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Eastern Nile Watershed Management Project

Cooperative Regional Assessment (CRA) for Watershed Management

TRANSBOUNDARY ANALYSIS
TEKEZI-ATBARA 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 Consultant (Egypt), Comatex Nilotica (Sudan) and T & A Consultants (Ethiopia).

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CONTENTS

ANNEXES

ACRONYMS

ACT	African Country Almanac
ADLI	Agricultural Development Led Industrialization
ACT	African Country Almanac
AHD	Aswan High Dam
BS-GRS	Beneshangul-Gumuz Regional State
CBPWM	Community Based Planning and Watershed Management
CGIAR	Consultative Group for International Agricultural Research
CFW	Cash for Work
CRA	Cooperative Regional Assessment
CSA	Central Statistical Office
CV	Coefficient of variation
DTM	Digital terrain Model
DIFID	Department for International Development
EEPFE	Environmental Policy Forum in Ethiopia
ENSAP	Eastern Nile Subsidiary Action Programme
ENTRO	Eastern Nile Technical regional Office
EROS	Earth Resources Observation Satellite
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FFW	Food for Work
f.o.b.	Forward on Board
FNC	Forest National Council
GAS	Gash Agricultural Authority
GEF	Global Environmental Fund
GIS	Geographic Information System
HCENR	Higher Council for Environment and Natural Resources
HELP	Hydrology for Environment, Life and Policy
IDEN	Integrated Development of the Eastern Nile
IDP	Internally Displaced Person
IFAD	International Food and Agricultural Development
IFPRI	International Food Policy Research Institute
IGADD	Inter Governmental Agency for Drought and Desertification
ILO	International labour Organization
ILRI	International Institute for Livestock Research
IUCN	International Union for Conservation of Nature and Natural Resources (World Conservation Union)
JAM	Joint Appraisal Mission
JIT	Jonglei Investigation Teak
JMP	Joint Multipurpose Programme
km	Kilometre
km^2	Square kilometre
km^3	Cubic kilometer (1 billion m^3)
MARD	Ministry of Agriculture and Rural Development

masl	Meters above sea level
MDG	Millennium Development Goal
MWR	Ministry of water Resources
MOPED	Ministry of Planning and Economic Development
MCM	Million Cubic Meters
MW	Mega Watt
MERET	Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods
MIT	Massachusetts Institute of technology
N	Nitrogen
NBCBN – RE	Nile Basin Capacity Building Network – River Engineering
NBI	Nile Basin Initiative
NCS	National Conservation Strategy
NGO	Non-government Organization
NSWO	New Sudan Wildlife organization
NTEAP	Nile Transboundary Environmental Assessment
NTFP	Non Timber Forest Product
ORNL	Oak Ridge National Laboratory
RFPA	Regional Forest Priority Area
SDIT	Southern Development Investigation Team
SDR	Sediment Delivery Ratio
SLM	Sustainable Land Management
SMF	Semi-Mechanized Farm
SNNPRS	Southern Nations, Nationalities and Peoples Regional State
SRTM	Shuttle Radar Terrain Mission
SWC	Soil and Water Conservation
SWHISA	Sustainable Water Harvesting and Institutional Strengthening Project
t	ton
UNDP	United Nations development Programme
UNEP	United Nations Environmental Programme
UNSO	United Nations Sudano-Sahelian Organization
USAID	United States Agency for International Development
USGS	United States geological Service
USLE	Universal Soil Loss Equation
WB	World Bank
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WM	Watershed Management
WUA	Water Users Association

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 Tekeze-Atbara 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;
- 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. This report constitutes the results of the last three stages.

The Tekeze-Atbara sub-basin covers an area of 227,128 km^2 (including the Mereb-Gash basin). This sub-basin extends from the north-western Ethiopia to the lowlands of Sudan, meeting the Main Nile approximately 285 km downstream of Khartoum. In Ethiopia, the Tekeze River travels more than 750 km from its source near Lake Ashange to the border with Sudan. In Sudan the river extends another 575 km in a north-westerly direction.

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 land policy issues in both Ethiopia and Sudan. It Ethiopia although land registration is proceeding, it has adopted a narrow focus and has not seized the opportunity to link land tenure security with land investment, poverty reduction and improved livelihoods. In Sudan the 1970 the

Unregistered Land Act is seen as the root cause of land tenure problems and natural resource conflicts in the north.

In both countries devolution of power to regions and states is an avowed government policy. There is a complex institutional framework within which interventions must be coordinated for effective watershed management to operate. Ethiopia has draft legislation to establish River Basin Organizations whose purpose is to address these problems. In Sudan, whilst there is provision for Strategic Land Use Planning at the State level this has not been implemented.

The physical and technical issues are then examined, in particular the issues of sheet and gulley soil erosion, high sediment loads in the rivers and the consequent siltation of both small dams in the highlands, in the Kashm el Girba and Aswan High dams and in the canals of the New Halfa Irrigation scheme. Estimates are made of the reductions in agricultural production due to soil erosion and to breaches in soil nutrient cycles and loss of nitrogen and phosphorous. Estimates are made of the loss of land due to "kerib" gully erosion.

Chapter 4 looks at the opportunities for in-country and trans-boundary benefits from watershed management activities in a basin-wide perspective. Opportunities to reduce soil erosion, nutrient breaches, declining soil fertility and crop production and sediment loads are assessed and where possible quantified. Some potential negative impacts of substantial reductions in sediment load such as river bed and bank erosion are noted. The need to undertake a comprehensive surveyed of under or non-utilized large semi-mechanized farms is stressed and opportunities to revert these lands back to the State for redistribution to small-scale cultivators, agro-pastoralist and pastoralists are identified. It is stressed that this should be part of integrated strategic and community level planning and supported by a strengthened agricultural extension and research. In-country and trans-boundary benefits accruing to the watershed management interventions are identified and quantified.

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 basin-wide watershed management planning; 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. A summary of cumulative benefits from watershed management interventions are provided in broad terms.

1. BACKGROUND

1.1 Introduction

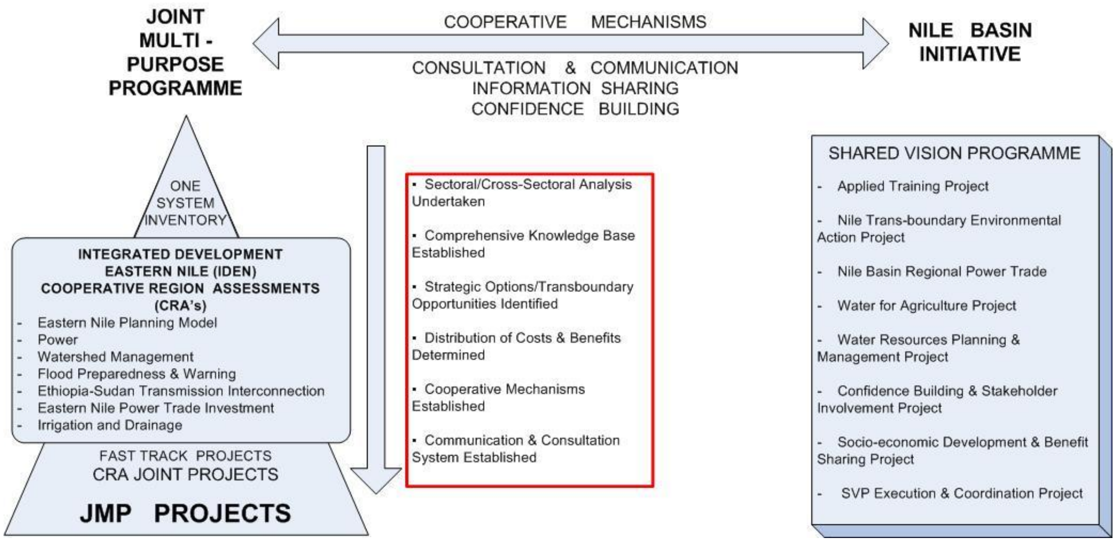
The Eastern Nile Basin Watershed Management Cooperative Regional Assessment (CRA) is in support of the Eastern Nile Subsidiary Action Programme (ENSAP). ENSAP, which includes Egypt, Ethiopia and the Sudan, seeks to initiate a regional, integrated, multi-purpose programme through a first set of investments.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

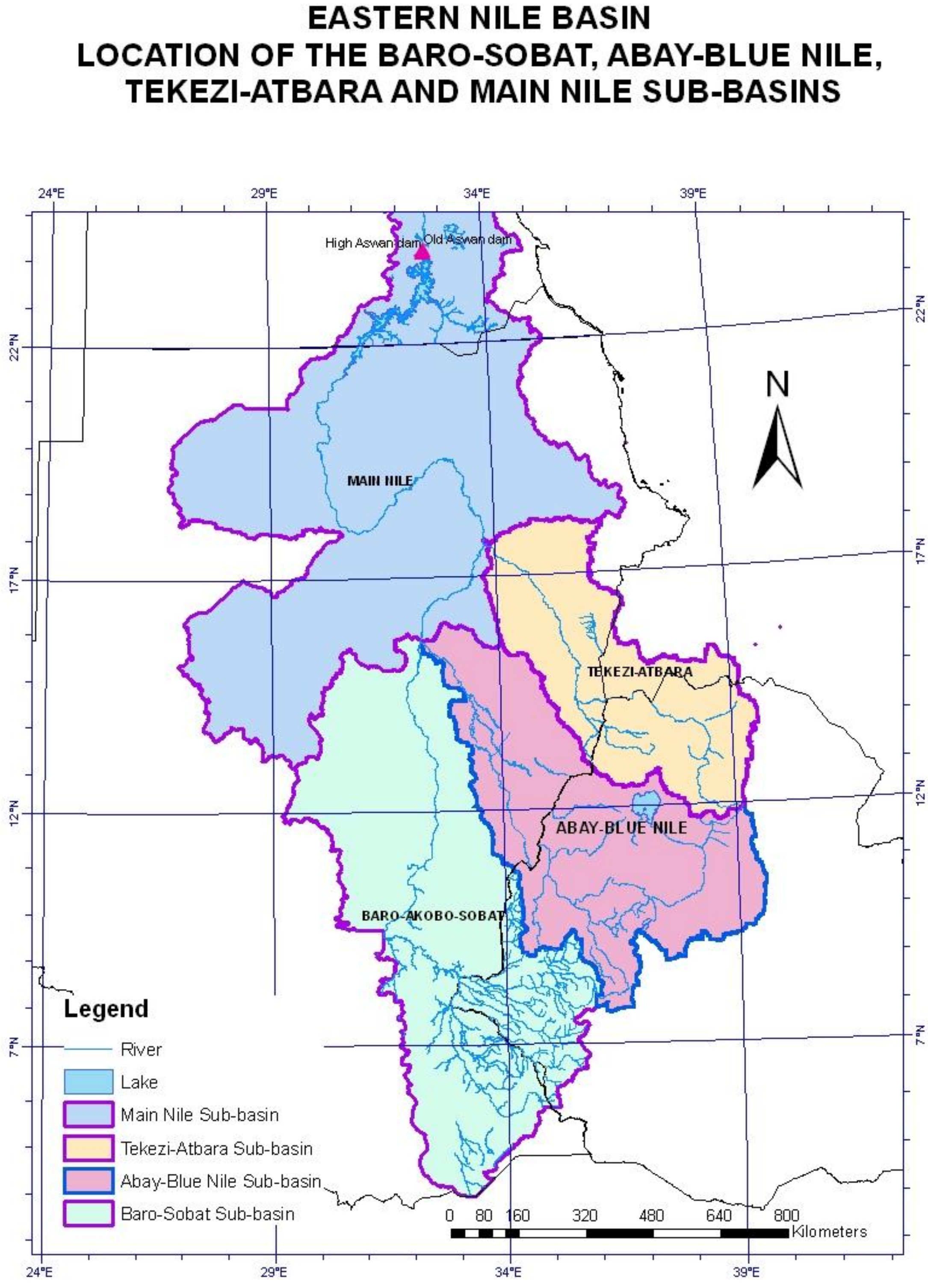
Figure 1. Relationships among and processes of the IDEN CRA's, the Joint Multi-purpose Programme and the Nile Basin Initiative's Shared Vision programme



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.



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 Analysis 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;
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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 Tekeze-Atbara 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 Tekeze-Atbara sub-basin covers an area of 227,128 km^2 (Map 1) (including the Mereb-Gash basin). This sub-basin extends from the north-western Ethiopia to the lowlands of Sudan, meeting the Main Nile approximately 285 km downstream of Khartoum. In Ethiopia, the Tekeze River travels more than 750 km from its source near Lake Ashange to the border with Sudan. In Sudan the river extends another 575 km in a north-westerly direction.

Compared with the drainage network in Ethiopia, the Sudanese portion of the Tekeze-Atbara watershed is characterized by a very low density of watercourses except in the south-west along the Blue Nile watershed where there are numerous intermittent khor channels.

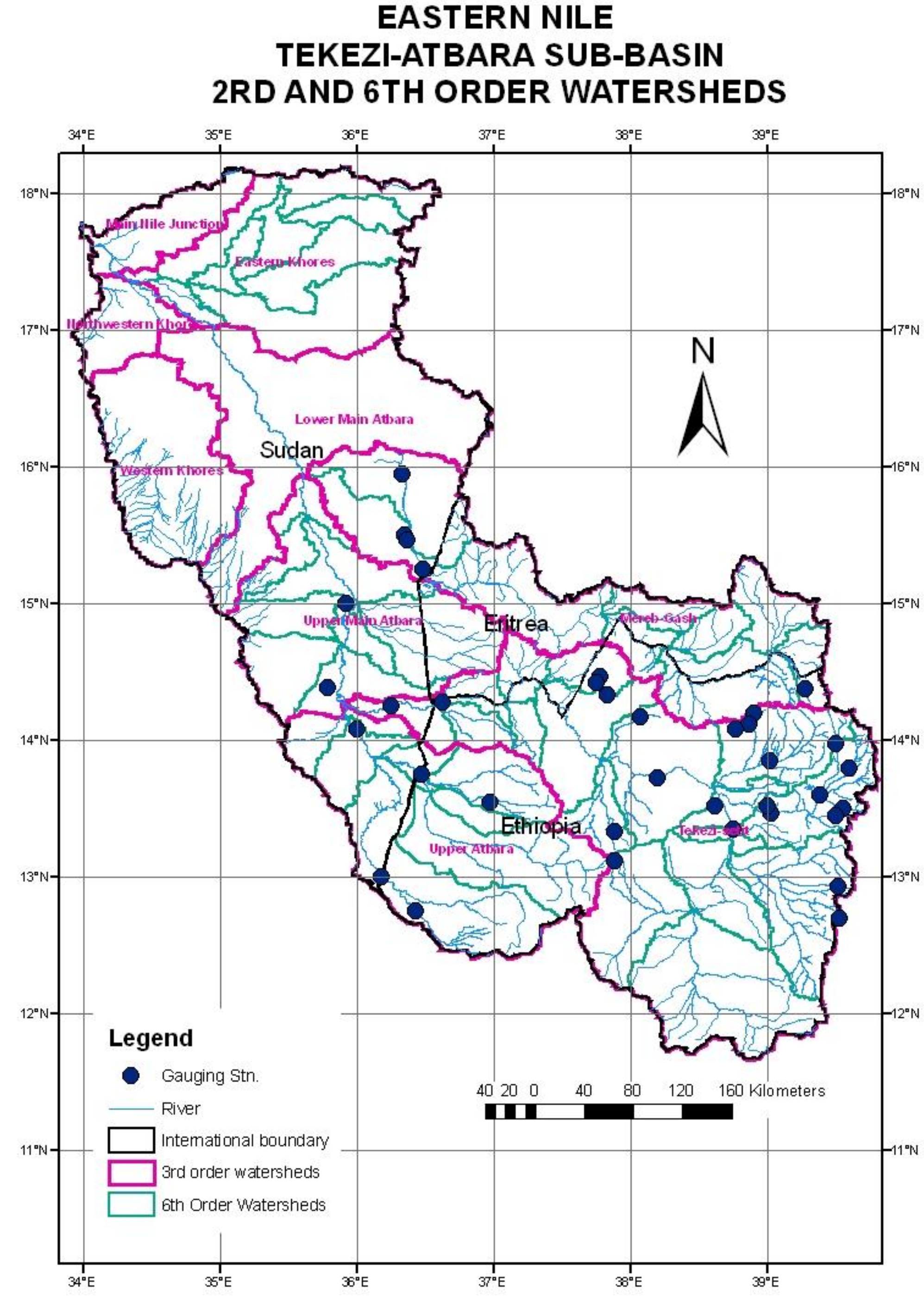
The Sub-basin is sub-divided into nine 3rd order and 69 6th Order Watersheds using the Pfafstetter system. This system is based on the topology of the drainage network and the drainage area (Verdin, 1997). The source of the data is the USGS/EROS gtopo30 HYDRO1k data set published by UNEP/DEWA/Grid. They are shown in map 2. The areas of the 3rd order Catchments are shown in table 2.

Table 2. Tekeze-Atbara Sub-basin: Areas of Third order catchments (km2)

3rd Order Catchment	Area (km2)	% of total Sub-basin area
Main Nile Junction	5,357	2%
Eastern Khors	23,117	10%
Northwestern Khors	4,339	2%
Western Khors	14,381	6%
Mereb-Gash	32,567	14%
Lower Main Atbara	23,853	11%
Upper Main Atbara	23,780	10%
Upper Atbara	30,908	14%
Tekeze-Setit	68,827	30%
	227,128	

Source: Basin boundaries: USGS/gtopo30/HYDRO30

The Kashm el Girba reservoir was constructed in 1964 on the Atbara River about 250 km from the border with Ethiopia with an initial capacity of 1.3 km^3.



Map 2. Tekeze-Atbara Sub-basin: 3rd and 6th Order Watersheds

Source: Basin boundaries: USGS/gtopo30/HYDRO30. Gauges/met stns. ENTRO GIS Database

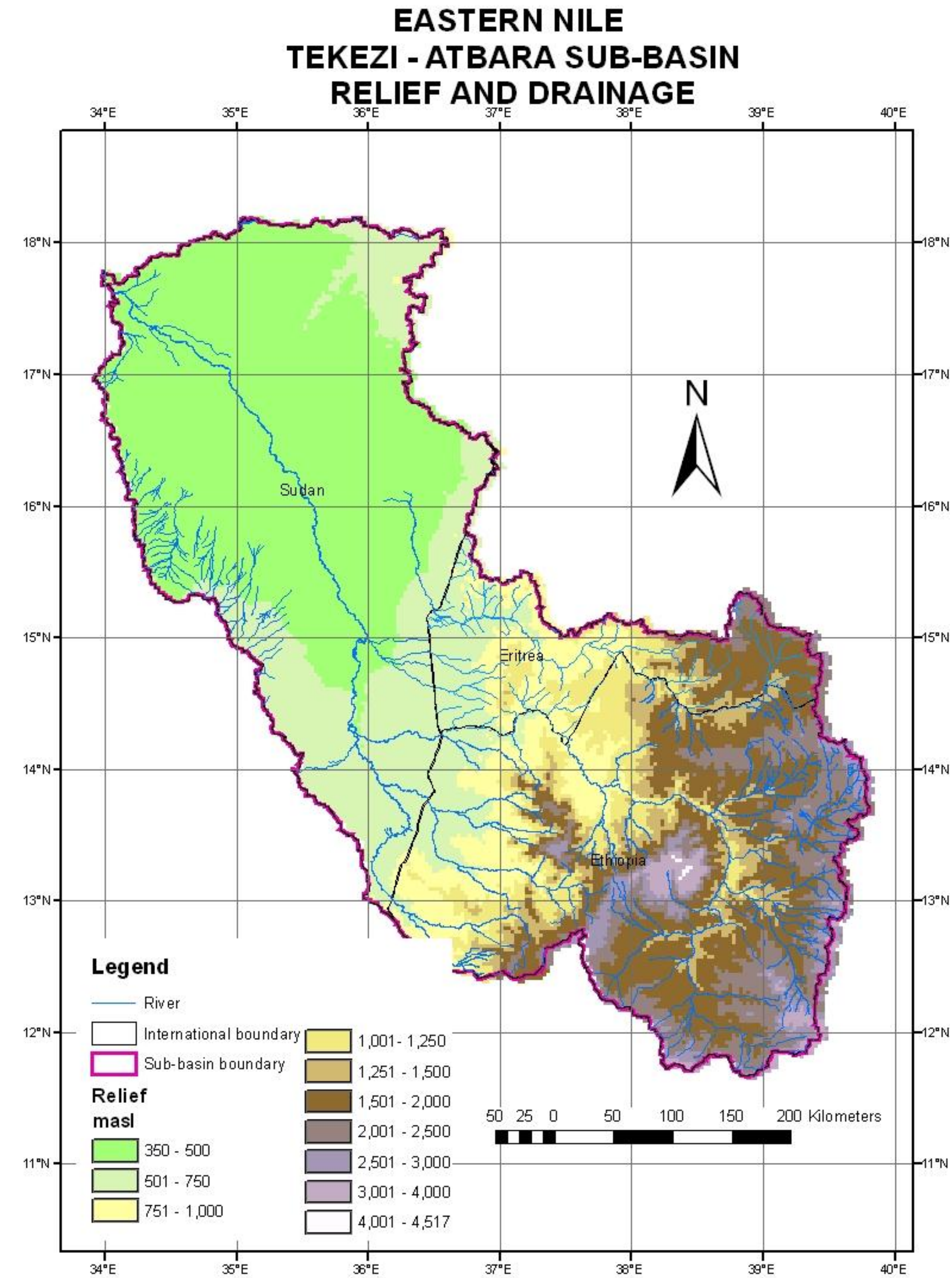
2.1.2 Relief

Two main landscape units are observed in Tekeze-Atbara sub-basin. A mountainous relief that extents in Ethiopia and Eritrea and a flat piedmont starting close to the Ethiopian border and extending across the Sudanese portion (Map 3).

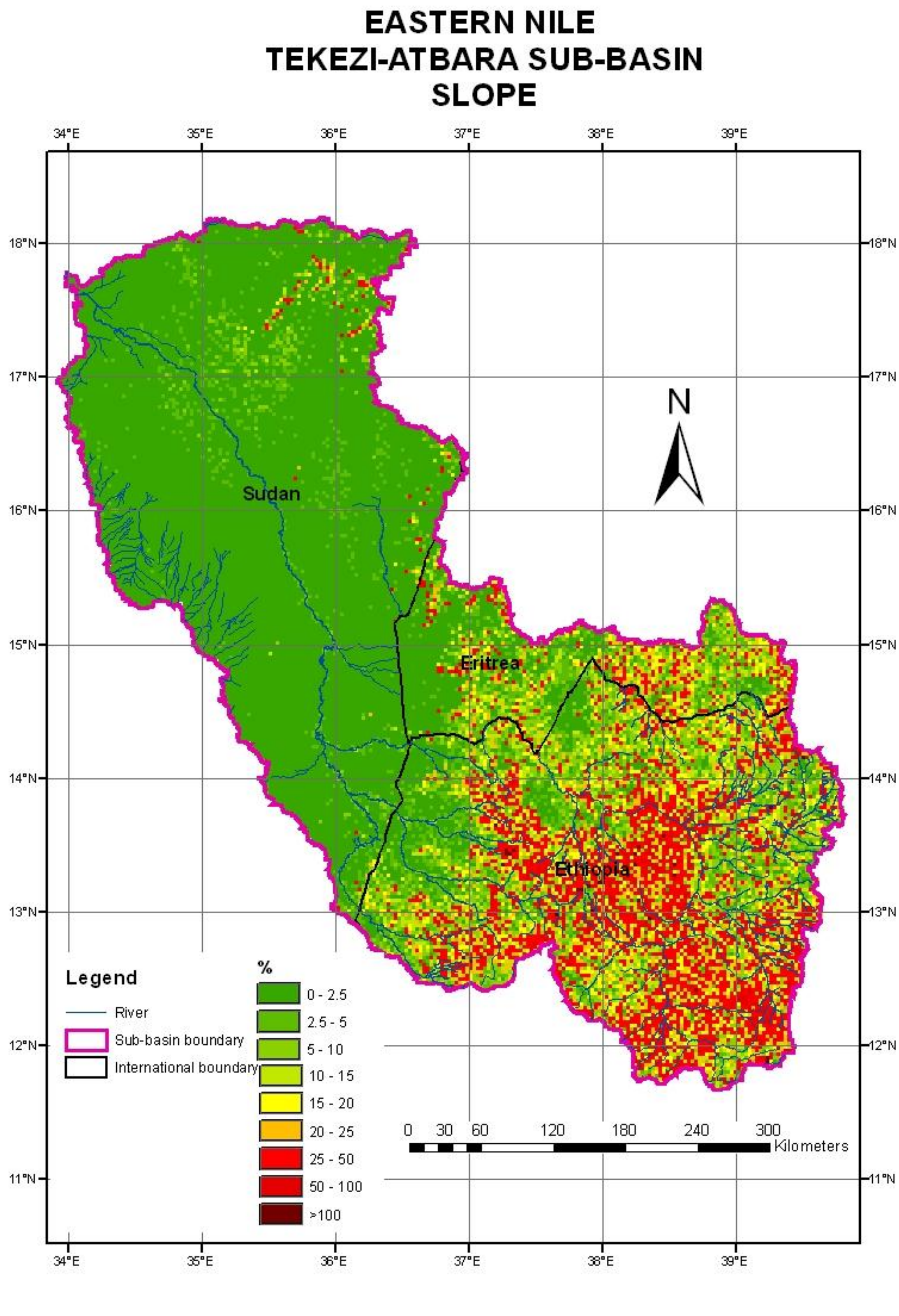
The incised nature of the Tekeze River in the Ethiopian highlands mirrors that of the Abay River. However, the altitude ranges are smaller within the Tekeze basin and the drainage pattern is more dendritic. The Tekeze basin is also characterized by the presence of isolated volcano necks contrasting sharply with the surrounding undulating relief. The upper reaches of the basin are surrounded by mountain ranges with a maximum altitude of 4,600 masl at the mountain of Ancua, part of the Ras Dashan system. Plateaus and benches terminate in steeply dissected escarpments, where resistant strata have been broken down by geological erosion. Extremely rugged topography exists where the highlands are cut into a number of blocks by deeply incised gorges of the Tekeze River and its tributaries.

In the Ethiopian and Sudan Lowlands the topography is almost flat or slightly undulating becoming increasingly more undulating to the east. The elevation of the lowlands varies between 500 and 1 500 masl. The lowland region between the Atbara River and the Blue Nile is occupied by the Butana Plains.

Given the extent of the lowlands, in proportion with the mountainous relief, most of the sub-basin is characterized by slopes lower than 2.5 percent (Map 4).



Map 3. Tekeze-Atbara sub-basin: Relief and drainage Source: Source: Shuttle Radar Terrain Mission (SRTM 90) digital terrain model.



Map 4. Tekeze-Atbara sub-basin: Slope (%)
Source: Derived from SRTM DTM using ARC-GIS Spatial Analyst

2.1.3 Climate

(i) Rainfall

The rainfall isohyets trend in a north-east to south-west direction, with rainfall decreasing north-westwards from where the river leaves Ethiopia. Rainfall ranges from about 2 120 mm/yr in the highlands of Ethiopia to less than 50 mm/yr at the junction with the Main Nile with a coefficient of variation (CV) as high as 100 percent (Map 5). The highest rainfall values are recorded in the mountainous ridge in the centre of the basin, and in the south and south-east, close to Lake Tana.

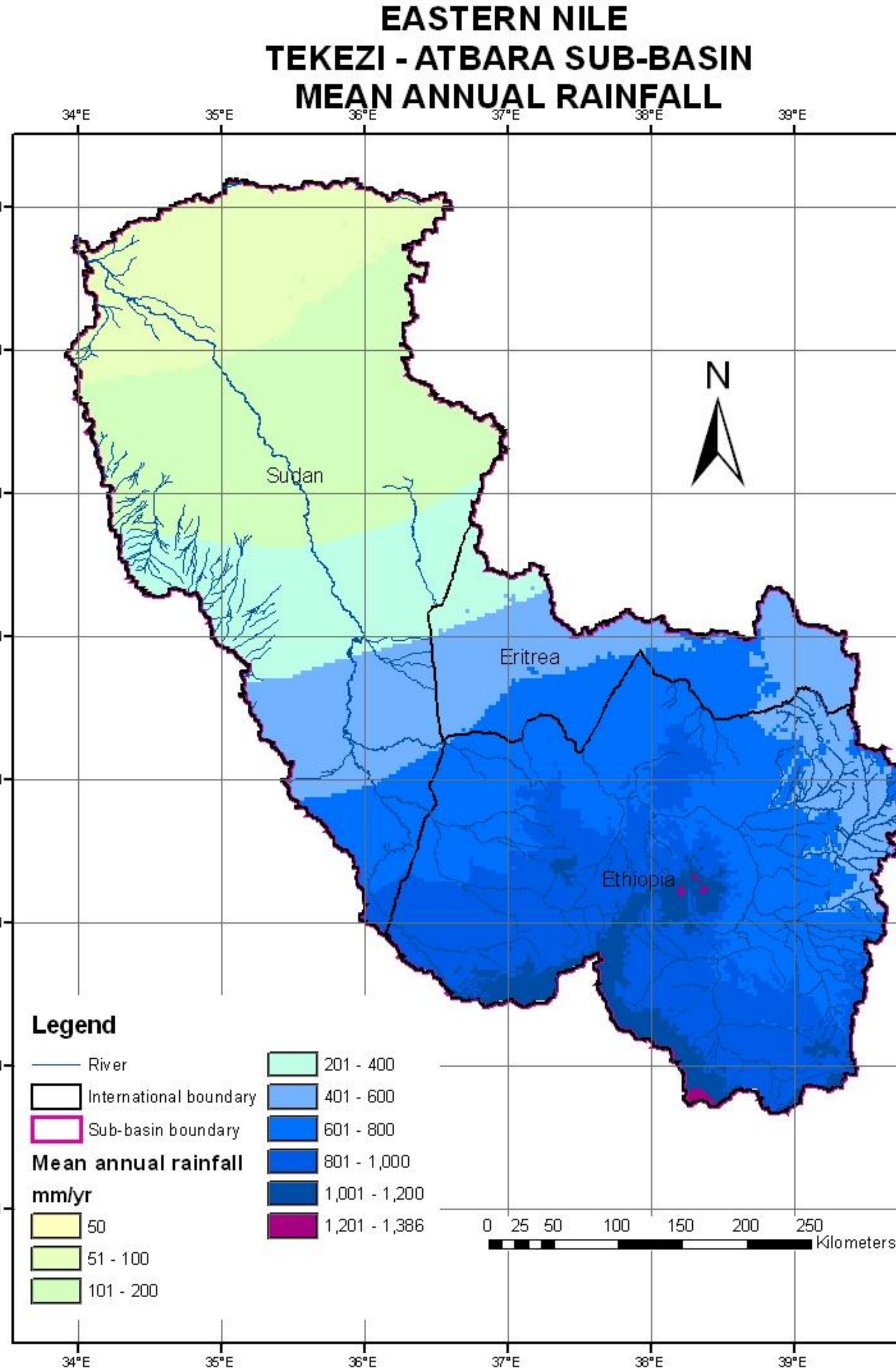
Within the highlands of Ethiopia, a uni-modal wet season is found to the west of the Simien massif. The wet season lasts about four months, from June to September. East of the Simien massif the rainfall pattern in bi-modal, characterized by two wet seasons. The "*Belg*", or short rainy season, occurs from mid-February to mid-May. However, the *belg* is characterized by inter-annual and inter-seasonal variations. This short rain period is of some agricultural importance, particularly in the north-east where annual rainfall is low. The "*Kiremt*" or main rainy season lasts from June to September.

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

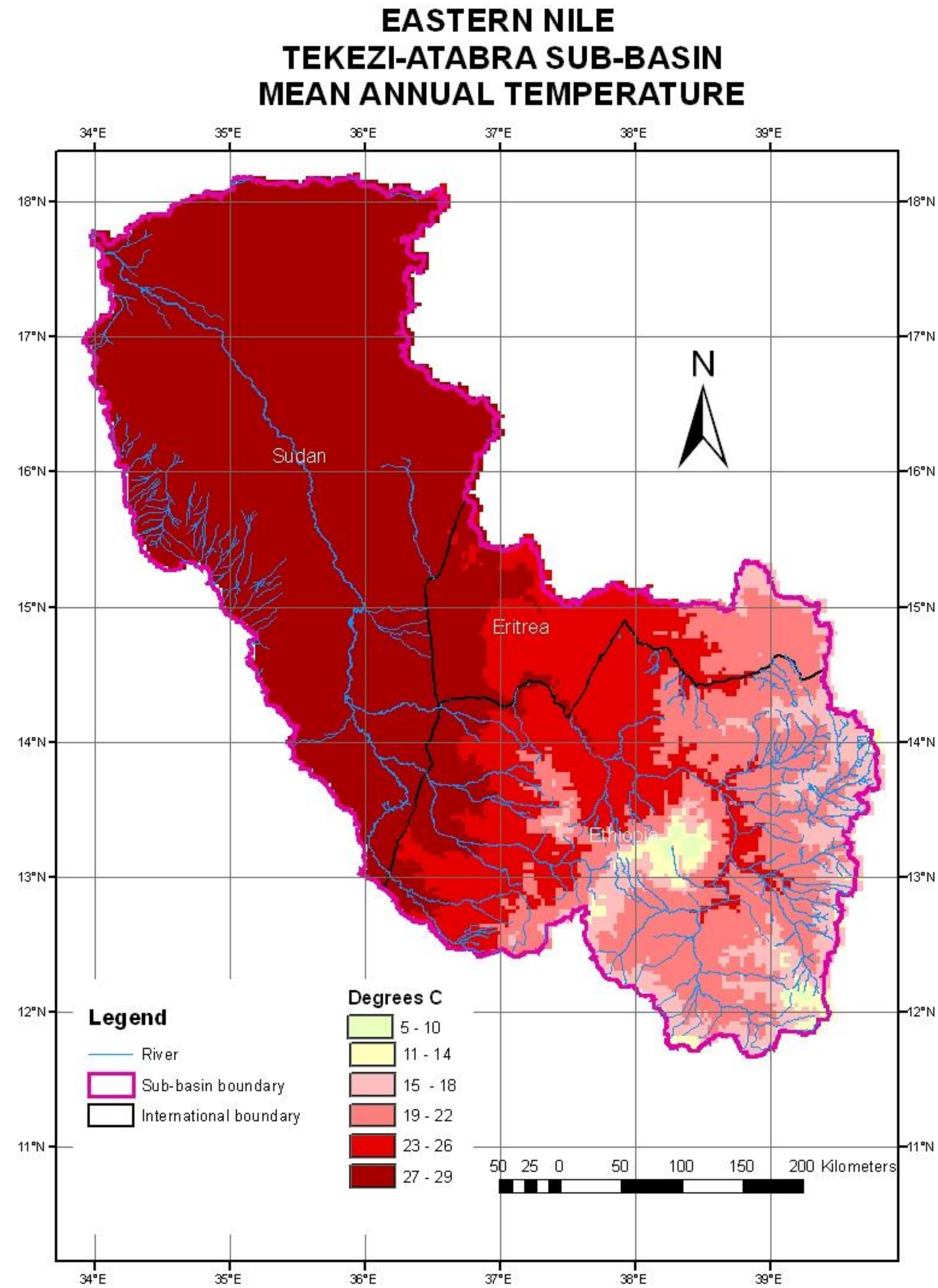
(ii) Temperature

Highest mean annual temperatures occur in the eastern clay plains of Sudan, rather than the north where minimum temperatures bring down the mean (Map 6). Daily minimum and maximum temperatures in January are 14°C and 33°C and those in May are 24° and 44°C respectively in Sudan.

The spatial distribution of temperature values is strongly related to altitude. The area located in the highlands of Ethiopia is characterized by lowest minimum mean monthly temperatures that range between 3 and 21^{o}C, and that occur between December and February.

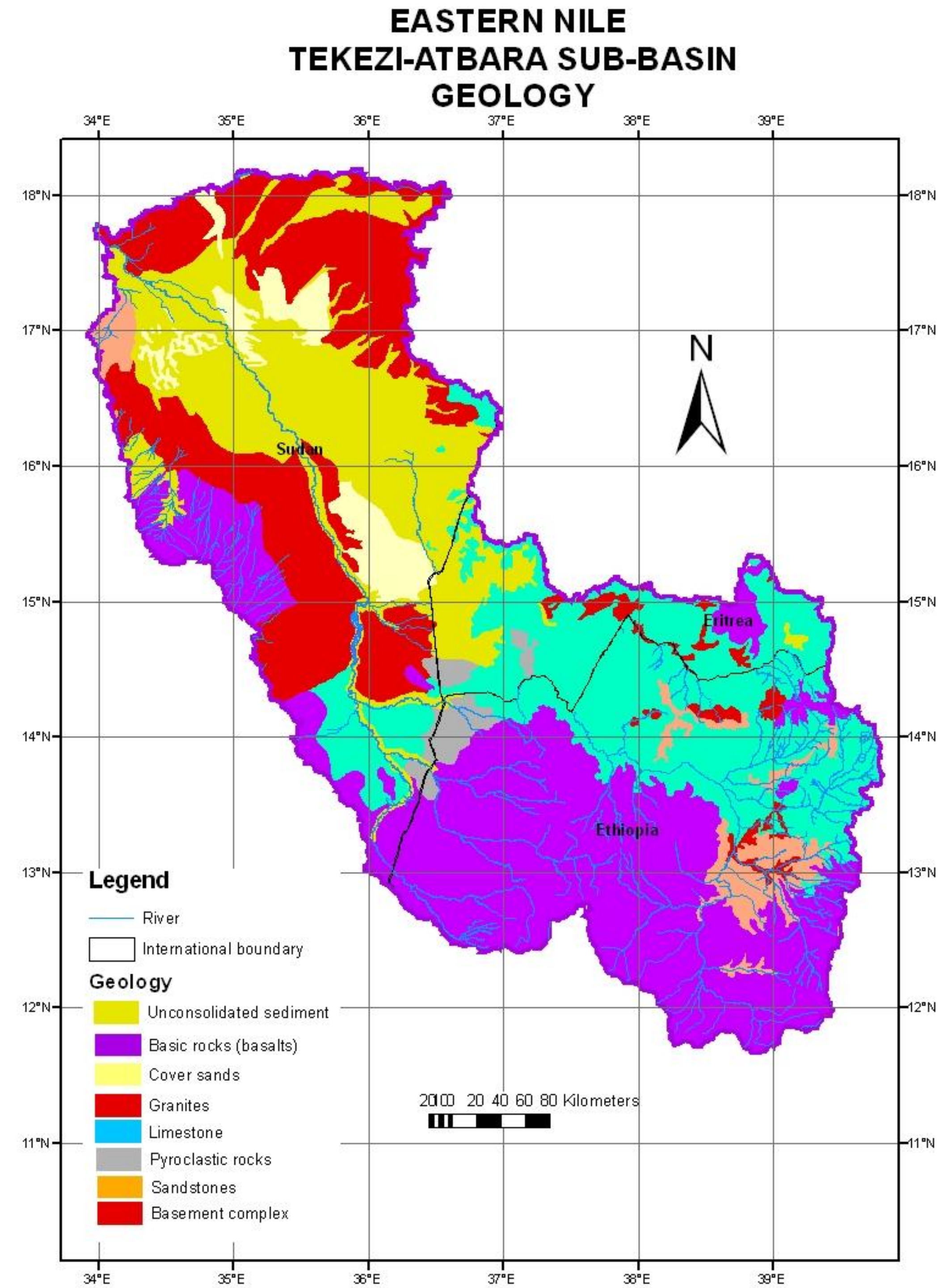


Map 5: Tekeze-Atbara sub-basin: Mean annual rainfall (mm/yr)
Source: ENTRO GIS Database



Map 6: Tekeze-Atbara Sub-basin: Mean Annual Temperature (degrees C)
Source: ENTRO GIS Database

2.1.4 Geology



Map 7. Tekeze-Atbara Sub-basin: Geology
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

The geology of Tekeze-Atbara sub-basin can be summarized as follows: the southern portion is composed of basic to ultrabasic rocks, mainly basalts, while the northern portion is composed of various layers of sedimentary rocks (including sandstones, shales and limestones), as well as metamorphic rocks, such as gneisses and marble.

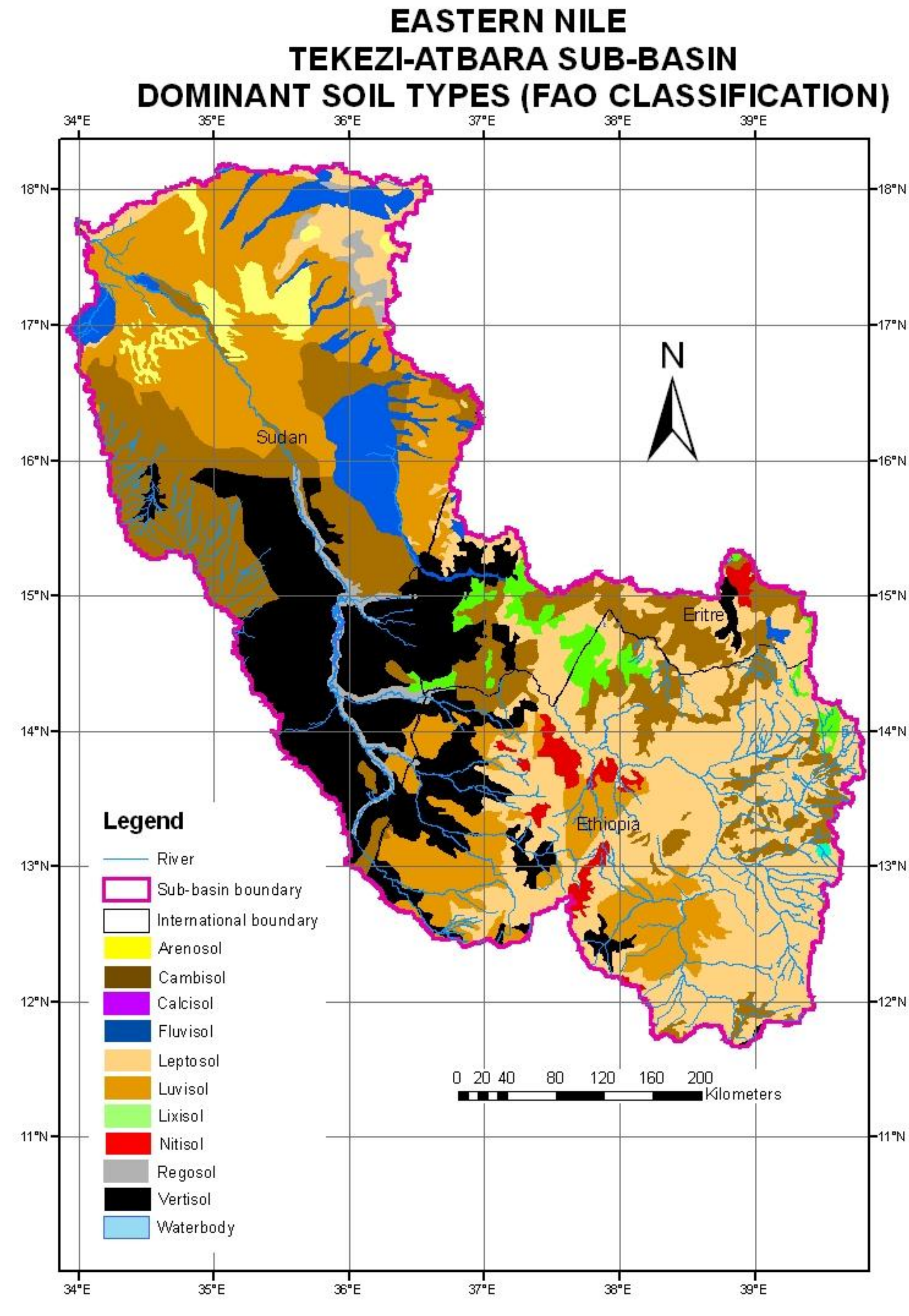
The lowlands include older Basement Complex rocks, the Nubian Sandstones, Tertiary unconsolidated sediments and Recent superficial wind blown sands. The Nubian Sandstones are located in the northwest corner and uncomformably overlie the Basement Complex rocks and comprise mainly sandstones, siltstones and conglomerates. Given the incised nature of the Tekeze drainage network in the highlands of Ethiopia, the sedimentary and metamorphic rocks are often exposed below the basalts.

2.1.5 Soils

Leptosols (28% of the area) are developed cover most of the Ethiopian highlands whilst Luvisols (26% of the area) are found on the shallower footslopes of the Highlands and the flat slopes of the lower Atbara valley towards the Main Nile. Cambisols are ranked third in terms of area (17%) and are mainly found in the middle Atbara valley with isolated pockets in the Ethiopian Highlands.
Vertisols are found on the flat interfluves between the Setit and Atbara rivers in Sudan. These are black heavy cracking clays. Fluvisols are found along the floodplains of the Atbara River. Arenosols with derived from on cover sands are found in the lower parts of the Atbara valley together with shallow Regosols.

Table 3. Tekeze-Atbara Sub-basin: Dominant Soil Types - % of Area (Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa)

Soil Type	% Area
Leptosol	27.7%
Luvisol	25.5%
Cambisol	17.4%
Vertisol	17.0%
Fluvisol	5.3%
Arenosol	2.5%
Regosol	2.2%
Nitisol	1.4%
Lixisol	0.9%
Calcisol	0.1%



Map 8. Tekeze-Atbara Sub-basin: Dominant Soil Types (FAO Classification)
Source: FAO, 1998 "Soil and Terrain Database for Northeast Africa

2.1.6 Vegetation

In Sudan the vegetation is closely related to rainfall with local edaphic variations whilst in Ethiopia temperature is also a controlling factor. Everywhere anthropogenic factors influence the vegetation types.

(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 "<u>Semi-desert Scrub</u>" is the most prevalent vegetation type, and comprises a varying mixture of grasses and herbs, generally with a variable scatter of shrubs upto 4 meters high interspersed with bare earth.

On sandy soils tree species include *Leptadenia pyrotechnica*, *A. Senegal* and *A. tortilis* subsp. *spirocarpa* and *raddiana*. On the clay plains there are a number of plant communities associated with specific habitat characteristics related to local topography and eroded, runoff and run-on sites. The most common tree species that have a wide "sociological tolerance" include (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*.

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

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

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

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

(iv) Acacia Thornland alternating with Grassland

Between the 360 mm and 570 mm isohyets on the heavy clays grassland merges into *A. mellifera* thornland. Other tree species include *A. nubica,* C*. decidua, Cadaba glandulosa, C. rotundifolia and Boscia senegalensis.* The last three species often persist after A. mellifera has been cleared. Much of this vegetation is being cleared for small-scale sedentary and large-scale semi mechanised agriculture.

Grass species include *Cymbopogan nervantus*, *Sorghum purpereo-sericeum*, *Hypparhenia ruffa*, *Tetropogan cenchriformis* and *Cenchrus cilliaris*. Sufficient grass dry matter is produced to provide material for annual burning.

(v) Acacia seyal-Balanites Savanna Woodland

Above 570 mm to the border with Ethiopia there is increasing dominance by *A. seyal* in association with *Balanites aegyptiaca*. *A. senegal* is retained for gum arabic harvesting whilst *A. seyal* is used for charcoal production. *B. aegyptiaca* becomes increasing prevalent because it is fire resistant, does not produce good charcoal and is hard to cut.

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

The grasses tend to occur in pure stands of *Hyparrhenia anthistirriodes* or *Cymbopogon nervatus* with *Sorghum spp*. in the higher rainfall areas. These grasses become largely unpalatable to livestock during the dry season. There is abundant material for annual fires.

(vi) Refugee camp

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

(vii) Terminalia-Combretum (Deciduous) Woodland

These woodlands are found in the higher rainfall areas, generally with above 700 mm mean annual rainfall. Apart from the two dominant species others include: *Boswellia papyrifera, Lannea schimperi, Anogeissus leiocarpus, and Stereospermum kunthianum.* The main land use systems are agro-pastoral and shifting cultivation.

(viii) Riverine Woodland

In the Lowlands (below 1,500 masl) pure stands of riverine woodland – “*sunt*” – are increasingly under pressure. The first trees to colonize a newly formed river bank are *Salix subserrata* and *Tamarix nilotica*. As the bank builds up xerophytic species such as *Ziziphus spina-christi* become established. On the lower terrace *A. nilotica* establishes itself, with *A. seyal* on the higher ground.

In the upper parts of the Tekeze-Atbara Sub-basin these are varied and have been little studied. They includes *Apodytes dimidiata*, *Carrisa edulis*, *Euclea racemosa*, *Ficus vasta*, *Syzygium guineense*, *Mimusops kummel*, Phoenix *reclinata*, and *Tamarindus indica*.

(ix) Montane High Forest

Highland high forest areas represent less than 2 % of the basin and are now much fragmented and located in relatively small patches on the north facing slopes of the Simien Mountains. The forest here comprises Mixed Juniper-Podocarpus Upland Evergreen Forest. The main canopy species are *J.procera* and *P. gracilor* between 20 and 30 meters high, with a well developed strata of small to medium trees, chiefly *O. europaea cuspidata*, *Allophylus abyssinicus*, *Celtis africana*, *Croton macrostachyus*, *Dombeya spp.*, *Ekebergia capensis*, *Olea hochstetteri* and *Prunus africana*.

On the east facing slopes is found a Single dominant Montane Dry Evergreen (*Juniperus procera*) Forest between 1,600 and 3,200 masl. Annual rainfall is between 500 and 1,500 mm. Mean annual temperature is between 12°C and

18°C. It comprises an open forest tending towards Juniper woodland with a canopy of 10 to 15 meters. The dominant species is *J. procera* often with *Olea europaea cuspidata* in the canopy. Species in an upper strata below the canopy include *Acokanthera schimperi*, *Bursama abyssinica*, *Calpurnia aurea*, *Dombeya torrida* and *Teclea nobilis*. In the lowest strata *Psydrax schimperii* and *Carissa edulis* occur. In some areas the number of *Juniperus* trees is very small and the canopy is then dominated by *O. europaea cuspidata*. Where disturbance has been more severe *A. abyssinica* dominates the canopy and few if any *Juniperus* or *Olea* are seen.

(x) Mountain Woodlands

These woodlands are found at higher altitudes above 2,500 masl. Common species are *A. abyssinica, Protea, Cussonia, Hagenia abyssinica, Erica arborea, and Hypericum.*

(xi) Afro-alpine Grasslands and Erica Woodland

These alpine grasslands are generally found above 3,200 masl. Mean annual temperature is generally below 11 degrees C and frost will occur most nights. No rainfall stations are found at this altitude but it is generally agreed that rainfall increases upto 3,800 masl and then starts to decrease. Palatable grasses found in this grassland type include *Eragrostis spp*., *Deschampsia flexuosa*, *Helictotrichon milanjianum*, *Molinia caerulia*, and *Poa spp*. On the higher areas of the Simien Mountains are fragmented areas of giant heather (*Erica arborea*) woodland.

2.1.7 Land Cover

Map 9 indicates the Land Cover for the Sub-basin. The data source for Sudan is the FAO Africover map and that for Ethiopia was WBISPP-MARD Land Cover Maps for Tigray and Amhara Regional States. The two land cover classifications were standardized to the FAO Land Cover Classification System (LCCS) (FAO, 2000).

Table 4 Tekeze-Atbara Sub-basin: Dominant Land Cover

Landcover Type	Area (ha)	% Total
Grassland	7,689,019	38.4%
Shrubland	4,826,757	24.1%
Bare land: Soil, Loose Sand	2,400,560	12.0%
Cultivated: Rainfed Crops: Small-scale: Sedentary	2,043,194	10.2%

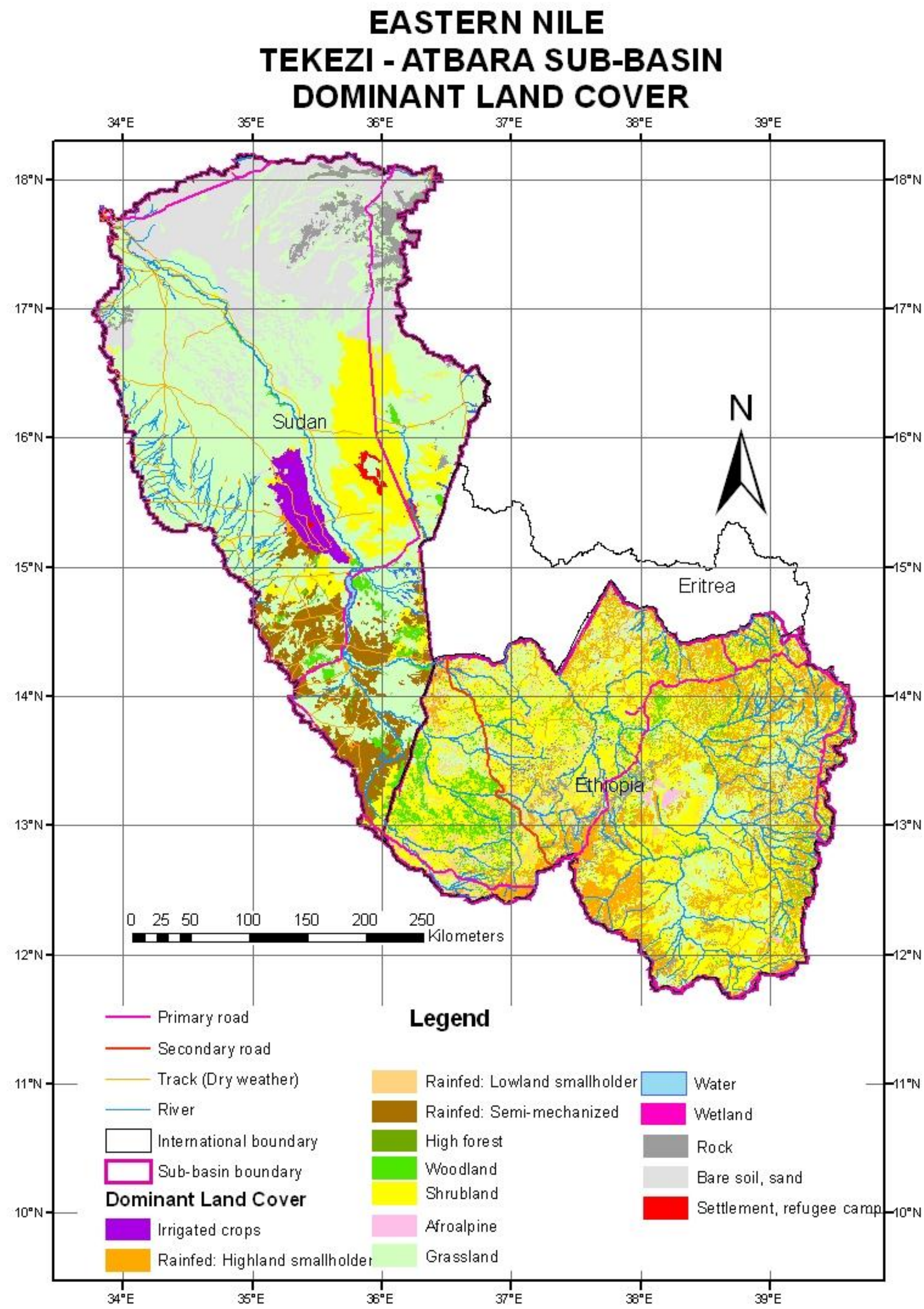
Cultivated: Rainfed Crops: Large-scale: Semi-mechanized	841,803	4.2%
Woodland	724,944	3.6%
Bare Land: Rock	634,320	3.2%
Cultivated: Rainfed Crops: Small-scale: Shifting	513,238	2.6%
Cultivated: Irrigated Crops: Large schemes: Freehold and Tenant	242,817	1.2%
Water, Reservoir	51,336	0.3%
Settlement: Refugee Camp	46,293	0.2%
Forest	11,636	0.1%
Swamp, wetland	87	0.0%

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

Bare land cover (rock and loose sand are found in the northern desert areas. Here drifting sand is a severe problem on cultivated land in the Lower Atbara. Occasional years of very good rainfall can transform areas of desert into valuable grazing areas known as "*gizzu"*. Elsewhere grassland and shrubland cover some 62 percent of the Sub-basin area. Grasses are mainly annuals in Sudan. 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. In Ethiopia perennial grasses predominate. In many areas high livestock densities have severely reduced the ground cover of these grasslands and shrublands.

The area of forest cover is very small and is confined to the extremely steep slopes of the Simien Mountains and along the rivers. The large Refugee camp has now largely been abandoned with the settlers returning to Ethiopia and Eritrea,

Sedentary rainfed small-scale cultivated land covering 10 percent of the area is located mainly in the Ethiopian Highlands, whilst shifting rainfed small-scale cultivation is located in the Ethiopian and Sudan Lowlands. Irrigated land comprising mainly the New Halfa and Gash Irrigation Schemes cover nearly 243,000 ha, whilst the large-scale semi-mechanized rainfed cultivated land 513,240 ha.



Map 9. Tekeze-Atbara Sub-basin: Dominant Land Cover
Source: FAO Africover Sudan (2002) & WBISPP-MARD (2001 -2003)

2.1.8 Hydrology

(i) Surface Water

The Atbara River contributes about 12.7% of the total discharge of the Main Nile and follows much the same seasonal pattern as the Blue Nile except that its discharge reduces to very low flows and sometimes to zero flow for almost four months of the year. The average discharge at Kashm el Girba station (1986-2000) was 11.45 km^3; that for the Kubur Station (1981-1999) on the Upper Atbara (i.e. above the Setit-Tekeze and Upper Atbara confluence) 7.42 km^3; and that for the Tekeze at Humera (1981-1984) 5.01 km3. There is a distinct difference in the amount of runoff between the Upper Atbara and the Tekeze. This is shown in Table 5, which indicates the area of catchment, total discharge and the runoff per km2.

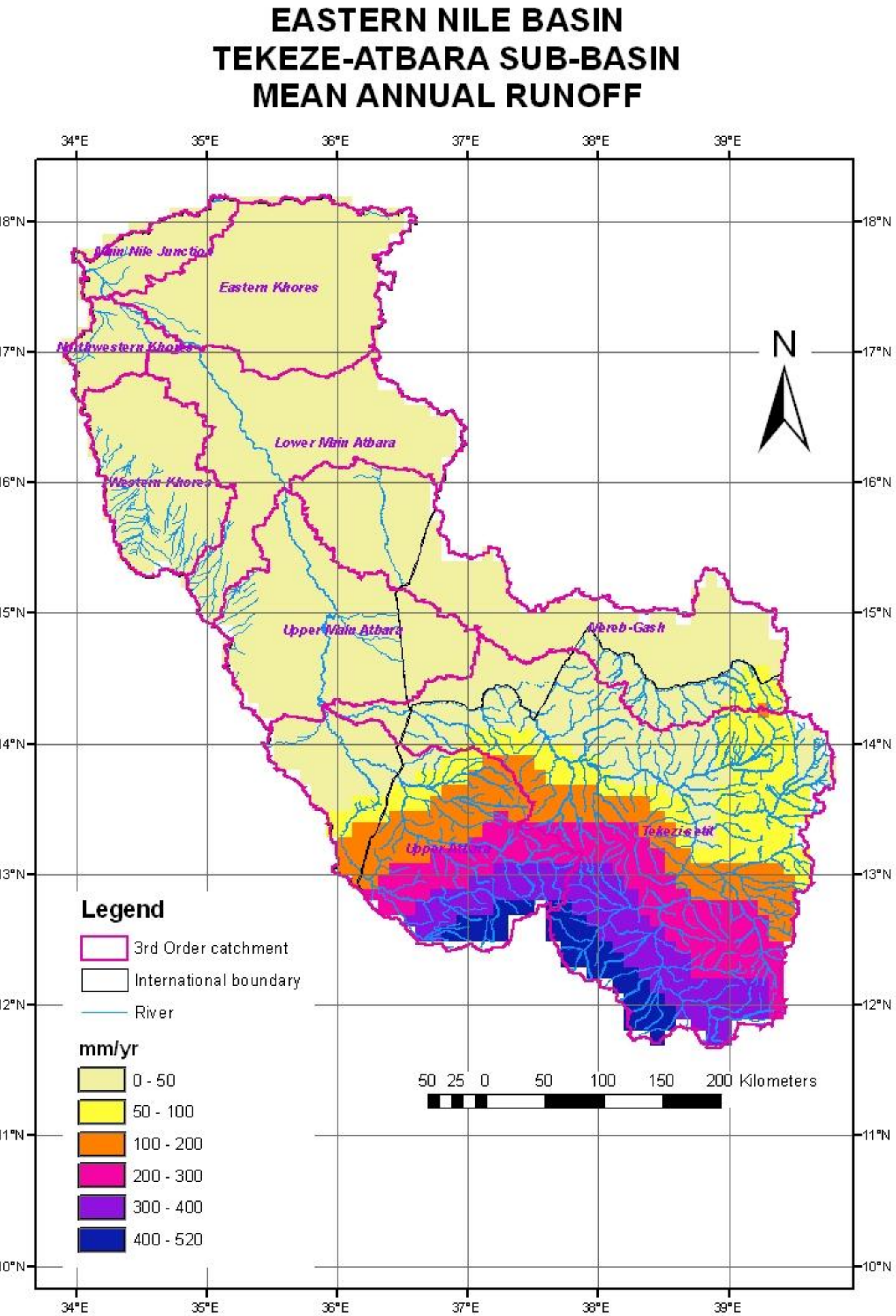
Table 5. Tekeze-Atbara Sub-basin: Area (km2), Discharge ('000 Mm^3) and Runoff/km2 for the Tekeze and Upper Atbara Catchments (using 1981 – 1984 data)

Catchment	Area (km2)	Discharge ('000 Mm^3)	Runoff Mm3/km2
Upper Atbara (Ethiopia)	21,933	3,442.7	**0.157**
Tekeze (Ethiopia)	63,967	5,009.0	**0.078**

Source: UNESCO-FRIEND Project (2002)

This clearly indicates a higher run-off per unit area in the Upper Atbara catchment compared with the Tekeze Catchment. The total runoff is 52,834 m^3 of water per km^2 per annum, compared with 169,612 m^3/km^2/yr for the Blue Nile, 28 833 m^3/km^2/yr for Baro-Akobo-Sobat. Most of the Tekeze-Atbara water comes from Ethiopia, even though 50 % of the sub-basin is located in Sudan. This high proportion of water coming from the highlands is related to the rainfall pattern, as it can be observed in Map 10.

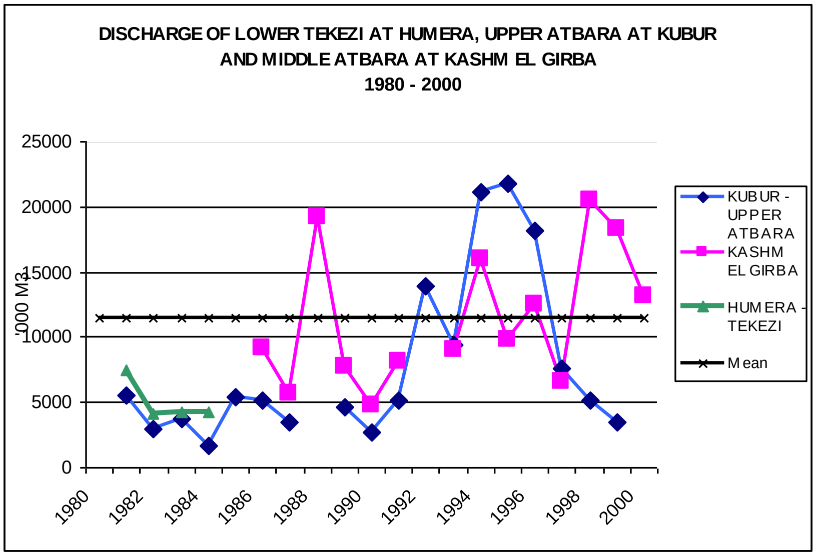
There is considerable year-on-year variation about the mean as can be seen in figure 2, which shows annual discharges. The highest discharge of 20,468 Mm3 occurred in 1997 and the lowest of 4,778 Mm3 in 1990. The station for Kashm el Girba is located below the dam and discharge may be affected by the water release regime of the dam. Thus in 1993 to 1995 discharges on the Upper Atbara appear to be higher than the main Atbara (i.e. Atbara + Tekeze).



Map 10. **Tekeze-Atbara Sub-basin: Mean Annual Runoff.**
Source: USGS/gtopo30/HYDRO30.

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

Figure 2. Annual discharge of the Middle Atbara (Kashm el Girba), Upper Atbara (Kubur), and the Tease (Humera) – 1980 -2000.



Source: Abdelsalem Ahmed (2006) and Ethiopian MWRI.

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

(ii) Groundwater

Given the extreme dissection of the terrain in the Highlands, groundwater resources are shallow and confined to fractured basement complex rocks, sandstones and basalts. Groundwater depth varies directly in accordance with landscape units, rainfall regions, seasons and geological basement. In general, the groundwater water table is located between 2 and 6 meters in valley bottoms, along main streams. This depth rapidly increases as landscape becomes mountainous or in the northern region, when rainfall conditions are more arid. The most common depth in the north eastern part of the basins is about 12 meters, while water depths in the plateau plains from Adwa to Endaslasie to Gondar are at about 4 meters.

Water yields in these basins range from 0.1 to 10 l/s, with mean values of about 2.6 l/s. The absence of uniform permeable sediments extending over large areas implies that extensive good aquifers do not exist in the basins of the Tekeze, Angereb and Goang rivers. Instead, exploitable groundwater occurrence is limited to isolated areas where groundwater potential may be the result of faulted and fractured zones in the rocks and weathered rocks. About 70 % of the total area of the basins is covered by non-porous volcanic and Precambrian rocks.

The remaining part consists of Mesozoic limestones, shales and sandstones of Antalo group and Jurassic Adigrat sandstone. Only some minor Quaternary alluvium exists in the western lowlands. Except for the Quaternary alluvium and tuff deposits, the storage and transport of the groundwater in all these rocks is limited and restricted to the faults, fracture joints and fissures. This means that water is transported not through primary porosity (as this is already filled up with cement of silica, calcium or other minerals), but through tectonic and karst features, broken dykes and dolerites.

In the Lowlands a quantitative assessment of groundwater in the Showak area (Ibrahim & Giddo, 1992) gives a storage capacity of the upper Nubian aquifer as 840 million m^3 and the safe yield is estimated at 8.4 million m^3. In the second major aquifer located in the Neogene-Recent Deposits ("Unconsolidated Sediments" in Map 4) 1km away from the banks of the Setit and Atbara Rivers the storage capacity is estimated at 222 million m^3 and the safe yield of 11.2 million m3.

2.2 Socio-economic Characteristics

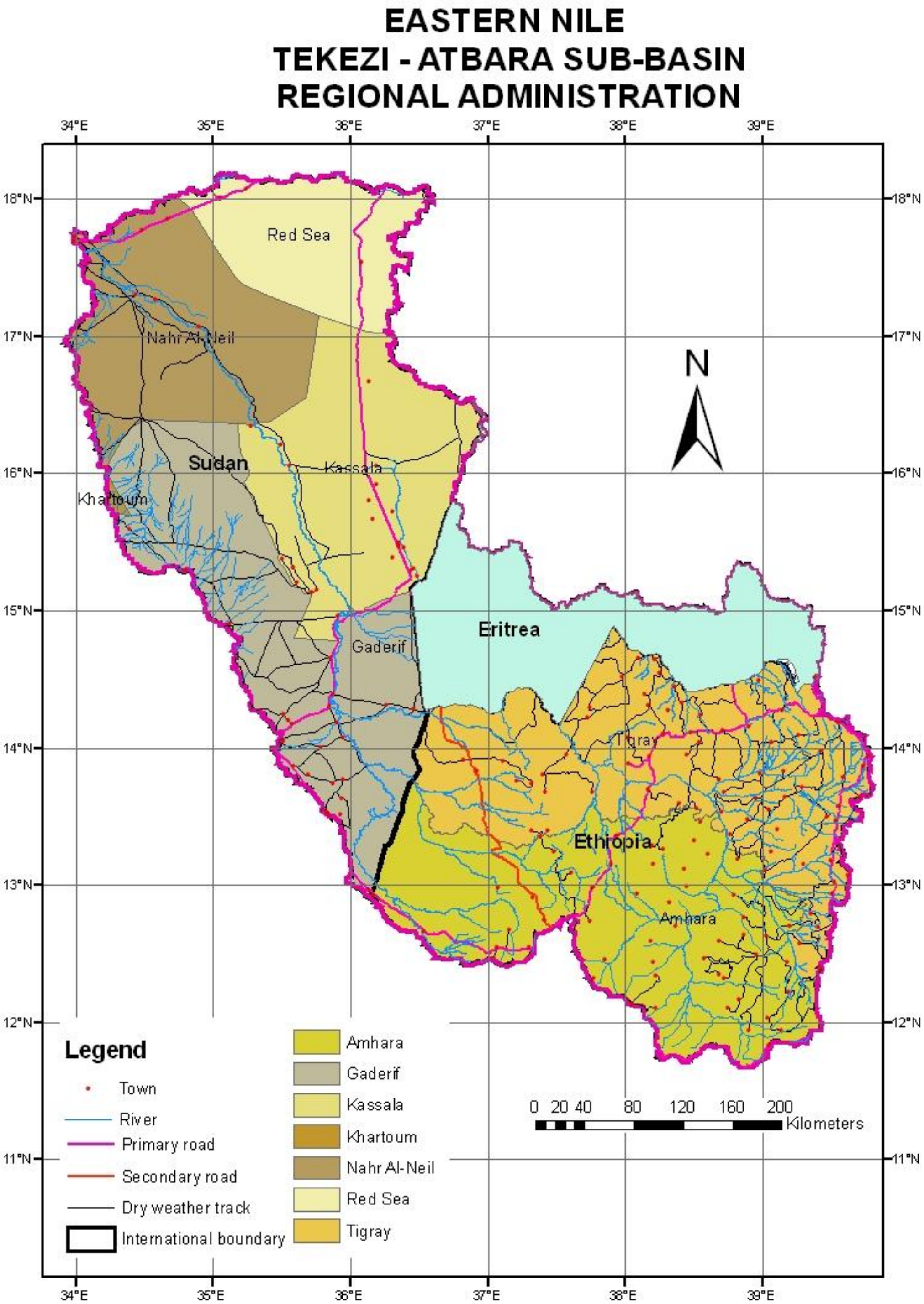
2.2.1 Administration

In the Sudan the Sub-basin encompasses 5 States whilst in Ethiopia it encompasses two Regional States (the equivalent level of administration). These are shown with their respective areas in table 6.

Table 6. Tekeze-Atbara Sub-basin: Administrative States/Regional States and their areas (km2)

State/Regional State	Area (km2)	% of Sub-basin
SUDAN		
Khartoum	341	**0.2%**
Nile	30,751	**14.0%**
Gadaref	45,269	**20.6%**
Red Sea	19,055	**8.7%**
Kassala	35,854	**16.3%**
Sub-basin	**131,270**	
ETHIOPIA		
Tigray	45,033	**20.5%**
Amhara	43,267	**19.7%**
Sub-basin	**88,300**	

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



Map 11. Tekeze-Atbara Sub-basin: Administrative States/Regional States

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

2.2.2 Population

(i) Population Numbers and Distribution

The LandScan 2002 Global Population Database developed by Oak Ridge National Laboratory (ORNL) of the United States provides 2002 population estimates on a 1km grid. This was clipped by the State and Regional State boundaries within the Sub-basin to provide population estimates within the Sub-basin by State/Regional state Map 12). National census estimates of the rural-urban distribution were used to provide estimates of total rural and urban populations. These are shown in table 7.

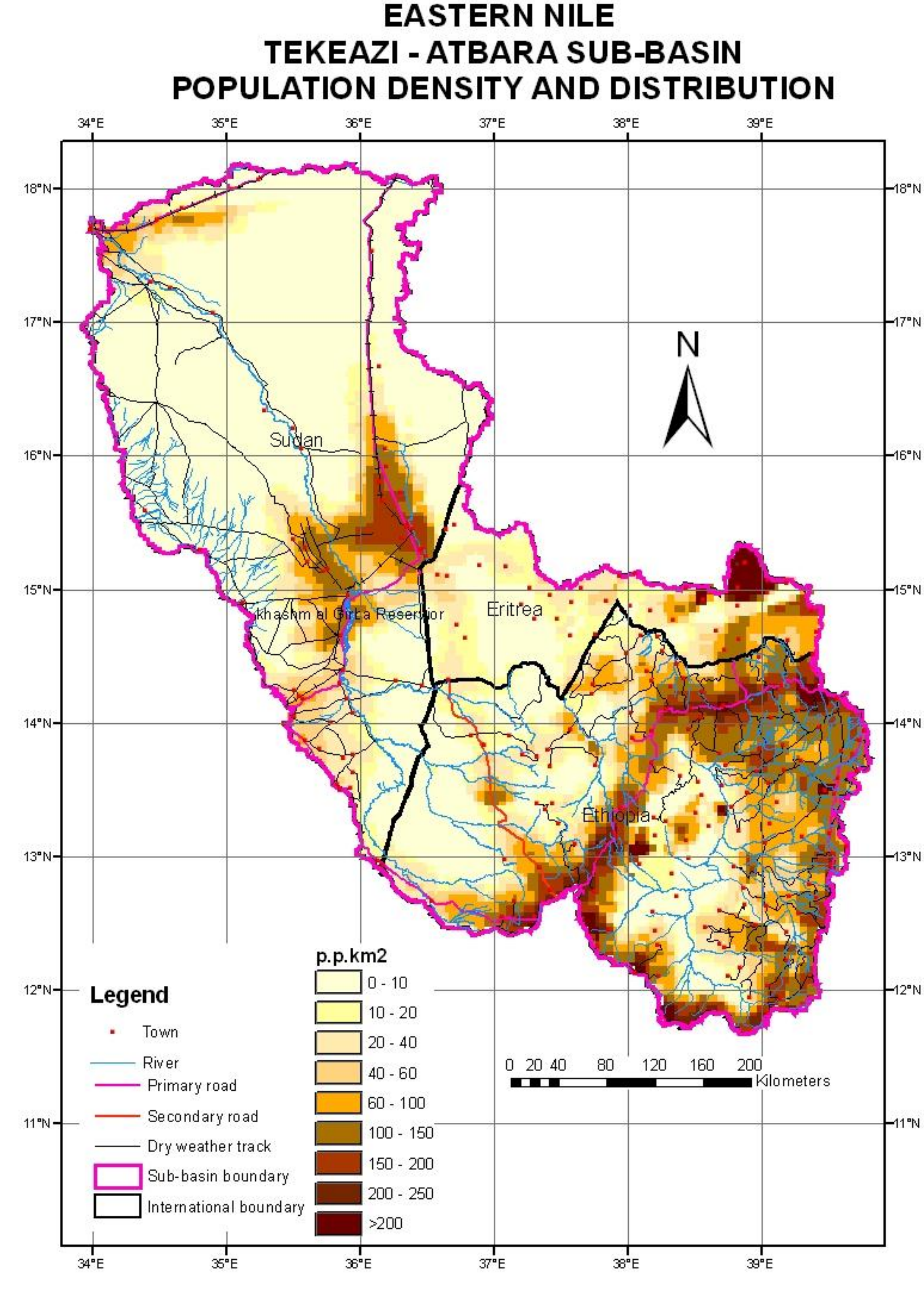
Table 7. Tekeze-Atbara Sub-basin: Total, Rural and Urban population estimates by State/Regional State for 2002.

State/Regional State	Total pop.	Rural pop.	Urban pop.	Rural %	% of Sub-basin total	Pop density ppkm2
Gaderef	665,368	473,077	136,719	71%	8%	18.1
Kassala	1,208,216	790,173	273,400	65%	14%	41.6
Nahr Al-Neil	222,968	147,828	49,818	66%	3%	8.8
Red Sea	50,729	33,177	11,479	65%	1%	3.3
Amhara	2,850,528	2,689,437	151,987	94%	34%	65.2
Tigray	3,475,111	2,885,582	489,519	83%	41%	76.8
TOTAL	**8,472,920**	**7,019,274**	**1,112,923**			**7.6**

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

Total population of the Sub-basin is 8.47 million. Some 75% of the Sub-basin's population lives in Ethiopia. In Sudan, Kassala followed by Gederef State have the highest population totals. Overall 83 percent of the Sub-basin's population is rural. The highest urban proportion is found in Kassala State closely followed by Nahr Al-Neil State. Population densities vary from 3.3 persons/km^2 in Red Sea State to 76.8 persons/km^2 in Tigray Regional State.

The spatial distribution of population within the Sub-basin is shown in Map 12. In Sudan there are three main concentrations of population: around Shuwak to the New Halfa irrigation scheme, across the river in and around Kassala town and along the road/rail route out of Atbara town. Elsewhere population densities are extremely low, most particularly in the north. In Ethiopia the population is mainly concentrated on the highland plateaus that surround the main Tekeze River. Within the inner Tekeze valley population densities are very low.



Map 12. Tekeze-Atbara Sub-basin: Population densities and distribution.

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 8.

Table 8. Tekeze-Atbara Sub-basin: States/Regional States - Demographic Characteristics

State	Rural Gth rate %	Urban %	% <15yrs	% >60yrs	Sex ratio M/F	Crude birth rate	Crude death rate	Infant mort. male**	**Infant mort. female****
SUDAN									
Kassala	2.50	34.6	41.8	4.2	98.2	37.8	10.5	107	**96**
Gederef	3.40	28.9	43.1	3.7	105.3	40.3	11.7	135	**122**
Nahr Al-Neil	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**
ETHIOPIA									
Amhara	2.81	5.7	43.3	6.0	99.9	36.6	10.9	83***	
Tigray	**4.62**	**17.0**	**44.2**	**6.3**	**97.1**	**37.5**	**11.8**	**90*****	

Source: Ethiopia: CSA, 1999. Sudan: UN Population Fund & Sudan Central Bureau of Statistics. (2002).
*Rural rate
** per 1000 live births
*** Male+female

The high population growth rates in Gaderef State and Tigray Regional State may be due to in-migration (Gederef) or returning refugees (Tigray). Red Sea State's growth rate is abnormally low. There is a distinct difference in urbanization rates between Ethiopia and Sudan. The high urbanization rate and male-female ratio for Red Sea State is due to the dis-proportionate influence of Port Sudan, which is outside the Nile Basin.

(iii) Literacy and Education

The literacy and primary school enrolment rates for the States/Regional States in the Sub-basin are shown in table 9.

Table 9. Tekeze-Atbara 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						
Kassala	44.7	52.9	35.8	274,713	103,131	37.5
Gederef	55.6	72.9	38.4	311,547	142,313	45.7
Nahr Al-Neil	65.2	75.0	56.6	186,851	147,477	78.9
Red Sea	47.9	54.5	40.1	154,210	69,290	44.9
ETHIOPIA						
Amhara	17.8	23.5	12.1	16,528,724	10,542,015	64.0
Tigray	20.5	27.8	13.6	5,749,924	3,378,386	59.0
SUB-BASIN				**23,205,969**	**14,382,612**	**62.0**

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

There are significant differences in literacy and primary School enrolment rates between Nile State and the others, with the former considerably above the Sub-basin average. In all States/Regional States female literacy rates are below those for males.

(iv) Water and Sanitation

The percent population with access to drinking water and sanitation facilities are shown in table 10.

Table 10. Tekeze-Atbara Sub-basin: States/Regional States – (a) Percent Population Access to Drinking Water, (b) Sanitation Facilities

(a) Drinking Water by Source

State	Main source of water							
	Piped into dwelling	Public tap	Deep Well/pump	Dug Well/ bucket	River/canal	Rainwater	Others	Missing
SUDAN								
Kassala	22.6	16	21	6.4	23.1	1.5	8.7	0.8
Gederef	12.6	18.8	27.7	13.9	13.8	9.4	3.6	0.2
Nahr Al-Neil	42.3	3.7	12.2	13.5	24.7	--	3.4	0.2
Red Sea	25.6	18.3	28.3	25.8	1.5	--	0.5	--
ETHIOPIA	**Tap**		**Protected wee/spring**	**Un-protected well/spring**	**River/lake/pond**			**Not stated**
Amhara	9.1		12.3	41.9	36.3			0.3
Tigray	13.8		7.4	36.3	41.9			0.5

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

Table 10 (b) Sanitation facilities by type

State	Flush to Sewage System	Flush to septic tank	Traditional pit latrine	Soak away pit	Others	Missing	No facilities
SUDAN							
Kassala	--	11.6	34.3	1.2	0.3	0.5	52.0
Gederef	--	5	31.7	3.1	0	0	60.1
Nahr Al-Neil	--	12.3	72.6	0.7	0.7	0.1	13.5
Red Sea	--	20.9	26.1	4.2	0.7	0.2	47.9
ETHIOPIA	**Flush - private**	**Flush - Shared**	**Pit - private**	**Pit - shared**		**Not stated**	**No facilities**
Amhara	1.6	1.2	18.2	16.4		1.2	61.4
Tigray	2.4	2.6	9.8	13.8		1.4	60.0

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

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

Abdalla A.A. Ahmed at al (2005) report that the WHO standard of 20 litres a day per person is rarely met in the Sub-basin because of water shortage or the cost of provision.

2.2.3 Livelihood Characteristics: Socio-cultural Aspects of the Population

(i) Poverty

The JAM (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. The poverty line in Ethiopia is set using a basket of food items sufficient to provide 2,200 kcals per adult per day. Together with a non-food component this represents Ebirr 1,070 in 1995/96 prices. Clearly, the two measures are not directly comparable.

In Sudan the JAM Report estimates the following poverty rates for the States within the basin:

Kassala	41 – 60%
Gaderef	41 – 60%
Nahr el-Neil	21 – 40%
Red Sea	61 – 70%

It is interesting that that the relative rating of these figures follow that of the provision of social facilities such as education and water. Thus Red Sea State has the highest rates of poverty and lowest rates of facility provision; Nahr el-Neil State has the lowest poverty rates and highest rates of facility provision; and Gaderef and Kassala States in–between.

The poverty rates for the two regional States in Ethiopia quoted by the Sustainable Development and Poverty Reduction Programme (FDRE-MOFED, 2002), are as follows:

	Rural	**Urban**	**Total**
Amhara	32%	35%	32%
Tigray	52%	65%	54%

In both Regional States rural rates have declined between 1995 and 2000, whilst urban rates had increased.

The published poverty rates in Ethiopia are lower than those in the Sudan. This has been noted in the Sudan Joint Assessment Mission (JAM) Report. It appears that the difference is likely to be more a question of difference in methodologies and definitions, than actual differences in poverty rates.

(ii) Socio-cultural Aspects of the Population

Within the Sub-basin the political boundary between Sudan and Ethiopia is mirrored by socio-cultural and physical boundaries. In the Sudan north of the Atbara River the major ethnic groups are the Hadandowa and Bani Amir accounting for 26 percent and 15 percent of the population respectively. Beja speakers constitute 43.9 percent of the population of the State and the next important language is Arabic with 30.6 percent of the population.

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

In Ethiopia in both Regional States located within the sub-basin one ethnic group tends to be predominant. In Tigray there are 8 ethnic groups represented in the Region. However, the majority group is Tigray comprising 95 percent of the rural population. There are over 55 ethnic groups represented in the Amhara Region. However, the main groups are Amhara with 91 percent and Agew with 4% of the rural population

The main highland groups of Tigray, Amhara and Agew are mainly sedentary agriculturalists who practice mixed crop and livestock farming. Rainfed crop production is based on cereals – sorghum, maize, teff, wheat and barley with increasing altitude. Cultivation is by a tine-based plough (maresha) of considerable antiquity. Farm sizes are small, generally less than 2.0 ha. Although irrigated cropping is widespread across the two Basins it is confined to small schemes from small to medium-sized dams. Crops are generally higher value vegetables or early maize. Livestock holdings are small with oxen used for draught power.

2.3 Agriculture

2.3.1 Main Agricultural land Use Systems

The main agricultural land use systems in the Tekeze-Atbara Sub-basin in Sudan and Ethiopia are relatively distinct except along the international border where the ago-environment in one case and cultural affinities in another have given rise to very similar systems. Nevertheless, three broad systems can be identified: (i) rainfed cropping, (ii) irrigated cropping and (iii) extensive livestock production (with minor cropping). Differences in the scale of operations, tenure type and to a lesser extent cropping patterns give rise to a number of recognizable sub-categories. These are summarized in table 11.

Table 11. Main Agricultural Systems in the Tekeze-Atbara Sub-basin

Main Category	Scale of operations	Tenure type	Main Components	Location
RAINFED CROPPING	Small-scale traditional; sedentary	State land: Individual and Communal use rights	Cropping (Cereals, pulses, oil seeds) Small Livestock holdings (Communal grazing, crop residues)	Ethiopia: Highlands
	Small-scale traditional; shifting – bush fallowing	State land: Individual and Communal use rights	Cropping (cereals, pulses): Small livestock holdings (Communal grazing, crop residues)	Ethiopia & Sudan: Lowlands
	Small-scale traditional: Run-off cropping/water harvesting	State land: Individual and Communal Use Rights	Sorghum, Millet (Oennisetum typhoides), okra, karkadeh, water melonlubia, seseme.	Sudan: Kassala, eastern "Border" area.
	Large-scale: Semi-mechanized	State land: Medium-term Leases	Cropping (Sorghum, cotton, sesame)	Ethiopia & Sudan: Lowlands
IRRIGATED CROPPING	Small schemes Small-scale operations (< 1.0ha) Gravity:	State Land: Individual use rights: additional to rainfed land	Cropping (cereals, vegetables)	Ethiopian Highlands
	Small-Moderate Schemes: Small-scale operations:	State Land: Individual use rights: Individual leases and some sub-leases	Geroof recession cropping+ supplementary gravity irrigation: Groundwater from matara: Date Palm	Lower Atbara, Sudan
	Large scheme: small-scale operations (<40 feddans) Gravity	State land: Individual long-term leases. Some freehold	Cropping: Cotton, Sorghum, wheat Small-livestock holdings	Sudan: New Halfa and Gash Schemes
	Large scheme: large-scale operations	State land	Cropping: Sugar	Sudan: New Halfa Sugar Scheme
LIVESTOCK	Small-scale: Extensive Pastoral Transhumant	State land: Communal use (grazing, water) rights	Cattle, small-ruminants	Sudan
	Small-scale: Extensive Agro-pastoral Transhumant-sedentary	State land: Communal use (grazing, water) rights	Cattle, small-ruminants Small-scale cropping	Sudan

Rainfed cropping operates at the traditional small-scale and the large and semi-mechanized scale (Map 13).

Traditional small-scale cropping is on State Land in both Sudan and Ethiopia. However, households have individual use rights for cropping and communal use rights for grazing and fuelwood collection. Mixed cropping and livestock production are the main production components. In the Highlands cropping is sedentary whilst in the lowlands it incorporates bush fallowing and shifting cultivation. In both the highland and lowland systems use of improved inputs (chemical fertilizer and seeds) is low.

In Ethiopia household cropland area is generally less than two hectares and often located on two or more plots of differing land-soil types. Cultivation is undertaken with oxen using the tine plough (*maresha*). The main crops are teff. sorghum and maize at lower altitudes with wheat and barley taking their place at higher altitudes. Livestock are an important component of the farming system. After millennia of cropping soils are at a very low level of fertility.

In Sudan close to the Atbara and scattered elsewhere are areas of smallholder rainfed cultivation. These are generally less than 10 feddans (4.0 ha) in size. Cultivation is often undertaken using hired tractors. They cover approximately 0.079 million feddans (33,180 ha) within the Atbara Sub-basin. Many are Lahawin pastoralists who lost the livestock in the droughts of the 1980's or felt that they had better claim land before other groups (e.g. the Falleta) did so (Morton, 1988). Bush fallowing is practiced to restore soil fertility and reduce weed infestation (particularly *striga*).

On the plains east and west of the Gash Delta in the "Border Area" and extending southwards onto the Butana Plains agro-pastoralists, sedentarized former pastoralists (mainly Beja but increasingly Rashyda peoples) and recent immigrants from West Africa use a number of run-off farming techniques (van Dijk & Mohamed, 1993, Critchley et al., 1988). The plains are cut by some 30 large *khors* and many small *khors* draining to the Gash River. Land preparation is generally manual with some use of tractors near Kassala. The main crop is sorghum, with millet, karkadeh, lubia and sesame with okra and watermelon as cash crops. Two techniques are recognised: traditional water harvesting and wild flooding. The former include run-off manipulation by U-shaped earth bunds or *teras* and brushwood panels or *libish*. Catchment:cultivated area ratios are generally above 2:1. In wild flooding no water is harvested, instead after the flood the land is planted directly.

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

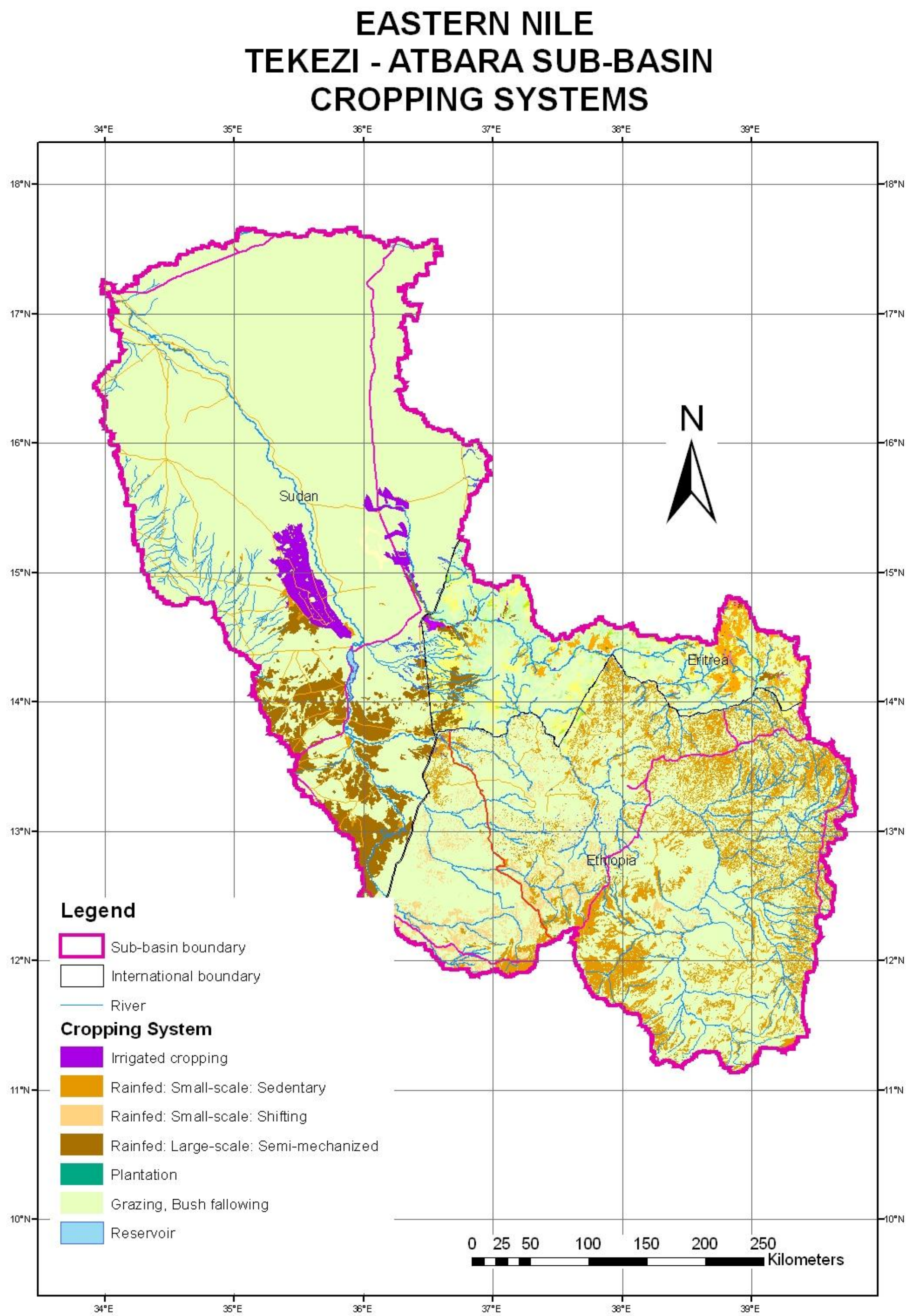
There are a number of sub-categories of irrigated cropping. A convenient division can be made firstly between large and small schemes[2]. In Ethiopia there are no

[2] The difference between the two is necessarily arbitrary but 5,000 ha is a convenient division.

large schemes but in Sudan there are two. The small schemes include both traditional and modern small schemes in Ethiopia. The large schemes are divided those with large and those with small-scale operations (not possible to separate out in Map 13 because of the small areas of the latter). The large scheme with large scale operations is in Sudan and is under sugar cane production (located in the New Halfa Scheme.

The two major schemes in Sudan in the sub-category are the New Halfa Irrigation Scheme and the Gash Flood Irrigation Scheme. The New Halfa Scheme is located below the Kashm el Girba dam totalling some 447,000 feddans (190,000 ha). The scheme was set up partly to resettle 7,000 Halfawi families who had been displaced by the rising waters of Lake Nasser/Nubia. In addition there were 20,000 local families. In 1970/71 the area under crops was 330,000 feddans but by 1982 had reduced to 145,000 feddans due to problems of siltation and loss of irrigation storage in the Kashm el Girba dam. Many families in the scheme retain a stake in pastoralism beyond the scheme and have mixed herds of cattle, small stock and camels (Babiker Abbas, 1997). During the dry season the animals feed of crop residues from the irrigation scheme and in the wet season the animals are moved to the Butana Plains.

Around Kassala in the Gash Delta is a large but variable area of flash flood irrigation. The floods average 88 days (Kirkby, 2001). Water is diverted into canals and so to large level areas known as "misgas". On the northern end of the Eastern Gash a different tyre of irrigation is found using pumped well water, mainly for vegetables and fruit trees. Originally small in number, they have increased substantially, and now use motorised pumps. Originally the scheme produced cotton, but now sorghum dominates with castor, sunflower and ground nuts. Vegetables are an increasingly important crop on the four large commercial farms in the northern delta. Many of the Hadendowa and Rashaida are still camel pastoralists or agro-pastoralist and in the wet season graze their animals north and west of the Gash delta. There is a similar area of flood irrigation to the northeast in the Tokar Delta, but this scheme does not have the canals of the Gash Delta.



Map 13. Tekeze-Atbara Sub-basin: Cropping Systems
Source: FAO Africover Sudan (2002) & WBISPP-MARD (2001 -2003)

The small irrigated gravity schemes in the Ethiopian Highlands comprise both traditional and modern schemes. Traditional irrigation has a long antiquity in Ethiopia and generally uses local materials (wood and stone), whilst the modern schemes generally use cement and brick for the main structures. Farmers have use rights to cropping in the same way as their rainfed land. Plots are small (< 1.0 ha). The main crops are cereals and vegetables.

Along the Lower Atbara *geroof* recession cropping is practiced on about 120,000 feddans (50,400 ha) on both sides of the river. Cultivators are both private investors and local communities. However, smaller releases from the Kashm el Girba dam have had a serious impact on water levels. Farmers were previously able to obtain two crops but can now only manage one crop. The MIWR are constructing canals to supplement water supply during low flows. Locally irrigation from groundwater from *matara* wells for date palm.

Above the dam are extensive areas of semi-mechanized rainfed farms that stretch over into the Blue Nile Sub-basin. The area within the Atbara Sub-basin is 2.00 million feddans (840,000 ha). However, a proportion of this has been abandoned. The main crops grown are sorghum and sesame. An ILO/UNHCR Study (1984) estimated that 70 percent was outside demarcated schemes. The lease-holders are predominantly merchants from Gederif, Khartoum and the north, but also include some wealthy pastoralists, particularly from the Shukriya and Dubania tribes.

In the rainfed small-scale systems and on the large irrigation schemes livestock are an important component and livelihood strategy despite the small number per household. They provide additional sources of income and thus help to spread the risks associated with rainfed cropping. In the highlands they are a valuable source of soil nutrients and in fuelwood scare areas of fuel. In Sudan dung is not used as farmers believe they are a source of weeds (Kibreab, 1996).

The extensive livestock production systems are distinguished (i) by the inclusion or not of some rainfed or residual moisture crop production, and (ii) the preponderance of cattle or of camels. The reliance on crop production may in fact change in both the short and long-term due to the high variability of rainfall. Over the past two decades many households have and are still making the transition from pastoralism to agro-pastoralism to sedentarized crop cultivation and vice versa as household and external conditions change. These changes in household production systems are the result of the massive losses in household and community livestock assets during the drought of the early 1980's exacerbated by the increasingly loss of wet season grazing areas and water resources from the big expansion of large-scale semi-mechanized farms during the 1980’s and 90’s. With the restoration of exports to Middle East livestock production makes a significant contribution to the agricultural GDP.

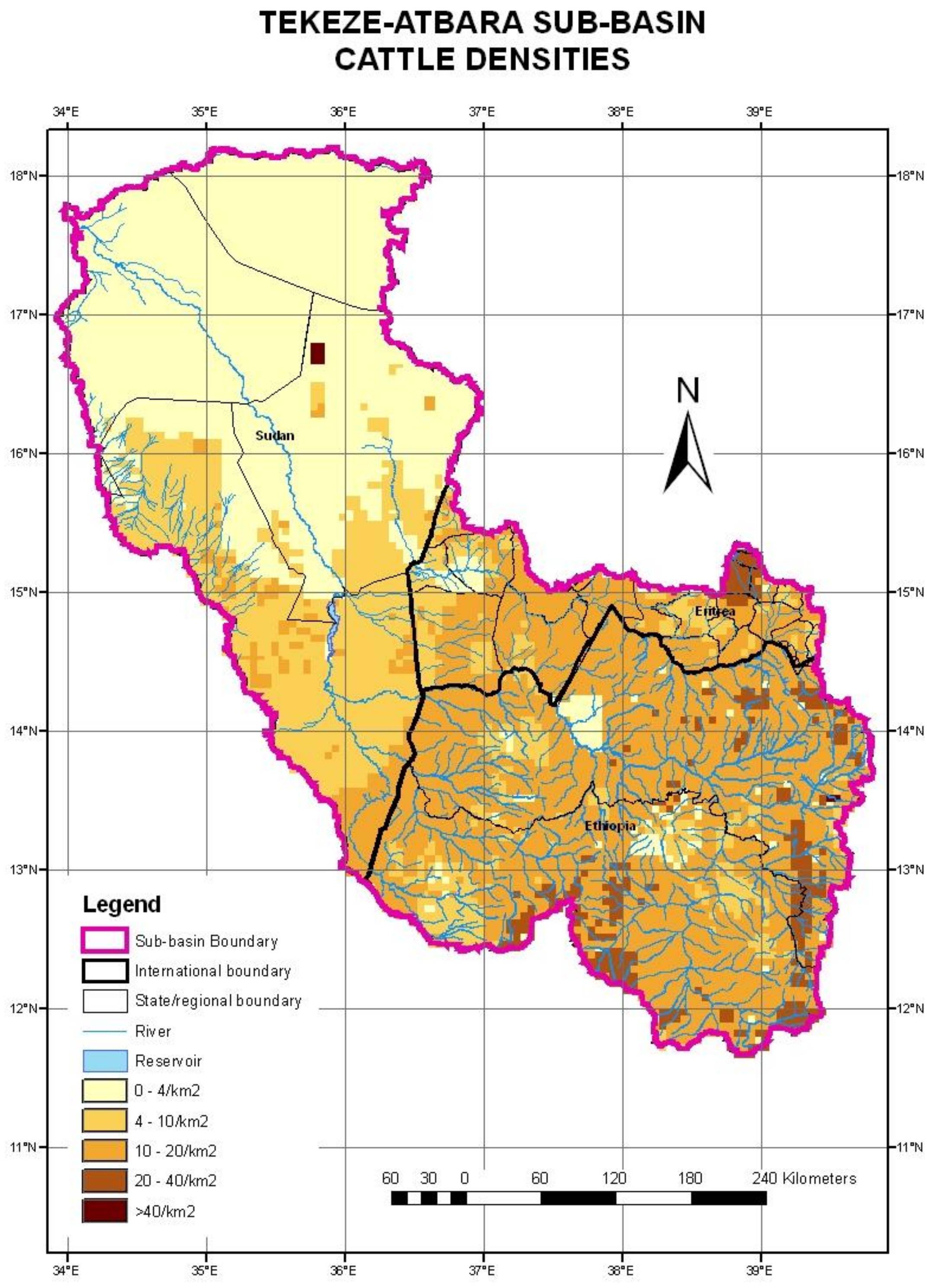
The mainly camel extensive livestock systems are mainly located in the arid and semi-raid northern parts of the Sub-basin although they move their herds southwards as far as the Butana Plains. Babiker Abbas (1995) in a survey of camel herding and ecology identified 4 main types of camel herding strategies based on herd size, feeding strategy, owner's occupation, camel uses and marketing. The first type comprised those herds belong to a single owner, keeping a small number of camels (mean 12 animals) depending mainly on trees and bushes in the riverine areas of the gash, Atbara and Main Nile. Herds are mainly males and are kept for transportation.

The second type comprises large herds (mean 80 camels) belonging to a group of traders or cultivators (mainly Bawadra and Rashaida peoples) who hire one or more keepers. These herd the animals widely across North-eastern Sudan and come to the eastern Butana during the rainy season. A third type are the herds belong to a single owner who is a true transhumant pastoralist graze only on natural browse and pasture. Herd sizes are variable (20 to 2100 with a mean of 62 camels). The herds use the Butana Plains in the wet season returning in the dry season to their homelands along the Atbara River (Kawahla, Shukryia, Lahawine, Arakakiyeen and Masalamyia) or along the Gash River or to Red Sea Hills (Rashaida)

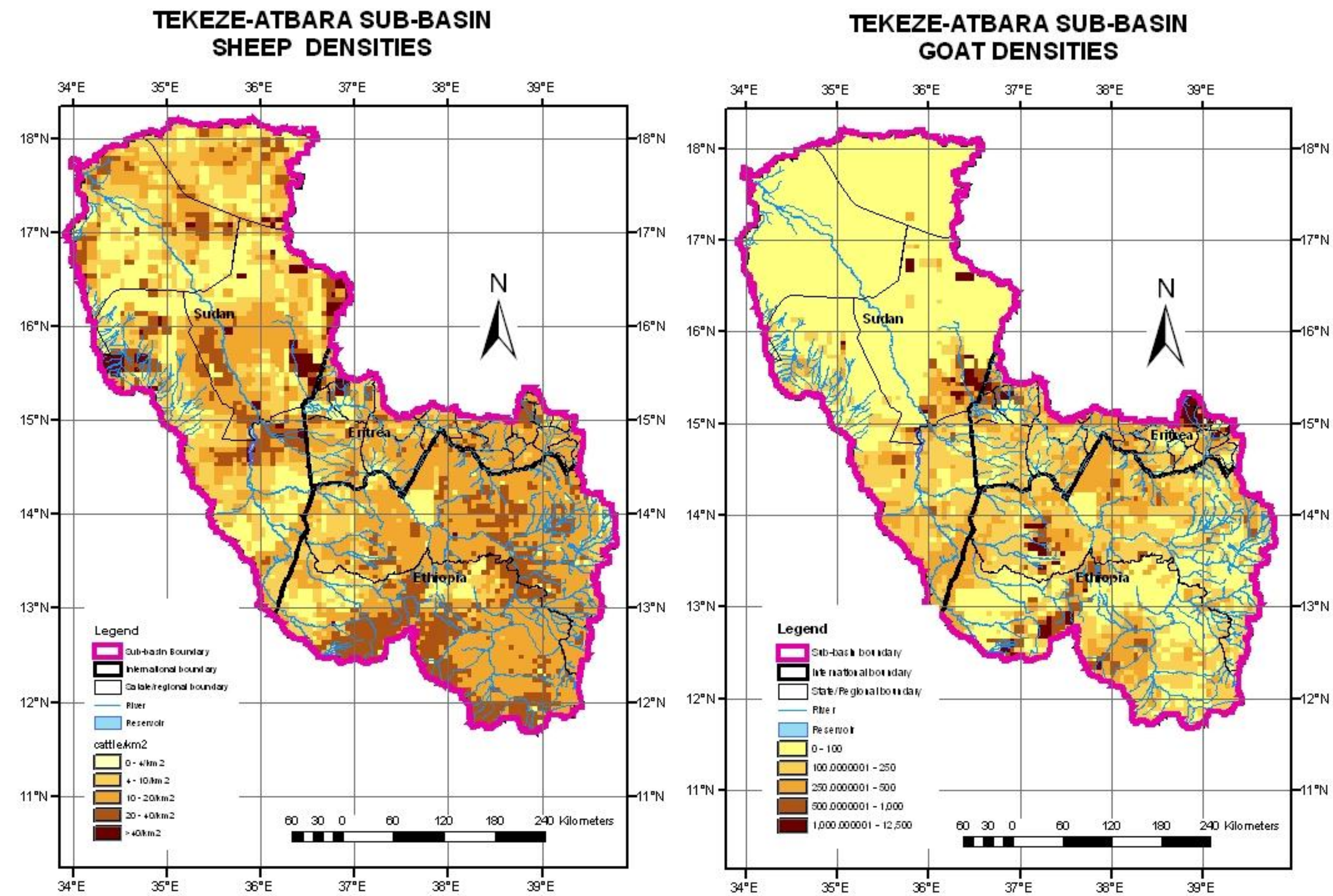
Data from the FAO Livestock Atlas for Africa are used to derived Map 14 and 15 to show the distribution of cattle, sheep and goats. Unfortunately, the FAO Data does not include camels, which are the most important livestock type in the northern parts of the Sub-basin, although the distribution of sheep mirror their distribution in the north to some extent.

The high densities of cattle in the Ethiopian Highlands and low densities in the Lowlands are readily apparent. In Sudan densities are relatively high along the upper Gash and Atbara as far as the New Halfa and Gash irrigation Schemes, where many irrigating households have substantial livestock holdings. Densities are also relatively higher in the northwest in the Butana Plains.

The distribution of sheep and goats is very different. Sheep are well distributed across the whole Sub-basin, and are well represented even in the north where cattle and goats are absent. Overall densities of sheep are nearly everywhere higher than goats. In Sudan they are the preferred animal for export to the Middle Eastern countries.



Map 14. Tekeze-Atbara Sub-basin: Cattle Densities
Source: FAO (2003)



Map 15. Tekeze-Atbara Sub-basin: Sheep and Goat densities.
Source: FAO (2003)

2.3.2 Agricultural Marketing

(i) Crop Marketing

In Ethiopia the State has withdrawn totally from agricultural marketing, whilst in Sudan the Government retains some controls in sorghum and gum arabic 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. Uncertainty as to the government's intents on whether to restrict sorghum exports also contributed to a decline in the area planted to sorghum on the semi-mechanized farms. 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.

In Ethiopia farmers bring their grain to markets 5 to 20 kms from their villages, with about 80 percent of their cash sales occurring immediately after harvest. There is little or no information available to farmers to enable them to determine what crops to plant and hoe much. Grain prices are generally not negotiated in advance and are seldom influenced by cultural or social relations between seller and buyer. Farmers sell to the small merchants or assemblers in the market towns.

Smaller merchants are constrained by lack of financial credit, storage, transport facilities and are subject to a low capital turnover. Because small traders' capital is tied up in inventory the large merchants can exert considerable influence on grain prices in the absence of any competition. Wholesale traders are the principal agents in inter-regional grain movements buying in surplus markets and selling in deficit markets and to Addis Ababa and regional capitals (Gebremeskal Dessalegn et al., 1998). They handle about 45 percent of the estimated 2.6 million tons of grain sold annually. This is approximately 28 percent of total annual grain output. At the national level the 10 percent of the largest traders command about 43 percent of wholesale trade.

Brokers are intermediaries between the wholesale traders and the merchants in the main markets (regional capitals and Addis Ababa). There are two types of brokers. The first is involved in storage, paying transport charges for wholesales, remitting money to the wholesaler and arranging return of empty sacks. The second merely facilitates the grains sales at the main market.

However, there is an increasing involvement in grain marketing of large incorporated private enterprises that may change the marketing structure by their superior access to credit, transport and connections with government. These currently control the marketing of fertilizer. Retailers in the towns buy from the wholesalers and sell in smaller quantities to consumers in convenient locations.

There are a number of characteristics of the grain marketing chain. Firstly, there is little transformation along the marketing chain. Bulk grain is sold in unprocessed form. Thus, few market services are provided by the intermediaries in the chain. Secondly, it is common to change the sack at any point in the chain where there is a change of ownership, thereby increasing the costs. Allied to this, there is a complete absence of a system of grading for grain. Consequently, traders generally trade with people they know, thus restricting the size of the market. Finally, one third of grain traded is sold by producers directly to consumers.

(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. Terminal markets are also located at Kosti and El Gedarif.

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 Ethiopia livestock markets function at three levels: primary, secondary and terminal markets. Primary markets are located at the village level with a supply of less than 500 head, where producers (farmers and pastoralists) sell to small traders, other farmers and pastoralists (replacement animals) and local butchers (Yakob Aklilu, 2002).
Secondary markets are trader and to some extent butcher dominated markets, with an average weekly volume of 500 - 1,000 head, consisting of finished, breeding and draught stock. These are located mainly at the Regional capitals. Though they serve local consumers, they mainly feed the terminal markets. The

secondary markets also supply live animal exporters and meat processors. Supply of livestock to the primary, secondary and terminal markets is through trekking. Traders and producers use traditional stock routes. Cattle are walked 35-40 kms and shoats 15-25 kms a day. Staging points are chosen according to customary practices. A 1995 study indicated that costs of a 100 kms trek are EBirr 1.15 per cattle and Ebirr0.16 per shoat. Weight losses of about 9 percent (18-40 kgs/head/trip) occur over a 7-8 days trek. Trucking is limited to large scale traders who purchase at distant primary and secondary markets to supply the terminal markets.

Farmers come to markets with no prior knowledge of prices and may take back animals if the price is too low. However, pastoralist who may have trekked some distance take what price is available.

2.4 Forestry and Agro-forestry

2.4.1 Forestry Contribution to the Economy

In Sudan in the Tekeze-Atbara Sub-basin approximately 3.0 million m^3 of wood fuel and charcoal (per capita consumption of 1.4 m^3) are consumed forming about 80 percent of the total energy consumption. Woodlands provide all building materials in rural areas. They constitute 33 percent of the livestock feed as browse. They also provide a number of non-timber forest products.

In addition to these products the woodlands give a number of services which have no direct monetary values such as environmental protection, increase in crop production, conservation of soil fertility, biodiversity, protection of cultural heritage, forming habitat for wildlife and eco-tourism attraction.

The contribution of forestry sector to the national GDP is around 3.3 percent in 1999 but taking into account the outputs collected/consumed by local communities the forestry sector's contribution to the national economy is around 12% of the national GDP (Forest Products Consumption Survey, 1995).

The situation in Ethiopia is not dissimilar to that in Sudan. In Ethiopia in the Tekeze-Atbara Sub-basin some 9.95 million m^3/yr of fuelwood and charcoal (wood equivalent) are consumed as fuel forming about 65 percent of domestic energy consumption. Browse is of little importance in the Ethiopian Highland livestock systems. However, resins are of importance in the Lowlands. As most passes into the domestic market through informal channels data on harvesting levels are not known, although national estimates are of 2,067 tons of gums and resins were harvested with 65 percent being consumed within the country, the remainder being exported. The official figures for timber production do not include timber and poles produced and used outside the official marketing structures, in particular, for domestic use in rural areas.

2.4.2 Agro-forestry

In Sudan the main components of agro-forestry are the harvesting of Gum Arabic and browse for livestock as mentioned above. However, Gum Arabic in the Tekeze-Atbara Sub-basin is approaching its northern limit due to the low rainfall and suitable areas may be confined to the south-eastern areas of the Sub-basin close to the border with Ethiopia. .

Currently, Gum Arabic production is unstable due to climatic factors and marketing policies, in particular the ban on private companies exporting unprocessed Gum Arabic. The floor prices paid by the government-owned Gum Arabic Corporation as a percent of export prices (f.o.b. Port Sudan) declined from 70 percent in 1994 to only 21 percent 2000/2001 (World Bank (2003). In 1990-1992 the government temporarily waived controls and the percent of export price rocketed to 160 percent! The gum Arabic plays an important role as major source of foreign exchange, accounting for 13.6 percent of the annual export income excluding petroleum.

In Ethiopia agro-forestry takes the form of planted trees (invariably *Eucalyptus spp.*) around the homestead and indigenous trees left in croplands. In Tigray planting of Eucalyptus has been banned on croplands. In many areas hillsides and other degraded areas previously under communal control are now being allocated to individual for tree planting. Planting of on-farm (i.e. homestead) trees began some five years after it took off in Amhara Region. In the Lowlands little Eucalyptus is grown with indigenous still in plentiful supply.

2.5 Transport and Communications

There is one major road linkage between Ethiopia and Sudan within the Tekeze-Atbara Sub-basin through Metema from Gonder to Gederef on the main Khartoum to Port Said road (Map 16). However, the Gonder to Humera Road in Ethiopia could easily be linked to the main Khartoum-Port Said road at Showak in Sudan.

Within Sudan there are two primary (asphalt) and one all-weather secondary roads.

(a) Primary Roads

Khartoum- Port Sudan
Atbara - Haiya (under construction)

(b) Secondary Roads

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

Within Ethiopia because of the extreme dissection of the highlands by the Tekeze River and its tributaries road infrastructure is not well developed. As can be seen on map 15 the all-weather roads tend to be confined to the ridges and plateaus between the deeply incised rivers. For example, the Tekeze has only two road crossings. Thus both road construction and vehicle running costs are high.

Within the Sub-basin the length and density of all weather and dry weather roads is as follows:

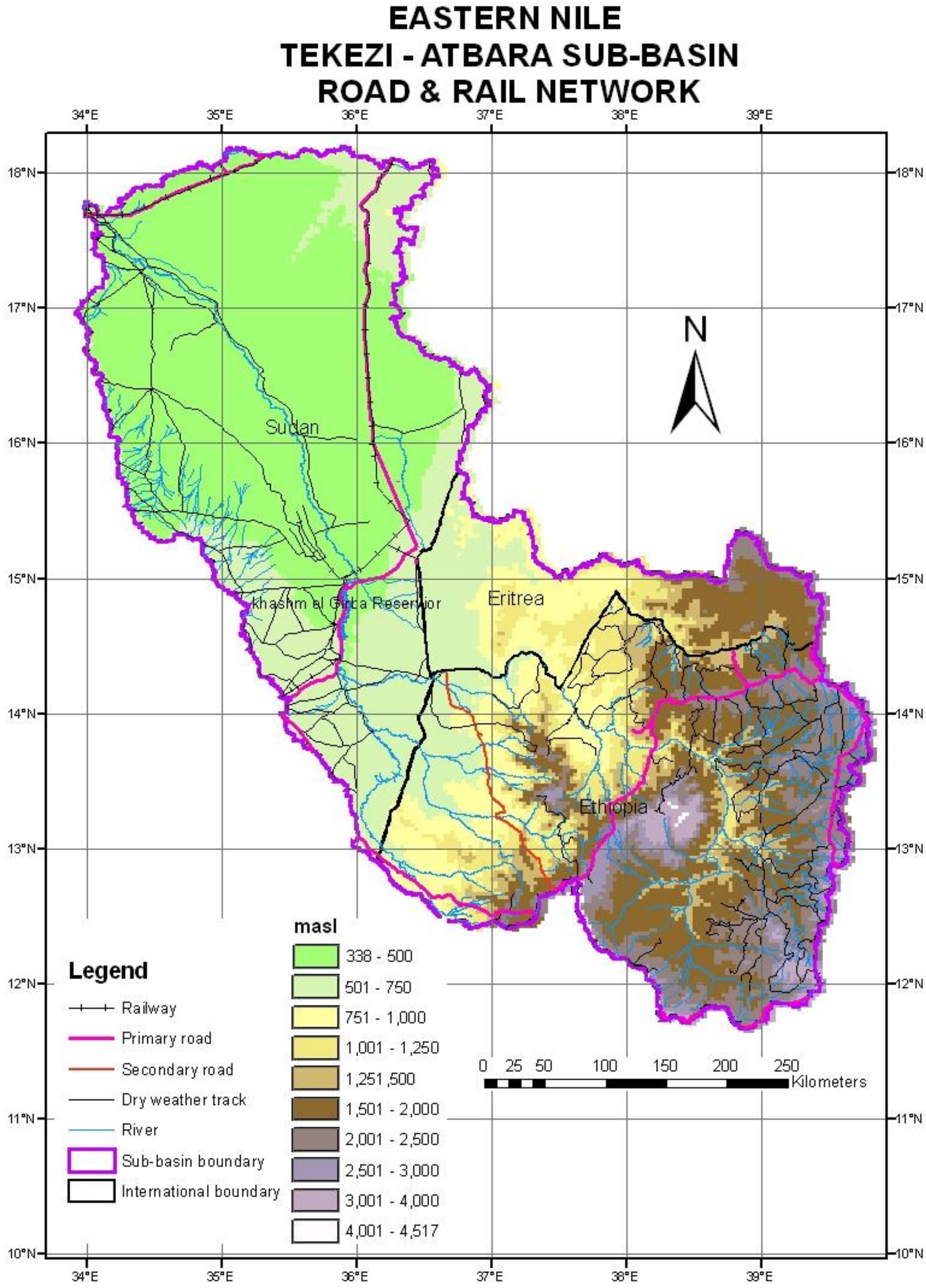
Table 12. Ethiopia – Tekezi sub-basin: Length and density of All-weather and Dry-weather Roads.

BASIN	TYPE	LENGTH (KM)	DENSITY (km/1,000km2)
TEKEZI	All weather	2,780	**32**
	Dry weather	1,171	**13**
	Total	**3,951**	46

The length of all-weather roads in the two basins is significantly greater than dry-weather roads. This may be a reflection of the degree to which dry weather roads have been mapped. The road density for Tigray and Amhara Regions are as follows:

Tigray	-	44km/1000km2	
Amhara	-	46	"
National	**-**	**31**	**"**

In terms of accessibility to all-weather roads some 39 percent of the Sub-basin area is further than 15 kms, which compares with 45 percent for the Abay Sub-basin and 63 percent for the Baro-Akobo Sub-basin. The areas of inaccessibility are located in the upper Tekeze Sub-basin and in the western Lowlands



Map 16. Tekeze-Atbara Sub-basin: Road Network.
Source: Afriroads

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

3.1 The 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 Tekeze-Atbara Sub-basin are highly varied and reflect not only the natural resource base, but also the complex social, cultural and economic characteristics of the land users and the economic, institutional and policy environment in which they operate. Land use systems have their own dynamics responding to endogenous and exogenous factors that have impacts on user livelihoods and the properties of natural resources and environmental services. This analysis seeks to establish any causal linkages between land use systems and trends in these properties and services.

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).

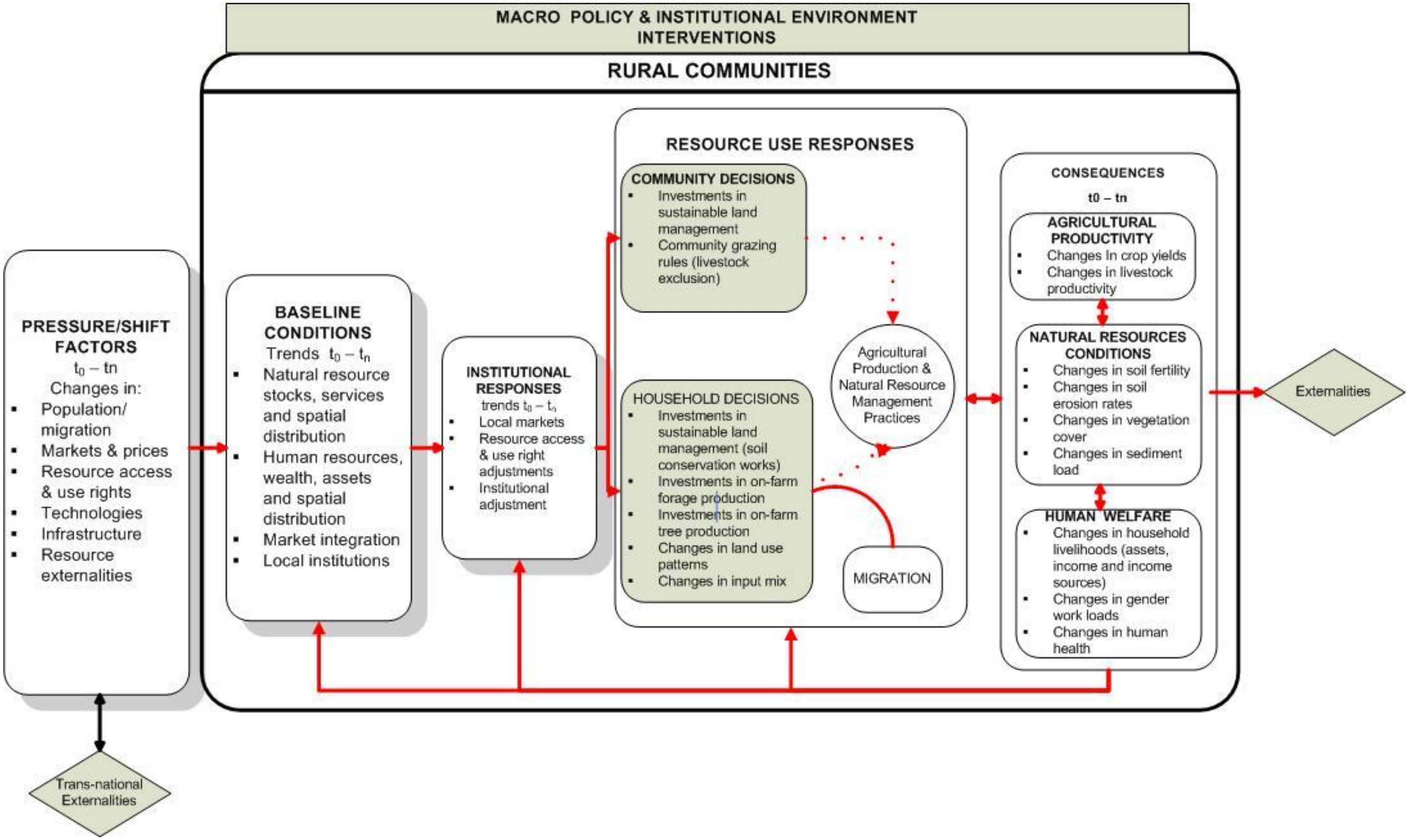


Figure 3. Framework of Analysis for Natural Resource Degradation in the Sudan.
Source: Scherr, S.J. et al., 1996

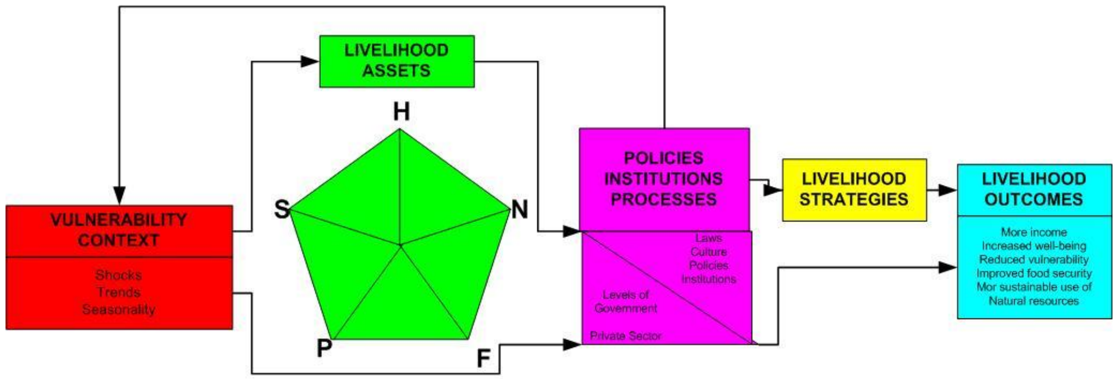
These shifts can in turn induce responses at the community and household level. Of particular importance and of relevance to the present analysis are the community and household decisions with regard to investments (or non investments) in agriculture, soil conservation, and small-scale irrigation. Other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

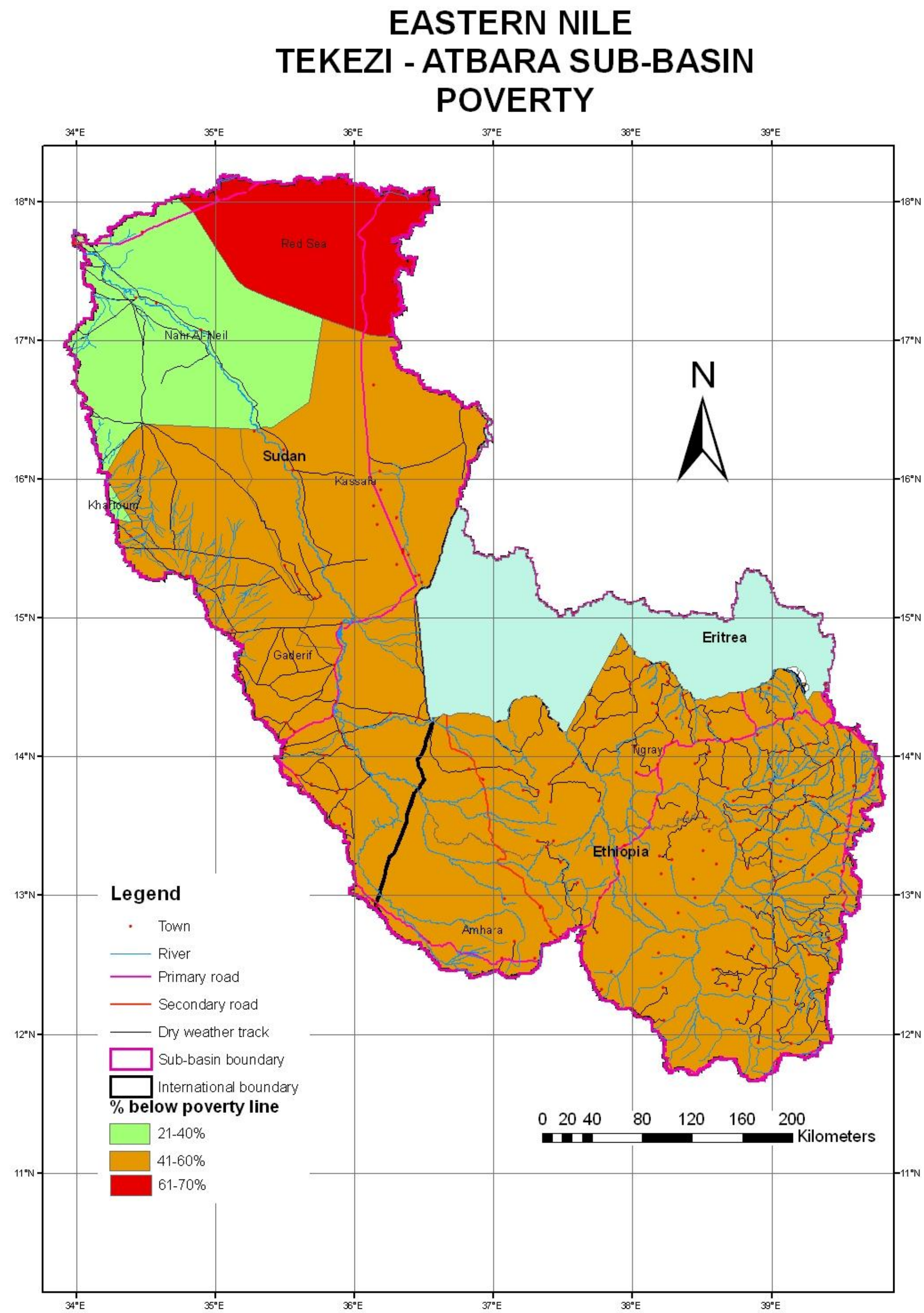
3.1.2 Patterns and Extent of Poverty

The basis for determining the poverty lines in Ethiopia and Sudan are different and thus can not be compared with each other[3]. The percentages of population below the official poverty line are shown in Map 17.

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

In Ethiopia a comprehensive review of poverty was undertaken (FDRE-MOFED, 2002) as input to the Country's Sustainable Development and Poverty Reduction Programme (SDPRP). Between 1995/96 and 1999/2000 in Ethiopia rural poverty rates declined by 4.2 percent, although it increased in urban areas (by 11.1 percent).

[3] Sudan US$1.00 per capita per day. Ethiopia basket of food and essential non-food goods worth EBirr 1,070.00 per capita per year (approx. US$0.34 per capita per day) in 1995/96 prices.



Map 17. Distribution of percent of population (Sudan- Total) and Ethiopia (Rural) below the official poverty line as determined in each country.
(Sources: Sudan (JAM, 2005), Ethiopia (FDRE-MOFED, 2002). Eritrea: No data.

3.2 The Macro Policy and Institutional Environment

The key policy issue in both countries is that of land tenure, although the details differ. In Ethiopia and Northern Sudan the state owns the land although in the Sudan some, but limited, rural freehold does occur[4].

In both Sudan and Ethiopia development policies are formulated from a predominantly economic perspective, with the following consequences:

- Natural Resource Management and SLM related strategies and principles are discussed only very briefly,
- only few policy documents, mainly those related to water resources development, refer to watershed management,
- very few policy documents contain an in-depth analysis of lessons learnt and too easily take the assumed success of previous activities for granted

3.2.1 Policy Issues in Ethiopia

(i) Validity of the ADLI policy

Berhanu Nega (2004)[5] questions the success of the ADLI strategy and advocates a more balanced development strategy with urbanization given as important a place as agricultural development. He stresses the importance of the overall very low labour productivity in agriculture as another, or even the main, reason inhibiting development of Ethiopian agriculture. On the basis of Government production statistics, he claims that whatever the achievements of ADLI in raising productivity in some specific areas, it has not been able to raise overall productivity at the national level. Poor extension coverage is not the reason, as some 34 % of the farmer population is said to participate in the ongoing extension program. The fact that more and more marginal land with less than the national average productivity is coming into cultivation, is given as a more plausible explanation.

The ADLI strategy is also said to be too much a supply side strategy with little consideration to demand conditions. In good harvest years because of the low purchasing power of the urban population and limited opportunities of exporting surpluses to the international markets, prices fall sharply and so discourage farmers to invest in surplus production.

[4] In Southern Sudan Land Policy is based on customary law, although there are considerable inconsistencies in how it is applied in the different regions.

[5] Berhanu Nega (2004) "Is Agricultural Development Led Industrialization a viable strategy for Ethiopia?" - Paper prepared for a symposium to celebrate the 50th anniversary of Alemaya University, 2004.

The author, quoting others, argues that recent history shows that the claim that agricultural development can be the engine for overall development is not correct. Rather that development of agriculture in Ethiopia is constrained by the low levels of urbanization.

Nevertheless, two points are clear:

- agricultural development should be based both on improved input supplies and on favourable market conditions,
- better linkages between the agricultural sector and others are indispensable for overall economic diversification and development.

In spite of the overall picture, small positive changes are noticeable during the last few years. Newly introduced water harvesting practices, together with small-scale and micro-irrigation development, have resulted in agricultural diversification. This can be observed in local markets, which show both a diversified supply of agricultural produce and an increasing demand (willingness to pay higher prices). Factors such as price liberalization, improved access to markets (new roads) and nutrition education are thought to be at the basis of it.

(ii) Land Policy and Institutional Issues in Ethiopia

In Ethiopia the Federal Government has overall responsibility for land Policy but devolves the Land Administration to the Regional Governments. However, there is no federal institution responsible for land administration (ARD, 2004). Rural dwellers have usufruct rights to land, may lease and bequeath to immediate relatives but may not sell or mortgage their land holdings.

The four large Regions (Tigray, Amhara, Oromiya and SNNP Regions) have issued their own Land Use and Administration Proclamations and are undertaking programmes of land registration. The current land registration programmes lack consistency, including the way land is administered and user rights granted (World Bank, 2005). The most noticeable differences are in their organizational structures, inheritance and the provisions of permitting sub-leases.

Currently, the land registration programmes have a narrowly technical focus. They are not taking the opportunities to link land reform and security of title with economic investment in sustainable land management, poverty reduction and improved livelihoods. A key constraint is that land cannot be used as collateral for formal credit.

Whilst in the Highlands the boundaries of the lowest administrative unit for land administration - the *kebele* – are well known and established, this is less so in the Lowlands, where there are relatively large areas that are not settled. Land for commercial agriculture is allocated by the Regional Investment Bureau but there is no formal cadastral survey, environmental impact assessment or monitoring of subsequent land development.

3.2.2 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 farm and pasture resources. Traditional corridors of animal movements were blocked generating increased levels of resource based conflict (JAM Report, 2005).

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.

3.2.3 Institutional Issues

(i) Complexity of the Institutional Framework

The Tekeze-Atbara Sub-basin encompasses three countries: Ethiopia, Eritrea and the Sudan. Currently there is very little coordination of Watershed Management activities across boundaries. Eritrea only has "Observer" status within ENSAP. However, Waterbury (2002) makes the point that effective international cooperative mechanisms depend as much on establishing effective cooperative mechanisms at the national level.

Both Ethiopia and Sudan are 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. Within Ethiopia there are two Regional State administrations (Amhara and Tigray) and with Sudan four State administrations (Red Sea, Nile, Kassala and Gederef).

(ii) Land Registration in Ethiopia

The national law vests primary rights in the state with the decentralised administration of land to the Regions. However, there is no federal institution responsible for land administration[6]. At the regional level institutional structures vary in each Region, each having adopted a different approach to land administration institutional structures. The current land registration programmes lack consistency, including the way land is administered and user rights granted[7]. The most noticeable differences are in their organizational structures, inheritance and the provisions of permitting sub-leases.

Currently, the land registration programmes have a narrowly technical focus. They are not taking the opportunities to link land reform and security of title with economic investment in sustainable land management, poverty reduction and improved livelihoods.

[6] ARD for USAID (2004) "Ethiopia: Land Policy and Administrative Assessment".
[7] World Bank (2005) "Rural Land Policy in Ethiopia: Aide Memoir",

(iii) The facilitating role of government

In Sudan and Ethiopia Government still maintains a strong control of all development activities in the country. The inherent danger to this is the adoption of a top-down approach and attitude. In a more open dialogue with development partners at all levels, government would benefit more from an exchange of knowledge and experience of other organizations and institutions.

Numerous activities of government capacity building are being undertaken but these alone will not be effective if not paralleled by a change in attitude. One of the main challenges is to improve information management (exchange of information between organizations, dissemination to lower levels, and building up of a common institutional memory). This would provide the fuel for the engine of up-scaling of successful but isolated development activities.

(iv) Watershed Management Planning and Capacity

There is a need to address discontinuities in the government structure with regard to the overall “cycle” of project identification, planning, coordination, stakeholder consultation and participation, and implementation. Currently, it is not clear who has the responsibility for watershed management and at what level. Thus, these responsibilities need to be better demarcated. It is not necessarily a problem that various organizations take up responsibilities in watershed management as long as there is a workable level of harmonization. In addition, those taking the responsibility or being given a mandate should be able to build up the required capacity to fulfil their task.

Watershed management planners should not plan in isolation but, at all levels, ensure timely consultation with implementers and beneficiaries. Plans should include arrangements for implementation, and at the lower levels, these should be agreed upon by implementers. In the ideal case, planners would also be responsible for (coordination of) implementation, provided that they have the capacity to do this.

In Ethiopia, whilst a Master Plan study has been undertaken for the Tekeze River Basin, there is no formal institutional mechanism for Basin-wide watershed planning and coordinated development activities. This is currently under review and a draft Proclamation setting out the institutional setup for river basin development almost complete. The objective of a River Basin Organization will be to:

"trigger, promote, coordinate, enhance and monitor the Integrated Water Resources Management process in the river basin falling within its jurisdiction and to administer the basin's water resources for the socio-economic welfare of

the people in an equitable and participatory manner without comprising the sustainability of the aquatic ecosystems".

The Tekeze Basin is one of the 12 basins designated. Each River Basin organization will have a Basin High Council with federal and Regional representation and with provision for other Stakeholders as considered necessary; and a River Basin Authority.

Whilst this may take care of institutional coordination and harmonization at the macro level there are no provisions for such coordination and harmonization at the small/micro watershed level. This has emerged as a problem with the small dam programme being undertaken independently of the watershed management programme, resulting in widespread sedimentation of dams. A moratorium has been placed on the dam programme until the institutional problems can be resolved.

In Sudan 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. Under the ENSAP programme four CRA's are being undertaken in the Tekeze-Atbara and the other Sub-basins within the Eastern Nile Basin.

There is still a need for improved awareness of watershed management concepts, principles and their implications. Watershed management planning at watershed level is a different subject than planning at the grassroots level. At **higher levels**, planning is strategic and concerned with development pathways in selected “development units or domains” (as used in this regional assessment), planning frameworks, and identification of priority areas. At the **lower level**, planning is concerned with modus of implementation.

Watershed management, as an integrated or holistic approach, should be interpreted more pragmatically. A **holistic approach** to watershed management will need to encompass a detailed and comprehensive understanding of the underlying social, economic and policy causes behind land degradation, poverty, food insecurity and a limited range of livelihood possibilities. In more pragmatic terms, holistic means e.g. that during situation analysis it should be realized that the causes of specific problems may need to be sought in other sectors or disciplines.

Integration does not mean that implementation has to cover all possible sectors of integrated rural development. It means that development or sustainable land management interventions are put into context one with another (e.g. SWC to increase moisture availability to agricultural production; improved stoves as to reduce the need for fuelwood and depletion of forest cover). Targets of integrated approaches should not be set too ambitiously and should not exceed implementers' capacities. The level of detail and relative levels of responsibility among the various stakeholders will depend on a thorough understanding of local circumstances and various options may emerge rather than a single "blueprint" for implementation.

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.

Ethiopia now has a substantial capacity building programme to support its decentralization policy and a Ministry of Capacity Building has been established (Ministry of Capacity Building, 2002). The "wereda" is seen as the front-line administrative unit for all development efforts. Increasing financial, administrative and technical

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.

3.3 Livelihoods, Poverty and Land Degradation

3.3.1 Vulnerability Context

Map 16 only provides averages across the State or Regional State and is unable to capture the distribution of poverty levels across the population at this level. It is known for example that tenants on the Gezira Scheme are barely able to make a living from current irrigated cropped area and cropping pattern (see paragraph 2.3.1 above). Given 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 are significantly higher in the traditional agricultural sector (see above). In Ethiopia even where there is a separation between urban and rural rates, simple averages mask a wide variation in poverty rates amongst individual households.

The lower rates of poverty in Blue Nile and El Gezira States are a reflection of the assured access to generally low risk irrigated cropland along the Blue Nile. An assured and low-risk production environment clearly reduces the incidence of poverty. It enables households to build up assets that reduce their vulnerability to sudden changes in circumstances. In these areas land is generally held in 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. In Blue Nile State rainfall is less variable than to the north in Gederef State and thus not as high a risk environmental.

Conversely, in the traditional rainfed cropping areas in Gaderef State rainfall is extremely variable in amount and timing, presenting a high risk environmental both for crop and livestock production. In the severe droughts of the early 1980's many pastoral peoples 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 land degradation (e.g. kerib land) or alienation of assets (e.g. to the large semi-mechanized farms).

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

In eastern areas of the Ethiopian Highlands rainfall variability is higher than the western parts and present a high risk environmental for rainfed cropping. Here it is exacerbated by the general low fertility status of soils and by their high degree of erodibility.

3.3.2 Livelihood Assets

The Ethiopian SDPRP Report outlines a number of other determinants of poverty. It is interesting that a number of these also occur in the analysis (World Bank, 2002) of Egypt's poverty and thus are likely to be applicable to Sudan also. The dependency ratio is very important in determining poverty status in rural areas. Studies indicate that if the dependency ratio increases by one unit, a household's probability of falling below the poverty line increases by 31 percent. Households with more children under 15 years and those with people older than 65 years are particularly vulnerable to falling into poverty. This underscores the importance of adult labour in the welfare of rural households.

Female headed rural households face a 9 percent higher probability of being poor than male-headed households although other factors such as age and education play an important role and need to be taken into consideration when targeting. Farm assets such as oxen are important poverty reducing factors: an extra ox reduces poverty probability by 7 percent.

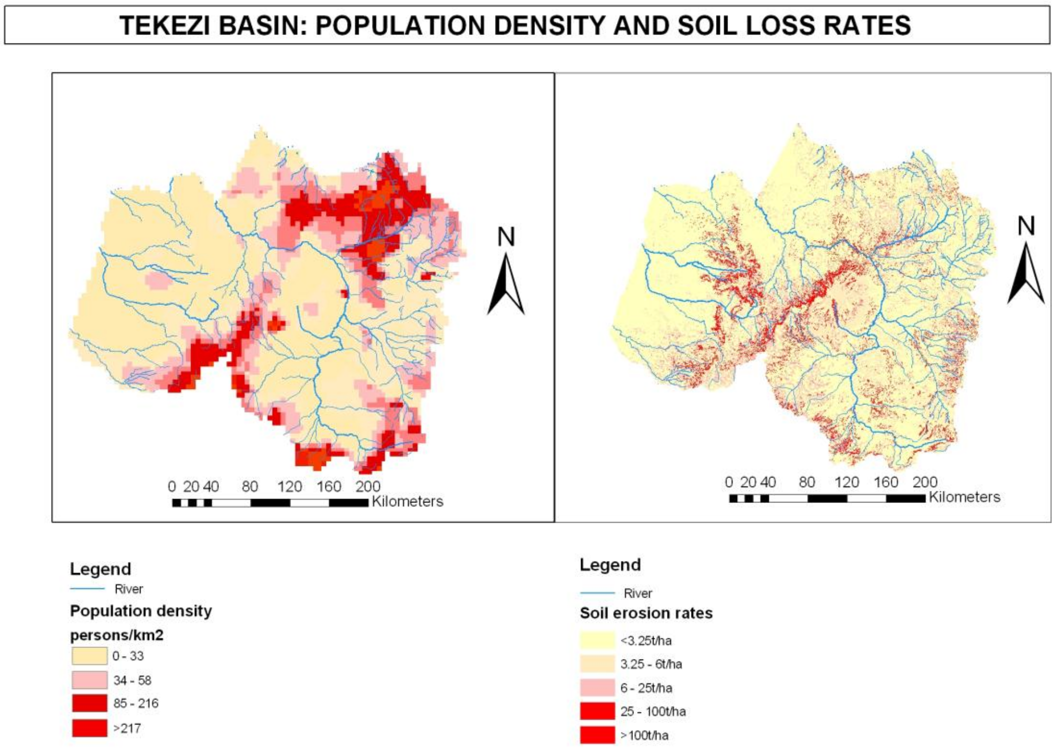
3.3.3 Livelihood Strategies

Households cultivating exportable crops (chat, coffee) have a much lower probability of being poor. Living near towns and better access to markets has a poverty reducing effect. Although counter-intuitively, households involved with off-farm activities, which are more likely to be available near towns, are 11 percent more likely to be poor. This is because such activities are seen as a coping mechanism for poor people rather than a way of accumulating wealth. In Sudan, temporary migration to access non-farm income is also a very common livelihood strategy. However, as discussed below this can negatively impact households' ability to invest in sustainable land management investments because of the reduction in households' human assets.

3.3.4 Population Pressure and Land Degradation

Currently there are two basic hypotheses regarding the relationship between population growth and land degradation. The “neo-Malthusian” hypothesis predicts that agricultural production is unable to keep pace with population growth leading to falling agricultural production per capita, and increasing negative impacts on natural resources including land, water, forests and biodiversity. More recently, a more optimistic perspective has developed following from the work by Ester Boserup (1965) and others. This perspective emphasizes the responses of households and communities to population pressures that include a reduction in fallow periods, intensified use of labour and land, development of labour-intensive technologies and institutional changes. However, more recent evidence suggests that more specific conditions seem to be needed to get a Boserupian scenario to operate. These have been identified in the Machakos study as secure tenure, efficient markets, cash crops, supporting social organization and proven SWC measures. The evidence accrued so far in Ethiopia is mixed.

Grepperud (1996) tested the population pressure hypothesis for Ethiopia using econometric analysis, and found that when population and livestock pressures exceeded a specific threshold rapid degradation of land takes place. The threshold was the population and livestock carrying capacity of the land. Pender et al (2001) found in Amhara region of Ethiopia that high population densities were related to the decline in fallowing and manuring. They also found the high population densities were related to increasing land degradation and worsening household welfare conditions. In Tigray high population density was related to more intense use of resources (more fertilizer, manure and intercropping) at the household level but increased land degradation at the community level. A comparison between population density and soil loss rates for the Tekezi basin is shown in Map 18.



Map 18. Ethiopia – Tekezi Basin: A comparison between the patterns of population density with soil loss rates.

Whilst there is some similarity in pattern along the south-western, southern and south-eastern edges of the basin, elsewhere the patterns are not directly coincident. For example, the areas of Eastern Zone in Tigray that have very high population densities are located on basalt derived soils that are less erodible than those derived from basement complex rocks and sandstones. This suggests that the relationship between population density and erosion is not a simple one.

In Sudan there are many references to the impact of the massive expansion of the Semi-mechanized farms on the loss of land both for cultivators and pastoralists. This in fact has caused extra pressure on natural resources in addition to that exerted by natural population increase. The eastern part of Sudan has seen a substantial increase in population from both West African countries as well as from western Sudan.

A major environmental impact of this land pressure has been the degradation of the rangelands in the Tekeze-Atbara Sub-basin (exacerbated in part by a decline in rainfall over the past two decades). In the rainfed croplands the environmental impact has been on reduced length of fallow periods and a consequent decline in crop yields. Other environmental impacts have been the additional pressure on the Dinder National Park and loss of habitat and species biodiversity.

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). These are particularly of relevance in traditional rainfed shifting cultivation agricultural system. Here there is a need for labour for the frequent clearing to access land of better fertility as well as for weeding. It is also true for pastoral families because of their need for herding different animal types (camels, cattle, sheep and goats) in different places and times. In efforts to maintain livelihoods some household members have had to leave the farm in order to seek wage employment (livelihood strategy). This has led to a reduction in households' human capital and the lack of labour for cultivation and herding (a negative livelihood outcome).

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. This allows 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).

In Ethiopia Mahmud Yesuf and Pender (2005) have undertaken a comprehensive review of research undertaken into identifying the determinants of the adoption or non-adoption of land management technologies in the Ethiopian highlands. This report and a number of IFPRI/ILRI reports on research undertaken between 2000 and 2004 provide a comprehensive picture of many of the underlying causes of land degradation in Ethiopia. Other useful reviews include the NTEAP (2005) Study, Alemayehu Tafesse (2005) and Herweg (1999).

Decisions to adopt sustainable land management technologies depend on households' asset endowments. Labour availability has been found to be a positive determinant of chemical fertilizer adoption, trees and terrace construction. However, simply using family size to measure labour availability was found to be misleading. The results of studies into the effect of farm size on land management technologies have been mixed. Both positive, negative and no relationships have been found between farm size and fertilizer adoption. However, with those technologies that take up space (terraces, bunds, trees) a positive relationships were found between farm size and adoption.

Livestock assets have been found to be positively related to adoption of fertilizer, planting of perennial crops, use of manure and contour ploughing. Gender (a human capital variable) does affect adoption of land management technologies. Male headed households use more labour and oxen draught power and apply manure, reflecting a cultural constraint on women ploughing in Ethiopia. The results for fertilizer adoption were mixed, with female headed households in northern Ethiopia likely to use more fertilizer and the reverse in southern Ethiopia. Positive relationships were found between education and adoption of soil conservation measures although the results for fertilizer adoption were mixed.

Related to poverty, household assets and the vulnerability context are the concepts of profitability of the improved land management technology, the farmers' perceptions of risk and of farmers' private discount rates. Private discount rates are a measure of a person's time preference or time horizon. The shorter the time horizon the higher is the discount rate. Short time horizons are the result of a number of factors, tenure insecurity, poverty, and high risk environment. Many farmers have high private discount rates – as high as 70 percent even in the high potential farming area around Debre Zeit near Addis Ababa (Holden et al., 1998). A number of studies have found that adoption of soil and water conservation technologies is negatively related to high discount rates. However, where a technology is risk reducing (e.g. terraces that conserve soil moisture) adoption is much more likely.

3.4.2 Policies, Institutions and Processes

Agricultural development and land tenure policies and institutions adopted by the Government of Sudan over the past three decades have seriously constrained the traditional rainfed agricultural sector's ability to invest in SLM strategies and investments. These include almost total focus of improved inputs, extension and research to the irrigation sector (World Bank, 2002). This has been compounded by the Land Policy that has favoured the expansion of the rainfed semi-mechanized farm sector with the impacts outlined above.

In the traditional small-scale traditional rainfed cropping systems periodic bush fallowing is vital to restore soil fertility and suppress noxious weeds (e.g. *striga*) and thus forms a major sustainable land management strategy. The massive expansion of large-scale semi-mechanized farms in the Sub-basin has severely reduced land available for bush fallowing in the traditional farming systems. This combined with population increases and expansion of cropland, have led to reductions in areas under fallow with a consequent decline in yields.

3.4.3 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 Non-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.

Howe and Garba (2005) found that reliance on traditional forms of transport pose considerable barriers to the development of an exchange economy and locks the farmers into subsistence form of livelihood. Pack animals offer a considerable advantage over human transport, with a cost reduction of approximately 50 percent. However, the average costs of mule transport of EBirr 16.7 ton/km compare very unfavourably of Ebirr 0.6-0.9 ton/km for local truck costs. With such high costs of transport for low value food crops such as maize or sorghum makes a net return unlikely.

However, the evidence from Ethiopia of better access to markets and adoption of soil and water conservation technologies is mixed. In the eastern parts of the Upper Abbay-Blue Nile Sub-basin households with poor access were more likely to adopt labour intensive SWC structures than those with good access. Declining fallows and increasing use of manure closer to towns suggested increasing intensification of agriculture where access was better.

The use of fertilizer was everywhere positively associated with increased accessibility.

The relationship between Non-farm employment and the adoption of SWC structures appears to be very context specific. In many areas adoption of fertilizer and SWC adoption was negatively associated with off-farm employment. However in the high agricultural potential areas the relationship was positive.

In Sudan, seasonal migration for non-farm income is has become an established livelihood strategy for many rural agricultural households. This has had a negative impact on crop and livestock production because of reduced household labour supply the high labour requirements for land clearing for shifting agriculture (Kibreab, 1996) and for transhumant herding (Abdel G.M. Ahmed, 2002). Given the booming service, construction and industrial sectors in Khartoum this trend is likely to continue. Improvements in land management (fertilizer, improved seeds, timely cultivation) can help in reducing labour requirements and thus release essential labour for non-farm income (see Lowe, 1983 for how this operated in Swaziland and Botswana).

Gordon and Craig (2001) point out that a sound and less risky agricultural base together with improvements in infrastructure, education, health and financial services provide a strong foundation for the expansion of opportunities for non-farm income. They suggest that the decentralization process that is now underway in e.g. Sudan and Ethiopia, offers a way forward. The proportions of households dependant on agriculture in Ethiopia and Sudan but increasingly less so in Egypt are 85 percent, 70 percent and 37 percent respectively. However, the contribution of agriculture to each country's GDP is only 45 percent, 37 percent and 8 percent respectively and declining in all cases, with the Service and Industrial sectors providing the remaining and increasing proportions. Much of the latter's activities are taking place in the major urban centres, but also in the small and intermediate centres.

(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. This is a complex subject in Ethiopia.

The Federal Rural Land Administration proclamation (No. 89/1997) defines in broad terms individual land use and disposal rights. It delegates responsibility for land administration to the Regions. The four large Regions of Tigray, Amhara, Oromiya and SNNP have also enacted Proclamations for the Administration and Use of Rural land. Currently a land registration programme is underway in these regions. However, land redistribution has not been ruled out in both federal and regional proclamations. A US-AID Study (ARD, 2004) indicated that reports from kebelle administrations that redistribution is possible even with Land Registration Certificates.

Land tenure issues and their impacts on land management and technology investment in Ethiopia have been well studied over the past decade, and Mahmud Joseph and Pender (2005) provide a very comprehensive summary of the empirical evidence that is now available. Much of the evidence relating to impacts of tenure issues on land management and potential investment in improved land management is also of relevance to the situation in Sudan even if the context is somewhat different.

Tenure insecurity in Ethiopia emanates from a number of causes. A major source was periodic land redistribution to reallocation land to land-poor households. In northern Ethiopia the indications are that in areas where redistribution has occurred investment in terraces was lower, but that the use of fertilizer and tree planting was higher. This suggests that redistribution may favour short term investments in land management but hinder long term investments. The investment in tree planting (a short to medium term investment) may be due to a desire to increase tenure security or merely because trees are normally planted around the homestead.

In Oromiya Region tenure insecurity derived not from redistribution but from the expected sharing of land among family members. In one area investment in coffee planting was reduced with increased tenure insecurity, but another study found that farmer’s resource poverty had a greater impact. A number of studies in northern Ethiopia also found evidence that resource poverty had a much greater effect on farmer’s decisions than tenure insecurity to adopt or maintain soil conservation structures.

It is also possible that lack of rights to transfer or mortgage land may reduce farmer’s incentives to invest in land improvement. A number of studies found that a perceived right to mortgage or to transfer use rights of land were positively associated with greater investments in constructing terraces and in tree planting. The evidence from studies on comparing land investments on owner-land and leased-land (mainly sharecropped) was mixed. Some studies found lower land investment on leased-land whilst other found no difference. However, on leased land the use of labour, improved seeds and fertilizer was lower as was production.

In summary the effects of tenure insecurity on land investments in Ethiopia appear to be mixed depending on whether the investments themselves affect security. Insecurity appears to hinder larger investments (e.g. terraces) than smaller and periodic investments (e.g. fertilizer, manuring). Redistribution is not the only source of insecurity, obligations to share land with younger family members is also an important source.

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 small-scale farmers and pastoralists, notwithstanding the voluminous literature on the impacts of land lost. Thus how far this is a factor in constraining decisions to invest in SLM investments is not clear. As indicated above the physical shortage of land may be a more deciding factor.

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

In Ethiopia the agricultural extension programme has strongly promoted fertilizer and improved seeds supported by credit. Studies indicate that greater access to credit increases farmers' likelihood of using fertilizer. However, risk is the crucial factor in the low rainfall areas in determining whether farmers will take credit for fertilizer even where it is readily available. The source can also determine the uptake of credit and specific use of the credit. This is probably a reflection of the technical advice that comes with the credit.

One study shows that credit uptake increased the adoption of fertilizer but reduced investments in soil and water conservation, contributing to increased soil erosion. The increase in fertilizer price since 2002 with the removal of the subsidy led farmers to increase the cultivation of crops requiring low fertilizer applications and reduce investment in soil conservation where the intervention was yield decreasing (e.g. soil bunds taking up cropland). Studies indicate that the impact of extension on the uptake of improved land management is probably more positive in the high potential areas.

In Sudan the neglect of the traditional rainfed cropping and 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). The inability of the large-scale semi-mechanized farm to use their land as collateral for credit may be an inhibiting factor in their adoption of SLM investments.

3.5 Physical and Technical Issues

3.5.1 Issues of Soil Erosion and Sedimentation

(i) Technical considerations

Soil sheet erosion rates have been determined using the Universal Soil Loss Equation (USLE) modified to Ethiopian conditions by the Soil Conservation

Research Project (Hurni, 1985) within the Geographic Information System (see Annex 1 for the full description of the methodology). Except for the kerib land in Sudan little work has been done in Ethiopia on gully densities and erosion rates. Taking research work undertaken in Tigray and in Zimbabwe an estimated contribution to sediment load of 20 percent of that of sheet erosion has been used. Estimates of gully erosion in the kerib land have been obtained using aerial photos (Hassan Fadun et al., 1999).

Not all sediment eroded within the landscape reaches the drainage system. The proportion that does is termed the sediment delivery ratio (SDR). The SDR is the ratio of sediment delivered to the drainage system as a proportion of the total soil eroded. Eroded soil not reaching the drainage system is deposited within the landscape at places where the energy for transport becomes insufficient. This is normally where the slope changes from steep to gentle (i.e. footslopes) or where the land cover changes to a type that causes the reduction in transport energy (e.g. area closures with substantial herbaceous and/or woody biomass).

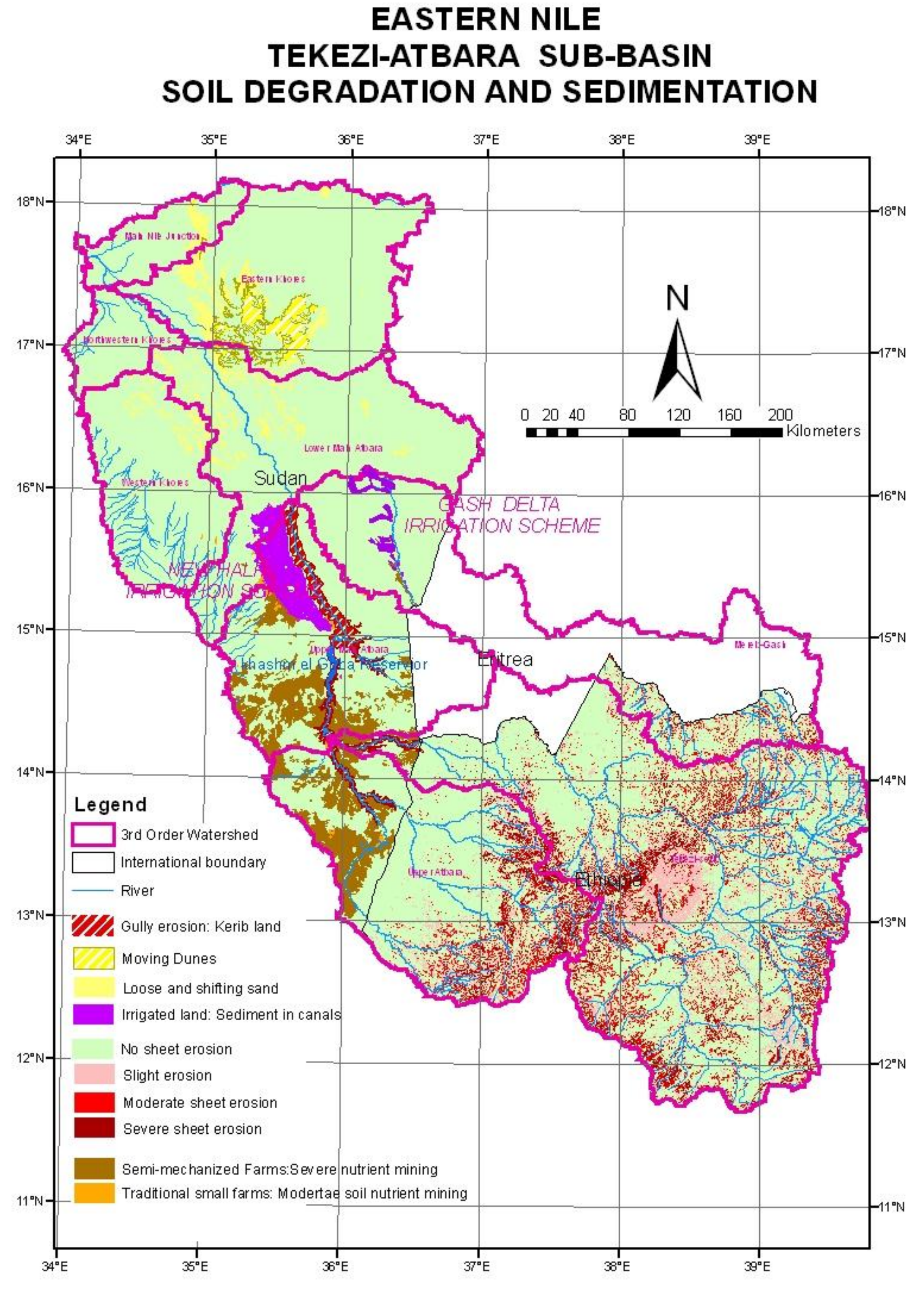
Once sediment reaches the drainage system there is a complex pattern of temporal and spatial lags between soil eroded in the landscape and the suspended sediment load in large rivers. These lags are caused by storage of variable lengths of time of sediment within the river system as sandbanks and alluvium in floodplains. As a general rule sediment yields (mass of sediment/unit area of catchment) decline with increasing catchment size (Walling, 1983), but there may be circumstances in which this does not occur (see below).

The locations of the various types and degrees of soil erosion and deposition within the Tekeze-Atbara Sub-basin are shown in Map 19.

(ii) Over-view

Most moderate to severe soil sheet erosion in the Tekeze-Sitit Watershed occurs in three main areas. The first lies to the southwest and west of the river and follows the ridge of steep land along two ridges from the Simien Massif trending to the southeast and the northeast. A second area is found on the eastern rim of the basin in the high basaltic mountains from Korem to Adi Gudem. A third area is found in the lower Werii valley whilst a fourth area is located on the high basaltic mountains to the west of Adigrat. Within the Angereb-Atbara Sub-basin the main area of high soil erosion hazard follows the western side of the spur of highland that trends north-westwards from the Simien Massif.

Gully erosion in the Ethiopian highlands is too small and localized to be mapped at scales of 1;50,000 or smaller. The kerib gully land along the Upper Atbara, the Setit and the main Atbara is sufficiently extensive to be able to be mapped. It occurs from just inside the Ethiopian-Sudan border on the Tekeze-Setit and the Upper Atbara and along the main Atbara below the junction to approximately 150 kms below the Kashm el Girba dam.



Map 19. Tekeze-Atbara Sub-basin: Distribution of Soil Degradation and Sedimentation.

On the large Semi-mechanized and small traditional farms the key soil degradation problem is nutrient mining. They are located south of the Atbara mainly within the Upper Main Atbara watershed.

The main areas of moving dune and shift sand are located in the north-eastern part of the Sub-basin. These are mainly a problem to local irrigated farms along the lower Atbara River.

The main locations for sedimentation are the Kashm el Girba dam, and the irrigation canals within the New Half Irrigation Scheme.

(iii) Sheet Erosion

(a) Scale and Extent

Most sheet erosion in the Sub-basin occurs in the Ethiopian Highlands. Some sheet erosion occurs within Sudan, mainly on and around the rock hills (*Jebels*), which have become devoid of vegetative cover. Most of this is deposited on the footslope and does not enter the drainage system. Some water induced soil movement also occurs on the flat clay plains, but given the poorly developed surface drainage system little sediment reaches the main rivers.

Within the Tekeze Sub-basin the main area of high soil erosion hazard follows the western side of the spur of highland that trends north-westwards from the Simien Massif. This continues over the watershed into the main Tekeze Sub-basin. Within the main Tekeze Sub-basin there are three main areas of high erosion hazard. The first lies to the southwest and west of the river and follows the ridge of steep land along two ridges from the Simien Massif trending to the southeast and the northeast. A second area is found on the eastern rim of the basin in the high basaltic mountains from Korem to Adi Gudem. A third area is found in the lower Werii valley whilst a fourth area is located on the high basaltic mountains to the west of Adigrat.

However, it is important to note that much of the Tekeze Basin is in a moisture deficit area with high evapotranspiration rates (see map), particularly in those areas at lower altitudes near to the main river. Many of these areas indicate a relatively low erosion hazard but will benefit significantly from soil-water conservation measures.

The total soil eroded within the landscape in the Tekeze Basin is estimated to be 100.5 million tons per annum[8] and that from cultivated land is estimated to be

[8] This estimate accords well with an estimate of 120 million m3 by the Ethiopian Valleys Development Authority in 1991.

27.2 million tons per annum. Thus over 70 percent of soil being eroded is from non-cultivated land, i.e. mainly from communal grazing and settlement areas.

Cultivated land that has soil loss rates of more than 12.5 tons per ha per annum and thus, subject to "unsustainable" (i.e. loss exceeds soil formation or 12.5 tons/ha/yr) covers some 749,000 ha.

Of the total 100.5 million tons of soil eroded a proportion is re-deposited within the landscape, the remainder reaching streams and rivers. The ratio of the amount of sediment reaching streams to the total eroded soil is known as the sediment delivery ratio (SDR). This is considered below in the section on sedimentation. At the Basin level the estimated SDR indicates that approximately 40 percent of sediment remains in the landscape and does not reach the stream system. This is much lower than the 90 percent estimated by the Ethiopian Highlands Reclamation Study (EHRS).

(b) Impacts on Agricultural production

On-site impacts of soil erosion are reductions in agricultural productivity. Productivity is reduced because of nutrient and organic matter losses and reduced water holding capacity caused by reduced soil depth.

The impact of reduced water holding capacity caused by soil erosion was estimated using the method used by the National Conservation Strategy of Ethiopia (NCS) (Sutcliffe, 1993). This relates declines in soil productivity to declines in the soil's water holding capacity using the soil life model of Stocking and Pain (1983) as the framework. Using a model developed by FAO (1986), the Water Requirements Satisfaction Index, the relationships were established between declining soil moisture capacity and crop yield, the minimum required soil depth for cultivation and the maximum depth beyond which there is no impact on crop and pasture yield. This method allows the calculation of different yield losses for different erosion rates. The areas of cropland under different soil erosion rates were obtained by overlaying the wereda map with the soil erosion map in the GIS. Yield reductions caused by different rates of soil loss are shown in table 13.

Table 13. Annual Grain yield reductions due to loss of soil due to soil erosion and thus reduction in soil water holding capacity

Soil loss t/ha/yr	Soil loss mm/yr	Annual Yield decline %
12.5	1	**0.2%**
25	2	**0.4%**
50	4	**0.8%**
100	8	**1.4%**

In the absence of remedial measures, crop losses from soil erosion accumulate until such time the soil profile is reduced to a depth where no production is possible. The total annual crop production lost due to soil erosion for the Tekeze/Atbara basin is shown in Table 14, together with accumulated losses for 5, 10 and 25 years.

Table 14. Annual and Cumulative losses of crop production due to soil erosion (tons)

BASIN	ANNUAL LOSS T//YR	5 YRS (tons)	10 YRS (tons)	25 YRS (tons)
Tekeze	**1,850**	**8,930**	**17,854**	**44,635**

The current annual crop grain production for the Tekeze Basin is 1.06 million tons. The annual loss due to soil erosion as a proportion of total production is 0.17 percent in the Tekeze Basin. However, after 10 years this rises to 2 percent and after 25 years to 4 percent.

(iii) Gully erosion

(a) Ethiopia

Although some work has been undertaken on gully formation and extension (Billii & .Dramis, 2003, Shibru Daba et al., 2003), there is no information on gully distribution, density, erosion rates and sediment delivery ratios. Barber (1984) considers that much sediment from gullies is deposited on lower slopes without entering the drainage system. Stocking (1996) working Zimbabwe estimated sediment from gullies contributed approximately 18 percent of suspended sediment loads. Loss of cropland from gully erosion was considered to be insignificant.

Very recently research by the Universities of Makelle, Ethiopia and KU Leuven, Belgium in Tigray (Nyssen, J et al., 2005) have provided information of gulley erosion rates, sediment yields and sediment delivery ratios in northern Ethiopia. They report that gullies were initiated by a variety of changes in environmental conditions: removal of vegetation between fields, Eucalyptus planting in valley bottoms and new road construction. Gullies followed a sigmoidal evolution in volume, with a rapid increase until the mid 1990's when the rate of growth declined to almost nothing. This has been due to the considerable development of soil conservation structures and communal area closures that have occurred since 2000.

During the period of most rapid gully growth, soil erosion rates were between 13 and 27 t/ha/yr. Currently, the rates have slowed to 1.1 t/ha/yr. The average rate of total years of gully evolution was 6.2 t/ha/yr and they recommend this figure for sediment budgeting where conservation measures have not been implemented.

The figure of 1.1 t/ha/yr is approximately 10 percent of the weighted average soil erosion rate of 9.7 t/ha/yr in the area. Approximately 50 percent of the sediment reached the drainage system, the remainder being deposited within the landscape.

Thus, where soil conservation measures have been introduced and gullies are relatively stable they contribute approximately 5 percent to sediment load. Where there are no conservation measures the average rate is 32 percent. A basin-wide estimate of 20 percent has been used in the analysis.

(b) Sudan

The key problem with erosion in Sudan part of the Atbara Sub-basin is the gully erosion along the banks of the Atbara River. This erosion leaves behind land known as "kerib" land. The Setit and Atbara Rivers as they leave Ethiopia are incised below the adjoining plains by about 30 – 50 meters.

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

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

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

There are two types of rainfed cropping: large and small farms. The former are the large semi-mechanized farms whilst the latter are small-scale farmers with farms of about 5 feddans each. It can be seen from the map that the extending kerib land threatens the small farms rather than the large semi-mechanized farms. These are people who can ill-afford to loose any land because their holding are so small.

Some 3,000 ha of land are lost each year – some 40 percent above and 60 percent below the Kashm el Girba dam. Assuming a depth of 0.5m this would involve the annual erosion of soil of approximately 6 million tons/yr above the dam, and 11.25 million tons/yr below the dam. In the absence of empirical data it is difficult to estimate how much reaches the drainage system. Some will be deposited on the floodplain as can be seen at the buried Government nursery near Showak. Some 79.2 million tons/yr reaches the Kashm el Girba Dam, and 68.61 million tons/yr and 7.37 million tons/yr cross the border in the Tekeze-Setit and the Upper Atbara-Angereb rivers. This leaves 3.22 million tons entering the rivers between the border and the dam (a SDR of 54%). Using the same SDR then some 6.08 million tons would enter the river below the dam.

There are two key issues in initiating any programme of arresting kerib land formation and its subsequent reclamation. The first is the compensation and reallocation of land to farmers whose land is used as the buffer zone to arrest kerib formation. The second is the question of land tenure of the reclaimed kerib land. Whilst community division and allocation of land is the current policy, consideration should be given to allocating the kerib land on an individual basis. This is now the strategy for reclaiming degraded hillsides in Tigray in the Upper Tekeze basin in Ethiopia and is proving extremely successful. In some cases landless households are being allocated degraded land and provided with technical and material support to undertake the reclamation work.

(iv) Loose and Shifting Wind Blown Shifting Sand

The main area where shifting wind blown sand is a problem is in the Gash Irrigation Scheme. In 1923 the irrigation Advisor the Sudanese Government noted the problem of drifting sand into the new canals, which suggests that there was no cover in the central area of the delta even then. A part of the problem is the gradual degradation of the flooded woodland due to extraction of fuelwood and wood for charcoal and house construction.

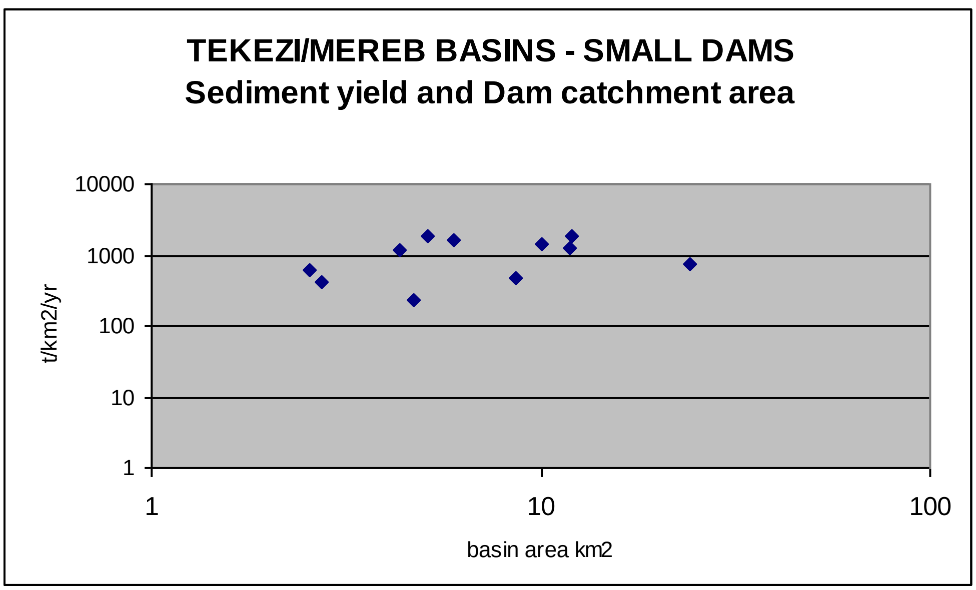
A second area is along the lower Atbara where drifting sand is covering fields and canals. A study by Mekii Abdel Latif (2005) found drifting sand a serious problem endangering crop production in a large number of villages. Approximately 30 percent of the cropland is invaded by sand. n irrigation ditches causes severe problems in water management and entails long hours of pump operation because of the increased porosity of canal linings. Wind-borne sand causes severe physical damage to plants often completely shredding leaves.

(v) Suspended Sediment in the Tekeze-Atbara River System

(a) Small Catchments

Sediment yields generally decrease with increasing catchment area (Walling, 1982). Considerable research has been undertaken by Makelle University and KU Leuven (Belgium) on sedimentation in small dams in Tigray (Nigussie Haregeweyne et al., 2005, Nigussie Haregeweyne et al (in press). They surveyed 54 recently built small dams in Tigray and found that 70 percent had significant siltation problems (in addition to problems of seepage and insufficient water supply). The estimated sediment yield varied from 237 to 1,817 t/km^2/yr with a mean of 909 t/km^2/yr (+/- 500 t/km^2/yr). The variation in sediment yield was attributed to differences in lithology, gully networks and human action. Research into small dam sedimentation in the Mereb-Gash basin (Colombo & Safatti, 2005) in Eritrea (in catchments between 6 and 12 km^2 in area gave sediment yields of between 1,624 and 1,816 t/km^2/yr. The scatter plot of the sediment yield to basin area results are shown in figure 5. This indicates a slight increase in sediment yield with increasing basin size but this is not statistically significant.

Figure 5. Tekeze and Mereb basins – Small Dam catchments: Relationship between sediment yield (t/km2/yr) and Catchment Area (km2)



(b) Basin-wide Sediment Loads

The average sediment yield, total sediment and estimated sediment delivery ratios for six stations in the Tekeze-Atbara Sub-basin are shown in table 15.

Table 15. Sediment yield, total sediment load and sediment delivery ratios for six locations in the Tekeze-Atbara Sub-basin.

River (/source)	Location	Area (km2)	Sediment yield (t/km2/yr)	Total sediment (million t/yr)	Total erosion (million t/yr) (incl. gulley sediment)	Sed. delivery ratio
Tekeze 1/	Embamade	25,063	798	36.40	60.7	58%
Tekeze/Setit	Showak	67,223	1,020	68.61		
Upper Atbara	Above Junction with Tekeze-Setit	15,390	479	7.37		
Angereb/Bahir As Salam	Junction with Upper Atbara	14,662	283	4.15		
Upper Atbara	Above junction with Angereb-Bahir As Salam	10,372	311	3.22		
Atbara 1/	Kashm el Girba	80,000	900	79.20	120.5	66%

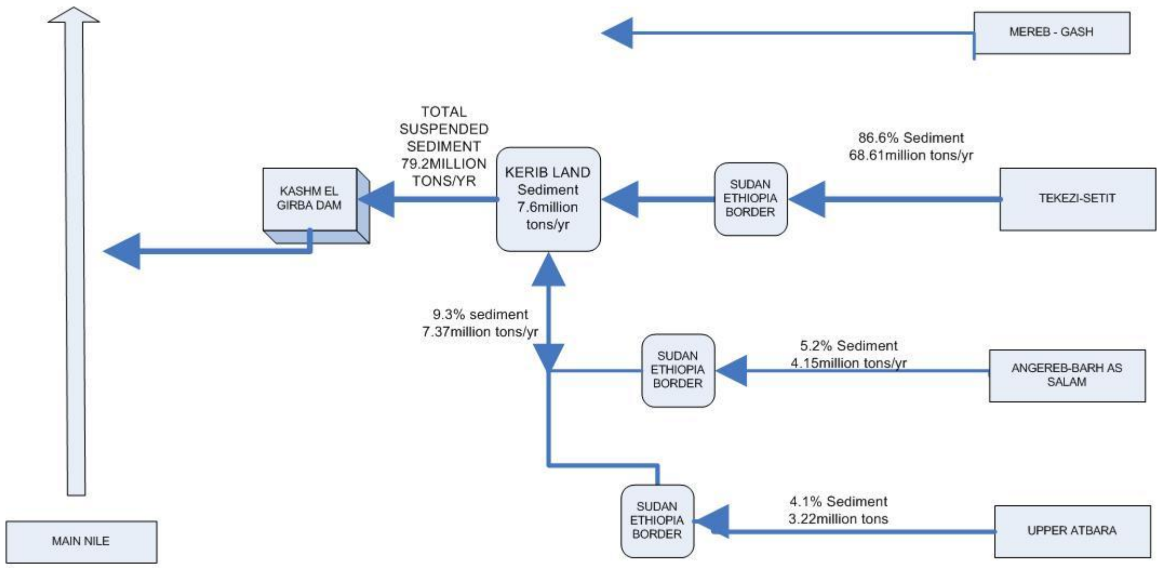
1/ Tekeze Medium Hydro-Project, 2001, UNESCO-HELP: Atbara (Ethiopia, Eritrea, Sudan): Basin Properties.

Kashm el Girbe is 180 kms below the border with Sudan whilst Embamade is close to the junction of the Tekeze and its tributary the Werii. Some sediment from the eroded *Kerib* land will be contributing to the sediment load in the Atbara within the Sudan[9], which could account for the slight rise in the sediment yield. Three of the stations are in the Angereb-Atbara Watershed. The relative positions are shown in figure 6.

The figures in table 8 indicate sediment yields of between 798 and 900t/km2/yr in the Tekeze-Setit Watershed. Those in the Angereb-Upper Atbara watershed vary between 283 and 489 million tons/km2/yr. The land cover in the Angereb-Upper Atbara Watershed is more dense that the Tekeze-Setit watershed.

The sediment delivery ratios over the whole basin are estimated between 58 and 66 percent. These estimates are close to those quoted by Walling (1982) for Texas, USA, well below the nearly 100 percent quoted for China and well above those for the central and eastern USA. They are certainly well above the rate assumed by the EHRS (of 10 percent) and by Barber (1984) of 2 to 3 percent.

Figure 6. Tekeze-Atbara Basin: Annual suspended sediment loads and percentages passing into the Kashm el Girba Reservoir.



TEKEZI-ATBARA SUB-BASIN
ANNUAL SUSPENDED SEDIMENT LOADS AND PERCENT OF TOTAL PASSING INTO KASHM EL GIRBA RESERVOIR AT SELECTED LOCATIONS

(c) Conclusions

There is no significant difference between the sediment yields of small and large catchments, with the mean of the small catchments close to that of the large catchments. This would appear to indicate there is little or no storage of sediment within the Tekeze-Atbara River system, a factor normally attributed to declining sediment yields with increasing catchment areas. However, this is to be expected given the steep gradients in both tributary and main rivers. Given the relatively high sediment delivery ratios and very similar sediment yields it would appear that the Tekeze-Atbara River system is relatively efficient in delivering and removing eroded sediment from the landscape.

The inference of this is that interventions to reduce in-field erosion are likely to have a relatively immediate impact on sediment loading in the river system.

(d) Sediment Passing into the Main Nile

An average of some 79.2 million tons of suspended sediment enters the Kashm el Girba dam each year. It is estimated that 10.12 million tons is retained within the reservoir under the current flushing regime (see below). This would indicate that some 69 million tons passes through the sluice gates. Some 14 percent of the annual flow is diverted to the New Halfa Irrigation Scheme. Assuming that the same proportion of sediment enters the scheme this would leave approximately 59 million tons of suspended sediment being carried below the irrigation intake. A further 6.08 million tons enters from the Kerib land below the dam making an estimated 65 million tons of suspended sediment entering the Main Nile.

Of the 142 million tons of suspended sediment in the Main Nile (at Dongola) some 25 percent is said to be derived from the Atbara. This would indicate that only 37 million tons enters the Main Nile from the Atbara. There is clearly a significant difference between 37 million and 65 million tons. The latter figure would indicate that the Atbara River contributes 45 percent and not 25 percent of the sediment at Dongola. Some sediment could be deposited on the Atbara Floodplain during high flows but this would have to amount to 28 million tons to account for the difference.

(vi) Dam and Reservoir Siltation

(a) Impacts of Soil Erosion

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

(b) Small dams

In Tigray in the Tekeze Catchment a recent survey of 54 recently built small dams found that 70 percent had significant siltation problems (in addition to problems of seepage and insufficient water supply) (Nigussie Haregeweyn et al., in press). As a result of these problems, and because of a shift in government focus to micro-irrigation, construction of "small" or "micro" dams" (i.e. dams for irrigation purposes, with a storage capacity of 0.5-3 million m3, equipped with a spillway) stopped in 2001. Construction of "ponds" (up to 0.5 million m3, for water supply or micro-irrigation and without a spillway) has continued although facing similar problems.

(c) The Kashm el Girba Dam

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

The main problem is siltation in the reservoir and the necessity to allow the rising flood peak to pass through the dam to reduce siltation and allow sediment in the dam to be flushed out. The dam was constructed in 1964 with a capacity of 1.3 km^3 to be able to irrigate an area of 0.5 million feddans (0.2 million ha). The mean annual suspended sediment load entering the reservoir is 79.2 million tons/yr.

Because of excessive siltation flushing in mid-August was instituted in 1971. Prior to flushing annual sedimentation was estimated at 12.3 million m^3 and with flushing 7.0 million m^3 (approximately 8.12 million tons), a trapping efficiency of about 10 percent. In 1990 capacity had been reduced to 0.62 km^3. [10] At the current rate of sedimentation it is estimated that in 2006 it has only 39.6 percent of its capacity remaining and capacity is being lost at the rate of 1.13 percent per annum.

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

These have had a substantial impact on the area irrigated in the New Halfa Scheme. The scheme covers some 447,000 feddans (190,000 ha) and was developed primarily to resettle people displaced by Lake Nubia at Wadi Halfa. It is designed to use 1.62 km^3 of water from the reservoir for irrigated cropping as follows:

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

By 1997 the area irrigated had been reduced as follows:

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

[10] Diab H Diab & Mufadel E.Ahmed "Environmental Degradation in the Nile Basin: River Atbara Case".

This is an overall reduction in area of 172,000 feddans (72,240 ha) some 52 percent. In addition crop yields declined over the same period. As a consequence crop production has declined significantly as shown in table 16.

Table 16. Average crop yields: 1967 and 1990 (tons/feddan)

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

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

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

(vii) The Gash Irrigation Scheme

(a) Background

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

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

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

(b) Impacts of Sedimentation

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

Average annual deposition of sediment in the canals is about 40 cms but at the entrance is 300 cms. This deposition reduces the efficiency of the canals, whilst breaks in the canals cause erosion and complete loss of control of the irrigation water. A further impact of canal sedimentation is wed infestation which further reduces water flow. Crusting of the sediment in the fields impedes water infiltration and plant germination. Deposition on the river bed leads to canal off-takes being much higher than the surrounding land. This further increases the damage caused by breaks in canal walls.

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

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

The sediment management cannot just work on one canal in isolation. The whole water and sediment transport must rise as one, so that there is an equal amount of sediment in each section of the system. Thus, every so often each off-take structure must be rebuilt at a higher elevation.

Because each flood is different in timing and amount, the management system must highly re-active to rapidly changing circumstances. There is therefore a designed flood area of 40,000 feddans, which means in practice that in many years there is excess water or that many fields are over-irrigated. This excess water is released to the *balag* forest or to the Gash Die where it supports the natural woodland.

3.5.2 Issues of Soil Degradation and Loss of Agricultural productivity

(i) Relevance to Transboundary Analysis

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

(ii) Ethiopia

(a) Burning of Dung and Crop Residues

In the Ethiopian Highlands the immediate causes are the burning of dung, removal of grain and soil erosion. It is estimated (WBISPP-MARD, 2002, 2003) that within the Tekeze Basin some 809,400 tons of dung collected from crop fields (about 40% of total dung produced) and some 902,370 tons of crop residues were burnt as household fuel. This resulted in a loss of some 17,460 tons of N and 3,990 tons of P.

(b) Nutrient Losses through Removal of Grain

An estimated 738,560 tons of grain is removed from cropland annually. This would account for an additional 14,770 tons of available N and 2,950 tons of available P being removed.

(c) Nutrient Losses from Soil Erosion

Another source of soil nutrient losses at the field level is soil erosion. Hashim et al (2000) estimate nutrient loss as:

*Nutrient Loss = Soil loss * Nutrient concentration of topsoil * Enrichment ratio*

where the enrichment ratio refers to the ratio of the additional minerals and organic matter in eroded soil compared with the original soil. Barber (1983) estimated enrichment ratios of 2 for N and organic matter. As only about 2 percent of the total N and 0.16 percent of P is available in any one year, replenishment costs should be based on this proportion. Using Barber's estimated annual nutrient losses from different soil erosion rates, and a sediment delivery to streams ratio of 59 percent, losses of available N would be approximately 1,886 tons with 810 tons of available P on 2.6 million ha of cultivated land from 27.2 million tons of soil that is eroded.

Against these N losses are annual increments of N from rainfall and asymbiotic and symbiotic fixation. For Ethiopia these are estimated to be 15 kgs per ha per annum (Sanchez, 1976). From external sources there is an annual increment of 39,320 tons of N. Storvogel and Smaling (1990) estimate that some 30 percent is lost through leaching and gaseous exchange (approximately 10,920 tons/yr). Thus, it would appear that there is a net loss of N of about 6,600 tons or 2.54 kgs/ha from burning dung and residues, grain removal and soil erosion.

However it is important to note, as Barber comments, "the prediction of soil nutrient losses is a very dubious and precarious exercise based on very limited amount of "hard" data and involving many estimates".

(iii) Sudan

(a) Semi-mechanized Farms:

Within the Tekeze-Atbara basin in Sudan there are approximately 2,004,050 feddans (841,700 ha) of large to medium semi-mechanized farms (SMF)[11]. However, a proportion of this land has gone out of production and in some cases has been abandoned. The FAO/WFP crop survey for 2005, estimated that cereal production from the SMF Sector for Gederef State was 589,000 tons. Average yields are 0.36 tons per ha, which suggests that approximately 1.636 million hectares were under crops. The Africover estimate for land under SMF's in Gederef State (in 2000) was 4.091 million hectares. This suggests that in 2005 (a good rainfall year with high sorghum prices) only 40 percent of the SMF land was cropped.

During the 1990's the area harvested on the SMF's contracted by 2.4 percent per annum whilst yields declined even further by 5.1 percent per annum (World Bank, 2005). This resulted in a decline of GDP from SMF sector of 6.7 percent.

These reductions in yield are partly due to a decline in soil fertility in the absence of fallowing or fertilizer application. There has also been a decline in productivity partly due to the build-up of weeds (including striga) and partly to an expansion onto marginal land resulting in destruction of soil structure, soil erosion and soil fertility. The removal of natural predators (snakes and cats) has led to an increase in rats and other vermin. Insect eating birds have disappeared leading to a big increase in the use of insecticides and insect damage.
With only approximately 36 percent of the land being cropped and yields declining at just over 5 percent per annum this represents a substantial waste of natural resources.

[11] Africover mapping of rainfed cropping with large to medium size fields.

(b) Small-scale Traditional Farm Sector

There is approximately 60,250 feddans (31,330 ha) of small-scale rainfed cropping. Spatial expansion of the traditional sector is severely constrained by the SMF's to the west and the State Forest reserves to the east. This is resulting in shortening fallow periods and thus declining crop yields. Sorghum yields in the traditional crop sector have declined in line with those in the SMF sector and are currently about 0.4 tons/ha, down from about 0.9 tons/ha in the 1970's.

3.5.3 Issues of Changes in Woody and Herbaceous cover within the Sub-basin

(i) Upper Catchments

Following the cessation of the civil war and return of large numbers of refugees from Sudan there was some expansion of agriculture in the Tigray region of the Tekeze basin. However, over the past five years little expansion of agriculture, and thus complete clearing of woody vegetation have taken place in the highlands as agricultural expansion has reached the limits of cultivable land.

Degradation of woody biomass is caused in the main by the removal of wood for household fuel. Removal of wood in excess of the sustainable yield (after accounting for removal of dead wood and fallen branches, leaves and twigs) leads to declining stocks, which in turn leads to declining yields and so to permanent degradation of woody biomass. It is estimated that in Tigray region currently wood consumption as fuel exceeds sustainable supply by 1.27 million tons per annum. Note that this does not include wood removal for new house construction and current house maintenance. The pattern of weredas consuming in excess of sustainable yield mirrors that of the weredas with high proportions of their area experiencing moderate to severe soil erosion.

Degradation of herbaceous biomass is caused mainly by overgrazing of livestock. An indicator of overgrazing can be determined by examining the livestock feed energy balance at the wereda level. Energy requirements of all livestock are computed using energy requirements for maintenance, draught power and lactation, and balanced against estimates of energy supply from natural pastures and crop residues (WBISPP (2003, 2004). In the Tekeze Catchment weredas along the eastern and north-eastern part of the basin, as well as those trending north-eastwards from the Simien Massif stand out as livestock feed deficit areas and thus likely to be severely overgrazed. Again the pattern generally mirrors that of weredas with high proportions of their area experience moderate to severe soil erosion.

(ii) Lower Catchments

In the Ethiopia Lowlands there has been a substantial increase in clearing woodland and shrubland for both small and large scale agriculture. This has occurred on the clay plains that extend into Ethiopia from Sudan. The area from Humera southwards to the Dinder watershed has seen voluntary resettlement of people from the Highlands as well as expansion of commercial agriculture. In the absence of monitoring of land use changes in this area it is not possible to quantify the amount of clearing that has taken place.

On the Sudan side of the border the expansion of semi mechanized rainfed agriculture commenced many decades before and has probably reached the limits of its expansion. As indicated above some 2.0 million feddans (0.84 million ha) have been cleared.

Over the past three decades the south-eastern part of the Sub-catchment has received large numbers of refugees from Eritrea and Ethiopia, as well as many immigrants from West African countries, and IDP's from western areas of Sudan. This massive expansion in population has had a severe impact on the remaining woodlands because of the demand for own-consumption of fuelwood as well as fuelwood collection and charcoal production as livelihood strategies. Kibreab (1996) estimates the rural per capita consumption of charcoal and fuelwood near Gederef to be 0.63 and 0.54 m3 /yr respectively: a total of 1.13 m3 /yr. Using this estimates approximately 2.43 million m^3 of wood are consumed annually forming about 80 percent of the total energy consumption. Woodlands provide all building materials in rural areas.

3.5.4 Trends in Soil Degradation in the Tekeze Sub-basin with no Watershed Management Programme

(i) Introduction

In the centuries before 1975 there had been a slow drift of people from the north moving south to less populated areas. Following the Land Reform of 1975 internal movement within rural areas became difficult particularly in the north where cropland was already short. Peasant Association[12] Committees allocated land and first preference was always given to dependants of existing families. Nevertheless, there was continued migration into the sparsely forested areas of the southwest.

During the early 1980’s a Resettlement Campaign resulted in large numbers of people being moved from the high population density areas to areas in the western Lowlands. Two strategies were followed: (i) movement to large

[12] Areas with defined boundaries approximately 1,500 ha in extent with about 300 – 400 families.

Resettlement Camps, and (ii) a less intensive approach where families were "integrated" into existing highland areas mainly in the southwest. There were many documented instances of involuntary resettlement and following the change in Government in 1991 many of the large Resettlement Camps emptied with people returning to their home areas.
Since 2003 a new official voluntary resettlement programme is in place (Government of Ethiopia (2003). Movement of settlers is confined to within-region movement only – no inter-Regional movement of people is envisaged (the "restricted" migration scenario of (Sonnerveld, 2004). The programme is designed to take into account lessons from resettlement programmes in the past.

Both the 1984 and 1993 CSA Population and Housing Census have data on the numbers of people who were born out the wereda they were living in the time of the census. There are two main of reasons why these censuses cannot be used to estimate the direction and size of population movements between 1984 and 1993. The Censuses do not indicate the weredas of origin of migrants. Secondly, many weredas have changed names, boundaries or have been amalgamated between the two censuses.

(ii) Methodology to Determine Expansion of Cultivated Land – 2005 to 2025

In order to make an approximate assessment of the possible trends in the expansion of cultivated land over the next 20 years a two pronged approach has been adopted. Firstly, a subjective assessment has been made based on observations made on land cover and settlement changes during field trips over a period of 20 years. Secondly, data at the wereda level on the population support capacity status[13] was used to define four categories of wereda:

- Category 1: weredas that (in 2005) were cultivating in excess of the land classified as being "arable" for rainfed cropping (i.e. FAO Crop Suitability Classes S1 to S3). These were said to be "Critical" in their population support capacity.
- Category 2: Weredas that were using all the land classified as being "arable. These were said to be "At capacity" in terms of the support capacity.
- Category 3: weredas that would reach their support capacity within 10 years at current population growth rates using current levels of farm technology.
- Category 4: weredas that would reach the support capacity by or after 20 years.

[13] Taken from the population support capacity analysis undertaken by the WBISPP for Tigray, Amhara, Oromiya, SNNPR, BSG and Gambela Regions.

It was assumed that weredas in the first category would be unable to expand their rainfed cropland any further and thus cropland soil erosion rates in the absence of SWC interventions would continue at their current levels. Weredas in category 2 would expand their area of cropland at the current population rates with each incremental farm family converting the current farm size (specific to each farming system) plus an addition 50 percent to cover the area for settlement upto the 5th year, when no further expansion would be possible. Using the same assumptions, weredas in the third category would be able to expand the area of cropland without restriction upto the 10th year and those in the 4th category would expand for the full 20 years.

(iii) Subjective Assessment of Population Movements

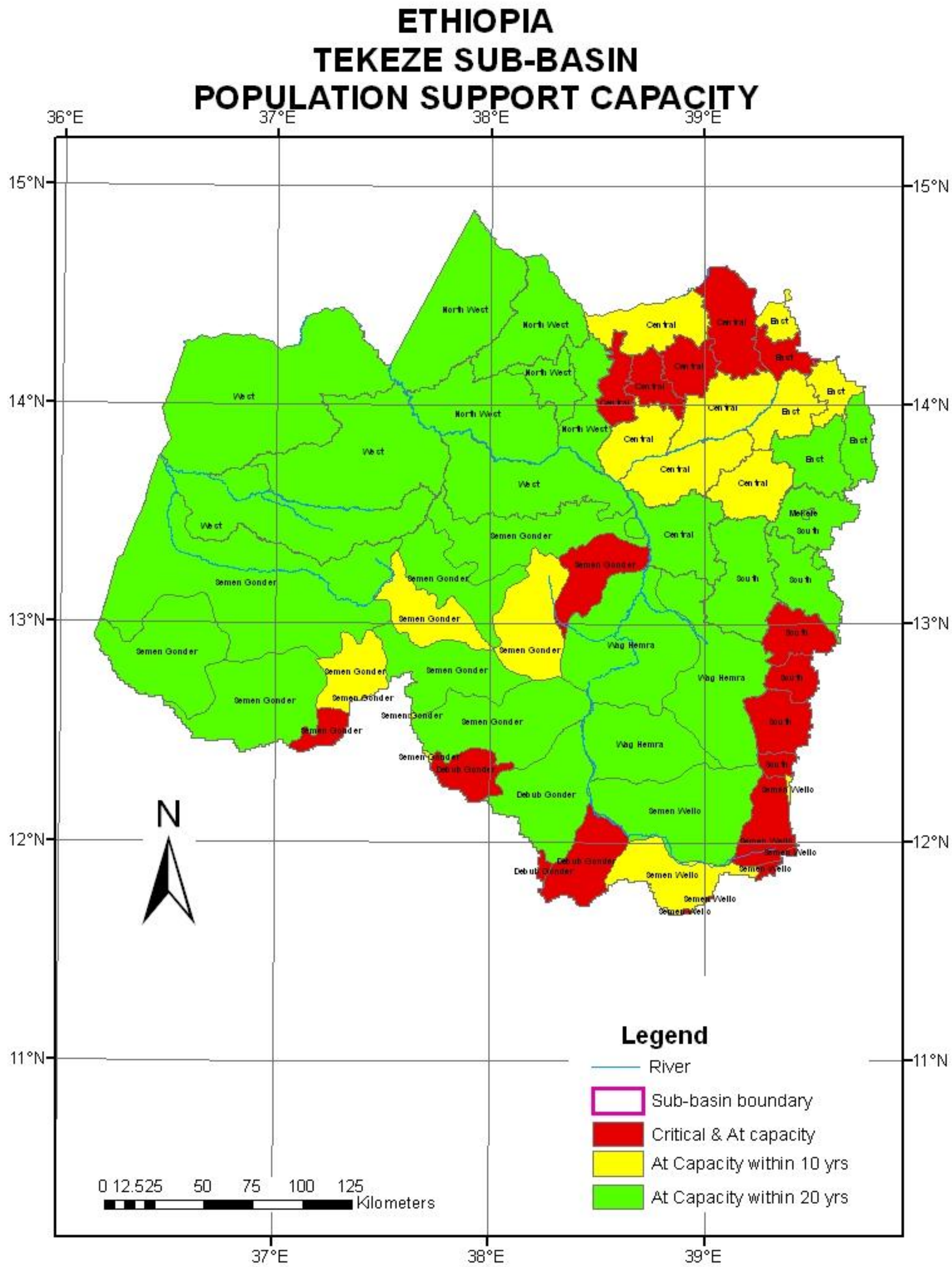
It is likely that there has been little expansion of cropland in the highlands of the Tekezi Basin after the return of refugees between 1991 and 1995. Most expansion has occurred in the inner parts of the middle Tekezi valley and in the western lowlands. The area around Humera has also seen resettlement sponsored by the Tigray regional Government.

In the western Lowlands generally slopes are shallow although the soils derived from the Basement Complex rocks are very erodible.

(iv) Assessment of Cropland Expansion using the PSC Categories

The spatial distribution of the three categories of weredas is shown in Map 20.

The number of weredas in category 2 is probably underestimated in the Tekeze Sub-basin because no account has been made of returning refugees following the cessation of the civil war. Additionally, in North Wello and Wag Lasta the potential arable land is of very low fertility and farmers do have sufficient oxen to plough the area required for subsistence. Most of the category 1 and 2 weredas are located in the eastern Highland areas of the three Sub-basins. A small area of category 1 and 2 weredas occurs in the northern part of the Baro-Akobo Sub-basin. Clearly, the main areas were unrestricted expansion of cropland will occur or the western Highland s and Lowlands.



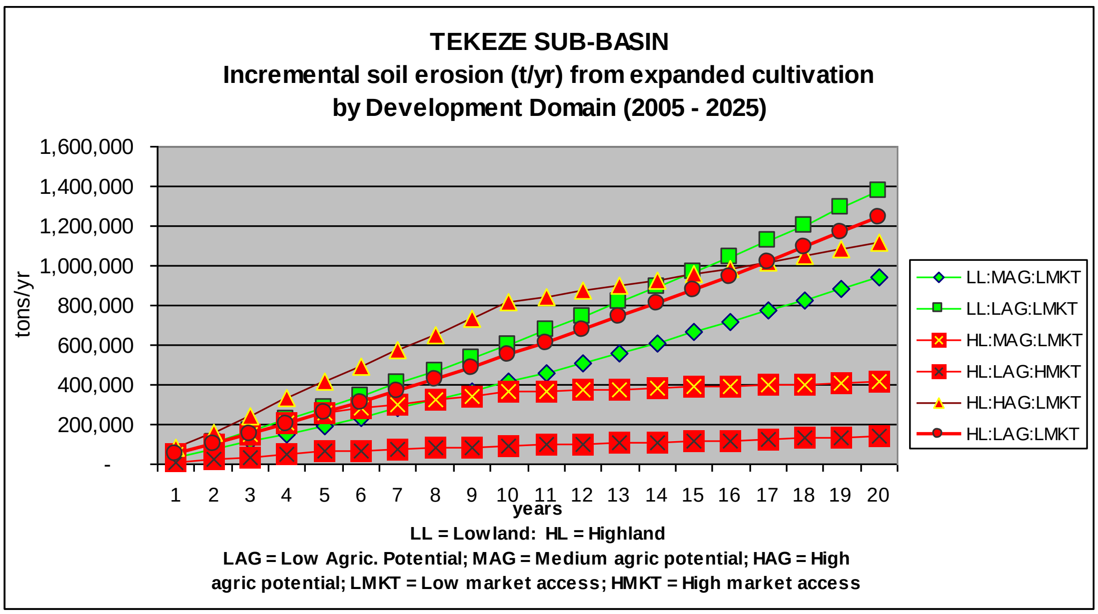
Map 20. Tekeze-Atbara Sub-basin: Ethiopia – Population Support Capacity
Source: WBISPP (2003)

The results of the analysis are shown in Chart form below for the three Sub-basins.

Tekeze Sub-basin

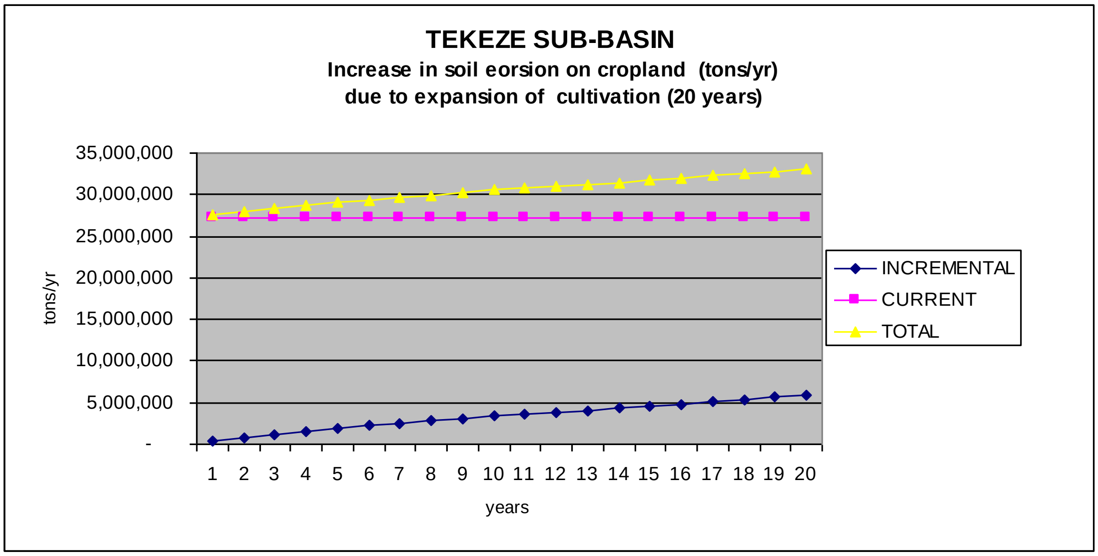
In the Tekeze Sub-basin the largest expansion of cropland will take place in the Highland Low Agricultural Potential-Poor Market Access Domain, followed by the two Lowland Domains (figure 7). As stated above the population support capacity analysis may overestimate the potential for expansion of cultivated land. The Highland Medium Agricultural Potential-Good Market Access domain has no potential and the Medium Potential-Poor market Access Domain has very limited (only 2 out 11 weredas) potential for expansion.

Figure 7. Tekeze Sub-basin: Estimated Expansion of Cropland by Development Domain (2005-2025).



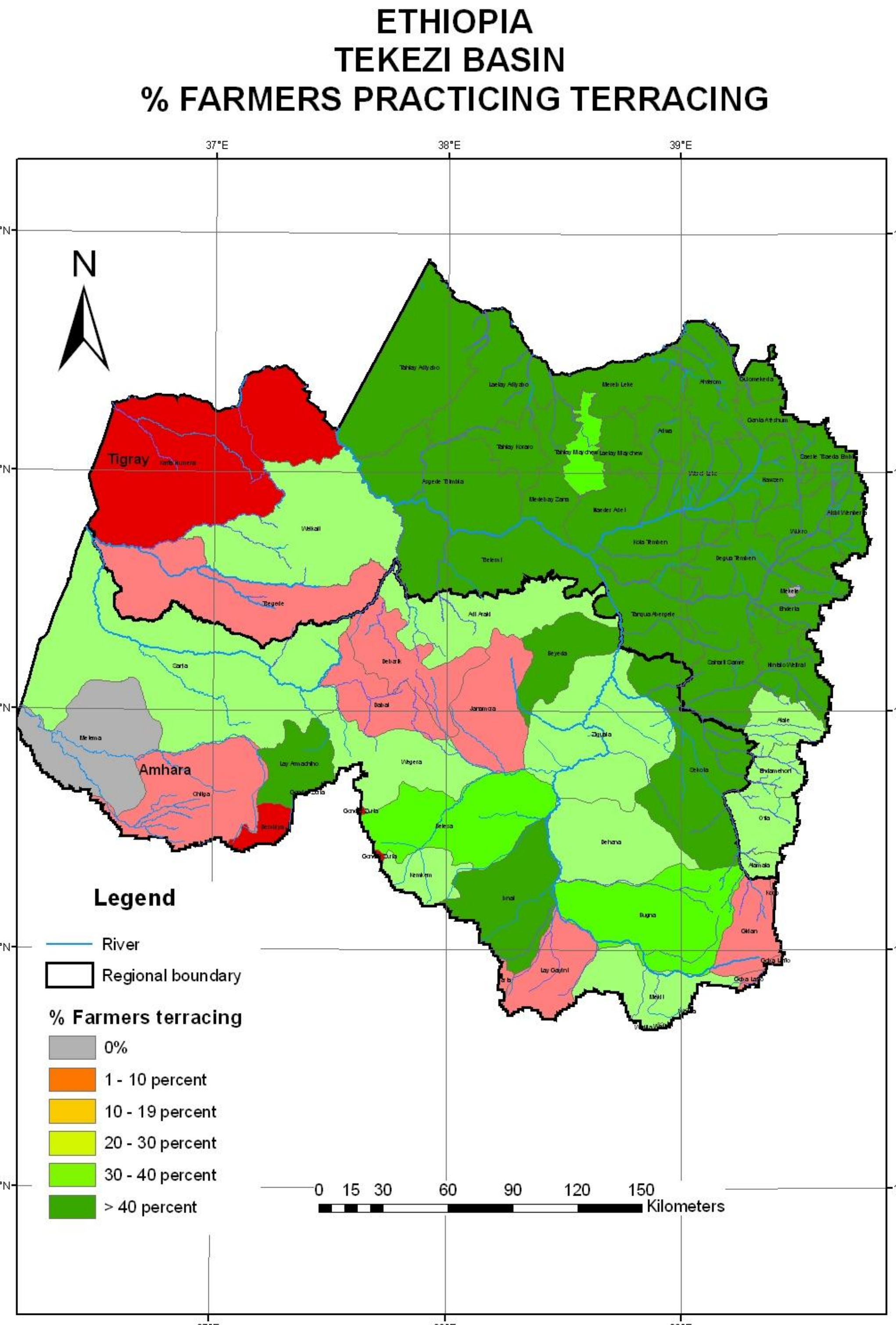
The additional soil erosion caused by the expansion of cropland is indicated in figure 8. The analysis indicates an increase by 2025 of approximately 7.15 million tons/yr or 21.7 percent on the current rates.

Figure 8. Tekeze Sub-basin: Incremental Amounts of soil erosion from expansion of cropland (tons/yr) in the period 2005 – 2025.



In the absence of preventative measures, declining soil fertility and organic matter content are likely to increase soil erodibility. However, there have been some increases in the adoption of soil and water conservation and soil improvement measures over the past ten years. Map 21 indicates the percentage of farmers who have adopted terracing. Adoption has been more successful in the eastern part of the Sub-basin where the positive impacts on soil-water conservation are more successful than in the wetter areas in the west. Overall, it appears that approximately 19 percent of cropland in the Abbay Basin has now been terraced. Not shown on the map are the adoption rates of soil bunds and grass strips.

An un-quantified area of cropland is also receiving improved tillage and soil amelioration measures (composting, contour ploughing, etc). One of the main causes of soil nutrient depletion is the burning of dung and residues and grain removal from fields without nutrient replenishment. However, the WBISSP Strategic Plan for Amhara Region reported a decline in residue and dung use for fuel as result of the very large increase in on-farm tree planting since 1991. The annual rate of decline is about 3 percent.



Map 21. Tekeze-Atbara Sub-basin: Ethiopia - Percentage farmers adopting terracing in Ethiopia.
Source: Mahmud & Pender (2005)

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 Ethiopia

4.1.1 Historical overview

In Ethiopia a major review of past watershed management activities started following the fall of the Derg and the formation of the Transitional Government of Ethiopia in 1991, although some evaluations had started before. A number of studies have evaluated the pre 1991 watershed management activities in particular the “narrative” or “discourse” that shaped the very large soil and water conservation programme that was implemented during this time (Hoben, 1995, Rahmato, 2003). Other studies have focussed on more technical aspects of the conservation structures (Herweg, 1992). An overall assessment has been provided by Alemneh Dejene (2003) and may be summarized as follows:

- In many areas there were substantial benefits with improved soil conservation, planting of woodlots and improved pastureland.
- Many structures were costly in terms of land taken out of production, labour inputs for physical structures were very high, and there was little attempt to incorporate indigenous soil and water conservation techniques. In some areas structures were technically inappropriate and caused water logging.
- The programme focussed narrowly on arresting soil erosion without considering the underlying causes of low soil productivity, the socio-economic factors and the need for immediate tangible benefits to be attractive to poor farmers.
- The programme adopted a very “top-down” approach in its planning and implementation. There was little or no consultation with farmers or communities on felt needs. Woodlots were implemented with no harvesting plans.
- Although a “watershed” approach was adopted the basin size was too large to acquire an understanding of the socio-economics of

land degradation and farmers willingness to invest in improved land management.

The result was that many structures and woodlots were destroyed following the change in government.

Since 1993 watershed management activities in Ethiopia have undergone a radical change in approach. Alemayehu Tafesse (2005) provides an overview and assessment. The major programme is the MERET (Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods") Project, which is a successor to the previous large scale Soil and Water Conservation Project (ETH-2488, Phase I, II, III, IV) that ran from 1982 to 2002. An assessment of this Project is provided by Gete Zeleke (2005).

The most important change has been from a highly centralized to a decentralized approach. The new approach uses local level participatory planning as its main tool. The community is in control of decisions regarding development options to implement. The focus is on resource conservation as well as productivity enhancement.

The basic unit for planning is a micro-watersheds (200-500 ha) at the Kebele level. However, although watershed logic is followed it respects community boundaries. Food for work is used for community motivation. Self-help is increasingly encouraged, however with limited results. Quality control and maintenance of good standards are seen as very important, but in reality are facing serious constraints that threaten sustainability. An appropriate and effective system of monitoring and evaluation should ensure timely and useful feed back to the overall programme.

4.1.2 Observations and Lessons Learnt

(i) Priority for interventions

The strong relation between SWC and food aid, the latter being concentrated in food deficit areas, has led to a relative neglect of this work in food sufficient or surplus areas such as West Gojam and Wellega in the Abay Basin and many parts of the Baro-Akobo basin. In these areas similar works are required but with an emphasis on erosion control. This is confirmed by many, also by the WFP Mid-Term evaluation (2005).

(ii) Innovative approaches

The better linkage between SWC, water harvesting and agricultural diversification (based on micro-irrigation) that have been introduced by the MERET project, were certainly innovative for the Ethiopian context. It is fully compatible with the “improved ADLI policy” and is now applied by all.

Promising trials of genuine community participation have been practiced in a SNV supported project in Bugna wereda (N.Wolo in Tekeze basin), and in a project of SOS-Sahel in Meket wereda in the far north of the Abbay basin. Agreements had been made with Kebele leaders that farmers could use the 20 days of unpaid “community participation” labour for SWC on their own lands, and that these lands were exempted from land re-distribution. In both cases, the wereda did not have the capacity to adopt these approaches after project termination in 2002. SOS-Sahel is still active in Meket, in capacity building to weredas and in impact studies of land certification. It is up-scaling local-level NRM to Wadla wereda.

(iii) Technology innovation

Some important technology innovations have taken place in watershed treatment. Currently these are at a small scale. The former GTZ-supported Integrated Food Security Project in South Gondar (ANRS), now coming under the SUN programme, had put the largest possible emphasis on biological measures, both for on-farm conservation and for gully stabilization. Introduction of Vetiver grass was strongly promoted there and by MFM in Illubabor in the Baro-Akobo Sub-basin.

The most substantial change has been the greater emphasis on water resource development enabling the expansion of micro-irrigation, and thus agricultural/ horticultural diversification and commercialization. This change has been introduced by the MERET Project but has now been adopted by most actors. Water resource development (e.g. construction of shallow wells) is a logical step following improved water retention through SWC measures. It proves to be most productive in watersheds where SWC is widespread. An example is the case of Abraha Atsbaha Tabia, in the Northern Zone of Tigray in the Tekeze-Atbara Sub-basin, where long term activities in separate Kebeles have now resulted in an aggregated protection of almost the entire watershed (of some 3,000 hectares).

(iv) Water harvesting

Water-harvesting (e.g. ponds, small earth dams, river diversion) has become an essential ingredient of SWC programmes, although it has known limitations. The IDEN-ENSAP Watershed management Study (ENTRO, 2003) reviewed water harvesting experiences in Ethiopia and concluded as follows:

- Pond and canal seepage are limiting factors, reflecting problems in design, construction and supervision.
- Inflows from harvesting areas have been less than expected due overly optimistic runoff coefficients.
- Excessive sedimentation is a problem, pointing to need to integrate water harvesting with the overall catchment management.
- Pond water is insufficient for dry season irrigation, and is often actually used for supplementary irrigation in the wet season.
- Water should be used on high value crops, but horticultural crops have high input costs and have limited storage capacity (where markets are thin).
- Water borne diseases (malaria and bilharzias) and safety need to be considered.
- Success was achieved where both technical and social aspects were adequately covered.

(v) Impacts and implementation efficiency

Local level watershed protection has been undertaken for three decades, at enormous cost. Large areas have been treated now, particularly in the Tekeze Sub-basin. The NRM Department in Tigray admits that “impacts are not yet in relation to the efforts made through time”, but that the achievements are considerable:

- about 25 % of cultivated land treated,
- 200,000 hectares under area closure,
- 300,000 hectares of natural forest being exploited in a proper way.

Improved crop transformation and improved livelihood conditions are also mentioned as main achievements.

Research activities (Mekele University, project’s own evaluations, and in earlier days, the SCRP) have shown that SWC has a positive impact in terms of erosion control, moisture retention and land rehabilitation. The Inter-University Cooperation project (IUC) of Mekele University estimates that terracing on cropland produces an average net increase in crop production (including the loss of land) of 3 %. Revival of natural springs is also mentioned as an important indicator.

However, the cost efficiency of all the work is rarely questioned. After many years of SWC practice, field observations still lead to similar conclusions:

- SWC implementation follows a blanket approach, structures are often over-designed; no flexibility or refinement in measures can be observed based on varying terrain conditions,
- maintenance is generally inadequate or lacking,
- there is a strong predominance of mechanical, loose rock structures which could be replaced in many places by cheaper, biological measures contributing in the same time to productivity,
- quality control is limited to target fulfilment and is not concerned with optimum impact of measures.

The type of data collected with regard to SWC implementation generally focuses on physical achievements (i.e. length of terracing, seedlings produced, etc).

After three decades of massive soil conservation campaigns, it is possible to trace exactly how much food was spent, but it is not possible to say what the impact has been on agricultural production, farm incomes, which areas have been covered (and even covered how many times) and whether the work was carried out in an efficient way.

(vi) Some selected cost figures

A few data on average overall costs of micro-catchment treatment are available:

- King and Leul Kasahay (2006) estimate the average cost of micro-catchment treatment following the CBPWM approach, at about US$180,000 for a catchment of some 200-500 hectares, i.e. about US$ 360-900/ha or ETB 3,000-8,000/ha.
- GTZ has calculated an average cost of US$ 115,500 (ETB 1 million) per micro-catchment, which is in the same order of magnitude (two thirds) of the previous estimate by King and Kasahaye.
- The evaluation report of Irish Aid activities calculated a cost of ETB 3,000 /hectare (85 % of which is SWC and gully treatment) for investment cost only and excluding project overheads. The same document reports the possibility to recover the program investment costs of ETB 1.8 million within 3 years.

- The IUC project (Mekele University) gave as a rough estimate an average cost of about ETB 5,000/hectare, to be repeated every 10 years.

- The MDG needs assessment document estimated unit costs of watershed treatment to amount to an average of 2,500 – 3,000 ETB/ha (based on standard WFP work norms, including materials and equipment but excluding project overhead costs).

The above indicative figures all relate to activities compensated in food or in kind, and are probably based on the same standard work-norms developed by MoARD and WFP. The variation is probably related to different average intensity of works assumed, and different proportions e.g. of hillside closure (relatively cheap) and gully treatment (expensive).

The dominant role of food aid is also expressed in WFP project budgets. In the overall budget for the 2003-2006 MERET programme, the combined cost of food commodity and of local transport/storage/handling amounts to US$ 40.7 million, which is 94 %, of the total WFP contribution plus 92 % of GOE contribution. Other direct operational costs (staff, training, capacity building, Monioring and Evaluation, equipment and materials) take only 6 % of the WFP contribution, and 8 % of the GOE contribution.

(vii) Budget transparency

The pattern of actors in watershed activities, amounts of work achieved, and budgets dispensed, is often complex, especially in weredas where several donors are active. It may be assumed that individual donors know what they have spent. Also, for larger donors, such as WFP, special regional and wereda project coordinators are nominated. But the form of support varies from direct compensation by food or cash to budget support, and is entered differently into the wereda overall budget (block grants, federal budget support, direct payment per activity. In addition, food-aid may be used for identical activities under different headings (FFW, employment generation under the safety net programme) and food is also distributed directly as relief aid.

Individual wereda technicians keep records of works performed within their respective areas or responsibilities. But no annual synthesis is made at the wereda level of all activities carried out, differentiating between donor, source of funding, and type of activity (paid or unpaid). Also, the conversion of works performed into areas treated, is a mathematical and artificial one. No cartographic record is kept of areas treated. After some years, as a result of high staff turn-over, nobody knows anymore who has done what and where.

The need for greater transparency and better record keeping is obvious. Given the ongoing land degradation and the enormous amounts of work ahead, it will be necessary to know better how and where to select future priority areas, and at what costs these could be treated.

(viii) Positive experiences but limited up-scaling

The recent document on a joint EEPFE/IFPRI stakeholder analysis (Gete Zeleke et al., January 2006) reports that "enormous efforts in massive land rehabilitation were undertaken since the 1980s, with the aim of arresting land degradation and improving rural livelihoods in the country. Despite these efforts, there has been limited success in controlling land degradation, in comparison to the efforts applied, the organizational structure and the resources mobilized. The problems with past conservation efforts were largely rooted in a lack of understanding of the important interface between resource conservation and agriculture, and of the factors that motivate farmers to invest in sustainable land management (SLM) over the long run.

(ix) The Role of Food/Cash for Work

The overriding role of food-for-work is often ignored. Possibly, the support provided by food or cash is taken for granted without realizing that,

- in the approach followed, it has only been the availability of food/cash that has made the work possible,
- the cost of watershed protection activities is almost entirely determined by the cost of food rations,
- the amounts of food/cash available automatically sets the upper limit for potential implementation achievements,
- the very existence of FFW/CFW has created a "dependency syndrome" and in general discourages individual initiative by farmers.

In a regional round table discussion on watershed management, with participants from many organizations (government, donors and NGOs) dealing with watershed management, "a number of participants held that food/cash-for-work is a major obstacle to scaling up. The concept has been institutionalized in such a way that farmers are unwilling to undertake any measures without payment, even when these are to their own benefit".

There are some examples of voluntary replication, for example in the Irish Aid supported activities in Tigray, where 200 hectares were said to have been implemented on a voluntary basis. Also some cases were reported and observed where farmers have dug shallow wells without external support (of a lower technical standard but unpaid).

In its cost-benefit analysis, the MERET project (WFP, 2005) also reports some (un-quantified) voluntary replication, especially of measures that can be implemented on individual basis and which contribute to production increase (mainly biological measures). The changing approach towards local level participatory planning (LLPP) is given as the main reason for improved farmers commitment and more positive appreciation of measures. Limiting factors for replication (of both labour intensive measures and private forestry activities) mentioned by farmers, are mainly inadequate availability of labour and lack of capacity and skills (almost 60 % of respondents). Lack of food aid or capital are mentioned by 35 % of respondents. Land tenure problems score surprisingly low (only 2 %).

According to GTZ replication rates are better in non-food-deficit weredas where farmers have not developed as strong a dependency syndrome. This is also experienced by others, e.g. the NGO “Menschen für Menschen” (People for people), working far from areas affected by the dependency syndrome, and facing no problems with their approach of genuine, unpaid, community participation.

(x) Building on the Past

The MERET/WFP project has been operating some 25 years (under different names), and offers a wealth of experience. The approach to this project has changed considerably over the years, reflecting experience of what does and does not work, and paralleling changes within government, as outlined above. Thus, the early approach to watershed management was large scale and top down; the achievements proved not to be sustainable and, in some cases, were detrimental. This has been attributed largely to the unmanageable size of the target areas and the lack of community participation (WFP mission 2002). Over the last 10 years, paralleling the decentralization process, the project has been re-designed to a ‘bottom-up’ project, owned and driven by communities. Target areas have been reduced to micro-catchments – or community catchments – on a scale of 200 to 500 ha. And the focus has shifted from protection – conserving the resource base – to production and improvement in rural livelihoods. This is in line with national policies and with international experiences. Most organisations working in watershed management now follow similar practices.

Overall, the various experiences provide guidance on what is implementable and at what rate. The 2005 guidelines Community-Based Participatory Watershed Development build on local experience and provide a reference to the projects.

The experiences in watershed management (including water harvesting) suggest a few key considerations for future projects:

- Community ownership and institutional structures are basic to project success
- The ‘building blocks’ for watershed management should be community catchments in the 200-500 ha range
- Larger projects (e.g. the current projects) should be seen as target areas for coverage by ‘micro-projects’ at the 200-500 ha level i.e. should be assemblages of micro-watersheds grouped and linked at a broader scale
- Conversely, larger projects can ‘add value’ by allowing physical integration of the micro-projects and by allowing a more holistic approach than possible at the micro scale
- Projects benefit from an ‘integrated’ approach. However, concepts on ‘integrated’ vary and rarely extend beyond agricultural production
- Due to the diversity of landscape and socio-economic conditions in Ethiopia, interventions need to be adapted to local conditions rather than following standard models.
- Implementation is easiest in areas offering most immediate benefits, i.e. in moisture-stressed areas. By extension, water conservation offers more immediate and visible benefits than soil conservation.
- Extensive support by Development Agents is required for project implementation. Optimum support levels are around 3 diploma level development agents per development centre. This has important implications for project implementation and management. The scale of the proposed projects will make major impositions on the capacity of the Regional Bureaux of Agriculture. Future projects may need to either provide support to these bureaux or to have a separate implementation management (albeit linked to the bureaux)
- Payment (food or cash for work) will most likely be required for a large part of project implementation.
- A key issue yet to be resolved is how to ‘scale up’ from the micro-watersheds to larger areas – a question to which upcoming watershed management projects should make an important contribution.
- It is difficult to sustain watershed management on increased productivity of food grains alone; diversification for cash crops adapted to local markets or other income generating activities is an essential part of the mix. This emphasizes the importance of markets and marketable products to offset the cost of investment in conservation.
- Key constraints are institutional capacity limitations at Regional, Wereda and Kebele/community levels; free grazing of livestock; the requirement of external support (generally food-for-work) to support community mobilisation; and lack of maintenance after completion of the project.

- There are no evaluation data available on post project benefits as compared to baseline situations. Most observers agree that, within the moisture deficit and food insecure Weredas, crop and forage production benefits are positive. MERET has undertaken an economic analysis which suggests that activities are economically viable.
- Despite the previous point, there is limited evidence of community driven watershed management and self-replication is limited. Efforts have been, and remain, primarily supply-driven by government and donor agencies, and supported by payment (food or cash for work).

(xi) Integrated watershed management

Considerable experience has been built up in the Eastern Nile Basin and elsewhere in the world on the technological aspects of integrated watershed management. In particular there has been an increasing emphasis on biological measures using where possible locally available materials and away from physical structures. Biological measures include those under the headings of better “land husbandry”, “crop husbandry” and “livestock husbandry”.

At the small dam watershed level, technical interventions will need to be developed in an integrated manner that takes into account the nested nature of watersheds and the hydraulic system. Small dams need to be integrated into other components of the watershed management plan with catchment management interventions being implemented in the upper micro-catchments and moving progressively downstream. Similarly, external water-harvesting measures will need to be similarly planned and executed. In-field water harvesting measures will need to be integrated with soil fertility enhancing measures if full benefits are to be achieved.

Proposed interventions will need to range beyond soil and water conservation technologies and include inter-linked technologies related to crop, animal and tree husbandry.

A thorough understanding of the land use systems and their inter-linking components will ensure that any potential technical interventions will not adversely impact on and where possible support the other components in the system.

4.2 Observations and lessons learnt for Watershed Development in Sudan

4.2.1 Land Development

Over the past four decades extensive areas have been cleared for large-scale mechanized rainfed cropping authorised and un-authorised. The impacts on natural resources and the traditional agricultural and pastoral sectors have been above in this Report and in the Sudan Country report.

The key lessons learnt from the development of the semi-mechanised farms have been the need for proper land use planning that takes into consideration the needs and aspirations of the local peoples and communities; the often complex linkages between the natural resource base and their livelihood strategies. The case of transhumant pastoralists is a particular case in point given their herding complex strategies over time and space. The elements of "proper" land use planning include a solid knowledge of the physical natural resource base, a thorough understanding of the local peoples' and communities' livelihoods (vulnerabilities, assets and strategies) and well established and transparent procedures for consultation and conflict resolution.

A lack of effective monitoring has allowed un-authorised land clearing and a lack of adherence to the environmental conditions attached to the leases. Despite a legal requirement to establish tree shelter belts little or nothing has been implemented by the lessees. A lack (until very recently) of a comprehensive social, economic and environmental impact evaluation of the semi-mechanized farm sector has meant that the very negative impacts on local peoples and communities' livelihoods, on the country's natural resource base and the local, regional and national economies have officially gone unrecorded.

4.2.2 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 possesses a defined area for disposition of land 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.

4.2.3 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.

4.2.4 Community-based Approach to Rinderpest Eradication

In the early 1990's cattle in the Southern Sudan were being decimated by rinderpest. Because of the security situation vaccination teams were unable to access many areas. From 1993 onwards a large scale community-based animal health worker (CAHW) system was developed. The programme was successful in eradicating rinderpest from Southern Sudan.

A subsequent evaluation (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;

4.2.5 The Role of Gum Producers' Associations in the Rehabilitation of Gum Arabic in North Kordofan

During the droughts of the 1980's there severe loss of gum arabic trees in North Kordofan. Higher prices during the early to mid 1990's encouraged farmers to restock their gum gardens and they were supported by the Restocking of the Gum Belt Project (RGB). In order to assist farmers in this process the project supported the establishment of Gum producers' associations (GPA) (Nagla Mahgoub Hamadain Jepory, 2003).

The main aims of the programme were to:

- reduce the dependence of farmers-gum producers on the informal credit system (*Al shail*);
- maintain cooperation amongst the groups in the rural areas through social organization;
- the sensitize the rural population and raise awareness about their environment and the role gum producing and trees have on it;
- activate cooperative marketing of agricultural products; and
- coordinate with companies and organizations working in the fields of rural development.

The establishment of the GPA followed an intricate system of village surveys, identification of potential members, financing and marketing. Civil society organizations such as the GPA's have proven that they are viable and effective.

4.2.6 Local level Land Use and State Level Planning

The resource use conflicts in and around the Dinder National Park have been described in 8.3.4 above. The terminal report of the 200-2004 Phase stated (inter alia) that land use planning was considered a pre-requisite for local peoples' livelihood security. In fact the project had undertaken Land Use and Livelihoods Participatory Planning Workshop to ascertain participants' interpretations on current land use problems.

The Terminal Report also identified a land use situation that was characterized by sever asymmetrical power relations and referred to the delays in developing State-wide Land Use Plans. However, whilst the lack of a State-wide Land Use Plan had not prevented some effective local level land use planning the need for such a Plan might be needed where resource conflicts extended beyond the locality. This is particularly so where it is necessary to plan and implement livestock trekking routes and water supply provision across and within areas of large-scale farms. The cases of the resource conflicts between pastoralists and semi-mechanized farms on the Butana Plains and the Funj are examples of these.

4.2.7 Improving Governance of land and water Resources

The on-going IFAD supported Land and water Governance project in the gash Delta is providing an example of an innovative approach to improved land and water governance in order to promote equity, economic efficiency and sustainability. Whilst this example refers to an irrigation scheme many of the principles that underlie the approach have relevance to other aspects of watershed management. The features of the innovations are:

- There is now a clear definition of roles, responsibilities, authorities, financing mechanisms among the three key stakeholders: the farming communities, the Gash Delta Agricultural Authority (GAS) and the Ministry of irrigation and Water Resources;
- Clear entry and exit rules for leaseholds have been established. Leaseholds would be would be fixed with increasing control of flood waters. Enforcement of entry and exit rules would be devolved to the Water Use Associations (WUA's).

- Land allocation, land development and water management at the lower levels and later to the block level is devolved to the water Users associations.

- WAU's would be established around existing farmers groups.

- Collection of water fees would be devolved to the WUA's.

These options were chosen by the farmers and the farmers Union played a key role in facilitating the initial and subsequent participatory phases. The introduction of these changes was facilitated by a commitment of the MIWR at both local and federal levels.

The key principles of this innovative approach and which have application elsewhere are:

- It puts people first. It reverses the traditional approach of starting with infrastructure.
- Effective land and water governance is at the core of the approach. Without security of tenure farmers are not likely to invest in land.
- If people are to engage effectively they need the capacity to do so. This means developing the institutional structures that enable individuals to function effectively as well as a favourable social and economic environment within which they can work. Individuals will need to develop new skills and practices.
- New institutional structures are needed but local, well established informal institutions (such as the Farmers Union) can provide the foundation on which to build.

4.2.8 Controlling Sand Encroachment

An assessment of lessons learnt from a number of sites in Sudan in controlling sand encroachment was made by the Drylands Coordination Group (Musnad and Nasr, 2004) and by UNEP. The key role played by strong community participation in shelterbelt establishment in Ed Debba in Northern State has been outlined in para. 4.2.3. At a more technical level the keys lessons learnt from an assessment of 19 sites across Sudan were as follows:

- the most effective shelterbelt design incorporated six external rows rectangular in shape, 6 times longer than tree height and orientated perpendicular to the wind. The belts should be 30-40 percent penetrable by the wind. Successive internal belts should be placed at distances 10 time tree height;
- Drip irrigation was found to be the most effective and efficient form of irrigation.

4.3 Opportunities for Watershed Management Interventions in the Tekeze-Atbara Sub-basin

4.3.1 Strategic Considerations

It is known from lessons learned that watershed management planning can be undertaken at various levels, but **implementation has to take place at grass root level**. The conventional options for purely administrative and regulative solutions to land and water use problems appear to have reached their limits. It is becoming increasingly apparent that a more consensual approach to natural resource management is a more attractive solution for harmonizing interests of resource users, managers and regulators. Allowing and facilitating local communities to develop their own resource management systems is proving a more effective, economic and efficient approach than central or regional government control.

Sustainability of achievements requires ownership of its users and these are the local communities. A sense of ownership is created only through their **genuine participation** in planning and decision making. Decision making should not be the privilege of nominated leadership only. Motivation for genuine participation can only be based on **tangible benefits** and a sustained resource-base. Many benefits can be achieved through integrated watershed management for improvement of livelihoods.

The requirement of genuine participation sets preconditions to the organizational structure and approach of watershed management projects. Emerging lessons from watershed management projects in Ethiopia, Sudan and elsewhere include the following:

- A participatory project cannot be target-driven right from its start. In its initial phase, the project design should focus on the process of establishing participation rather than on seeking to achieve physical targets. It also requires appropriate institutional development at community-level; appropriate in the sense that institutions are created (or strengthened if already existing) to respond to the emerging needs, and may therefore differ from place to place. Needs depend on priorities in watershed management activities, functionality of existing traditional institutions and prevailing group dynamics within a community. A standardized institution for all communities (such as a village watershed committee) will be an imposed one and will undermine the feeling of project ownership in the community.

- It is important to strive for a simple organizational and coordination structure, based on existing structures and clearly stipulating linkages with higher levels (need for support.

- Institutional arrangements are required that allow for multi-disciplinary and multi-agency collaboration and across ministries, contributing to breaking through single sector approaches.

4.3.2 Technical Interventions: Levels and boundaries of analysis

It is often stated that a watershed approach to development conflicts with the administrative and political reality and that their boundaries rarely coincide. Implementation activities are initiated and carried out within an administrative jurisdiction. This argument is countered by pointing out that the physical world has no respect for administrative or political boundaries and activities in the upper part of a watershed can serious impact on people in the lower parts in another administrative or political jurisdiction. In practice the two approaches need to be complementary and an administrative/political realism should be superimposed on watershed planning to obtain administrative support and action.

Watershed management is a system-orientated concept with a holistic approach to problems and potentials. For this reason it will be necessary to identify "bundles" of interventions that complement each other where possible in a synergistic way. Given the cross-sectoral, sustainable livelihoods and poverty focus of the Watershed Management CRA with its stated objective of tackling the underlying problems of natural resource degradation in the East Nile Sub-basins, many of these "bundles" will comprise technological, institutional and policy components.

Most technological interventions are targeted at the agricultural[14]/pastoral household and rural community level although some are targeted at medium scale watersheds. The organizational, institutional and policy interventions/recommendations are targeted at the higher administrative and political levels.

In addition, strategic choices in development have to be made to achieve the following:

- balanced identification of priority areas for watershed protection, based on an agreed set of criteria;

[14] Included here are tenant farms on government irrigation schemes, farm workers on large-scale mechanized farms and as well as smallholder farmers.

- dual attention for both rehabilitation of degraded food-insecure areas and timely protection of strongly eroding high potential areas.

4.3.3 Technological Interventions: Basic Considerations

Considerable experience has been built up in Ethiopia, Sudan and elsewhere in the world on the technological aspects of integrated watershed management. In particular there has been an increasing emphasis on biological measures using where possible locally available materials and away from physical structures.

A thorough understanding of the land use systems and their inter-linking components will ensure that any potential technical interventions will not adversely impact on and where possible support the other components in the system.

At the micro/mini watershed level technical interventions will need to be developed in an integrated manner that takes into account the nested nature of watersheds and the hydraulic system. For example the development of small dams should be integrated into other components of the watershed management plan with catchment management interventions being implemented in the upper micro-catchments and moving progressively downstream. Similarly, external water-harvesting measures will need to be similarly planned and executed. In-field water harvesting measures will need to be integrated with soil fertility enhancing measures if full benefits are to be achieved. Proposed interventions should range beyond soil and water conservation technologies and include inter-linked technologies related to crop, animal and tree husbandry.

4.3.4 Targeting Interventions

(i) Development Domains

In Ethiopia the MoARD Guidelines for Watershed Management provide details of many land management options. The suitability of these options depends on the bio-physical and socio-economic characteristics of a particular area. Given the large number of agricultural/pastoral household units and their extremely wide range of environmental, social and economic circumstances, it is necessary to stratify households and communities into some form of spatial unit. For this reason it has been necessary to sub-divide the three Sub-basins into spatial units of similar environmental, socio-economic (include market access) conditions and related problems and potentials. These form the basis of "**Development Domains"** (Pender, Place & Ehui, 1999). These have a common set of interventions, impacts, costs and benefits (Map 22).

Three criteria have been used to define the Development Domain: (i) agricultural potential, (ii) accessibility to markets, and (iii) Highland or Lowland.

Agricultural potential is defined on length of growing period (LGP) and rainfall variability (CV). Thus high agricultural potential weredas have LGP >6months or 4 months with rainfall CV <100 percent. Low agricultural potential weredas have an LGP <3 months or 4 months with rainfall CV >100 percent. Medium potential weredas lie between these values.

Access to markets is also a key factor in targeting interventions. Areas with good access to markets have advantages in terms of producing high value perishable crops, livestock intensification and greater possibilities for off-farm income. Conversely, areas remote from markets will need to focus more on higher value but easily transportable commodities such as small livestock and apiculture. Good market accessibility is defined as being within 4 hours vehicle travel time to a town of >50,000. Highland and Lowland are defined as >1500 masl or <1,500 masl respectively. Pender at al (1999) used population density as their third criterion. However, in Ethiopia the Highland/Lowland distinct covers not only population density but a range of socio-cultural and environmental factors.

Within each Development Domain are a number of Farming Systems that have been described in the Sub-basin Socio-economic descriptions. The distribution of In terms of targeting specific land management technologies the available evidence suggests that there is a clear distinction between frequently moisture stressed and areas that are infrequently stressed. The pattern of high risk of moisture stress is similar to that of the Development Domains but includes a southward extension just to the west of the eastern rim of the Abay Basin. This area does not receive the short (or *belg*) rains experienced by the area just to the east and is not picked up in the wereda level analysis.

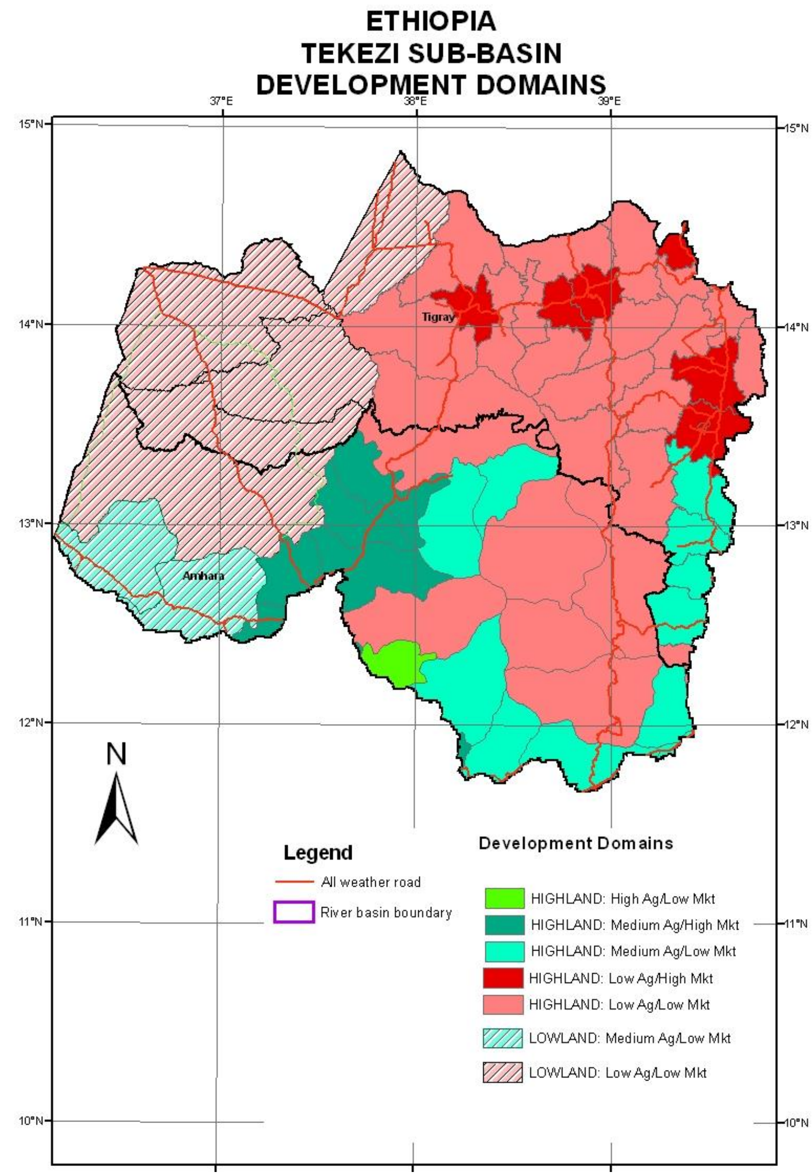
Highland domains with high agricultural potential generally occur to the west whilst those with lower potential occur in the drier east. Lowland Domains have medium agricultural potential given their higher rainfall. A matrix showing the occurrence of the Farming Systems within each Domain is shown in table 17.

Table 17. Ethiopia – Tekeze Sub-basin: Occurrence of Farming Systems within Development Domains.

FARMING SYSTEM	ACCESSIBILITY	HIGHLAND			LOWLAND		
		High Potential	Medium Potential	Low Potential	High Potential	Medium Potential	Low Potential
T1	High Mkt Access						
T1	Poor Mkt Access					**X**	**X**
T2	High Mkt Access		**X**				
T2	Poor Mkt Access	**X**	**X**				
T3	High Mkt Access						
T3	Poor Mkt Access		**X**				
T4	High Mkt Access			**X**			
T4	Poor Mkt Access			**X**			

FARMING SYSTEMS – TEKEZE SUB-BASIN:
T1 = LOWLAND SORGHUM+MILLET+TEFF (INCLUDES SHIFTING SORGHUM)
T2 = TEFF+MAIZE+SORGHUM
T3 = TEFF+WHEAT+SORGHUM
T4 = TEFF+WHEAT+BARLEY (INCLUDES WHEAT+BARLEY)

The Highland teff+maize+sorghum farming system that occurs through western Amhara Region occurs in both medium and high agricultural Development Domains as does the Lowland Sorghum+Millet+Teff farming system.



Map 22. Ethiopia – Tekeze Sub-basin: Development Domains.

(ii) Question of Priorities

Whilst a distinction is made between "High", "Medium" and "Low" Agricultural potential areas this is done to more effectively target technical and other strategic interventions and in no way suggests any priority for implementation. Opinion appears divided on whether resources should be targeted only at food deficit weredas (as defined by the MoARD/BoARD's). An analysis by WBISPP indicates that some "Medium to High Agricultural Potential" weredas may be experiencing structural food deficits even in years with average rainfall.

A strong case can be made for conserving areas with high and medium agricultural potential as well as those areas with severe land degradation. The former currently supply a substantial proportion of the food surplus that could supply food deficit areas either through normal marketing channels or through government assisted food for work programmes. Clearly, farmers' decisions to invest in sustainable land management in the high-medium potential areas are different from those in the low potential areas and thus different forms of government support strategies may be required. It is thus not a question of which areas to prioritize. It is a question of where to target specific interventions that are appropriate to specific areas.

4.3.5 Technological Interventions by Development Domain

The following sets out a number of basic interventions by Development Domain. Many of the interventions require that they be integrated with other interventions. Some interventions are applicable to more than one Development Domain.

(i) HIGHLAND: High to Medium Agricultural Potential (Very low to low moisture stress risk) with Good market Access: - Located mainly in the Abay Basin.

(a) Overall Strategies:

These areas provide the greatest potential for agricultural development and are already some of the food surplus producing areas. A wide range of marketable agricultural production strategies are available. However, these areas are experiencing soil nutrient mining and declining soil fertility levels. With high population densities farm sizes are small. A key strategy is to intensify crop and livestock production taking advantages of synergies between crop and livestock production.

(b) On-farm Interventions:

External inputs: The use of fertilizer and improved seed is likely to be profitable in these areas given the declining nutrient status. Current fertilizer application rates and fertilized area are (except for Illubabor) already some of the highest in the two basins (but still only 20 – 45 kgs/ha). This intervention requires credit availability, nutrient responsive varieties and complementary crop and soil husbandry measures.

Improved Crop Husbandry: These include crop rotation, intercropping and strip cropping. Food self sufficiency is required as food insecurity pushes farmers to cereal mono-cropping. When integrated with external inputs increases water and nutrient availability.

Improved Soil Husbandry: The use of manure and compost increases soil organic matter and nutrients and increases water holding capacity. This intervention requires sufficient quantities of manure and residues, and labour. These interventions need to be integrated with improved animal husbandry interventions and the use of inorganic fertilizer.

Improved tillage: Contour ploughing assists in reducing runoff and soil movement.

Grass strips: Most effective on slopes less than 15 percent but can be used on steeper slopes. Best integrated with on-farm forage interventions and limited livestock access. Can also be integrated with on-farm multi-purpose tree production.

Fanyaa Juu: Graded in high rainfall areas and level elsewhere. Can be integrated with grass strips and trees to increase stability. However, they have high construction and maintenance labour requirement.

On-farm Forage Development: (i) Backyard improved forage: forage grasses (e.g. including but not limited to *Pennisitum purpureum*, *Panicum maximum*), tree legumes (*Leucaena leucocephala*) and pigeon pea. Undersowing into maize or sorghum with appropriate forage legumes. (ii) Improved hay production in drainage lines and bottomlands. (iii) Improved storage and treatment of crop residues.

On-farm Tree development: In many areas of Amhara Region the market for Eucalyptus coming saturated and there is a need to move away from Eucalyptus spp. to multi-purpose trees (for forage, small poles and fuelwood). This intervention could be integrated with the on-farm forage and the grass strips interventions.

(c) Interventions on Communal Lands

Cut-off Drains: A pre-requisite for in-farm soil conservation measures is a cut-off drain above cultivated areas. Even by themselves they can reduce in-field run-off and soil movement. However, it is important that water collected in the drain is safely disposed of into waterways.

Road and track drains: run-off from roads needs to be controlled with small check dams and safe outlets to streams.

Gully Stabilization: This requires the integrated stabilization of both the gully and its catchment area. This will require a combination of livestock exclusion (in both catchment area and gully), and vegetative and structural measures (check dams, etc) within the gully. This intervention can be integrated with a communal forage development programme.

Communal Forage Development: To be effective and sustainable this is best undertaken at the sub-kebelle (tabia) level. This intervention usually requires some form of area closure with cut-and-carry, or controlled grazing or controlled hay production and harvesting. The site of the intervention can vary from steep and degraded hillsides, poorly drained valley bottoms, and stream edge buffers. A key object is to reduce livestock movement. The process of natural re-generation can be supplemented with over-sowing of herbaceous (*Pennisitum purpureum*, *Panicum maximum*) or tree legumes (*Leucaena leucocephala*) and pigeon pea but this increases costs. The intervention can also be integrated with communal tree production.

Communal Tree Production: This is best integrated with communal forage development in area closures. As with communal forage development clear management and harvesting plans need to be established at the outset.

Small-scale Supplementary/full Irrigation: For high value marketable crops (vegetables, green maize). Given the good market access high value perishable crops can be grown. Alternatives are supplementary irrigation for larger areas when supplies are high and prices lower, and full irrigation of smaller areas when supplies are low and prices are higher.

(d) Other Strategies

Non-farm labour: Proximity to urban centres provides potential opportunities for non-farm labour, sales of fuelwood and handicrafts. To be sustainable this strategy requires skills training in such activities as brick-laying, carpentry, metal work, handicrafts, etc.

(ii) HIGHLAND: High to Medium Agricultural Potential (Very low to low moisture stress risk) with Poor Market Access: Located mainly in the Abay Basin.

(a) Overall Strategies:

The opportunities for marketable agricultural development in these areas are much more limited. Use of external inputs may be privately unprofitable (to farmers) but may be economically cheaper than importing food into the area (Pender at al., 1999). Marketable agricultural products will be limited to high value, low volume and non-perishable products. These could include crops such as onions and peppers, small livestock such as sheep and goats, and honey production. In parts of Ethiopia improved goat production by women has proved very successful, particularly for women-headed households. The strategy for own-consumption agricultural production should be to ensure food security. The long-term Government strategy is to improve accessibility to markets through feeder road and farm to market road construction.

(b) On-farm Interventions

Improved Soil Husbandry: The use of manure and compost increases soil organic matter and nutrients and increases water holding capacity. This intervention requires sufficient quantities of manure and residues, and labour. These interventions need to integrate with improved animal husbandry interventions.

Improved tillage: Contour ploughing assists in reducing runoff and soil movement.

Grass strips: Most effective on slopes less than 15 percent but can be used on steeper slopes. Best integrated with on-farm forage interventions and limited livestock access. Can also be integrated with on-farm multi-purpose tree production.

Fanyaa Juu: Graded in high rainfall areas and level elsewhere. Can be integrated with grass strips and trees to increase stability. However, they have high construction and maintenance labour requirement. Given the lack of market opportunities and thus high private costs involved, a case can be made for some form of subsidy given the potential reduction in externalities.

On-farm Forage Development: Backyard improved forage: forage grasses (e.g. including but not limited to *Pennisitum purpureum*, *Panicum maximum*), tree legumes (*Leucaena leucocephala*) and pigeon pea. The focus of the intervention is on improving small ruminant productivity.

On-farm Tree development: Given the lack of markets on-farm tree production will be for own consumption only.

(c) Interventions on Communal Lands

Cut-off Drains: A pre-requisite for in-farm soil conservation measures is a cut-off drain above cultivated areas. Even by themselves they can reduce in-field run-off and soil movement.

Road and track drains: run-off from roads needs to be controlled with small check dams and safe outlets to streams.

Gully Stabilization: This requires the integrated stabilization of both the gully and its catchment area. This will require a combination of livestock exclusion (in both catchment area and gully), and vegetative and structural measures (check dams, etc) within the gully. This intervention can be integrated with a communal forage development programme.

Communal Forage Development: To be effective and sustainable this best undertaken at the sub-kebelle (tabia) level. This intervention usually requires some form of area closure with cut-and-carry, or controlled grazing or controlled hay production and harvesting. The site of the intervention can vary from steep and degraded hillsides, poorly drained valley bottoms, and stream edge buffers. A key object is to reduce livestock movement. The process of natural re-generation can be supplemented with over-sowing of herbaceous (*Pennisitum purpureum*, *Panicum maximum*) or tree legumes (*Leucaena leucocephala*) and pigeon pea but this increases costs. The intervention can also be integrated with communal tree production.

Small-scale Supplementary Irrigation: For high value non-perishable marketable crops (onions, garlic, peppers) using supplementary irrigation for maximum area (given good storability season price fluctuations are small).

(d) Other Strategies

Honey production: In densely populated areas where land is short honey production is not affected by land or cash constraints. Improved hive can substantially increase production.

(iii) HIGHLAND: Low Agricultural Potential (moderate to high moisture stress risk) with Good Market Access: Located mainly in the Tekeze Basin.

(a) Overall Strategies:

A key strategy is the conservation of soil moisture to reduce risk of crop failure as well as to reduce the risk of using inorganic fertilizers. Soil and water conservation structures should be integrated with other improved crop and soil husbandry measures. Relatively higher urban market prices for cereals in these areas are likely to make fertilizer use profitable in years of average to good rainfall. Some form of crop insurance may be feasible in these areas. Urban centres in close proximity may provide opportunities for non-farm employment.

(b) On-farm Interventions

Improved Soil Husbandry: The use of manure and compost increases soil organic matter and nutrients and increases water holding capacity. This intervention requires sufficient quantities of manure and residues, and labour and thus need to be integrated with improved animal husbandry interventions.

Improved tillage: Contour ploughing assists in reducing runoff and soil movement.

Grass strips: Given the low and variable rainfall grass strips are not likely to be successful on their own, but might be used to supplement physical structures.

Stone terraces: These are more efficient in retain soil moisture that bunds or grass strips. In many parts of the Development Domain surface stones are readily available. The high rate of adoption indicates that many farmers appreciate their use for soil and soil moisture conservation.

On-farm Forage Development: tree legumes (*Gliricidia sepium*) which could be used to supplement low quality native grasses, grasses (e.g. including but not limited to *Pennisitum purpureum*, *Cenchrus ciliaris*) and pigeon pea for supplementary feeding of calves and lactating cows.

On-farm Tree development: In Tigray (and increasingly in Amhara) Region land on degraded hillsides is being allocated to individual households for tree production (tree planting on cropland is prohibited). Cultivation of tree legumes (*Leucaena leucocephala*, *Sesbania sesban*) on these individual hillside plots (as dual purpose forage and fuelwood trees).and of *Stylosanthes spp*. (Stylo). Stylos are very hardy and resistant.

(c) Interventions on Communal Lands

Cut-off Drains: A pre-requisite for in-farm soil conservation measures is a cut-off drain above cultivated areas. Even by themselves they can reduce in-field run-off and soil movement.

Road and track drains: run-off from roads needs to be controlled with small check dams and safe outlets to streams.

Gully Stabilization: This requires the integrated stabilization of both the gully and its catchment area. This will require a combination of livestock exclusion (in both catchment area and gully), and vegetative and structural measures (check dams, etc) within the gully. However, given to low and variable rainfall, vegetative measures will require longer to establish than in high rainfall areas. Initially, there may be a need for more emphasis on physical structures to allow vegetative measures time to establish.

Communal Forage Development: To be effective and sustainable this best undertaken at the sub-kebelle (tabia) level. This intervention usually requires some form of area closure with cut-and-carry, or controlled grazing or controlled hay production and harvesting. The site of the intervention can vary from steep and degraded hillsides, poorly drained valley bottoms, and stream edge buffers. A key object is to reduce livestock movement. The time taken for vegetation to recover will be longer than in high rainfall areas and harvesting of grass and trees will need to be delayed. It will be important that individual measures for improved fodder production are in place before closure.

Small-scale Supplementary/full Irrigation: For high value marketable crops (vegetables, green maize). Given the good market access high value perishable crops can be grown. Alternatives are supplementary irrigation for larger areas when supplies are high and prices lower or full irrigation of smaller areas when supplies are low and prices are higher.

Water-harvesting: This refers to the collection of water into small ponds or micro-dams for small-scale irrigation, human and/or livestock water supplies.

(iv) HIGHLAND: Low Agricultural Potential (Moderate to high moisture stress risk) with Poor Market Access: Located mainly in the Tekezi Basin.

(a) Overall Strategies:

A key strategy is the conservation of soil moisture to reduce risk of crop failure. Soil and water conservation structures should be integrated with other improved crop and soil husbandry measures. The opportunities for agricultural development for marketable produce in these areas are much more limited. The strategy for own-consumption agricultural production should be to ensure food security. Marketable agricultural products will be limited to high value, low volume and non-perishable products. These could include crops such as onions and peppers, small livestock such as sheep and goats, and honey production. In parts of Ethiopia improved goat production by women has proved very successful, particularly for women-headed households. The long-term Government strategy is to improve accessibility to markets through feeder road and farm to market road construction.

Improved Soil Husbandry: The use of manure and compost requires sufficient quantities of manure, residues and labour. Given the poor accessibility to markets, the strategy for improved livestock production is to focus on small ruminants. Quantities of manure are likely to be limited and reserved for marketable products such as onions and peppers grown on backyard gardens or in-fields.

Improved tillage: Contour ploughing assists in reducing runoff and soil movement and is already widely practiced.

Grass strips: Given the low and variable rainfall grass strips are not likely to be successful on their own, but might be used to supplement physical structures.

Stone terraces: These are more efficient in retain soil moisture that bunds or grass strips. In many parts of the Development Domain surface stones are readily available. The high rate of adoption indicates that many farmers appreciate their use for soil and soil moisture conservation.

On-farm Forage Development: tree legumes (*Gliricidia sepium*) which could be used to supplement low quality native grasses, grasses (e.g. including but not limited to *Pennisitum purpureum*, *Cenchrus ciliaris*) and pigeon pea for supplementary feeding of oxen and small ruminants for sale.

On-farm Tree development: In Tigray (and increasingly in Amhara) Region land on degraded hillsides is being allocated to individual households for tree production (tree planting on cropland is prohibited). As the pole markets are inaccessible the focus should be on cultivation of tree legumes (*Leucaena leucocephala*, *Sesbania sesban*) on these individual hillside plots (as dual purpose forage and fuelwood trees).and of *Stylosanthes spp*. (Stylo). Stylos are very hardy and resistant.

(c) Interventions on Communal Lands

Cut-off Drains: A pre-requisite for in-farm soil conservation measures is a cut-off drain above cultivated areas.

Road and track drains: run-off from roads needs to be controlled with small check dams and safe outlets to streams.

Gully Stabilization: This requires the integrated stabilization of both the gully and its catchment area. This will require a combination of livestock exclusion (in both catchment area and gully), and vegetative and structural measures (check dams, etc) within the gully. This intervention can be integrated with a communal forage development programme.

Communal Forage Development: To be effective and sustainable this best undertaken at the sub-kebelle (tabia) level. This intervention usually requires some form of area closure with cut-and-carry, or controlled grazing or controlled hay production and harvesting. The site of the intervention can vary from steep and degraded hillsides, poorly drained valley bottoms, and stream edge buffers. A key object is to reduce livestock movement. The process of natural re-generation can be supplemented with over-sowing of herbaceous (*Pennisitum purpureum*, *Panicum maximum*) or tree legumes (*Leucaena leucocephala*) and pigeon pea but this increases costs. The intervention can also be integrated with communal multi-purpose tree production.

Small-scale Supplementary Irrigation: For high value non-perishable marketable crops (onions, garlic, peppers) using supplementary irrigation for maximum area (given good storability season price fluctuations are small).

Water-harvesting: This refers to the collection of water into small ponds or micro-dams for small-scale irrigation, human and/or livestock water supplies.

(d) Other Interventions

Honey production: In densely populated areas where land is short honey production is not affected by land or cash constraints. Improved hive can substantially increase production.

(v) LOWLAND: Medium to High Agricultural Potential (Moderate to low moisture stress risk) with Poor Market Access: Located mainly in the Abay Basin and small area in the south-western part of Tekezi Basin

(a) Overall Strategies:

Soil fertility rather than soil moisture is the key constraint to crop production. South of the Dinder River tsetse fly infestation and trypanosomiasis is the key constraint to livestock production. Malaria is the key constraint to human settlement across the whole area.

Three overall development strategies are available in these areas. (i) Intensification of existing bush-fallowing cultivation; (ii) development of medium to large scale commercial agriculture, and (iii) large-scale irrigation.

(i) Intensification of Existing Extensive Cultivation

Currently most cultivation in this domain follows a bush-fallowing system. Locally cultivation is becoming more sedentary where fallow periods are becoming too short to enable vegetation to recover. Only in these areas are intensification interventions likely to be adopted.

Improved Soil Husbandry: In the absence of bush fallowing the range of appropriate improved soil husbandry interventions are limited. Use of chemical fertilizer would not be economic given the poor accessibility, high costs of transport and lack of markets. Weed composting is a traditional method of improved soil husbandry practiced in south and south-western Ethiopia and would be appropriate in this Development Domains Intensification is likely to take place of soils of highest fertility: alluvial and colluvial soils.

Small ruminants: As areas of vegetation are permanently cleared around villages and the tsetse challenge is reduced keeping of small ruminants is possible and provide an additional livelihood strategy.

(ii) Development of Large and medium Scale Semi-mechanized Agriculture

Since 1991 the State Farm rainfed sector has almost ceased to operate and one large State Farm in the Lower Didessa Valley has been totally abandoned following soil fertility decline. There has been a slow growth of the private large-scale rainfed cropping sector in the western Lowlands in the Beles, Dinder and Tekezi basins since the Investment Proclamation in 1995. Land is held on long-term leases from the Regional State Government. The main crops have been sesame and cotton. Most of these farms are located in areas close to the large mechanized farms in Sudan just across the border. In Sudan and in the lower Didessa Valley, the absence of 25 percent fallowing or soil fertility maintenance, soil fertility decline and falling yields have been experienced.

(iii) Large-scale Irrigation

There is one major irrigation scheme currently under development in the upper Beles Valley with plans to irrigate 5,000 ha. Others are planned in the Lake Tana Basin, the Anger and Didessa valleys south of the Abay River, as indicated in table 20.

(v) LOWLAND: Low Agricultural Potential (Moderate to low moisture stress risk) with Poor Market Access: Located in the Tekezi Basin.

(a) Overall Strategies:

Soil fertility and soil moisture are both constraint to crop production. Tsetse fly is not present in this Development Domain. Malaria is the key constraint to human settlement across the whole area.

Three overall development strategies are available in these areas. (i) Intensification of existing bush-fallowing cultivation; (ii) development of medium to large scale commercial agriculture, and (iii) large-scale irrigation.

(i) Intensification of Existing Extensive Cultivation

Currently most cultivation in this domain follows a bush-fallowing system. Currently population densities are so low that there is no immediate danger of fallow periods are becoming too short to enable vegetation to recover. However this may change if there is substantial development for resettlement, large scale rainfed or irrigated farming.

Small ruminants: As there is no tsetse challenge keeping of small ruminants is possible and can provide an additional livelihood strategy.

(ii) Development of Large and medium Scale Semi-mechanized Agriculture

The same caveats apply regarding soil fertility as in the Development Domain to the south apply here also. In addition, there is an added constraint of a much higher risk of soil moisture deficits occurring in this Development Domain.

(iii) Large-scale Irrigation

There is one major irrigation scheme being considered in the Humera area with plans to irrigate 43,000 ha.

4.3.6 Potential Impacts in Reducing Soil Erosion and Sedimentation

(i) Reducing Soil Erosion on Cropland and Non-cropland in the Ethiopian Highlands

There is currently a vigorous programme of watershed management interventions being undertaken in the Ethiopian Highlands of the Tekeze Sub-basin. Because of the significant and visible benefits to physical soil and water conservation structures partly to reduction of soil erosion but mainly to increased soil moisture and thus soil nutrient availability, there has been a substantial investment in these structures by farmers. The structures are mainly stone bunds and terraces.

After land taken up by the structures is taken into account crop yield increases of 7 percent were recorded. It has been estimated that stone bunds trap 64 percent of soil moved, with the remaining 36 percent then some percent passing through.

All cropland with slopes exceeding 5 percent were assumed to require SWC measures. It is estimated that 50 percent of land that requires SWC measures has already been treated (map in Pender and Mahmud, 2005). At the current rates of implementation it is possible to complete the remaining 50 percent within the next 10 years.

No information is available on the amount of gullies on crop or communal lands that have been treated. It was assumed that including reclamation work that had been in the past and adding this to the amount that could be achieved in the next 10 years some 60 percent of gullies on cropland would have been treated at the end of 10 years. From research undertaken in Tigray sediment retention after reclamation is 85 percent.

With these assumptions soil movement on cropland (including gullies) could be reduced from 32.84 million to 12.46 million tons. Assuming sediment delivery ratio of 60 percent (and 15 percent from gullies) then sediment to the Tekeze river system within Ethiopia could be reduced by 6.28 million tons.

(ii) Increasing Vegetative Cover and Reducing Soil Erosion on Non-cropland in the Ethiopian Highlands

It is estimated that some 73.3 million tons of soil per annum are moved from non-cropland. An estimated 20 percent of additional soil is removed by gully erosion totalling some 87.96 million t/yr. "Non-cropland" is essentially communal lands that are used for grazing and fuelwood collection, and include the under-utilized degraded lands. These lands are generally much steeper with shallow soils that are unsuitable for crop production. They comprise some 73 percent of the total area. They are currently overgrazed and subject to unsustainable wood removal for household energy supplies.

However, there has been a strong programme of reclamation of these degraded communal lands in the upper Tekeze Sub-basin within the past decade. It is estimated that 200,000 ha of communal lands have been closed and a further 300,000 ha of natural woodland/shrubland is conserved and under sustainable management. The 500,000 ha constitutes approximately 15 percent of the non-cropland in the Highlands of the Sub-basin. These areas are closed to livestock and managed for cut-and-carry forage, community and individual woodlots.

Surveys have demonstrated that soil retention by these areas is almost 100 percent for catchment areas many orders larger than the closed area. As well as soil retention infiltration to groundwater is increased. Soil fertility increases leading to increased biomass production. Vegetative reclamation of gullies (with some physical structures) has been shown to be effective in reducing erosion rates by over 90 percent.

Thus, the opportunities for significant reducing sediment delivery to the river system are very substantial. Assuming that an additional 25 percent of the non-cropland could be brought under closure or sustainable forage and/or woodland management over the next 10 years (bringing the total to 40%) this could reduce sediment delivery to the river system by approximately 15.83 million tons per annum. Assuming also that within 10 years some 40 percent of gullies on non-cropland can be reclaimed then gulley reclamation could add a further reduction of 0.75 million tons per annum.

(iii) Opportunities for Sediment Retention by the Small Dam Programme

(a) Potential Sediment Reduction

Although the primary purpose of the dams is small scale irrigation, human and livestock water supplies a secondary impact is retention of sediment derived from crop and non-cropland soil (sheet, gully and river bank) erosion.

Current sediment yield rates for small dams (0.5 – 3 million m^3) average about 900t/km^2. At these yield rates the economic life is extremely short and currently the programme is on hold until the institutional problems of integrating the watershed management programme with the small dam programme can be resolved.

Assuming that these issues can be resolved, sediment yield rates could be reduced to at least the current minimum of 250t/km^2. With an average catchment of 10 km^2, a sediment retention rate of 80 percent[15] and assuming a ten year programme of 500 small dams within the Tekeze Catchment, there is the potential to reduce sediment load in the Tekeze by some 1.0 million tons /yr (2,000 t/yr/dam). This would have benefits in reduced sedimentation in Kashm-el Girba and the Aswan High Dams, and in reduced sedimentation in the irrigation canals of the new Halfa Irrigation Scheme.

(b) Other Costs and Benefits

However, there are other costs and benefits. There are at once (i) one in-country cost (provision of dead storage), (ii) other potential in-country costs (increased incidence of malaria and schistosomiasis) (iii) some in-country benefits (increased crop and livestock production, improved health from better water supplies), and (iv) some trans-boundary costs (reduced water yield through irrigated crop evapo-transpiration and thus reduced water for downstream users in Sudan and Egypt).

The health impacts of small dam construction in terms of bilharzias and malaria in the Tekeze Catchment have been quantified. The surveys compared disease incidence and health expenditures in villages within 3 kms distant and villages 8 kms or more from small dams (Ersado, Archer & Alwang, 2001), Ersado, 2005). The study examined (*inter alia*) the impact of small dams and irrigation on production and consumption gains against health costs. The study reveals that whilst agricultural yield and farm profits have increased as a result of the dams, the ensuing sickness from water vector diseases have led to significant declines in labour productivity and subsequently depressed the expected returns from the

[15] Only one of the 54 dams examined in the Tigray study had spilled since construction.

water investment. The health related problems also led to a reduction in off-farm income activities further adversely affecting households' livelihoods. To prevent such health hazards there would have to be a permanent malaria control programme within 5 kms of any dam. This would then transfer the current private costs being borne the local farm families to a public cost borne by the state.

The Feasibility Study for the TK5 Medium Hydro-power Dam on the Tekeze estimated the reduction of water yield from the construction of 20 micro dams (average 125,000m^3 capacity) as between 80 to 200 million m^3 per year. However, this figure appears very high. Waterbury and Whittington (2000) estimate an irrigation usage of 1.0 million m^3 per dam (irrigating 200 ha). This does not take into account seepage and evaporation losses from the dam itself.

Assuming a 50 ha dam with an annual evaporation rate of 1.5 meters would mean the dam would lose 75,000m^3. Seepage would return water to the river system via groundwater and thus is not lost. Some 250 dams would reduce water yield (using the lower estimate) by approximately 269 million m^3/yr or 5.4 percent of the Tekeze flow at Humera. In practice actual irrigated areas appear to about 75 ha, less than half the assumption used above.

(v) Opportunities for Sediment Retention by the TK5 Medium Hydro-power Dam on the Tekeze River

The TK5 Dam currently being constructed on the Tekeze River near Embamade is mainly or hydro-power generation and flood control. 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 km^3 and a trapping efficiency of 100 percent to determine the economic life of the dam. However, 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 21.77 million tons per year, a reduction of approximately 9.33 million tons/yr.

(vi) Opportunities for Arresting Kerib Land formation in Sudan and its Restoration

Reclamation of kerib land would be pointless without taking steps to arrest its extension and encroachment into the adjoining croplands. The only way to achieve this is to take a buffer zone about 200 meters wide from the kerib edge out of cultivation and to plant deep rooting trees. It is essential that all livestock be excluded from the buffer as well as the kerib land. This would prevent the annual loss of 1,200 ha of smallholder farmland currently affecting communities whose livelihoods have already been constrained by the alienation of land for the Semi Mechanized Farms.

The short term strategy for reclamation would be livestock exclusion and land preparation in micro-catchments for multi-purpose tree production. Sown grasses could be used for cut and carry of fodder. There may be longer term opportunities to use some of the reclaimed land for crop (sorghum and sesame) production. Restoration of kerib land below the Kashm el Girba dam would be extremely difficult given the low rainfall.

A key issue is the question of land tenure of the reclaimed kerib land. Whilst community division is the current policy, consideration should be given to allocating the kerib land on an individual basis. This is now the strategy for reclaiming degraded hillsides in Tigray in the Upper Tekezi basin in Ethiopia and is proving extremely successful. In some cases landless households are being allocated degraded land and provide d with technical and material support to undertake the reclamation work.

4.3.7 Opportunities to Reduce Soil Degradation and Loss of Agricultural productivity in the Tekeze-Atbara Sub-basin

(i) Soil Nutrient Losses in the Highlands of the Sub-basin.

(a) Burning Dung and Crop Residues

In a number of ways the investments required to reduce soil nutrient losses due to the burning of dung and crop residues is simpler and has a more immediate impact than reducing soil loss through erosion. On the supply side it requires a substitution by wood for dung and residues. As nearly 90 percent of rural domestic energy is for cooking, it is unlikely in the fore-seeable future to see a significant switch to kerosene, LPG or electricity for cooking, unless there is a large element of subsidy both for the capital investment and subsequent fuel purchase. On the demand side it requires a switch to more efficient stoves.

In the Abay basin, particularly in the west where there has been a very substantial increase in on-farm tree planting, the process of fuel substitution is already underway (WBISPP/MoARD, 2001). Since 1984 per capita dung use as fuel has been declining at an annual rate of nearly 3 percent or by one third in 16 years. As the increased rate of on-farm tree planting in Tigray commenced some years after that in Amhara Region this process of fuel substitution will also be delayed. The WBISPP Survey in 2002 in the Tigray Region indicated that at that time dung and residue consumption as fuel was still increasing. However, as trees planted in the initial years of the programme mature this process is likely to be reversed and a similar decline in dung use occurring. Additionally, increased woody biomass from hillside closures will increasingly become available further reducing the use of dung and residues.

Thus, assuming an estimated annual reduction in nutrient losses through burning of dung and residues of about 3 percent, then an annual reduction of about 530 tons on N and 120 tons of P can be expected.

The opportunities for reduced fuel consumption through improved stoves are limited in Tigray because the traditional Tigray rural wood stove is already an extremely efficient stove.

(b) Grain removal

The reduction in nutrient losses through grain removal can only be achieved by the application of organic (manure, compost) or chemical fertilizer. Organic fertilizers are being used but generally only of fields close to the homestead. The use of chemical fertilizer is conditioned by a farmer's land, labour and financial assets as well as access to seasonal credit. Farmers' perception of the risk to low and variable rainfall is high in the climatic environment of the Tekeze Sub-basin and is a constraint to investment in chemical fertilizer for rainfed cropping in the eastern parts of the Sub-basin. The current losses of N would require 32,135 tons of Urea.

(c) Soil Erosion

The retention of soil nutrients potentially lost through soil erosion by stone bunds is not quite the same as that for soil retention. This is because soil organic matter and nutrients are preferentially removed by a factor of about 1.2 (the nutrient enrichment ratio). Thus, nutrient lost to cropland is the 36 percent of soil passing through the stone bunds multiplied by the factor of 1.2. Thus, some 4,865 tons of the present loss of 8,563 tons of N could be retained behind the stone bunds.

(ii) Opportunities to Arrest the Declining Rainfed Crop and Livestock Productivity in the Lowlands of Sub-basin.

(a) Semi Mechanized farms

There are three major problems with respect to low and declining crop productivity:

- low soil fertility (leading to weed infestation, particularly striga);
- hard plough pan restricting deep root penetration (leading to low plant water uptake); and
- plant-soil moisture stress in low rainfall years.

However, there are a number of opportunities to arrest declining yields and increase productivity of rainfed sorghum.

Two approaches are possible with respect to low soil fertility: (i) use of chemical fertilizer, and (ii) periodic fallowing. In the frequent low rainfall years the use of chemical fertilizer particularly on the surface can have a detrimental impact on crop yield by causing surface root development and drying out of soil. Deep placement of fertilizer has been found to increase root develop, water uptake and grain yield, particularly of non drought-resistant varieties. Periodic fallowing uses up land but is effective in restoring soil fertility and suppressing weeds. Clearly there are trade-offs between the costs of fertilizer and the cost of leaving 25 percent of the land fallow each year.

Research at the Gezira Research Station (Salih, 1997) demonstrated that sub-soiling (SS) produced a 25 and 13 percent increase in yield of irrigated cotton over disc harrowing and three bottom disc ploughing. This indicates that positive impacts from sub-soiling can be expected on rainfed sorghum.

It has been found that planting sorghum in the furrow or within tied ridges can increase sorghum yields by 60 to 90 percent of traditional flat planting on clay soils in a low rainfall year. In a wet year there was no impact of crop yield.

Drought-resistant varieties of sorghum (e.g. *Gadambalia*) are now available are would be suitable for the rainfed cropping in the Atbara Sub-basin.

There are likely to be positive synergistic effects of using deep-placed fertilizer, sub-soiling, in-furrow planting and use of drought resistant varieties. Carried out on a large scale, yields could be expected to increase from the current 150 kgs/feddan (360 kgs/ha) to 336 kgs/feddan (800 kgs/ha).

(b) Opportunities to arrest the decline in crop and livestock productivity of Traditional Smallholder farms, Agro-pastoralists and Pastoralists and develop Sustainable Livelihoods

A key problem of the traditional rainfed smallholder farms is the declining period of fallow caused by restrictions on lateral expansion by SMF's to the west and State Forests to the east. The problems are similar with the respect agro-pastoralists and pastoralists and the loss of extensive wet season grazing areas to the SMF's and the consequent overgrazing and degradation of the rangelands.

It was estimated (para. 3.1.3 (c) above) that in 2005 (a good rainfall year with high crop prices) only 40 percent of the SMF's were being cropped. Given the recommendations of the JAM for a more equitable access to natural resources, as a first step it would be appropriate to undertake a survey of all SMF's to determine which areas were legally or illegally held, those areas being regularly cropped, areas which were under-utilized (cropped occasionally) and those which had been abandoned. This would enable a thorough review of all government leases. Illegally held, under-utilized or abandoned land could then revert back to the State. Provisions could be made for the State to purchase back leases of farms that were strategically important in the land redistribution and land use planning exercise.

The second step would be to undertake at the State level (but within nationally laid down guidelines and principles) a strategic land use planning exercise in consultation with all concerned stakeholders. This would seek to redistribute land that had reverted to State control, to smallholder rainfed farmers, agro-pastoralist and pastoralists based land suitability for rainfed cropping, intensive and extensive livestock production and where possible on the principle of prior use (i.e. the land was used by a concerned group (or groups) prior to alienation). It would important to clearly define access and use rules for individually and communally held land to ensure sustainability of natural resource use and to avoid resource use and access conflicts. Where possible, existing formal or informal institutions for land and water allocation would be used and strengthened.

Control of some of the State Forests adjoining communities could be passed from the FNC to those communities following a participatory planning exercise to develop a forest management and harvesting plan. The Community Forest Management Plan (FMP) would set out sustainable harvesting rotations for fuelwood and charcoal production, royalty rates and the establishment of a Community Development Fund in to which royalties would be paid.

The third step would be to provide a comprehensive programme of technical support (crop and animal husbandry), effective input distribution (improved seed, fertilizer and veterinary medicines) and accessibility to short and medium term credit. The support programme would include improved physical accessibility (feeder roads), human and livestock water supplies, water harvesting and small scale irrigation, social infrastructure and services (health and education).

(c) Joint Ventures: Semi-mechanized farms and Traditional Farming Sector

There is a legal requirement that registered farm (e.g. Semi-mechanized farms) should retain at least 10 percent of their land under forest or plant at least 10 percent of their land to shelter-belt. Currently this is not being enforced. An option recommended by screening study of the fast track watershed management projects is that enforcement of the rule by the State (through fines or taxes) would develop a local community private sector that could provide a full range of shelter-belt services to private farmers and thus supporting livelihoods in the local communities. These services would include nurseries, planting, maintenance, harvesting, etc. The scheme would require FNC authentication and FNC technical support to communities.

4.3.8 Opportunities to Reduce Sedimentation in the Gash Delta

Much of the upper Mereb-Gash River Catchment lies within Eritrea. Currently Eritrea only has observer status within the ENSAP. Although no details are available it is known that Eritrea had a comprehensive watershed management programme under implementation. These clearly represent opportunities for reducing sediment loads in the Mereb-Gash River. Also, there are potentially a number of cooperative activities of mutual benefit and these are explored below.

As with Ethiopia there are both in-country benefits (and costs) and trans-boundary benefits and possible costs. Potential benefits are a significant reduction in sediment load of the Mereb-Gash River, and the benefits that would accrue to the Gash Delta Irrigation Scheme in terms of reduced expenditures on desilting of canals and intakes. A potential cost might be a significant reduction in or attenuation of the flood peak, given the short growing season and strong dependency on the amount of the flood on the area prepared for cultivation.

4.4 Potential In-country Benefits to Watershed Management Interventions in the Tekeze-Atbara Sub-basin

4.4.1 Reduction in Soil Erosion and Soil Degradation

(i) Ethiopia

(a) Benefits from Reduction of Soil Erosion and Increased Moisture Retention

Currently, soil erosion on cropland in the highlands of the Sub-basin is incurring an annual accumulating loss (through the reduction in soil moisture holding capacity) of an estimated 1,850 tons of grain per year that will reach an accumulated loss of 44,635 tons in 25 years times. In the absence of preventative measures this will continue to accumulate each year thereafter. **A 100 percent coverage of cropland incurring unsustainable soil loss (estimated to be 649,400 ha)** would reduce current annual losses of soil and soil moisture holding capacity to 40 percent of current rates achieving a saving of 60 percent of current annual accumulating losses. This would yield an accumulating annual benefit of 1,110 tons of grain per year – in livelihood terms sufficient to sustain 5,550 adults per year, or 139,000 people by the year 2030.

In addition to preventing loss of soil moisture holding capacity, construction of stone bunds results in a 7 percent yield increase in crop yield from increased soil moisture retention and thus increased nutrient availability. Thus even bunds on land not suffering from unsustainable soil loss would yield increased benefits. Assuming 50 percent of all cropland is covered with stone bunds there would be an annual additional increase in production of 37,100 tons of grain per year - sufficient to feed 185,500 people a year.

(b) Soil Nutrient Losses

Assuming an estimated annual reduction in nutrient losses through burning of dung and residues of about 3 percent, then an annual reduction of about 530 tons of N producing an annual saving about 3,180 tons of grain can be expected.

The reduction in nutrient losses through grain removal by the application of organic (manure, compost) or chemical fertilizer is difficult to estimate. Assuming conservatively that an increase in fertilizer uptake of 50 kgs of urea by 20 percent of farmers was possible, this would yield an annual increase in grain production of approximately 138 kgs of grain per farmer or 16,375 tons/yr additional production.
The retention of soil nutrients potentially lost through soil erosion by stone bunds assuming a100 percent coverage of cropland with an unsustainable soil loss rate would achieve a saving of about 29,180 tons of grain.

(ii) Sudan

(a) Benefits from arresting Kerib Land formation and Restoration of Existing Kerib Land

There is the potential to reclaim nearly 81,000 ha of kerib land. Assuming a mix of multi-purpose trees and herbaceous forage producing a sustainable yield of 200 kgs of woody biomass and 400 kgs of herbaceous biomass per hectare per year over 60 percent of the area, such a restoration programme could yield nearly 10,000 tons/yr of wood (or 2.000 tons/yr of charcoal) and 20,000 tons/yr forage of (enough to feed nearly 10,000 tropical livestock units).

(b) Benefits from arresting decline in crop yields on the Semi-Mechanized Farms

Assuming that only 40 percent of the area mapped as large farms is actually cropped in an average year, there is the potential to improve crop production of 801,620 feddans (336,680 ha) raising sorghum yields from 360 kgs/ha to 800 kgs. Assuming that 25 percent of the land is rested (in lieu of fertilizer) annually this is reduced to 601,200 feddans (252,500 ha). If there is a 60 percent adoption rate this would yield an annual additional production of 111,105 tons/yr of sorghum. The current annual decline in production of 6,000 tons would be halted, although this would be offset by the production foregone of about 30,000 tons/yr of land put under fallow. The net annual incremental production would of the order of 85,100 tons/yr.

(c) Benefits from a large-scale redistribution of Land to Small-scale Farmers, Agro-pastoralist and Pastoralists

The exact area of alienated land that might revert back to the state will only be known after a comprehensive and detailed survey has been undertaken. How that land might be redistributed amongst the potential stakeholders (sedentary cultivators, agro-pastoralist and pastoralists) can only be determined through a process to be determined by the newly established Land Commission. Thus, no attempt is made here to assess what may and to whom benefits might accrue to such a re-distribution.

4.4.2 Potential benefits from a Reduction in Sediment Load of the Mereb-Gash River

Much of the upper Mereb-Gash River Catchment lies within Eritrea. Currently Eritrea only has observer status within the ENSAP. Although no details are available it is known that Eritrea had a comprehensive watershed management programme under implementation. This clearly represents an opportunity for reducing sediment loads in the Mereb-Gash River.

As with Ethiopia there are both in-country benefits (and costs) and trans-boundary benefits and possible costs. Potential benefits are a significant reduction in sediment load of the Mereb-Gash, and the benefits that would accrue to the Gash Delta Irrigation Scheme in terms of reduced expenditures on desilting of canals and intakes. A potential cost might be a significant reduction in or attenuation of the flood peak, given the short growing season and strong dependency on the amount of the flood on the area prepared for cultivation.

Also, there are potentially a number of cooperative activities of mutual benefit and these are explored below.

4.5 Other Strategic Interventions

4.5.1 Incentives

(i) Ethiopia

A distinction needs to be made between incentives for on-farm (i.e. private) soil conservation investments and those for community investments. Clarity is required in implementing food for work as an incentive and food for work as direct food relief.

The Federal Rural Development Policy reflects the new ideas and intentions with regard to the role of food aid. It advocates the replacement, where possible, of food for work (FFW) by cash for work (CFW) and, if food is to be used (e.g. for direct relief), it is preferred that food to be procured from local sources.

A different basis needs to be created for motivating and/or compensating farmers to contribute to community work. Some measures for consideration are:

- establish a transparent distinction between on-farm work, voluntary as much as possible, and off-farm development activities that can be compensated by FFW or CFW,
- abandon the application of FFW for on-farm work, and promote the integration of SWC as to become part and parcel of farming practices,
- to harmonise the above measures with ongoing FFW through the WFP-MERET project,
- create alternative, off-farm opportunities for employment and income generation (cash-for-work, farm inputs for work),
- replace "Community Participation" and mass mobilisation campaigns by voluntary work in farmers own village areas on locations selected by farmers themselves,
- ensure that farmers exempted from Community Participation are not loosing opportunities of working in other schemes of employment generation,
- ensure that SWC treated areas will be exempted from land redistribution.

Introduction of such measures requires action at all levels, focussing in the first place on changing attitudes, both of farmers (driven by a food dependency syndrome), authorities (still used to top down planning and implementation) and donors (putting too little emphasis on impact monitoring and cost effectiveness).

The overall objective would be to achieve **genuine community participation** in development activities by empowering, facilitating and assisting local communities in:

- fully integrating SWC activities into farming practices,
- implementing these on a voluntary unpaid basis, and
- allowing farmers to take their own decisions with regard to implementation locations.

(ii) Sudan

Hitherto food aid has been serving as a life-saving instrument in Sudan. With the changing circumstances its role is likely to change. It is generally recognized that it should be linked to improved livelihoods and the broader sectoral interventions such as agriculture, natural resources, education and health. Thus, it could be linked to distribution of agricultural inputs, agro-forestry, water development and pasture rehabilitation. Other activities could include road repairs and construction, food for education and health related interventions.

There is an ongoing debate on the relative merits of providing food versus cash. Both have their advantages and disadvantages in the Sudanese context. The advantages of food transfers are as follows:

- in areas of chronic food shortages providing food increases its availability and brings food prices down;
- they provide a protection against inflation as a transfer in the form of food is self-indexed and the cost of inflation is borne by the provider[16];
- giving food is quickest way of improving nutrition;
- providing free or subsidized food is effectively an income transfer as it is possible to trade food for cash or other goods;
- food transfers ensure that the beneficiaries will allocate a higher proportion of an additional unit of food income towards food consumption.

The main disadvantages of large-scale transfers of food are the disincentive effects they have on domestic production and trade. Such transfers could

[16] FAO/WFP (2006) op. cite.

depress market prices leading to serious erosion of profits for domestic producers such that farmers reduce or move out of production.

The main advantage of a cash transfer is that it allows consumers more control over their decisions based on the particular conditions they face. They are a more efficient way of transferring income than pure food transfers. Food can be converted to cash but it involves transfer costs. Cash transfers are generally less distortive to the local economy than large food transfers. In conditions where markets are functioning well cash transfers can augment the development process by creating additional effective demand for goods and services boosting trading and productive activities.

The main disadvantage of cash transfers is that their real value is dependant on the rate of inflation. There is a real possibility of more inflation in food and other prices following a large scale cash transfer programme, particularly where markets are functioning poorly and the economy is relatively closed. Additionally, large cash transfer programmes are the greater risks of fraud theft and administrative leakages, relative to food transfer programmes.

The probable solution for Sudan is to continue with food transfers in locations where food shortages exist due to lack of production or lack of transport infrastructure. Pilot cash programmes should only be considered where the enabling conditions: markets and infrastructure exist and where the scope of food transfers is relatively small and so avoid inflationary pressures.

4.5.2 Resettlement of Population

In Ethiopia in the centuries before 1975 there had been a slow drift of people from the north moving south to less populated areas. Following the Land Reform of 1975 internal movement within rural areas became difficult particularly in the north where land was already short. Peasant Associations [17]Committees allocated land and first preference was always given to dependants of existing families. Nevertheless, there was continued migration into the sparsely forested areas of the southwest.

During the early 1980’s a Resettlement Campaign resulted in large numbers of people being moved from the high population density areas to areas in the western Lowlands. Two strategies were followed: (i) movement to large Resettlement Camps, and (ii) a less intense approach where families were “integrated” into existing highland areas mainly in the southwest. There were many documented instances of involuntary resettlement and following the change in Government in 1991 many of the large Resettlement Camps emptied

[17] Areas with defined boundaries approximately 1,500 ha in extent with about 300 – 400 families.

with people returning to their home areas, although in two areas (the Beles Valley and Assossa) many families remained.

A recent study of the negative impacts of land degradation on agricultural production and strategies to alleviate these (Sonnerveld (2002) took as one of its assumptions that population was free to move within and outside the area of ethnic origin of the farmers (migration scenario). Migration within areas of ethnic origin coupled with soil conservation gave an increase in annual agricultural production of 3.28 percent and 3.8 percent with unrestricted migration. With no migration but with soil conservation the annual increase in agricultural production was 0.19 percent.

Since 2003 a new official voluntary resettlement programme is in place (Government of Ethiopia, 2003). Movement of settlers is confined to within-region movement only – no inter-Regional movement of people is envisaged - the "restricted" migration scenario of Sonnerveld (2004). The programme is designed to take into account lessons from resettlement programmes in the past. These include:

- Desperate people will move spontaneously (14 million people face food shortages in Ethiopia),
- Voluntary resettlement is essential for success,
- Resource user rights of host communities must be respected,
- Participants must be fully informed in order to make choices,
- Potential conflicts can be reduced by remaining within Regional boundaries[18],
- Risks to environment and environmental factors affecting health must be taken into account,
- The Programme must be designed with rules of access and institutionalised implementation (not as a campaign driven by the present emergency, and
- Incentives must built in at each level of design and seek to achieve sustainability.

The GoE has identified the following areas with the estimated number of population to be resettled in the Tekeze Sub-basin as follows:

[18] Although as recent events in southern and south-western Ethiopia this is not a guarantee that ethnic conflict over natural resources will not arise.

- Humera, Tegede, Metema

The Government proposes that amounts of land to be allocated to settlers and to be leased to Commercial Farming must be identified at the same time, and investment and resettlement plans must be harmonized. Initially settlers will be allocated use rights for three years after which if land management is successful full use rights are to be issued for a period to be determined by government.

The programme started in 2003 and is being implemented with domestic funds. A number of potential risks were identified and counter-measures specified in the planning stage. These include:

- Risk of pressure from above for speedy implementation: (built-in triggers in source and target areas with regard to preparedness, suitability and capacity).

- Risk of exposure to malaria and other diseases: (health resources to be made available including clinics, bed-nets provision, etc.)

- Environmental damage (Environmental assessments to be undertaken, potential for forestation and carbon sequestration to be explored).

- Potential conflict over resources, competing claims for land: (land made available to be subject to public consultation, mechanism for adjudication of claims and for compensation to be put in place).
- Insufficient capacity for implementation: (keep demands on local capacity to a minimum, draw on Capacity Building for Decentralized Service delivery programme).

- Dependency on initial food aid and lack of sustainability: (efforts made to bring attitudinal change in programme design and implementation).

- Budget constraint and delays in funding: (proposed budget considered adequate.)

4.5.3 Improving Rural and Urban Domestic (traditional/biomass) Energy Systems.

(i) Ethiopia

The focus here is on domestic biomass (or “traditional”) energy sources. “Modern” energy sources are considered only in respect of their role as substitutions for biomass sources.

The reason for this focus on biomass energy is because of its very large contribution to household energy consumption, even where modern energy sources (electricity, LP gas, kerosene) are available. This is because a large proportion of household energy is used for cooking and the relative total costs of using biomass fuels for cooking is often lower than modern fuels, particularly when the capital costs of modern energy stoves are taken into account. The widespread and increasing total consumption (with rising population) of biomass fuels has obvious implications for vegetation cover and land degradation. The continued use of biomass fuels and emissions of smoke and corrosive gases in enclosed kitchen spaces also have very important implications for the health of women and children.

Many recent studies of rural (and to a much lesser extent urban) energy consumption have revealed an often complex spatial and seasonal patterns to the various biomass fuels consumed (wood, charcoal, crop residues and cattle dung). Generally there is a clear distinction between rural and urban household consumption patterns with the consumption of a higher proportion of modern energy, and within biomass fuels of charcoal.

Within the Sub-basin there are four broad patterns of rural domestic biomass energy systems. In highland Ethiopia a broad distinction can be made between the more humid western and the more arid eastern part related in part to the better natural vegetation cover and also to the much higher number of on-farm planted trees in the higher rainfall areas of the west. The higher number of on-farm trees in the west is also due to the better road system and well developed markets for construction poles. In the western parts wood fuel and crop residues tend to predominate, whilst in the drier east wood, crop residues and dung are used. In the western Lowlands of Ethiopia where population densities are much lower and tree cover still intact, wood is generally the only fuel used.

WBISPP (2005) surveys indicate that women and girls are most involved in collecting biomass (mainly wood) fuels. They spend on average 6 and 3 hours per week respectively collecting biomass fuels, compared with one and half hours per week for men and boys. Women spend an additional 14 hours a week transporting biomass fuels. Boys and girls spend on average 6 hours and men 2 hours per week transporting biomass fuels. The burden of collecting and transporting biomass fuels involves considerable energy - most particularly on children and women. This has negative impacts on nutrition. The considerable time spent on collecting and transporting fuel means less time for other activities (child rearing) and rest. In addition, women and children are exposed to natural hazards and injury.

In the World Bank funded "Access to Energy" Project a number of strategies are currently being pursued. In summary these are:

1. Improved Biomass Energy Utilization Technologies for Rural and Urban Households: Support to private investment in construction and dissemination.

Improved Mitads: The annual reduction in wood use for mitad baking by year 10 would be 7.8 million tons per year.

Lakech Charcoal Stove: publicity campaigns by Regional Bureaus of Rural Energy to maintain the momentum of stove adoption over the ten year period.

Improved ceramic '*gounziye*' Stove with an annual fuelwood saving of 1.8 million tons per annum after ten years.

2. Improved and Sustainable Supplies of Traditional and Improved Biomass Fuels

On-Farm Tree Production: main strategy for supplying fuelwood and poles for rural consumption, and partially meeting urban demand for these products. Sales of fuelwood and poles by farmers to rural and urban markets will support farm income generation and improving rural livelihoods. The programme will also support, and seek to accelerate, the integration of on-farm tree production with crop and livestock production, and sustainable land management.

Sustainable Management of Highland Woodlands and Shrubland Remnants: "hillside closure" to be self-financing by the Communities themselves. Payment of guards and other expenses will be met from fees and charges for cut and carry of hay, fuelwood collection, tree harvesting, etc as may be determined by each individual Community. No external investment funds are required.

Sustainable Management of Highland Forests: develop regional overall land use plans for these forests, and provide support communities to manage High Forests within their jurisdiction.

Sustainable Management of Lowland Woodlands and Bamboo Resources: to ensure the long term sustainable management and utilization of the Ethiopian lowland woodland resources and their associated areas of Lowland Bamboo.

Promotion of Efficient and Sustainable Production of Charcoal: promote the concept of Group Charcoal Burners who would adopt the improved kilns.

Production of Modern Fuels: Ethanol: to be developed and funded by private enterprise with possible concessional funding from the Global Environmental

Fund under the "Clean Development Mechanism". Support to comprehensive programme of consumer education.

Briquetting of Agri-residues and Charcoal: Briquetting of agri-residues and charcoal are to be developed and funded by private enterprise.

(ii) Sudan

A similar group of strategies are being adopted in Sudan with perhaps more emphasis on the extension of the use of LPG for household energy (MEPD-HCENR, 2003, UNDP-World Bank, 1988). In Sudan the problem has been approached both from the supply and the demand side. On the supply side a number of strategies have been developed. These include:

- regulation of forest clearing activities under the mechanized farming schemes to retain 10 percent of wood cover;
- improving existing arrangements for the protection and management of woodlands both within and outside forest reserves to improve wood fuel supply;
- increasing wood supplies through tree planting;
- conserving wood supplies through improvements to charcoal production.

On the demand side the key strategies again have been to promote increases in the fuel utilization efficiency:

- institutional strengthening of the National energy Agency (NEA) to enable it to management a fuel utilization efficiency research programme;
- promotion and dissemination of fuel efficient stoves for household cooking;
- identification and dissemination of technology to improve energy utilization efficiency of small wood-based industries.

Increasingly the use of LPG is being promoted for household energy use, particularly in urban areas and more recently in some rural areas.

(iii) Key benefits

In both Sudan and Ethiopia key benefits for these supply and demand side strategies are to increase wood fuel supply on a sustainable basis; to reduce demand for wood fuel and charcoal through increased fuel efficient stoves and through the increase use of LPG. These in turn will reduce the rates of deforestation and increase vegetative cover. Increased stove efficiency and the use of LPG reduce smoke inhalation and reduce the incidence of respiratory diseases particularly to those most exposed: women and children. Thus they will make a substantial impact on peoples' livelihoods, health and well-being.

4.5.4 Improving Rural-urban socio-economic linkages in the context alternative livelihoods.

One of the primary objectives of the Framework for Watershed Management is “to create alternative livelihoods”. The proportion of households dependant on agriculture in Ethiopia is 85 percent although the contribution of agriculture to the country’s GDP is only 45 percent and declining, with the Service and Industrial sectors providing the remaining and increasing proportions. Much of the latter’s activities are taking place in the major urban centres, but also in the small and intermediate centres.

Experience suggests a number of possibilities for small and medium sized urban centres (Barret et al., 2001, World Bank 2004). These include:

- Increasing rural agricultural income by acting as demand and market nodes for agricultural produce from rural hinterlands.
- Reducing costs and improving access to a range of public and private services and goods from within and outside the immediate region by acting as a centre for production, processing and distribution of goods and services to rural hinterlands.
- Becoming centres for growth and consolidation of non-farm economic activities and employment for rural residents through the development of small and medium size enterprises or the relocation of branches of large private or public enterprises.
- Attracting rural migrants through the demand for non-farm labour.

A study on employment and labour mobility in Ethiopia (RESAL-Ethiopia, 1999) concluded that migratory labour is an important source of additional income for poor rural households and likely to play an increasing role as a coping mechanism for households facing food insecurity. It noted that little attention has been devoted to this topic than hitherto. Another study in Ethiopia (Berhanu Nega, 2004) also noted that the development of the non agricultural sector in general and the issue of urbanization in particular should be taken very seriously. The study questioned whether development of the agricultural sector by itself could serve as the engine of growth for industrialization.

A number of key strategies have been identified:

- Develop and improve access to markets through improved road and other forms of communication (e.g. telecommunications);

- Improve access to capital and credit sources;
- Provide basic technical skills (e.g. bricklaying, carpentry, etc) to improve employability;
- Provide support to traders through improved working capital and credit (they provide the link between farmers and non-farm activities and between local, national and international markets).

Together with accessible markets, access to credit and input supplies are main ingredients for rural development. Despite a number of efforts in the past, all three are poorly developed, let alone their appropriate linkage. The Millennium Development Goals Needs Assessment Report (Seme Debela et al., 2004) reports, that “consumption levels of fertilizers and pesticides are one of the lowest in the world, and that there is an enormous potential for agricultural development if inputs are made available timely and at affordable prices and acceptable quality and quantity, supported with favourable policy environment.”

As far as credit and inputs are concerned, it is very difficult to get out of the vicious circle of poor farmers, high interest rates of private credit providers, low reimbursement rates, limited government capacity to provide soft loans, and non-sustainability of incidental soft loan systems through projects/programmes with a limited duration. Bad experiences in the past (failures of blanket-wise input promotion not suited to all conditions) have made farmers even more reluctant to take credits for agricultural investments.

The importance of soft loans is emphasized by many. The evaluation report of Irish Aid activities in Tigray mentioned access to credit as the best secondary project benefit to farmers. The Report suggests using part of the compensation in cash for community work for the creation of revolving funds for credit supply services.

Ready-made solutions to the credit/supply issue do not exist but a number of preconditions need to be considered:

- more site-specific extension messages need to be developed as to replace previous blanket approaches,
- extension and input supply systems should become more problem-oriented and demand-driven,
- both the demand and supply side should develop in line with market-oriented agricultural development,
- supply systems should be developed by the private sector and not by government,

- institutional development at grassroots level should be promoted to better represent farmers' interests (appreciation of extension messages, knowledge of the market, negotiating interest rates).

Successful examples of credit supply (e.g. by Menschen für Menschen in Merhabete, Mida and Dera weredas in the Abbay basin) are based on short term inputs, like providing a starting capital, with appropriate institutional arrangements for long term application. Institutional arrangements need to be based on existing (banking) structures. Revolving funds created and managed by some NGOs within the framework of their ongoing activities are likely to collapse after phasing out of the project.

A number of overall policy issues have been identified as of considerable importance in relation to local economic development in small and intermediate urban centres (Satterthwaite and Tacoli, 2003). These support and reinforce some of the issues previous identified. They include:

- Transport and communications infrastructure are very important although of themselves will not guarantee local economic development.

- Decentralization has great potential in terms of efficiency and accountability but there are a number of cost and other considerations. In particular there is a need to address: (i) access to adequate financial resources, (ii) a favourable climate for local institutions (e.g. land tenure systems, institutional structure of markets, a broader national development strategy that is export orientated).

- Better integration of local, regional and national planning.

- Capacity building of local institutions especially where decentralization is recent.

- Strengthening of local democracy and civil society to make it easier for poor groups to have their needs taken into consideration.

4.6 Potential Transboundary benefits

4.6.1 Overall Downstream Impact on Sedimentation in the Tekeze-Atbara River System from Upstream Watershed Management and Dam Operation Activities

Overall, an achievable watershed management programme involving stone bunds, area closures and conserved and sustainably managed woodlands and shrublands could achieve nearly a 31 percent reduction in suspended sediment in the Tekeze river system. The suspended load of the Setit at Shuwak could be reduced from 68.6 million tons to about 47.1 million tons per annum. A similar programme in the Angereb and Upper Atbara Rivers in Ethiopia could reduce the sediment load there from 7.37 million tons to 5.06 million tons. The total reduction of sediment entering the Kashm El Girba Reservoir would be of the order of about 23.8 million tons per annum.

Although details are not available of how the Tekeze TK5 Medium Hydro-power will be operated in detail, assuming a flushing regime similar to Kashm el Girba and a mean annual sediment retention of 30 percent. The current sediment load passing the dam site is 31.1 million tons/yr. The watershed management interventions would reduce this to 18.062 millions tons. Some 5.598 million tons/yr would be retained in the reservoir. This would further reduce the amount of sediment entering Kashm el Girba reservoir to 37.0 million tons/yr or a 40 percent reduction in sedimentation of the reservoir and also an equivalent reduction in the sedimentation of the canals of the New Halfa Irrigation Scheme.

There are two potential negative impacts of this substantial reduction in sediment load and these both occurred in the main Nile below the Aswan High Dam following closure of the dam and a 90 percent reduction in sediment load. The first involves erosion of the river bed and transportation of this downstream given the higher energy potential of the river following sediment reduction. Within the Highland parts of the sub-basin bed sediment is likely to be relatively thin given the steep gradients of the main streams and rivers and the relatively high efficiency in transporting sediment through the system

Erosion is likely to be concentrated in the Sudan reach of the Atbara and on into the Main Nile. It is likely to be greatest where the sediment from the kerib land has lodged in the valley bottom. This may have implications for sedimentation in the Kashm el Girba Dam with eroded bed sediment replacing suspended sediment for a time. Experience from the Nile below the AHD was that erosion occurs in steeper reaches and deposition occurs in less steep reaches until some form of equilibrium is reached.

A second potential negative impact is an increase in river bank erosion. The Atbara for the first 200 kms of its course in Sudan is incised some 50 meters or more below the surrounding clay plains, and thus does not have the river bank structure that is present in its lowest reaches and along the Main Nile. River bank erosion is thus more likely in lower than the upper reaches.

As the bed sediment is normally of larger particle sizes than suspended sediment the eroded bed sediment is unlikely to substantially contribute to the suspended load, and will move downstream in relatively short annual movements with flood peaks.

4.6.2 Overall Downstream Impact on Sedimentation in the Mereb-Gash River System from Upstream Watershed Management and Dam Operation Activities

The hydrological and geomorphological conditions in the Mereb-Gash Catchment are similar to those in the Tekeze Catchment. It is therefore reasonable to assume that a watershed management programme in the Eritrean part of the upper catchment of the same order of magnitude as that in Ethiopia could have a similar impact on sediment yield.

On average some 11.4 million tons of sediment are deposited in the delta annually. A similar 40 percent reduction in sediment load would mean only 6.84 million tons would be deposited. As with the Atbara there would be benefits but also potential costs. The benefits would derive from a much reduced effort in cleaning intakes and canals and replacing structures.

However, a substantial reduction in sediment load could result in erosion of the main river bed leading to river channel incision. This would occur initially in the upper parts of the delta. This could in turn result in canals and their intakes at the upper end of the delta being left stranded well above the river level and making it difficult or even impossible to get water into the present canal system.

4.7 Potential Regional/Global Impacts

4.7.1 Carbon Sequestration

Under the Kyoto Protocol there is provision for carbon trading between developed and developing countries. Currently these are only eligible for re-forestation rather than reductions in woody biomass consumption (e.g. through the use of improved stoves) or avoiding deforestation (e.g. through intensified agriculture). Nevertheless as Niles et al (2002) state future changes to the Kyoto Protocol may include these criteria or that parallel carbon markets outside the Kyoto Protocol may develop.

By way of example, currently in Tigray Region, the unsustainable proportion of wood consumption as fuel (i.e. the proportion of total consumption in excess of sustainable yield) is releasing the following amount of greenhouse gases (WBISPP/MoARD (2005):

Carbon (C)	974,800 tons
Carbon dioxide (CO_2)	3,974,800 tons

Whilst the present system of national accounting depreciates manmade capital no account is made for the depletion or degradation of natural resources: they are viewed as a "free gifts of nature (Ahmed Yusuf et al., 1987). Similarly no account is made for increases in natural capital (e.g. through new discoveries of minerals, improved surveys, tree planting, major land improvements, changes in prices and thus of values on natural resource stocks). According to current national accounting practice changes in man-made capital (i.e. investment) are recorded and form part of the GDP/GNP, It has been suggested that increases or decreases in "natural capital" be similarly treated.

The burning of woody biomass stocks for fuel in excess of sustainable yield and for clearing for agriculture and settlement permanently reduces the Nation's woody biomass "capital". One component of the environmental value of woody biomass is its value for sequestering carbon and so contributing to a reduction on global warming. Under the Kyoto Protocol a "market" for sequestered carbon now exists. If the discounted value of US$7.63 per ton of carbon is used, then the current annual release of 0.974 million tons of carbon from burning woody biomass stocks incurs a potential loss of income of US$1.86 million (EBirr 16 million).
The Net National Income (NNI), which is the GDP less the depreciation of capital is the nearest measure of the nation’s sustainable income. However, as currently measured it does not take into account “depreciation” or depletion or permanent degradation of the nation’s “natural capital”, i.e. soil, water, forests, etc. The estimated value of woody biomass stocks destroyed in Tigray estimated at EBirr 16.0 million. This figure represents the depreciation of the Region’s wealth and is the amount by which the NNI should be reduced to reflect true sustainable income.

Conversely, and based on recent carbon trading values if just 25 percent of the carbon released from burning of woody biomass stocks in excess of sustainable yield in Tigray Region (1.385 million tons in 2000) could be sequestered through a 10 year programme of community managed woodlands and forest this could yield a potential income of US$ 2.64 million over the same period.

4.7.2 Biodiversity

Pagiola (1997) reports that there are positive benefits to biodiversity from practicing sustainable land management practices. These include an increase in below ground biodiversity including organisms such as insects and other invertebrates that play a vital role in maintaining soil fertility. However the greatest impacts on biodiversity are indirect. By increasing the lands productivity this reduces the need to clear more agricultural land and thus reducing deforestation and preserving biodiversity. Increased livestock pressure on rangelands initially changes the species composition and cover. The proposals to reduce pressure on rangelands in Sudan will have a positive impact on increasing biodiversity.

The Ethiopian Highlands are one of the six Vavilov centres of crop endemism. Of particular importance is the gene pool of the cereal crop barley, included within which are strains resistant to rust. An Ethiopian variety of barley crossed with other varieties helped save the United States barley crop from being devastated by rust and so saved the united States millions of US$. In situ conservation of the barley, teff and wheat gene pools are of global significance.

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

This chapter looks forward to the second component the Distributive Analysis and to the third component the "Cooperative Mechanisms" which will examine the differing levels of cooperation, the fourth component which is the development of a Long-term Watershed Management CRA and the fifth component the identification of the next round of potential Watershed Management projects. The chapter thus represents a current stage of thinking and analysis.

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 these benefits in the Tekeze-Atbara Sub-basin given the coincidence of highland/lowland and trans-boundary elements of the basin, from catchments in the Ethiopian highland to those in Sudanese lowlands. These have been detailed in para. 4.6 and 4.7. and relate to the substantial reductions in sediment load in the Tekeze-Atbara River system. These in turn will have important benefits from the river (economic 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.

The substantial reductions in sediment loads will have important positive economic benefits derived from the river. These relate in particular to the increased water available for irrigation by reductions in the rates of sedimentation in the Roseires and Senner Reservoirs and also to the improved irrigation water delivery efficiency from reductions in sediment in the irrigation canals.

In addition the TK5 hydro-power dam on the Tekeze can generate electricity which can be exported to the Sudan. Flow moderation from this dam can impact upon the seasonal availability of water through the system, thereby facilitating downstream irrigation in the New Halfa Scheme in the dry season. However, upstream flow moderation can have negative impacts where there is reduction of high flows which are important for ecological reasons with the loss of silt or water flow into specific areas.

Benefits: 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. This Watershed Management Cooperative Regional assessment involving Ethiopia, Egypt and Sudan is a typical example.

The potential for these benefits in the Tekeze-Atbara Sub-basin is beginning to appear with increased collaboration between Ethiopia, Egypt and the Sudan in hydropower production and trade. Such benefits will also appear as a regional market develops along the Northwest Ethiopia-Metema-Khartoum corridor.

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 economic and social 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 Tekeze-Atbara 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 Tekeze-Atbara River the sharing of flow, sediment and meteorological data collection has a number of advantages to Sudan and Egypt. Once the Tekeze TK5 dam is 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 to plan the operation of the Kashm el Girba and the Meroe 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 Sub-basin 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 sub-basin.

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

A Sub-basin wide sharing of flow and meteorological data combined with satellite imagery and the analysis cold cloud temperatures 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. The combination of rainfall estimation and the rainfall-runoff model allows river flows to be forecast up to three days ahead (Sutcliffe and Lazenby, 1998).

This has advantages to both Ethiopia and Sudan in terms of an early warning system and for efficient dam operation. Such a system could be extended to the Mereb-Gash and the Upper Atbara Catchments.

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. 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. The Tekeze-Atbara Sub-basin covers some 22.7 million hectares and monitoring landcover changes across the whole Sub-basin 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 Catchment) 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;

- Assessing landcover and woody biomass changes in reception areas where voluntary resettlement is being undertaken (e.g. Humera);

- 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 Gonder Zone in Amhara region and Western Zone in Tigray Region).

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

5.3.1 Setit-Tekeze Catchment

The Setit-Tekeze River provides nearly two thirds of the flow and 90 percent of the total sediment. Considerable watershed management developments are taking place in the upper catchment and the Tekeze TK5 Dam is under construction. Studies have been carried out for the Upper Atbara Irrigation Project. This involves the construction of a storage reservoir with an initial capacity of 1.5 km^3 at Rumela on the Setit River. The irrigated area would be about 300,000 feddans (120,000 ha) and the water requirement about 2.0 km^3 per year.

Given the various ongoing and planned watershed management and other development activities, it would be advantageous to undertake a cooperative Sub-basin study. This could examine the ongoing and future watershed management programme in the upper catchment, the operation of the Tekeze TK5, the Upper Atbara irrigation Dam, the Kashm el Girba Dam and the Meroe Dam, the planned irrigation, rainfed and rangeland development activities of the lower catchment. The objective would be to determine the optimal basin-wide utilization of resources. The various problems of erosion, kerib formation, reservoir and irrigation canal sedimentation, decline in soil fertility and rangeland productivity, and could be addressed in an integrated way.

5.3.2 The Upper Atbara-Angereb Catchment

Currently, the Upper Atbara-Angereb Catchment within Ethiopia is relatively undeveloped. Although only supplying a third of the flow of the main Atbara the sediment loads are relatively low. On the Sudan side of the border is a considerable belt of woodland and shrubland that is under Forest Reserve. However, the wooded clay plains on the Ethiopian side offer considerable potential for rainfed cropping and livestock production and parts are now being developed for sesame production. A key problem of the area is water supplies as the rivers generally do not flow for part of the dry season. Groundwater resources are known from the alluvial aquifers but the main Nubian sandstone aquifer lies below the basalt and requires considerable technical expertise to locate.

The cooperative development of a Catchment Watershed Management Plan could ensure that the sediment loads in the two main rivers continue to remain low. Expertise that has been developed in the Sudan in avoiding problems of rainfed cropping on the clay soils would be of considerable use to land developers in Ethiopia. A joint groundwater survey of the Lowlands could reduce costs and increase accuracy. There are thus a number of mutually beneficially cooperative activities.

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:

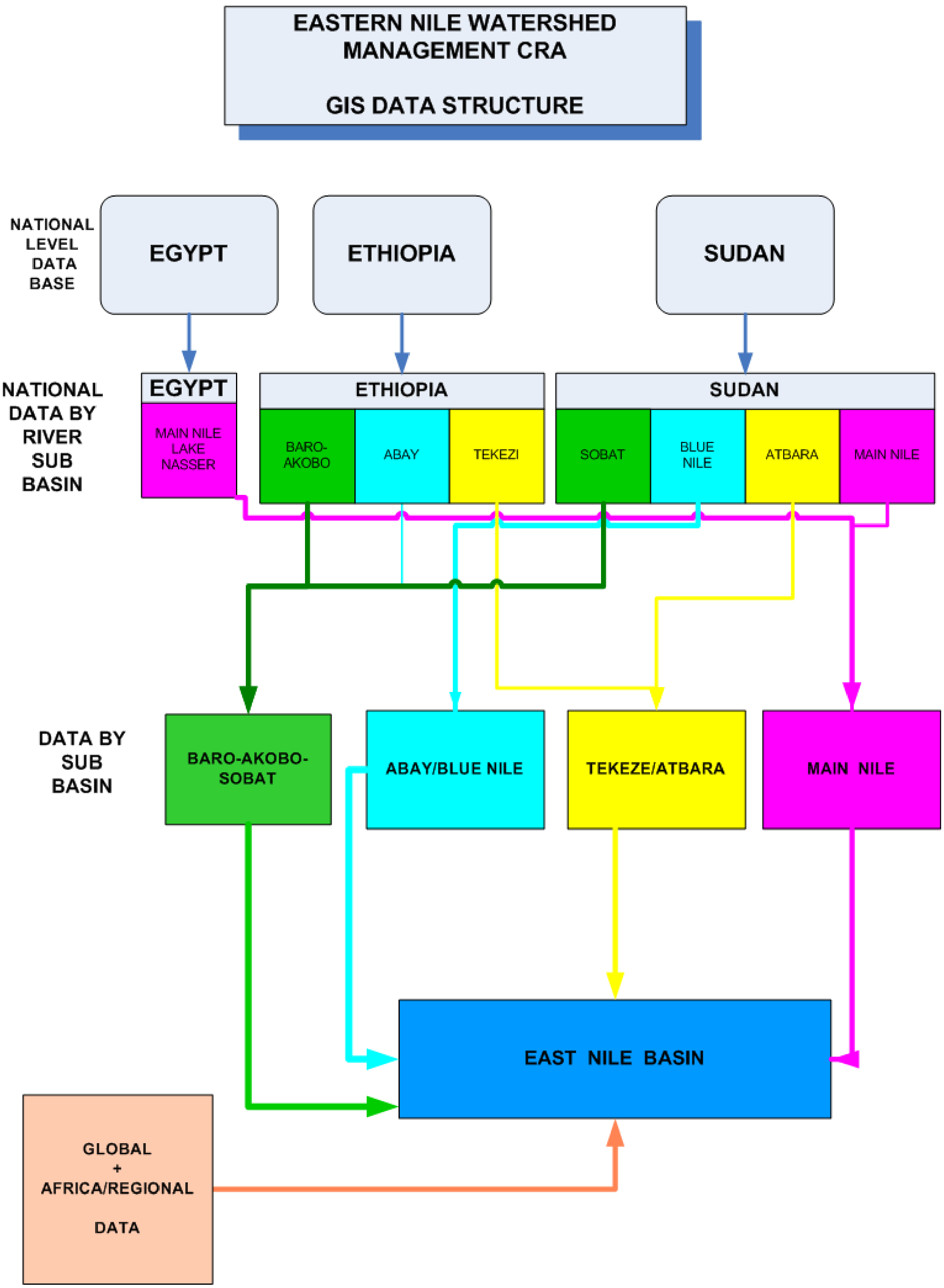
- Eastern Nile Planning Model,
- Flood Preparedness and Early Warning,
- Ethiopia-Sudan Transmission Interconnection,
- Eastern Nile Power Trade Investment
- Irrigation and Drainage

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 that will be considerable use to the Eastern Nile Planning Model, as well as to the Irrigation and Flood Preparedness CRA's (figure 9). 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.

Figure 9. Watershed Management CRA: GIS Database Structure



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.

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. The results from the this four year programme will provide a valuable input to the joint Watershed Management planning exercises for the Tekeze-Atbara Sub-basin.

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

Currently there is little or no cross-border trade within the Tekeze-Atbara Sub-basin between Sudan and Ethiopia nor has there been a history of such trade. Sudan's agricultural sector within the basin is based on irrigated cotton for export, irrigated and rainfed cereal cropping for home consumption self-sufficiency and a livestock sector for both home consumption and export. In Ethiopia the agricultural sector is primarily based on cereal and livestock production for own consumption. The Sub-basin's agriculture has no export component. Sudan has a comparative advantage in terms of petroleum products.

Nevertheless, the western Lowlands of the Tekeze-Atbara Sub-basin within Ethiopia have recently begun to see development of their natural resource potential. Vertisols cover some 940,000 ha in the Lowlands. Just across the border in Sudan in the Tekeze-Atbara and Abay-Blue Nile Sub-basins are 841,700 ha of semi-mechanized rainfed cropping, with a marketing structure relatively well developed. That area is connected to Khartoum and to Port Sudan by a major highway and railway, and by a new all-weather road from Gonder just to the north of Lake Tana to Metema, which then links to the Gederef-Khartoum Highway. A rail link to western Ethiopia from Sudan has also been mooted.

With the development of the western Lowlands of Ethiopia for agricultural and given the ease of access westwards (as distinct to those of the Addis Ababa metropolitan area), coupled with the markets in Sudan it is likely that some trans-boundary trade could develop between the two countries. Initially, this would be for commodities (grains, small low value consumer goods) that have an advantage in price on one side of the border or the other. Additionally, Port Sudan offers an alternative port to Djibouti for these western areas of Ethiopia. The possibility exists for a joint strategic food grain reserve that could provide a measure of food security for both countries.

The potential for trans-boundary tourism is weak. Ethiopia's tourism sector is geared to the northern "cultural" circuit and the Simien National Park, whilst that of Sudan is geared to the "cultural" route along the Nile and to a very small extent licensed hunting.

Thus on balance significant economic growth will only occur with the development of value-added activities within the sub-basin that are related to the agricultural development. With improved access and a freer of movement of people (e.g. visas and work permits) and given the rapidly expanding industrial and construction sector, Sudan could provide a source of alternative livelihoods through short or long-term non-farm work.

5.6 Potential Positive Interaction among Interventions

There are a number of ongoing and potential watershed management interventions with the Tekeze-Atbara Sub-basin that are essentially "in-country" rather than trans-boundary and to a large extent are being undertaken independently of each other.

Upstream the major on-going activities that are relatively independent of each other are the soil and water conservation programme, the small dams programme, the livestock forage development component of the National Livestock project and the construction of the Tekeze TK5 dam.

Potentially, there would be considerable advantages in integrating the small dams programme with that of soil and water conservation and this is under active consideration. The lack of integration between these two programmes has seen the rapid silting-up of most of the dams constructed to date and to the placing of a moratorium on the programme. The soil and water conservation programme has in recent years broadened considerably in scope and now integrates many agricultural activities (crop and livestock development) at the micro watershed level. The advantages of integration and the often positive inter-action among various components have generally been recognized although the detailed modus of implementation has often still to be adapted to particular local circumstances.

The positive interactions among such interventions as stone bunds, livestock closure areas, stream bank protection, water harvesting and small woodlots on degraded hillsides in reducing soil erosion, promoting increased crop and pasture productivity have been clearly demonstrated in the research work being undertaken under the auspices of Mekele University and documented in the Ethiopia Country Report. The case of gully reclamation being accelerated by the location of enclosed areas in the gully catchment areas have demonstrated how positive interaction between interventions can occur. The case of the Eucalyptus woodlot located in a valley bottom and the subsequent drying out of small swamp and the formation of a valley bottom gully also demonstrate some of the negative interactions that can occur.

Taken together the watershed management programme in the Tekeze Catchment and the Tekeze TK5 Dam have the potential in combination to effect a significant reduction in suspended load of the Tekeze River (para. 4.4.1). The positive impacts this reduction will have on the operation of the Kashm el Girba reservoir and the New Halfa Irrigation Scheme have also been outlined.

Downstream in the clay plains of Sudan are a number of ongoing and potential interventions that have potentially positive interactions. The sustainable reclamation of the kerib land along the Atbara upstream of the Kashm el Girba Reservoir will not only prevent further loss of valuable cropland belong to small farmers, but also provide an opportunity to produce fuelwood and fodder on individual plots. Cessation of the gulley erosion will result in a reduction in sediment delivery to the Atbara and so prolong the life of the Reservoir and reduce sediment entering the Irrigation Scheme and so reducing operation and maintenance costs.

An integrated programme of land redistribution based on land capability and local participation, supported by legal guarantees for tenure security and by technical assistance and logistical support for crop, livestock and tree production has enormous potential for positive interactions in terms of increasing soil fertility and increasing crop production, reducing pressure on rangeland and increasing livestock production, reducing pressure on woodlands and developing community development funds and overall reducing the potential for conflict between groups of people.

5.7 Cumulative Impacts of Watershed Management Interventions in Broad terms

5.7.1 Positive Impacts

There are two main positive measurable impacts of the proposed watershed management interventions: (i) increased crop' fodder and wood production (and reduced losses), and (ii) reduced sediment load in the Tekeze-Atbara River system. The assumptions and details of these have been outlined in chapter 4. Table 18 and End figures 1, 2 and 3 provide a summary.

Table 18. Summary of Cumulative Benefits to Watershed Management Interventions.

Impact	Amount
Reduction of crop production foregone:	
- burning dung & residues	3,180 tons grain/yr
- grain removal: use of fertilizer	16,375 tons grain/yr
- nutrient lost in soil erosion	29,180 tons grain/yr
- lost soil moisture holding capacity: 1st year	1,850 tons grain/yr
- lost soil moisture holding capacity: 25th year	44,635 tons grain/yr
Increase in crop production (SMF's):	85,100 tons grain/yr
Kerib reclamation	
- Prevention of land lost	1,200 ha of cropland
- Fuelwood production	10,000 tons/yr
- Forage production	20,000 tons/yr

Clearly, these will have very positive impacts on peoples' livelihoods through increased production, reduced vulnerability, increased livelihood assets and a wider range of livelihood strategies.

In terms of sediment reduction the cumulative impact of all the watershed management interventions would be to reduce the current sediment load in the Setit-Tekeze from 68.60 million tons to 42.00 millions tons, and that of the Atbara-Angereb from 7.37 million tons to 4.42 million tons. Total sediment entering the Kashm el Girba Reservoir would be reduced from 75.97 million tons to 46.42 million tons.

With the completion of the Tekeze TK5 dam and assuming the full impact of the Watershed Management Interventions annual sediment load would reduced by a further 5.60 million tons. Sediment entering Kashm el Girba would now be 40.82 million tons or just over a 40 percent reduction. There would be cumulative impacts of reducing reservoir storage losses and reducing sedimentation in the New Halfa Irrigation canals.

Not measured but noted is the on-going watershed management programme in Eritrea would be likely to have a similar impact on sediment reduction in the Mereb-Gash River system.

5.7.2 Negative Cumulative Impacts

It must be recorded that these substantial reductions in sediment load will have potentially negative impacts on erosion of sediment of river beds and a potential increase in river bank erosion.

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