Nile Basin Initiative

Nile Technical Regional Office (ENTRO)
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EASTERN NILE TECHNICAL REGIONAL OFFICE

Eastern Nile Watershed Management Project

Cooperative Regional Assessment (CRA) for Watershed Management

TRANSBOUNDARY ANALYSIS
MAIN NILE SUB-BASIN
FINAL

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This report was prepared by a consortium comprising Hydrosult Inc (Canada) the lead company, Tecsult (Canada), DHV (The Netherlands) and their Associates Nile Consultants (Egypt), Comatex Nilotica (Sudan) and T & A Consultants (Ethiopia).

DISCLAIMER

CONTENTS

ANNEXES

ACRONYMS

AHD	Aswan High Dam
AHDLA	Aswan High Dam Lake Authority
CGIAR	Consultative Group for International Agricultural Research
CRA	Cooperative Regional Assessment
DIFID	Department for International Development
DRI	Drainage Research Institute
EEAA	Egyptian Environmental Affairs Agency
EIA	Environmental Impact Assessment
ENSAP	Eastern Nile Subsidiary Action Programme
ENTRO	Eastern Nile Regional technical Office
FAO	Food and Agricultural Organization
FNC	Forest National Corporation
f.o.b.	Forward on Board
GALD	General Authority for Lake Development
GEF	Global Environmental Fund
GIS	Geographic Information System
HADA	High Aswan Dam Authority
HELP	Hydrology for the Environment, Life and Policy
IDEN	Integrated Development of the Eastern Nile
IDRC	International Development Research Council
IFPRI	International Food Policy Research Institute
IGADD	Inter Governmental Agency for Drought and Desertification
IWRM	Integrated water Resources Management
JAM	Joint Appraisal Mission
JMP	Joint Multipurpose Programme
km	Kilometre
km^2	Square kilometre
km^3	Cubic Kilometer (1 billion cubic meters)
masl	meters above sea level

MCM	Million Cubic Meters
MERET	Managing Environmental resources to Enable Transitions to more Sustainable Livelihoods
MHPUNC	Ministry of Housing, Public Utilities and New Communities
MIT	Massachusetts Institute of Technology
MOH	Ministry of Health
MSR	Ministry of Scientific research
MW	Mega Watt
MWRI	Ministry of Water Resources and Irrigation
N	Nitrogen
NBCBN-RE	Nile Basin Capacity Building network for River Engineering
NBI	Nile basin initiative
NRC	National Research Council
NRI	Nile Research Institute
NTEAP	Nile Transboundary Environmental Assessment Project
NWRC	National water Research Council
ORNL	Oak Ridge National Laboratory
RIGW	Research Institute for Ground Water
SLM	Sustainable Land Management
SRTM	Shuttle Radar Terrain Mission
SWC	Soil and Water Conservation
SWHISA	Sustainable Water Harvesting and Institutional Strengthening in Amhara
t	ton
UNDP	United Nations development Programme
UNESCO	United Nations Scientific and Cultural Organisation
USLE	Universal Soil Loss Equation
WB	World Bank
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WFP	World Food programme
WSM	Watershed Management

ACKNOWLEDGEMENTS

This Trans-boundary Sub-basin Report has benefited considerably from written comments and recommendations received from the three National Steering Committees, the World Bank and ENTRO.

The Consultants wish to acknowledge and express their sincere appreciation to the three national Steering Committees, World Bank Staff members and ENTRO Staff members for their very positive comments and recommendations on the four Transboundary Analysis Sub-basin Reports.

EXECUTIVE SUMMARY

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 the opportunities and benefits of cooperation in watershed management. This Report examines the Main Nile Sub-basin. The analysis has been 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;
- 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.

The first two stages are complete. National level reports were produced for Egypt, Ethiopia and Sudan. These were considered at a Regional Workshop held in Alexandria, Egypt from 24th-26th July 2006 and subsequently revised in response to comments received from the three National Coordinating Committees, ENTRO and the World Bank. This report constitutes the results of the last three stages.

Chapter 2 provides an understanding of the basin-wide bio-physical and socio-economic situation. Chapter 3 examines the basin-wide watershed management issues. It first examines the institutional issues in both Egypt and Sudan. In Sudan devolution of power to regions and states is an avowed government policy. However, in both countries there is a complex institutional framework within which interventions must be coordinated for effective watershed management to operate.

The physical and technical issues are then examined, in particular the issues of moving sand dunes covering farmland and tipping into the Main Nile, drifting sand into Lake Nubia/Nasser, river bank erosion, sedimentation in Lake Nubia/Nasser, desertification and the potential environmental problems from the very substantial developments proposed for Lake Nasser and its environs.

Chapter 4 looks at the opportunities for in-country and trans-boundary benefits from watershed management activities in a basin-wide perspective. Opportunities are presented to reduce the encroachment of moving sand dunes; reduce river bank erosion; reduce wind blown sand into Lake Nasser/Nubia; improve livelihoods for the peoples around the lake; and address the potential negative environmental impacts that might result from the proposed developments around the Lake and its environs.

Finally the trans-boundary analysis examines a number of opportunities for cooperative watershed management and other cooperative activities. A framework for analysis is presented that identifies four types of benefits: to the river (ecological), from the river (socio-economic), reducing costs because of the river (political-economic) and finally beyond the river (economic and social). Some potential modes of cooperation are identified: basin-wide information exchange on hydrology and land cover; coordinated environmental planning and monitoring of Lake Nasser/Nubia and its environs; synergies from outputs of the various CRA's and coordinating activities in a number of other international programmes; trans-boundary trade and economic development and potential positive interactions amongst the proposed interventions.

1. BACKGROUND

1.1 Introduction

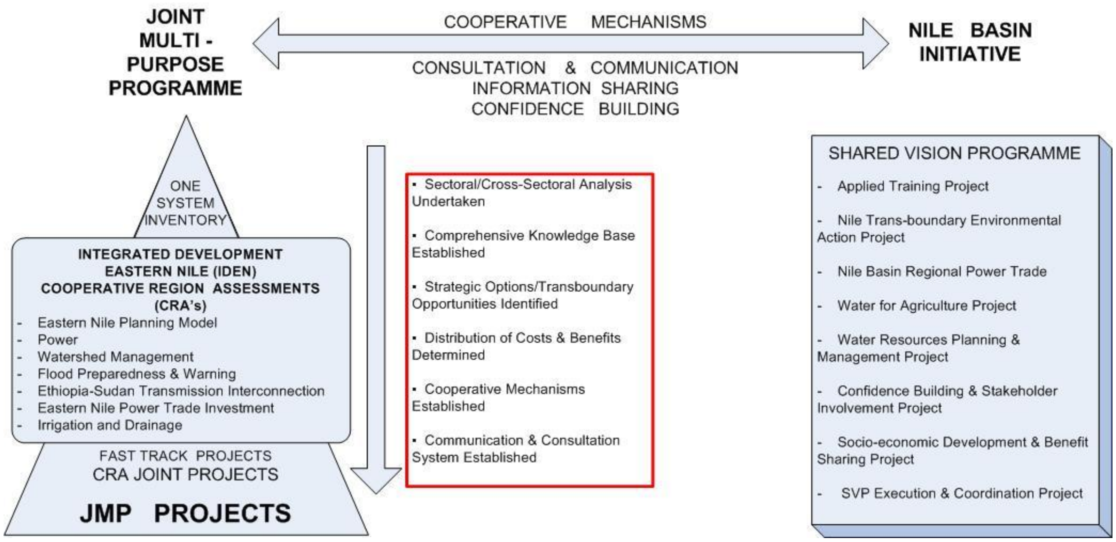
The Eastern Nile Basin Watershed Management Cooperative Regional Assessment (CRA) is in support of the Eastern Nile Subsidiary Action Programme (ENSAP). ENSAP, which includes Egypt, Ethiopia and the Sudan, seeks to initiate a regional, integrated, multi-purpose programme through a first set of investments. 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 trans-boundary 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 trans-boundary 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

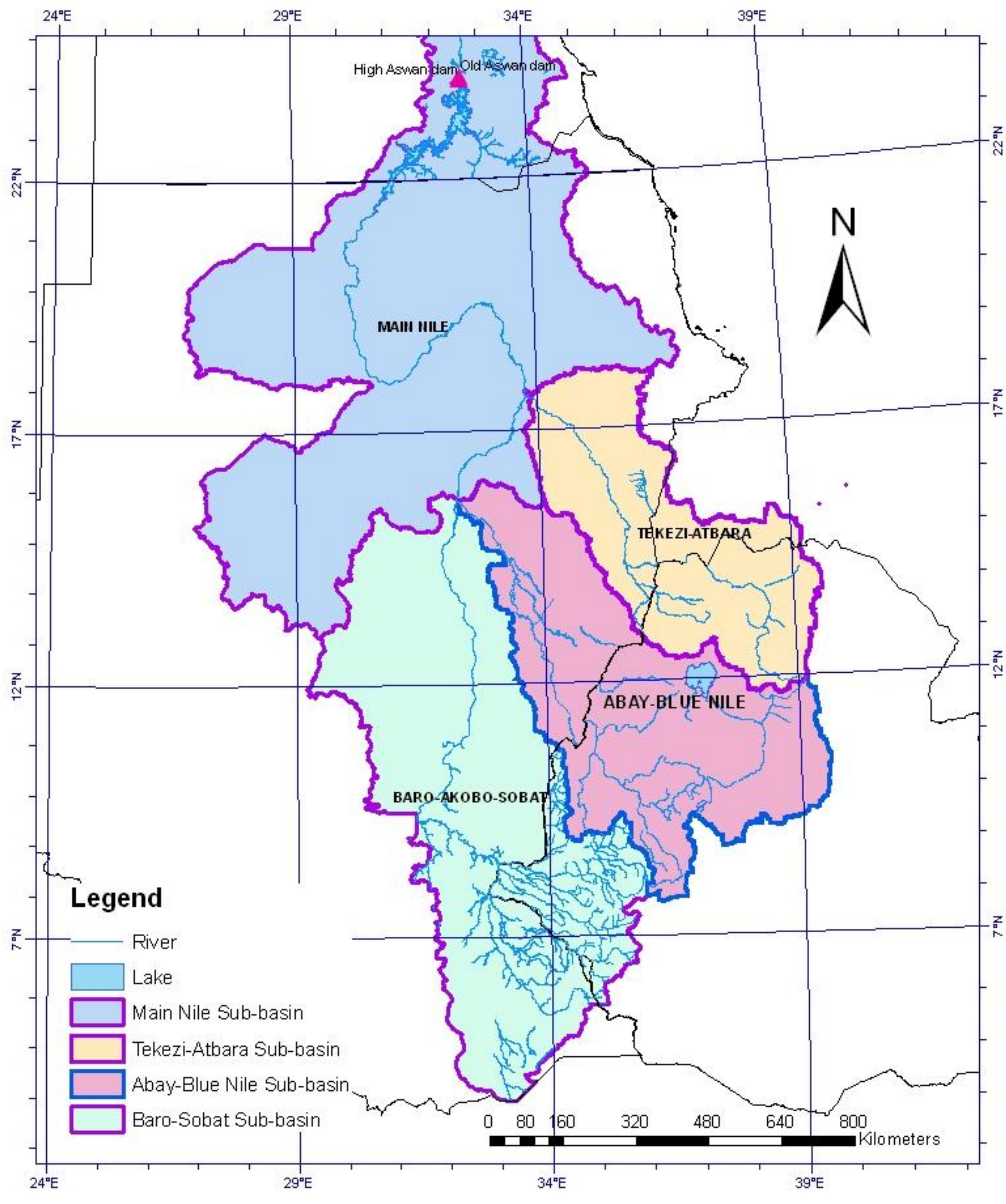


1.2 Primary Objectives of the Watershed Management CRA

The project focuses on four watersheds: the Abay/Blue Nile, Tekeze/Atbara, the Baro-Sobat-White Nile and the main Nile from Khartoum to the Aswan High Dam (Map 1). 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.

EASTERN NILE BASIN
LOCATION OF THE BARO-SOBAT, ABAY-BLUE NILE, TEKEZI-ATBARA AND MAIN NILE SUB-BASINS



Map 1. Eastern Nile Basin: with the Tekeze-Atbara, Abay/Blue Nile, Baro-Akobo-Sobat and the Main Nile Sub-basins.
Source: Basin boundaries: USGS/gtopo30/HYDRO30.

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. Terminology is generally based on area (although 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		Strong
Watershed	25 -1,000km^2		Moderate
Sub-basin	1,000 – 10,000km2	Guder, Anger	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 basins 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 loosing 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 trans-boundary opportunities to improve livelihoods and achieve poverty reduction. Finally, a Watershed perspective will enable the identification of basin-wide synergies from cooperative trans-boundary 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 is being 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 focussing 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 Sub-basin Reports

1.4.1 The Whole process

The National and Sub-basin Transboundary component and the Distributive Component form a sequential set of analyses each building upon and contributing to the next. The three sets of Reports when completed will form a whole.

The National level analysis includes (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) a discussion on policy and institutional issues conducive as well as hindering successful interventions on the national level; and (v) an outline of the long-term capacity building and monitoring needs to evaluate successes/impacts of interventions on the watershed on local livelihoods, agricultural output and sedimentation control.

The Country-level trans-boundary analysis provided a "with borders" view whilst the Sub-basin-level analysis provides a “without borders” view of the watershed system and associated livelihoods. The analyses identify opportunities for increasing the net benefits of watershed management interventions in the basin. The Distributive Analysis component will then reinsert borders, to analyze the distribution of costs and benefits that will accrue across countries under alternative watershed management intervention scenarios.

1.4.2 Transboundary Analysis Component

The Transboundary component comprises an integrated, national and a 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 the opportunities and benefits of cooperation in watershed management. The analysis is being 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;
- Distil from the system-wide analysis the greatest system-wide opportunities for high impact cooperative watershed management.

The first two stages are complete. National level reports were produced for Egypt, Ethiopia and Sudan. These were considered at a Regional Workshop held in Alexandria, Egypt from 24th-26th July 2006 and subsequently revised in response to comments received from the three National Coordinating Committees, ENTRO and the World Bank.

The four Trans-boundary Sub-basin Reports constitute the final three stages in the Transboundary Analysis Component. The results of the Country level and the Sub-basin level analyses will then feed into the Distributive Analysis component.

In this Report chapter 2 consolidates the results of the national level analysis into a system-wide analysis of watershed behaviour and associated livelihoods for the Main Nile Sub-basin. Chapter 3 identifies the common watershed management problems and issues experienced within each Sub-basin. The linkages between the watershed management problems that were identified at the national level are now articulated at the Sub-basin level.

Chapter 4 examines the opportunities and potentials for in-country and trans-boundary benefits accruing from watershed management interventions. In particular, potential additional cross-border benefits that may accrue to interventions not identified in the national level analysis are now identified. Thus, some interventions may accrue benefits in only one country, but it is important to identify interventions that can also accrue benefits in downstream countries. Additionally, some benefits may accrue across the Eastern Nile Basin as well as globally. Some impacts of national level watershed management interventions may have potential negative impacts on downstream and these also need to be identified and mitigating measures proposed.

In chapter 5 basin-wide opportunities for cooperative watershed management activities and related activities are examined. Thus, as well as cross-border benefits from national level interventions, additional benefits may accrue to cooperative interventions. These can include interventions that re-enforce or mutually support other IDEN and JMP interventions. There may also be potential benefits from linkages to other on-going national (the MERET and SWHISA programmes in Ethiopia) and international level programmes (for example the CGIAR project for improving livestock water productivity in the Nile Basin).

Potential synergies and the cumulative impacts of the various proposed interventions are examined. This analysis looks beyond the traditional watershed management options to other cooperative options that include but are not limited to trans-boundary biodiversity conservation, trans-boundary agro-industrial development, trans-boundary livestock disease control, trans-boundary watershed management planning, and trans-boundary watershed management monitoring.

The revised Country Reports now constitute the Annexes to the four Sub-basin reports and contain the detailed national-level analysis. What were identified as National concerns in the Country reports are now located within the specific Sub-basin context. Of necessity, the detailed results from the Country reports are consolidated and where necessary summarized in the Sub-basin Reports.

2. BASIN-WIDE BEHAVIOUR AND LIVELIHOODS: BIO-PHYSICAL AND SOCIO-ECONOMIC SITUATION

2.1 Bio-physical Situation

2.1.1 Watershed and Rivers

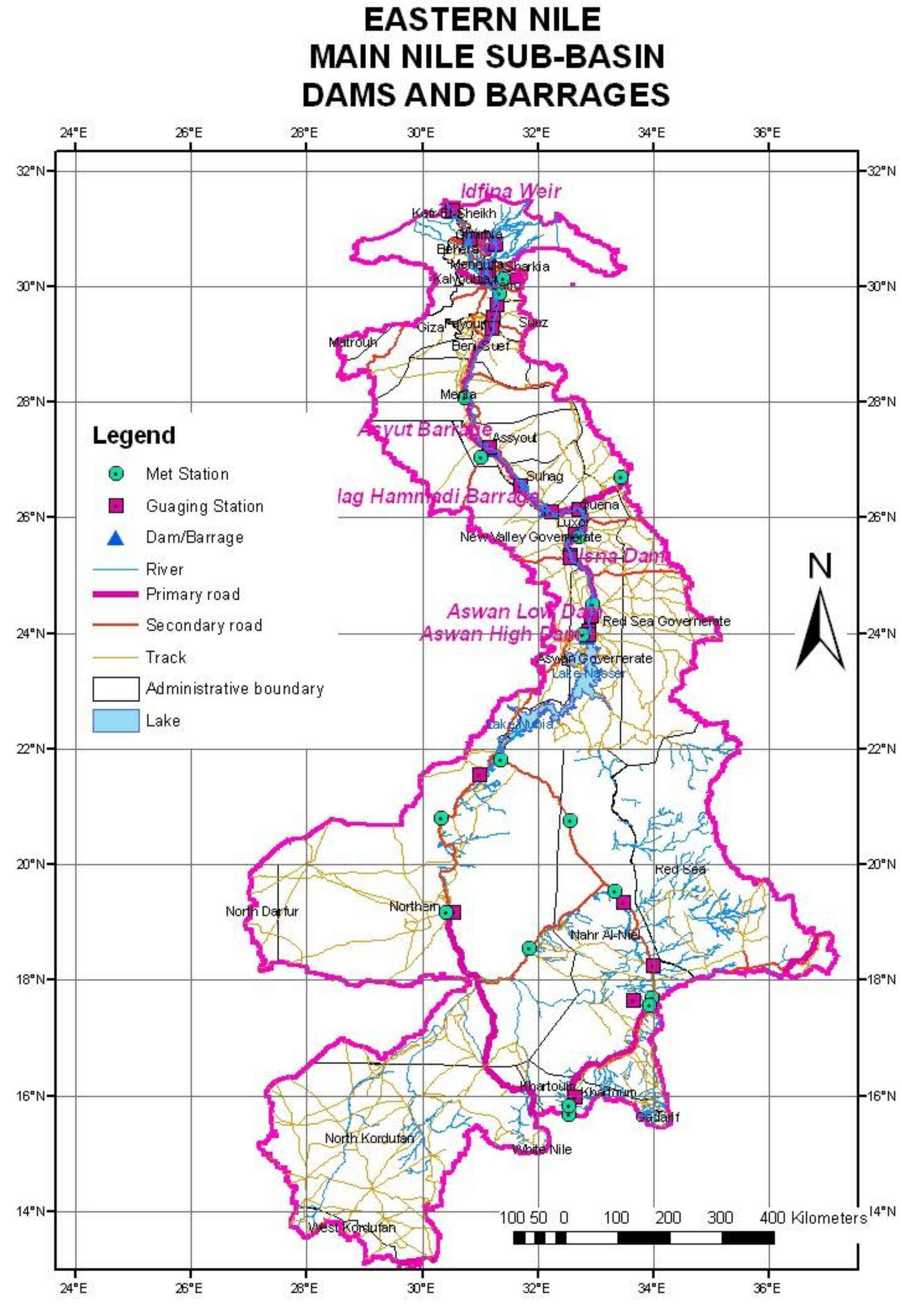
The Main Nile sub-basin covers an area of 656,398 km^2 (Map 1), including the catchment of Lake Nasser to the Aswan High Dam (AHD). This sub-basin extends from the junction of the White and the Blue Niles at Khartoum in the south to the Aswan High Dam in the north, over 14 degrees of latitude. From Khartoum to Wadi Halfa it is 1,490 kms.

Its only tributary along the way is the Tekeze-Atbara River at Atbara. Except in years of exceptional rainfall (e.g. August 1988) there is no other inflow. Between Khartoum and the AHD there are no dams except for on-going construction of the Meroe Dam at the Fourth Cataract.

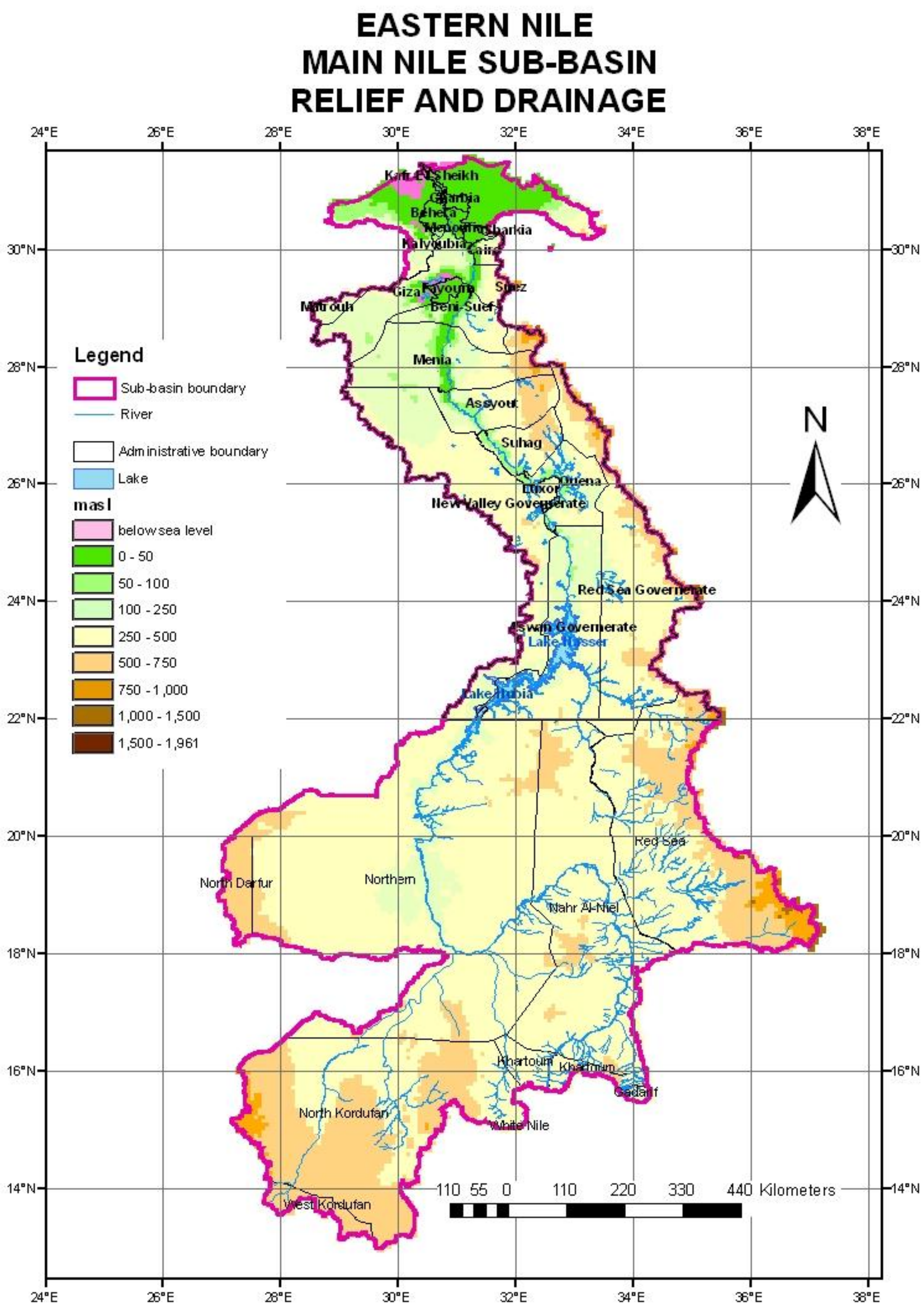
2.1.2 Relief

Except for the Sabaloka gorge about 80 kms north of Khartoum the Main Nile flows through an arid plain with the occasional rocky outcrops. To the eastern edge of the Sub-basin are the Red Sea Hills that rise in parts to 1,800 masl. On the western edge reaches up to a broad plateau in Northern Darfur and Northern Kordofan at about 1,500 masl. 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.

The river profile shows a gentle gradient to the 5^{th} Cataract, followed by a steep segment between the 5^{th} and 4^{th} cataracts. Again there is a gentler gradient between cataracts 4 and 3, followed by a steep reach between cataracts 3 and 2 just above Wadi Halfa. The gradient is extremely variable: ranging between a minimum of 3.2 m per 10,000 and a maximum of 1 m per 1000. Average channel width is about 600 m.



Map 2. Main Nile Sub-basin: Dams and Barrages
Source: Basin boundaries: USGS/gtopo30/HYDRO30. Gauges/met stns. ENTRO GIS Database



Map 3. Main Nile Sub-basin: Relief and drainage

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

2.1.3 Climate

(i) Rainfall

In Sudan annual rainfall isohyets generally run southwest to northeast, ranging from less than 25 mm in the north to 400 mm (Yagoub Abdalla Mohamed, 2005) 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;

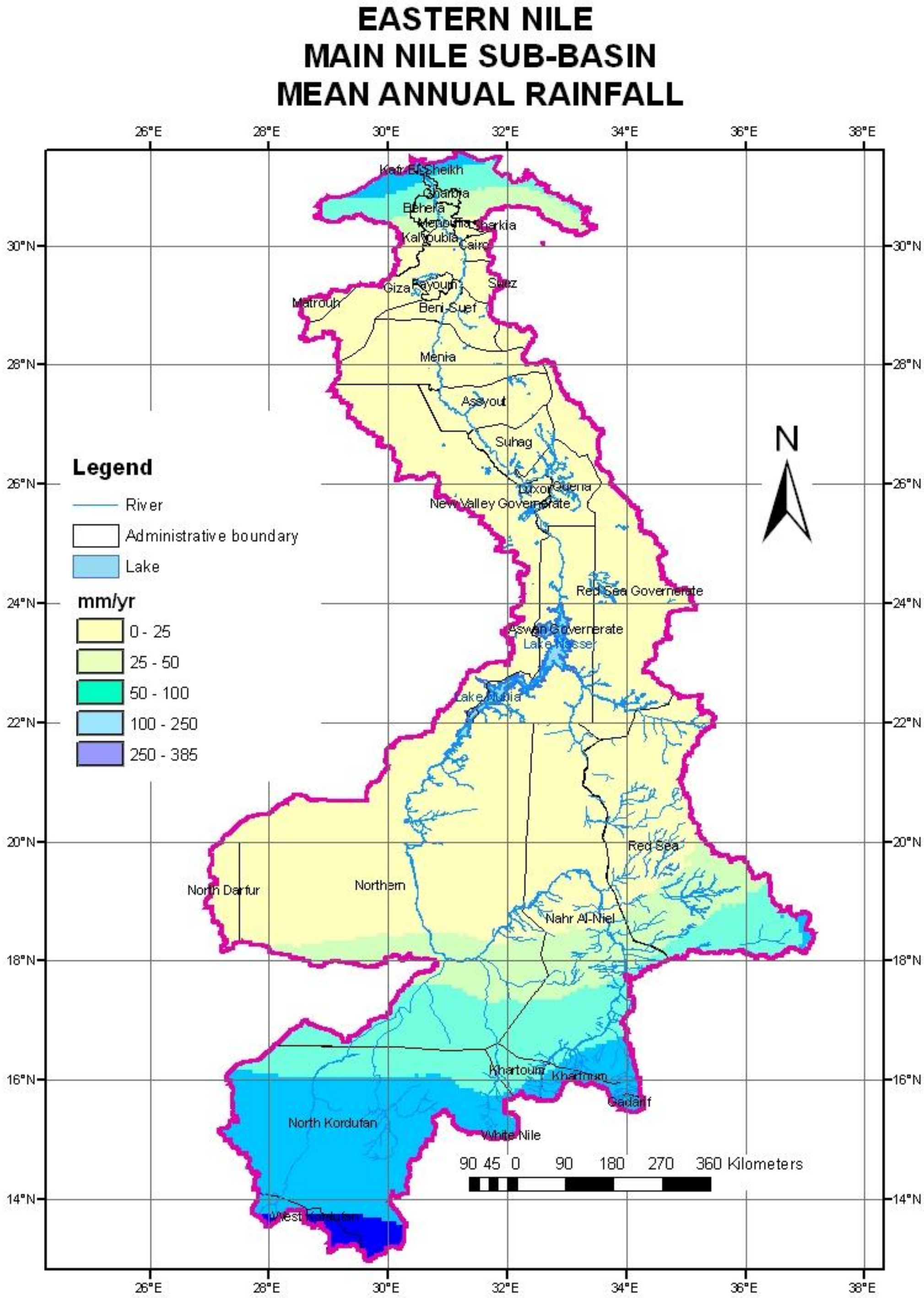
In Egypt most rain falls along the coast as indicated in Map 4 but even the wettest area, around Alexandria, receives only about 200 mm of precipitation per year. Moving southward, the amount of precipitation decreases drastically. Cairo receives a little more than one centimetre of precipitation each year. The areas south of Cairo receive only traces of rainfall. Some areas receive no rain at all during a number of years and then experience sudden downpours that result in flash floods.

(ii) Temperature

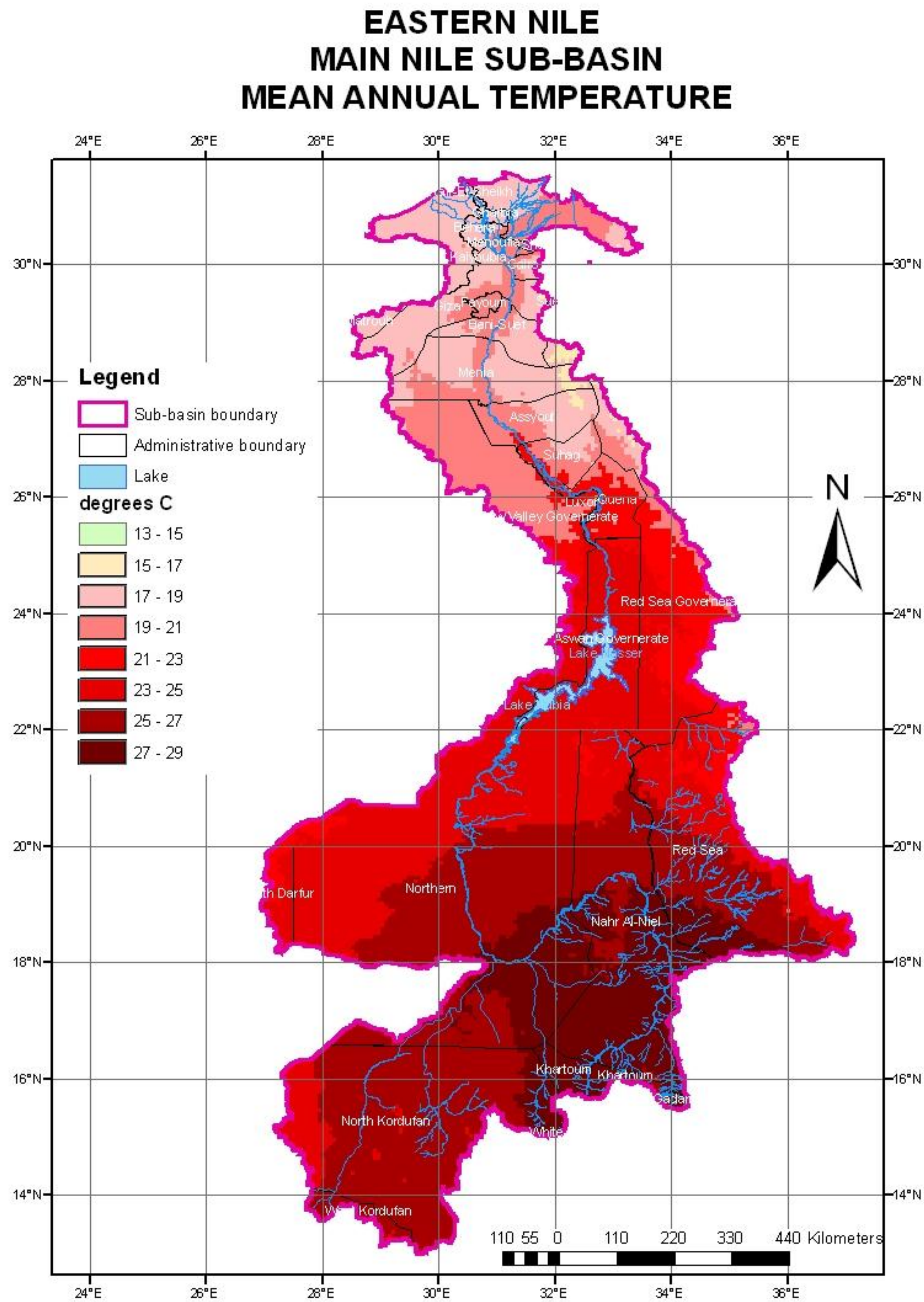
In Sudan daily minimum and maximum temperatures in January are 14°C and 33°C and those in May are 24° and 44°C respectively. Highest mean annual temperatures occur in the eastern clay plains, rather than the north where minimum temperatures bring down the mean (Map 9). Daily evaporation rates range from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

Egypt has two seasons: a mild winter from November to April and a hot summer from May to October. In the coastal regions, temperatures range between an average minimum of 14^{o} C in winter and an average maximum of 30 ^{o} C in summer. Temperatures vary widely in the inland desert areas, especially in summer, when they may range from 7 ^{o} C at night to 43 ^{o} C during the day. During winter, temperatures in the desert fluctuate less dramatically, but they can be as low as 0 ^{o} C at night and as high as 18 ^{o} C during the day.

The average annual temperature increases in the southward direction from the Delta to the Sudanese border, where temperatures are similar to those of the open deserts to east and west. Throughout the Delta and the northern Nile Valley, there are occasional winter cold spells accompanied by light frost and even snow. At Aswan June temperature can be as low as 10 ^{o} C at night and as high as 41 ^{o} C during the day when the sky in clear.

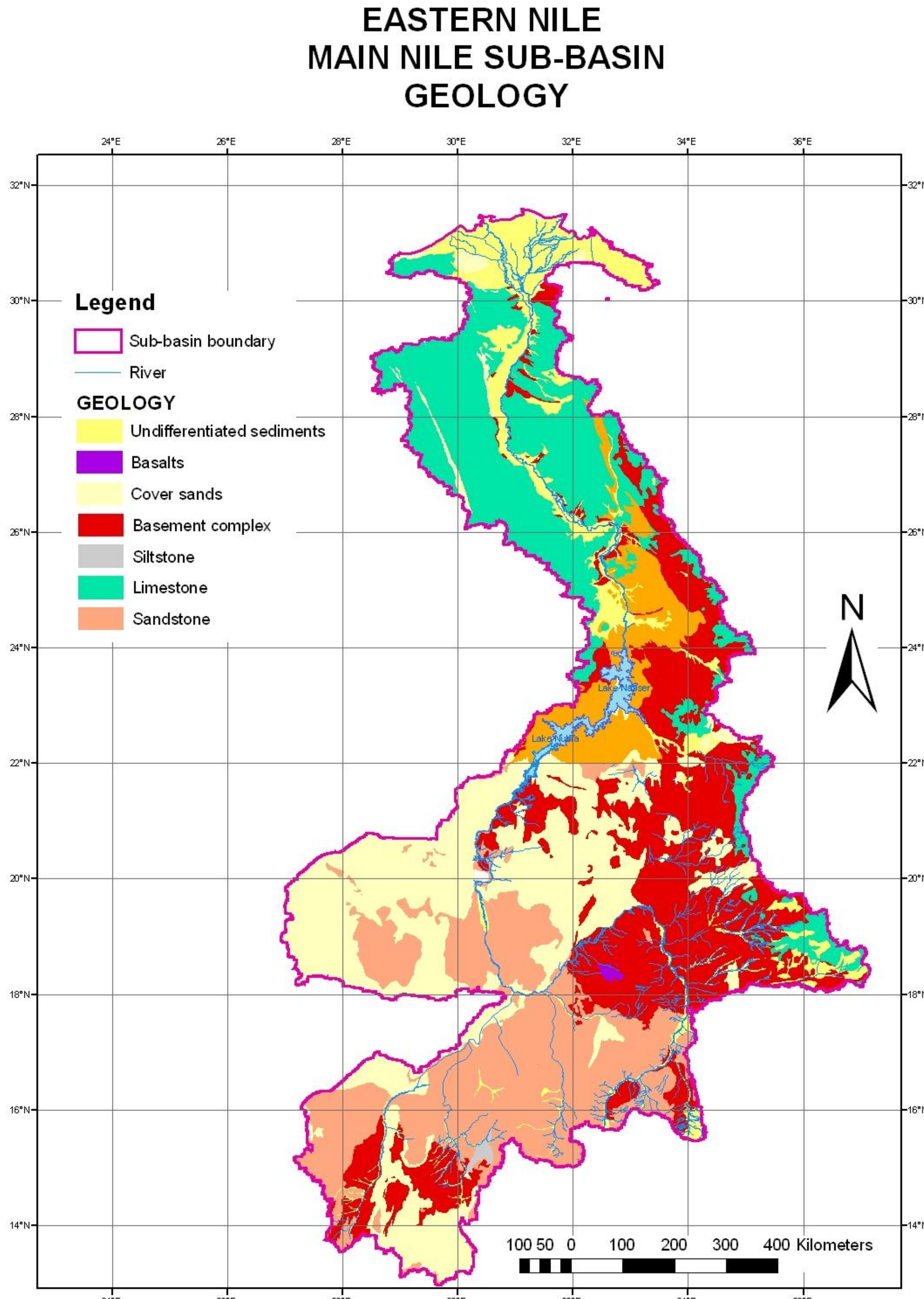


Map 4: Main Nile Sub-basin: Mean annual rainfall (mm/yr)
Source: ENTRO GIS Database



Map 5: Main Nile Sub-basin: Mean Annual Temperature (degrees C)
Source: ENTRO GIS Database

2.1.4 Geology



Map 6. Main Nile Sub-basin: Geology
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

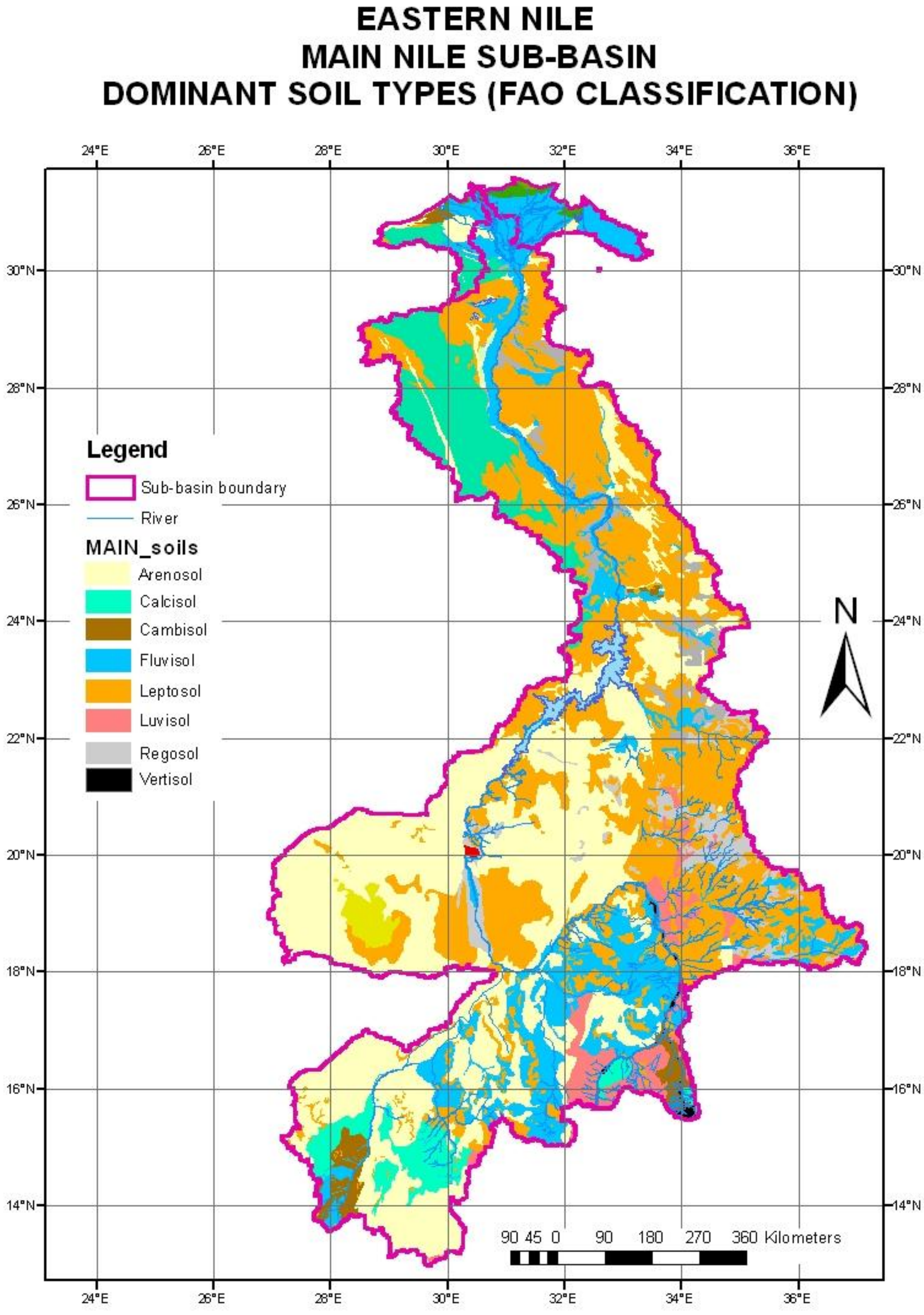
The main underlying geological formations within the Main Nile Sub-basin include the older Basement Complex rocks, the Nubian Sandstones, Tertiary unconsolidated sediments and Recent superficial wind blown sands. The Basement Complex comprises gneisses, schists, marbles and intrusive granites and basic 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 and Egypt. The Recent deposits include the Nile alluvium, sand dunes and the black clays of the flood plains.

2.1.5 Soils

In northeast Sudan 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 Sub-basin Arenosols are widespread. They are derived from unconsolidated sediments and textures and 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.

The dominant soil types around Lake Nasser are Leptosols on rock and Arenosols derived from the cover sands. Locally Calcisols are found derived from crystalline limestones. In valley bottoms Fluvisols are very important as they comprise the main soils for irrigation around the Lake shore and in the Wadi Allaqi where they have been intensively studied (Biggs et al., 1993). Their parent material is from one or more of three sources: sediment in the lake, wind blown sand and flowing water. Laboratory analysis of the soils in the Wadi Allaqi indicated that wind blown sand was the least significant although there is some reworking of fine sediment by wind. Running water (although extremely infrequent) represented the most important source of soil parent material.

The greatest effect on soil quality is the influence of lake water on soil properties. The position of the lake shore is highly variable depending on the annual variations superimposed on larger long-term variations. Annual variations are in the range of 6 to 7 meters, whilst the 1978 -1988 range was 27 meters. Two processes are important: deposition of silt from the lake during inundation and changes in chemistry of the surface soil layers during and immediately after inundation. The lake sediment is identifiable by its high content of shells and may contain high amounts of soil nutrients. Soils located at higher elevations and which are inundated less frequently have a lower pH – from 9.00 where the soil is frequently inundated to 8.00 where inundation is less frequent, whilst the subsoil remains constant at 8.8. Less frequently inundated soils also have high oxidized iron contents that could have important consequences of the soil's ability to supply phosphate and some trace elements (Biggs, op.cite).



Map 7. Main Nile Sub-basin: Dominant Soil Types (FAO Classification)
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

2.1.6 Vegetation

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 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 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.

There is a zoning of vegetation around the Lake Nasser/Nubia from the water's edge. Normally, this stretches only tens to hundreds of meters from the Lake shore but along the Wadi Allaqi this zoning has been stretched over some 30 kms from the lowest water mark recorded to the highest at 177.5 masl (Biggs op. cite). Annuals characterize the zone closest to the water's edge typically dominated by *Glinus blitoides*, together with *Portulaca oleracea, Helianthemum spinum, Amaranthus blitoides* and the grasses *Erogrostis aegyptica, Fimbrystilis bis-umbellata* and *Crypsis schoenoides*.

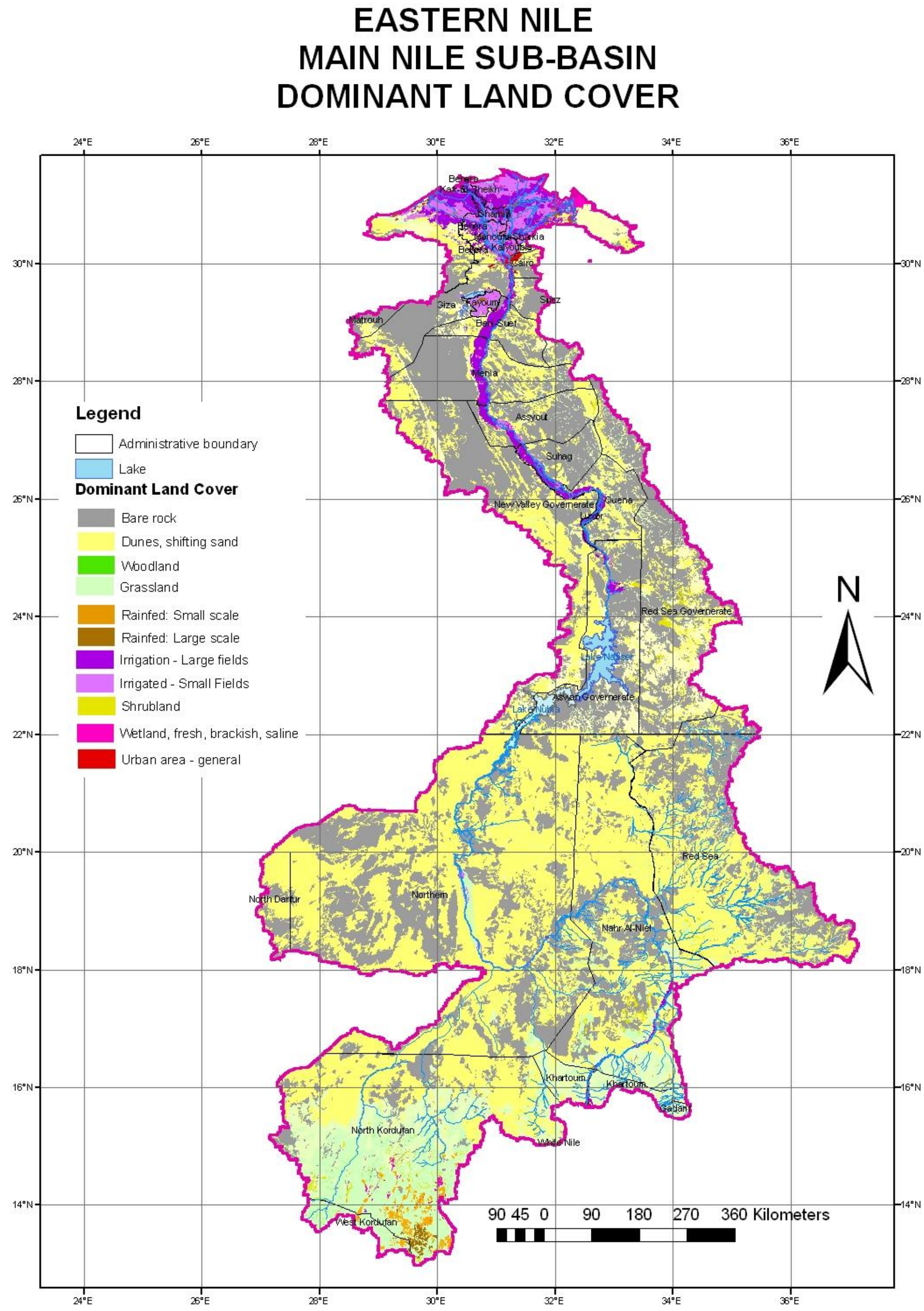
In the middle zone *Tamarix nilotica* is dominant. In the central section the stands are mono-specific, and individual plants may be large, exceeding 5 meters. The highest zone is characterized by a vegetative type dominated by the composite shrub *Pulicaria crispa* that replaces *T. nilotica*. It appears to mark the highest levels attained by Lake Nasser. Associated with *P. crispa* are *Acacia ahrenbergiana*, *A. raddiana*, *Cassia senna* and *Citrillus colocynthis*.

A recent study (Springuel et al., 1997) suggests that the *Tamarix nilotica* community is both new and almost unique within this desert area. It has a clear affinity with the flora present in earlier pluvial periods in this area of North Africa. Evidence for this is provided in fossil plant remains found in sand hillocks of the upper wadi Allaqi dated to about 500-800 years BP. There is no record of *T. nilotica* being found in its present position prior to the filling of Lake Nasser other than along the river bank zone.

Burning and cutting of *T. nilotica* by local communities, as well mechanical clearing by the Aswan high Dam lake Authority are leading to its destruction. The upper Pulicaria community is being uprooted by machine and taken by the truck load as fuel.

2.1.7 Land Cover

The relative proportions on the various land cover types are indicated in table 2 and shown on Map 8.



Map 8. Main Nile Sub-basin: Dominant Land Cover
Source: FAO Africover Sudan & Egypt

Table 2. Main Nile Sub-basin: Land Cover (km^2) and % of total.

Bare land: Rock, Bare Soil	585,105	65%
Bare land: Loose sand	125,684	14%
Grassland	83,924	9%
Shrubland	38,080	4%
Cultivated land: Irrigated Crops: Large fields	18,755	2%
Cultivated land: Irrigated Crops: Small fields	15,440	2%
Bare land: Dunes	12,460	1%
Water (reservoirs, dams, ponds, river)	9,023	1%
Rainfed Crops: Small fields	4,466	0.5%
Built up: Urban	2,396	0.3%
Bare land: salt crusts	1,804	0.2%
Woodland	1,772	0.2%
Rainfed: Large fields	1,190	0.1%
Retreat Flood cropping	210	0.0%
Permanent Swamp	147	0.0%
SUB-BASIN	**900,456**	

Over 80 percent of the surface area is "bare land": rock, bare earth, shifting sand, dunes and salt crusts. Grassland and shrubland, much of it very sparse, cover another 13 percent. Irrigated cropland (cereals, vegetables and tree crops) cover 4 percent and water 1 percent. The remaining 1.5 percent of land has the remaining land cover types.

The large expanse of shifting sand to the northeast of the Dongola Reach of the Main Nile where shifting dunes meet the river can clearly be seen. Similarly the expanse of shifting sands to the west of Lake Nasser/Nubia is in sharp contrast to the rock to the east of the Lake.

2.1.8 Hydrology

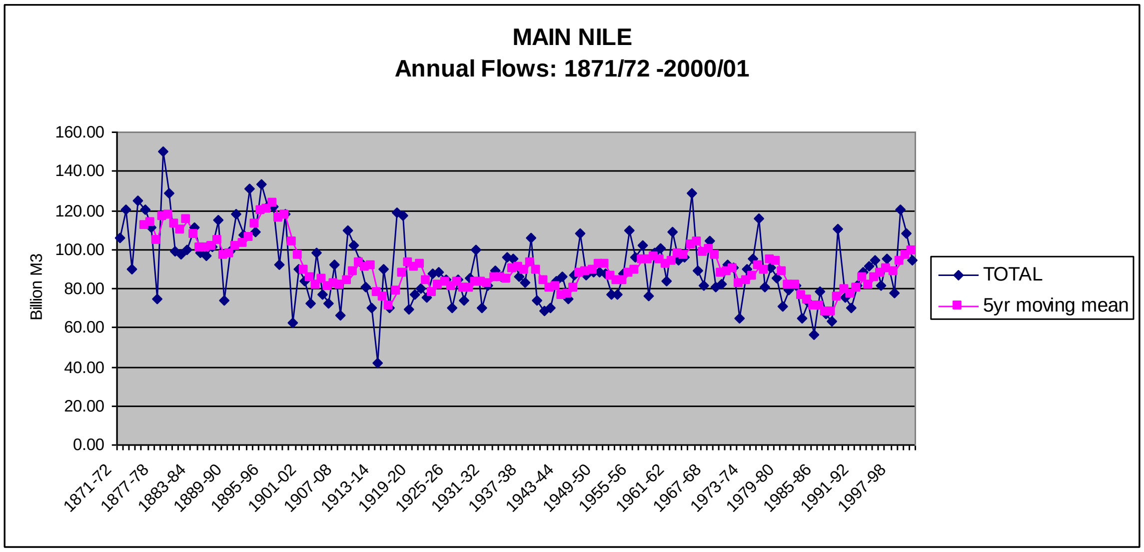
(i) Surface Water

The average annual flow of the Main Nile at Tamaniat is approximately 72.691 km^3 (1911 – 1995). The river flows through a series of cataracts with a total drop of 192 m (from 375 masl at Khartoum to 183 masl at Lake Nubia/Nasser) over a length 1,490 kms (Sutcliffe & Parks, 1999). The seasonal flow pattern exhibits the combined characteristics of the two main tributaries with the seasonal patterns of the Blue Nile and Atbara superimposed on the regular pattern of the White Nile.

Within the Sub-basin there are a number of ephemeral streams (wadis and khors) that flow during the rain season. However, the more important of these, the Gash on the east bank does not reach the Main Nile.

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. 2).

Figure 2. Main Nile: Annual Discharges and 5 year moving mean. 1871/72 -2000/01



Source: MWRI (Cairo)

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 Meroe 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 1,250 MW, 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 Massachusetts Institute of Technology (MIT) (Paris, Yamana and Young, 2004) and (iii) by the Eawag Institute, 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) Groundwater

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

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

Basement complex rocks only have a limited ground water yield. The Nubian sedimentary formation forms the most extensive and largest ground water basin in Egypt. Although recharge from rainfall is very limited a substantial annual amount is received from the Nile River system. The quality is good to excellent with salinity values rarely exceeding 600 mg per litre.

The Nubian sedimentary formation forms the most extensive and largest ground water basin in Sudan and Egypt. 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 alluvial basins are located along most seasonal streams and are recharged from rainfall and season flows.

The long axis of the Wadi Allaqi follows fault zone between the basement complex rocks to the northeast and the Nubian Sandstones to the southwest. These are overlain by unconsolidated wadi sediments of Holocene and Recent age when the local climate was wetter. The Wadi floor has a very gentle gradient of 0.5 degrees. Groundwater is from two sources. The first is deep percolating water from the Red Sea Hills over which there is varying amounts of rainfall annually. This is normally 30 meters below the surface and of poor quality. The second source of groundwater is from the Lake. This is usually available about 2 to 3 meters below the surface, and is extremely variable because changes in Lake level. (One meter change in Lake level causes a one kilometer change in inundation of the Wadi.) The quality of the water is good.

This source is of considerable importance to the cultivators in the Wadi who utilize the shallow groundwater for irrigation after the residual moisture from the season lake flooding has been used up.

2.2 Socio-economic Characteristics

2.2.1 Administration

In Sudan the Main Nile Sub-basin encompasses 8 Administrative Regions and in Egypt three Governorates as shown in table 3.

Table 3. Administrative Regions within the Main Nile Sub-basin with area (km^2)

Region	Area (km2)	% of Sub-basin
SUDAN		
North Darfur	8,689	**1.3%**
North Kordofan	123,958	**18.9%**
West Kordofan	6,409	**1.0%**
Northern	230,080	**35.1%**
Khartoum	12,129	**1.8%**
Nile	105,195	**16.0%**
Gaderef	1,468	**0.2%**
Red Sea	98,747	**15.0%**
EGYPT		
Aswan	27,608	**4.2%**
Red Sea	30,856	**4.7%**
New Valley	11,258	**1.7%**
SUB-BASIN	**656,398**	**100.0%**

Source: ENTRO GIS data base:

The main States in terms of area are North Kordofan, Northern, Nile and Red Sea.

2.2.2 Population

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

Table 4. Population of States and Governorates within the Main Nile Sub-basin.

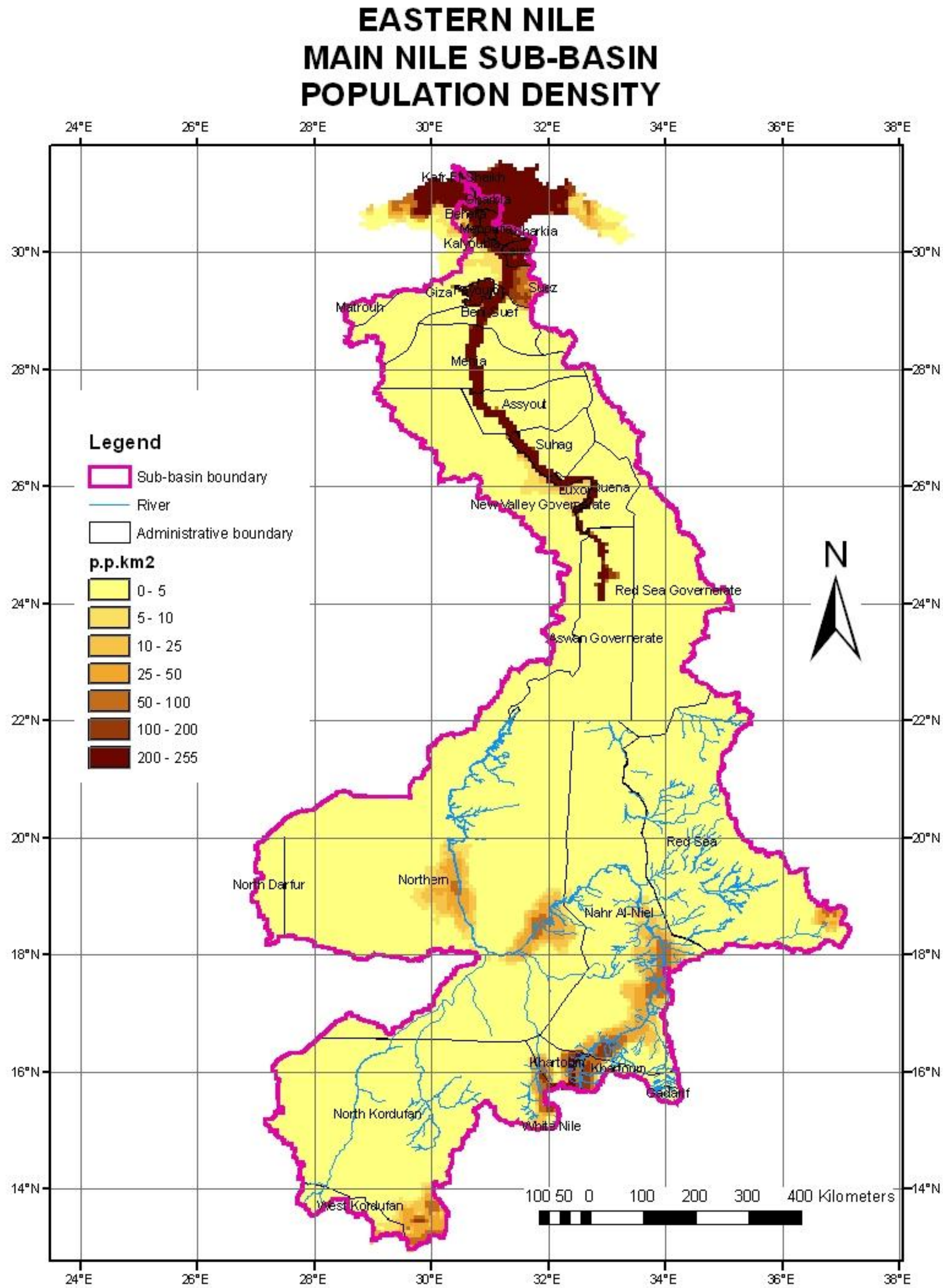
State/Governorate	Population
SUDAN	
Northern	1,179,399
Nile	701,256
Red Sea	2,048,041
EGYPT	
Aswan	169,647
Red Sea	1,120,275
New valley	186,375
SUB-BASIN	5,404,993

Source: Sudan: UN Population Fund & Sudan Central Bureau of Statistics. Egypt: Central Agency for Public Mobilization & Statistics, Cairo.

(ii) Population Distribution

Population densities are shown in Map 9. 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.

In Egypt the population is naturally, concentrated along the Nile River.



Map 9. Main Nile Sub-basin: Population densities and distribution.
Source: LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL)

(ii) Demographic Characteristics

Population growth rates and other demographic characteristics are shown in table 5.

Table 5. Main Nile Sub-basin: States/Governorates - Demographic Characteristics

State	Rural Gth rate %	Urban %	% <15yrs	% >60yrs	Sex ratio M/F	Crude birth rate*	Crude death rate*	Infant mort. male /1000 births	**Infant mort. female /1000 births**
SUDAN									
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**
EGYPT									
Aswan	1.63***		38.2	6.4	100.4	26.3	6.4	24.5 **	
Red Sea	**1.83*** **		**35.1**	**3.5**	**131.7**	**26.3**	**6.4**	**25.9** **	

Source: Sudan: UN Population Fund & Sudan Central Bureau of Statistics. Egypt: Central Agency for Public Mobilization & Statistics, Cairo.
* National
** Male+female
*** Urban+rural growth rate

Population growth rates are low, between 0.52 and 1.9 percent 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.

(iii) Literacy and Education

The literacy and primary school enrolment rates for the States/Governorates in the Sub-basin are shown in table 6.

Table 6. Main Nile Sub-basin: States/Regional States – Literacy and Primary School Enrolment Rates

State	Literacy >15yrs % Average	Literacy >15yrs % Male	Literacy > 15yrs % Female	Pop. 6-13yrs	Total Primary school enrol.	% enrol.
SUDAN						
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
EGYPT						
Aswan		93.7	94.3	287,555	n.d.	71.9*

Source: Sudan: UN Population Fund & Sudan Central Bureau of Statistics. Egypt: Central Agency for Public Mobilization & Statistics, Cairo.
* = National (Preparatory+Primary)
nd:= No details at Governorate level

There are very clear differences in literacy and primary School enrolment 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.

In Egypt male and female literacy rates in Aswan are almost equal.

2.2.3 Livelihood Characteristics: Socio-cultural Aspects of the Population

(i) Sudan

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).

(ii) Egypt: Around Lake Nasser

(a) The Ababda and Bishari

There are two main ethnic groups who live in the eastern part of the Lake Sub-basin: the Ababda who comprise some two thirds of the population and the Bishari who make up the other third. The Ababda have live in the southern part of the Eastern Desert for centuries although since the end of the 19^{th} century many have migrated to the towns of the Nile Valley. The current population is estimated to be 15,500.

The Bishari are more recent arrivals. Traditionally they lived in the Gebel Elba Region in the Red Sea Hills along the border with Sudan. Most have arrived since the 1970's to take advantage of the opportunities presented by the seasonal inundation.

There is little difference between the livelihoods of the two groups. Their economy is based on five elements (Briggs et al., 1993). In order of preference these are: (i) charcoal production, (ii) sheep herding, (iii) camel herding and (iv) collecting medicinal plants, and (v) residual moisture cultivation.

There are seasonal differences: with charcoal production and sheep herding taking place between December and April, cultivation between May and September, and camel herding and medicinal plant collection throughout the year. In the hill areas to the east winter rains are common and people migrate there for sheep herding and charcoal production. One person can produce five sacks of charcoal at £E50 (US$14 at 1993 prices) a sack. For a production unit of three people over a four month production season this can realize an income of E£3,000 per household. Overheads are negligible and harvesting is reported to be sustainable. Sacks are transported to Allaqi by camel and then either sold to truck drivers of a local quarry, AHDLA or WFP, or get lifts on such lorries.

In the summer they return to Lake shore to take advantage of the cooler temperatures near the lake and the retreating lake for cultivation of the residual moisture and the grasses that grow on the moisture. This system of seasonal transhumance allows the forage resources in the hills and in the lower Wadi Allaqi to recover. However, the attractions of the Lake shore and lower Wadi inundation area means that movements to the hills are getting shorted putting a strain of the forage resources near the lake.

Cultivation depends initially on residual moisture but as the season progresses on well water. Cultivation takes place in fenced plots 50 by 50 meters. Most plots have more than one well. Wells deeper than 3 meters are avoided because of the labour involved. Most wells are only used for one season as they are frequently inundated the following rise in Lake level. Small gardens of 5 by 5 meters are constructed within the plot and fed by small canals from the well. Crops include maize, water melon, okra, marrow, beans and millet.

Camels roam freely and are not herded and can roam for up to six years. Medicinal plant collection is carried out locally as and when time permits.

(b) Dabuka (Camel trains)

Since inundation started in the early 1970's the Wadi Allaqi has become a major stopping over point for the *dabuka* (camel) trains from Sudan. Abu Hamed and Atbara are the main collecting points for the journey of 10 to 11 days following the Wadi Gabgaba for much of the way to Wadi Allaqi. The final journey of 3 to 4 days is to Daraw, north of Aswan where most camels are slaughtered for meat.

The Wadi Allaqi, because of the arm of Lake Nasser extending into the wadi fulfils a major role in this system. Although a healthy camel can go for 14 days without water, a ten day journey should present no problem. In practice the available water in the Wadi Allaqi is extremely important for the maintenance of camel and thus meat quality.

It is estimated that 100,000 camels in over 300 *dabuka* a year make the journey from Sudan by this route. Economically the dabuka drovers provide a source of trade, a means of transport to Aswan and Daraw and a source of information of the location and quality of pastures through the areas they have traversed.

(c) Other Cultivators

After 1988 reservoir levels began to rise, with full storage levels again reached during the 1990s. In 1989 the World Food Program (WFP) agreed to launch a joint program with the High Dam Lake Development Authority whereby WFP would provide food for work to reclaim land along the lake shore for agriculture as well as for the eventual construction of 33,000 houses (Poeschke 1996). By the mid-1990s 10,000 feddans had been reclaimed in three upper reservoir areas that Nubians had first attempted to pioneer in the late 1970s. Nubians, however, are only one of the people involved; others included non-Nubian fisher/farmers from Upper Egypt as well as Beja pastoralists from the eastern desert and the Red Sea coast who have begun to graze and water their stock around the edges of the reservoir. Whether or not the Nubians, as the former residents of the area, will be able to compete successfully against these other pioneers remains to be seen.

2.3 Agriculture

2.3.1 Main Agricultural land Use Systems

(i) Overview

In the Main Nile Sub-basin there is very little rainfed cropping. In Sudan a small area of small-scale rainfed cropping occurs in Northern Kordofan based on sorghum. In Egypt in the delta near to the coast there is some rainfed olive production.

In general two broad systems can be identified: (i) rainfed cropping, (ii) irrigated cropping and (iii) extensive livestock production (with minor cropping). Differences in the scale of operations, tenure type and to a lesser extent cropping patterns give rise to a number of recognizable sub-categories. These are summarized in table 7.

Table 7. Main Agricultural Systems in the Main Nile Sub-basin

Main Category	Scale of operations	Tenure type	Main Components	Location
	Small-scale:(<40 feddans) Pump	Individual Freehold	Cropping: Sorghum, wheat, Alfalfa	Main Nile, Lake Nasser
	Small-scale (<40 feddans): Basin irrigation	State land: Lease and sub-leases	Cropping: Sorghum, wheat, alfalfa	Main Nile, Sudan
	Small-scale (< 40 feddans): Groundwater: well pump	State land: Leases and Sub-leases	Cropping: Date palm	Main Nile
	Small-scale: Groundwater: well: hand	Community land	Cropping:	Lake Nasser: Wadi Allaqi
	Large scheme (>40 feddans): Pump from Lake	State land: :Leases	Cropping	Egypt, Lake Nasser
	Large scheme: small-scale operations (<40 feddans) Gravity	State land: Individual long-term leases	Cropping: Cotton, Sorghum, wheat Small-livestock holdings	Egypt, Lake Nasser
	Large scheme: large-scale operations	State land: Long term Leases	Cropping:	New Valley Scheme: Tushka Depression
LIVESTOCK	Small-scale: Extensive Pastoral Transhumant	State land: Communal use (grazing, water) rights	Cattle, small-ruminants, Camels	Sudan
	Small-scale: Extensive pastoral Transhumant-sedentary	State land: Communal use (grazing, water) rights	Camels	Sudan, Egypt: lake Nasser – Red Sea Hills

(ii) Irrigated Cropping

There are a number of sub-categories of irrigated cropping. A convenient division can be made firstly between large and small schemes[2]. Large schemes are found on the western side of Lake Nasser and in the Tushka Depression.

In Sudan along the banks of the Main Nile are a significant number of small-scale irrigators using a variety of irrigation methods. Pumped irrigation straight from the river is common. The pump schemes along the Main Nile in Sudan have freehold tenure dating back to the early 20th century. In addition, 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.

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.

In the Wadi Allaqi on the eastern side of Lake Nasser cultivation depends initially on residual moisture left by the flooding of Lake Nasser but as the season progresses on well water. Cultivation takes place in fenced plots 50 by 50 meters. Most plots have more than one well. Wells deeper than 3 meters are avoided because of the labour involved. Most wells are only used for one season as they are frequently inundated the following rise in Lake level. Small gardens of 5 by 5 meters are constructed within the plot and fed by small canals from the well. Crops include maize, water melon, okra, marrow, beans and millet.

In 1989 the World Food Program (WFP) agreed to launch a joint program with the High Dam Lake Development Authority whereby WFP would provide food for work to reclaim land along the lake shore for agriculture. The long-term goal is to settle nearly 1 million people by the year 2017. By the mid-1990s 10,000 feddans had been reclaimed in three areas that Nubians had first attempted to pioneer in the late 1970s. The Nubians are only one of the people involved; others included non-Nubian fisher/farmers from Upper Egypt as well as Beja pastoralists from the eastern desert and the Red Sea coast who have begun to graze and water their stock around the edges of the reservoir. The number of beneficiaries and area cultivated are indicated in table 8.

[2] The difference between the two is necessarily arbitrary but 40 feddans is a convenient division.

Table 8. Small-scale Irrigation around Lake Nasser, 2006.

Location on Lake Nasser	No. of Groups of beneficiaries*	No. of persons*	Agriculture area		Total area feddans
			Cultivated	**Uncultivated**	
East	53	159	1073	900	1973
North	166	471	3356.5	835.5	4192
South	95	379	2338	4467	6805
Total	**314**	**1,009**	**6,768**	**6,202**	**12,970**

Source: General Authority for Development of AHD Lake (GAD-AHD-Lake), 2006 (High Dam Development Authority), Agricultural Sector

***** Number of settlers

The main cropping patterns are shown in table 9. Vegetables dominate the cropping patterns. Currently settlers cultivate only in the winter and return to their original homes in Spring to earn additional income (CDS/DDC, 2004).

Table 9. Cropping Pattern of cultivated areas of and around Lake Nasser during 2005/06 Winter season (October- May).

Crop	Area feddans
A. Field Crops:	
Wheat	323
Onion	28
Faba bean	28
Egyptian clover	50
Fenugreek	7
Lupin termes	13
Corn (Zea mays)	102
Sub-Total	**551**
B. Vegetables:	
Tomatoes	1,049
Eggplant	200
Sweet Pepper	248
Water melon	1,415
Cucumber	163
Squash	269
Cantaloupe	73
Sub-Total	**3,427**
C. Medicine & Aromatic plants	**16**
Total	**3,984**

Source: (1) See Table 4.1; (2) Aswan Agric. Directorate.

In terms of large-scale schemes the Tushka Project is one of Egypt's mega projects, which is currently under construction. Rather than only using the Tushka depression for drawing off excessive floodwaters from Lake Nubia, the goal of the Tushka Project is to use water pumped from the reservoir to irrigate hundreds of thousands of feddans and to resettle in the Tushka project two million Egyptians from the Nile Valley.

There are a number of components of the Project (MWRI & South Valley Dev. Project, 2006). The Mubarak Pump station has an intake channel 4.5 kms long, of which 3 kms is underwater. The station itself has 24 centrifugal pumps that can pump from 147 to 182 masl to delver to the Sheik Zayed Canal at 201 masl. The Main Canal is 50.8 kms long, with a bed width of 30meters, a top width of 58 meters, a water depth of 6 meters and freeboard of 1 meter. The Main Canal has a Control Regulator at km30. A distribution regulator at km 50.8 divides the flow into two branches: one north and the other south. The south branch is siphoned underneath the Tushka Spillway. The branches in turn divide into Sub-canals 1 and 2, and 3 and 4.

Sub-canals 1 and 2 will serve 120,000 feddans each under the management of the Kadco and South Valley Companies respectively Sub-canal 3 serving 100,000 feddans is being financed by the Abu Dubai Fund whilst Sub-canal 4 serving 200,000 feddans is dedicated to an Egyptian Company. Thus, there is potentially a total area of 540,000 feddans (226,800 ha) that can be irrigated.

All canals are lined and the main regulators are linked electronically. The most modern methods of irrigation will ensure water use efficiency. Surface water will be supplemented by groundwater from a number of productive wells (currently 85). The wells will eventually irrigate 60,000 feddans. There will be strict controls on the use of agro-chemicals.

The water requirement for the area has been estimated at 5 km^3 for the first stage of cultivating 500,000 feddans. Water for the project will be obtained from saving in current water use by limiting the area under rice and sugar cane, converting to drip and sprinkler irrigation systems, re-use of drainage water and savings in eliminating wastage from domestic use.

(iii) Livestock Production

Three livestock production systems are distinguished by herd composition and production intensity: (i) extensive herding of mixed herds of cattle, small stock and camels, (ii) extensive herding of camels only, and (iii) intensive dairy production.

The extensive cattle, small stock and camel herding systems are located in the south-western part of Sub-basin in North Kordofan. They are followed by the Zagawa, Kawahia and Kababish peoples who move north in the wet season to take advantage of the annual grasses that flourish at this time, moving back again at the end of the rains. Their herds are mixed: cattle, sheep and camels.

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.

In the Wadi Allaqi and the Red Sea Hills are the Ababda who comprise some two thirds of the population and the Bishari who make up the other third. There is little difference between the livelihoods of the two groups. Their economy is based on five elements. In order of preference these are: (i) charcoal production, (ii) sheep herding, (iii) camel herding and (iv) collecting medicinal plants, and (v) residual moisture cultivation. There are seasonal differences: with charcoal production and sheep herding taking place between December and April, cultivation between May and September and camel herding and medicinal plant collection throughout the year. In the hill areas to the east winter rains are common and people migrate there for sheep herding and charcoal production. Camels roam freely and are not herded and can roam for up to six years.

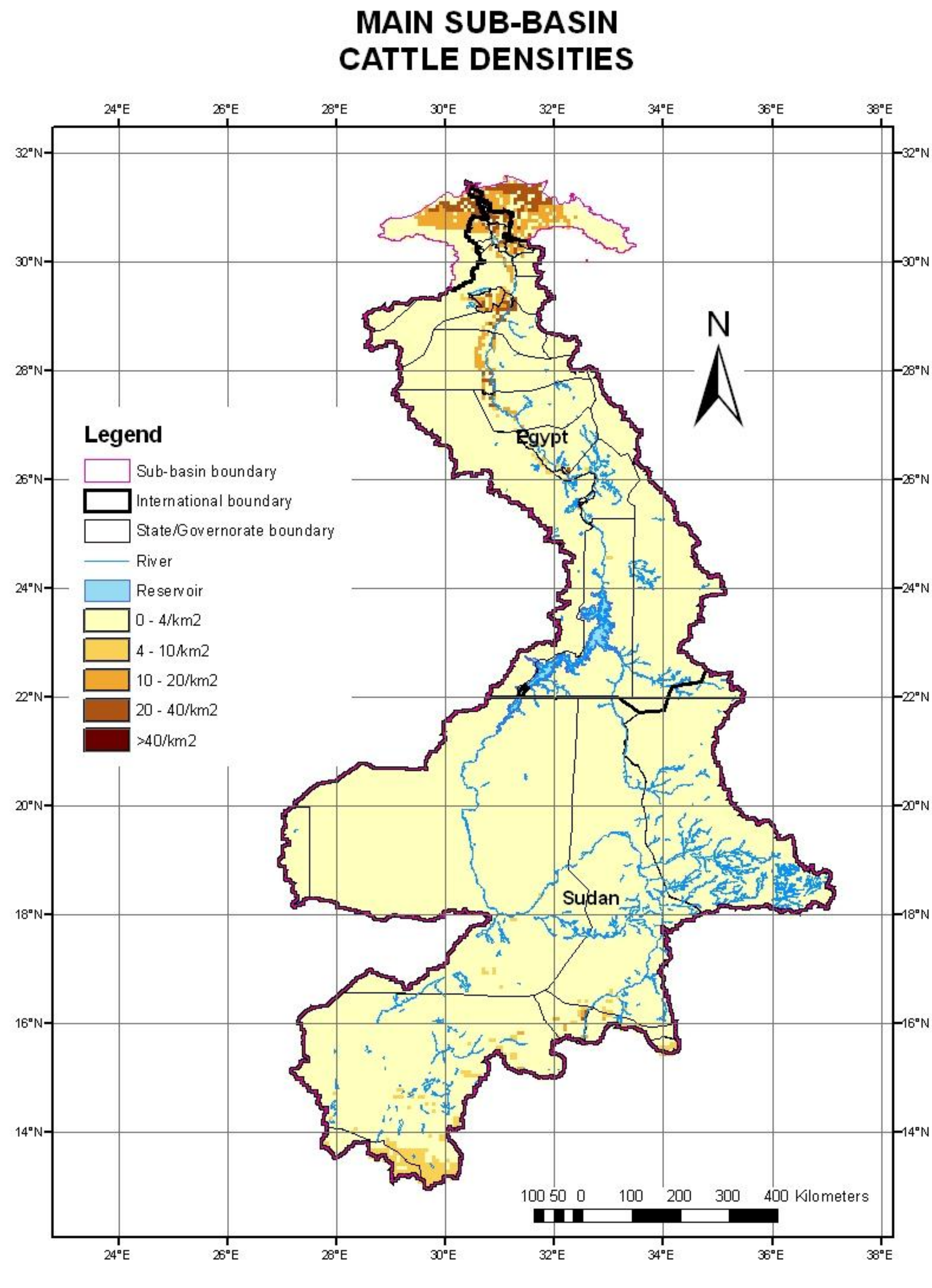
Since inundation started in the early 1970's the Wadi Allaqi has become a major stopping over point for the *dabuka* (camel) trains from Sudan. Abu Hamed and Atbara are the main collecting points for the journey of 10 to 11 days following the Wadi Gabgaba for much of the way to Wadi Allaqi. The final journey of 3 to 4 days is to Daraw, north of Aswan where most camels are slaughtered for meat.
The Wadi Allaqi, because of the arm of Lake Nasser extending into the wadi fulfils a major role in this system. Although a healthy camel can go for 14 days without water, a ten day journey should present no problem. In practice the available water in the Wadi Allaqi is extremely important for the maintenance of camel and thus meat quality. It is estimated that 100,000 camels in over 300 *dabuka* a year make the journey from Sudan by this route. Economically the dabuka drovers provide a source of trade, a means of transport to Aswan and Daraw and a source of information of the location and quality of pastures through the areas they have traversed.

Intensive dairy production is located in the Nile Delta and to some extent near all the major towns and cities.

Data from the FAO Livestock Atlas for Africa are used to derived Map 10 and 11 to show the distribution of cattle, sheep and goats. Unfortunately there is no data on the distribution of camels.

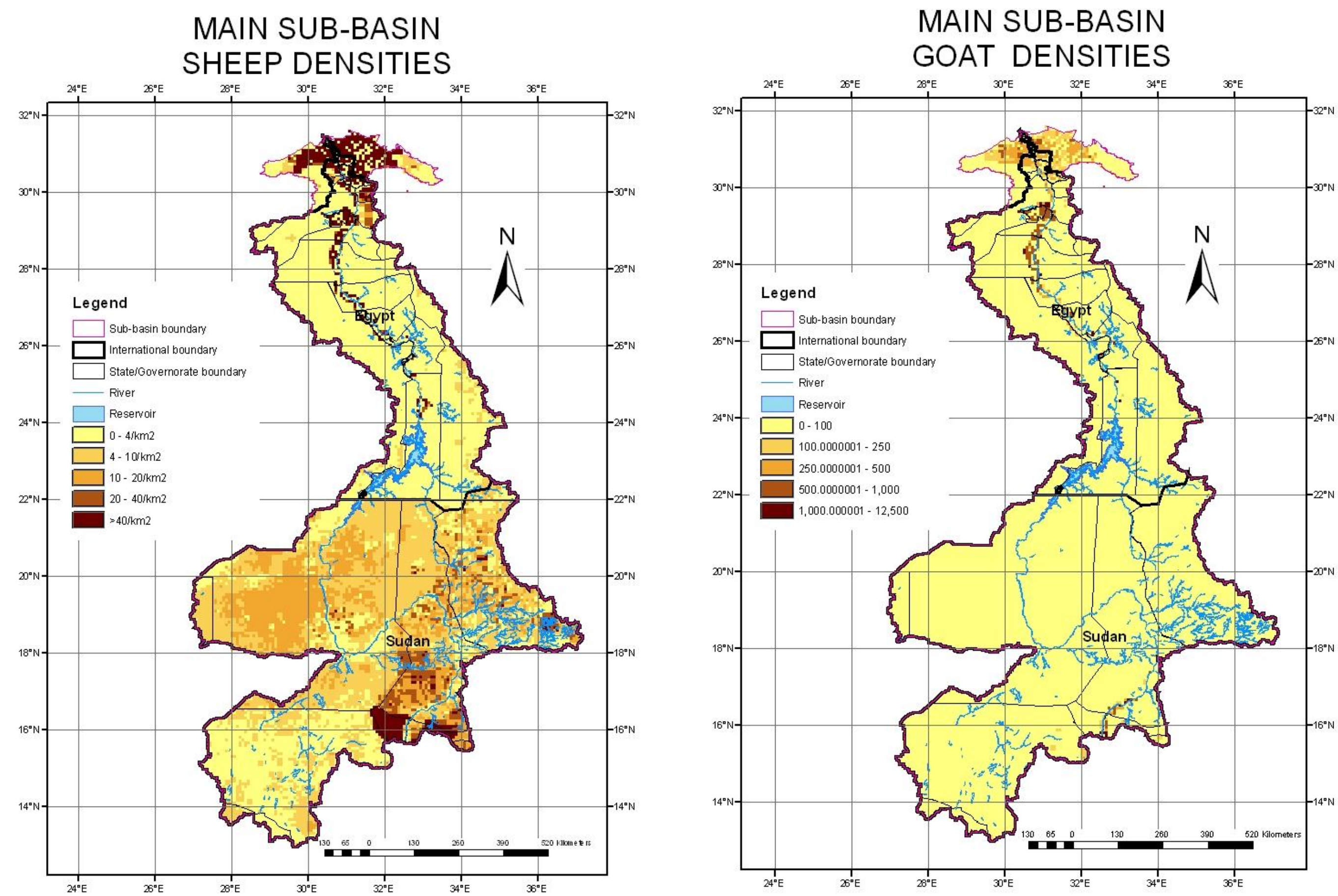
In Sudan low densities of cattle occur in North Kordofan , which are the northern extent of the mixed herding systems to the west of the White Nile Valley. In Egypt cattle are found along the narrow belt of irrigated land along the Nile and most particularly in the Nile Delta.

In Sudan high densities of sheep are found just to the north of Khartoum and in moderate densities throughout Northern and Nile States. In Egypt moderate densities of sheep are found in the Red Sea Hills and along the Nile, with high densities in the Nile Delta. Goat densities are everywhere very low except in the Nile Delta where moderately high densities are found.



Map 10 Main Nile Sub-basin: Cattle densities

Source: FAO (2003)



Map 11. Main Nile Sub-basin: Sheep and Goat Densities
Source: FAO (2003)

2.3.2 Agricultural Marketing

(i) Crop Marketing

During the 1990's the Government of Sudan 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. 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.

A number of the settlement schemes around Lake Nasser are awaiting good road access. Currently good road access and distance to markets is a constraint to vegetable marketing in the schemes.

(ii) Livestock Marketing

In Sudan 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.

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. 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.

In Egypt the big camel market is at Daraw, north of Aswan where most camels are slaughtered for meat. Cattle and sheep markets operate in all the major towns along the Nile and the Delta.

2.4 Forestry

In Sudan the only area of woodland and shrubland is located in the southwest corner in North Kordofan. These are heavily harvested for fuelwood and charcoal.

Around Lake Nasser Field staff estimate that fuelwood and charcoal constitutes only 20% of the population's energy needs. For the remaining 80% they depend on kerosene. Tree cutting for charcoal production in the hills to the east of Wadi Allaqi is reported to be currently (1993) sustainable.

2.5 Fisheries in Lake Nasser

In Egypt the fisheries sector and activities in Lake Nasser is under the control of the General Authority of HD Development (GA-HDD). There are four major Fishermen Associations comprise about 5,000 fishermen, have been earning a livelihood on the lake.

Measuring 1.25 million feddans, with some 32 species of fish to its name, Lake Nasser was providing adequate supplies until the early 1980s, when production started to plummet. Over the last two decades fishermen have proceeded with their work despite the steady decrease in the quantity of fish they produce—from 34,000 tons in 1981 to a mere 8,000 in 2000. Recorded total fish catch during 2004 was 12,434 tons, and 15285 tons during 2005.

The most important species in the fish landings in AHD are *cichlidae* with *Tilapia nilotica* and *Tilapia galilaea* forming about 90 % of the total fish landings (Rashid, 1995). Cyprinids *Labeo nilotica* and *L. horie* rank second and together with *Barbus bunni* formed 6 %. The catfish *Bagrus* spp. and the large species *Clarius lazera* is the next rank contributor. The characins *Alestes baremose, Alestes dentex* and the tiger fish *Hydrocynus* spp.*,* centropomids *Lates niloticus*, synodontids and schilbeids, notable for their habitat of swimming upside down at the surface, close the list of predominant species. It has been shown that seasonality plays an important role in fish landing with the period of March to April, which coincides with the peak spawning of Tilapia in Lake Nasser, being characterized by the highest fish landings.

Because the Government was concerned about plummeting production figures, in 2000 so Law 324, was issued, re-allocated fishing space, giving the fishermen’s associations only 60 per cent, with 40 per cent handed over to six private-sector companies - a move that generated unrest among fishermen, resulting in conflict between the associations and the governorate. The companies, promised to increase production to over 40,000 tons per year by fishing at lower depths and developing breeding farms, thereby exploiting the full potential of the lake (Dena Rashed, 2005).

Lake Nasser is characterized by the existence of many khors and lagoons on its banks. The number of the important khors is 85; 48 on the east bank and 37 on the west bank. Khors are considered suitable habitat for fish rearing due to slow water current and phytoplankton growing in them.

According to 1985 studies, there were 1,683 boats used in fishing in the lake with an average catch of about 10 tons per boat per year. Fisheries studies records 57 different fish species in Lake Nasser, most dominant species are tilapia spp, mainly Nile Tilapia (HD Development Authority, 1981).

The fishing surface of the lake is divided into two fishing areas (zones). Firstly, fishing in shallow water khors around the shores represents about 20% of the lake surface (about 250,000 feddans). The formation of flood khors and lagoons on and around the lake shores provides natural habitat for Nile Tilapia breeding. Tilapia tends not to migrate from these habitats therefore, restocking the lake with Tilapia fingerlings is one way to increase production and to introduce the aquaculture technology to the lake.

Fishing in deep water represents 80% of the lake surface (around one million feddans). Despite, presence of phytoplankton in deep water very few fish live in deep water. This may need to introduce new deep water fish species to develop fisheries in these areas of deep water in the lake shores and areas around it.

A Japanese study stated that the lake potential is estimated at 80,000 tons per year. The governorate of Aswan information states that 60,000-70,000 tons of fish are yearly smuggled out of the lake. To reach the potential of 80,000 tons, some infrastructures are a must. These include: (i) establish 3 new fish hatcheries, (ii) 3 docks for boats, (iii) ice factories and (iv) fish processing and canning factory.

The GA-HDD aims to promote fish production in Lake Nasser. During year 2005, the Authority released and restocked 17.35 million Tilapia fingerlings in the lake and from Sahra Hatchery (7.7 million), Garf Hussein Hatchery (5.65 million) and Abo Simbal Hatchery (4.0 million).

2.6 Transport and Communications

The only transport linkage between Egypt and Sudan is by boat on Lake Nasser/Nubia.

Within Sudan over much of the Sub-basin road network is very poor given the vast expanse of desert. 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)

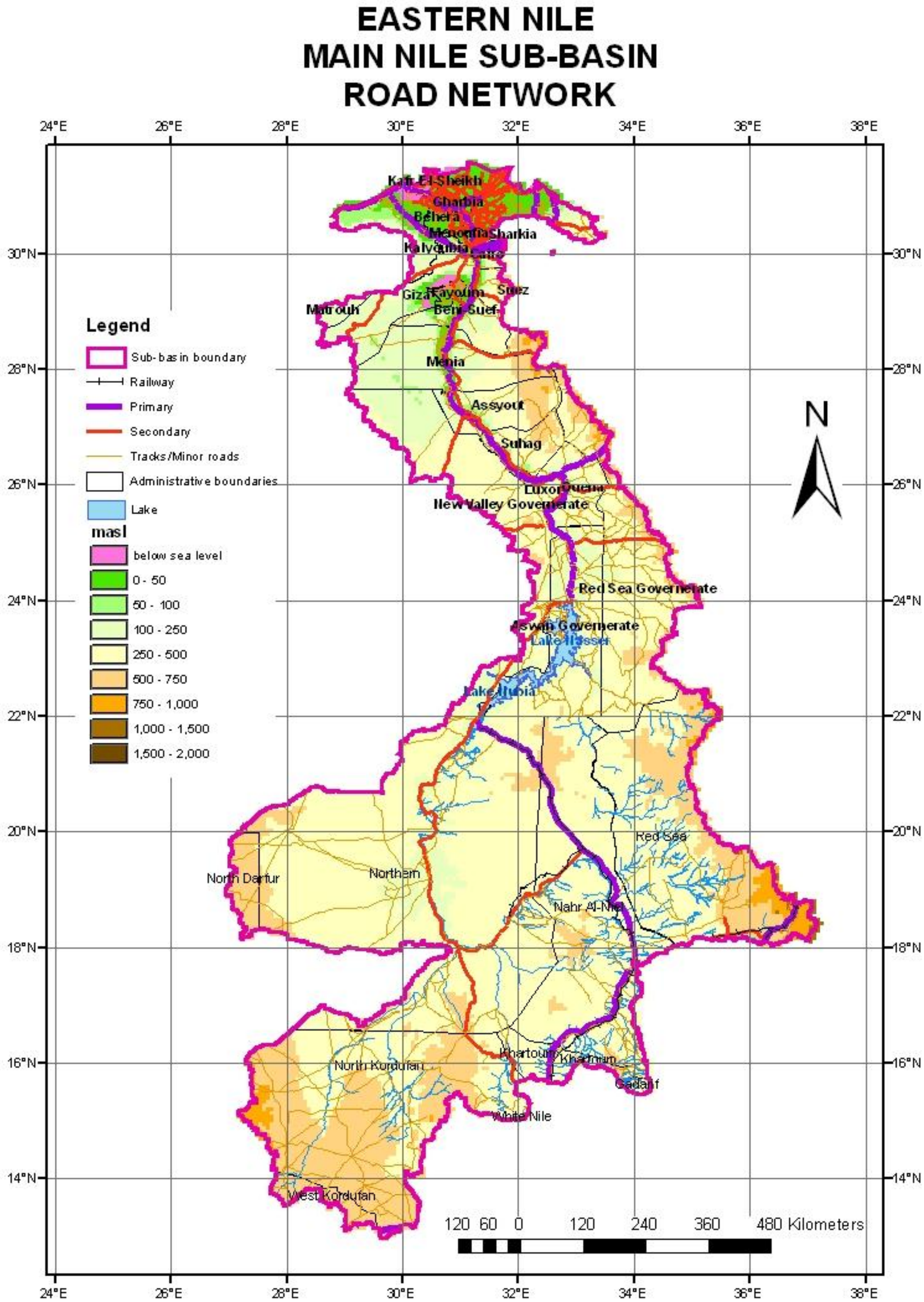
(b) Secondary Roads

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.

Around Lake Nasser there are two primary (asphalt) roads and many tracks. The two primary roads are from Aswan to Abu Simbol and Aswan to Wadi Allaqi.



Map 12. Main Nile Sub-basin: Road network
Source: AfriRoads.

3. SUB-BASIN-WIDE WATERSHED MANAGEMENT AND SUSTAINABLE LIVELIHOOD ISSUES

3.1 Underlying Causes of Natural Resource Degradation

3.1.1 The Framework of Analysis

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 Main Nile Sub-basin are 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.

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 (Scherr et al., 1996) (fig. 3). Pressure or "shift" variables (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).

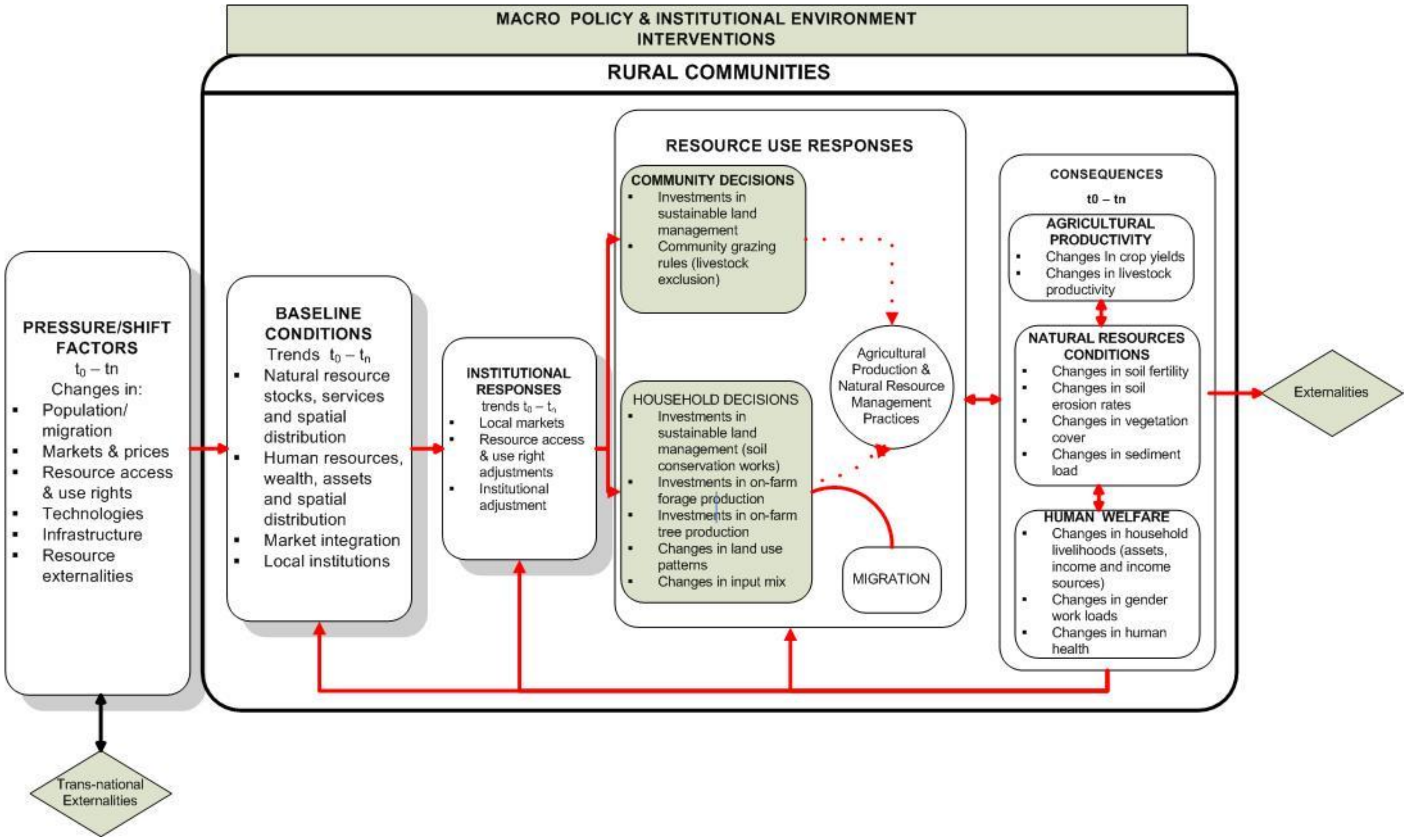


Figure 3. Framework of Analysis for Natural Resource Degradation in the Sudan.
Source: Scherr, S.J. et al., 1996

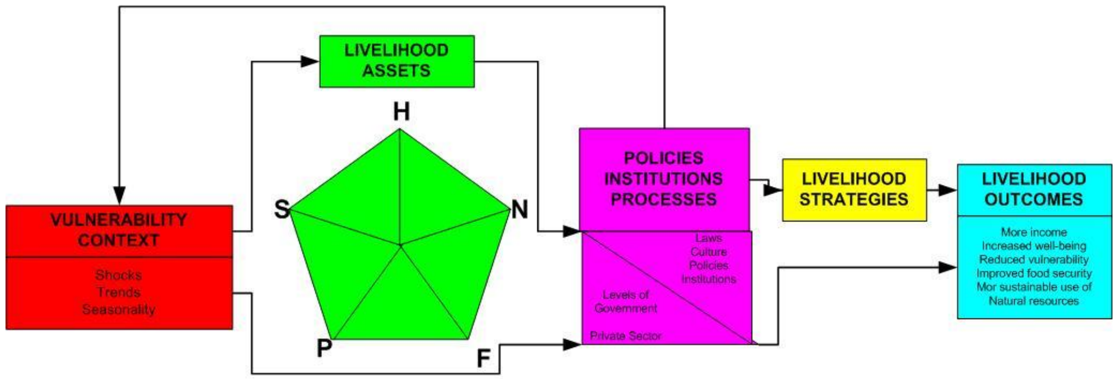
These shifts can in turn induce responses at the community and household level. Of particular importance and of relevance to the present analysis are the community and household decisions with regard to investments (or non investments) in agriculture, soil conservation, and small-scale irrigation. Other 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.

The "poverty-natural resource nexus is where livelihood activities of households and the communities to which they belong, and the natural resource base interact. These are represented by the two boxes in figure 10 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 4). 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.

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. These frameworks have been used to analyse why rural households do or do not adopt sustainable land management (SLM) strategies and investments.

Figure 4. 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

Source: DIFID (2001)

3.1.2 Patterns and Extent of Poverty

(i) Sudan

In Sudan the JAM Report (2005) defined the poverty rate in Sudan as the proportion below 40 percent of an economic status index based on asset ownership. Unfortunately the index is not defined.

Two states in particular stand out as having high rates of poverty: Red Sea and North Kordufan. In contrast to Northern and Nile States they do not have the advantage of the secure water supply of the Nile. In Red Sea State the rural people are almost entirely pastoralists whose livelihoods are extremely vulnerable due to the poor resource base and highly variable rainfall. Recently, mechanisation of the pot facilities at Port Sudan has closed off a potential source of wage labour (Manger, 1994). North Kordufan faces similar problems of pastoral and agro-pastoral livelihoods that are extremely vulnerable to highly variable rainfall and soils with low moisture holding capacities. The high poverty rates are inter-related to the much lower school enrolment rates and provision of basic services (see para. 2.2.3 above).

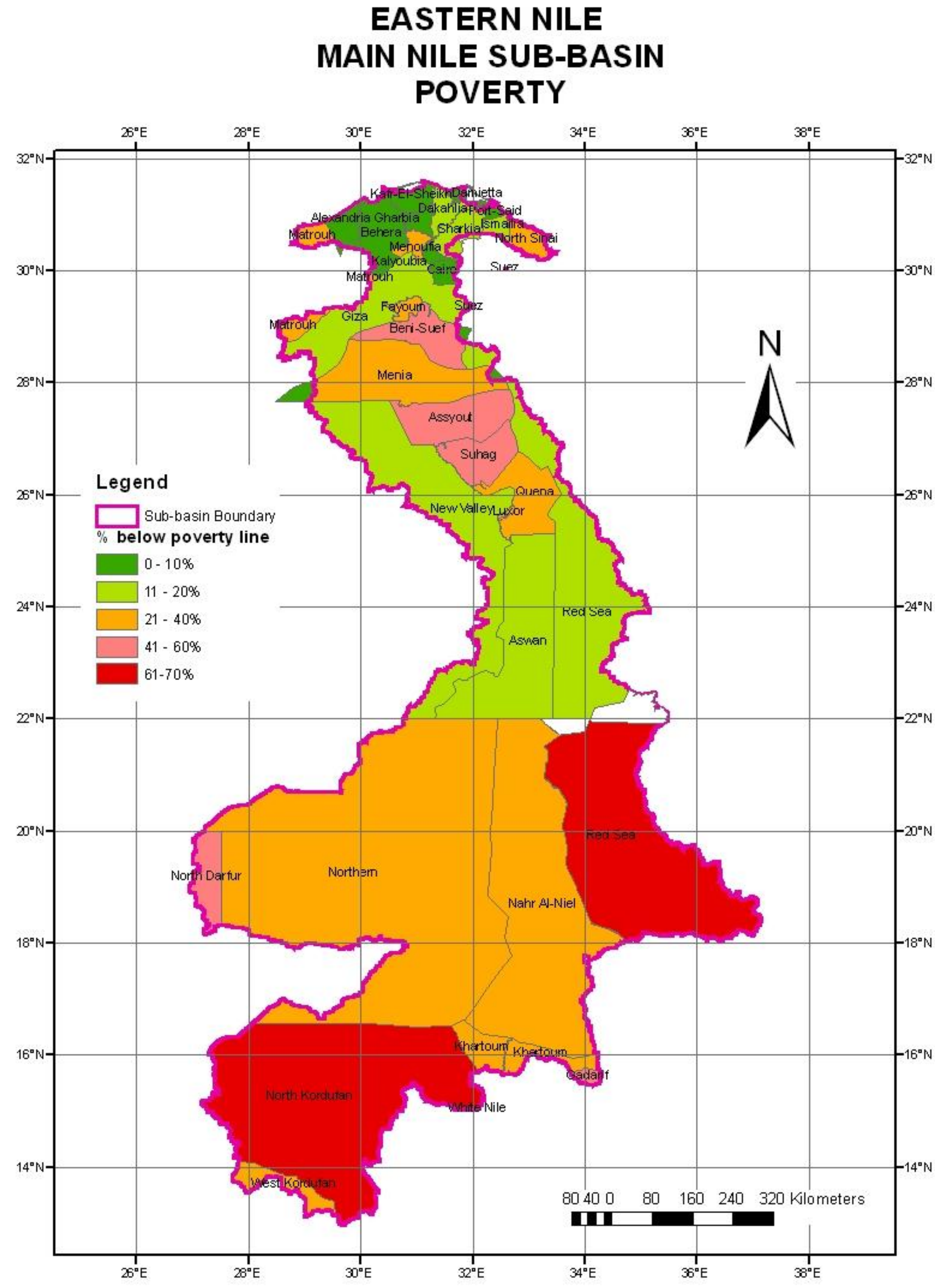
(ii) Egypt

Two recent studies by IFPRI (Lofgren, 2001) and by the World Bank (Heba El-Laithy et al., 2003) review the structure and distribution of poverty in Egypt over the recent past. Lofgren (2001) reviews development strategies adopted in Egypt since the 1970's to determine if alternative strategies could have done more to reduce poverty. The World Bank study (2003) uses two household expenditure surveys undertaken in 1995/96 and 1999/2000 to examine the evolution of poverty in Egypt between these years and reveals the structure and geographic patterns. The World Bank study by El-Laithy and colleagues took into account regional and rural-urban differences in prices and demographic composition of households when calculating poverty rates. It used a minimum food basket linked to normative nutritional requirements. This was costed using regional prices and compared with the poverty line defined as the second quintile of expenditure distribution. They found that whilst poverty declined as a whole in the study period there were significant differences in poverty alleviation across regions and across different employment sectors.

Map 13 indicates the patterns of poverty across the Main Nile Sub-basin. It important to note that poverty rates in Egypt and Sudan can not be directly compared because of the different methods of calculation. In Sudan the highest poverty rates occur in Red Sea and North Kordofan States followed by North Darfur. Northern and Nile States with their secured irrigation along the Main Nile have the lowest rates.

In 1999/20000 the poverty rate across Egypt stood at 16.7 percent (approximately 10.7 million people). However, urban rates were only 9.2 percent compared with 22.1 percent for rural areas. The distribution of rural poverty across the Governorates is shown in Map 10. Governorates in the central part of the Nile Valley have the highest rural poverty rates.

Whilst the Aswan, New Valley and Red Sea Governorates have rural poverty rates below the national average there are four groups that have been identified who are likely to be below the poverty line. The first of these are the two tribes who live in the Wadi Allaqi on the eastern side of the Lake: the Ababda and the Bishari Bedouin (Briggs et al., 1993) and whose economy comprises the five elements described in para. 3.3.2 (i).



Map 13. Main Nile Sub-basin: Poverty Rates.

Sources: Sudan - JAM Report (2005). Egypt - World Bank 2003.

The second group are located in the new settlement areas west of Lake Nasser in three communities of Kalabsha, Khor Galal and Garf Hussien (IDRC, 2004). The IDRC project identified the settlers' lack of knowledge of desert agriculture and an undeveloped marketing system as hindering the agricultural development. A third group comprise fisher people of the lake: the Saiydis, (an upper Egyptian peasant population), from two governorates with a long history of fishing immediately north of Aswan and a few Nubians being fishers even in Old Nubia. The state of the fishery has remained relatively undeveloped with fisher people living either in their boats or in temporary shelters in 150 fish camps.

3.2 The Macro Policy and Institutional Environment

The key policy issue in Sudan is that of land tenure. In Northern Sudan the State owns the land although some but limited rural freehold does occur.

3.2.1 Land Policy Issues in the Sudan

The root cause of land tenure problems in the North is the 1970 Unregistered land Act which stated that "*any land of any kind occupied or unoccupied which has not been registered before the commencement of the Act shall be the property of the government and shall be deemed to have been registered as such*". Under this law vast areas of subsistence farm land, forest and pasture have been converted for cash crop production without replacing the lost pasture resources. Traditional corridors of animal movements were blocked generating increased levels of resource based conflict.

Apart from the freehold land (that constitutes about 1 percent of the area) there are two main types of agricultural land: (i) registered land, and (ii) unregistered land. The registered leases are typically for 25 years, carry use rights and lease conditions relating to environmental protection and sub-leasing. However, the leases normally cannot be sold and thus cannot be used as collateral for formal credit. Unregistered land with tradition use rights has usually been established through unlawful settlement and clearing and cultivation by individuals and groups. Communal land is under the control of the community or local ethnic group. Such land can normally be inherited but it cannot be used for collateral.

The current land policy thus limits access to credit for the vast majority of farmers who cannot use land as collateral. Secondly, the policy of 25 year leases does not provide incentives for sustainable land development and capital improvement. Thirdly, on land not demarcated by cadastral surveys, conflicting land use rights have been a source of conflict, especially between pastoralists and sedentary farmers.

Although the JAM states that land reform is a necessary pre-requisite for improved agricultural productivity and poverty reduction, the Report is silent on how this will be achieved. A Land Commission has been appointed and is currently considering the matter.

3.2.2 Land Policy in Egypt

Lofgren (2001) has examined the natural resource and human assets of rural households in Egypt. The 1952 Revolution effected land reform and expanded education and health facilities, which boosted incomes and reduced inequality and poverty. In recent years there has been some reversal of these developments. Land tenancy laws, which under the 1952 land reform gave tenants formal contacts of near-to full ownership, have been reversed in favour of land owners. A conclusion in the same study is that a pro-poor redistribution of land assets by the Government over the past two decades could have improved the welfare of the poor and reduced inequality.

3.2.3 Institutional Issues: Complexity of the Institutional Framework

(i) International Cooperation between Egypt and Sudan

The Main Nile Sub-basin encompasses two countries: Egypt and the Sudan. Currently there are a number of collaborative mechanisms between Egypt and Sudan that partly emanate from the 1959 Water agreement and partly from a shared concern over Lake Nasser/Nubia. The latter cooperation is mainly in the field of sediment research, whilst the former relates to information sharing with respect to water utilization.

Given the substantial developments that are proposed for Lake Nasser/Nubia and its environs and its very fragile ecosystems there is clearly a need for a comprehensive and integrated framework for the sustainable management of its land and water resources. The area is within two countries, three Governorates and there are a number of central Government Ministries actively involved in current and planned development activities.

Both Sudan and Egypt have a proprietary interest in the Lake and the existing cooperative activities e.g. in monitoring sedimentation, need to be expanded to encompass a wide range of mutual concerns. These can include joint environmental monitoring of water in the Lake and the Nubian Aquifer, joint monitoring of river flows and suspended sediment and joint Lake planning and management.

(ii) Institutional and Capacity Issues in Sudan

Sudan is implementing devolution of substantial authority for planning and implementing development activities to Regional Administrations. Whilst allowing for development activities to be more closely aligned with regional/local aspirations, there are potential problems for coordination in river basins that encompass more than one administrative Region by the addition of another layer of administration. There is provision for State-wide land Use Planning although this has yet to be implemented. As yet there is no provision for a Basin-wide institutional setup on the lines of the Ethiopian model or at the small/micro-watershed level. The UNESCO-HELP Project has proposals to undertaken Basin-wide integrated studies of the Gash, Atbara and Blue Nile Basins and under ENSAP there are the four Cooperative Regional Assessments currently being undertaken.

Devolution of responsibilities to lower levels of government administration is an official policy of both governments. A constraint to its effective implementation in both countries is the low level of capacity: both in numbers and technical expertise, particularly at the lowest levels.

In Sudan "Capacity Building and Institutional Development" is the first of nine "clusters" of the Joint Appraisal Mission's Report and is seen as fundamental to the success of Sudan's programme of equitable and sustainable development.
In both countries these are long-term programmes and there will be no quick solution to this problem. The JAM is aiming to have effective institutions and the desired capacity by 2011.
In addition to capacity at the local level is the issue of low levels of funding. One example is the inability of the Forest National Corporation (FNC) to undertaker the shelterbelt programme between Dongola and Korti to arrest the moving dunes. The FNC is dependant to a large extent on generating revenues for its work particularly through licensing charcoal production and timber harvesting. These opportunities are not available in this area and resource must be made to external sources.

(iii) Institutional and Capacity Issues in Egypt

(a) Agriculture, fisheries and forestry development

There are a number of organizational and Institutional Issues related to agriculture and fisheries development.

- Lack of effective coordination among the authorities concerned with land and water management. The two main Ministries are Ministry of Water Affairs and the Ministry of Agriculture and Land Reclamation.

- Lack of continuity in phases of implementation, which leads to delay in the accomplishment of the entire settlement.

- Lack of collective planning for project management by the real beneficiaries.
- Multiplicity of agencies supervising the reclamation and farming process (i.e., ministries of Agriculture, Water Resources and Irrigation, Housing and New Communities and the municipal authorities).

- Absence of an accurate data base with the executive authorities, and a well-defined chronological program for settlement and environmental impacts.

With respect to forestry, the current organizational setup is that The Lake Nasser Development Authority of the Ministry of Agriculture and Land Reclamation is responsible for all agricultural activities, research and extension work in the area. Though an excellent effort is presently being made with regard to forestry activities a specialized section or division with sufficient numbers of specialized personnel and labourers is needed as the expected work volume will increase.

Though agricultural companies and farmers working in the area have established or willing to establish tree shelterbelts, windbreaks and woodlots this needs to be made a legally binding policy. Forest products harvest and removals should be officially controlled to make the protection measures which are to be implemented more effective.

(b) Watershed Management and Water Quality Issues

In relation to water quality in its Charter and Law 48 of 1992, the MWRI is responsible for providing water of suitable quality to all users. To accomplish this goal, the Ministry has to ensure that appropriate measures are undertaken to protect both the quantity and the quality of Egypt's water resources. Included amongst its responsibilities are the issue and cancellation of discharge permits into Egyptian waterways; inspection of waste water treatment facilities; setting standards and regulations for water discharges into water bodies; monitoring municipal and industrial discharges; and ensuring the Ministry of Health carry out samples and analyses of discharges. The MWRI has delegated the water quality monitoring related tasks of both surface and groundwater to the National Water Research Centre (NWRC). NWRC, in turn, consists of the following institutes:

- Nile Research Institute (NRI).
- The Drainage Research Institute (DRI).
- Research Institute for Ground Water (RIGW).

In practice, very little has been done. Water quality management occupies a relatively small proportion of the overall activities of MWRI (NBI:NTEAP, 2006).

Law 93 of 1962 stipulates standards for wastewater discharge and gives responsibility for monitoring discharges of waste water to both the Ministry of Health (MOH) and Ministry of Housing, Public Utilities and New Communities (MHPUNC). Under Law 48 of 1992 the MOH is charged with setting standards for municipal, industrial and river vessels' effluent discharges into water bodies. The MHPUNC is responsible for planning and constructing sewerages and waste water treatment and disposal systems.

The legal framework for environmental protection has been established under Environmental Protection Law No. 4, 1994, which established the Egyptian Environmental Affairs Agency (EEAA). The Law authorizes EEAA to operate a national environmental monitoring network covering land, water and air; to undertake monitoring of existing establishments; and to develop alternative mechanisms for pollution control (e.g. water and sewerage disposal charges).

Until 1982 the Ministry of Scientific Research (MSR) through the National Research centre (NRC) undertook a large water quality monitoring programme of the Nile system but now due to financial constraints only monitors waste water treatment plants in the Great Cairo area.

It would appear that there is the potential for overlapping mandates and duplication of efforts between central Ministries with respect to water pollution control. The Country Paper for the Arab Republic of Egypt notes that water pollution control has "not been guided by a comprehensive assessment of Egypt's environmental needs" and that pollution control "has not received adequate attention". The One Source Inventory Environmental Theme Report cited the following issues with regard to water quality (Rifat Abdul Wahab, 2006):

1. All monitoring programs are focused only on the conventional parameters but do not cover the sediment and fish samples. Moreover, very limited data is available about the micro-pollutants (pesticides, heavy metals and hydrocarbons).

2. There is a high incidence of water-borne diseases in Egypt, especially in Delta region. In the same time, little attention is paid to pathogenic organisms & parasites in water in the current monitoring programs.

3. The essential components for effective environmental monitoring are consistency and continuity. If the database or collection system from one source is inconsistent with the base or system used by another source of data, conclusions cannot (or should not) be made based on comparison of the two data sets. In Egypt there are many governmental and academic bodies collecting data but it is rare to find full comparability between any two sources.

4. Furthermore, environmental data need consistency and continuity over time because it is generally changes, deterioration or improvement that is of interest. Many Egyptian data sets have begun as part of a development project supported by donor funds. Unfortunately many lapses once the foreign-assisted project is finished. For decision making purposes, monitoring the state of the environment over time needs to be supplemented with information concerning violations of the laws. Data concerning violations is not available because of lack of enforcement of existing laws.

5. There is a lack of inter-ministerial cooperation and data sharing. Many available reports related to water quality issues relied on old water quality data, which minimize the benefit of these studies.

6. Another important concern is the reliability and validity of the data. In view of the lack of uniformity among the various measurement programs, available data exhibit both random and systematic errors.

In terms of sedimentation, since 1973 the NRI has been undertaking intermittent monitoring of the delta development resulting from sedimentation in Lake Nasser/Nubia by undertaking bathymetric surveys using some 21 transverse cross-sections in Egypt and 19 in Sudan. However, there is need to undertake a complete hydrographic survey for the whole lake to have a complete bathymetric map in order to develop a more accurate estimate of sediment volumes and distribution. Additionally, detailed information is required on physio-chemical and bio-chemical characteristics of the Lake deposits as part of a comprehensive long-term sediment monitoring programme (ENSAP-Watershed Management Project, 2006).

Currently the High Aswan Dam Authority (HADA) has started a monitoring programme of wind blown sand entering Lake Nasser/Nubia with the installation of 4 monitoring stations. This programme needs to integrated with the main Lake monitoring system to determine the provenances of Lake deposits (i.e. river-borne and wind borne) and their respective contributions.

(c) Environmental Impact Assessment

Under Environmental law 4 of 1994 the EEAA is mandated to undertake Environmental Impact Assessments (EIA's). Environmental Management Units have been established in all Governorates. Both general and sectoral guidelines have been developed, which define the content of EIA Reports. Three types of projects are identified in a preliminary screening exercise:

- White List Projects: only minor environmental impacts anticipated.
- Grey List projects: proposed activities may lead to substantial environmental impacts and for which an EIA is required, and

- Black List projects: Activities for which a complete EIA is mandatory.

The EIA procedures are now well established but a number of specific issues have been identified (NBCBN-RE, 2005):

- there is a need for capacity building for Consultants (the EEAA currently relies on Consultants to review EIA Reports);
- the review process and quality of EIA Reports needs to be strengthened by providing clear and detailed guidelines and criteria;
- the environmental data required to undertake EIA's is limited and difficult to obtain, and at times costly. (EEAA is currently establishing a computerised environmental database); and
- public participation in EIA's is not mandatory and often ignored. There is need to develop participation in EIA's.

(d) The Need for Integrated Lake Basin Development Planning and Implementation

Given the substantial developments that are proposed for Lake Nasser/Nubia and its environs and its very fragile ecosystems there is clearly a need for a comprehensive and integrated framework for the sustainable management of its land and water resources. The area is within two countries, three Governorates and there are a number of central Government Ministries actively involved in current and planned development activities.

Both Sudan and Egypt have a proprietary interest in the Lake and the existing cooperative activities e.g. in monitoring sedimentation, need to be expanded to encompass a wide range of mutual concerns. These can include joint environmental monitoring of water in the Lake and the Nubian Aquifer, joint monitoring of river flows and suspended sediment and joint Lake planning and management.

3.3 Livelihoods, Poverty and Land Degradation

3.3.1 Vulnerability Context

Map 13 only provides averages across the State or Governorate and is unable to capture the distribution of poverty levels across the population below this level. Given that the Sudanese poverty rates quoted here are "total" a higher incidence of poverty in rural areas may be masked by much lower urban rates. The JAM Report acknowledges that poverty rates in the traditional agricultural sector are significantly higher in the traditional agricultural sector (see above).

In Sudan the lower rates of poverty in Northern and Nile States are a reflection of the assured access to generally low risk irrigated cropland along the Main Nile. Conversely, in the arid areas in Red Sea State in Sudan and the Red Sea Hills in Egypt rainfall is extremely variable in amount and timing, presenting a high risk environmental both for livestock production. In the severe droughts of the early 1980's many pastoral peoples in Sudan lost nearly all their livestock assets. Here, the opposite conditions prevail, where it is not possible to build-up household assets, and there are many cases where these have actually declined through degrading pastures.

Where livestock are the main livelihood capital assets these 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.

3.3.2 Livelihood Assets

Livelihood assets include human, social, natural, physical and financial capital. Kishk (1994) pointed out that in Egypt less than 10 percent of land holders have more than 45 percent of the agricultural land whilst more than 57 percent of agricultural land holders have less than 25 percent of the land. More 90 percent of Egyptian farmers have less than 2 ha of agricultural land. His study in Middle Egypt found that given the very small plot sizes that many Egyptian farmers are barely able to make a living from current irrigated cropped area and cropping pattern. Although illegal, many small farmers resort to selling their land to builders. In 1987 net returns to food cropping were US$ 439 /ha/yr whereas land for building was selling for US$ 0.2 to US$ 5.0 million /ha. The FAO Aquastat Survey for Egypt found that farmland urbanization represented a serious threat to agriculture in Egypt (FAO, 2005).

The World Bank (2003) study found that key determinates of poverty in Egypt are education (human capital), employment status (financial capital) of the household head and large family size. Private sector employees were twice as likely to be poor than those employed in the public sector because of the lack of security in employment. The largest proportion of poor is concentrated in the agricultural and construction sectors.

In Sudan in Northern and Nile States an assured and low-risk production environment because of access to irrigation land along the Main Nile 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 freehold 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.

3.3.3 Livelihood Strategies

In the Wadi Allaqi and the Red Sea Hills where the Ababda and the Bishari adopt a number of livelihood strategies. These include sheep herding, camel herding, charcoal production, collecting medicinal plants and residual moisture crop cultivation. By adopting a range of strategies they reduce their vulnerability to natural and non-natural hazards and shocks. Similarly, many of the settlers on the Lake shore resettlement schemes adopt a strategy of leaving during the summer months to return to their home areas in Middle Egypt for wage employment and thus increasing family income.

Many of the irrigators along the Main Nile in Sudan have livestock holdings to broaden their range of livelihood strategies and thus reduce their vulnerability to hazards and shocks. By combining camels and sheep in their herds the transhumant pastoralists also reduce vulnerability to natural hazards, spreading risk and extending the range of alternative income sources.

In Sudan transhumant pastoralists adopt flexible herding systems tracking the northward movement of the rain belt to take advantage of the annual grasses that quickly grow following the rains, and then moving back to the dry season home base close to the Nile or the Atbara Rivers.

3.4 Poverty Natural Resource Degradation Nexus: Determinants of Household and Community Decisions to Invest or Not Invest in Sustainable land Management Strategies and Investments

3.4.1 Livelihood Assets

In Sudan decisions to adopt sustainable land management technologies depend on households’ asset endowments (human capital) and on community mutual support networks (social capital). Community mutual support networks and mechanisms (social capital) are particularly important to pastoralists in high risk environments. These included a number of mechanisms for transferring livestock between families after losses incurred during a drought as "obligatory" gifts – in practice a form of capital investment. In this way it enables a household's herd to be restocked. With the almost total loss of livestock assets during the very severe droughts of the early 1980's these mutual support mechanisms have been put under very severe stress and have in a number of cases broken down completely (Omer E. Egemi, 2002).

3.4.2 Other Determinants of Household Decisions to Invest or Not Invest in Sustainable land Management Strategies and Investments

Whilst household "poverty" itself may be a constraint to invest or not in SLM investment other factors are also involved. These are included in the "pressure/shift" factors of the IFPRI framework and are endogenous to the household and its assets.

(i) Poor Access to markets, roads and off-farm employment opportunities and Land Degradation

Better access to markets and roads mean lower transport costs for agricultural inputs and outputs and thus lower input costs and higher market prices. Thus better access is likely to lead to increased adoption of improved land management technologies, and poor access to lower adoption rates. However, better access may lead to better opportunities for off-farm employment. Here the potential impact on adopting or not adopting improved land management technologies is ambiguous as off-farm employment may reduce labour inputs but increase availability of financial capital for on-farm investment.

These constraints have been noted on the Resettlement Schemes around Lake Nasser where poor road access and long distances severely constrains marketing of produce.

(ii) Issues of Land Tenure Insecurity

Issues of land tenure here include insecurity of tenure, ability to use land as collateral and the transferability of property rights and the impacts these have on land investment or factor (land, labour or capital) allocation. In Sudan the research literature is silent on the impacts the massive expansion of the large-scale semi-mechanized farms have on perceptions of tenure insecurity on the part of pastoralists notwithstanding the voluminous literature on the impacts of land lost. The problem here is reductions in wet season grazing areas on the Butana Plains have led to an "inadvertent" pressure by the pastoralists on the rangelands leading to rangeland degradation. Possible solutions such as de-stocking or aerial seeding are clearly out of the question.

There is no evidence of tenure insecurity on the part of leaseholders of irrigated land along the Main Nile. In Egypt settlers on the Lake shore resettlement Schemes have the opportunity for permanent security of tenure after a specified period on the scheme.

(iii) Impact of Agricultural Extension, Research and Credit Programmes on adoption of Land Management Technologies

In Sudan the neglect of the traditional pastoral sector in terms of extension, research and credit has been highlighted as a key constraint to their development and adoption of SLM investments (World Bank, 2002).

3.5 Physical and Technical Issues

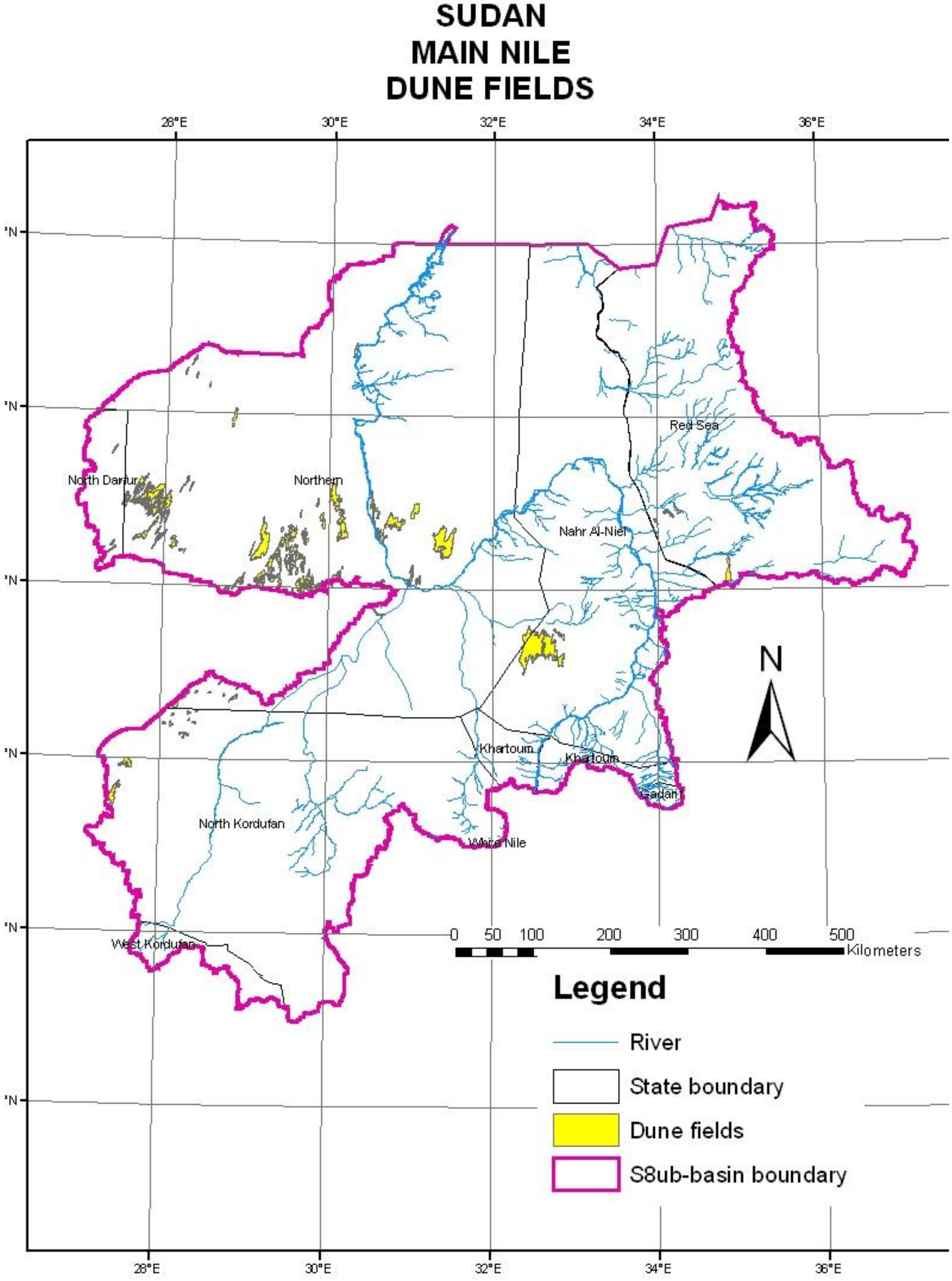
3.5.1 Assessment of the Extent, Trends and Impacts of Moving Sand Dunes

Moving sand dunes can overwhelm settlements, fields and roads. The distribution of dune fields in the Main Nile Basin is shown in Map 10. 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 Dongola and Karima. There are 14 smaller dune fields: four are on the river and ten are close by (see Map 14). Three larger fields are located 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.

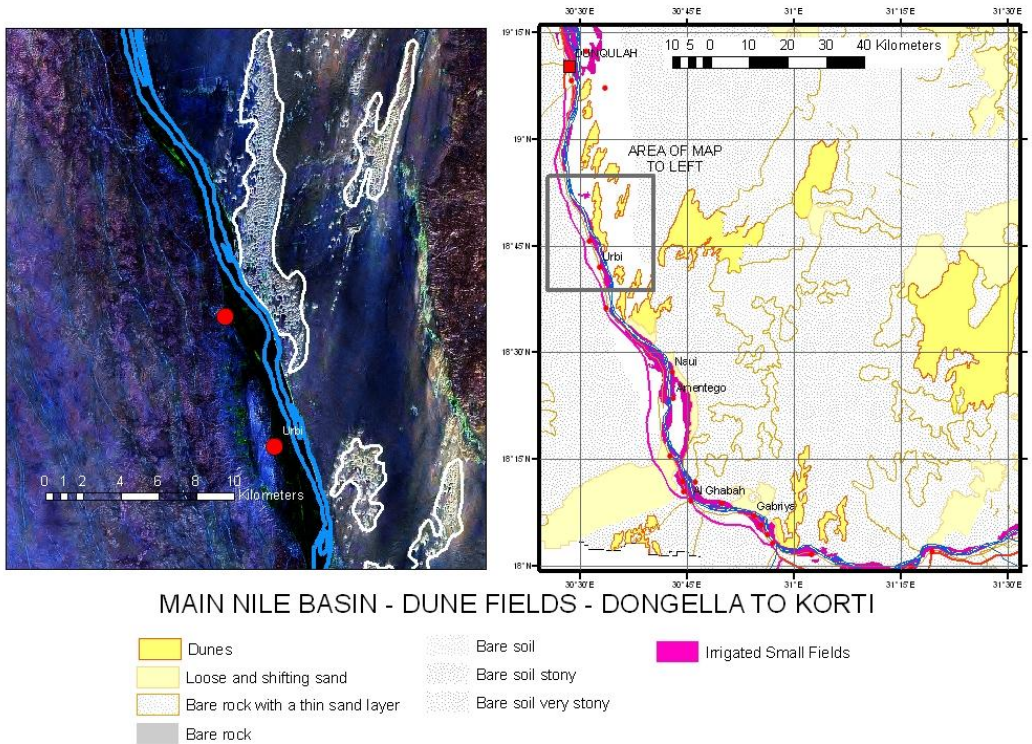
Those on the river present a hazard for tipping sand into the river, whilst the other 10 are a hazard to settlements and irrigated fields (Map 15). The latter currently do not present an immediate problem. The smaller dune fields total some 67,000 feddans (14,300 ha). However, they are generally elongated 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.

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). 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.



Map 14. Sudan - Main Nile Sub-basin: Distribution of Dune Fields



Map 15. Sudan – Main Nile Sub-basin: Dune Fields – Dongola to Korti.

3.5.2 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 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.

3.5.3 Assessment of the Extent, Trends and Impacts of Desertification in the Main Nile 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 centred 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 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 (Benkhe & Scoons, 1993).

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.

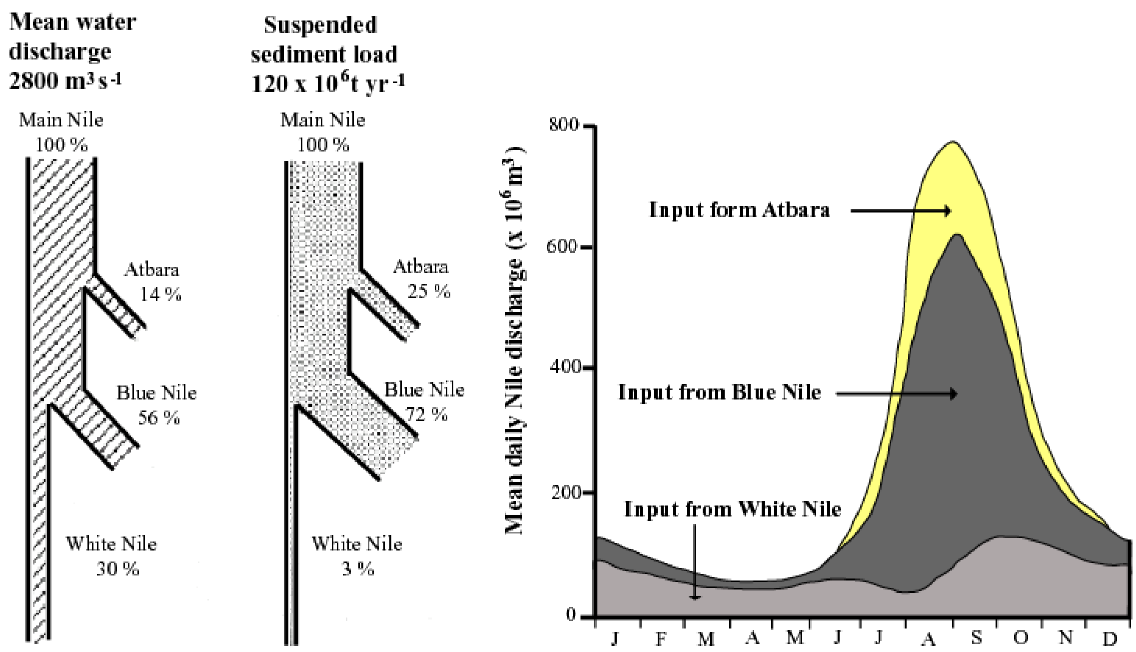
The World's Bank forestry sector review of 1986 reported 50,000 km^2 of woodland are lost annually and that the total area affected by some form of environmental degradation is 650,000 km^2 which is equivalent to 60% of Sudan useful land area. In the west and north of Sudan, long stable sand dunes have 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.

3.5.4 Assessment of the Origins, Extent, Trends and Impacts of Upstream Sedimentation in Lake Nasser/Nubia

(i) Origins and Rates of Sedimentation

The suspended sediment load entering Lake Nasser/Nubia is almost entirely from the Ethiopian Highlands (Figure 5). Some 97 percent is derived from the Blue Nile (72%) and the remainder from the Atbara (25%). The mean water discharge differs considerably with the White Nile contributing 30 percent and the Blue Nile and the Atbara 72 and 25 percent respectively.

Figure 5. Mean Discharge and Suspended Sediment Load for the Nile Basin.



The concentration of suspend sediment entering Aswan High Dam Reservoir also has a seasonal variation similar to the flow hydrograph. However, the peak discharge and peak suspended sediment concentration do not occur simultaneously. The suspended sediment concentration rises to a maximum (5,000 ppm) many days before the peak of water discharge. The lag time between the peak of the water discharge and the suspended sediment concentration varies from year to year, and on average is approximately 10 days.

Shalash (1980) estimated an average annual rate (1958-1979) of sediment inflow of 130 million tons, outflow of 6 million tons and a net sedimentation rate within the reservoir of 124 million tons. Although in a second paper Shalash (1982) estimated the total annual inflow as 142 million tons, the average rate of outflow as 6 million tons with a net sedimentation within the Lake of 136 million tons. Using an average sediment density of 1.56 g cm^{-3} and corrected for compaction (dry weight density of 2.6 g cm^{-3} and a porosity of 40 %), the amount of annually retained sediment of 136 million tons of suspended sediment corresponds to an accumulated volume of 87 million m^3 per yr (Shalash, 1982).

El-Moattessem and Makary (1988) using sediment and discharge data from Dongola (Sudan) from May 1964 to December 1985, estimated the total volume deposited within the Lake as 1,657 million m3 or 75 million m^3 per yr. Using the Shalash conversion factor this is equivalent to 117.2 million tons per yr. The calculated volume for the same period from the hydrographic survey was 1,647 million m^3 very close to the estimated figure. At this rate the dead storage capacity of 31.6 km3 would be lost in 420 years (close to the design life of 450 years).

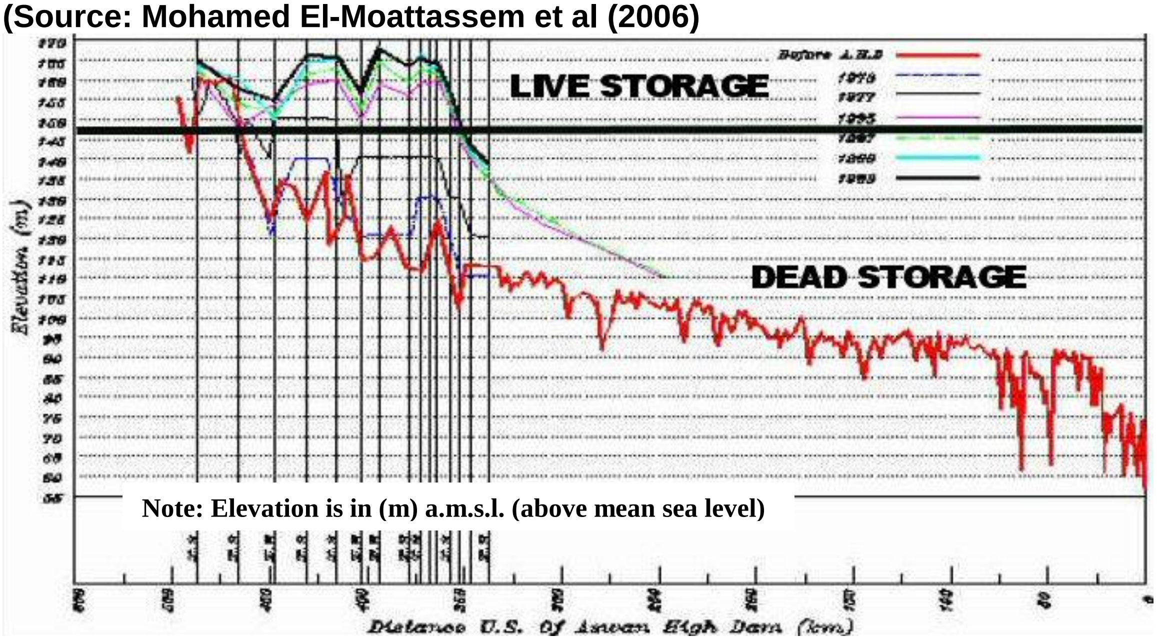
El-Manadely (1991) and Abdel-Aziz (1991) used a one dimensional model and estimated the total volume of deposits in the reservoir between 1964 and 1988 at 2,650 million m^3 or 106 million m3 per year. Dead storage would be lost in 300 years at this rate of sedimentation.

Based on sedimentation data over a 5 years study interval between 1987 and 1992 by Eldardir (1994) a sediment volume of 119 million m^3 per yr was estimated to be annually deposited in the AHD Reservoir. This is equivalent (using Shalash's conversion factors) to 186 million tons per year (for the study period). This result implies that after the 41 years since the AHD closure in 1964, the reservoir has lost ~ 11 % of its dead storage capacity (~ 0.3 % annually). At this accumulation rate the dead storage capacity in 360 years.
However, it is important to note that there is considerable annual variation in sediment load, ranging from 50 and 228 million tons.

(ii) Spatial and Volumetric Extent of Sedimentation

The extent of the sediment has been measured by Mohamed El-Moattassem et al, 2005). The sediment deposition is concentrated at the head of the Lake mainly in the Sudan. Figure 6 describes the longitudinal section of the lowest bed elevation of Aswan High Dam Reservoir (AHDR) from year 1964 to 2003 using bathymetric data collected by the Nile Research Institute (NRI).

Figure 6: Longitudinal bed elevation profile for Aswan High Dam Reservoir (Source: Mohamed El-Moattassem et al (2006)



Since 1973 cross-section measurements have been taken at selected points the follow changes in the lake bed. By 1973 about 20 meters of sediment had been deposited near the Second Cataract (345-370 kms upstream from the Aswan High Dam). From Km 345 to km 285 the deposits decreased to less than 1 meter forming an inland delta some 85 kms long. By 2000 the maximum deposits had reached 60 meters near the Second Cataract and deposition of sediment now reached 120 kms from the dam. Thus, the inland delta had extended some 165 kms and now stretched 250 kms.

(iii) Future Trends under Present Sedimentation Rates

El-Moattessem et al (2006) used a two dimensional hydrodynamic and sediment model to investigate the long term sedimentation The model was run using a time series of seven flood years (2003-2010) followed by five low flood years (2011 – 2015). For the seven high flood years, the whole bed level will raise by approximately 3.5 to 1.5 m in the inlet zone (i.e. from km 500 to km 370 upstream AHD), and by 1.5 to 0 m in the rest of AHDR. During the successive five low flood years, the bed level is predicted to increase by a value between 2.5 and 2.0 m at the inlet zone and by 2.0 to 0 m in the rest of AHDR.

3.5.5 Impacts Downstream of the Aswan High Dam

(i) From the AHD to the Delta

It has been shown that, prior to the AHD construction and operation in 1964, approximately 75 % of the Nile sediment load was carried to the Mediterranean Sea (Shalash, 1982) – with the remaining 25 percent being deposited on the river bed and on irrigated land. Since the operation of the AHD in 1968, the sediment balance has been drastically modified.

Studies from the eighteenth century, and confirmed by more recent ones, have shown that during the natural hydrologic regime of the Nile River the annual deposition rate on the river bed and the often cultivated side banks was around 1 mm/yr accounting for 7 % of the annual average suspended sediment load (Shalash, 1982). About 24 million tons/yr of nutrient-rich sediments were deposited mainly on the Egyptian flood plains before the AHD construction. At present only 2.1 million tons/yr are left in the Nile water to be deposited on Egyptian soils (Balba, 1979).

The low sediment content (25 and 40 mg l^{-1}) in the water downstream of the dam combined with more bank exposure due to low water levels accelerated degradation of the Nile channel. Field measurements over a period of 15 years after the AHD construction showed rates of river bed degradation between 2 and

5 cm/yr depending on the rate of decrease in water levels (Abu Zeid, 1987). Similar results were found by Kotob and Mohaleb (1981) after the first 12 years of the AHD operation, when annual bed degradation rates as high as 3 cm yr^{-1} were measured (table 10).

In addition to the bed degradation, bank erosion was also observed along the river channel which was partially caused by local efforts for river regulation before closing the AHD (Abu-Zeid, 1987).

Table 10. Maximum drop in river bed and water level downstream AHD between 1964 and 1978 (after Abu-Zeid, 1987) and

Location downstream from AHD	Distance from AHD [km]	Max. drop in river bed [cm]	Max. drop in water level [cm]
Aswan Dam	6.5	12	58
Esna Barrage	165	25	76
Naga Hammadi Barrage	359	25	75
Assuit Barrage	539	2	55

Prior to the closing of the Aswan High dam some 124 million tons/yr of suspended sediment passed Gaafra[3] some 35 kms below the dam (Shalash, 1982). Data on suspended sediment recorded at Cairo from 1919 to 1926 averaged 61 million tons/yr. Thus some 63 million tons of suspended sediment was deposited in basins and fields between the two locations. It has been reported (Rosenburg, 2006) that farmers have had to use about 1 million tons of fertilizer to compensate for the loss of the fertilizing properties of the sediment. However Abu-Zeid and El-Shibinbi (1997) report that most of the sediment used to be deposited in basin irrigation areas, which are no longer used since the system of irrigation has changed. They report that the net annual amount of Azote lost is only about 1,800 tons, which has been replaced by lime nitrate fertilizers.

(ii) Impacts on the Coast and Mediterranean Sea

Observations since 1898 at the Nile delta and the littoral zone indicate active coastal erosion processes along the Mediterranean shore. Explained by recent hydrological changes in the Nile River regime, and the missing supply of suspended solids, the costal erosion was recently associated with a general subsidence (Frihy, 1998; Elraey et al., 1995; Stanley, 1996)

Studies by Stanley and Wingerath (1996) have shown that clay-sized material (< 2 μm) is the major fraction transported from the lake behind AHD to the river

[3] An estimated 10 million tons/yr was retained behind the old Aswan dam.

below. Based on kaolinite tracer analyses, this material was found to be of aeolian origin due to erosion of lake-margins and river banks (and possibly wind blown sand).

In contrast to nutrient rich seas such as the North Sea or the Arabian Sea, the Mediterranean Sea is relatively nutrient poor, which contributes to its low level of primary productivity. This is due to the west-east surface current bringing in low nutrient water from the Atlantic and nutrient-rich bottom water to flowing east to west back out into the Atlantic. An additional factor is the low levels of nutrient rich river runoff. The Levantine Basin is relatively isolated by a sill between Sicily and North Africa.

Before the High Dam was built during an average Nile flood the total discharge of nutrient salts was estimated to be 5,500 tons of phosphate and 280,000 tons of silicate. The nutrient rich flood water was approximately 15 kilometers wide, had sharp boundaries and it extended along the Egyptian coast and could be detected off the coasts of Israel and southern Turkey (Sayed El-Sayed & van Djiken, 1995). This nutrient rich water resulted in exceptionally rich blooms of phytoplankton that provided food for sardines and other pelagic fish.

Following closure of the Aswan High dam the fishery in the eastern Mediterranean suffered a severe decline. The impoundment of the nutrient-rich floodwater at the AHD was postulated as a main cause of this decline. The lack of nutrient-rich Nile sediment deposited in the AHD Reservoir caused a decline in the fish catch from nearly 35,000 tons in 1962 to less than a quarter of this by 1969. Hardest hit were the sardine fishery. From 18,000 tons in 1962, a mere 460 tons was landed in 1968. The shrimp catch dropped from 8,300 tons in 1963 to 1,128 tons in 1969.

Thirty years on studies reveal that the ecosystem is in fact adjusting (Sayed and Djiken). Catches of sardines have increased and this is an important indicator. However, scientists are at a loss to explain the mismatch between the low level primary productivity and the relatively high levels of fish production. One possible cause is the substitution of natural nutrients in the Nile water by nutrients from chemical fertilizers in drainage waters (Nixon, 2004).

3.5.6 Assessment of the Extent, Trends and Impacts of Wind Blown Sand Sedimentation

(i) Origins

Map 4 indicates that the most extensive areas of sand are to the west and that the prevailing winds are from the northwest. Both factors, which when combined explain the problem of drifting sand into the Lake.

(ii) Extent

The Dam Authority in collaboration with the Environment Research Institute is undertaking some research studies on wind speed, sand dunes movements, types and quantities of sand, estimates of sand volumes which are deposited into the lake using sand traps in 12 stations on the western side of the lake where there are active sand movements. The purpose of this research is to find the most effective ways of solving the problem.

It has been estimated that the moving sand amounts to $700m^3$/km annually and that wind blown sand constitutes 1 to 2 percent of sediment entering the Lake. Thus, approximately 1.36 million tons are blown into the lake annually.

According to a study carried out by the Public Corporation for the Development of the High Dam Lake of the Ministry of Agriculture and Land Reclamation the woody vegetation in the area is mainly desert scrub including; *Tamarix mannifera* (Tarfa or Abal) which grows very densely and to very appreciable sizes in seasonally inundated areas or in areas which are not regularly inundated to a distance of three kilometers from the lake, *Salsola javanica (G*hazal Tree), *Salsola baryosma* (Khirait), *Acacia ehrenbergiana* (Salam), *Acacia nilotica, A.nubica, A.seyal, A.radiana, Fedherbia albida, A.laeta, A.tortlis, Silvadora persica, Leptadenia pyrotechnica, Capparis deciduas, Cadaba glandulosa , Maerua crassifolia and Balanites* aegyptiaca. From the air the Tarfa seems to grow in a form of a belt along the lake shore. It is not known how effective this belt of trees is in preventing wind blown sand reaching the Lake.

(iii) Trends

It was reported that a main source area for the sand is the Tushka Depression. If a large area of the depression is developed for irrigation it is possible that the amount of sand entering the Lake will be reduced. Moattessem (2005) has called for more research in order to determine a more accurate estimate of sand entering the lake. This is currently being undertaken by the AHDA and ERI.

3.5.7 Low Agricultural and Fisheries Productivity around Lake Nasser

(i) Low Agricultural productivity

There are many causes of low productivity in the areas of and around Lake Nasser, they can be classified as, technical, Economic and institutional problems, but not excluding other problems, i.e. Marketing and Agricultural processing and transportation.

(a) Technical Problems:

- Lack of an appropriate soil texture and composition.
- Difficulty of levelling the surface layers; and therefore, slope cultivation is commonly used.
- Fluctuation of Lake water level during growing season.
- Absence of organic matter.
- Lack of macro-and micro-nutrients.
- Shallowness of top soil.
- Presence of soluble or less soluble salts such as calcium carbonates and gypsum.
- Continual change in the surface layer as a result of wind movement.
- The presence of certain harmful elements such as boron and selenium.
- Salinity and alkalinity problems.
- Drainage problems.
- Lack of research/extension.
- Lack of certified seeds.

(b) Economic problems

These include:

- Lack of sufficient investments in infrastructural facilities. This problem was further aggravated by inadequacy of monetary liquidity, prolonged procedures of lending.
- Inability of the official investments to create integrated settled communities in and around the lake to attract new settlers from the Nile Valley and Aswan-which are already overpopulated and parts of their croplands are lost to urban uses.
- Inaccessibility to credit by the new graduates and beneficiaries thus impeding their ability to fully use their lands.
- Marketing accessibility.

3.5.8 Low Fisheries Productivity in Lake Nasser

There are a number of problems related to the low productivity of fisheries in Lake Nasser. These include:

- Fishermen use illegal fishing methods including nets with mesh smaller than the legal limit.

- Unlicensed boats.

- Smuggling of fish.

- Over-fishing: excessive and indiscriminate fishing occurs in the lake.

3.5.9 Potential Environmental Issues of Large Scale Development and Settlement in and Around Lake Nasser

(i) Introduction

There are a number of potential environmental issues related to the very significant developments that are proposed for the area in and around Lake Nasser. The proposed developments include:

- Substantial agricultural development around the shores of Lake Nasser including both small and large scale agriculture (para. 3.8.2) and both above and below the full supply level, and involving substantial resettlement of population around the Lake;

- Substantial (500,000 feddans) agricultural development in the Tushka Depression, again involving substantial resettlement of population in the development area;

- Mining in the Wadi Allaqi;

- Expanded tourism both on and around the Lake;

- Increase in Lake Transport resulting from the large-scale economic developments.

(ii) Agricultural Development around Lake Nasser

There are two main strategies for agricultural expansion. The first is agricultural development above the high water level (182 masl) that will require pumping. Two types of pump are proposed: large fixed electric pumps and small portable motor pumps. This development could be large and small scale. The second strategy is the development of land below the full supply level using residual soil moisture and supplementary irrigation (mobile pumps or temporary wells).

The estimates of suitable land above the high water level vary from 0.103 million to 3.82 million feddans. Currently the first phase development is envisaged to be 50,000 feddans in four designated areas (see Map 9).

Below the full storage level it is estimated that there is the potential to develop 200,000 feddans. Given the seasonal and year-on-year fluctuations in the Lake level and as a consequence the lateral area available for cultivation this figure is not fixed.

There are a number of potential impacts that such a substantial development could have on the environmental with the Lake Nasser/Nubia catchment. The use of fertilizers and agro-chemicals and their leakages in drainage water into the Lake is an immediate and obvious concern. Currently, experience from the Wadi Allaqi indicates that the regular inundation of the Lake and the nutrients it brings with the sediment is sufficient to keep soils fertile (Biggs et al., 1993) in particular in terms of nitrogen and phosphorous.

However, there is insufficient experience to say that this will be a permanent feature. Whilst, cultivation without fertilizers and agro-chemicals may provide adequate yields for the small-scale subsistence farmer they may not be adequate for the large-scale commercial operation. Given the very light textures of the soils the use of chemical fertilizers could give rise to a serious increase in nitrogen levels in the Lake where eutrophication would be possible outcome. Currently, the levels of substances in the lake are well below the danger levels but the use of insecticides and herbicides could rapidly change this.

Currently, there are strict controls on the use of fertilizer and agro-chemicals close the Lake shore. The Bio-organic Control project at Aswan has developed a number of biological controls of plant pests that will obviate the need to use insecticides and fungicides. However, there is an urgent need to establish a comprehensive system of monitoring of agricultural developments and of water quality in the lake.

Large-scale agricultural development will bring with it a number of additional impacts. There will be a substantial rise in the population: some temporary such as the winter cultivators who come from the middle Nile Valley each year to grow vegetables on the residual moisture, but others permanent such as the labourers and support staff for the large-scale developments. These people will require housing and supporting utilities: electricity and water. This will require careful settlement and supporting infrastructure planning as well as adequate waste disposal facilities to prevent pollution of both the Lake and the groundwater resources.

(iii) Agricultural development of the Tushka Project

The Tushka Project aims to develop some 500,000 feddans of land using water from the Sheik Fayed canal and from local groundwater resources. Much of this development will be large-scale and thus the numbers of people is likely to smaller than if this was a resettlement scheme for small farmers.

The Government has already installed strict regulations on the use of fertilizers and agro-chemicals. Nevertheless, there will need to be a comprehensive system of monitoring install at the outset if severe pollution of groundwater is to be prevented. Similarly, there is a need for careful planning of settlements and supporting infrastructure and waste disposal facilities.

The modelling by Jeongkon Kim and Mohamed Sultan (2002) to investigate the long-term hydrological impacts of the proposed large scale irrigation development in the Tushka Depression has indicated the danger to the Nubian aquifer of irrigation drainage water causing flooding and salinization. Again, a comprehensive system of groundwater monitoring should be in place at the outset if these negative impacts are to be avoided.

3.5.10 Mining and Quarrying

There is substantial mining and quarrying taking place within the catchment of Lake Nasser/Nubia. Whilst much is of low environmental impact where a number of mining and quarrying activities are concentrated, in for example the Wadi Allaqi Biosphere Reserve the potential for negative environmental impacts increases. The area was a source of gold in ancient times and currently gold exploration is taking place. The Wadi is already linked to Aswan by a tarmac road thus providing easy access.

All applications for mining and quarrying in the lake Nasser/Nubia catchment should be subject to strict environmental impact studies to ensure that environmental damage to the lake and its surrounds does not occur.

3.5.11 Expansion of Tourism

Adding Lake Nubia to tourist destinations around Aswan has considerable potential, especially during the winter months. Already the rebuilt Abu Simbel temple complex is a major tourist attraction by both boat and plane. In 1989 the Government began cooperating with UNESCO in making other archaeological sites available to local and international tourists. During the salvage operations of the 1960s these had been grouped in three locations, the first being close to the western end of the dam and the other two also on the west bank-approximately 100 and 200 kilometers up the reservoir from Aswan. The first site is already accessible as the other two will be once connecting roads are built from the now tarred Aswan-Abu Simbel highway. As for the town of Abu Simbel, by the mid 1990s it had a total population of approximately 5,000 people.

Currently Abu Symbol does not have a waste water treatment plant (NBI-NTEAP (2005) although one is proposed. Given the other developments taking place or proposed on the western side of the Lake it is likely the town of Abu Symbol will grow in population. Again, careful planning of housing and infrastructure will be required to avoid pollution of the lake and groundwater resources.

3.5.12 Increased Use of the Lake for Transport

The lake itself is a substantial tourist attraction for boat tours, fishing and boating. Any significant increase in motor powered boats on the Lake carrying large numbers of passengers has the potential to cause considerable environmental damage.

Given the potential for substantial agricultural, tourist and mining development it is likely that commercial lake traffic could increase significantly given the relatively poor road development. This could add to the potential to cause environmental damage.

4. OPPORTUNITIES FOR IN-COUNTRY AND TRANSBOUNDARY BENEFITS FROM WATERSHED MANAGEMENT ACTIVITIES FROM A BASIN-WIDE PERSPECTIVE

4.1 Observations and lessons learnt for Watershed Development in Sudan

4.1.1 Land tenure and Land Use

Yagoub Abdalla (2003) has detailed the complexities and some the lessons learnt relating to land tenure and land use in Northern Sudan. This can be summarised as follows. The Land Settlement and Registration Act of 1925 provides for rights and interests over land use such as cultivation, pasture, wood cutting, occupation, passage, water resources. Local customary systems of land tenure ("*dar*") operate in lands away from the Nile river. The Native Administration exercised rights of land distribution through sheikhs. Each village posses a defined area for disposition to individuals. Land not distributed is left ("ghifar") for distribution to migrants or held as a reserve. This land is used as communal grazing for the villagers and transhumant pastoralists.

Unfortunately the Unregistered Land Act of 1970 (that gave government ownership of "unregistered" land) did not provide for existing and long-established usufruct rights. The subsequent expansion of the semi-mechanized farms particularly affected pastoral rights of passage, water and grazing over large areas of "unregistered" land.

The situation was further complicated when the Native Authorities were abolished in 1972 and their land distribution powers initially transferred to the local government officers and later to the State. Neither level of government were conversant with the tradition systems of land use not did they have knowledge for planning or controlling land use. This created an administrative vacuum. The Native Authorities were reinstated in the late 1980's although as Abdel Ghaffaar Ahmed (2002) many of the traditional hierarchy did not have detailed knowledge of the traditional systems, and settled agricultural interests that had assumed influence in the intervening period were antagonistic to the needs of transhumant pastoralists..

In 1984 the Civil Transaction Act introduced the Islamic principal of "*manfaa*" (usufruct). This has been defined as the right to use land the ownership of which belongs to another. Usufruct rights include those of (i) cultivation, (ii) pasture use, and (iii) forest products. More importantly, the same Act contains general principals and guidelines for granting benefits over agricultural land. These include (i) protection of the integrity of villages, natural resources, the environment and animal assets, (ii) agriculture has priority over other benefits where it s production is beneficial to the public.

Finally, the Constructive Planning and Land Disposition Act of 1994 established two inter-level councils at the State level for planning and policy making for land use and land disposition: one for urban and one for agricultural purposes. The latter is normally composed of representatives of all natural resource institutions plus the survey and land registration departments.

The picture that emerges from the experience of the past 35 years is the need for a land use plan. Such a "Plan" would need to bring together in an equitable and transparent manner the various systems of land allocation and use rights: traditional, Islamic and State. In this way the Plan would provide a framework in which effective policies and legislation could develop.

4.1.2 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.

A joint SOS/FNC natural forest project in Western Sudan demonstrated that a joint community and government partnership can be an effective way of managing and conserving natural forests. The communities established Village Forest Societies who together with the local leadership actively managing the forests areas, harvesting and fire control.

4.1.3 Community-based Approach to Rinderpest Eradication

Whilst this lesson learnt is from Southern Sudan, it has relevance for animal disease control for the pastoral and agropastoral groups in the Main Nile Basin. 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 (Cately et 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;

4.1.4 The Role of Civil Society: An Example of the 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.

4.1.5 Improving Governance of land and water Resources

This example comes from the Gash Delta but has equal relevance for the small scale leaseholders along the Main Nile in Sudan. 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 <u>existing</u> 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.

4.2 Observations and lessons learnt for Watershed Development in Egypt

There are two ongoing programmes around Lake Nasser aimed at assisting the pastoralists of the Wadi Allaqi and also the settlers in the new settlement schemes around the lake.

4.2.1 The Ababda and the Bishari Peoples of the Wadi Allaqi

The Ababda and the Bishari people have shown remarkable flexibility and adaptability in the livelihood systems to the changes in the environmental occasioned by the construction of the Aswan High Dam, the subsequent filling of the reservoir and its annual and decadal changes in water levels. Their livelihood strategies have expanded to include charcoal production and irrigated crop production. The ephemeral pastures resulting from the annual inundations of the Wadi floor enable then to bring their sheep flocks from the Red Sea Hills during the summer months. They have been able to take advantage of the new road constructed (for quarrying) to ship their charcoal to Aswan. The wadi has also become an important stop over for the *dabuka* trains from Sudan providing yet another potential source in income from trade and another source of transport to Aswan.

Nevertheless, the adoption of irrigated cropping was supported initially by WFP Food for Work programme in 1990 for three years. Once the incentives ceased most households interest in irrigated plots waned (Biggs et al. 1993) and a survey in 1993 most households placed cultivation as a livelihood strategy last behind charcoal production, sheep-herding, camel-herding and collecting medicinal plants. The conclusion from a study of the livelihood system in the Wadi Allaqi was that the most "ecologically and economically sound method of development in the area is to build from "below" within the existing framework of the Bedouin economy. Two potential pathways for development were identified as greater use of existing vegetation resources for charcoal production and livestock grazing.

4.2.2 The Settlement Schemes around Lake Nasser

As part of a national strategy to combat poverty through agricultural development of reclaimed land the Government of Egypt plans to settle approximately one million people around Lake Nasser by the year 2017. Past Egyptian experience in reclaimed desert areas indicates that new settlers are highly vulnerable to difficulties and hardships, in particular poor adaptation to new social and environmental contexts, poor nutrition and sanitation, education and transportation (CDS with DDC, 2004).

An IDRC supported programme is working with three settler communities west of the lake. The project is an "action research" aimed at anticipating and developing ways of avoiding the experiences outlined above. The main thrust of the project is participatory research to improve incomes and mitigate environmental threats to human health. The project's strategic concept is "agro-ecology" with its focus on sustainability, enhancing household assets and increasing income from agriculture. Experience to date is that with the limited social, health and educational services (only primary schooling available) and lack of connection to the national grid dissuades permanent settlement. Many settlers follow a migratory pattern growing a short winter season crop and return to their home areas to earn additional income.

Many settlers rely on cash loans or advances from produce merchants in order to establish crops on their new farms. If production is insufficient to cover the loan a debt cycle and economic dependence on the home community is strengthened. The Project has found that this is a very danger, given the settlers poor knowledge of desert agriculture. As the settlements are an agglomeration of people from different places there is little social capital (e.g. social support networks). Despite very impressive research into bio-fertilizers and bio-control of pests in the laboratory because of the lack of resources there is little by way of extension. There is a lack of market information and forecasting leading to over production of a certain crop, saturation of the nearby Aswan market and depressed prices. Consequently many settlers frequently send their produce to Cairo and the delta cities further raising costs and reducing profitability.

The High Dam Lake Development Authority (HDLDA), WFP and the Project are addressing these problems by identifying with the settlers the key social, legal, policy, cultural and environmental factors that either encourage or impede the adoption of sustainable agricultural practices and to develop a better understanding of the potential impacts both on the settlers' livelihoods and the environment. As with the development experience in the Wadi Allaqi the key lesson learnt is the need to work with the concerned communities and to develop development pathways that are appropriate and sustainable.

4.3 Opportunities for Watershed Management Interventions in the Main Nile Sub-basin

4.3.1 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$ 1,900/ha) and those of the shelterbelt (US$ 50,000/km). Thus to develop 14,000 ha of new irrigable land would cost approximately US$ 26.3 million. The 80 kms shelterbelt needed to protect the new land would cost approximately US$ 4 million or some 15 percent of the total costs. It would make sense to incorporate the planting of the shelterbelts into the overall design of the Meroe Irrigation 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.

4.3.2 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 1km 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.

4.3.3 Opportunities for extraction and use of sediment deposits

Mohamed El-Moattessem (2005) has reported that the prospect of dredging some of the sediments and using this material for some industrial and/or agricultural purpose has been under investigation by the Nile research Institute. The composition of the sediments has revealed that the sediments have a value for both industrial and agricultural use. Among these include radio-active materials, ceramics and metallic minerals. The sediments are very suitable for the manufacture of bricks and sand. It was found that when processed the sediments could be used for animal food fillers and as a fertilizer.

A detailed cost benefit analysis of both the dredging operation and the various conversions sis required. The report examined various dredging techniques depending on depth and composition of the sediment. Two sites have been identified: the first at Abu Simbel in the main lake channel and the second south of the first but closer inshore. Three dodging configurations were described. The first incorporating a removable cutter suction dredger transporting the dredged material through floating and shorter pipelines up to 1,500m form the dredged site. The second system is similar to the first but dumps the material into a hopper barge. The third system is similar to the second but can operate in depths up to 50 meters.

4.3.4 Opportunities and potential activities to reduce sedimentation from wind blown sand

The meeting with the National Working Group revealed an excellent appreciation of the role of tree shelterbelts and windbreaks as well as the establishment of woodlots in the protection of agricultural land and irrigation canals, increase of agricultural crop production and soil conservation. At a higher level the council of ministers issued a directive for the establishment of a shelterbelt above the 182 meters contour round the lake.

Planting of shelterbelts is already familiar in the area. A shelter belt of 1,500 meters for Aswan town is established. In Tushka area at Abu Simbel Agricultural Research Station trials of establishing shelterbelts on irrigation canals and windbreaks around agricultural farms seem to be successful. Such activities have been undertaken by the research station and the Saudi Company for a distance of 30 km. The French project is still considering the feasibility of establishing shelterbelts. Tree species used in the area are:

Casuerina spp.
Acacia sp.
Khaya senegalensis
Leucenia glaucca
Eucalyptus spp.

It can be noted that shelterbelts and windbreaks are essential for the increase of agricultural crops production, protection of irrigation canals and the agricultural land itself. Tree species which are suitable for the site and meet various needs are to be used. Reservation and official registration of all natural Tarfa areas around the lake and its protection will help in creating a belt which can reduce the volume of sand blown into the lake. Using appropriate silvicultural practices and forest management techniques the *Tarfa* can produce good quality sawn timber as well as fuel wood.

4.3.5 Opportunities and potential activities to support sustainable livelihoods and increased income generation

(i) Wadi Allaqi

For the Ababda and the Bishari people two potential pathways for development were identified as greater use of existing vegetation resources for charcoal production and livestock grazing and a change from cash vegetable cropping to fodder production.

Research indicates that an open-canopy *Acacia* woodland cover could be established fairly readily over the Wadi Allaqi proving shade and a sustainable source of fuelwood and charcoal. The trees would require irrigation or shallow groundwater for their initiation but thereafter could exploit deeper groundwater. Given the very good returns to charcoal production this would ensure that such production was sustainable in the long-term by increasing the amount of woody biomass in the area. Increased shade would benefit both humans and livestock in the hot summers. It would also reduce pressure on the Acacia trees in the Red Sea Hills.

A second pathway would be to substitute fodder crops (Lucerne) for vegetables (currently grown as a cash crop for the Aswan market) that could be sold to the dabuka as well as providing feed for their own animals. This would be in-keeping with their traditional livelihood strategy of sheep and camel production.

(ii) The Resettlement Schemes around Lake Nasser

The proposed interventions are broad and varied embracing work in the fields of agriculture soil and water conservation, micro- finance, capacity building, institutional strengthening, information technology, better settlement conditions and community development. The goal of these interventions is to improve the socioeconomic conditions, especially farming conditions, and the livelihoods of settler communities living in desert fragile ecosystem in and around Lake Nasser as well as in Eastern and Western deserts. These interventions include:

- Extend improved agricultural practices suitable for desert farming developed at the research station to farmers: particularly in the fields of bio-fertilizer and biological pest control.
- In parallel - strength the two way linkages between research, extension and farmers.
- Develop micro-credit-line for crop production to avoid indebtedness to traders.
- Accelerate the provision of social services (secondary education and health) to reduce seasonal migration from the schemes.
- Develop transportation and marketing accessibility and commodity price information to enable settlers to better plan crop mixes and seasonal patterns.
- Establish and support partnership and participation of community-based management of natural resources in a sustainable way based on agro-ecosystem action research.
- Coordinate work in different fields through vertical and horizontal coordination among concerned agencies, authorities, ministries and NGO’s.

- Study and mitigate salinity, alkalinity and drainage problems in Tushka project, Abu Simble area and around the lake area.

4.3.6 Opportunities and Potential Activities to Avoid Environmental Damage from Economic Development

A number of current and planned economic activities have been identified that have the potential to cause substantial environmental damage to the lake and its environs. These include large scale irrigated agricultural development, large scale resettlement of people, development of tourism around and on the lake, development of mining and quarrying and increased boat traffic on the Lake,

The Lake and its surrounds encompass three Governorates and the development activities are within the mandate of a number of local and central government departments. On-going research in such areas as irrigated cropping, bio-organic pest control, sedimentation, hydrology, wind blown sand, ecology, sociology and geology is being carried out by a number of national and international organizations, institutes and universities.

There is clearly a need for an overarching organization that can undertake the integrated planning, development coordination and monitoring of activities in terms of their environmental, economic and social impacts. As many of the development activities are at an early stage there is an opportunity to establish such an organization. Given the fact that the Lake is shared by both Egypt and Sudan there is an opportunity to establish a joint secretariat that could undertake joint sharing of information on development intentions and monitoring results.

4.4 Potential Transboundary benefits: Overall Downstream Impact on Sedimentation in the Main Nile from Upstream Watershed Management and Dam Operation Activities

4.4.1 Current and Proposed Interventions and Dams

The analyses described in Chapter 3 into sedimentation in Lake Nasser/Nubia assumed that the sediment load would remain constant in the future. In fact there are a number of on-going and potential developments that could significantly alter this assumption.

In both the Tekeze-Atbara and the Abay-Blue Nile Sub-basins there are substantial watershed management programmes on-going and proposed. (The programme in the Baro-Akobo catchment the programme is much more modest.) There are currently three on-going dam construction projects being implemented: one on the main Tekeze River (TK5) in Ethiopia, a second on the Beles River (a tributary of the Abay River) also in Ethiopia, and a third on the Main Nile (Meroe) in the Sudan.

4.4.2 Watershed Management Programmes in the Abay-Blue Nile and Tekeze-Atbara Sub-basins

In the trans-boundary analysis for the two Sub-basins, assuming a full ten year programme of comprehensive watershed management measures on crop and non-cropland as well as a substantial and concurrent micro-dam programme, potential reductions in sediment loading in the Tekeze-Atbara and Abay-Blue Nile Rivers were estimated. These are summarized in table 11.

Table 11. Estimated Potential Reductions in Sediment loads in the Tekeze-Atbara, Abay-Blue Nile and Baro-Akobo-White Nile Rivers resulting from the implementation of a comprehensive Watershed Management Programme

Sub-basin/Intervention	Reduction in sediment load (million tons/yr	Current Sediment Loads
TEKEZE-ATBARA (SDR = 59%)		
WSM: Cropland	5.8	
WSM: Non-cropland	17.6	
WSM: Gulley rehabilitation	1.8	
Micro-dams: sediment retention	1.0	
TOTAL: WSM	**26.2**	**70.9***
ABAY-BLUE NILE (SDR = 45%)		
WSM: Cropland	29.8	
WSM: Non-cropland	23.6	
WSM: Gulley rehabilitation	2.4	
Micro-dams: sediment retention	0.5	
TOTAL: WSM	**56.3**	**140.0****
BARO-AKOBO-WHITE NILE (SDR = 22%)		
WSM: Cropland	2.7	
WSM: Non-cropland	0.2	
WSM: Gulley rehabilitation	0	
Micro-dams: sediment retention	0	
TOTAL: WSM	**2.9**	**9.5**
TOTAL: TEKEZE-ATBARA + ABAY-BLUE NILE	**82.5**	**142.0*****

* entering Kashm el Girba Reservoir
** entering Roseires Reservoir
*** entering Lake Nasser/Nubia

Assuming that most of the sediment in the Baro-Akobo is deposited in the flanking swamps and alluvial flats, and the Jebel Aulia dam, the total potential reduction in sediment load from the Ethiopian Highlands would be approximately 82.5 million tons/yr.

4.4.3 Sediment Retention in Dams Under Construction and Proposed

The suspended sediment load at the site of the Tekeze dam is estimated to be 31.1 million tons/yr. It has not been possible to determine the trapping efficiency and what if any, the flushing regime will be. As the dam is for hydro-power generation the aim will be to keep this to a minimum and substantial sedimentation can be expected. The consultants' report (Tekeze Medium Hydro-Power Project) assumed a dam-storage of 4.54 billion m^3 and a trapping efficiency of 100 percent to determine the economic life of the dam. Assuming that a "flushing" regime similar to Roseires, Sennar and Kashm el-Girba is practiced the trapping rate could be reduced to 30 percent, thus reducing the annual suspended sediment load from 31.1 million tons to 9.33 million tons per year.

The suspended sediment load on the Beles River is estimated to be 1.56 million tons/yr. The dam is for power generation and irrigation. Assuming a 30 percent trapping rate the sediment reduction would amount to 0.468 million tons per year.

The Meroe Dam is a very substantial structure with a storage capacity of 8.3 km^3. As the dam is below the confluence of the Atbara all sedimentation studies have assumed a suspended sediment load at the site as that at Dongola (about 142 million tons/yr). The dam is fitted with deep sluices and 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, the supervising consultants, (ii) a study by MIT, and (iii) by the Eawag, Switzerland.

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.

It is not possible to estimate with certainty what the impact on suspended sediment loads of the Atbara and Blue Nile a major soil and water conservation and small dam programme will be. It has been estimated (Tekeze Medium Hydro-power Study) that 20 micro dams will reduce run-off between 80 million and 200 million m^3/yr. Assuming 1 ton of suspended sediment for 440 million m3, a 100 micro dams could reduce total suspended sediment load by 0.5 to 1.3 million tons/yr.

There are a number of other potential large dams in the Eastern Nile basin that are now being seriously considered that will also have substantial impacts on suspended sediment loads downstream. The largest of these is the Karadobi Dam on the Abay within in Ethiopia. The Pre-feasibility Study (Norplan-Norconsult-Laymeyer, 2006) estimates the trapping efficiency of 86.5 percent over a 50 years period and trapping between 60.5 and 99.4 million tons a year. Thus the suspended sediment of the Abay/Blue Nile entering Sudan would be reduced to between 9.4 and 15.5 million tons per year.

A second example is that of the proposed Baro 1 and 2 Multi Purpose Dams on the Baro River, the main tributary of the Sobat. Current suspended sediment load at the dam site is estimated to be 0.415 million tons per year. To simulate forest removal an increased sediment load of 1.339 million tons per year was used. A trapping efficiency of 100 percent was assumed in the calculations of the life of the dead storage. It is estimated that the two dams would reduce sediment load in the Baro River by 0.406 million tons.

It is clear that even with the current dam building programme there are likely to be substantial reductions in suspended sediment entering Lake Nasser in the future.

Table 12. Egypt – Lake Nasser: Estimated Suspended Sediment Retention in Reservoirs of Dams Currently Under Construction and of Proposed Dams in Ethiopia and Sudan.

Dam	Low sediment retention (million tons/yr)	High sediment retention (million tons/yr)
A. UNDER CONSTRUCTION		
Tekeze (Atbara)	9.33	31.10
Tana-Beles (Blue Nile)	0.47	1.56
Micro dams – Ethiopia	0.50	1.30

Meroe (Main Nile)	33.00 [1]	97.24
Total	**43.30**	**131.16**
B. PROPOSED		
Karadobi	60.50	99.40
Baro 1	0.42	1.34
Total	**60.92**	**100.74**

1. Assumes 120 million tons + reduced sediment load at Meroe due to reductions in Ethiopia (109.7 million tons)
2. Assumes 142 million tons + reduced sediment load due to reductions in Ethiopia (108.04 million tons)

Table 13. Egypt – Lake Nasser: Estimated Net Suspended Sediment Reaching Lake Nasser/Nubia after Retention in Reservoirs of Dams Currently Under Construction and Proposed Dams in Ethiopia and Sudan.

	Low sediment retention (million tons/yr)	High sediment retention (million tons/yr)
Dams Under Construction	76.70	10.8
Plus proposed Dams	36.26	7.30

Assuming a current mean annual sediment load of 142 million tons entering Lake Nasser/Nubia, sediment rates could reduce by between 25 and 91 percent with current dam construction in the East Nile Basin. With the Karadobi and Baro 1 dams this reduction could rise to between 74 and 95 percent.

Clearly, this takes no account of the certain degradation of river beds and increased bank erosion that will occur because of the increased energy of the Main Nile, Blue Nile and Atbara Rivers within Sudan. This will certainly provide an increased contribution to suspended and bed load sediment. In addition, there is a potential problem of sediment in the delta at the entrance to Lake Nubia being eroded and carried further into the Lake towards the dam wall.

5. BASIN-WIDE OPPORTUNITIES FOR HIGH IMPACT COOPERATIVE WATERSHED MANAGEMENT ACTIVITIES

5.1 Framework for Analysis

5.1.1 Types of Cooperative Benefits

A framework for analysing types of benefits from cooperative action with respect to international rivers has been prepared by Sadoff and Grey (2005). It identifies four types of benefits that can be achieved. These benefits can be economic, social, environmental and political. The framework assumes no hierarchy with regard to the magnitude of potential benefits. This will depend on the particular circumstances, the type of cooperative actions and costs involved. Neither does the framework assume a particular sequencing in which the cooperative actions should be followed although cooperative activities could be linked. Starting with ecological cooperative activities could lead to political cooperation. Conversely a setback in political cooperation could be a constraint to ecological or socio-economic cooperation.

Increasing benefits to the river (Ecological and subsequently Socio-economic cooperation)

Cooperation can enable better management of river-related ecosystems, providing benefits to the river and underpinning all other benefits that can be derived from the river. These include benefits such as better water quality and river flow characteristics across a basin which come from activities such as headwater management and wetland maintenance.

There are a number of examples of potential benefits in the Main Nile Sub-basin given the strong hydrological coupling of the Main Nile with the three other up-stream Sub-basins in terms of water flows and sediment loads.

Benefits: Increasing benefits from the river (Primarily Economic)

These types of benefits derive from efficient and cooperative management and development of shared rivers to increase benefits which are obtained from the river, usually in terms of production benefits, such as agricultural output and hydro power development. They may also include flood / drought management, navigation and environmental conservation, and water quality improvement for abstraction and recreation. These benefits may emerge through the coordination of dam and irrigation management throughout the river basin system.

There is considerable potential for these benefits in the Main Nile Sub-basin. For example the Meroe hydro-power dam can generate electricity which can be exported to Egypt. Flow moderation from this dam can impact upon the seasonal availability of water through the system.

Reducing costs because of the river (Politico-economic)

A third type of benefit derives from lessening tensions through cooperation, so that less costs are incurred on military expenditure and surveillance needed due to tensions caused by a shared river resource.

Benefits: Increasing benefits beyond the river (Economic and Social)

With high levels of cooperation, it may be possible for economic integration to occur between states along an international river with regional infrastructure developed, and economic activities planned along the river course, not on the basis of national self-sufficiency, but in response to economic comparative advantage and efficiency, so as to maximize benefits from the basin as a whole rather than within each country separately.

The potential for this type of benefit in the Main Nile Sub-basin is beginning to appear with increased collaboration between Ethiopia, Egypt and the Sudan in hydropower production and trade.

5.1.2 Benefit Sharing: The Distribution of Costs and Benefits

For regional river basin planning to occur across the two countries there will be a need for assessment of the costs and benefits to each country of the proposed land uses and investments, and if necessary for benefit sharing arrangements to be developed under an appropriate coordination mechanism.

To get to the stage where Type 4 benefits are achieved through basin-wide assessment of comparative advantage and optimal use of the resources requires a high level of trust and confidence between states, as well as an overall mechanism which can undertake planning and development, as well as manage associated benefit sharing arrangements. Benefit sharing could be particularly important in the case where one country, such as Ethiopia as a headwater country, forgoes agricultural development of its western Lowlands and maintains a vegetated landscape in that area in order to reduce sediment loads, help moderate flows in the down-stream river system and so reduce the need for dams to control river flows.

If beneficial developments are forgone in Ethiopia, (such as agricultural resettlement opportunities in the lowlands), the country could expect some payment from the downstream beneficiaries to make its own actions worthwhile. (How such funds are distributed between the Federal and Regional governments in Ethiopia would be another issue requiring sensitive investigation and resolution.) A similar within-country situation could be encountered, especially in Ethiopia with the different regional governments in the upper sub-basin and the lower sub-basin.

Integrated basin-wide development and water resource management is the goal for ensuring sustainability and productivity of rivers, while unilateral action for maximising local and national benefits irrespective of negative impacts elsewhere in the system, is least desirable. In moving towards coordinated and collaborative action in the basin, the benefits have to be worth the costs for all parties involved or some benefit sharing and compensating arrangement has to be put in place. To move in this direction it is necessary to improve perception of the potential benefits, from the obvious to the less obvious, and to understand the distribution of benefits and costs in order to achieve an arrangement which stakeholders see as fair.

5.1.3 Modes of Cooperation

Sadoff and Grey (2005) envisage a continuum of modes of cooperation from unilateral action (i.e. with no cooperation) to activities involving coordination (communication and sharing of information on national plans), to collaboration (adaptation of national plans for mutual benefits) and finally to joint actions (joints plans, joint investment).

Unilateral action in a sub-basin means no cooperation; foregoing opportunities for mutual benefits and through uncoordinated activities increasing the possibility of reduced flows or increased sediment loads.

Coordination can be achieved, for example, by cooperative collection and or exchange of hydrological information that could lead to such benefits as improved flow forecasting for floods or droughts. Exchanging information on national sub-basin development plans could assist national planners in avoiding conflicting projects. Extending the boundaries of cost-benefit analysis of catchment developments to include an assessment of trans-boundary downstream impacts is another example. Cooperative Regional Assessments (CRA’s) permit a sharing of information and provide a basis for equal acquisition of information. Coordination may enable countries to secure some type 1 and type 2 benefits.

Collaborative activities could include adapting national sub-basin plans to either secure regional gains or avoid harm to other riparian users. This mode of cooperative activity could secure type 1 and 2 benefits. Where countries are able to share these benefits this could lead to type 3 or even type 4 benefits. For this to occur then there needs to be some form of agreed benefits sharing mechanisms.

Finally, joint action occurs when the sub-countries countries jointly design, invest and implement shared river development. In the present case the Joint Multi Purpose (JMP) programme is a prime example.

Sadoff and Grey make the point that the continuum is non-directive, dynamic and iterative. By non-directive it is not intended to infer that more cooperation is necessarily better. It is dynamic because various points along the continuum will more appropriate for different activities at different times. Finally, the continuum is iterative because successful initial cooperative activities may spawn new opportunities for cooperative action.

5.2 Cooperative Activities involving Coordination: Basin-wide Information Exchange

5.2.1 Hydrology and Sedimentation

Given the large seasonal variation and very rapid response times in stream flows of the Main Nile River due the highly seasonal nature of rainfall in the Ethiopian Highlands, the sharing of flow, sediment and meteorological data collection has a number of advantages to Sudan and Egypt. Once the Tekeze TK5 dam and Meroe Dams are completed the sharing of information on reservoir releases would also be needed to complement the flow information. Such information provided on a timely basis would enable Sudan and Egypt to plan the operation of the Meroe and Aswan High dams more effectively, and allow the forward planning of flushing and retention operations, and thus power generation and irrigation scheduling.

Sutcliffe and Lazenby (1994) have pointed out that the one major gap in the investigation of the hydrological regimes of the Nile Basin is the measurement and analysis of erosion and sediment load: particularly for the Abay-Blue Nile and Tekeze-Atbara Sub-basins. Monitoring of suspended sediment loads throughout the Abay-Blue Nile, Tekeze-Atbara and Main Niles at the outlets of micro-catchments, sub-catchments and catchments of varying size would provide a more complete understanding of the linkages between catchment size, geomorphology, soils and land use and the sediment dynamics within the all of the sub-basins.

With the possibility of significant reductions in suspended sediment from catchments in the Abay-Blue Nile and the Tekeze-Atbara Sub-basins as a result of Watershed Management interventions (soil and water conservation structures, water harvesting and small dams, and the TK5 and Meroe dams) it will be important to monitor any changes in bed sediments and bank erosion in the Main Nile Sub-basin. The proposed integrated erosion-sediment monitoring programme that has been proposed for the Abay-Blue Nile and Tekeze-Atbara Sub-basins in Ethiopia could be combined with the bed and bank monitoring programme downstream in Sudan to provide a complete system-wide understanding of erosion, sediment delivery, suspended sediment, and bed aggradation and degradation.

Currently, some 96 percent of suspended and bed load sediment of the Main Nile is deposited in Lake Nasser/Nubia. In 2000 the delta deposits were 60 meters deep near the Second Cataract and deposition of sediment reached to within 120 kms of the dam. Since 1973 the inland delta had extended some 165 kms and now stretched 250kms. In addition, there is a significant amount of wind blown sediment entering the Lake. There an urgent need to refine and extend the current sediment monitoring and modelling work being undertaken by Prof. Dr. Moattessem and colleagues at the NRI. Baseline data of the bathymetry of the Lake, sediment cores and sediment provenance is required. The monitoring system is particularly important in view of the substantial watershed management interventions and dam construction activities outlined above.

The sharing of flow and meteorological data combined with satellite imagery and the analysis cold-cloud temperatures across all three Sub-basins up-stream of the Main Nile Sub-basin would enable timely and accurate forecasting of flood flows. The three main components of such a system are (Hardy et al., 1989): the collection of cold cloud duration data and their conversion to rainfall estimates in real time; the conversion of rainfall estimates to river flow estimates at key sites; and the modelling of the flood flow down the main channels to forecast levels and flows at key points.

This has advantages to Ethiopia, Egypt and Sudan in terms of an early warning system and for efficient dam operation.

5.2.2 Land Use/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 in the three upstream Sub-basins. 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 Sub-basin. 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 all three upstream Sub-basins at relatively frequent intervals (say five years) would be extremely demanding in resources. Although, it must be said that within the northern lower basin land cover changes are likely to be small. If the whole Sub-basin 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-Sub-basin monitoring a reduction in the resources required could be achieved if a more focused assessment was made of landcover changes in key thematic or Sub-catchment priority areas. These might include but be not limited to:

- Assessing landcover changes in the upper catchments of key river basins (e.g. the Upper Tekeze or Upper Abay Catchments) as an input to analyzing sedimentation rates and changes in flood frequency and the need for developing catchment management plans and activities;

- Assessing changes in vegetation cover in woodland areas on the frontiers of agricultural expansion (e.g. in the Upper Baro-Akobo Catchment;
- Assessing landcover and woody biomass changes in reception areas where voluntary resettlement is being undertaken (e.g. Humera: lower Tekeze Catchment);
- 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 Commercial agriculture (e.g. the western Lowlands of the Tekeze and Abay Catchment).

5.3 Cooperative Activities involving Coordinated WSM Planning (Effective/Optimal Basin-wide Utilization of Resources)

5.3.1 Research and Monitoring of sedimentation in Lake Nubia/Nasser

A key problem with respect to Lake Nubia/Nasser is the formation of the delta in the Lake Nubia portion of the Lake which is now extending into the Lake Nasser portion. There is an urgent need to undertake a full bathymetric survey and to establish a system of regular monitoring to determine the rate of building. This information could be jointly obtained and shared between Sudan and Egypt. Coupled with a joint basin-wide hydrology and sediment monitoring system in the three upstream Sub-basins this would enable more effective modeling of future sediment deposition both laterally and longitudinally in the delta.

5.3.2 A joint Environmental Planning and Monitoring System for lake Nubia/Nasser

Given the shared interests of both Egypt and Sudan in maintaining the pristine environmental nature of the Lake in the face of increasing development pressures from agriculture, mining and tourism its would be advantageous to establish a joint Lake Environmental Planning and Monitoring System. The planning and monitoring system could have mutually agreed environmental standards for most of the identified potential developments that might take place with the Lake catchment. There could be a sharing of data, information on future developments and impacts of current developments without the need for a joint physical organization. The essentials of the system would agreed standards and sharing information and experience.

5.4 Achieving Synergy from outputs from The Watershed Management CRA and from Coordinating Watershed Management Activities with other Programmes

5.4.1 Introduction

There are two aspects: firstly achieving synergy between the analysis and outputs of the ongoing CRA's, the ENSAP Joint Multi-purpose Programme (JMP) planning and the NBI Shared Vision Programme (SVP), and secondly between Watershed Management activities and activities related to the other CRA subject matter (e.g. irrigation development, flood control and management). The opportunities for the first are relative are of a relatively short time span, whilst the latter belong to the long term.

5.4.2 IDEN CRA's, the JMP and the SVP Programme

The IDEN CRA's include:

- Eastern Nile Planning Model,
- Flood Preparedness and Early Warning,
- Ethiopia-Sudan Transmission Interconnection,
- Eastern Nile Power Trade Investment
- Irrigation and Drainage

The outputs of the Watershed Management CRA are of immediate and direct relevance to the Joint Multi-purpose programme, the Eastern Nile Planning Model and the Irrigation and Flood Preparedness CRA's in terms of data and information relating to erosion and sedimentation, to on-going livelihood strategies and to the identification of some of the underlying causes of natural resource degradation and the levels and patterns of poverty. Given the limited resources available to ENTRO it is important that data and information collection efforts should not be duplicated.

The Watershed Management CRA has developed a substantial Geographic Information System (figure 7) that will be considerable use to the Eastern Nile Planning Model, as well as to the Irrigation and Flood Preparedness CRA's.

Additionally, synergy could be achieved in the collaborative development by the CRA Teams of the Cooperative Mechanisms. Some of these mechanisms will cater for activities in more than one CRA area. Some Cooperative Mechanisms that serve Watershed Management activities can also serve those for Irrigation and for Flood Preparedness. This is particularly so in the case of coordination of information sharing, but possibly less so in cases of joint actions (e.g. joint planning exercises).

With respect to CRA outcomes and in the case of the CRA's covering Transmission Inter-connection and Power Trade Investment the possible linkages are less obvious. Outcomes from the Watershed Management CRA of information on constraints to and potentials of agricultural production; on livelihood strategies; and levels and distribution of poverty will be of use in the development of power trade investment interventions. This information would be useful in developing potential demand scenarios for likely patterns of domestic power demand.

The SVP has eight projects designed to build a strong foundation for cooperative action. They are essentially capacity building projects. Although each has a separate focus they build on each to form a coordinated programme. The projects of most relevance to the Watershed Management CRA are as follows:

- The Applied Training Project for integrated water resources management (IWRM);

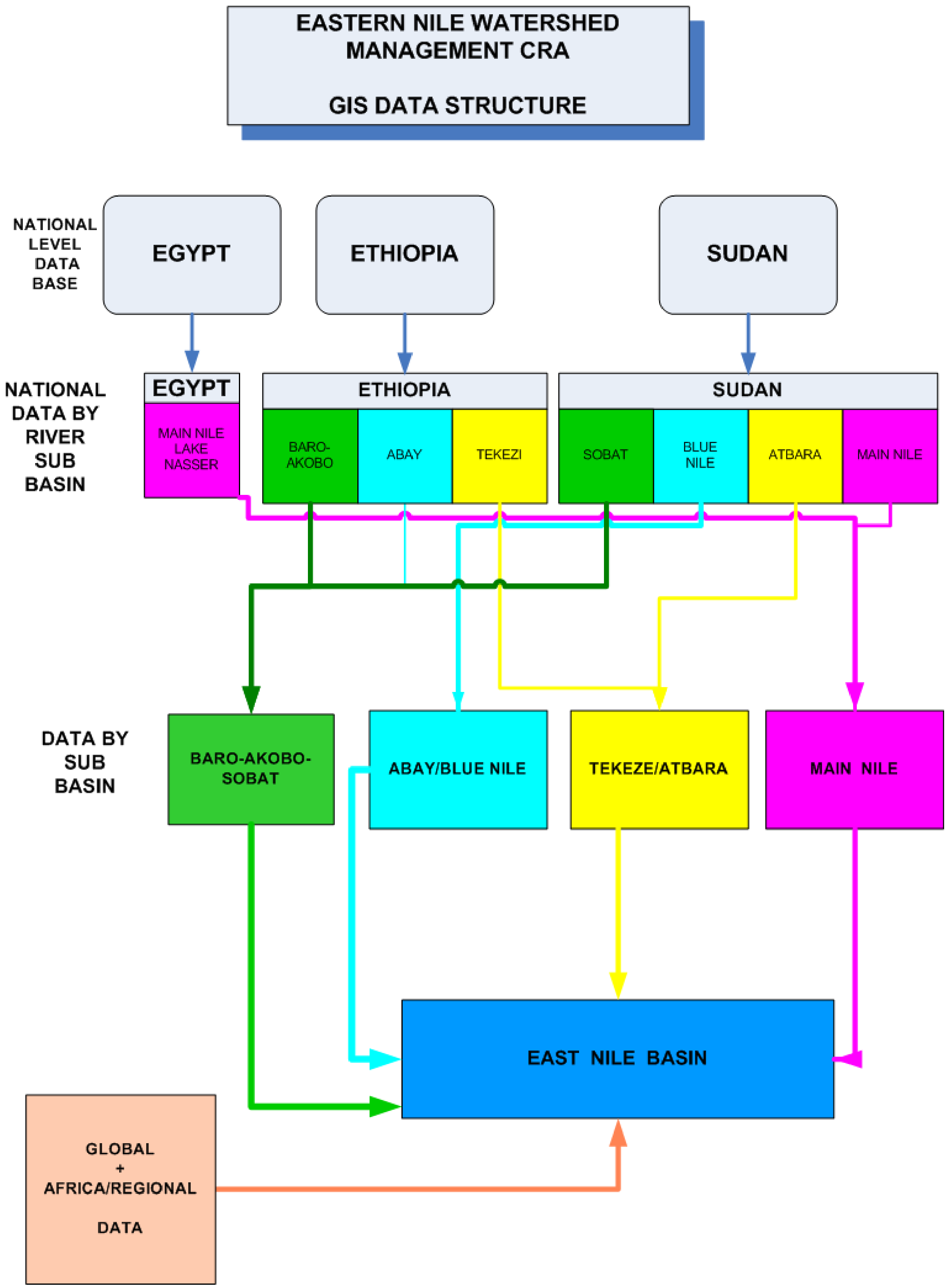
- Water for Agriculture Project to provide a basis for increased availability and efficient use of water for agriculture;

- Nile Transboundary Environmental Action Project (NTEAP) to promote cooperation in environmental management;

- Water Resources Planning and Management Project to build skills in the analysis of hydrology and the characteristics of the Nile basin system;

- Socio-economic Development and benefit Sharing Project is building network of professionals to explore alternative Nile Basin development scenarios and benefit sharing schemes.

Figure 7. Watershed Management CRA: GIS Database Structure



The outputs of the Watershed Management CRA touch on all these Projects and provide valuable information on the core areas of each the programmes. The Watershed Management CRA GIS database will provide useful data for Water Resources Planning project. Some the analysis that is being undertaken in the Distributive Analysis of the Watershed Management CRA will be of practical use to the Socio-economic Development and Benefit Sharing project. Similarly, outputs from the NTEAP activities in the Dinder National Park have informed this CRA on lessons learnt in developing a community-based approach to biodiversity and natural resource conservation.

5.4.3 Other International Programmes

There are a number of national and international programmes where cooperation and collaboration could yield mutual benefits. At the basic level this could take place through sharing information, experiences and lessons learnt. At a more higher and elaborate level this could take the form of joint activities in research, technical support and joint projects.

One example of a current joint programme is the "Hydrology for the Environment, Life and Policy" (HELP) programme that involves scientists from Sudan, Ethiopia and Egypt in a collaborative applied research programme under the auspices of the UNESCO Chair in Water Resources (UCWR). The Gash, Atbara and Blue Nile have been nominated as HELP basins.

A second initiative of relevance to cooperative watershed management activities is the Nile Basin Capacity Building Network for River Engineering (NBCBN-RE), which covers the whole of the Nile Basin. Based at the Delta Barrages in Cairo, Egypt the Network has the following objectives:

- to make optimal use of existing capacities and institutes inn the field of river hydraulic engineering and connecting specialized institutions and experts;
- to enhance communication between experts and institutions;
- to improve access to education and training within the region;
- to facilitate research on river engineering;
- raise awareness concerning the central role of the River Basin as the management unit of international waters among politicians and professionals;
- to develop a Regional information centre and database accessible to members of the network.

The Network undertakes a considerable training and research programme. The research programme is organized around six research clusters: river morphology, hydropower, GIS and modelling, river structures, environmental aspects and flood management.

On a different note there is the "Improving Livestock Water Productivity in the Nile Basin", a project of the CGIAR Challenge program on Water and Food. The aim of the project is to help to produce more food with less water through water-friendly livestock production. The programme is of particular importance to sustainable watershed management activities. The project is researching ways of using crop residues more efficiently and thus increasing the overall productivity of transpired water. Improved livestock feeding systems such as cut and carry combined with conservation tillage reduces grazing pressure on communal pastures, reduces water runoff and erosion and increases infiltration. The project is looking at ways in which livestock can be successfully integrated into large irrigation schemes such as the Gezira, where livestock currently provide nearly a third of farmers' income.

The World Bank funded TerrAfrica Project is also of relevance to the Distributive Analysis component of the Watershed Management CRA and vice versa. The TerrAfrica Project a multi-stakeholder partnership which seeks to enable the scaling-up of mainstreaming and financing of Sustainable Land Management (SLM). The project is developing a set of analytical tools to strengthen the knowledge of land degradation and of its effects, with the objective of mainstreaming SLM in the development agenda of Sub-Saharan Africa. Among these tools, TerrAfrica is supporting the development of a framework to assess the impact of land degradation and the benefits of SLM: the *"Cost-Benefit Framework for pro-SLM decision-making in Sub-Saharan Africa"*. The framework is intended to present the extent, severity and impact of land degradation, in order to provide information on the costs of degradation, benefits of SLM practices, and trade-offs involved in policy choices that could guide decision-making, with the aim of supporting the mainstreaming of SLM.

This multi-country project will be implemented in two pilot countries - Ethiopia and Ghana - and aim at further strengthening the country dialogue and enabling environment for SLM scale up through a combination of in depth analytical work and capacity building, particularly on the economics of land degradation. This is viewed as one of the important underpinnings in support of the mainstreaming of sustainable land management (SLM) into decision-making and investment operations. More specifically, this project would aim at (1) increasing capacity for analytical assessment of economic and environmental costing, and (2) enhancing and improving stakeholder dialoguing, information exchange and cooperation towards SLM. The results and the lessons learnt from this multi-country project will be shared and possibly replicated regionally through the TerrAfrica platform.

Clearly the analytical work that forms the basis of the Distributive Analysis component is of direct relevance to the TerrAfrica Framework. Both projects have established and are continuing contacts, and are sharing information and concepts.

5.5 Transboundary Trade and Economic Development

Egypt and Sudan share Lake Nasser/Nubia. On the Egyptian side there are plans for considerable developments in agriculture, mining and tourism. It is probably with tourism that there is most potential for trans-boundary cooperative development. The archaeological treasures along the Main Nile in Upper Egypt and northern Sudan offer considerable potential for joint development by both countries. Lake Nasser/Nubia and the Nile River provide a line of water communication that be used as a tourist attraction in its own right.

The second area of potential trans-boundary economic cooperation lies in the dredging and use of the sediments in the delta as outlined in chapter 4. As the sediment is located in both countries a joint assessment and exploitation would make economic sense and provide mutual benefits to each.

REFERENCES

Abu-Zeid, M.A. and F.Z. El-hibini (1997) "Egypt's High Aswan Dam", Water Resources Development: 13 No. 2, pp.209-217.

Balba, A.M. (1979) "Evaluation of changes in the Nile Water Composition Resulting from the Aswan High Dam" J. of Envir. Quality 8: 37-49.

Briggs, J et al (1993) "Sustainable Development and Resource Management in Marginal Environments: Natural Resources and their Use in the Wadi Allaqi Region of Egypt", Applied Geography 13, pp. 259-284.

Coppock (1993) in “Range Ecology at Disequilibrium”, Ed. Roy H Behnke, Ian Scoons, and Carol Levin, ODI, IIED & Commonwealth Secretariat, London.

El-Moattessem M. & Abdel-Aziz, T.M. (1988) "A Study of the Characteristics of Sediment Transport in the Aswan High Dam Reservoir", report No. 117, Cairo, Egypt.

Eldaardir, M (1994) "Sedimentation in the Nile High Dam Reservoir: 1987 – 1992, and Sedimentary Futurological Aspects", Sediment Egypt 2, 23-39.

Elraey, M et al (1995) "Change detection of the Rosetta Promontory over the last 40 years" Int. J. Remote Sensing 16: 825-834.

FAO (2006) "The New Generation of Watershed Management Programmes and projects. FAO Forestry paper 150", FAO Rome.

Frihy, O.E. et al (1998) "Change detection of the north-eastern Nile delta of Egypt: shoreline changes, spit evolution, margin changes of Manzala Lagoon and its Islands" Int. J. Remote Sensing 19: 1901-1912.

Hardy et al (1989) "The use of satellite derived rainfall estimates as inputs to flow prediction in the river Senegal", IAHS Pub. 181 (New Directions for Surface Water Modelling: Ed. M.L. Kavas)

Haug, R (2000) “Livelihood Security among Pastoralists in Northern Sudan”, NORAGRIC Working Paper 19.

Hellden, U (1988) "Desertification Monitoring: Is the Desert Encroaching?", Desertification Control Bulletin 17, 8-12, UNEP, Nairobi.

Helden, U (1992) ""Desertification: Time for an assessment.", Ambio 20: 372-383.

Hulme, M & M. Kelly (1993) "Exploring links between desertification and climatic change", Environment 35: 4/11, 39-45.

Jeongkon Kim & Mohamed Sultan (2002) "Assessment of the Long-term hydrological impacts of Lake Nasser and related irrigation projects in South-western Egypt", J. of Hydrology 262, Issues 1-4, 68-83.

Kotob, M & Mottoleb, M.M. (1981) "Effect of the Aswan High Dam on the regime of the river downstream Esna Barrage", High Dam Side-effects Research Institute, Cairo.

Lahmeyer International (2001) "Meroe dam Project: Project Assessment Report", for MIWR, Khartoum.

Lamprey, H.F. (1988) Report on the desert encroachment reconnaissance in northern Sudan", Desertification Control Bulletin 17: 1-7.

Moattassem, M (2005) "Aswan High Dam Environmental Side Effects", paper presented at Watershed Management Workshop, Bahir Dar, November, 2006.

NBI-NTEAP (2005) "Nile Basin Water Quality: Monitoring Baseline report: Egypt", NTEAP.

Nixon, S (2004) "The Artificial Nile", American Scientist 92: 158-165.

Obeid Mubarak, M (1982) “The Vegetation of Sudan”, in “A Land Between Two Niles”, ed. M.A.J. Williams & D.A. Adamson, A.A. Balkema.

Norplan-Norconsult-Laymeyer (2006) Pre-feasibility Study of the Karadobi Multi Purpose Project", for Ethiopian MWR, May 2006.

Olssen, I (1993) "On the Causes of Famine, Drought, Desertification and Market Failure in the Sudan" , Ambio, 22, 395-403.

Paris, A, T.Yamana and S.Young, (2004), "Sustainability Considerations in the Design of Big Dams: Meroe, Nile Basin", May 19, 2004.

Sadoff, C.W. & D. Grey (2002) “Beyond the river: the benefits of cooperation on international rivers”, Water Policy 4: 389-403.

Sadoff, C.W. & D. Grey (2005) “Cooperation on International Rivers: A Continuum for Securing and Sharing benefits”, Water International 30: No. 4: 1-8.

Sayed El-Sayed & van Djiken, G.L. (1995) "The South-eastern Mediterranean Ecosystem re-visited: Thirty years after the construction of the Aswan High Dam", Quarterdeck 3.1, Texas A & M University.

Shalash, S (1980) "Effect of sedimentation in Aswan High Dam reservoir", Nile Research Institute, Cairo, Egypt.

Shalash, S. (1982) " Shalash S (1982) Effects of sedimentation on the storage capacity of the Aswan High Dam reservoir. Hydrobiologia 92: 623-639.

Springuel, I. et al (1997) "The Plant Biodiversity of the Wadi Allaqi Biosphere Reserve (Egypt): Impact of Lake Nasser on a desert wadi ecosystem", Biodiversity & Conservation, Vol. 6, No. 9, pp. 1259-1275.

Stanley, D.J. (1996) " Nile Delta: Extreme case of sediment entrapment on a delta plain and consequent coastal land loss" Marine geology 129: 189-195.

Sutcliffe, J.V. & J. Lazenby (1994) Hydrological Data Requirements for Planning Nile Management", in P.P.Howell & J.J.Allan "The Nile: Sharing a Scarce Resource", CUP

Teodoru, C, A.Wuest & B.Werhli, (2006) "Independent review of the Environmental Impact Assessment for the Meroe Dam project, Nile River, Sudan.", March 15, 20056.

Tucker C.J. et al (1991) "Expansion and contraction of the Sahara desert from 1980 to 1990", Science, 253: 299-301.

UNDP/World Bank (1988) “Sudan: Wood Energy/Forestry Project: Map 1 – Desertification and Rainfall”, World Bank, Washington DC.

UNDP/World Bank (1988) “Sudan: Wood Energy/Forestry Project: Map 1 – Desertification and Rainfall”, World Bank, Washington DC.

Westoby M et al (1989) "Opportunistic rangeland management for rangelands not at equilibrium", J. of Rangeland Management, 42: 266-274.

Yagoub Abdalla Mohamed (2005) “Country Case Study: Sudan”, prepared for ENTRO, Nov. 2005.