.

The subject has been touched upon in the section of natural resource use competition and conflicts, and in the section of large scale semi-mechanized farming. The World Bank Country Economic Memorandum (World Bank, 2003) outlined a number of problems relating to current land tenure and land policy in Sudan:

- it limits access to credit to the majority of farmers who cannot use land as a collateral,
- it does not provide incentives for sustainable land development and management, leading to continual cultivation and destruction of soils in the semi-mechanized farms,
- because land has not been demarcated, there are conflicting land use rights between pastoralists and sedentary crop farmers, which has led to civil strife,
- reform is inseparable from need for rural reconstruction and establishing agricultural credit institutions.

The issues of resource conflict related land tenure rights has been described in detail for the rangelands in and the Atbara-Blue Nile Basins in chapter 7 and Blue Nile and Sobat River basins in chapter 8.

A key problem has been the lack of a National or Regional Land Use Plans that could strategically guide land development activities. Thus the expansion of the mechanized farm sector was largely uncontrolled. No assessments were made on the environmental, social or economic impacts of these very large developments.

It is understood that States are mandated to develop Regional land Use Plans but as yet no guidelines appear to have been issued. There is some debate as to whether there should be a national Land Use Plan that would provide at least a strategic framework for State Plans. A pre-requisite of any National or State Land Use Plans is a thorough reform of the Land Tenure Policy.

8.2.6 Agricultural Extension and Availability of Credit

Related to poverty and household assets are the concepts of profitability of the improved land management technology, the farmers' perceptions of risk and farmers' private discount rates. Private discount rates are a measure of a person's time preference or time horizon. The higher the discount rate the shorter the time horizon. Short time horizons are the result of a number of factors, tenure insecurity, poverty, and high risk environment. Many farmers have high private discount rates – as high as 70 percent. A number of studies have found that adoption of natural resource conservation technologies is negatively related to high discount rates. However, where a technology is risk reducing (e.g. water harvesting, soil moisture conservation structures, small-scale irrigation) adoption is much more likely.

Currently credit and extension for the traditional agricultural sector are very weak. The extension worker-to-farmer ratios are very low indeed. Credit and input supply services have hitherto focused on the large-scale irrigation sector. The main problems are non-viable collateral, small loan levels, geographical distance and logistics of recovery. Attempts have been made to form cooperatives but without success. However, this situation may soon improve with the signing of a Micro-finance project between the GoS and the World Bank for a sum of US$ 269 million over 6 years. This will be aimed in part at the traditional agricultural sector (FAO/WFP, 2006).

8.2.7 Profitability of Existing Technologies

In Sudan sorghum yields from the semi-mechanized and traditional farming sectors have been declining over the past 30 years. This has been attributed to reductions in soil fertility due to continuous cropping, the expansion onto marginal land and the lack of support services such as research, extension and credit to the traditional smallholder sector. In the Eastern Nile Basin low and erratic rainfall provides a high risk environment for rainfed crop production.

Fertilizer and chemical use is almost all applied to the irrigated areas, with a small experimental use on the semi-mechanized farms. Currently it is difficult to say what are, if any, the factors inhibiting the uptake of improved land management practices in the traditional smallholder sector in Sudan because of the lack of availability of these inputs.

8.3 Main Nile Sub-basin

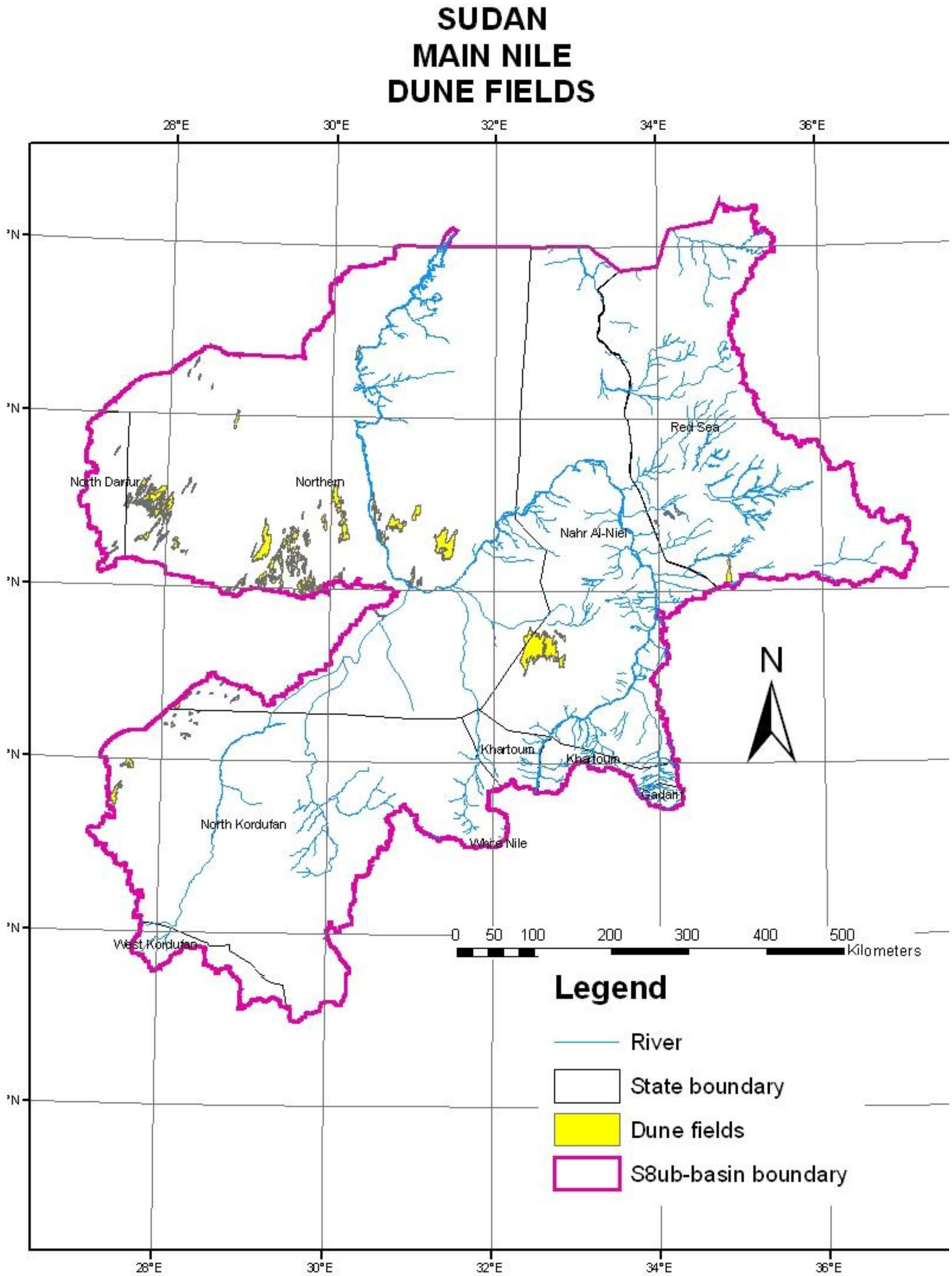
8.3.1 Assessment of the Extent, Trends and Impacts of Shifting Sands

Moving sand dunes can overwhelm settlements, fields and roads. The distribution of dune fields in the Main Nile Basin is shown in Map 46.

The dominant wind direction is from the northeast. Thus the most hazardous dunes are located to the northeast of the Nile. These are located between Dongella and Karima. There are 14 smaller dune fields on (4) or close (10) to the river, and three larger fields 20 to 60 kms from the river. The source areas for the dune fields are the very extensive areas of loose and shifting sand that overlies the rock pavement as well as the three larger dune fields to the northwest.

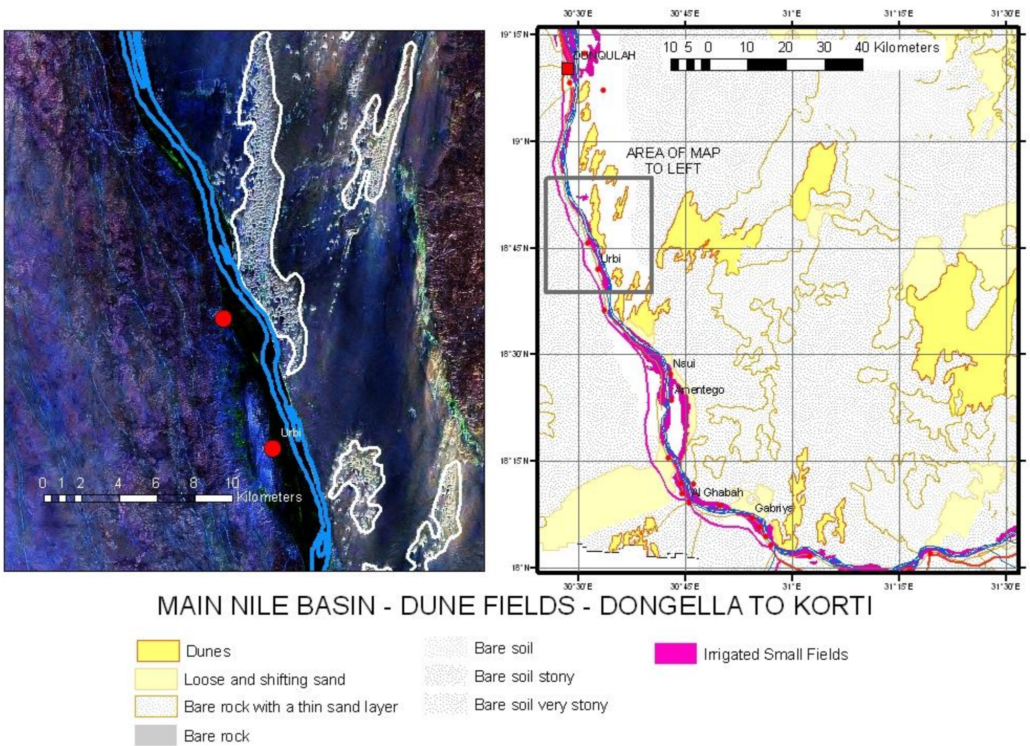
Those on the river present a present hazard for tipping sand into the river, whilst the other 10 are a hazard to settlements and irrigated fields. The latter currently do not present an immediate problem.

The smaller dune fields total some 67,000feddans (14,300 ha). However, they are generally elongated and aligned in the main wind direction some 2 to 4 kms wide although 5 to 15 kms long. This means they present a narrow advancing front, which reduces the length of tree breaks required to halt the dunes.



Map 46. Sudan - Main Nile Sub-basin: Distribution of Dune Fields
Source: Sudan FAO Aficover, 2003

An examination of the Africacover map of the area reveals that approximately 6,200 feddans (2,570 ha) of currently irrigated land that is immediately threatened. There is an unknown area of potentially irrigable land currently not developed, estimated at 33,000 feddans (13,860 ha).



Map 47. Sudan – Main Nile Sub-basin: Dune Fields – Dongella to Korti.
Source: Landsat imagery, 2000.

In the absence of any measurements it is difficult to estimate the amount of sand tipping into the River. Two of the 14 dune fields abut the river, each with a front of about 2.6 kms.

8.3.2 Assessment of the Extent, Trends and Impacts of River bank Erosion

River bank erosion occurs at any point along the course of the Main Nile from Khartoum to Lake Nubia. Evidence from fossil meander belts in the Gezira and Butana plains indicates that river meandering and movements of meanders downstream that are causing river bank erosion and subsequent sedimentation are a natural phenomena. However, in a number of areas this natural process has been accelerated through human interference of the river hydrology.

In the Ed Debba-Dongola reach tipping sand from shifting dunes is said to cause shifts in the main channel, which cause bank erosion downstream. In other areas inappropriate landuse (e.g. banana plantations, clay pits for brick making) is said to be a major cause of bank erosion.

Environmental impact studies (Laymeyer International, 2001, Paris et al., 2004) of the Meroe Dam indicate sediment retention rates of between 30 and 90 percent. Added to this will be substantial daily changes in discharge related to the hydro-power operation procedures. These reductions in sediment load and frequent changes in discharge will increase substantially existing rates of bank erosion. In addition river bed scouring is likely to increase leading to sand island formation. These processes in-turn will lead to increased bank erosion. The official Environmental Impact Assessment of the Meroe Dam recommends a comprehensive system of monitoring of banks and installations such as ferry landings to determine the extent of the impact.

8.3.3 Assessment of the Extent, Trends and Impacts of Desertification in the Main Nile and Atbara Sub-Basins

The concept of "desertification" has been heavily discussed in the literature since 1977 UNEP's Desertification Conference held in Nairobi. Desertification has been described as the continuous and sustained diminution or destruction of the biological potential of the land in arid or semi arid environments. Most researchers credit Aubreville (1949) with the term. The debate revolves around whether Man or Climate is to blame. The early debates centered on Man as the primary cause with the cultivation of marginal lands and particularly overgrazing.

By the 1980's researchers at the University of Lund working in the Sudan (Hellden, 1988, Olssen, 1993) and other Sahelian countries began to question the emphasis on human impacts. In particular, the work of Lamprey (1988) was called into question. By using precipitation in conjunction with agricultural statistics in combination with remote sensing they concluded that climate was the driving force behind desertification. A better understanding the Southern Oscillation and its cycles now explained in past the droughts (Hulme and Kelly, 1993).

Work by Tucker et al (1991) documented vegetation changes in the Sahara from 1980 and 1990 and showed that increased greenness with increased rainfall that followed the dry period of 1980-1984. This was later combined with ground photography to demonstrate the "reversibility" of degradation by Helden (1992).

More recently the debate has swung back and both climate and human impacts on drylands have been shown to interact. Research has shown that even though satellite images can detect no changes in greenness – the vegetation composition can change often un-noticed. These may be of invasive species leading to reduction in forage productivity. The vegetation thus represents a new state (Westby et al., 1989) and a return to earlier vegetation may not be possible.

In areas of rainfall above 500 mm annual rainfall livestock numbers will tend in the long term and in the absence of external or internal controls, to stabilize at about the ecological carrying capacity. For short periods (1 or 2 years) numbers may rise be above the long term carrying capacity as mortalities reduce (i.e. over stocking), but will fall for a short period below the long term carrying capacity as mortalities increase (i.e. under stocking). These rangelands have been termed as being at equilibrium.

Rangelands in areas with less than 500 mm of annual rainfall have been said (Coppock, 1993) to be at “disequilibrium”. In the Main Nile and Atbara Sub-basins most of the area receives less than 500 mm of annual rainfall. In these conditions there is no stable or constant “carrying capacity” because rainfall variability is so great that forage production fluctuates widely from year to year and from place to place. In response the pastoralists adopt an “opportunistic” strategy of herd splitting and moving the split herds to areas with the most appropriate feed.

Rangelands in the Main Nile and Atbara Sub-basins are reported to have degraded over the past two decades with increased presence of species of poor forage quality. This has been caused in part by the reduction in rainfall in the early 1980's exacerbated by the increased gazing pressure caused by the loss of rangeland to the large expansion of the semi-mechanized farms.

The World's Bank forestry sector review of 1986 reported 50,000 km2 are lost annually and that the total area affected by some form of environmental degradation is 650,000 km2 which is equivalent to 60% of Sudan useful land area. In the west and north of Sudan, long stable sand dunes have been reported to be moving and threatening agricultural land and that the Nile banks between Karima and Delgo in the Northern State are now threatened by drifting sand. Ali and Bayoumi (1999) reported that the desert area in western Sudan has increased from 205,000 km2 as reported by Harrison and Jackson (1958) to 340,000 km2 in 1982 and that the boundary of desert shifted about 200 km south at a rate of 8 km per year.

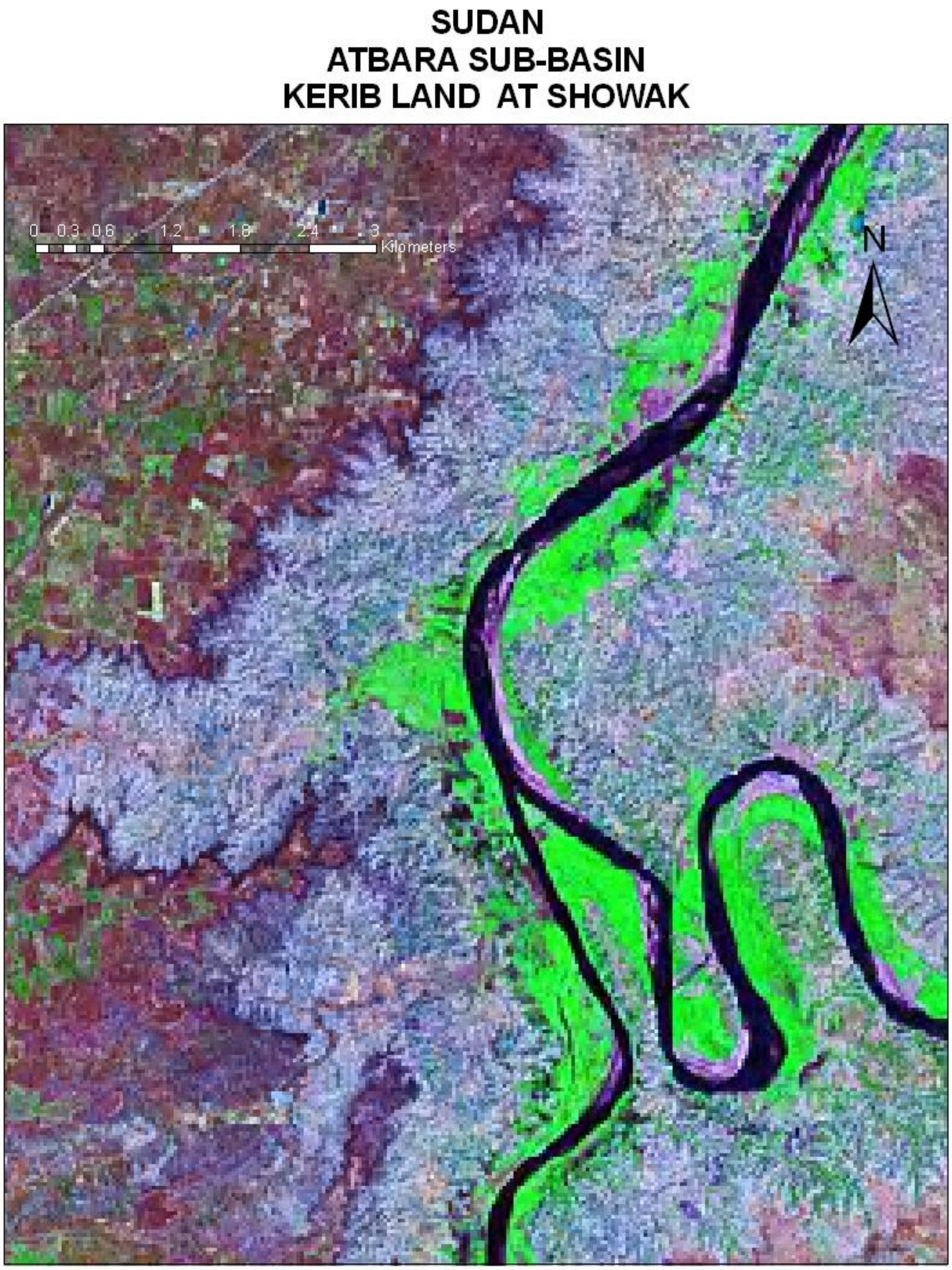
8.4 Atbara Sub-basin

8.4.1 Assessment of the Extent, Trends and Impacts of Erosion

The key problem with erosion in the Atbara Sub-basin is the gully erosion along the banks of the Atbara River. This erosion leaves behind land known as "kerib" land. The Setit and Atbara Rivers as they leave Ethiopia are incised below the adjoining plains by about 30 – 50 meters. The kerib land (light blue) around Showak can be seen on the Landsat TM image (Map 46) with the gullies reaching back into the cultivated land on the plains above the river. Along the river itself is irrigated or flood retreat cropping (bright green).

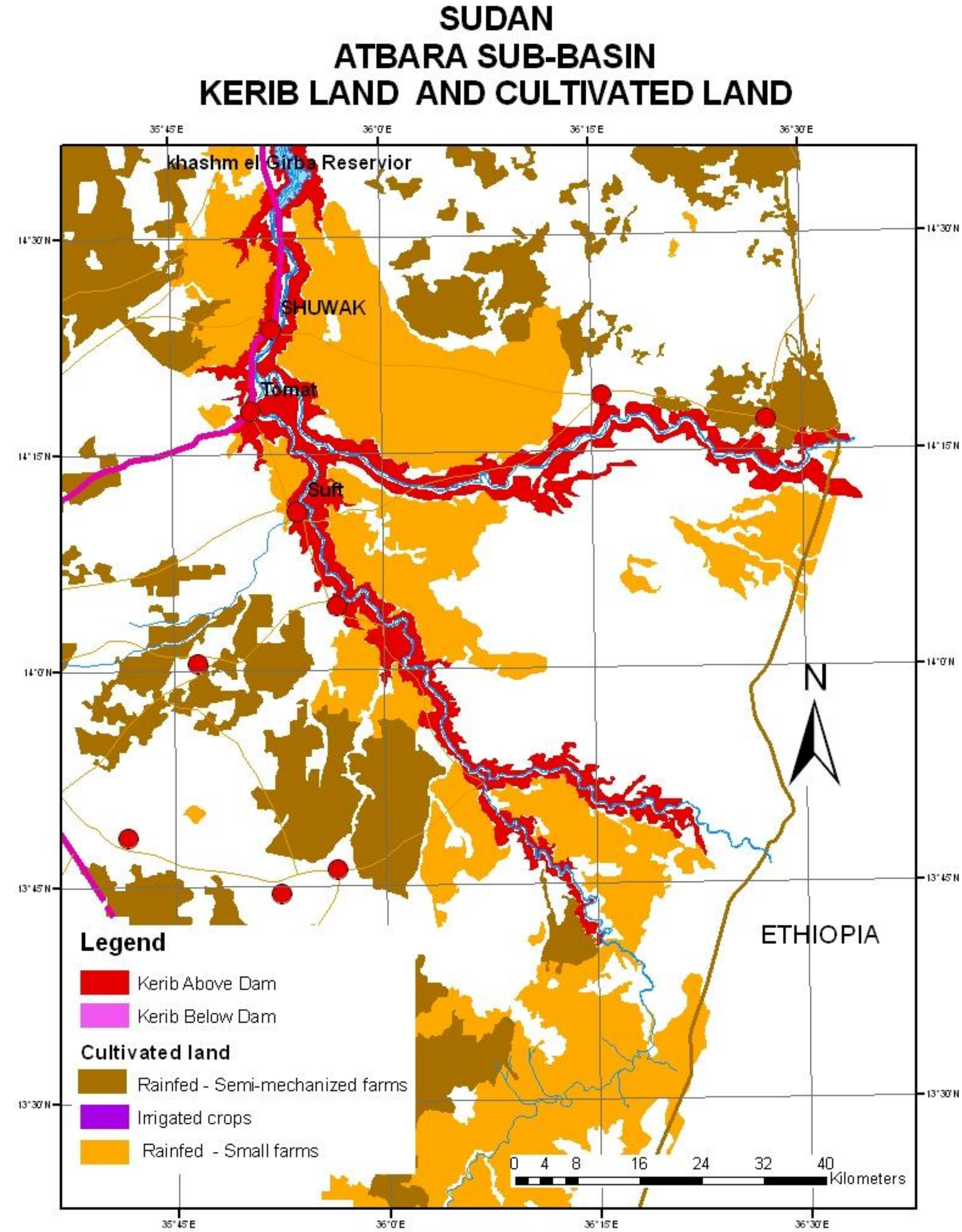
The plains are overlain with Vertisols (black cracking clays). The Vertisols develop very wide cracks during the dry season. At the onset of the rains water enters the cracks. Whilst the soils are covered with deep rooted vegetation there is no problem as roots take up any excess sub-soil water.

However, once this vegetation is removed there is excess water in the subsoil and tunnels develop along the deep cracks. These eventually collapse leaving an incipient gulley. These gradually extend back into the plain stripping the soil away from the underlying weathered rock. The weathered rock is quickly gullied. It is estimated from examining successive aerial photos that the kerib land is stripping back at a rate of 100 meters a year, which is 10 hectares per kilometer on each side of the river or approximately 3,000 hectares of land a year in total. Most of this land lost is under cultivation.



Map 48. Atbara Sub-basin: Kerib land around Showak at the junction of the Atbara and Setit Rivers.

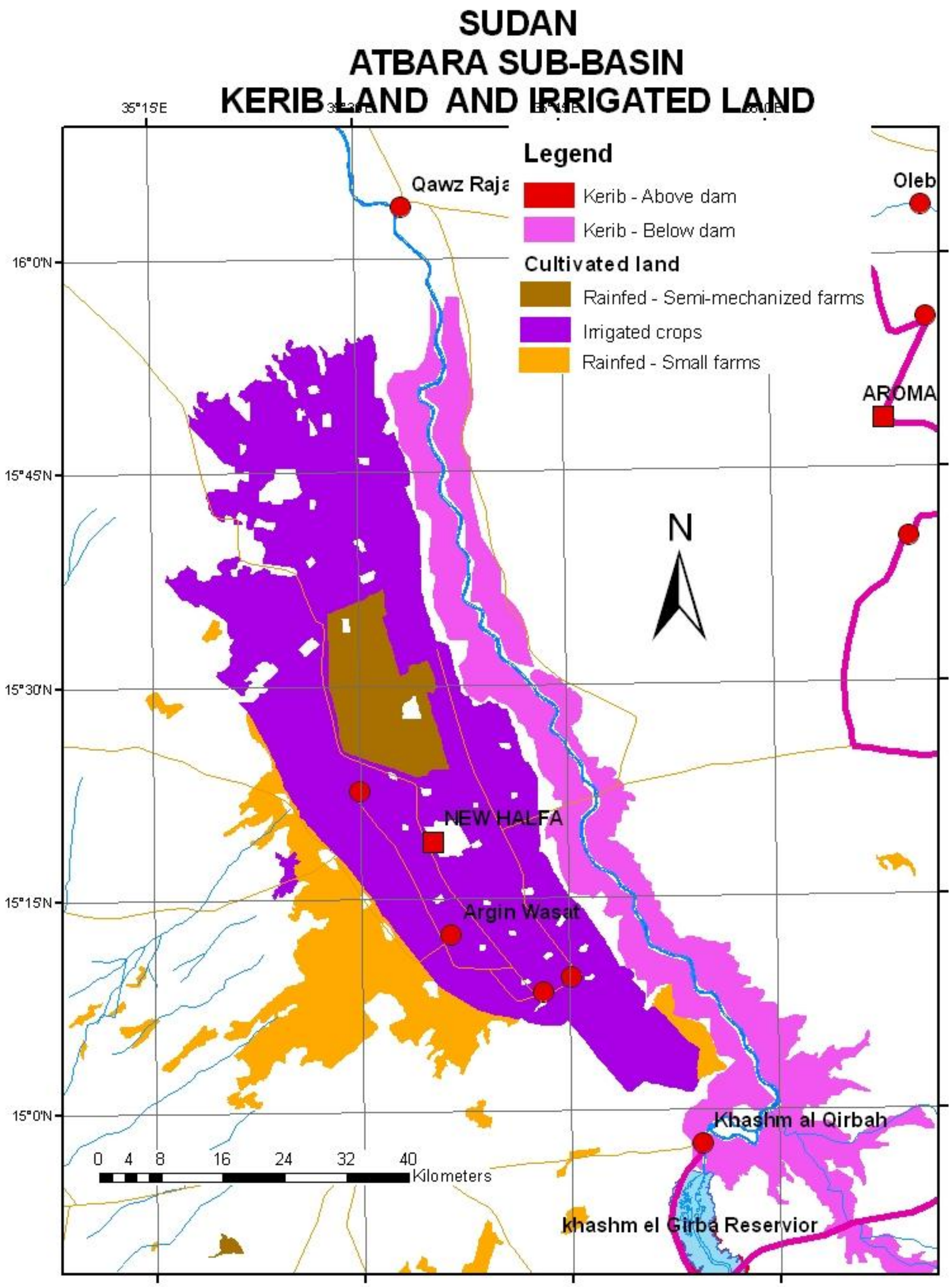
A survey undertaken in 1990 estimated 300,000 feddan (1,680 km2) of kerib land. An interpretation of 2005 Landsat TM imagery gave an estimate of 359,286 feddans (2,012 km2), of which some 145,536 feddans (815 km2) are above the Kashm el Girba dam and 213,759 feddans (1,197 km2) below.



Map 49. Atbara Sub-basin: Kerib Land in Relation to Irrigated and Rainfed Cropland.

Source: Sudan FAO Africover, 2003

Map 49 shows the distribution of kerib land above the Kashm el Girba Dam in relation to the patterns of rainfed cropping. Two types of rainfed cropping are recognized: large and small farms. The former are the large semi-mechanized farms whilst the latter are small-scale farmers with farms of about 5 feddans each. It can be seen from the map that **the extending kerib land threatens the small farms rather than the large semi-mechanized farms**. These are people who can ill-afford to loose any land because their holding are so small.



Map 50. Atbara Sub-basin: Kerib Land in Relation to the New Halfa Irrigation Scheme.
Source: Landsat interpretation

One component of restoration of the kerib land is to ensure that deep rooting vegetation covers the ground for 200 to 500 meters from the headwaters of the gullies. The difficulties of implementing this treatment are obvious. A substantial;

number of small farmers will have to loose their land. Kerib land below the dam adjoins the New Halfa irrigation scheme (Map 50).

It is not clear whether this kerib land is active or not. At points long the river there are places where it directly abuts the irrigation land. Map 51 indicates that the gullies may be breaching the irrigated land.

Map 51. Atbara Sub-basin: Kerib Land abutting the New Halfa irrigation Scheme.

8.4.2 Assessment of the Extent, Trends and Impacts of Sedimentation of the Atbara River

The mean annual suspended sediment load of the Atbara River at Kashm el Girba is estimated to be 79.2 million tons per year with an additional 41.3 million tons bedload. This gives a sediment yield over the whole catchment of 900 tons/km2/yr. On the Tekeze River in Ethiopia at Embade gauging station the sediment yield is 798 tons/km2/yr. Generally sediment yields decrease with increasing basin size (Walliong, 1982). The kerib land only starts on the Tekezi/Setit just inside the border within Ethiopia. The additional sediment yield could be ascribed to sediment derived form the kerib land. Nevertheless, the bulk of the sediment originates within the Ethiopian Highlands.

The Kashm el Girba dam was completed in 1964 to provide for irrigation of the New Halfa scheme, domestic water (to Shuwak and Gederef towns), hydro power generation and flood control. The reservoir covers an area of 125 km2 and extends 80 kms upstream of the dam.

The main problem is siltation in the reservoir and the necessity to allow the rising flood peak to pass through the dam to reduce siltation and allow sediment in the dam to be flushed out. The dam was constructed in 1964 with a capacity of 1.3 billion m3 to be able to irrigate an area of 0.5 million feddans (0.2 million ha). The mean annual suspended sediment load entering the reservoir is 79.2 million tons/yr.

Because of excessive siltation flushing in mid-August was instituted in 1971. Prior to flushing annual sedimentation was estimated at 12.3 million m3 and with flushing 7.0 million m3, a trapping efficiency of about 8 percent. In 1990 capacity had been reduced to 0.62 km3 (Diab and Mufadel Ahmed, 2003). At the current rate of sedimentation it is estimated that in 2006 it has only 39.6 percent of its capacity remaining and capacity is being lost at the rate of 1.13 percent per annum.

In addition there is a problem of siltation in the irrigation canals leading to excessive weed growth, reduced water delivery and increased costs of desilting.

These have had a substantial impact on the area irrigated in the New Halfa Scheme. The scheme covers some 447,000 feddans (190,000 ha) and was developed primarily to resettle people displaced by Lake Nubia at Wadi Halfa. It is designed to use 1.62 km3 of water from the reservoir for irrigated cropping as follows:

Cotton (summer):	110,000 feddan (46,200 ha)
Groundnut (summer):	110,000 feddan (46,200 ha)
Wheat (winter):	110,000 feddan (46,200 ha)
Total:	330,000 feddan (138,600 ha)

By 1997 the area irrigated had been reduced as follows:

Cotton:	56,000 feddan(23,520 ha)
Groundnut	47,000 feddan (19,740 ha)
Wheat	55,000 feddans (23,100 ha)
Total:	**158,000 feddans (66,360 ha)**

This is an overall reduction in area of 172,000 feddans (72,240 ha) some 52 percent. In addition crop yields declined over the same period. As a consequence crop production has declined significantly as shown in table 44.

Table 44. Average crop yields: 1967 and 1990 (tons/feddan)

Period	Cotton	Wheat	Groundnut
1967 - 71			
Area (feddans)	110,000	110,000	110,000
Yield (tons/feddan)	0.67	0.44	0.48
Total production (tons)	**74,370**	**48,840**	**53,280**
1984 – 1990			
Area (feddans)	56,000	47,000	55,000
Yield (tons/feddan)	0.37	0.38	0.53
Total production (tons)	**20,720**	**17,860**	**28,090**
% Reduction on 1967	**72%**	**63%**	**47%**

Source: Diab H. Diab & Mufadal E Ahmed (op. cite)

Sedimentation has caused the river bed at the reservoir tail to rise some 10.5 meters blocking the intake of the water supply for Gederif town (population in 1993 600,000). In 1988 the river overflowed its channel and flooded the treatment plant. Two 25kva generators, two diesel raw water pumps and a stilling basin were covered with sediment. During the dry season the river retreats to the eastern bank and a 300m channel has had to be cut to divert water to the treatment facilities. Three phases of expansion of the water works have had to be cancelled. Available water in Gederif town is down to 15l/day/capita well below the WHO standard.

8.4.3 Assessment of the Extent, Trends and Impacts of Environmental Degradation in the Gash Delta

(i) Background

The Gash rises as the Mereb River and in its upper reaches forms the border between Ethiopia and Eritrea. On debouching onto the plains near Kassala the river forms an inland delta where the water is used for flood irrigation, tree irrigation and finally surface flow is totally lost through evaporation and deep percolation. The mean annual discharge is 680million m^3, although it can range between 140 and 1,260 million m^3. The estimated bed load 0.5 to 1.5 million tons per year and the suspended sediment load some 4 to 11 million tons (UNESCO-HELP, 2004). Euroconsult (1988) estimated that some 11.4 million tons of sediment are added to the delta each year.

Annual flows are extremely variable and are concentrated within three months of the year. During the dry season the river ceases to flow. The amount of flood controls the amount of land that can be irrigated that year. It is difficult to manage the irrigation system because the river changes or re-shapes its course every year.

The water management system uses flush (or flood) irrigation. This was chosen because of the open Gash Valley there are no suitable dam sites. Flood on the eastern Gash are controlled using river walls, spur dykes and diversion structures.

(ii) Impacts of Sedimentation

The river bed is rising at a rate of 3 cms per year. However, during the flood at Kassala bridge the river bed may be scoured to a depth of several meters. The sediment is only deposited where water goes. Under natural conditions the distributaries were free to wander across the delta fan. Under the water management system used today sediment is deposited along the canals.

Average annual deposition of sediment in the canals is about 40 cms but at the entrance is 50kms. This deposition reduces the efficiency of the canals, whilst breaks in the canals cause erosion and complete loss of control of the irrigation water. A further impact of canal sedimentation is wed infestation which further reduces water flow. Crusting of the sediment in the fields impedes water infiltration and plant germination. Deposition on the river bed leads to canal off-takes being much higher than the surrounding land. This further increases the damage caused by breaks in canal walls.

Currently only 40,000 feddans can be irrigated due to breaks in the canals and sedimentation. In the 1930's some 300,000 feddans could be irrigated. Each year some 10,000 to 15,000 tons a year are dredged from each of the seven canals. In most years maintenance is required particularly around the off-take structures to avoid them being undercut or by-passed. Many off-take structures have to be reconstructed completely.

In an effort to reduce sedimentation in the canals, the sluices are kept shut during the first flood with heaviest sediment load – much in the same way the Roseires, Senner and Kashm el Girba dams are flushed.

The sediment management cannot just work on one canal in isolation. The whole water and sediment transport must rise as one, so that there is an equal amount of sediment in each section of the system. Thus, every so often each off-take structure must be rebuilt at a higher elevation.

Because each flood is different in timing and amount, the management system must highly re-active to rapidly changing circumstances. There is therefore a designed flood area of 40,000 feddans, which means in practice that in many years there is excess water or that many fields are over-irrigated. This excess water is released to the *balag* forest or to the Gash Die where it supports the natural woodland.

(iii) Impacts of Excess Draw-Down from Wells

Farmers have practiced perennial horticulture based on wells near Kassala since the 19^{th} century. By the 1950's there were 500 wells along the river. The number continued to increase because there are no restrictions on abstraction. In many cases diesel pumps have replaced the traditional shadufs and Persian wheels. The watertable is now extensively below 40 meters and falling. Previously, the gardens were small plots of fruit trees. These have been replaced in many cases by large fields on mono-cropped bananas and other fruit crops with high inputs of fertilizers and biocides.

(iv) Deforestation

It is unlikely that tree cover in the area was very extensive because of the very low rainfall. Woodland would be present only where surface was present or nearby, along the river or its khors. When under natural conditions a khor changed its course the tree cover along the old course would die off and new trees establish along the new course.

In 1923 the irrigation Advisor the Sudanese Government observed very dense ("impenetrable") woodland 24 kms north of Kassala, although he notes the problem of drifting sand into the new canals, which suggests that there was no cover in the central area of the delta.

However, more recent reports have raised concern about the shortages of fodder, fuelwood and building poles. DHV in 1989 noted with alarm the large amounts of charcoal being exported from the area to Kassala town, Port Sudan and even Khartoum. Further degradation of woodland is caused by lopping braches for fodder and the burning of woodland during hunting. Trees are also removed from the *misgas* when leveled mechanically. Some species such as the doum palm have almost completely disappeared.

8.4.4 Assessment of the Extent, Trends and Impacts of Natural Resource Degradation of the Semi-mechanized Farms in the Atbara, Blue Nile and Sobat-White Nile Sub-basins

Within the three Sub-basins in Sudan there are approximately 16.98 million feddans (7.13 million ha) of large to medium semi-mechanized farms (SMF)[11]. However, a proportion of this land has gone out of production and in some cases has been abandoned. The FAO/WFP crop survey for 2004 estimated cereal production from the SMF Sector for the three Sub-basins as 986,000 tons. Average yields are 0.36 tons per ha, which suggests that approximately 6.52 million feddans (2.74 million hectares) were under crops. This suggests that in 2004 (an average rainfall year) only 38 percent of the SMF land within the three Sub-basins was cropped.

Land is rented from the government at about £S1 per feddan (0.4 ha). Sorghum occupies about 80 percent of the area, with sesame and some cotton occupying the remainder. According to an ILO report in 1976 the advantages were seen to be:

- Employment generation,
- Contributing to expanded food supply for domestic consumption and for export.
- Have a low demand for public services and support compared with peasant agriculture or large irrigation schemes.
- Mobilizes private investment.

However, the complete removal of vegetation and the consequent removal of natural predators (snakes and cats) have led to an increase in rats and other vermin. Insect eating birds have disappeared leading to a big increase in the use of insecticides and insect damage.

The soils of the Butana Plains require that at least 25 percent of the land should be fallowed at any one time. Soil analyses indicate the absence of a reserve of weatherable minerals capable of releasing plant nutrients and a low level of total available plant nutrients. Traditional farmers aver that land should not be cultivated continuously for 5 years without being left to rest for a further six to ten years.

[11] Africover mapping of rainfed cropping with large to medium size fields.

In the Gederef area the available evidence shows that yield potential on newly cleared land declines from 1,000 kgs per feddan to about 100-200 kgs per feddan after 6 to 10 years of continuous cropping (Kibreab, 1996). Continuous mono-cropping of sorghum mines soil nutrients. It is reported that the SMF's cultivate continuously without using fertilizer for 6 – 8 years then abandon the land and open up new land illegally in un-demarcated areas. Traditional farmers extend the period of cultivation by rotational cropping sorghum with sesame.

Continuous cultivated results in a loss of soil structure and an increase in sand fraction. This is further exacerbated by soil compact from the use of heavy machinery. All lead to a reduction in soil moisture holding capacity. As crop residues are cleared from fields (to facilitate mechanical cultivation) soil organic matter also declines further reducing soil moisture holding capacities. Given the low and variable rainfall in the Sub-basin this has a significant negative impact on crop yields.

During the 1990's the area harvested on the SMF's contracted by 2.4 percent per annum whilst yields declined even further by 5.1 percent per annum (World Bank, 2005). This resulted in a decline of GDP from SMF Sector of 6.7 percent. These declines are due to a decline in soil fertility in the absence of 25 percent fallowing, a build-up of weeds (including striga) and to an expansion onto marginal land.

Using the above area decline figures for the Atbara and Blue Nile Sub-basins would indicate that some 50,000 feddans (21,000 ha) a year are being abandoned. Assuming an average yield of 0.210 tons per feddan, there is an annual (cumulative) reduction in production due to declining yields of 20,400 tons of sorghum.

8.4.5 Assessment of the Extent, Trends and Impacts of Natural Resource Degradation of the Small-scale Traditional Farms in the Atbara and Blue Nile Sub-basins

Approximately 1,129,240 feddans (474,280 ha) of small-scale rainfed cropping has been mapped in the Atbara (7 percent) and the Blue Nile (93 percent) Sub-basins. The problem of soil nutrient depletion and degradation on traditional held land is not as severe as on the SMF land. This is because traditional farmers are to some extent able to fallow their land. In addition they do not use heavy machinery to cultivate the land. Finally, most traditional farmers practice crop rotation with sorghum followed by sesame, which although does not increase soil fertility does reduce the build up of weeds (particularly striga).

Nevertheless, because of the encroachment of the SMF's the land available for fallowing has decreased leading to longer periods of cultivation. This in turn leads to declining soil fertility and an increase in weeds. Farmers' do not use manure on their fields as they say that it spreads weed seeds and leads to a build of weeds. Crop residues are removed from fields as livestock feed, construction material and to facilitate tractor operations. A survey undertaken in Gederef District some 93 percent of farmers reported that crop yields have declined drastically over time (Kibreab, 1996). They reported that the average holding of 25 feddans (10.5 ha) was no longer sufficient to provide subsistence and a small surplus, whereas some 20 years ago 3 feddans (1.26 ha) was sufficient. This indicates another impact of declining soil fertility – the need to increase the area cropped – with the consequent impact of reducing the pool of land for fallowing.

8.4.6 Assessment of the Extent, Trends and Impacts of Conflict over Natural Resources: Loss of Rangeland for Pastoralists in the Atbara and Blue Nile Sub-basins

Conflict over natural resources occurs everywhere although the levels and intensity of conflict vary. Conflicts may have social, political or economic dimensions and can occur at all levels from the household, local, regional, national and global (Buckles and Rusnak, 1999).

Conflicts occur for a number of reasons. Firstly, natural resources form part of inter-linked environmental systems where activities at one site can generate effects at a far off site. River basins are a clear example, where upstream soil erosion can result in down stream sedimentation. Often the exact nature of these linkages is not clearly understood: the soil erosion-sedimentation linkage is an example.

Secondly, natural resources are embedded in social and economic systems where complex inter-relations exist among a wide range of stakeholders: small-scale farmers, transhumant pastoralists, large-scale mechanized farmers, managers of state owned irrigation schemes, downstream water users. This is the nexus of a complex arena of power play and influence amongst the various stakeholders.

Thirdly, natural resources are subject to increasing scarcity and change. With increasing rural population, pressures on natural resources increase through the expansion of agricultural land, increased numbers of livestock and the need for increased grazing area, and the increasing demand for biomass fuel sources. In many cases these pressures are exacerbated by external factors. These “exogenous” pressures are frequently a result of State policies.

Finally, natural resources often have strong “symbolic” values to the various stakeholders. Natural resources are not merely material resources to compete over but are also a “way of life”, often linked to an ethnic identity and also to a set of gender and age roles (e.g. amongst pastoralists).

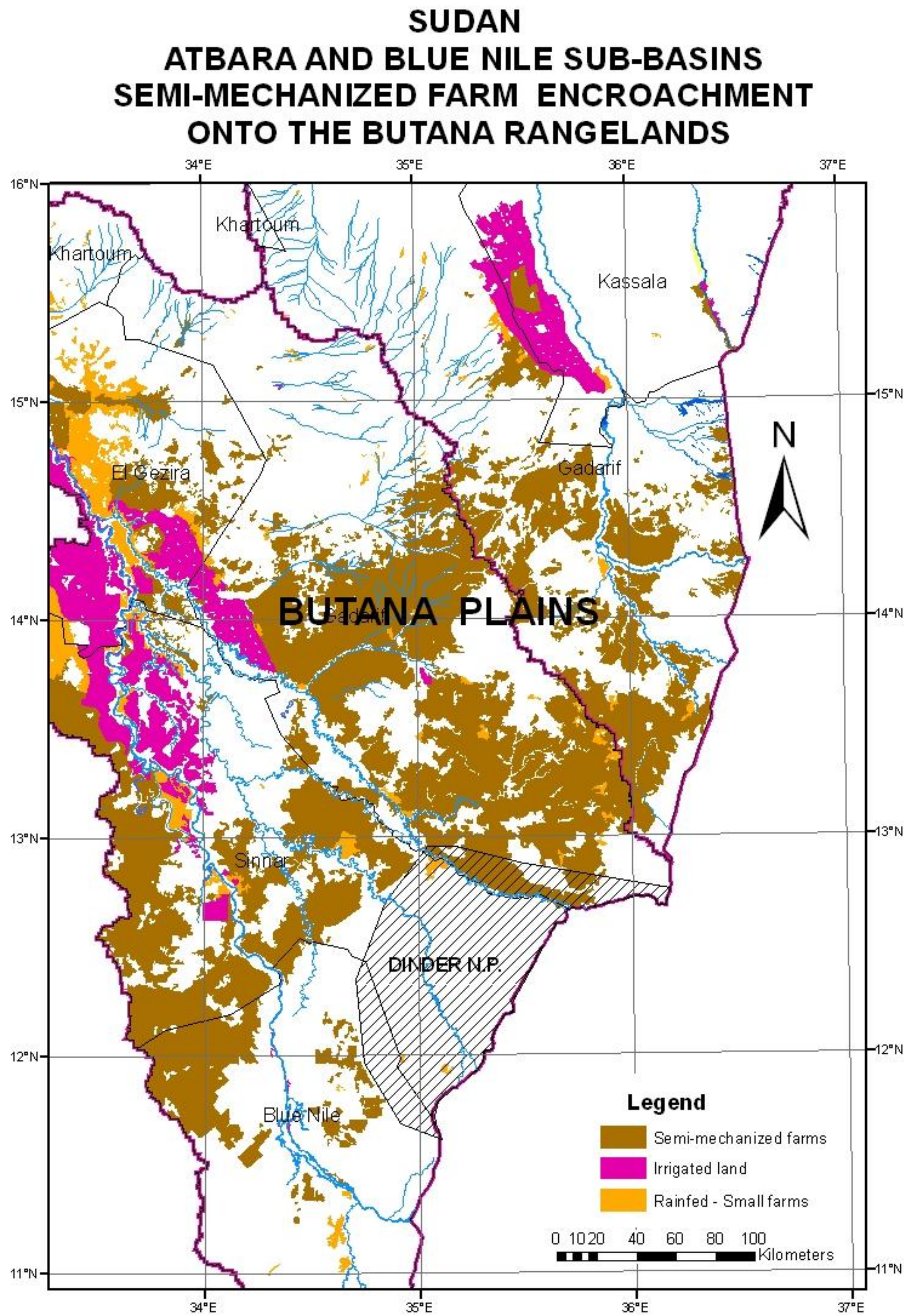
Pastoralist use large areas of the Atbara and the northern Blue Nile Sub-basins that constitute the Butana Plains. Over the past three decades there has been a massive expansion of semi-mechanized farms over the wet and more latterly the dry season grazing areas of a number of pastoralists groups (Babiker Abbas, 1995). As well as taking up valuable pastures these large farms have formed an effective barrier cutting off the wet season grazing areas of the western and northern Butana. The eastward expansion of the SMF's have more recently encroached on the dry season grazing areas close to the border with Ethiopia.

As the pools dry up and grazing becomes short on the Butana Plains at the end of the wet season the herds move to the south to the Rahad and Dinder Rivers. With the smaller areas of pastures because of the encroachment of the SMF's, pasture deficits are occurring earlier, and the southward movements of livestock now occur before the harvesting of crops in southern Gederef. This has led to a surge of conflicts between the Commercial Farmers and the pastoralists.

Further conflicts have arisen between the interests of the State in conserving natural resources and biodiversity in the Dinder National Park and natural resource users in the surrounding area (Yagoub Abdalla Mohamed, 2005). The Park has an area of 1.6 million feddans (896,000 ha). The Park is a source of water and fodder during the dry season and given the lack of water and fodder in the traditional dry season areas, the pastoralists have no option but to encroach into the park.

A further factor in the assessment of conflict over natural resources and rangeland degradation has been the steady increase since the 1940's of people from western Sudan and even from further west from Chad and Nigeria. More recently as a result of drought and civil war there has been a larger and more sudden influx of displaced peoples both from within Sudan and from Ethiopia and Eritrea[12].

[12] Most of the latter have returned to Eritrea and Ethiopia.



Map 52. Atbara and Blue Nile Sub-basins: Encroachment of Semi-mechanized Farms onto Butana Rangelands
Source: Sudan FAO Africover, 2003

8.5 Blue Nile Sub-basin

8.5.1 Assessment of the Extent, Trends and Impacts of Erosion

(i) Gully Erosion (Kerib)

The main erosion problem in the Blue Nile Sub-basin is the gully erosion along the Blue Nile and Dinder Rivers producing kerib land. The Dinder is gullied for about 50kms upstream from its confluence with the Blue Nile. The Rahad River does not appear to be affected except very locally near its confluence with the Blue Nile. However it is not as extensive nor has it gullied back to the same extent as it has along the Atbara. Most the kerib land along the Atbara has gullied upto 2.5 kms from the river, whilst along the Dinder it about 500 meters. It is possible that the Dinder is not as incised as the Atbara River.

As no information is available on erosion rates it is difficult to estimate the impact on loss of cultivated land.

(ii) River Bank Erosion

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

8.5.2 Assessment of the Extent, Trends and Impacts of Sedimentation

Studies by the Hydraulic Research Station of Sudan (Salih Hamid Hamid, 2001) report that peak sediment concentrations in the Blue Nile, Rahad and Dinder rivers are 7,000 ppm, 1,200 ppm and 500 ppm respectively. Infrequent, unsystematic and incomplete suspended sediment data for the El Deim gauging station is available. This has been analyzed by Group 1 of the NBCBN/River Morphology Research Cluster (Ahmed Musa Siyam et al., 2005). They estimated that the long-term mean annual suspended sediment load at El Diem to be 123M tons. They estimated bedload to be 15 percent giving a total mean annual sediment load of 140M tons. This figure gives an annual sediment yield for the

Blue Nile basin in Ethiopia of 700t/km2/yr and a sediment delivery ratio of 45 percent. This figure is similar to SDR's quoted by Walling (1983)[13] for central and eastern USA. The estimate is lower than that for the Tekezi basin (between 800 t/km2/yr and 65 percent respectively).

The two main dams in the Blue Nile Basin are Roseires completed in 1966 with a storage capacity of 2.4 km^3 and the Sennar completed in 1925 with a capacity of 0.7 km^3. The hydro-electric facilities at each of the dams have installed capacities of 250MW and 15MW at Roseires and Sennar respectively.

Both dams are affected by siltation. The Sudan Ministry of Irrigation and Water Resources report that sedimentation in the Roseires Dam rose from 300 million m^3 in 1970 to 1,264 million m^3 in 2000 resulting in a loss of 38.3 percent of its designed capacity. It has completely filled the dead storage and is now reducing the live storage. The present storage capacity is just sufficient the present irrigation demand in a year with 80 percent reliability. Currently, the retaining wall is being heightened by 10 meters. This will increase the live storage by almost three times to about 7.0 km^3.

Siltation the Sennar Dam has reduced the live storage from 600 to 480 million m^3 a reduction of 20 percent. As well as the loss of storage impact on crop area that can be irrigated there is also a reduction of hydro power generation. In addition, there is damage to turbine blades caused by the heavy suspended sediment.

Because the dam gates have to be kept open and turbines closed down during the high flood peak to avoid excessive siltation there are corresponding losses of irrigation water and hydro power.

It is estimated that sediment concentrations in the water diverted into the Gezira Irrigation scheme have increased by a factor of four times over the past 50 years[14]. Measurements of quantities entering the Scheme and that cleared have been undertaken by Hydraulic research Station at Wad Medani since 1988 and are shown in table 45.

Table 45. Quantities of Sediment Entering the Gezira Scheme and that cleared for the period 1988-2000.

Year	Entering Gezira Scheme			Silt Cleared	
	million tons	million m^3	Cumulative	million m3	cumulative
1988/89	6.96	8.70	8.70	6.44	6.44
89/90	4.66	5.83	14.53	6.52	12.95
90/91	6.60	8.25	22.78	12.84	25.80
91/92	7.70	9.63	32.40	13.48	39.28

[13] Walling,D.E. (1983) “The Sediment Delivery Problem", J. of Hydrology vol. 68, pp. 209-237.
[14] DIFID (accessed 2006) "Large scale Irrigation: Sediment Control".

92/93	4.24	5.30	37.70	10.34	49.62
93/94	4.00	5.00	42.70	12.00	61.62
94/95	3.60	4.50	47.20	13.49	75.11
95/96	8.00	10.00	57.20	14.20	89.30
96/97	5.60	7.00	64.20	10.25	99.55
97/98	6.50	8.13	72.33	10.03	109.58
98/99	7.40	9.25	81.58	6.92	116.50
99/00	8.51	10.64	92.21		
00/01	9.00	11.25			
01/02	10.00	12.51			
02/03	7.80	9.75			
03/04	9.70	12.13			

Source: Younis Abdalla Gismalla (2001 & 2005) "Sediment Monitoring Programme: Data Collection and Analysis for season 2000 and 2004", HRS, Wad Medani.

Generally some 90 percent of the sediment enters the scheme from the 1st week in July and the 3rd week of August (7 weeks). The proportion of the total entering the Managil Canal varies between 38 and 47 percent that of the Gezira canal.

Once into the system the sediment is deposited in the canals in varying proportions. The distribution pattern between 1988 and 1991 is shown in table 46.

Table 46. The Pattern of Sediment Deposition in the Gezira Scheme: 1988-1991.

Year	Sediment Input at km 57		Sediment deposit in canals						Total		Sediment passing into fields	
			Main & branch		Majors		Minors					
	mcm	%	mcm	%	mcm	%	mcm	%	mcm	%	mcm	%
1988	12.45	100.0	0.62	5.00	2.86	22.97	4.11	33.01	7.59	60.99	4.86	39.01
1989	5.83	100.0	0.29	5.00	1.34	23.00	1.92	32.96	3.55	60.96	2.27	39.04
1990	8.28	100.0	0.41	5.00	1.90	22.96	2.73	32.99	5.04	60.95	3.23	39.05
1991	9.78	100.0	0.49	5.00	2.25	23.02	3.23	33.04	5.97	61.06	3.81	38.94

Source: World Bank, 2000

Although the total amounts changes each year, the relative distribution of sediment among the various canal types remains very constant: with approximately 60 percent remaining ion the canals, and the remaining 40 percent passing into the fields.

Desilting of the 17,244 kms of irrigation and 10,650 kms of drainage canals in the Gezira scheme alone is an enormous and expensive operation. The estimated costs in 1995/96 to 1997-98 are shown in table 47.

Table 47. Expenditures on major operation and maintenance activities by the irrigation Water Corporation (IWC) – 1995/96 to 1997/98 (millions SD)

Actual annual expenditure	95 - 96		96 - 96		97 - 98	
	Amount	%	Amount	%	Amount	%
Silt removal	619.0	63.1	1,400.7	67.6	1,336.6	**51.6**
Weed removal	41.5	4.2	12.5	0.6	30.2	**1.2**
Pump OM	118.5	12.1	174.3	8.4	188.4	**7.3**
Other OM	201.9	20.6	484.9	23.4	1,035.5	**40.0**
TOTAL	**981.0**	**100.0**	**2,072.4**	**100.0**	**2,590.7**	**100.0**

Source: World Bank (2000)

Because of the slow moving water and siltation weed growth is an additional problem.

High sediment loads in the rivers used as sources for domestic and industrial water supplies cause problems and additional expenditures for water treatment plants.

8.5.3 Assessment of the Extent, Trends and Impacts Wetlands

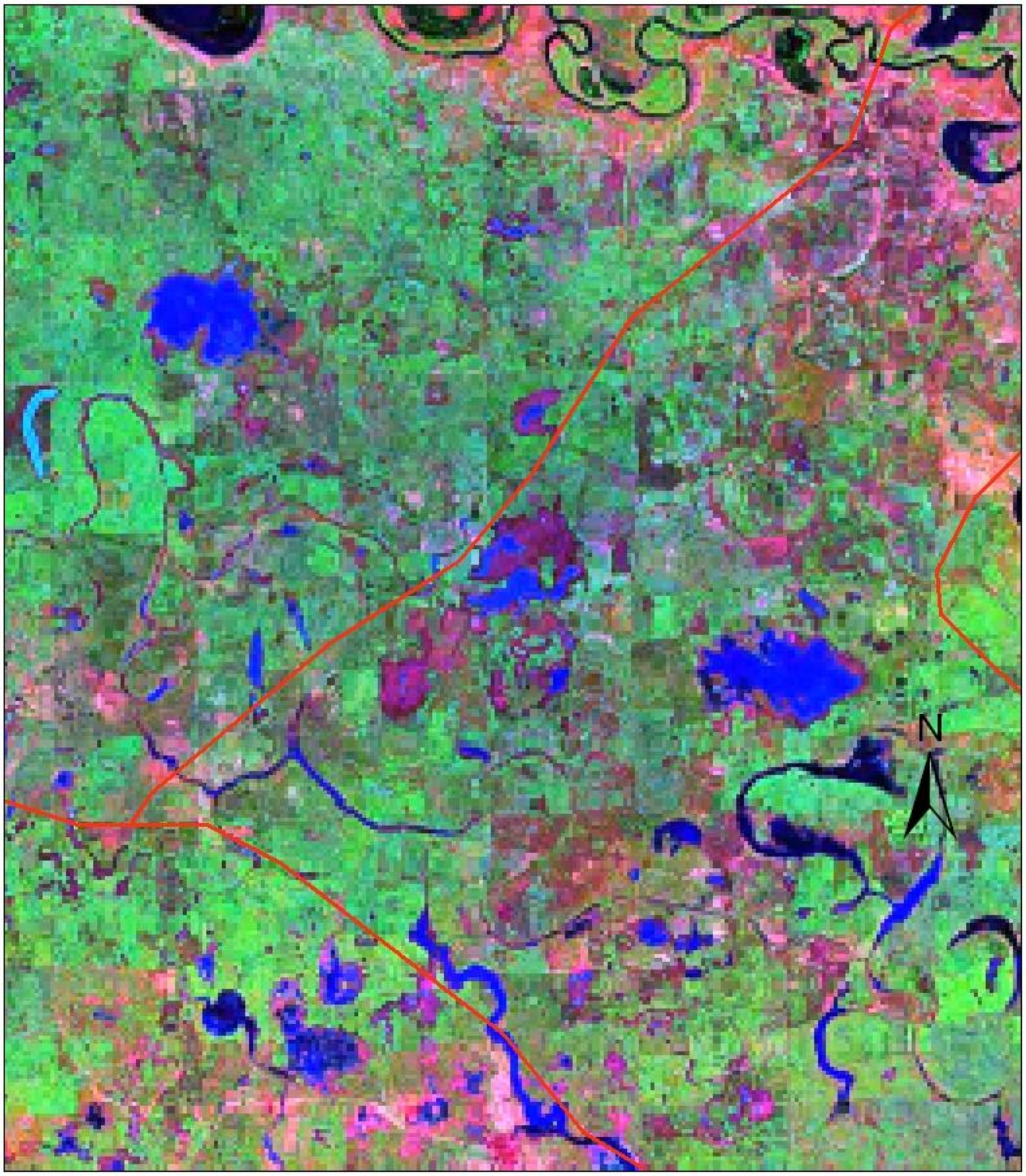
Wetlands are important components of the hydraulic system. However, they are part of environmental, socio-economic and household livelihood systems which influence and are influenced by them (Abbot and Aferwork Hailu, 2001). The hydrological system is the key environmental linkage. Upper-catchment and upstream wetland land use affects spring and stream flows and groundwater recharge. These in turn affect the sustainable on-site wetland use such as cropping, grazing and reed collection. Similarly, these on-site activities will affect users of the wetland downstream. These complex hydrological processes have implications for wetland management and management institutions not only at the local level, but also at the State and National levels in terms water policies, institutional and cooperative mechanisms and legislation.

The agricultural system has close linkages to the wetland system through cropping systems within the wetland, grazing systems and other extractive systems (reed cutting, apiculture, medicinal plant collection). The system has internal linkages to population growth, labour and oxen constraints, indigenous knowledge, urban market opportunities (e.g. for vegetables), livestock holdings and the need for forage.

Both systems have very close linkages to households and their livelihood assets and their food security strategies. Wetland cultivation and grazing provide important elements in households' food security strategies. Wetland conservation, which protects the natural state of wetlands has important social and economic benefits to local users. It is the poorest members of the community who rely most heavily on wetlands for collection of reeds and craft products for sale as well as for water supply. Conversion to agriculture can seriously jeopardize the hydrological functioning of the wetland and reduce or destroy its environmental services (stabilizing runoff, water purification, hydrological recharge, biodiversity) and natural products (reeds, water supply, medicinal herbs).

The main wetlands in the Blue Nile Sub-basin are located on and between the Dinder and Rahad rivers and are locally known as "*maya'as*". These are depressions along and between the rivers. The area way from the river is covered with fossil streams and rivers. The depressions are abandoned meanders which have formed forming "ox-bow" lakes. These lakes however are ephemeral as they gradually silt up, fill with swamp vegetation and then as they silt up dry out.

SUDAN
BLUE NILE SUB-BASIN
MAYA'A WETLANDS
AND SEMI-MECHANIZED FARMS



Map 53. Blue Nile Sub-basin: Example of Maya'a Wetlands between the Dinder and Rahad Rivers.

The vast majority of these wetlands are found outside the Dinder National park and most are within large to medium semi-mechanized farms. The area shown in map 53 is largely covered with large rainfed farms. There appears to be very few of these wetlands within the park. Thus the greatest danger to the Dinder-Rahad wetlands is from agriculture.

This area is frequently subject to severe flooding. Wetlands have the capacity to "buffers" flood peaks allowing the flow to pass through the system more easily. Many of the Dinder-Rahad wetlands are now cutoff from the main river systems by the expansion of large-scale rainfed agriculture. It is not known how far this is responsible for the recent flooding and far they are due to silting up of small lakes and ponds from sediment derived from the Ethiopian highlands. However, it is a subject that requires immediate and detailed investigation.

8.5.4 Competition between Biodiversity Conservation and the Human Utilization of Natural Resources in the Dinder National Park

The Park, which was proclaimed in 1935 is located within three States: Sennar, Blue Nile and Gedarif. It boundaries follow to the north of the Rahad in the north, to the south of the Dinder in the south and the Ethiopian border to the east, and covers an area of 8,960 km^2. It is also a designated Biosphere Reserve and has been designated under the Ramsar Convention as an international Wetland. Immediately across the border within Ethiopia the Amhara regional State have designated an area as the Alatish National Park

The Park lies on a transition ecotone between two floristic regions: the Ethiopian High Plateau and the arid Saharan-Sudanian biomes. It also lies along the boundary of two major faunal Realms of the world: the Palearctic and the Ethiopian. It is also located along a major north-south flyway of migratory birds.

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

- The proximity of the Park to the desert and semi-desert makes it an important buffer zone for the vegetation cover of central Africa in addition to its significance in providing genetic material for the rehabilitation in the semi-arid and arid areas.

- The park is an important watershed area protecting the most important feeders of the Blue Nile, the Dinder and Rahad rivers.

- The Park, together with the southwestern corner of the Ethiopian Plateau make a complete Ecosystem for wild animals, for which the Park is the dry season habitat for migratory species.

- The park supports a high diversity of fauna and flora, including such animals of international conservation importance as the African elephant, African buffalo and the lion.

There are three groups of people who have an interest in the park. The first is the original inhabitants of the areas - a small group of Maganu people who continue to live in the southeastern part. This community has a unique culture that needs to be preserved. They depend on subsistence farming in the rainy season and supplement their diet by collecting fruits and wild honey. In the dry season they move to the Dinder for fishing.

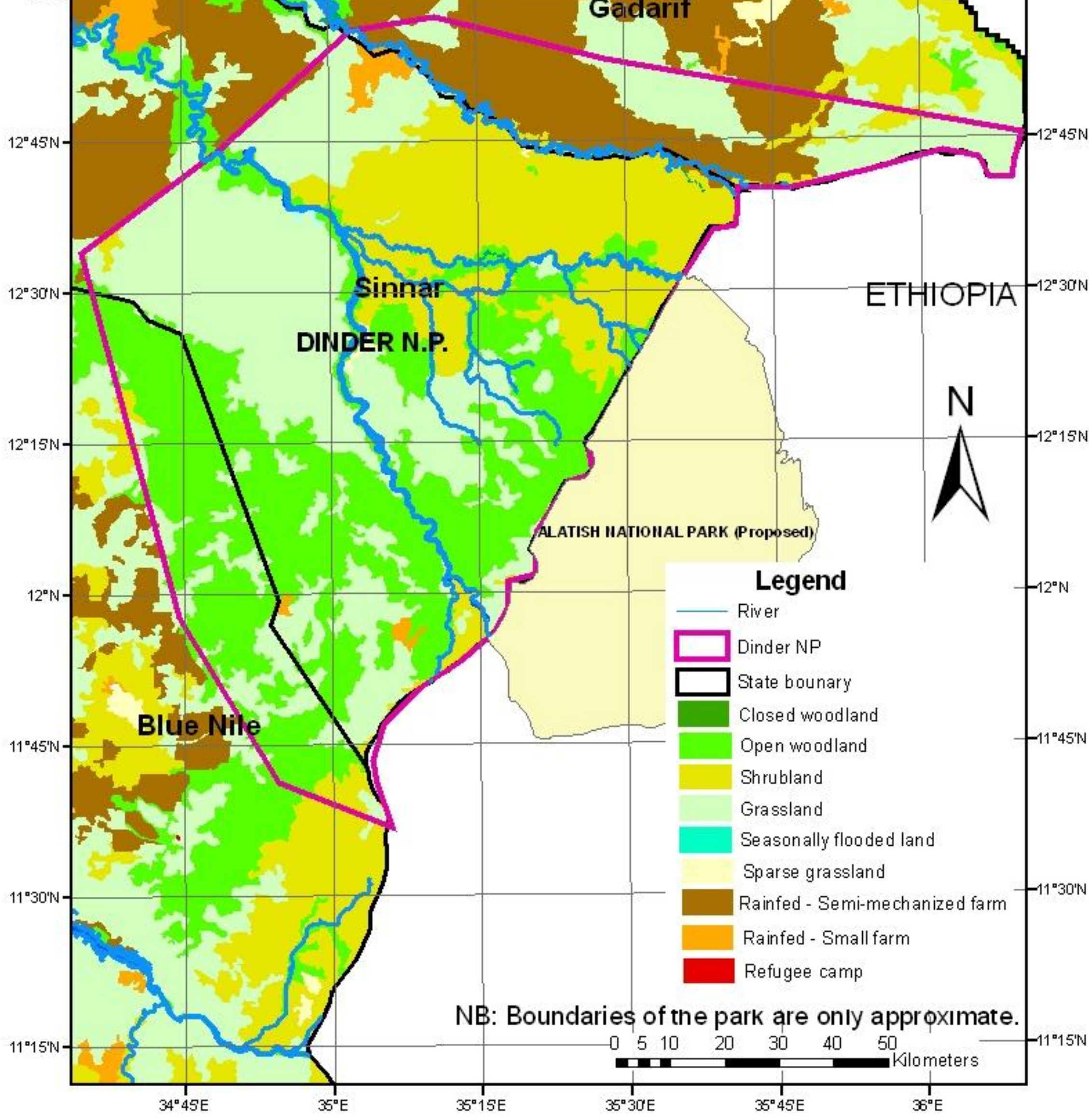
The second group are pastoralists and agro-pastoralists who enter the Park in the Dry Season looking for forage and water because much their rangeland has been converted into semi-mechanized farms. Included in this group are the Um Barrarow or Falata who use the Park in the dry season along the Dinder River and move into Ethiopia during the wet season. They burn the tall grasses in the dry season to make green grass available, but in doing so eliminate susceptible herbs and shrubs.

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

The Dinder and the Rahad Rivers and their tributaries drain the Park. They rise in the Ethiopian Highlands and are highly seasonal almost drying out in the dry season. Due to the abrupt change in gradient the rivers meandering a large number of cut-off meanders have been formed locally called *Maya'as*. They are generally flat and cover an area some 0.16 to 4.5 km2. Rain and flood water fill them during the rainy season. The maya'as provide a valuable source of water and forage for domestic livestock and wildlife, as well as unique habits rich in biodiversity.

Under natural conditions there is a constant evolutionary sequence of the formation of young maya'as that are deeper with clear water. Gradually they pass through stages of becoming gradually silted up. Over long periods of time with the meandering new maya'as are being formed. The spectrum runs from young productive maya'as to old non-productive dry ones.

With the accelerated erosion in the Ethiopian Highlands this gradual and long term evolutionary process has been disturbed because increased flood peaks and high sediment loads. The area is now subject to annual flooding and many of the Maya'as are becoming silted up with a consequent loss of habitat biodiversity and forage productivity.



Map 54. Sudan: Dinder Landcover in the Dinder National Park and Surrounding Area

8.5.5 Assessment of the Extent, Trends and Impacts of Loss of Rangeland for Pastoralists in the Blue Nile and northern Sobat-White Nile Sub-basins

(i) Background

Pastoralist use large areas of rangeland in the Blue Nile and Sobat Sub-basins. As with the Atbara and northern Blue Nile Sub-basin the pastoralists and agro-pastoralists in the southern Blue Nile Basin and the northern Sobat Sub-basin have come into conflict with other land users over scare natural resources.

The area in question[15] lies south of the Gezira and the Managil Irrigation schemes, to the north of the *Khor Yabus* and the Machar swamps, with the White Nile to the west and the Blue Nile to the east. However, access to the Blue Nile is not possible because the of the many pump irrigation schemes.

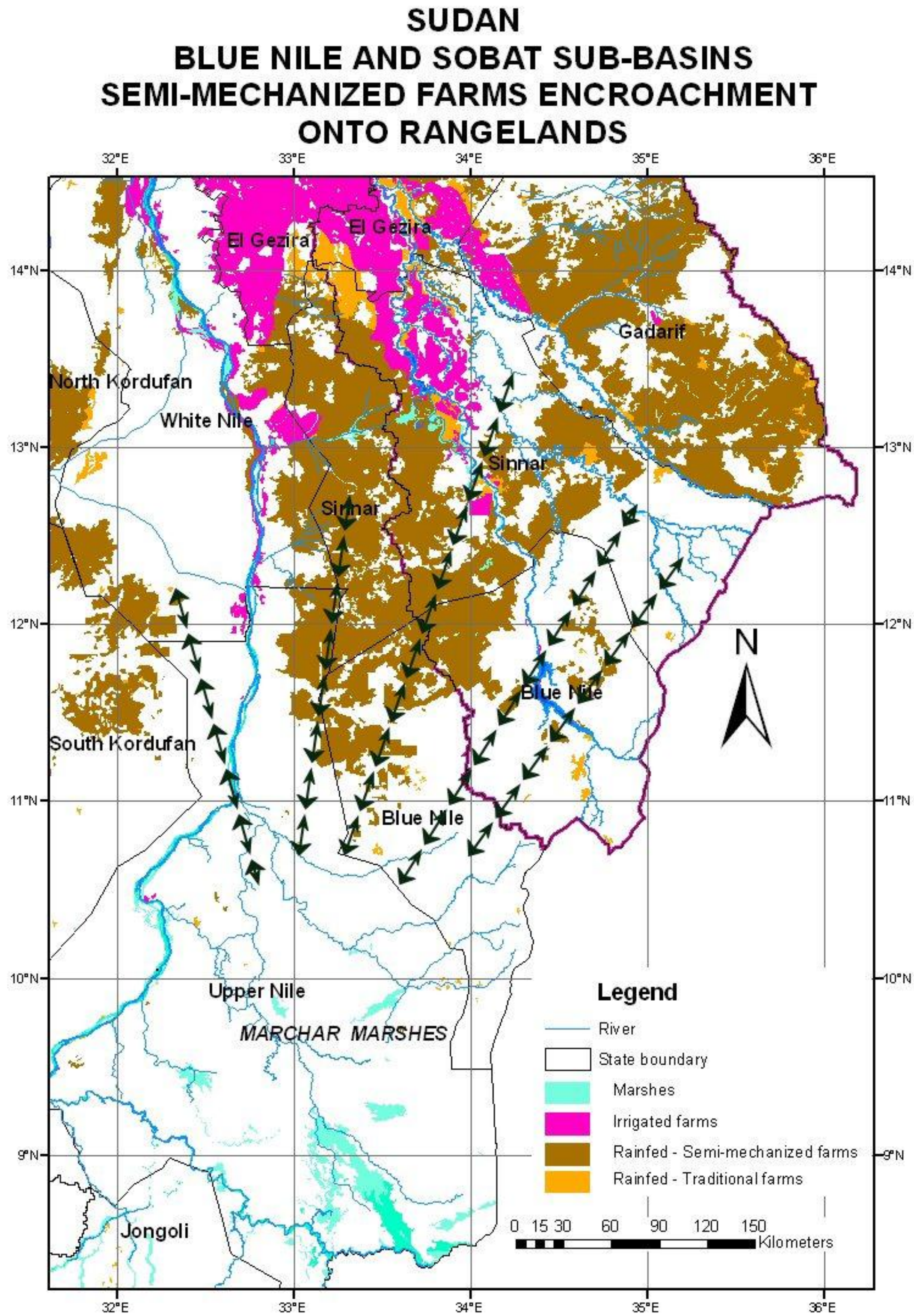
The area comprises mainly a clay plain with the Ingessana Hills rising some 300m above the plain. Mean annual rainfall varies 400 mm in the north to 700 mm in the south, falling between July-September. Natural vegetation types mirror the rainfall pattern with scrub-grassland in the north, merging into Balanites-Acacia seyal shrubland/woodland then into savanna woodland. The southern boundary comprises the Machar Swamps. In the higher rainfall areas biting flies are especially troublesome during the rainy season precluding livestock at this time.

(ii) Stakeholders

The primary stakeholders involved are as follows:

Rufa'a al-Hoi: an Arab speaking Muslim nomadic people with sheep, cattle and camels are divided into two groups: the northern Badiya located on the Blue Nile (dry season) and who move north towards the Dinder River (wet season); and the southern Badiya who 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. They see the whole area as their homeland ("*dar*") and traditionally held rights of land distribution, rights that waned following the abolition of the Native Authorities and never recovered following their reestablishment. These rights have recently been seriously challenged by sedentary peoples, including sedentarized Rufa'a al-Hoi.

[15] known as the "Funj".



Map 55. Blue Nile and Sobat Basins: Encroachment of Semi-mechanized farms onto Pastoral Grazing Areas
Source: Sudan FAO Africover, 2003.

Kenana: an Arab speaking pastoralists who move between the Blue Nile northwards beyond the Dinder River. They come into contact with the northern Badiya group of Rufa'a el-Hoi along the Blue Nile.

Ingessana: name given to the people living in the Ingessana Hills with a distinctive language and culture. They are predominantly agriculturalists cultivating the foothills. Cattle, goats and camels are socially and economically important. Livestock are kept in the hills during the wet season and move either south-eastwards to the Machar Marches and the Yabus, and to the east to the Blue Nile and the border with Ethiopia. They maintain a spirit of cooperation with the Rufa'a al-Hoi and many Ingessana work as herders for them.

Fulani: 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 a 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.

Baggara: an Arab speaking pastoral people from west of the White Nile who 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, their home area being west of the White Nile.

Sedentary Peoples: as well as the Ingessana there are a number of smaller groups who practice sedentary agriculture. These include the Berta, Gumuz and Burun, and along the Blue Nile many peoples from western and northern Sudan who arrived after the Mahdist rule. 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.

Owners of Large-scale Semi-mechanized Farms: Development of the "Mechanized Cultivation Schemes" (MCS's) started in Dali in 1956 and continued through the 1960's and 1970's but accelerated in the 1980's under the Government's policy of agricultural transformation. Their farms now cover a large area between the White and Blue Niles as far south as Roseires on the Blue Nile and Renk on the White Nile

(iii) Change in Resource Use and Livelihoods: 1970 -2000

The large semi-mechanized farms that were developed from the early 1980's now completely block the grazing routes of the Rufa'a al-Hoi and the Fulani to the wet season grazing areas in the north around Jebel Moya and Jebel Sang. This has removed an enormous grazing resource and water points (hafirs) from their control as they are now confined to areas south of the Khor Doleib. In addition, the development of the mechanized farms cleared large areas of the gum trees (A. seyal), which had provided an important component of the livelihoods of the Rufa'a al-Hoi.

Two additional factors have had a major impact on the livelihoods of the pastoral peoples in this area. Firstly was the 1983-84 drought, which decimated many of the herds and from which a significant number of families never recovered. The second major factor was the civil war that put the grazing areas of the southern limits out of bounds for the Rufa'a el-Hoi, the Fulani and the Ingessana. This further constricted the remaining grazing areas (Abdel Ghaffar Ahmed, 2002).

(iv) Environmental and Social impacts

Environmental Impacts: These factors have had impacts on the grazing strategies. Herds must now remain in the Dry Season grazing areas much longer and have to suffer the depravations of biting flies. Camps stay much longer in the same place and around these areas the vegetation has been permanently removed. Elsewhere the rangeland has become seriously degraded.

Social Impacts: The Fulani now move westwards (instead of southwards) in the Dry Season bringing them into conflict with Baggara. With such a restricted area for grazing, the potential for conflict among the four pastoralist groups and the sedentary peoples has also heightened, particularly during the cropping season, with increased incidence of crop damage from grazing animals. Traditional conflict resolution mechanisms are breaking down with the changing power relationships between the various groups. Conflicts are more often taken to the courts rather than being settled on the spot.

Impacts on Livelihoods: The Rufa'a el-Hoi have been particularly affected. Livestock feed deficits combined with drought have decimated the herds of many families. This combined with the loss of the gum gardens has left many families destitute. The mechanized farms have taken over the land previous used for cropping. The net result is that some 75 percent of the Northern Badiya and some 20 percent of the Southern Badiya have become forced to sedentarize. This in turn has lead to problems as the sedentarized Rufa'a el-Hoi try to settle on land they see as their right they come into conflict with the now powerful interests in the sedentarized village councils, and find difficulty in gaining access to crop land.

8.6 Sobat-White Nile Sub-basin

8.6.1 Introduction

It is important to note that in this Sub-basin there are very close linkages between hydrology and ecology, and between the ecology and livelihood systems. Whilst much is known in general regarding these relationships there is a lack of detailed knowledge most particularly of the hydrology. It is known, for example that the hydrology of the Sobat and its wetlands (such as the Gambela Wetlands, the Machar Marshes and the Akobo-Sobat Marches) are subject to considerably more variability than for example that of the Bahr el Jebel and the Sudd Wetlands. The extreme seasonal and year-on-year variability have important implications for the livelihood systems and the way that they have adapted to these.

The rich diversity of hydrological and ecological conditions has given rise to a rich diversity of livelihood and socio-economic systems. These have over time developed a close response the seasonal changes in hydrology and ecology. Thus, any proposals for interventions in the hydrology require a detailed and sensitive understanding of these relationships.

The complex ecological conditions make for rich and varied patterns of habitats and species and genetic bio-diversity. The wetlands in particular support very distinctive flora and fauna that is uniquely adapted to conditions in the swamps. As with the hydrology there is a dearth of information on the ecology and biodiversity status of the Sub-basin.

Much of the variability in the hydrology is because some 70 percent of the water in the Sobat Sub-basin originates in the high rainfall areas of the Ethiopian Highlands. Formerly these highlands comprised vast areas of sparsely populated High Forest. These provided for relatively stable hydrological conditions. Under an exponentially increasing population pressure supplemented in part by in-migration, large areas are being converted to small and large scale agriculture. Additionally, there are plans to tap the hydro-power and irrigation potential of the main rivers. These changes will have significant impacts on flow regimes and sediment loads.

The Sub-basin has seen some 30 years of civil war. As a result, the complex livelihood systems and the social networks that supported them have been seriously disrupted. 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. Additionally, much of the social and economic development that was taking place just prior to onset of the Civil War has been destroyed, severely damaged or lost.

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. Some 268 kms of the canal were constructed before the on-set of the Civil War and its future is still undecided. 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.

Significant developments are taking place in the Sub-basin with regard to oil exploration and 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 immense problems in the Sub-basin of initiating and sustaining all aspects of rural and urban development, reducing poverty, developing sustainable livelihoods and restoring economic and social networks. The CPA and JAM have set in considerable detail the modalities and conditionalities required to achieve these. However, in terms of watershed management and seeking to achieve sustainable livelihoods the key problems can be summarized as follows:

- The need to obtain a detailed knowledge of the complex hydrology-ecology systems in the whole of the Sobat-White Nile Sub-basin (in both Ethiopia and Sudan). Whilst the Bahr el Jebel was thoroughly studied as part of the Jonglei Canal investigations, the Sobat-White Nile Sub-basin was not studied in detail. This will involve establishing an effective and consistent hydrological and climatic monitoring network.

- The need to obtain a detailed knowledge of the relationships between the hydrology-ecology and livelihood systems and their dynamics, as a basis for effective and sustainable development planning and implementation. Already by the early 1980's socio-economic conditions in the Sub-basin (and that of the Bahr el Jebel) were changing rapidly from those studied in the 1950's and 60's (Howell et al., 1988). Twenty years of civil war will have caused further changes.

- The need to determine the potential impacts of upstream hydrological developments (dams, hydro-power, irrigation) on the sensitive hydrological-ecological and livelihood systems downstream in both Ethiopia and Sudan.

- The need to make a full inventory and status assessment of the habitat and species bio-diversity as a basis for effective and sustainable conservation planning.

- The need to determine the potential impacts on the hydrology, ecology and livelihoods of the continued development of the oil sector in the Sub-basin and develop an effective monitoring system

Given the complexity of the social and economic issues and the paucity of technical data, this report can only make a very provisional assessment of the potential impacts that some of the current and proposed developments may have on the Sub-basin specifically in watershed management terms.

8.6.2 Sensitive Hydrological-Ecological System of the Machar Marshes

(i) Potential Impacts in Changes in the Flow Regime of the Baro River

Spills from the Baro occur when the monthly flow exceeds about 1.500 km^3 per month and are concentrated between the Khor Jakau and Baro Mouth. The JIT estimated the total mean annual spill is about 2.820 km^3 but varies widely between 1.00 and 5.00 to 6.00 km^3. Sutcliffe and Parks (1999) estimated the 1950 – 1955 (low rainfall years) spill at 2.328 km^3. Using the flow data (1967 – 2003) from the Baro Multi-purpose Project Feasibility Study (Norplan, Norconsult and Lahmeyer Int., 2006) and using the 1.500 km3 per month, indicates a spill of about 2.465 km^3.

Whilst a number of dams have been proposed in the Baro-Akobo catchment those designated Baro 1 and Baro 2 have been studied to feasibility level. That Report 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 main Nile."

An examination of the current and projected discharges of the Baro River at Gambella Table 48) indicate that the reduction in high flows will reduce the amount of spill by about 20 percent from 2.465 km^3 to 1.965 km^3, some 0.500 km^3. The main impact of this will be the degree and extent of flooding of the "toich" grasslands. Assuming the same flood coefficient as the Sudd (Sutcliffe and Parks, 1999) of 1 meter depth and taking into account rainfall and evaporation, this would indicate a reduction of flooding of about 410 km^2. Using Sutcliffe and Parks estimate of 3,350 km^2 of flooded area this is a decrease of about 12 percent. As this represents valuable dry season grazing for pastoralist groups that use the area during the dry season, it is suggested that this cannot be considered an "insignificant" impact.

Table 48. Projected Change in Baro Discharge at Gambella from the Baro Multipurpose Project: Potential Impact on Baro Spills to the Machar Marshes.

	Jan	Feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	**Dec**
Current (m3/s)	86	58	50	56	136	360	647	873	1008	665	271	**129**
Current (Million m3/mth)	230	140	134	145	364	933	1,733	2,338	2,613	1,781	702	**346**
>1,500million m3/mth (To Machar)							233	838	1,113	281	**=2,465**	
Projected (m3/s)	131	106	91	91	145	324	584	794	970	657	292	**166**
Projected (million m3/mth)	351	256	244	236	388	840	1,564	2,127	2,514	1,760	757	**445**
>1,500million m3/mth							64	627	1,014	260	**=1,965**	

Source: Norplan et al (2006)

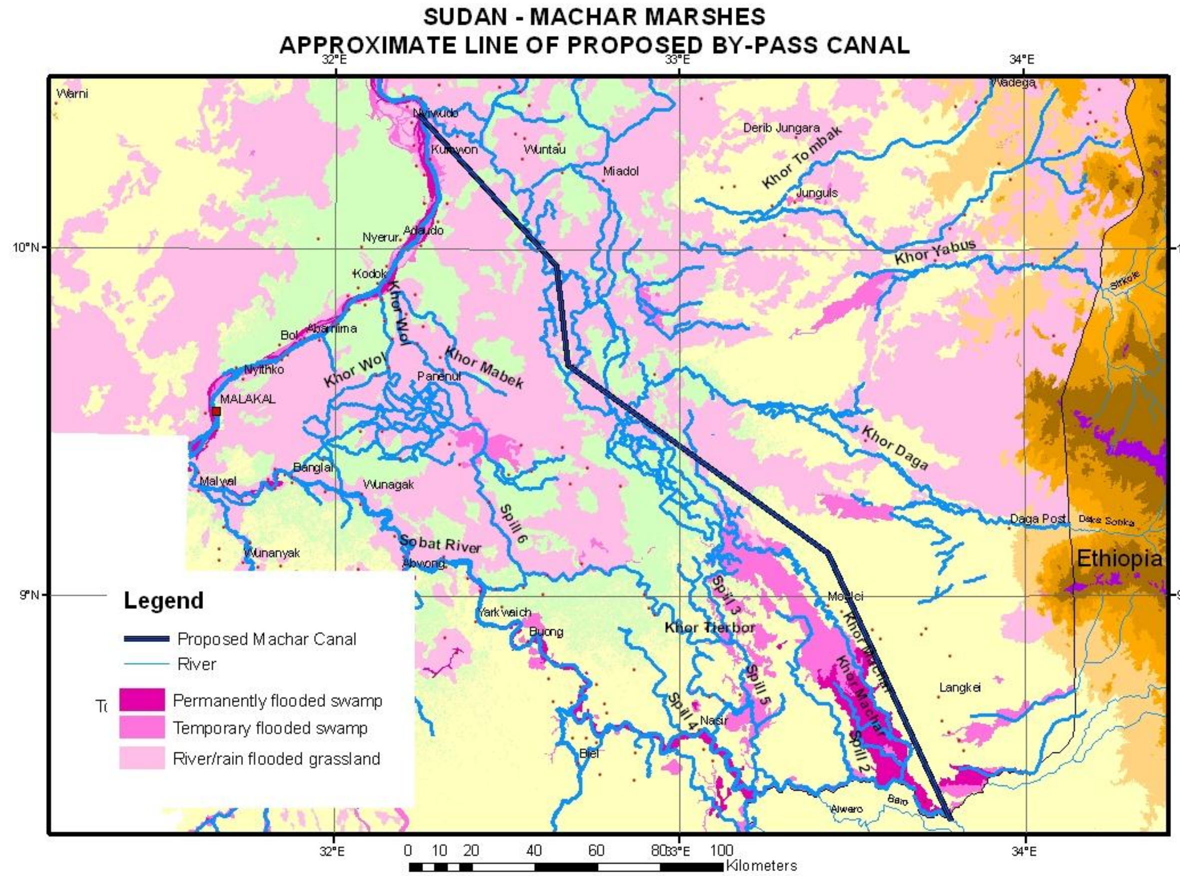
(ii) Potential Impact of a Machar Marshes Canal or Embankment along the Sobat.

One of the plans for increasing the flow of the White Nile and providing "new water" for downstream users is the "Machar Mashes Scheme". The plans envisage a canal from the Baro downstream from Jokau, just within Sudan to an outlet above Melut on the White Nile, a distance of some 300 km (Map 56).

The annual benefits were estimated by the JIT to be 4.4 km^3. The MIT study estimated a potential gain of 8.0 km3, although Sutcliffe and Parks (1999) have seriously questioned this estimate. Hurst et al (1947) pointed out a key disadvantage of the scheme was that in low years the losses are much reduced and that water in the canal "could also be reduced to the point of vanishing altogether". A very recent study by Waterwatch (2006) estimated a gain flow to the Sobat River by embankment (not a canal) of 1.65 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[16]. In addition the canal would cut across livestock trekking routes between dry and wet season pastures.

[16] Howell, P & M. Lock (193) "The Control of the Swamps of Southern Sudan: drainage schemes, local effects and environmental constraints on remedial development of the flood region", op. cite

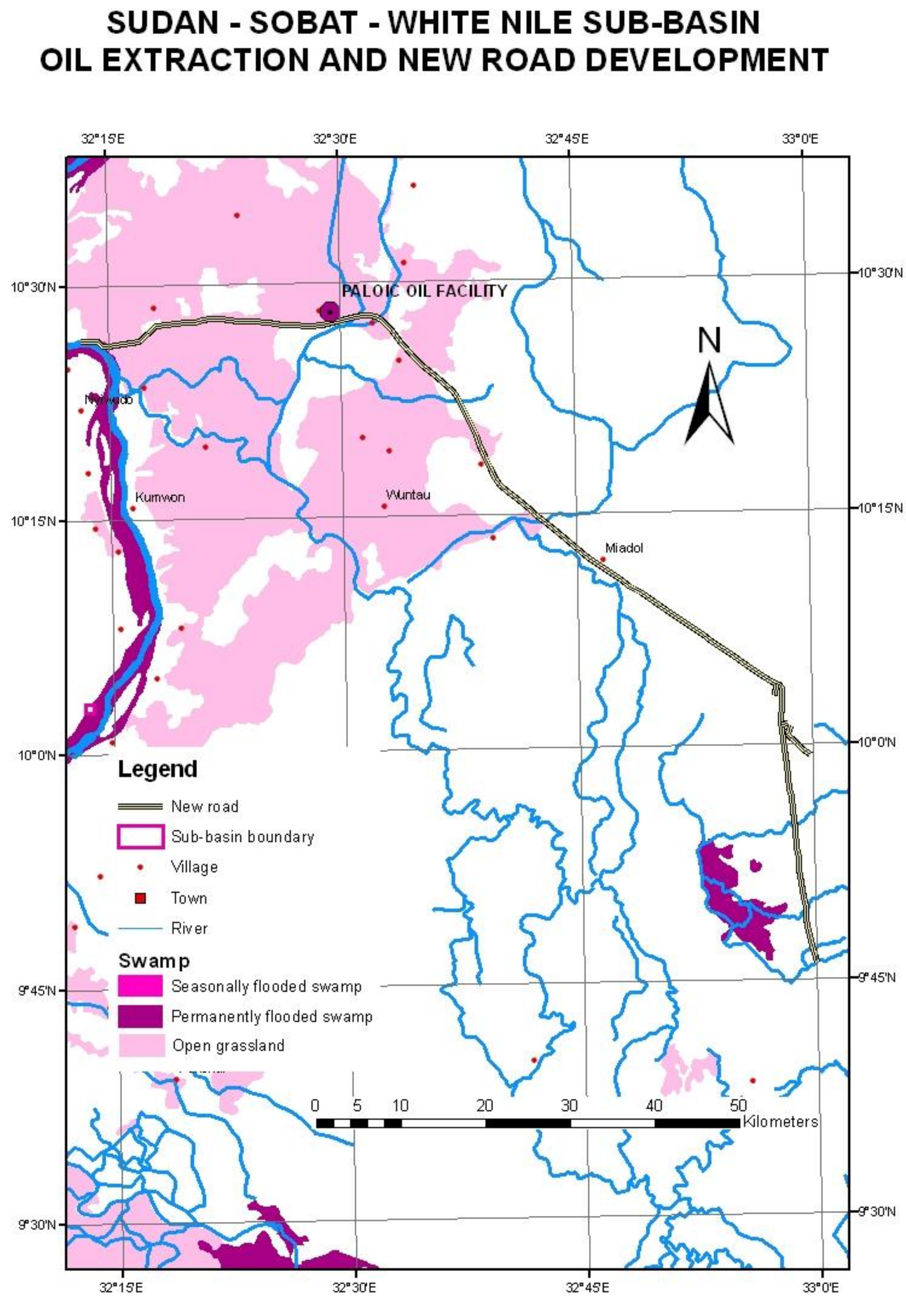


Map 56. Sudan – Sobat-White Nile Sub-basin: Approximate Alignment of the Proposed Machar Canal.

(iii) Potential Environmental Impacts of Oil Exploration and Extraction

The most immediate impacts of oil development activities within the Machar Marshes relate to activities associated with (a) exploration, and (b) extraction. The former tend to be temporary but extensive, the latter permanent but more concentrated. 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 (Map 57). 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.

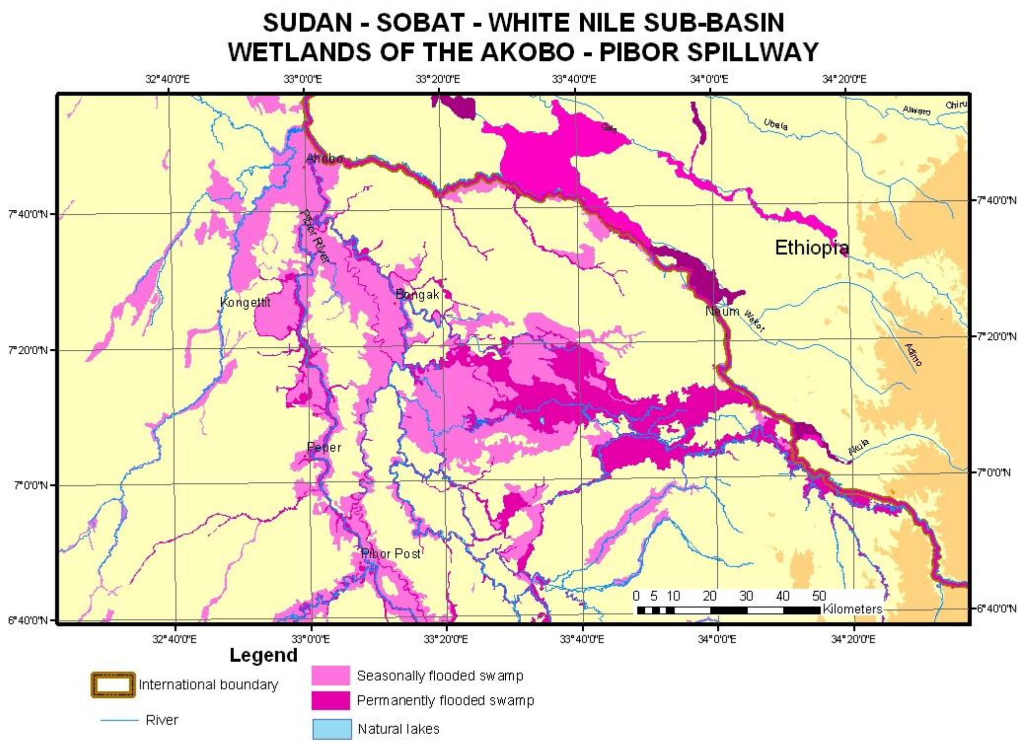


Map 57. Sudan – Sobat – White Nile Sub-basin: Oil and Road development in the Machar Marshes.

8.6.3 Wetlands of the Akobo – Pibor Spillway

There is no mention in the Nile Basin Study by Hurst nor in Jonglei Investigation Study Report of the spillway between the Akobo and the Pibor, which lies to the east of Pibor Post. Associated with this spillway is an extensive area of wetland of both seasonal and permanent swamps. There are approximately 230,000 ha of permanently flooded swamp and 250,000 ha of seasonally flooded swamp. This is several orders higher than the permanent and seasonally flooded swamp in the Machar Marshes and represents a vast area of importance for biodiversity conservation. It is known that vast herds of White Eared kob (*Kobus kob leucotis*) use this area as part of their migratory routes. There is also a population of Nile Lechwe (*Kobus megaceros*).

As with the Machar Marshes these wetlands depend to a large extent on spill water from one river to another. Thus 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. This could have serious impacts on the ecology 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.



Map 58. Sudan – Sobat – White Nile Sub-basin: Wetlands of the Akobo-Pibor Spillway

8.6.4 Potential Environmental Impacts of Returning Refugees and Displaced Peoples

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.

There is a need to mitigate the negative environmental impacts that returning refugees and IDPs will have on the natural resource base through increased deforestation and destructive agricultural practices for instance. While the re-establishment and diversification of agricultural, livestock and fishing activities will be absolutely vital to ensure the livelihoods of returning refugees and displaced people, it is also crucial that this is done in an environmentally sensitive way so as to ensure their long-term viability and avoid recurring conflicts and tensions over natural resources allocation and utilization.

During the civil war there was an absence of any formal management of Southern Sudan's natural resources and the destruction of many valuable natural resources. There is now an urgent need to develop a strategy for the rehabilitation and sustainable management of the natural resources based on comprehensive inventory and a clear definition of the powers and responsibilities of the various levels of government and local communities. These arrangements must also link to the livelihood needs of the returning communities and ensure that sustainable incomes can be generated.

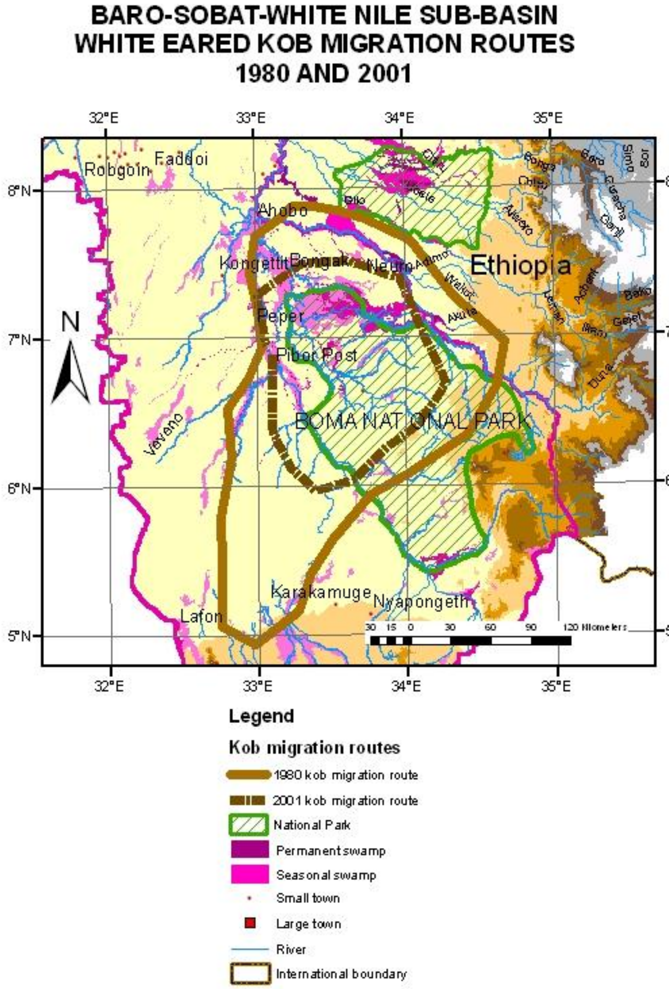
In the short term much will depend on local community initiatives in the allocation of land for cultivation and grazing, woody biomass resources for fuel and house construction. Communities will need to undertake careful and agreed local land use planning and resource allocation to avoid conflict between existing and returning peoples and between resource uses. Community development efforts can be done through the promotion of agro-forestry, household woodlots, improved energy efficient stoves, regulation of charcoal production and the development of local institutions for community-based management of natural resources.

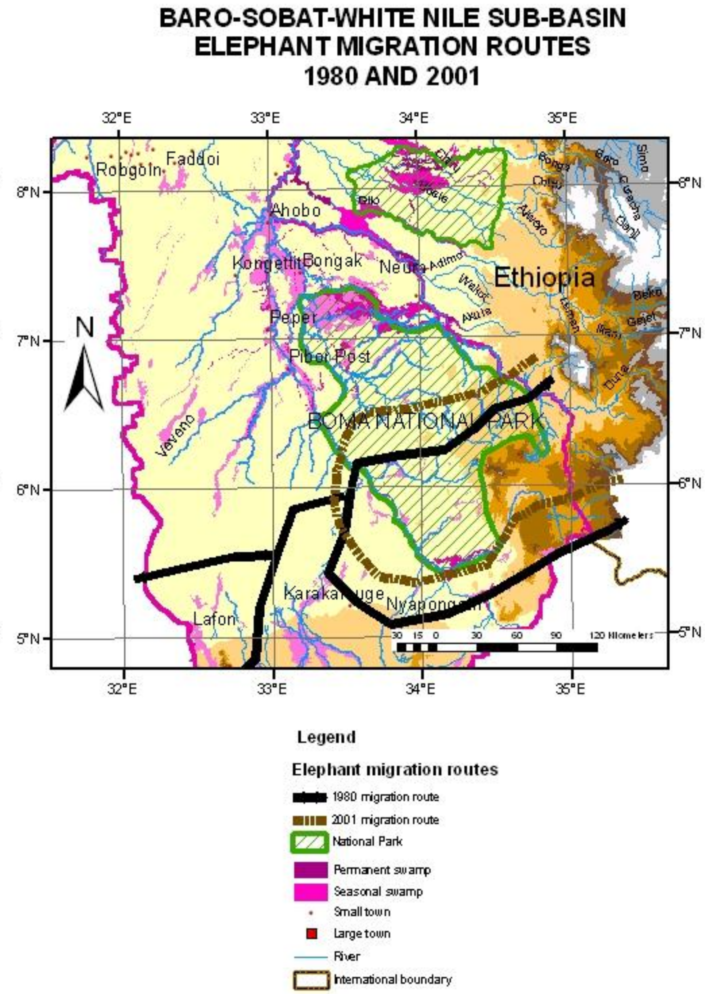
8.6.5 Loss of Biodiversity: Boma National Park

The Boma National Park lies close to the Ethiopian border and just 70 kms southwest of the Gambela National Park. It is located between the River Kagen in the west and the Oboth in the east, and from the River Kurin in the south to the Guom swamps in the Akobo-Pibor Spillway. Although the Park was established in 1977 it has been neglected as indeed has the area generally. This is in part 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 percent 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. Hunting and wild food collecting was a coping mechanism adopted by all peoples as an alternative livelihoods strategy, although the degree to which this strategy was adopted varied among the different groups.





Map 59. **Baro-Sobat-White Nile Sub-basin: Migratory Routes of White-eared Kob and Elephant: 1980 and 2001**
Source: Deng, 2001)

A major wildlife inventory had been 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 49. The big increase in hunting has caused the migratory routes of White-eared Kob and Elephant to change over 20 years (Map 59).

Table 49. Comparison between Wildlife Population estimates in the years 1980 and 2001.

Species	2001 count Wet season	1980 count Wet season	1980 count Dry season
White-eared Kob	176,120	680,716	849,365
Lesser Eland	21,000	2,612	7,839
Oribi	3,920	2,939	2,264
Reedbuck	28,840	2,000	3,000
Road Antelope	1,960	2,059	3,085
Mangalla Gazelle	280	5,933	21,678
Warthog	280	293	4,868
Ostrich	3,640	1,306	2,151
Tiang	N.S.	24,078	29,460
Lelwel Hartebeest	5,600	8,556	47,148
Zebra	N.S.	24,078	29,460
Buffalo	N.S.	2,965	11,179
Giraffe	N.S.	4,605	9,028
Waterbuck	N.S.	620	2,462
Steinbuck	N.S.	292	1,981
Grants Gazelle	N.S.	1,222	1,811
Elephant	N.S.	1,763	2,179

Source: Deng, 2001.
N.S. – Not seen

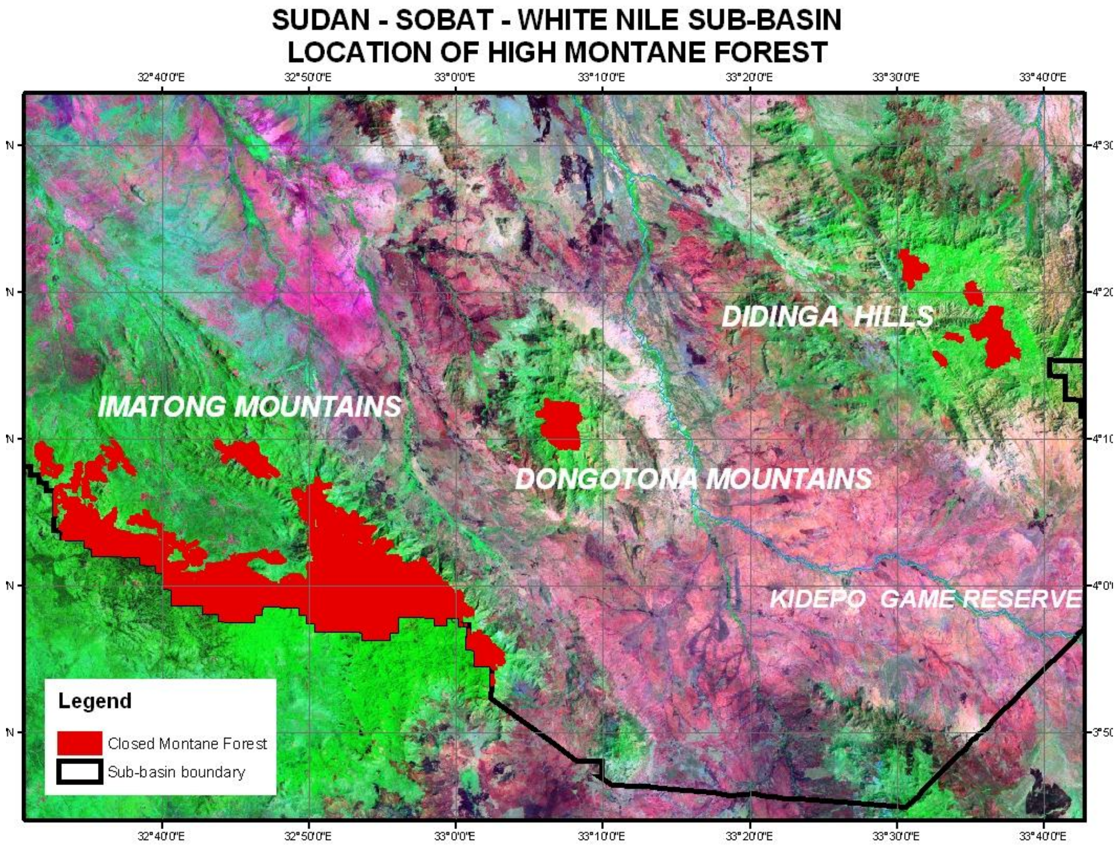
The vegetation survey revealed an increase in tree densities an indication of habitat improvement and stability.

8.6.6 Deforestation of Montane High Forests

The forests were gazetted as a forest reserve in 1952 but 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 and 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, 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 (map 60).



Map 60. Sudan – Sobat – White Nile Sub-basin: Location and extent of closed Montane Forests in the southern Mountains within the Sub-basin.

8.6.7 Infestation of the White Nile with Water Hyacinth

Water hyacinth (*Eichhornia crassipes*) appeared in the White Nile in 1957 in the area of the Sudd. It has since spread north and southwards[17]. It is also reported to have appeared in the Baro in Ethiopia about 1976[18] and is thus most certainly to be in the Sobat system.
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

[17] Abdalla Abdelsalem Ahmed (2006) One System Inventory: Water resources: Sudan", ENTRO, May 2006.
[18] EWNHS (1996) "Important Bird Areas of Ethiopia (Gambela region)", EWNHS & Bird Life International.

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 km3 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 (from Sudan Steering Committee comments)

A study in the Nile system in Egypt (Batanoumy and El-Fiky, 1975) showed how rapid its growth can be. A plantlet with a 450 cm2 basal area, 40g fresh weight and 7.4 leaves attained a basal area 1.0827m2, a fresh weight of 1,244 kgs and had 208 leaves in 50 days in a drainage ditch. During that period a plant would produce 43 new offsets on average. Such a plant after 200 days during the growing season would produce 3,418,800 new offsets with an area of 1.493 km^2. In middle Egypt during winter the plant growth is very slow due to low temperatures: a factor not likely to occur in the Soba-White Nile Sub-basin.

9. IDENTIFICATION OF WATERSHED MANAGEMENT INTERVENTIONS

9.1 Overview of Lessons learnt

9.1.1 Community Participation

The community driven Area development Schemes (ADFS) have been cited as an example of successful rural development (Yagoub Abdalla Mohamed, 2005). An assessment of the programme found that:

- the programme had broken new ground in fostering the principals of local participation in the development process;
- the programme had succeeded in developing grass-roots institutions;
- a change had been witnesses in the attitude and thinking of all stakeholders: beneficiaries, government officials and development workers with respect to a participatory approach;
- the programme had established close linkages between environment, proper resource use and development; and
- Traditional organizations played important roles in mobilizing villages for self-help activities.

The Mission Completion Report of the Screening and Ranking of the Six Proposed Fast Track Watershed Management Projects in Sudan (ENTRO, 2005) reported many instances of successful natural resource conservation projects that had been achieved through effective community participation. In the Upper Atbara near Shuwak a local NGO had mobilized a community through active participation in a number of environmental management activities (soil terraces, eradication of mesquite, distribution of gas stoves, etc). In the Lower Atbara the mission found a strong basis for community participation that had developed out of the ADS programme. Here it was the Women's' Voluntary Society with 33,000 members.

Near Dongola an NSO and SOS Sahel supported projects were very strong in empowering villagers and implemented successful shelter-belts to combat encroaching sands. A later evaluation indicated that to be sustainable the project should have involved the FNC from the outset as they would be responsible for support on completion of the UNSO and SOS Sahel support.

9.1.3 Community-based Approach to Rinderpest Eradication

In the early 1990's cattle in the Southern Sudan were being decimated by rinderpest. Because of the security situation vaccination teams were unable to access many areas. From 1993 onwards a large scale community-based animal health worker (CAHW) system was developed. The programme was successful in eradicating rinderpest from Southern Sudan.

A subsequent evaluation (Catleyet al., 2005) of the success of this programme determined a number of factors in its success:

- regardless of the relief environment an understanding of livelihoods and attention to local knowledge and skills, local institutions (e.g. the cattle camps) and local demand was developed and encouraged;

- from the onset of the programme payment for services was adopted and accepted, and the basic principle of payment for clinical services established and so ensuring the sustainability of the programme;

- the international agencies, NGOs and donors were persuaded to adopt an innovative and flexible approach to the programme allowing for experimentation and evaluation;

- community involvement was not restricted to planning and design but extended to include impact assessment and evaluation;

9.1.3 The Role of Gum Producers' Associations in the Rehabilitation of Gum Arabic in North Kordofan

During the droughts of the 1980's there severe loss of gum arabic trees in North Kordofan. Higher prices during the early to mid 1990's encouraged farmers to restock their gum gardens and they were supported by the Restocking of the Gum Belt Project (RGB). In order to assist farmers in this process the project supported the establishment of Gum producers' associations (GPA) (Nagla Mahgoub Hamadain Jepory, 2003).

The main aims of the programme were to:

- reduce the dependence of farmers-gum producers on the informal credit system (*Al shail*);
- maintain cooperation amongst the groups in the rural areas through social organization;
- the sensitize the rural population and raise awareness about their environment and the role gum producing and trees have on it;
- activate cooperative marketing of agricultural products; and
- coordinate with companies and organizations working in the fields of rural development.

The establishment of the GPA followed an intricate system of village surveys, identification of potential members, financing and marketing. Civil society organizations such as the GPA's have proven that they are viable and effective.

9.1.4 Local level Land Use and State Level Planning

The resource use conflicts in and around the Dinder National Park have been described in 8.3.4 above. The terminal report of the 200-2004 Phase stated (inter alia) that land use planning was considered a pre-requisite for local peoples' livelihood security. In fact the project had undertaken Land Use and Livelihoods Participatory Planning Workshop to ascertain participants' interpretations on current land use problems.

The Terminal Report also identified a land use situation that was characterized by sever asymmetrical power relations and referred to the delays in developing State-wide Land Use Plans. However, whilst the lack of a State-wide Land Use Plan had not prevented some effective local level land use planning the need for such a Plan might be needed where resource conflicts extended beyond the locality. This is particularly so where it is necessary to plan and implement livestock trekking routes and water supply provision across and within areas of large-scale farms. The cases of the resource conflicts between pastoralists and semi-mechanized farms on the Butana Plains and the Funj are examples of these.

9.1.5 Improving Governance of land and water Resources

The on-going IFAD supported Land and water Governance project in the gash Delta is providing an example of an innovative approach to improved land and water governance in order to promote equity, economic efficiency and sustainability. Whilst this example refers to an irrigation scheme many of the principles that underlie the approach have relevance to other aspects of watershed management. The features of the innovations are:

- There is now a clear definition of roles, responsibilities, authorities, financing mechanisms among the three key stakeholders: the farming communities, the Gash Delta Agricultural Authority (GAS) and the Ministry of irrigation and Water Resources;
- Clear entry and exit rules for leaseholds have been established. Leaseholds would be would be fixed with increasing control of flood waters. Enforcement of entry and exit rules would be devolved to the Water Use Associations (WUA's).

- Land allocation, land development and water management at the lower levels and later to the block level is devolved to the water Users associations.

- WAU's would be established around existing farmers groups.
- Collection of water fees would be devolved to the WUA's.

These options were chosen by the farmers and the farmers Union played a key role in facilitating the initial and subsequent participatory phases. The introduction of these changes was facilitated by a commitment of the MIWR at both local and federal levels.

The key principles of this innovative approach and which have application elsewhere are:

- It puts people first. It reverses the traditional approach of starting with infrastructure.
- Effective land and water governance is at the core of the approach. Without security of tenure farmers are not likely to invest in land.
- If people are to engage effectively they need the capacity to do so. This means developing the institutional structures that enable individuals to function effectively as well as a favourable social and economic environment within which they can work. Individuals will need to develop new skills and practices.
- New institutional structures are needed but local, well established informal institutions (such as the Farmers Union) can provide the foundation on which to build.

9.2 Strategic Options

9.2.1 Strategic Considerations

It is known from lessons learned that watershed management planning can be undertaken at various levels, but **implementation has to take place at grass root level**. The conventional options for purely administrative and regulative solutions to land and water use problems appear to have reached their limits. It is becoming increasingly apparent that a more consensual approach to natural resource management is a more attractive solution for harmonizing interests of resource users, managers and regulators. Allowing and facilitating local communities to develop their own resource management systems is proving a more effective, economic and efficient approach than central or regional government control.

Sustainability of achievements requires ownership of its users and these are the local communities. A sense of ownership is created only through their **genuine participation** in planning and decision making. Decision making should not be the privilege of nominated leadership only. Motivation for genuine participation can only be based on **tangible benefits** and a sustained resource-base. Many benefits can be achieved through integrated watershed management for improvement of livelihoods.

The requirement of genuine participation sets preconditions to the organizational structure and approach of watershed management projects. Emerging lessons from watershed management projects in Sudan and many other countries, include the following:

- A participatory project cannot be target-driven right from its start. In its initial phase, the project design should focus on the process of establishing participation rather than on seeking to achieve physical targets. It also requires appropriate institutional development at community-level; appropriate in the sense that institutions are created (or strengthened if already existing) to respond to the emerging needs, and may therefore differ from place to place. Needs depend on priorities in watershed management activities, functionality of existing traditional institutions and prevailing group dynamics within a community. A standardized institution for all communities will be an imposed one and will undermine the feeling of project ownership in the community.

- It is important to strive for a simple organizational and coordination structure, based on existing structures and clearly stipulating linkages with higher levels (need for support.

- Institutional arrangements are required that allow for multi-disciplinary and multi-agency collaboration and across ministries, contributing to breaking through single sector approaches.

9.2.2 Land Policy Reform

A key problem of the traditional rainfed smallholder farms is the declining period of fallow caused by restrictions on lateral expansion by SMF's to the west and State Forests to the east. The problems are similar with the respect agro-pastoralists and pastoralists and the loss of extensive wet season grazing areas to the SMF's and the consequent overgrazing and degradation of the rangelands.

It was estimated that in 2005 (a good rainfall year with high crop prices) only 40 percent of the SMF's were being cropped. Given the recommendations of the JAM for a more equitable access to natural resources, as a first step it would be appropriate to undertake a survey of all SMF's to determine which areas were legally or illegally held, those areas being regularly cropped, areas which were under-utilized (cropped occasionally) and those which had been abandoned. This would enable a thorough review of all government leases. Illegally held, under-utilized or abandoned land could then revert back to the State. Provisions could be made for the State to purchase back leases of farms that were strategically important in the land redistribution and land use planning exercise.

The second step would be to undertake at the State level (but within nationally laid down guidelines and principles) a strategic land use planning exercise in consultation with all concerned stakeholders. This would seek to redistribute land that had reverted to State control, to smallholder rainfed farmers, agro-pastoralist and pastoralists based land suitability for rainfed cropping, intensive and extensive livestock production and where possible on the principle of prior use (i.e. the land was used by a concerned group (or groups) prior to alienation). It would important to clearly define access and use rules for individually and communally held land to ensure sustainability of natural resource use and to avoid resource use and access conflicts. Where possible, existing formal or informal institutions for land and water allocation would be used and strengthened.

Control of some of the State Forests adjoining communities could be passed from the FNC to those communities following a participatory planning exercise to develop a forest management and harvesting plan. The Community Forest Management Plan (FMP) would set out sustainable harvesting rotations for fuelwood and charcoal production, royalty rates and the establishment of a Community Development Fund in to which royalties would be paid.

The third step would be to provide a comprehensive programme of technical support (crop and animal husbandry), effective input distribution (improved seed, fertilizer and veterinary medicines) and accessibility to short and medium term credit. The support programme would include improved physical accessibility (feeder roads), human and livestock water supplies, water harvesting and small scale irrigation, social infrastructure and services (health and education).

9.2.3 Food Aid and Incentives

Hitherto food aid has been serving as a life-saving instrument in Sudan. With the changing circumstances following the CPA its role is likely to change. It is generally recognized that it should be linked to improved livelihoods and the broader sectoral interventions such as agriculture, natural resources, education and health. Thus, it could be linked to distribution of agricultural inputs, agro-forestry, water development and pasture rehabilitation. Other activities could include road repairs and construction, food for education and health related interventions.

There is an ongoing debate on the relative merits of providing food versus cash. Both have their advantages and disadvantages in the Sudanese context. The advantages of food transfers are as follows:

- in areas of chronic food shortages providing food increases its availability and brings food prices down;

- they provide a protection against inflation as a transfer in the form of food is self-indexed and the cost of inflation is borne by the provider (FAO/WFP, 2006);

- giving food is quickest way of improving nutrition;

- providing free or subsidized food is effectively an income transfer as it is possible to trade food for cash or other goods;

- food transfers ensure that the beneficiaries will allocate a higher proportion of an additional unit of food income towards food consumption.

The main disadvantages of large-scale transfers of food are the disincentive effects they have on domestic production and trade. Such transfers could depress market prices leading to serious erosion of profits for domestic producers such that farmers reduce or move out of production.

The main advantage of a cash transfer is that it allows consumers more control over their decisions based on the particular conditions they face. They are a more efficient way of transferring income than pure food transfers. Food can be converted to cash but it involves transfer costs. Cash transfers are generally less distortive to the local economy than large food transfers. In conditions where markets are functioning well cash transfers can augment the development process by creating additional effective demand for goods and services boosting trading and productive activities.

The main disadvantage of cash transfers is that their real value is dependant on the rate of inflation. There is a real possibility of more inflation in food and other prices following a large scale cash transfer programme, particularly where markets are functioning poorly and the economy is relatively closed. Additionally, large cash transfer programmes are the greater risks of fraud theft and administrative leakages, relative to food transfer programmes.

The probable solution for Sudan is to continue with food transfers in locations where food shortages exist due to lack of production or lack of transport infrastructure. Pilot cash programmes should only be considered where the enabling conditions: markets and infrastructure exist and where the scope of food transfers is relatively small and so avoid inflationary pressures.

9.2.4 Enforcement of Environmental Policy and Legislation

Given the rapidly changing pace of development in the oil and industrial sectors it will be important that existing environmental policies and legislation are enforced. This has been noted by the JAM as a prerequisite to achieve the Millennium Goal (MDG) 7 (Environmental Sustainability). This is no more so than in the oil exploration and drilling sector whose activities are often located in fragile environments.

In Southern Sudan the JAM recommends that environmental concerns be mainstreamed at the outset into all key decisions. The Report identifies the need for a comprehensive environmental diagnostic and the creation of a detailed Environmental Action Plan.

9.2.5 Technical Interventions: Levels and boundaries of analysis

It is often stated that a watershed approach to development conflicts with the administrative and political reality and that their boundaries rarely coincide. Implementation activities are initiated and carried out within an administrative jurisdiction. This argument is countered by pointing out that the physical world has no respect for administrative or political boundaries and activities in the upper part of a watershed can serious impact on people in the lower parts in another administrative or political jurisdiction. In practice the two approaches need to be complementary and an administrative/political realism should be superimposed on watershed planning to obtain administrative support and action.

Watershed management is a system-orientated concept with a holistic approach to problems and potentials. For this reason it will be necessary to identify "bundles" of interventions that complement each other where possible in a synergistic way. Given the cross-sectoral, sustainable livelihoods and poverty focus of the Watershed Management CRA with its stated objective of tackling the underlying problems of natural resource degradation in the East Nile Sub-basins, many of these "bundles" will comprise technological, institutional and policy components.

Most technological interventions are targeted at the agricultural[19]/pastoral household and rural community level although some are targeted at medium scale watersheds. The organizational, institutional and policy interventions/recommendations are targeted at the higher administrative and political levels.

In addition, strategic choices in development have to be made to achieve the following:

- balanced identification of priority areas for watershed protection, based on an agreed set of criteria (see for example the criteria established for prioritizing the Watershed Management Fast Track Projects);

- dual attention for both rehabilitation of degraded food-insecure areas and timely protection of strongly eroding high potential areas,

[19] Included here are tenant farms on government irrigation schemes, farm workers on large-scale mechanized farms and as well as smallholder farmers.

9.2.6 Technological Interventions: Basic Considerations

Considerable experience has been built up in Sudan, the Eastern Nile Region and elsewhere in the world on the technological aspects of integrated watershed management. In particular there has been an increasing emphasis on biological measures using where possible locally available materials and away from physical structures.

A thorough understanding of the land use systems and their inter-linking components will ensure that any potential technical interventions will not adversely impact on and where possible support the other components in the system.

At the micro/mini watershed level technical interventions will need to be developed in an integrated manner that takes into account the nested nature of watersheds and the hydraulic system. For example the development of small dams and hafirs should be integrated into other components of the watershed management plan with catchment management interventions being implemented in the upper micro-catchments and moving progressively downstream. Similarly, external water-harvesting measures will need to be similarly planned and executed. In-field water harvesting measures will need to be integrated with soil fertility enhancing measures if full benefits are to be achieved. Proposed interventions should range beyond soil and water conservation technologies and include inter-linked technologies related to crop, animal and tree husbandry.

9.3 Technological Interventions

9.3.1 Proposed Interventions for Improved Agricultural productivity on the Semi-mechanized Farms

The problems of low productivity of the semi-mechanized farms have been set out in chapter 3. Table 50 illustrates summary of the root causes and different interventions, activities and policies proposed as well as expected outputs to remove and/or mitigate root causes.

Table 50. Root Causes, Proposed Interventions and Output.

Problem	Root Causes	Interventions	Output
1. Low yield	1. Water availability, Number of irrigations, rainfall amount and distribution. 2. Improper land preparation. 3. Low yielding varieties. 4. Lack of certified seeds. 5. Lack of Agricultural inputs. 6. Inadequate research/extension services. 7. Mismanagement of agri-practices. 8. Lack of financial/credit lines. 9. High production cost. 10. Lack of institutional framework. 11. Lack of National Land use plan. 12. Lack of horizontal and vertical coordination. 13. Weak marketing/transportation network. 14. Land tenure	* Strengthen irrigated schemes operation and maintenance activities. * Water and soil conservation measures including water harvest. * Use of proper implementation for land preparation. * Introduce high yielding adapted varieties and use certified seed. * Supply needed agricultural inputs at reasonable prices. * Strengthen and enhance Research/extension and technology transfer to outreach small farmers. * Improve agri-practices management. * Provide agricultural schemes with credit line at a low rate of interest. * Use low-input technology to reduce production cost and increase yields to optimize returns * Ser the institutional framework among different organizations. * Start a National land use mapping. * Enhance and support coordination. * Support marketing/transportation network. * Policy of land tenure.	- Water management plan. - High on-farm water efficiency. - Water & Soil conservation plan. - Better soil chemical/physical conditions. - High yields & more income. - Low production cost & more net return. - Technology transfer plan. - Soil and water improvement. - Financial support plan. - Land tenure policy. - Site specific technology release. - Institutional strengthening and capacity building. - Land use policy. - Market accessibility plan. - Soil improvement plan.
2. Irrational land use by Mechanized rainfed schemes	1. Horizontal expansion. 2. Absence of any control by technical agencies or land use department.	* Enhance vertical expansion. * Define the mechanized scheme borders and shelter belts areas.	- Scheme management. - Institutional frame.

Table 50. Continued

Problem	Root Causes	Interventions	Output
3. Land degradation.	- Shortcoming in the planning of Mechanized scheme. - Lack of Land use policies. - Break down of traditional systems of land use. - Lack of land use planning. - Lack of awareness. - Expansion of uncontrolled mechanized farming. - Overgrazing. - Improper land preparation. - Removal of forest and plant cover. - Lack of proper soil management. - Lack of soil and water conservation programs. - Depletion of soil fertility. - Run-off and gully erosion. - Wind-blown sand. - Trespassing. - Clearance of tree cover and shelterbelts. - Lack of detailed soil surveys.	* Site selection plan, Nomadic rights, stock routes plan. * Wildlife sanctuaries protection. * Design land multi-use system. * Enhance community partnership and participation in management. * Coordinate different activities among authorized agencies. * Training of stakeholders. * Capacity building. * Control and authorize sites and areas of mechanized farming. * Corridors for nomads. * Fire lines. * Land use planning. * Proper tillage implements. * soil improvement and water harvest. * Fertilizer application. * Shelter belt and reforestation. * Awareness campaigns. * Capacity building and institutional strengthening. * Mobilization of stakeholders and community leaders. * Surveys.	- Land use plan and policy. - Income generation activities. - Trained & skilled stakeholders. - Land use plans. - Control trespassing. - Yield increase. - New job opportunities. - Storing soil fertility. - Community awareness and Mobilized stakeholders. - Land use maps.

Table 50. Continued

Problem	Root Causes	Interventions	Output
4. Inefficient irrigated schemes	- Low irrigation intensity, less than 50%. - Institutional weakness. - Land tenure arrangements. -Crop rotation. - Centralized decision-making. - Centralized irrigation water management. - Irrigation infrastructure. - No formal credit institutions available. - Lack of improved seed. - Lack of Hybrid varieties. - Inadequate Research/extension services.	* Improve irrigation operation and maintenance. * Training the staff and farmer leaders. * Introduce new land tenure arrangement. * Free crop rotation, and integrate animal raising in cropping system. * Decentralize decision making and water management. * Develop infrastructure. * Support financial institution. * Seed multiplication programs. * Breeding and release of new improved varieties. * Support and enhance research and extension services. * Finance research and extension activities.	- Possible level at 75%. - Strong institutions & capable staff. - Land tenure policy and plans. - Generate more income. - Free- market roles. - Improved infrastructure. - Credit line. - Certified seeds. - Improved varieties. - Increase farmer and scheme income. - Technology transfer. - Farming site-specific problem solving. - Yield increase.
5. Weed infestation	- Improper cultivation methods. - Improper land preparation. - Inefficient weed control programs.	* Improved cultivation methods. * Adequate land preparation. * Integrated weed management program. * Environment protection.	- Less weed infestation. - Crop yield increase. - IPM and weed management program. - Environmental Impact Assessment (EIA) - Clean- organic cultivation.
Problem	**Root Causes**	**Interventions**	**Output**
6. Lack of data base and monitoring frame work.	- Lack of horizontal coordination. - Absence of data-base. - Lack of information and dissemination technology. - Shortage of trained personal.	* Data base establishment. * Hard and software. * Information system management (ISM). * Training. * Establishment of participatory monitoring system.	- Scientific data. - Reliable information. - ISM. - Trained staff. - Monitoring system.

It will also be important that the 10 percent shelterbelt regulation be enforced. Linkages could be established with local communities to supply seedling and undertake establishment and maintenance on a contract basis. A more flexible approach to planting patterns should be permitted, thus allowing for fencing field boundaries.

With the implementation of livestock routes ("nomad paths") and water points between the dry and wet season grazing areas pastoralists could take advantage of the abundant supply of crop residues as livestock feed.

Further consideration of the table shows that these interventions will lead to the following results:

1. A well articulated management plan allowing agriculture sector to benefit from the Sudan natural resources.
2. Land use plans in areas of irrigated, traditional and mechanized rainfed farms to ensure sustainable management of resources
3. Rehabilitation of degraded areas through establishment of woodlots, control bush fire and avail grazing and water for livestock owners.
4. Incorporation of pastoralists and agro-pastoralists in land use plans.
5. Further scientific research, and technology generation.
6. Establishment of well designed monitoring system.
7. Vital role of extension and technology transfer.
8. Soil and water conservation, i.e. water harvest and soil improvement.
9. Protection of natural resources via community participation and land tenure policies.
10. Generate more income, good opportunities and better livelihood.

9.3.2 Shifting Sand Dunes

Considerable experience has been built in the area both at the Government (FNC), the Community and individual farmer levels. A number of interventions have been proposed:

(i) A 10 km external shelter-belt at Argi as an emergency measure to protect the village and its croplands: 500 feddans (280 ha) existing and 16,000 feddans (8,960 ha) potential cropland (4,000 beneficiaries).

(ii) A 40 kms "External" Shelter-belt protecting the three villages of Argi, Abkar and Afaad to protect the existing 4,000 feddans (2,240 ha) and 17,000 feddans (9,520 ha) of potential cropland (10,000 beneficiaries).

(iii) A full shelterbelt from Letti to El Bar (as proposed by UNSO) protecting all 14 villages (43,000 beneficiaries): total area of potential cropland not known.

A key issue in making any decision is the question of the possibility that a new irrigation canal will be constructed on the east bank from the Meroe Dam. The dam is due to be completed in 2008. It is anticipated that the dam and the canal could have a tremendous impact on the current agricultural systems. The basin irrigation systems would be affected by the altered timing, duration and volume of the flooding.

The estimated investment costs of the new irrigation land (US$ 800/ha) and those of the shelterbelt (US$ 50,000/km). Thus to develop 10,000 ha of new irrigable land would cost approximately US$14 million. The 40 kms shelterbelt needed to protect the new land would cost approximately US$2 million or some 14 percent of the total costs. It would make sense to incorporate the planting of the shelterbelts into the overall design of the Project. Given the extent of the new irrigation areas the full shelterbelt from Letti to El Bar should be planted.

Communities are extremely reluctant to invest time or labour in the planting of external shelterbelts (i.e. well beyond the village limits). Thus, whilst internal belts can be within the control and be implemented by the villagers, the external belts will have to be undertaken as public works.

The Fast Track Watershed Project Evaluation Team recommended that any future shelterbelt plans be designed to protect the future agricultural systems that are adapted to the new flood and irrigation regimes. Survey, planning and design work should start immediately using knowledge of the alignment of the new canal, potential irrigable areas and likely impacts on current basin and well irrigation systems.

Whilst they may not be the long-term answer to dune encroachment they have been assessed as the most appropriate until some new technology is available. The success of previous shelterbelt projects in the area has been assessed to be due to the strong community participation in the projects. Any future shelterbelt project in the area should take note of this.

Whilst mesquite is preferred by a number of communities and experts FRC have screened some 40 species they consider suitable and have identified 6 species that are drought and salt tolerant. Techniques of establishment using groundwater are well known in Northern State. Dunes within the belt would be stabilized with date palm branches, trees and Salsaf and other grass species.

9.3.3 River bank Erosion

Current bank protection measures include revetments to stabilize the banks and groynes to deflect strong currents from the bank. The latter have not been very successful. Deep rooting trees appear to be the most effective at stabilizing and protecting banks from erosion. However, as most of the land alongside the river is privately owned this involves private investment decisions. Where shallow rooting bananas produce much higher profits that deep rooting citrus the temptation is to invest in the crop with the highest profits.

Clear land use zoning in a 1 km buffer zone on each side of the river could help to prevent tipping of material into the river and extraction of sand fore building and other purposes.

9.3.4 Arresting and Reclaiming Kerib Land

Reclamation of kerib land would be pointless without taking steps to arrest its extension and encroachment into the adjoining croplands. The only way to achieve this is to take a buffer zone about 200 meters wide from the kerib edge out of cultivation and to plant deep rooting trees. It is essential that all livestock be excluded from the buffer as well as the kerib land.

The short term strategy for reclamation would be livestock exclusion and land preparation in micro-catchments for multi-purpose tree production. Sown grasses could be used for cut and carry of fodder. The longer term strategy would be to use some of the reclaimed land for crop (sorghum and sesame) production.

A key issue is the question of land tenure of the reclaimed kerib land. Whilst community division is the current policy, consideration should be given to allocating the kerib land on an individual basis. This is now the strategy for reclaiming degraded hillsides in Tigray in the Upper Tekezi basin in Ethiopia and is proving extremely successful. In some cases landless households are being allocated degraded land and provide d with technical and material support to undertake the reclamation work.

9.3.5 Resolving Conflict over Access to Rangeland Resources

The two main areas encompass the Butana Plains in the Atbara-Blue Nile sub-basins and the Funj area south of the Blue Nile covering the Blue Nile and northern Sobat Sub-basins.

There are a number of strategies that can be pursued. Officially recognized livestock routes (Nomad Paths) together with water points should be demarcated and established in collaboration with the large-scale farmers. This will enable easy access to the wet and the dry season grazing areas. It would also allow more use to be made of the currently under-utilized 4 million tons of crop residues, enough to feed nearly 2 million head of cattle.

Current proposals to re-seeding State Forest land (in the dry season grazing areas) and 60 percent of the Butana (in the wet season grazing area) should be implemented. This would relieve grazing pressure particularly that within the Dinder National Park.

As part of the overall reform of the land tenure policy clearly defined and integrated land use plans need to be developed to determine a more equitable distribution and sustainable utilization of natural resources.

9.3.6 Conservation of Wetlands

Whilst the wetlands within the Dinder national park are now part of a well developed conservation programme those outside the park have no protection. The greater proportion of these wetlands now lie within large areas of semi-mechanized farms. Little is known of the contribution to the hydrology of the Dinder and Rahad drainage systems nor of their biodiversity value. Indeed, they have not been mapped by the recent Africover mapping project. None of the wetlands that can be seen on the Landsat image in Map 23 has been mapped. The whole area is shown as "Cultivated land".

A first step would be to undertake a detailed inventory and study of their distribution, their hydrology in relation to the Dinder-Rahad system (in particular to the seasonal flooding), their biodiversity status and their utilization by local peoples. Given the integrated nature of the catchment in Ethiopia and Sudan the study should encompass the whole of the Dinder-Rahad Watershed. From this a conservation and management plan could be developed in participation with land-owners and users.

With respect to the Machar Marshes and those of the Akobo-Pibor Spillway there is an urgent need to undertake a full hydrological-ecological and livelihoods study of this area. This should form part of the overall natural resources inventory and strategic planning that has been recommended by the JAM. Again given the totally integrated nature of the Baro-Pibor-Sobat Sub-basin the study should cover the whole watershed system.

9.3.7 Rehabilitation of Reserve Forest and State Forest Reserves

There are some 1,195 Forest Reserves covering 7 million feddans (3.9 million ha) located within the Atbara, Blue Nile and Sobat Basins. In addition there is an unknown but even larger area of State Forest land. Much of this has become degraded under pressure from charcoal and fuelwood extraction and logging. Much of it requires restocking. The FNC have limited resources to undertake this work.

Much of the Forest lies within close proximity to communities. Whilst the FNC employ a few local people in their nurseries the forests contribute little in terms of support to livelihoods. The FNC control all wood extraction and charge royalties that provides a substantial proportion of their funds. However, they are only able to effectively manage a small proportion of the state forest land.

In the 1980's a similar situation existed in Mali. In the 1990's under a GEF support programme substantial blocks of State Forest were handed over to communities who then entered into contracts with the Charcoal producers to sustainably harvest woodlands within their control with the revenues going into a Community Development fund. The role of the State Forest organization was limited to providing technical advice on sustainable harvest cycles. It is suggested that this could be a viable strategy for many forest lands within close proximity to rural communities.

9.3.8 Small Watershed Management Planning

In most areas of the Atbara, Blue Nile and northern Sobat Sub-basins development of local water supplies is a critical need. Hitherto small-scale surface and ground water developments have not been on sufficient scale to causes any major negative impacts. However as developments accelerate there will be a need to take a watershed management approach. The impact assessment will have to be undertaken on specific developments to ensure that downstream users are not adversely affected.

Given that much of the water in these catchments originate within Ethiopia the watershed assessment should cover the watersheds both sides of the border.

10. LONG TERM CAPACITY AND MONITORING NEEDS

10.1 Capacity Needs

Currently Sudan is going through the long process of decentralizing and devolving more authority to the States and Localities. A keep problem in effectively implementing such a policy is the capacity at the State and Locality levels. Currently the capacity at these levels is limited in staff numbers and technical expertise.

10.2 Monitoring Needs

During the preparation of this Report it has become apparent that there is an amount of data appropriate for watershed management planning available in Sudan. However much of this data are quickly becoming out of date or the data which is available is fragmentary in time and place. Two main areas of data that require to be filled are (i) detailed landcover mapping, and (ii) long-term and consistent sedimentation data at various scales. These are considered in more detail below.

A third area that requires more research (rather than monitoring) is in the field of poverty and livelihood strategies, and relationships between sustainable land management and determinants of farmers' investment decisions.

10.2.1 Land degradation and Sedimentation Control

There is little or no consistent monitoring of gully or river bank erosion. The kerib land development is relatively easy to monitor using satellite imagery. River bank erosion is much more difficult given its sporadic and scattered nature and is better undertaken using ground surveys.

The linkages between erosion, sedimentation within the landscape and delivery to the drainage system are still very imperfectly understood. This requires a system of small-watershed monitoring and given the limited amount of sediment derived from these sources (compared with the sediment derived from the catchments in Ethiopia) it would be difficult to justify.

A regular system of monitoring suspended sediment loads in the Blue Nile, Atbara and Main Nile as a well as in the Gezira Irrigation Scheme has recently been upgraded by the Hydraulic Research Station and a consistent data base is being developed. However, there is a need to extend the network of states to cover the catchments within the whole range of sizes to determine factors such as catchment characteristics (soils, landuse, topography), size and integration within the drainage system.

10.2.3 Desertification and Sand Encroachment

The point has been made that "desertification" is more often detected by a change in species composition than by identifying and monitoring the "desert front" on aerial or satellite images. Thus a series of permanent ground transects should be established with accurate located sample spots in areas of representative vegetation. These could then be relatively easily monitored together with observations of climatic and human land use variables.

10.2.4 Land Use and land Cover

The objective of establishing a land use /land cover monitoring system is to capture the dynamics of landcover and land use in terms of location. Knowledge of the rates of conversion of forest, woodland and shrubland to agriculture and on the specific locations and extents of these conversions would also be a great value in evaluating and reformulating policies and plans on watershed management. In addition the results could be used for monitoring:

- agricultural and rural development;
- domestic bio-energy supply;
- forestry and woodland management and conservation:
- resettlement planning, implementation and monitoring;
- disaster preparedness planning and monitoring;
- water development;
- many other facets of natural resources management and conservation.

For this reason, and given the scarce resources and expenses required to undertake mapping landcover changes, consideration should be given for a wider role for mapping landcover changes (i.e. not only landcover monitoring for watershed management).

Two alternative (though not necessarily mutually exclusive) approaches to monitoring landcover are possible.

The first alternative is to attempt to monitor changes in land cover over the whole country. Any monitoring system must have information on the baseline situation at one point in time (whether past or present) from which changes in the future can be measured. Monitoring landcover changes across the whole country at relatively frequent intervals (say five years) would be extremely demanding in resources. If the whole country is to be monitored then some form of sampling may have to be considered as an alternative to complete re-mapping with all the implications for obtaining statistically reliable data that sampling entails.

Rather than whole-country monitoring a reduction in the resources required could be achieved if a more focused assessment was made of landcover changes in key thematic and geographical priority areas. These might include but be not limited to:

- Assessing landcover changes in the upper catchments of key river basins (e.g. the Dinder-Rahad) as an input to analyzing household energy supply changes, sedimentation rates and changes in flood frequency and the need for developing catchment management plans and activities;

- Assessing changes in cover in the forest and woodland areas on the frontiers of agricultural expansion;

- Assessing landcover and woody biomass changes in reception areas where voluntary resettlement is being undertaken;

- Assessing woody biomass changes in areas of high-intensity agriculture to monitor on and off farm tree and shrub cover;

- Assessing landcover and woody biomass changes in areas of active expansion of large and small-scale agriculture.

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