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Eastern Nile Watershed Management Project

Cooperative Regional Assessment (CRA) for Watershed Management

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FINAL REPORT

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DISCLAIMER

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ABBREVIATIONS AND ACRONYMS

B:C Ratio	Benefit-Cost Ratio
Bloc	Bicarbonate Fund
BS-G	Beneshangul-Gumuz
CBD	Coffee Berry Disease
CIF	Cost, Insurance and Freight
CPA	Change of Productivity Approach
CRA	Cooperative Regional Assessment
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
CSA	Central Statistical Authority
DFID	Department for International Development
EARO	Ethiopian Agricultural Research Institute
EDRI	Ethiopian Development Research Institute
EHRS	Ethiopian Highlands Reclamation Study
EIA	Environmental Impact Assessment
ENSAP	Eastern Nile Subsidiary Action Programme
ENTRO	Eastern Nile Technical Regional Office
EPIC	Erosion Productivity Impact Calculator
ETB	Ethiopian Birr
EL	Egyptian Pound
FAO	Food and Agricultural Organization
Fed	Feddans
FOB	Free on Board
GEF	Global Environmental Fund
GAIL	Gross Annual Immediate Loss
GDCL	Gross Discounted Cumulative Loss
GDFL	Gross Discounted Future Loss
GDP	Gross Domestic Product
GIS	Geographic Information System
Ha	Hectare
IBRC	Institute for Biodiversity Research and Conservation
IDEM	Integrated Development of the Eastern Nile
IFPRI	International Food Policy Research Institute
IGADD	Inter Governmental Agency for Drought and Desertification
IIED	International Institute for Environment and Development
ILO	International Labor Office
IPCC	International Panel on Climate Change
ERR	Internal Rate of Return
IUCN	International Union for the Conservation of Nature
IWMI	International Water Management Institute
JAM	Joint Appraisal Mission
JMP	Joint Multipurpose Programme
Km	Kilometer
Km^2	Square kilometer
KWh	Kilowatt Hour
LDC	less Developed Country
M	meter
M^3	cubic meter
MAI	mean annual increment
MASL	meters above sea level
$M\ m^3$	Million Cubic Meters
MERET	Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods
MARD	Ministry of Agriculture and Rural Development
MoPED	Ministry of Planning and Economic Development
MWR	Ministry of Water Resources
MTPR	Marginal Time Preference Rate
MW	Mega Watt

N	Nitrogen
NBI	Nile Basin Initiative
NCS	National Conservation Strategy
NPV	Net Present Value
NTFP	Non-Timber Forest Product
OM	Operating and Maintenance
P	Phosphorous
PEA	Preventive Expenditure Approach
PV	Present Value
PVINR	Present Value of Incremental Net Returns
RCA	Replacement Cost Approach
RUSLE	Revised Universal Soil Loss Equation
SCC	Sudan Cotton Corporation
SCRP	Soil Conservation Research Project
SDD	Sudanese Drachma
SIDA	Swedish International development Agency
SL	Sudanese Pound
SWC	Soil and Water Conservation
T	ton
TGE	Transitional Government of Ethiopia
UNFCCC	United Nactions Framework Convention on Climate Change
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
USLE	Universal Soil Loss Equation
US$	United States Dollar
WB	World Bank
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WSM	Watershed Management

EXECUTIVE SUMMARY

Chapter 1 introduces the Watershed Management Cooperative Region Assessment (WM – CRA) and the approach that has been adopted to developing the framework. The objectives and scope of Distributive Analysis, which is the subject of this Report, are outlined. The linkages between the Transboundary Analysis, which has preceded this component and the Cooperative Mechanisms component which follows are explained.

Chapter 2 commences with an explanation of the approach and methodologies adopted in the assessment the impacts of the proposed interventions. The chapter concludes with an outline of the organization and layout of the results of the analysis.

Chapter 3 provides a macro framework for the development of the Watershed Management programme of interventions. It commences with a summary of the poverty and environment degradation nexus and provides an overview of the incidence and prevalence of poverty and the specific determinants of poverty for each of the three countries. The chapter examines some of the experience gained to date in identifying conditions that support or constrain adoption of investments by households and communities of sustainable natural resource management practices. The chapter goes on to briefly outline the current national macro development policies, strategies and programme to provide the context for the proposed Programme of Interventions. Given its importance for future watershed management and agricultural development the potential impacts of climate change are outlined and some of the key issues that are raised. Finally, an overview is provided in matrix form of the proposed 10 year programme of direct and supporting interventions.

Chapters 4 through to 7 relate to each of the four Sub-basins on a country by country basis. The first section of each chapter provides an analysis of the potential impacts of the Watershed Management Programme as a whole. It is recognised that there are many synergistic effects between the direct and the supporting interventions that do not emerge in an impact analysis of any single intervention. The benefits are identified firstly at the household and community level, the national level (within the Sub-basin), the Sub-basin and Regional level and finally the Global level.

Household and Community Level:

The results of the benefit:cost analysis of on-farm and community interventions demonstrate that there is significant potential for arresting degradation of the natural resource base, increasing agricultural productivity, increasing food supply with improved levels of nutrition and health, reducing vulnerability to climatic, social and economic shocks.

Areas of food deficits are currently well served by a number of watershed management support programmes. However, there is an urgent need to extend support to households and communities in apparently more favourable areas where there is clear evidence that the high costs of initial labour requirements are an impediment to adoption of SWC measures on cropland and non-cropland.

Interventions that increase the easy accessibility of fuel wood (on-farm tree planting) together with the reduction in firewood consumption (improved stoves) will considerably reduce the work loads of women and children. In addition, there will positive impacts on their health and well-being through reduced smoke inhalation thus reducing the incidence of respiratory diseases.

The supporting interventions will have substantial positive impacts on households and communities. Measures to increase market accessibility and integration such as feeder roads and extension of telecommunications will reduce market transaction costs thus benefiting both producers and consumers. This will result in an expansion of local economic multipliers particularly through increased purchases of local non-tradable goods as well as backward (increased purchases of inputs) and forward multipliers (from an increase in marketed agricultural goods). These will in turn increase employment opportunities in many small urban centres. At the national level regional multipliers will also increase: backward and forward as well as the growth of tertiary and secondary urban centres thus stimulating Sub-regional economies.

National level:

Increased physical accessibility together with the capacity building, literacy and skills training interventions will increase access to information, social services (health and education) and knowledge of improved technology. Support to the agricultural Extension and Research Services with improve linkages between farmers, extension and research workers will increase the relevance of research to the traditional rainfed farming sector.

At the national level, by targeting the traditional agricultural sector (rather than the commercial agricultural sector) a proportionally greater impact will be achieved in reducing the numbers of households living below the poverty line.

Sub-basin level:

At the Sub-basin level, whilst currently there is little trans-boundary trade between Ethiopia and Sudan, with the expansion of the Sub-regional economies on both sides of the border together with improved cross-border roads links the potential for increasing integration of Sub-region economies of both countries becomes possible, most particularly in the Tekeze-Atbara and Abbay-Blue Nile Sub-basins. Closer cooperation with crop early warning systems, establishing joint strategic grain reserves and local purchases of grains for food relief will enable faster responses to local food shortages on both sides of the border.

The quantifiable benefits of reduced erosion in the Ethiopian Highlands and sediment loads in the Abbay-Blue Nile and Tekeze-Atbara river systems on reducing costs within Sudan of dredging of power intakes and irrigation canals, loss of power generating potential due to the need for reservoir flushing, are relatively small in comparison to the national benefits. Nevertheless, these reductions will also contribute to reductions in costs that it has not been possible to quantify: of pump and turbine damage and the removal of sediment for domestic and industrial water supplies. WSM measures in the upper Dinder and Rahad catchments will reduce sedimentation of the maya'a wetlands thus reducing the incidence of flooding of agricultural lands.

Global Level

At the global there are a number of opportunities for increasing the sequestration of carbon dioxide and for conserving genetic, species and habitat biodiversity. The opportunities for carbon sequestration are particularly substantial in the area of increase soil carbon – a hitherto neglected area. Soil carbon increases under well managed or enclosed pastures and rangeland. Preliminary quantification of this impact is made in the third section of each chapter. The proposed interventions for establishing a Transboundary Park incorporating the Dinder and Alatish Parks will bring substantial benefits to conserving biodiversity in this important area. Similar benefits will accrue with trans-boundary cooperation in the Gambella and Boma National Parks.

Impacts and Costs of Continued Natural Resource Management Practices

The second section of each country within the Sub-basin examines the impacts and costs of the continued natural resource management practices. This is essentially a "without programme" or "business as usual" scenario. Many of these costs are cumulative and the analysis provides results for the current year and after 25 years. A summary of the results by Sub-basin at National, Regional and Global levels is given in the table below.

Resource	1 year US$ million	% year 1	25 years US$ million	% year 25
ABBAY-BLUE NILE				
National	221.2		757.5	
Regional	3.7		86.9	
Global	285.9		1,131.2	
Benefits	11.6		263.9	
NET COSTS	**499.2**	74%	**1,711.7**	38%
TEKEZE-ATBARA				
National	44.4		105.4	
Regional	-		-	
Global	4.2		4.2	
Benefits	-		-	
NET COSTS	**48.6**	7%	**109.6**	2%
BARO-SOBAT-WHITE NILE				
National	59.1		1,628.6	
Regional	1.1		27.9	
Global	23.9		617.3	
Benefits	7.7		7.7	
NET COSTS	**76.4**	11%	**2,266.1**	50%
MAIN NILE				
National	47.2		418.7	
Regional	-		-	
Global	-		-	
Benefits	-		-	
NET COSTS	**47.2**	7%	**418.7**	9%
NET COSTS: EASTERN NILE BASIN	**671.4**		**4,506.10**	

Impacts, Cost and Benefits of the Direct Interventions

The third section in each chapter then details the impacts, costs and benefits of the direct interventions as far as these could be quantified. A national outline budget is presented to provide a preliminary estimate of the costs of the Sub-basin programme. The final section summarizes the quantifiable economic and environmental costs and benefits for the sub-basin as a whole, separating out for each country the costs and benefits accruing at the national, Regional and Global levels, together with an estimate of the economic B:C ratios.

A key finding of the financial analysis is that a number of interventions have substantial initial costs in terms of labour for construction and establishment. For a number of interventions it takes a number of years for benefits to be realized (e.g. on-farm tree planting) or benefits only slowly accrue (e.g. SWC measures). The high personal discount rates of many rural farmers and pastoralists and their risk-averse approach to production means that they are extremely reluctant to invest in the interventions notwithstanding their long-term profitability. In economic terms most interventions show positive B:C ratios indicating they can be justified in social and environmental terms. One exception is the establishment of shelterbelts in the Semi-mechanized farms, where the income forgone from crop production reduces the B:C ratio to below unity even with a zero discount rate.

The summary results for the Eastern Nile Basin are shown in the table below. The overall B:C ratio is 2.8. The incremental benefits comprise 92 percent national, 2 percent regional and 5 percent global. The overall net present value of the benefits using a real discount rate of 10 percent over 50 years is US$ 8,510 million.

Economic Costs and Benefits of WSM Interventions in the Eastern Nile Sub-Basin

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
ETHIOPIA							
National							
Soil conservation: Bunds	165.6	519.9	1,414.9	1,548.3	76.9	133.3	1.7
Soil conservation: Grass strips	576.8	582.9	1,155.8	1,208.6	6.2	52.8	8.6
Fertilizer/Improved seed	558.5	721.0	1,810.3	2,616.3	162.4	-	0.0
On-farm Forage	0.7	23.0	217.3	565.2	22.2	347.9	15.6
On-farm Trees: Fuelwood	1.3	28.9	219.3	497.8	27.6	278.5	10.1
On-farm Trees: Crop Production saved: Soil N retained	-	-	-			140.8	
Improved stoves	-	5.8	-	83.0	5.8	83.0	14.4
Area enclosure	576.5	1,161.5	1,085.5	9,138.1	585.0	8,052.6	13.8
Small-scale Irrigation	49.4	415.6	120.6	881.0	366.2	760.4	2.1
Small-scale Irrigation: Multiplier Impacts	-	-	-	-	-	134.5	
Supporting Interventions					1,137.4		0.0
Sub-total	**1,928.8**	**3,458.6**	**6,023.7**	**16,538.3**	**2,389.8**	**9,983.8**	**4.2**
Regional	-	-	-	-	-	-	
Global							
Soil conservation: Soil Carbon seq.	-	-	-	-	-	66.4	
On-farm Trees: Tree carbon	-	-	-	-	-	19.1	
Improved Stoves: Fuel saving: Tree Carbon seq.	-	-	-	-	-	8.4	
Enclosed areas: tree carbon	-	-	-	-	-	394.9	
Enclosed areas: Soil carbon	-	-	-	-	-	170.1	
Sub-total	**-**	**-**	**-**	**-**	**-**	**658.8**	
TOTAL ETHIOPIA	**1,928.8**	**3,458.6**	**6,023.7**	**16,538.3**	**2,389.8**	**10,642.6**	**4.5**
SUDAN							
National							
Traditional Rainfed Farms: Crop production	808.7	1,311.0	1,338.3	2,560.2	502.3	1,221.9	2.4
Semi-mechanised farms: Crop production	351.9	1,024.4	503.3	1,396.2	672.5	892.9	1.3
Semi-mechanised farms: Charcoal production	-	46.3	-	30.2	46.3	49.0	1.1
Semi-mechanised farms: Residue: Livestock feed						15.7	
Reclamation: Kerib land	0.0	3.2	0.0	8.1	3.2	8.1	2.5
Supporting Interventions					1,052.2		
Sub-total	**1,160.6**	**2,384.8**	**1,841.6**	**3,994.6**	**2,276.5**	**2,187.6**	**1.0**
	-						
Regional							
Increased irrigation water	-	-	-	-	-	10.5	
Reduced OM Costs: Irrigation schemes	-	-	-	-	-	33.6	
Reduced fertilizer value: Sediment	-	-	-	-	-	(9.8)	
Kerib land: Reduced sediment load Atbara						0.1	
Kerib land: Reduced fert. Value Sediment						(0.0)	
Sub-total	**-**	**-**	**-**	**-**	**-**	**34.3**	
Global							
Traditional Rainfed Farms: Soil carbon	-	-	-	-	-	22.7	
SMF's : Soil carbon	-	-	-	-	-	11.7	
SMF's : Tree Cover: Soil carbon	-	-	-	-	-	39.3	
Kerib land: Soil carbon	-	-	-	-	-	0.5	
Sub-total	**-**	**-**	**-**	**-**	**-**	**34.4**	
TOTAL: SUDAN	**1,160.6**	**2,384.8**	**1,841.6**	**3,994.6**	**2,276.5**	**2,256.3**	**1.0**
EQYPT							
Regional							
Reductions in lost Power Generation						16	
Reductions in lost Irrigation Water						243	
TOTAL: EGYPT	**-**	**-**	**-**	**-**	**-**	**277.0**	
TOTAL: SUB-BASIN	**3,089.4**	**5,843.4**	**7,865.3**	**20,532.9**	**4,666.3**	**13,175.9**	**2.8**

all costs and benefits are PVs over 50 years at 10% discount rate

Finally Chapter 8 examines some possible options for sharing the distribution of costs and benefits firstly at the Regional (Basin-wide) and secondly at the Global level. At the Regional level "process financing" is seen as an incremental way of developing confidence and capacity of the riparian countries. Among alternative options to direct financing from bi-lateral and International Development Banks are Trust Funds, Revolving Funds and Public-Private Partnerships. At the Global level the Global Environmental Fund (GEF) and the Carbon Fund are two of the most accessible financing sources.

1. INTRODUCTION

1.1 Eastern Nile Basin Watershed Management Cooperative Regional Assessment (CRA)

The Eastern Nile Basin covers 1.7 million km^2 and has a population of 49.5 million people in three countries (Map 1). It has been divided into four Sub-basins: the Baro-Sobat-White Nile, Abbay-Blue Nile, Tekeze-Atbara and the Main Nile from Khartoum to the Aswan High Dam. It encompasses an immense range of agro-ecological conditions and agricultural systems. The scale and complexity of watershed management problems in the three countries and four Sub-basins have been articulated in the three Country Reports and the four Trans-boundary Sub-basin reports.

The project focuses on four watersheds: the Baro-Sobat-White Nile, the Abay/Blue Nile, Tekezi/Atbara and the main Nile from Khartoum to the Aswan High Dam. 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, and
- Prepare for sustainable development orientated investments.

The EN WM-CRA is time bound and process orientated. Based on information collected in each of the three countries the regional assessment analyzes watershed management interventions and proposes longer-term activities at the Regional level. The specific objectives of the CRA are:

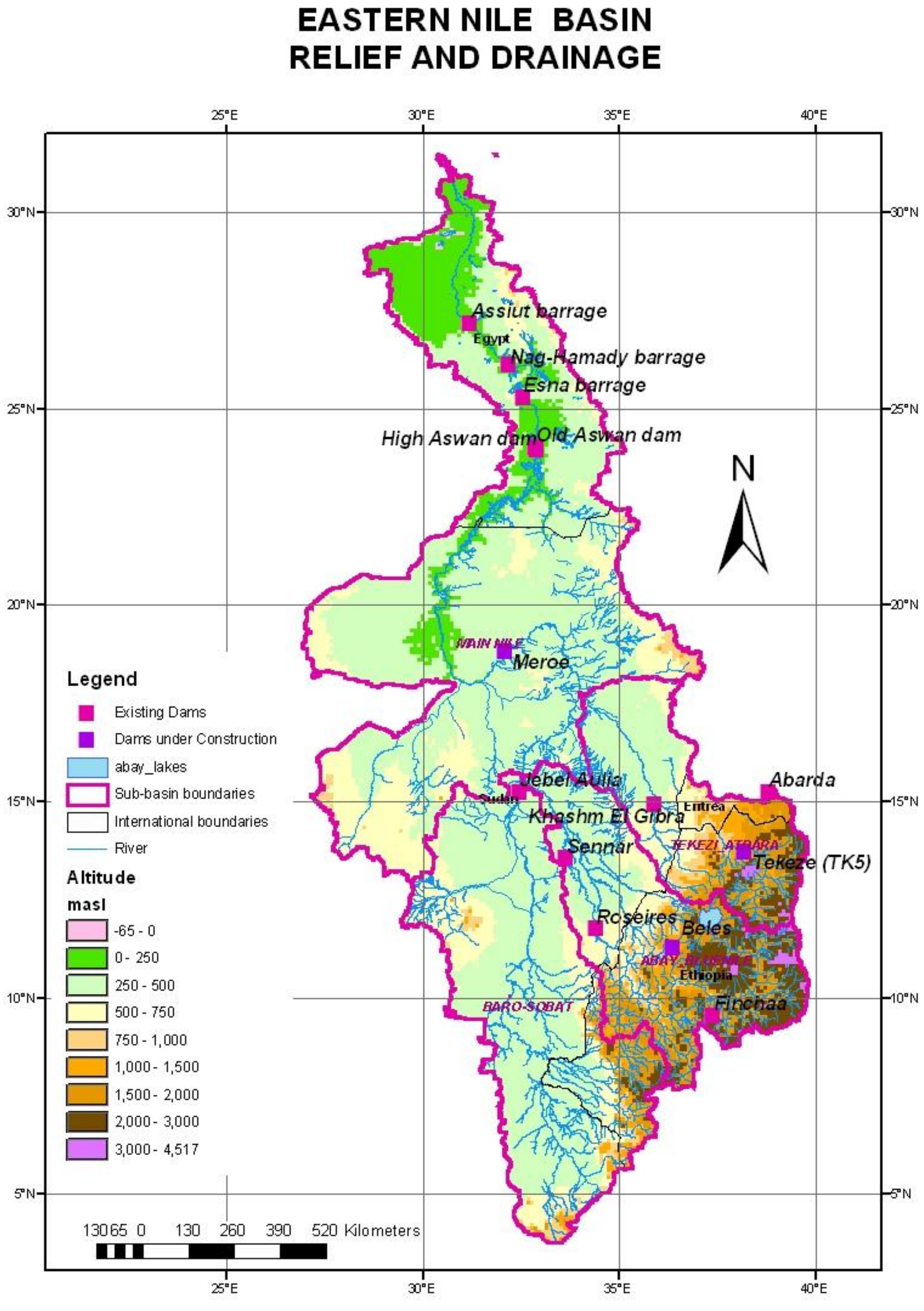
- To analyse the baseline conditions, status and trends in natural resource management in each Sub Watershed,
- To undertake a detailed problem-solution analysis to identify the proximate and the underlying causes of land degradation, and the upstream and downstream impacts,
- To review and incorporate lessons learnt from experiences of watershed management in the Eastern Nile Basin and elsewhere,
- To analyse optimal alternatives for watershed management interventions and associated benefits in downstream and upstream locations,
- To determine the distribution of costs and benefits of alternative watershed management interventions ,
- To identify the nature and scope for generating regional public goods (i.e. positive spill over effects into neighbouring countries) through watershed management projects,
- To identify the challenges, opportunities and benefits for cooperative watershed management,
- To design future/long term cooperative regional activities,
- To identify possible next round of watershed management projects,
- To prepare a summary of important watershed management considerations and linkages to be considered in the context of developing a multi-purpose programme.

1.2 Approach Adopted in Developing 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.)



Map 1. **Eastern Nile Basin. Relief and Drainage**

The approach that has been adopted in developing a framework for watershed management for the Eastern Nile Basin is 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 has been 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 avoids 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 enables the identification of basin-wide synergies from cooperative trans-boundary interventions.

An 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.

1.3 Objectives of Distributive Analysis

The main objective of this component is the analysis of the distribution of the effects (environmental, social and economic) that will impact across the three countries from watershed management (WSM) interventions within the Eastern Nile Basin.

It is considered that an understanding of the distribution of these impacts (positive and negative) emanating from watershed management activities will promote consensus and cooperation. This is seen to be particularly significant in the context of the Joint Multi-purpose Programme (JMP) currently being developed.

1.4 The Scope of the Distributive Analysis

The report examines potential watershed management (WSM) interventions in terms of four key areas:

(i) The description of the WSM interventions, their locations and their associated effects.

(ii) The current costs of natural resource degradation and thus the cost of doing nothing,

(iii) The distribution of social, environmental and economic impacts of a watershed management programme, and

(iv) The potential mechanisms for alternative distributions of the costs.

Cooperative Regional Assessments are strategic and reconnaissance in nature and are not intended as "Project Impact Analyses"[1]. The Terms of Reference accept that because specific projects will not be identified then costs (and benefits) will be difficult to identify and that only broad indications or qualitative descriptions may be possible. The analysis in this Report has sought as far as is possible to firstly quantify and secondly to place values on both costs (negative impacts) and benefits (positive impacts). Where insufficient or lack of data makes this impossible, given the time and resources available, these are indicated. In many cases these can be analyzed in greater detail in the proposed long-term Watershed Management CRA.

[1] ENTRO "Terms of Reference: Watershed Management CRA".

1.5 Linkages from the Transboundary Analysis and to the Cooperative Mechanisms Analyses

The Watershed Management CRA comprises six components:

i. Transboundary Analysis
ii. Distributive Analysis
iii. Cooperative Mechanisms Analysis
iv. Design Long term Watershed Management CRA
v. Develop Project profiles
vi. Executive Summary of the whole CRA

The Transboundary Analysis identified a range of watershed management problems and issues at the country level that were elaborated upon in the three Country Reports. The subsequent analysis then consolidated the three Country Reports into four Sub-basin Reports. These reports provided a "without borders" analysis of each of the four Sub-basins of the Eastern Nile Basin and identified opportunities to increase net benefits of watershed management interventions in the basin.

The Distributive Analysis is a logical sequence to the Transboundary Analysis. This component re-inserts borders, to analyze the distribution of the impacts (positive and negative) that emanate from the interventions proposed in the Transboundary Analysis across the three countries. Of particular concern is to assess the relative distribution of both negative and positive impacts.

The Cooperative Mechanisms Analysis that will follow this Distributive Analysis component will determine the levels and the processes of cooperation that will be required to effectively implement the watershed management interventions.

2. APPROACH AND GENERAL METHODOLOGY

2.1 The Context of the Analysis

This chapter sets out the approach and methodologies adopted in assessing the impacts, costs and benefits of the broad sets of interventions identified in the Transboundary Analyses seen necessary to achieve the sustainable watershed management of the Eastern Nile Sub-basin.

The broad objectives of the sustainable Watershed Management framework encompass immediate concerns such as arresting current degradation processes of the natural resource base in order to stabilize and increase agricultural productivity. But at a different level, they also seek to address such concerns as poverty alleviation, support to sustainable livelihoods and within the ENSAP context promoting confidence and trust among the Eastern Nile Countries.

The Eastern Nile Basin covers an extremely complex array of natural resource, social, economic, cultural and political characteristics and associated issues. The range of potential stakeholders is extremely wide. It includes households, communities, local, Regional/State/Governorate, National and International governments, organizations and institutions and Civil Society at all levels.

The potential impacts of the proposed watershed management interventions have implications at the local, national, regional (Sub-basin and Basin) and global scales. Some of these impacts can be physically quantified and valued in terms of costs and benefits, some physically quantified and valued in terms of costs although their benefits may be valued only with the application of considerable resources; and finally there will be some impacts difficult or given the resources available impossible to quantify. The impact assessment is thus presented with complex problems of analysis and those of presentation.

This chapter firstly sets out the approach adopted in the analysis and methodologies used and then outlines the organization and layout of the results.

2.2 Approach and Methodologies Adopted

2.2.1 Approach

The analysis adopted a three stage process:

1. A framework for setting the context of the Watershed Management programme was established. The purpose of this was identify the main

underlying causes of poverty and their relationships to the current management practices related to natural resource base in the ENB. The main national policies and strategies being adopted in terms of poverty reduction and supporting agricultural development were identified.

2. From the Transboundary Analysis an impact assessment was made of the current resource-based management practices at the local sub-basin and global levels. Where possible these were quantified and economic values calculated. This provided the Base Scenario – the without Watershed Management interventions against which the impacts of the proposed interventions could be compared.

3. The macro framework and the impact assessment of current practices enabled a broad programme to be developed of Direct Interventions together with their Supporting Interventions. The potential impacts of these were assessed at the local, Sub-basin and Global levels. Where possible these were quantified and economic values calculated. Those impacts that could be quantified and valued were aggregated by Sub-basin firstly to the country-level and then to the whole Sub-basin. Costs and benefits were identified at three levels: (i) National, (ii) Regional (Sub-basin, Basin levels, and (iii) global.

2.2.2 Methodologies

The detailed explanations of the various impact assessments and input-output relationships are set out in Annex 1. The explanation that follows sets out in broad terms the methodology and approach that were adopted in the present analysis.

(i) Establishing the Impacts of Current Practices and Proposed Interventions

a. Qualitative Assessments

Impacts of the Supporting Interventions are the most difficult to quantify except at the immediate level (e.g. numbers of D.A.s trained). Thus the impacts of the Capacity Building and Support Interventions to Extension, Micro-credit and Non-farm Income generation can only be addressed in qualitative terms. At the project level cost-effectiveness analysis of a number of alternative ways of achieving the desired outputs is often undertaken.

Potential impacts of Supporting Interventions such as Strategic and Local Level Land Use Planning on rates of deforestation can be quantified to some extent because the areas involved are known and the costs of "No Intervention" have been established. Examples can be given on costs avoided if assumptions are made regarding specific areas that are protected or are designated to traditional or large-scale commercial agriculture.

The quantitative assessment of impacts of increased market accessibility and integration on agricultural production have been undertaken for Ethiopia (Chamberlin et al., (2006) and the East African countries (Omamo et al.,(2006) using a country-wide dynamic agricultural multi-market economic model coupled with a Geographic Information System and a Dynamic Research for Management model (DREAM). However the enormous data-requirements for such modeling preclude their use in this analysis. However, the main conclusions of these analyses are used to indicate potential benefits from increased market accessibility and integration.

b. Socio-Ecological Modeling

Socio-ecological modeling has been used to identify the environmental, social and economic impacts of wetland conversion for agriculture in the Ethiopian Highlands of the Baro-Akobo Sub-basin (Dixon, 2000). This analysis reveals the extremely complex nature of the inter-relationships between ecology, hydrology and local livelihood strategies. Whilst the analysis did not quantify many of these, sufficient detail is provided to undertake a qualitative impact analysis.

c. Establishing Physical Impacts of Current Resource Management Practices and Interventions on Production

There has been and continues to be considerable research into soil erosion in the Ethiopian Highlands: that of the Ethiopian Highlands Reclamations Study (EHRS, 1985); in particular the results of the Soil Conservation Research Project (SCRP) under the auspices of the University of Berne over a long period of time in the 1980's and 90's; results from the current collaborative programme of research between the University of Makelle and Research Institutes in Belgium. All these were particularly useful in establishing production relations between agricultural productivity and land degradation.

The Hydraulic Research Station of the Ministry of Irrigation and Water Resources in Sudan has undertaken considerable research into reservoir sedimentation. The Nile Research Institute in Cairo has over many years undertaken research into sedimentation in Lake Nasser and river bank erosion below the Aswan High Dam.

These and other research results were used in the quantification of impacts of current practices and of potential impacts from proposed interventions. Detailed information on these relationships is set out in Annex 2.

d. GIS Modeling

The Woody Biomass Inventory and Strategic Planning Project (WBISPP) of the Ethiopian Ministry of Agriculture and Rural Development (MARD) undertook GIS modeling of potential soil erosion rates for the whole of Ethiopia using the revised universal soil loss equation (RUSLE) calibrated for Ethiopian conditions. Whilst the limitations of RUSLE are well known, applied consistently it provides a comparative estimate of soil erosion hazard over an extremely large area without the huge data requirements of other more complex methods. A detailed explanation of the data sets used and the results obtained are set out in Annex 1.

(ii) Alternative Evaluation Methods

a. Cost Effectiveness Analysis (CEA)

The impacts of some of the Supporting Interventions may not be easily measured in monetary terms and the usual CBA decision criteria cannot be used. In many of these cases cost effective analysis can assist in choosing among alternative interventions where they achieve the same result (Belli et al., 2001). For example there may be three alternative methods of training Development Agents. In the present analysis this question is not examined as it assumed that the most cost-effective methods are being used.

b. Multi-criteria Analysis (MCS)

This is another approach that also has a number of variants. Standard CBA reduces everything to a single evaluation measure (B:C ratio, NPV, IRR). Many impacts of watershed management interventions are embedded in a system of broader national objectives e.g. sustainable livelihoods, poverty reduction, food security, environmental protection. Often it is necessary to seek satisfaction of a number of objectives: e.g. minimizing soil erosion, increasing crop production achieving minimum daily calorie supply.

MCA is a method of achieving this but it does require the analysis to have a set of weights for each of the objectives. These are normally set in an interactive manner with a group of policy makers. It requires that objectives or standards are very clearly specified. There are a number of problems in implementing the method. The weights of one group may differ considerably from another group with significant impacts on the final result. The mathematic framework imposes constraints on the ability to effectively represent the planning problem. de Graff (1993) states that the methods are not easy to explain and choosing the best technique from the many that are available may be difficult. For these reasons MCA was not used in the present analysis.

c. Cost-benefit Analysis (CBA):

Cost benefit analysis is the standard method of evaluating interventions and projects and has been used in the present analysis. It consists of impact analysis followed by valuation of the identified impacts. All direct, indirect and external effects are incorporated into the impact analysis. The object is to compare the present value of a stream of benefits to a stream of costs. Discounting is used to calculate the present value of future costs and benefits. Evaluation can be based on a number of decision criteria – internal rate of return (IRR), benefit-cost ratio (B:C) and net present value (NPV). Given the programme would be implemented under budget constraints and that the interventions are not mutually exclusive (e.g. two or more interventions using the same site) the benefit cost ratio was used (Gregersen et al., 1987, Gittinger, 1982).

A distinction is made between financial (from the private interests of the stakeholders) and economic analysis (from the interests of social welfare of the nation). Social cost benefit analysis includes special concerns for the distribution of the costs and benefits, whilst environmental cost benefit analysis incorporates environmental concerns. The latter has been used in the present analysis.

(iii) Valuation Methods Used in the Benefit-Cost Analysis

A distinction is made between financial analysis on the one hand and economic, social and environmental analysis on the other.

a. Financial Analysis

Financial analysis looks at the profitability of an investment from the individual farmers or community's point of view. It focuses on the financial incentives to invest in sustainable land management (SLM) practices.

In the financial analysis only costs and benefits that actually accrue to the farmer are used and these are valued at the prices the farmer actually faces. No attempt is made to adjust these for distortions that may results from market failures or government policies. Nor is any attempt made to consider downstream effects of the farmers activities.

Financial analysis has been used in the present analysis to determine the private (farmer, community) profitability of a particularly intervention where it was possible to quantify the physical parameters.

b. Economic, Social and Environmental Analysis

Economic analysis (and its extensions social and environmental) cost benefit analysis assess the impacts of interventions on the economy as a whole. The analysis examines whether the intervention will contribute to the development of the total economy. Market prices must be adjusted to take into account distortions due to market failures and government policies. Thus taxes and subsidies are not included.

In the present analysis market prices were adjusted to take account of distortions caused by market failures and government polices, all taxes and subsidies were eliminated, and import/export parity prices used for goods that were deemed tradable. Non-tradables were converted using conversion factors calculated for the WFP's benefit-cost analysis of its Soil and water Conservation and Forestry Measures (WFP, 2005) and those for Sudan were derived from the World Bank's domestic resource cost analysis undertaken for its joint evaluation with the GoS of the Gezira irrigation scheme (World Bank, 2003).

As well as local costs and benefits the impacts of current resource management practices and those of the proposed interventions have regional and global costs and benefits (James, 2005, Pagiola et al., 2004). Total economic value comprises three values:

- **Use values**: divided into direct, indirect use and option or bequest values: Examples of direct use values include timber harvesting and sustainable harvesting of non-timber forest products (NTFP's) maintained and of indirect use values include watershed services (flood dampening, low flows maintained) and carbon sequestration. Option values include preserving an "option" to use environmental goods or services in the future - either by oneself – an "option" value or by other people - a "bequest" value.

- **Non-Use Values**: represent the enjoyment people have simply knowing that a resource exists (e.g. montane forests, whales) even if they never expect to use that resource themselves.

Regional costs and benefits include downstream reservoir sedimentation and loss of storage capacity (or the reduction in sedimentation as a result of a comprehensive upstream watershed management programme). Global costs include the loss of biodiversity caused by deforestation and global benefits include the increase in soil carbon sequestration (and reduction of atmostspheric carbon dioxide) caused by improved soil management practices.

Two methods of valuation are possible: market-based and survey-based methods. Market based methods use actual costs involved (cleaning sediment from irrigation canals. Where markets do not exist then surrogate or proxy market prices may be used. For example no market exists for soil nitrogen. In the present analysis its value in increasing crop yield and the market value of the increased crop is used.

Survey-based methods can be used to "construct" markets where neither markets nor surrogate markets exist. These include surveys to ascertain how much people have spent to visit a National Park (travel cost method); to measure peoples' willingness to pay for a good or service or their willingness to accept compensation for the loss of a good or service; or to ask people to rank their preference for a non-monetary good or service (e.g. forest products) and "anchoring these to a good that can be valued (e.g. a bore-hole) (IIED, 1994).

Because of time and resource constraints the present analysis has not undertaken any survey-based methods of valuation. However, it has taken advantage of such surveys that have been undertaken in Kenya (Wass, 1995) to obtain values for forest services that are deemed to be very similar to those in Ethiopia.

(iv) Spatial and Time Frames

Four spatial time frames were used in the analysis. The lowest level was the farm or a unit area (1 hectare) of Communal land. Where site specific data on impacts was not available (e.g. specific locations of deforestation or shelterbelt establishment in the Semi-mechanized Farms) a more aggregated level of analysis was used. In the case of deforestation the area estimates were available at the wereda and thus Sub-basin level, and for the Semi-mechanized farms from the area data available at the Sub-basin level.

The time frame for the financial local level analysis was 25 years to represent one generation of time. The programme is scheduled to be implemented over 10 years. This was taken as it was considered that this would be the time required to undertake a programme of the magnitude that would be sufficient to have any discernable impact at the spatial scale of the Eastern Nile basin. Because many of the interventions have a negative return in the first year or more, with an investment programme of 10 years many benefits would not start to have an impact on the overall programme until after 10 or more years. For this reason a time scale of 50 years was used for the national/Sub-basin level and Sub-basin/Basin level analyses[2].

(v) Discount rate

There is a vast and voluminous literature on the use of discount rates in benefit-cost analysis. In the present analysis for both the financial and the economic-environmental analysis a real rate of 10 percent was used. For the financial analysis this represents the farmers/community's own discount rate. In the economic analysis this is the rate that government uses for its own

[2] In the 1st Draft of this Report a time frame of only 20 years was used. This resulted in negative net benefits in a number of interventions that had long initial periods of negative benefits with the positive benfits only being reached close to the end of the 20 years.

investment evaluation. In most cases the benefit-cost ratios exceeded unity by a considerable order of magnitude. In these cases sensitivity analysis was undertaken by adjusting the market prices to determine if this would adversely affect the benefit-cost ratio. It is recognized that many smallholder farmers in Ethiopia and Sudan have high personal discount rates because of their vulnerability to shocks and risk-averse nature (Shiferew and Holden, 2005). In these cases the discount rate was increased. Where the B:C ratio was close to or less than unity (e.g. the establishment of shelterbelts on the Semi-mechanized farms) a lower rate of 5 percent was used to determine the relative impact on the B:C ratio.

(vi) Measures of Programme Worth

a. Perspective of the Farmer or Community in the eastern Nile basin

The financial analysis determines an intervention's worth to a farmer or community and whether or not they are likely to make the necessary investments. There are two measures of concern to a traditional rainfed farmer in the Eastern Nile Basin: the first is the overall profitability of the investment and probably more importantly, what will be the pay-back period – or when will the farmer or community start to recoup the initial costs of the investment. Here the (undiscounted) cash flow analysis can reveal how long this period is likely to be. The longer the payback period – notwithstanding the eventual profitability – will indicate the possible need for incentives, credit or direct support (as afforded by the asset development component of the safety Net Programmes).

b. Perspective of the Government

Governments are likely to be concerned about both the private and the public measure of the overall profitability of the proposed individual and the overall programme of interventions. They are concerned about the private profitability as a measure of the target beneficiaries' likelihood of adopting the improved measure and the possibility of having to use incentives or financial or other support to encourage individual investment. The use of the financial cash flow analysis in this regard has been described above. The financial analysis can also indicate the size of the resources required from Government for budgetary purposes but not to determine whether the Programme will make a positive contribution to the economy. The economic analysis provides this information.

Other measures of overall worth of an intervention or programme of interventions are the net present value (NPV) and the internal rate of return (IRR). The NPV is the difference between the present value of the discounted costs and benefits. If the difference is positive this means the investment provides a return greater than could have been obtained investing the money at the rate of interest equal to the discount rate. The IRR is the discount rate that is necessary to make the NPV equal to zero. A third measure is the discounted benefit:cost ratio which is the ratio of present value of incremental benefits to the present value of the incremental costs.

Governments will normally be concerned about the overall contribution of the programme to the national economy and in the case of the present analysis to the Sub-basin and Eastern Nile basin as a whole. Here the economic analysis provides the basis for comparison. It is the total net present worth that is the economic objective that governments seek to maximize for the investment of available scarce resources (Gregersen et al., 1987). The IRR and the B:C ratios do not give any indication of the magnitude of the net benefits. Thus the NPV should always be part of the assessment of an individual intervention or the programme of interventions.

Whilst it is not intended that the proposed interventions should be ranked it may be required that they be compared. The interventions that form part of the Programme under analysis are not mutually exclusive interventions. That is to say there are no interventions that would compete for the same site, they are termed independent interventions. Gittinger (1982) has compared the three measures of worth for (i) independent interventions with no constraint on costs, (ii) independent interventions with constraints on costs, and (iii) mutually exclusive projects within a given budget. The interventions in the proposed programme fall within (ii) above.

Gittinger states that for these independent interventions with constraints on costs is possible to use all three measures of worth but that that only the discounted B:C ratio is the most appropriate. Gregersen et al (op. cite) illustrate this using an example of 5 independent projects with a budget constraint of US$ 300,000. This is reproduced below.

Table 1. Comparing the Use of NPV and B:C ratio for Comparing Interventions

Project	Costs	Benefits	NPV	B:C ratio
A	300,000	310,000	10,000	1.033
B	100,000	108,000	8,000	1.08
C	100,000	108,000	8,000	1.08
D	50,000	52,000	2,000	1.04
E	50,000	53,000	3,000	1.06

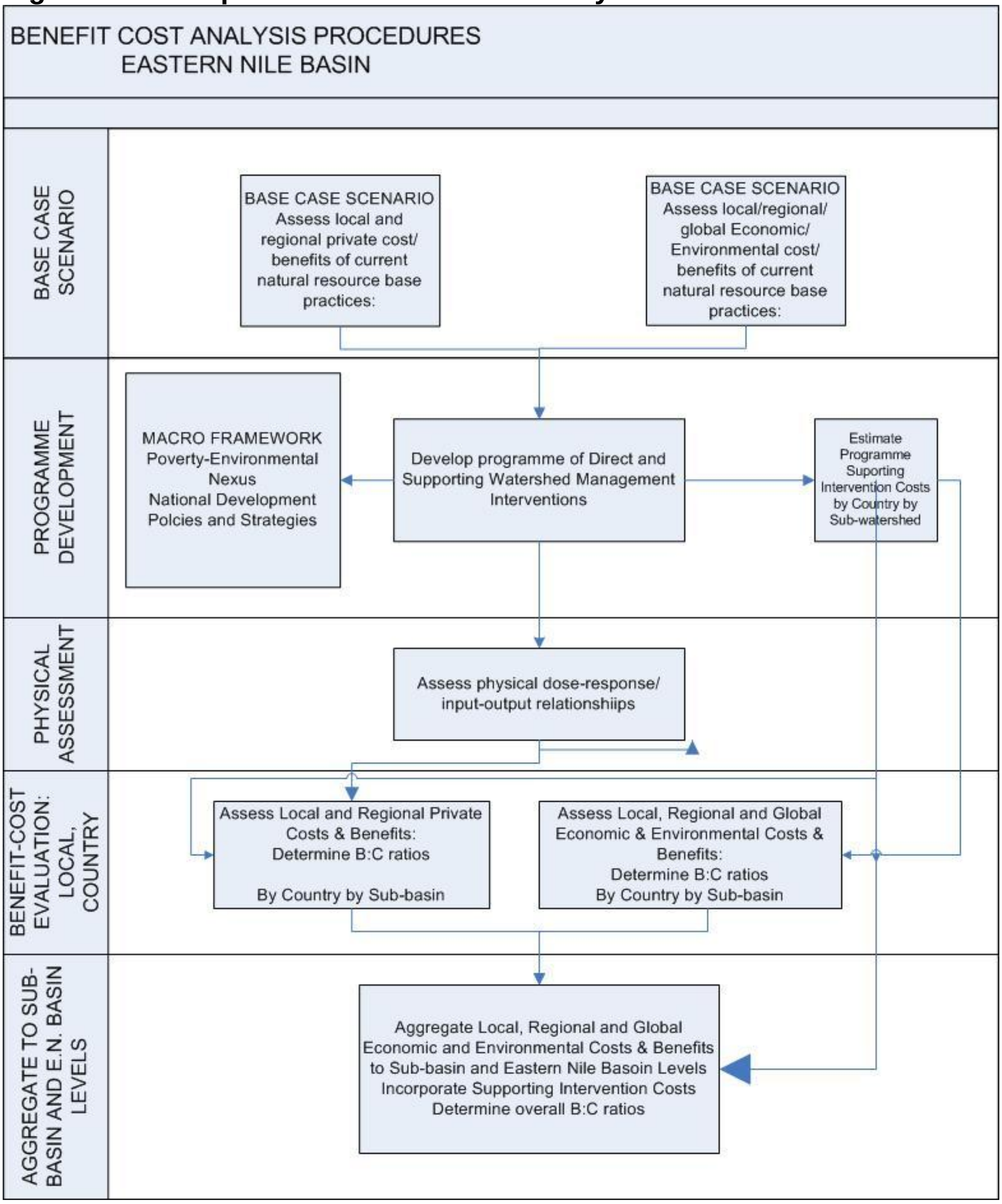
Source: Gregersen et al., (1987)

Ranked only by NPV then Project A would be selected as it maximizes NPV and uses up the available budget. If the projects are ranked by B:C ratio then Projects B, C, D and then E would be selected just using up the budget. The reason why NPV is not appropriate for comparing projects is that it says nothing about returns per unit of scarce resources (i.e. the budget).

(vii) Sequence of Analytical Activities

The analysis followed a sequence of analytical activities (figure 1).

Figure 1. Sequence of Benefit Cost Analysis Procedures



The first step was to identify and assess the physical negative and positive impacts of current management practices on the goods and services provided by the natural resource base. Where possible these were valued using market and surrogate market prices. The analysis was undertaken at the farm/community level, then at the national level for each of the four sub-basins. These were then aggregated to the Sub-basin level and finally to the

Eastern Nile Basin level. This provided the base case scenario – the without Watershed management Interventions Scenario.

The results of the context analysis: the incidence and underlying causes of poverty and relationships in complex poverty-environment nexus; the current national development policies, strategies and programmes as they impact on watershed management; and the analysis of the impacts of current resource management practices formed the basis for the formulation of the three ten year National/Sub-basin level watershed management programmes' direct and supporting interventions. The budget implications of these national programmes were assessed in very broad terms using existing programme unit-costs wherever possible. The costs of the direct interventions were incorporated into the benefit cost analysis at the local and national levels. The costs of the Supporting Interventions were carried forward to the National-Sub-basin and the Sub-basin level benefit cost analysis.

The financial and the economic-environmental benefit cost analysis were undertaken using market and surrogate market prices adjusted as appropriate for the economic analysis. These were aggregated first to the national level by Sub-basin and then to the Sub-basin Level. The analysis separately identified the costs and benefits at the local/national, the Regional (i.e. Sub-basin) and the Global levels. The costs of the Supporting Interventions were also included into the overall national level analysis. A final aggregation was made to cover the whole of the eastern Nile basin.

2.3 Organization and Layout of the Results

The results of the analysis are organized in the same manner as the B:C analysis sequence but with the additions of those impacts deriving from the Interventions of the programme as a whole and those impacts from the Supporting Interventions.

Chapter 3 outlines the macro framework for the Watershed management programme outlining:

- The incidence and determinants of poverty in the three countries, and constraining and enabling factors that promote investment in SLM practices;
- The main national development and poverty reduction policies, strategies and programmes,
- The potential impacts of climatic change,
- A summary of the Watershed management Interventions, their cost implications, direct and indirect impacts.

Chapters 4, 5, 6 and 7 examine for each Sub-basin the costs of current natural resource management practices; the impacts of the Programme as a whole taking into account that there will be considerable synergy between supporting and direct interventions; and the impacts, costs and benefits of the direct interventions. The four chapters are intended to be self-standing and thus there may be some repetition of finding. For each of the four Sub-basins (chapters 4, 5 6 and 7) the results are organized as follows:

1. Impacts of the proposed watershed management Programme as a whole
   - i. Household/Community
   - ii. National
   - iii. Regional/Sub-basin
   - iv. Global

BY COUNTRY

2. Costs of continued Natural resource Management Practices.

4. Impacts of the Direct Interventions including the benefit:cost analysis
   - i. Local (farm and community)
     - Financial Cost benefit Analysis
     - Other local impacts
   - ii. National
     - Aggregated Financial Cost Benefit Analysis
     - Other national impacts
     - Budget requirements
   - iii. Regional
     - Aggregated Economic-Environmental Cost Benefit Analysis
     - Other Regional Impacts
   - iv. Global

Chapter 8 examines the options for alternative distributions of the costs and benefits (i) at the Eastern Nile Basin level, and (ii) at the global level.

3. MACRO FRAMEWORK FOR SUSTAINABLE WATERSHED MANAGEMENT

3.1 Poverty and Natural Resource Degradation Nexus

This section briefly recounts the complex relationships between poverty and the natural resource base in each of the three countries. Poverty is both a cause and a resultant of natural resource degradation (Scherr, 1999). In all three countries poverty is most prevalent amongst the rural households whose livelihoods depend on agriculture. Nevertheless, the determinants and context of poverty are not confined to natural resource degradation but encompass other aspects of livelihoods: education, health, access to knowledge and information, and the wider socio-economic framework of markets, prices, technology, credit, government development polices and strategies. This suggests that simply approaching poverty reduction by arresting resource degradation through technical measures may be insufficient if the other determinants and issues related to the broader socio-economic framework are not addressed.

Population pressure is often cited as a cause of 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 (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, recent evidence suggests that more specific conditions appear 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.

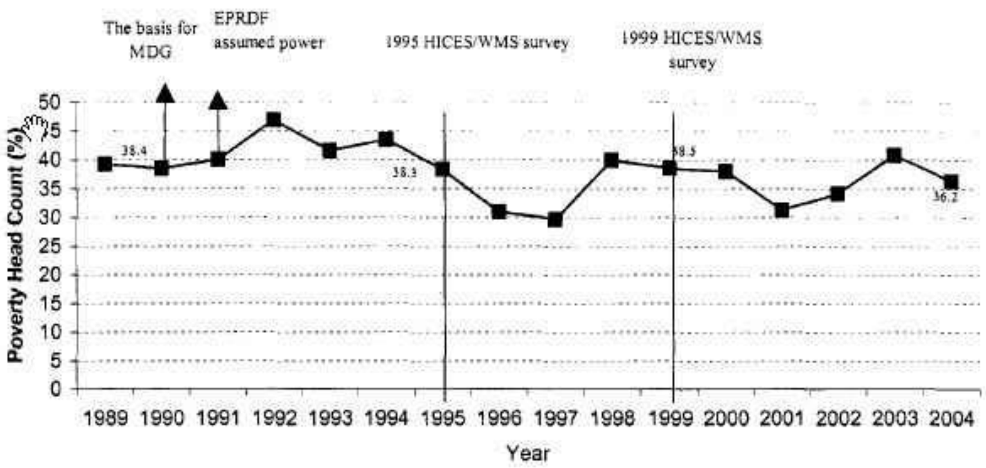
3.1.1 Ethiopia

(i) Incidence of Poverty

The poverty line in Ethiopia is set using a basket of food items sufficient to provide 2200 kcals per adult per day. Together with a non-food component this represents ETB 1,070 in 1995/96 prices. The proportion defined as poor in 1999/2000 was 45 percent in rural areas and 37 percent in urban areas.

According to the Sustainable Development and Poverty Reduction Plan of 2002 (SDPRP) rural poverty declined by 4.2 percent between 1995/96 and 1999/2000 although it increased in urban areas by 11.1 percent. However, a longer term analysis (World Bank, 2005) indicates that overall poverty declined only marginally between 1990 and 2004 (from 38.4 to 36.2 percent) due in large measure to no or even slightly negative growth in the agricultural sector (figure 2).

Figure 2. Evolution of poverty incidence in Ethiopia between 1989 and 2004.



Source: World Bank, 2005

The analysis highlighted the volatility of poverty incidence: thus poverty declined between 1994 and 1997 but increased between 1997 and 1999. Also, the average numbers hide a substantial amount of moving in and out poverty described as "churning on the margins" (Little et al., 2004). Vulnerability to poverty is high: it is estimated (World Bank, 2004) that two out three Ethiopians will be poor at five out the next ten years. Drought and highly variable rainfall are the major sources of vulnerability as are highly volatile inter-annual cereal prices. Some 75 percent of the population is estimated to be at risk to malaria and there is an increasing incidence of HIV/AIDS in rural areas. Both present significant vulnerability risks.

(ii) Determinants of Poverty

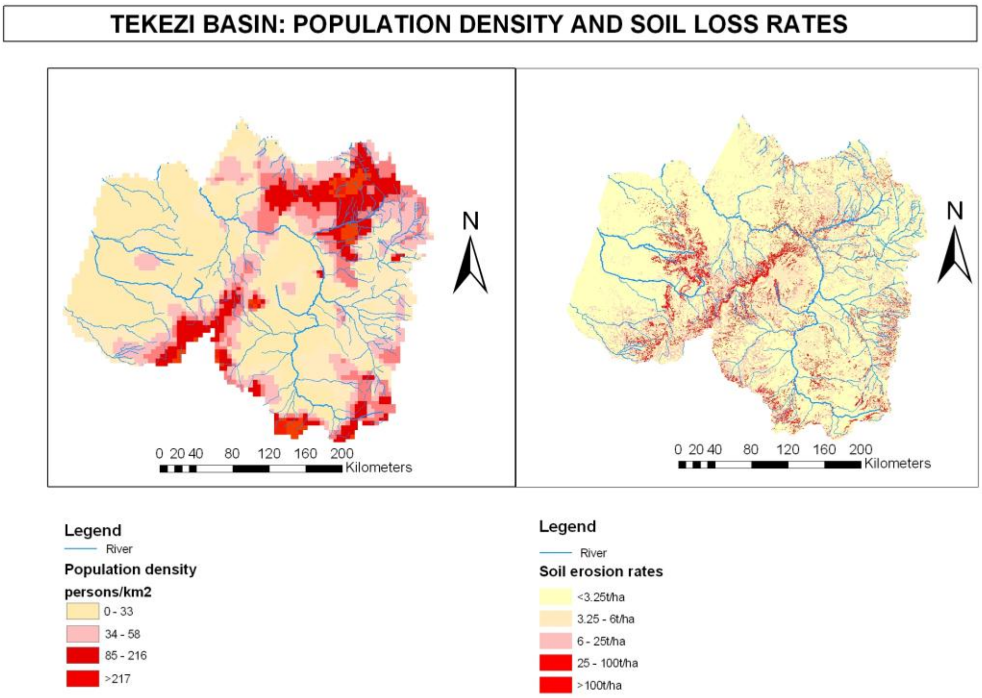
(a) Degrading natural Resource Base

The key underlying cause of poverty in Ethiopia is the degrading natural resource base (Alemneh Dejene, 2003). Some of the physical and economic impacts are estimated for each of the Sub-basins in chapters 4 to 7 of this report. However, these figures alone can not portray the full picture of the social and economic costs to the population. Ersado et al., (2003) have studied the severe negative impacts of poor nutrition and health of rural families' ability to adopt improved agricultural technologies. Families are locked into a downward spiral of increasing poverty and increasing degradation of their natural resources. As the research data in the previous section has shown large numbers of households are constantly "churning" in and out poverty. The degrading resource base increases households' vulnerability to natural (drought) and social (sickness) shocks. Alternative livelihood strategies are increasingly restricted.

(b) Population Pressure and Resource Degradation

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 that high population densities were related to increasing land degradation and worsening household welfare conditions. In Tigray high population densities were 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 2.



Map 2 Ethiopia – Tekezi Basin: A comparison between the pattern of population density and soil loss rates.

Whilst there is some similarity in pattern along the southwestern, southern and southeastern 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.

(c) Other Contributing Determinants

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.

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. Farm assets such as oxen are important poverty reducing factors: an extra ox reduces poverty probability by 7 percent. Households involved with off-farm activities 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.

(iii) Poverty and Household and Community Decisions to Invest in Sustainable Land Management technologies

At the heart of the poverty-environment nexus is the ability and willingness of households and communities to invest in sustainable land management technologies and thus break out of the poverty-environmental degradation cycle. Readon and Vosti (1997) note that "welfare" poverty can miss a potentially large group of households who are not absolutely poor. However, their surplus above the "poverty line" is too small for them to make any significant investments in conservation or intensification measures. A review of empirical research in Ethiopia has revealed many of the complexities involved (Mahmud Yesuf & Pender, 2005).

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 and household assets are the concepts of profitability of the improved land management technology, the farmers' perceptions of risk and farmers' private discount rates. Private discount rates are a measure of a person's time preference or time horizon. The 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 or bunds that conserve soil moisture) adoption is much more likely.

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 poses 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 ETB 16.7 ton/km compare very unfavorably with ETB 0.6 to 0.9 ton/km for local truck costs. Such high costs of transport for low value food crops such as maize or sorghum make a positive net return unlikely.

The evidence from Ethiopia of better access to markets and adoption of soil and water conservation technologies is mixed. In Tigray and eastern Amhara 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 off-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 potential area of Amhara region the relationship was positive.

Empirical studies on productivity and economic impacts of land management practices are few but consistent. Some studies show that short run returns from physical SWC structures are positive in moisture stressed areas but negative in higher rainfall areas. More often returns in the long-term are positive but the "pay-back" period are too long for most farmers. Returns from fertilizer use show the opposite trend: with higher returns in high rainfall areas and lower in moisture stressed areas.

In moisture stressed areas internal rates of return to stone terraces varied between 20 and 50 percent. Again in moisture stressed areas other land management practices demonstrated increased productivity: contour ploughing (25% higher productivity), reduced tillage (57% higher productivity), and manure and compost (15% higher productivity). The impact of chemical fertilizer was insignificant and showed a high variability in productivity response indicating a higher risk.

In the higher rainfall areas returns to conservation structures were low with internal rates of return of less than 10%. The exception was grass strips which produced a positive net present value even with discount rate of 50% and loss of 10% of land. Even higher rates of return were obtained if forage grass was planted on the strips. However, their lack of adoption in the area studied indicated that factors such as the practice of uncontrolled grazing in the dry season, poor extension services and tenure insecurity may also responsible. However, two NGO's - GTZ and SOS Sahel have demonstrated that widespread adoption is possible.

Benefits to physical structures were low where soils were deep (more than 1 meter) or very shallow where yields were already very low. This finding suggests targeting areas with rapidly degrading but still productive soils.

(iv) Macro Policy and Institutional Environment

(a) Land Tenure Security

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 (to cater for new allocations) has not been ruled out in both federal and regional proclamations. A US-AID Study (ARD-USAID, 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 Yesuf 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 southern Ethiopia 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 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) more 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.

(b) Impact of Agricultural Extension and Credit programmes on adoption of Land Management Technologies

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.

(c) Impact of Public Projects

Public projects such as food for work have been in operation for nearly three decades. Their potential impact on private land management is subject to much debate. Advocates assert that these programmes promote improved land management by relieving financial constraints and there are additional benefits in terms of acquired skills through "learning by doing". Critics argue that they adversely affect improved land management through competition for labour.

The empirical evidence is mixed. Both evidence for adverse effects of food for work and no effects on the adoption of improved land management have been found, although some evidence may be anecdotal than empirical. A recent empirical study (Hoddmot, 2003) has found no evidence that food aid fosters dependency and creates disincentives.

One finding of interest is that food for work was associated with less use of labour, oxen and manuring but increased use of seed, suggesting that seeds are substituting for labour-intensive inputs. Another study indicated that food for work could promote SWC investments if they are applied within agriculture, but not if applied outside agriculture (e.g. road construction).

(d) Institutional Issues

The main institutional issue which affects the sub-basins is that they are divided between two or more Regional governments so management of the Sub-basin requires coordination between different Regional governments. Several resource management issues specifically require inter-Regional coordination due to hydrological flows, land use impacts, wildlife movements and the transboundary nature of forests. The institutional issues not only involve coordination but also getting the Regions to give equal, or appropriate, attention to the issues of the sub-basin.

For example, in the Baro-Akobo Sub-basin only one of these regions is fully within the basin and for two of the others their land in the sub-basin is rather remote from the Regional headquarters and sometimes is given limited attention compared to other issues closer to the centre of power. The other major institutional issue is the need for coordination between sectoral agencies, as they have competing interests about how best to use the resource base. For instance during the Derg government there were major conflicts between the agencies responsible for agriculture, forestry and coffee with each seeing a different model of how to use forest land in this area, with conflicting policies pursued and different advice given to farmers.

At present there is no coordination of Regional governments' actions, while sectoral coordination within Regions is limited to annual financial planning.

(e) Policies and Prioritization

National policies are reasonably well developed in Ethiopia and Regional interpretations of these have been developed in the last five to ten years. While Master Plans exist for all Sub-basins they have a rather narrow focus and are not formally recognized or used.

In fact it has been argued that over the last 20 years Ethiopia has seen a policy focus on the degraded parts of the country – seeking to achieve food security in these areas, while other areas if they are food secure have been assumed to be relatively well-off and without problems. The result has been what one organization has called “fading prosperity” in the coffee producing parts of the Baro-Akobo Sub-basin and what another has seen as the neglect of progressive desertification (EUE, 2001; NAP for CCD, 2002). This is certainly the case in Western Wellega in terms of land degradation and across much of the upper Baro-Akobo Sub-basin in terms of forest loss. There has been limited attention given to this area by the Federal Government and no recognition of this area as one of the last resource rich frontiers in the country.

Technical policies are designed and implemented in isolation and without a coherent framework. In many areas these lack sensitivity, having been designed with national priorities in mind or adjusted only to the main characteristics of a region with little attention to the specific conditions in the parts of the sub-basin which are in the region. Examples of such policies include:

- emphasis on Regional or national revenue generation and food security needs which leads to investment policies and wetland drainage demands which are not in line with the needs of the local communities,

- environmentally inappropriate policies such as population concentration and the emphasis *teff* cultivation on fragile soils and research on maize cultivation in wetlands,

- lack of recognition of the links between sound agricultural land management in the high rainfall areas and forest, between forest and hydrology / hydro power development, and between wetland drainage and spring loss with its health implications,

- over-prescriptive training of DA's and their inability to analyze and adapt to different farming systems, and

- settlement measures and local resource impacts.

Decentralization should have helped improve policies so that they are sensitive to regional variations but this is adaptability is still generally quite limited.

(f) Policy practice and the ability of the state

While the government federally has specific policies to support the sustainable use of the country’s resource base, practice on the ground is far from achieving this. The reasons relate to inappropriate policies, conflicting policies, poor training of Development Agents, lack of staff and resources, and an inability to liaise with the local population and build support. One example is the inability of the state to control land use is designated in designated Regional Priority Forests and Regional Parks. This has led to these areas being regarded as "open access" resources. This has been partly caused in most cases by the absence of clearly demarcated and gazetted boundaries, but is also due to the inability of the state to enforce legislation.

3.1.2 Sudan

(i) Incidence of Poverty

The extent and dynamics of poverty in the Sudan since the 1990's has been examined by the Joint Assessment Mission - JAM (2005). It is estimated that about 60 to 70 percent of the population in the North is living below US$ 1.00 a day, whilst estimates in the south put the proportion at 90 percent. Despite the sustained growth since 1997 many experts believe that poverty has remained widespread and has actually increased. The gap between the "haves" and the "have nots" has increased. Thus whilst the traditional agricultural sector has shown a rebound in the past decade this is only to levels that prevailed before the massive droughts of the early 1980's.

(ii) Determinants of Poverty

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

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

The low rates of poverty from El Gezira to Northern State are a reflection of the assured access to generally low risk irrigated cropland along the Blue and Main Niles. 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.

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

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

(iii) Poverty and Household and Community Decisions to Invest in Sustainable Land Management technologies

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

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

(iv) Macro Policy and Institutional Environment

(a) Institutional Issues

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

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

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

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

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

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

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

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

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

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

- weakening of traditional solidarity and social support mechanisms.

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

(c) Land tenure and Resource Conflict

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

The World Bank Country Economic Memorandum (World Bank, 2003) outlined a number of problems relating to current land tenure and land policy in Sudan:

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

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

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

(d) Agricultural Extension and Availability of Credit

Related to poverty and household assets are the concepts of profitability of the improved land management technology, the farmers' perceptions of risk and farmers' private discount rates.

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

(e) Profitability of Existing Technologies

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

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

3.1.3 Egypt

(i) Incidence of Poverty

Two recent studies by IFPRI (Lofgren, 2001) and by the World Bank (Heba El-Laithy et al., 2003) review the structure and distribution of poverty in Egypt over the recent past. Lofgren (2001) reviews development strategies adopted in Egypt since the 1970's to determine if alternative strategies could have done more to reduce poverty. The World Bank study uses two household expenditure surveys undertaken in 1995/96 and 1999/2000 to examine the evolution of poverty in Egypt between these years and reveals its structure and geographic patterns. This brief review focuses on rural poverty.

Lofgren examines natural resource and human assets of rural households. The 1952 Revolution expanded education and health facilities, which boosted incomes and reduced inequality and poverty. In recent years there has been some reversal of these developments. Public education has deteriorated and become more expensive. Other things being equal, these reduce the share of the poor in the skilled labour market and in labour and land incomes. Additionally, consumer subsidies to households have declined from 11 percent in 1979 to 2 percent in 1997.

The World Bank study by El-Laithy and colleagues took into account regional and rural-urban differences in prices and demographic composition of households when calculating poverty rates. It used a minimum food basket linked to normative nutritional requirements. This was costed using regional prices and compared with the poverty line defined as the second quintile of expenditure distribution. They found that whilst poverty declined as a whole in the study period there were significant differences in poverty alleviation across regions and across different employment sectors.

In 1999/2000 the poverty rate across Egypt stood at 16.7 percent (approximately 10.7 million people). However, urban rates were only 9.2 percent compared with 22.1 percent for rural areas. The Governorates with the highest rural rates are located between Luxor and El-Fayoum. The three Governorates around Lake Nasser have rates below the national average.

Across Egypt rates declined from 19.4 to 16.7 between 1995/96 and 1999/2000. But Upper Egypt rural rates increased from 29.3 to 34.2 percent in the same period. Whilst the Aswan, New Valley and Red Sea Governorates have rural poverty rates below the national average there are three groups that have been identified who are likely to be below the poverty line. The first of these are the two groups who live in the Wadi Allaqi on the eastern side of the Lake: the Ababda and the Bishari Bedouin (Briggs et al., 1993).

The second group are located in the new settlement areas west of Lake Nasser in three communities of Kalabsha, Khor Galal and Garf Hussien (IDRC, 2004). The IDRC project identified the settlers' lack of knowledge of desert agriculture and an undeveloped marketing system as hindering the agricultural development.

A third group comprise fisher people of the lake: the Saiydis, (an upper Egyptian peasant population) from two governorates with a long history of fishing immediately north of Aswan and a few Nubians being fishers even in Old Nubia. The state of the fishery has remained relatively undeveloped with fisher people living either in their boats or in temporary shelters in 150 fish camps.

(ii) Livelihoods and Determinants of Poverty

Livelihood assets include human, social, natural, physical and financial capital. Kishk (1994) pointed out that in Egypt less than 10 percent of land holders have more than 45 percent of the agricultural land whilst more than 57 percent of agricultural land holders have less than 25 percent of the land. More 90 percent of Egyptian farmers have less than 2 ha of agricultural land.

His study in Middle Egypt found that given the very small plot sizes that many Egyptian farmers are barely able to make a living from current irrigated cropped area and cropping pattern. Although illegal, many small farmers resort to selling their land to builders. In 1987 net returns to food cropping were US$ 439 /ha/yr whereas land for building was selling for US$ 0.2 to US$ 5.0 million /ha. The FAO Aquastat Survey for Egypt found that farmland urbanization represented a serious threat to agriculture in Egypt (FAO, 2005).

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

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

(iii) Macro Policy and Institutional Environment

(a) Land Policy in Egypt

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

(b) International Cooperation between Egypt and Sudan

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

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

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

(c) Agriculture, fisheries and forestry development

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

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

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

- Lack of collective planning for project management by the real beneficiaries.

- Multiplicity of agencies supervising the reclamation and farming process (i.e., Ministries of Agriculture, Water Resources and Irrigation, Housing and New Communities and the municipal authorities).

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

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

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

(d) Watershed Management and Water Quality Issues

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

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

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

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

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

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

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

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

(e) Environmental Impact Assessment

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

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

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

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

(f) Institutional Issues Relating to Settlement and Small-scale Irrigation around Lake Nasser

There are two key Government organizations of relevance to the implementation of the National master land Use Plan to settle 1 million people around the Shores of Lake Nasser: the first is the Ministry of Agriculture and Land Reclamation and the second is the High Dam Lake Development Authority (HDLDA). HDLDA is a semi-autonomous body of the Ministry of Agriculture and Land Reclamation (MALR). MALR is responsible for the civil engineering aspects of the land reclamation as well as agricultural production. HDLDA is responsible for promoting production, collecting quantitative data on agricultural activities assessing settlers qualifications, obtaining food aid (through World Food Programme), and establishing Agricultural Cooperatives.

HDLDA has an Agricultural Research Centre in Aswan and provides extension services to settlers. However despite impressive research results in the laboratories extension activity is minimal and sporadic due to limited resources and expertise in communicating with farmers. Until recently (2005) there had been years of no contact between the Directorate of Agriculture in Aswan and HDLDA (CDS, 2006). This is lack of contact is now being rectified and is enabling direct contact to be made between the farmers and the Directorate of Agriculture.

3.2 National Macro Development Policy Framework

This section outlines the national macro development policy frameworks of Ethiopia and Sudan and of Egypt (with particular respect to Lake Nasser and its environs). This is to set the proposed Watershed Management interventions into the context of the broad national development policies and strategies.

3.2.1 Ethiopia

At the core of Ethiopia's macro development policy is the Agricultural-Development-Led-Industrialization (ADLI) strategy. This is a strategy "in which agriculture and industry are brought together in a single framework, wherein the development of agriculture is viewed as an important vehicle for industrialization by providing raw material, a market base, surplus labour and capital accumulation" (MFED, 2001). In addition there are number of other policy and strategy documents including:

- Rural Development Policies, Strategies and Instruments,
- Land Policy,
- Food Security Strategy,
- Productive Safety net Programme, and
- Voluntary Resentment programme

In terms of implementation the Governments Sustainable Development and Poverty Reduction Programme (SDPRP) of 2001 and its successor the Plan for Accelerated and Sustainable Development to End Poverty (PASDEP) of 2006 are the key strategy documents. Amiss Tahoma (2006) has summarized the main development thrusts of the two documents as follows:

Main thrusts of SDPRP

- ADLI
- Civil Service and Justice Reform
- Capacity Building
- Governance, decentralization and empowerment

Main thrusts of PASDEP

- Massive Push to Accelerate growth
- Geographically Differentiated Strategy
- Addressing the Population Challenge
- Strengthening Infrastructure
- Managing Risk and Volatility
- Scaling up to Reach the Millennium Development Goals (MDG's)
- Creating Jobs.

Four pathways for agriculture are identified in the PASDEP: (i) Smallholder Intensification, (ii) Commercialization, (iii) off-farm diversification and urbanization and (iv) resettlement and migration.

Intensification entails enhancing smallholders' access to inputs (improved seeds, fertilizers, oxen). It shifts its previous focus on food crops to ensure food self-sufficiency to the production of marketable farm products – both for domestic and export markets – by both large and small farmers. Elements of this strategy include a shift to higher valued crops, a focus on high-potential areas, facilitating the development of large-scale commercial agriculture, and better integrating farmers with markets.

For the first time in over 30 years commercialization of agriculture now receives considerable prominence. Elements include rural roads, irrigation development, a change in delivery for extension and research, selected government support for commercialization where there are gaps in private provision. Some 35 commodities have been identified that have potential for high growth.

Although ADLI strategy recognized the importance of linkages between agriculture and other sectors in fact there has been little development of these linkages (Amdissa Teshome, 2005, Berhanu Nega, 2004). Diversification is targeted at the household and the national level. At the household level crop diversification will be facilitated through provision of seed, irrigation and improved marketing and support given to diversification into other farm enterprise (livestock fattening, honey production). Support would also be provided to encourage transfers into non-farm employment through skills training and education. It recognizes that the hundreds of small towns "represent tremendously important growth poles" and that the urban sector will be an important element. Rural-urban linkages will be strengthened through improved access roads, improved telecommunications, development of micro-credit markets and rural electrification.

Linked to diversification are proposals for resettlement. Voluntary resettlement aims to relocate rural families to areas where there is sufficient land and rainfall as a way of ensuring food security. It is planned to resettle 2.2 million people (440,000 households and so reliving pressure in the land-stressed highlands.

The Food Security Strategy focuses on chronically food insecure households and incorporates many of the elements of the PASDEP. The productive

Safety Net Programme also targets chronically poor households and aims at preventing household asset depletion and creating community assets through public works. It is seen as an instrument for balancing pro-poor growth with the shift to commercialization and economic growth. PASDEP is thus an umbrella policy and strategy that brings all sectoral and cross-cutting policies and strategies under one umbrella.

3.2.2 Sudan

(i) Decentralization

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

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

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

(ii) National Comprehensive Strategy

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

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

(iii) Comprehensive Peace Agreement

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

The CPA provides for a socially informed land tenure policy and legislation as it accords specific reference to ownership of land and natural resource. It calls for competency in land administration, provides for incorporation of customary laws and practices and establishes an independent Land Commission for the purposes of arbitration, rights of claims in respect to land, land compensation and the possibility of recommending land reform policies.
The CPA is expected to have many implication (institutional and administrative) - e.g. the establishment of a Land Commission for the south parallel to existing central institutions responsible for land and natural resources management.

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

(iv) Joint Assessment Mission

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

The JAM report has stated that the foremost challenge is to minimize the negative environmental impacts that returning refugees and Internally

Displaced Populations (IDPs) may pose on the natural resources base through increased deforestation and destructive agricultural practices

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

(v) Poverty Reduction Strategy Plan

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

PRSP main objectives are:

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

3.2.3 Egypt (Lake Nasser and Environs)

(i) Master Land Use Plan 1987 - 2017

A Master Land Use Plan of Egypt was prepared in 1986. It concluded that the construction of the Aswan High Dam (AHD) not only made the intensification of agriculture feasible in the old lands but also it could be extended to new “reclaimed” areas. Some 650,000 fedddans (273,000 ha) out of 805,000 feddans (338,100 ha) of land reclaimed during 1960-70 was made possible due to the increased supply of water from AHD. The total land that can be reclaimed is subject to water availability.

The strategy for agricultural development up to 2017 has a number of aims.

(i) To increase the annual rate of growth in agricultural production from 3.4% to 3.8% during the remaining period of the Fourth 5-Year Plan, and to 4.1% annually up to 2017. This goal is attainable only through vertical and horizontal expansion of plant and animal production, which will have positive impacts on job creation, producer incomes and the overall standard of living of the rural population.

(ii) To reclaim no less than 150,000 feddans (63,000 ha) annually. The Master Plan assesses the reclaimable and cultivable lands in the Delta, Southern Valley, East Owaynat, the area of and round Lake Nasser and East and West of Suez Canal by the year 2017 at about 3.4 million feddans (1.43 million ha). The inhabited area would reach 25% of the total area of Egypt.

(iii) To increase the agricultural production horizontally and vertically through the efficient allocation and use of soil and water resources. The maintenance and development of the natural resource base is an integral part of Egypt's sustainable agricultural development program.

(iv) To develop a national strategic reserve of the basis food commodities by focusing on the efficient use of the available resources and redirecting investments to such areas that help fulfill the increasing food needs of the population. This shall be accompanied with rationalization of food consumption levels, reduction of post-harvest losses.

The Master Land Use Plan indicates that around Lake Nasser and in the Tushka Depression there are about 2.88 million feddans (1.21 million ha) of land reclaimable using Nile water and 0.55 million feddans (0.23 million ha) reclaimable by ground water. The main reclaimable areas around Lake Nasser are located in the East bank of the Lake in Wadi El-Allaqi and Wadi El-Targi. Those in the west bank are found in Wadi Kurker, Kalabsha, Dekka, Marwa, Tushka, Abu Simbal, Khor Sara, Tomas and Affia (Desert Research Center, 2005).

However, there are a number of conflicting estimates regarding the actual potential for land reclamation around Lake Nasser. Aerial photos show that 1.5 million feddans (0.63 million ha) are reclaimable in the elevated area of and around Lake Nasser (Encyclopedia of Southern valley and Tushka, 1999). Hanna and Osman (1993) stated that more than one million feddan (0.42 million ha) can be reclaimed around the reservoir. The Egypt Water Master Plan (1986) however, shows only about 195,000 feddans (81,900 ha) of high priority to be reclaimed out of 781,600 feddans (328,270 ha). In 1987, a joint study between Cairo University and MWRI showed that the arable area of and around Lake Nasser is about 103,500 feddans (43,470 ha).

The Government's initial plan is to cultivate 50,000 feddan (21,000 ha) around Lake Nasser's shores. They are situated on the western shore, and only one area of 9,000 feddans (3,700 ha) on the east side shore, i.e. the Wadi Allaqi area. On the west side the three areas are: Wadi Kurker, 14,000 feddans (5,880 ha), Kalabsha, 22,000 feddans (9,240 ha), and Abu Simble 5,000 feddans (2,100 ha).

Studies carried out by the Desert Research Center (DRC, 1999) show that lifting water from Lake Nasser depends on the elevation above sea level (masl). Two methods can be used:

(i) Lifting water for high lands (above 182 masl) by using giant pump stations and floating pipe line then connected to affixed pipe line on land.

(ii) Lifting water for Lake Shore farming and irrigation by using small mobile pump motors that the farmer moves from field to another. These pumps are connected to a flexible hose and then to 4-6 aluminum pipes.

As part of the national strategy to combat poverty, the Government of Egypt plans to settle approximately one million people on reclaimed desert in the area around Lake Nasser by the year 2017. In order to avoid any negative impacts there are a number of research projects being undertaken to develop sustainable strategies for improving the socioeconomic conditions, health and livelihoods of poor and marginalized settlers living in fragile ecosystems.

The Ministry of Water Resources and Irrigation (MWRI) has prepared a National Water Policy to the year 2017 including three main themes:

- optimal use of available water resources;
- development of water resources; and
- protection of water quality and pollution abatement.

(ii) Water Master Plan

At present, Egypt is addressing the issue of limited water quantity by managing the demand side. MWRI formulated a water master plan in 1981. This plan is currently being updated. The process of updating the water Master Plan aims to allocate available water resources according to various needs and demands that are feasible from the economic perspective. It also aims to gain social acceptance and political support. The Water Master Plan is updated through the National Water Resources Plan (NWRP) project.

The NWRP has been operated since 1998 and is jointly funded between MWRI and the Netherlands Government. This project is directed towards developing a National Water Resources Plan that describes how Egypt will safeguard its water resources both quantity and quality and how it will optimize the use these resources in response to the socio-economic and environmental conditions.

3.3 Potential Impacts of Climatic Change

3.3.1 Impacts on Nile Flows

Evans (1994) has provided a summary of the history of the Nile flows that have fluctuated widely over the geological past. Even within the past 100 years the Nile discharge has fluctuated from a low of 42 km^3 in 1984 to a high 120 km^3 in 1916. Inter-decadal fluctuations have also been considerable with a mean discharge of 84 km^3 between 1900 and 1959 and only 72 km^3 between 1977 and 1987, a 15 percent decline. These fluctuations are the result of a number of natural and anthropogenic processes operating at different temporal scales. Natural processes include evaporation and precipitation whilst anthropogenic include changes in landcover (and thus runoff) and abstraction (for irrigation and water supplies).

Gleick (1991), Abourgila (1992), Hulme (1994), Nieman et al (1994), Johnson and Curtis (1992), Conway (1993), Conway and Hulme (1996), Yates (1998), Strzepek and Yates (2000), Sene et al., (2001), Mohamed et al., 2005) and Conway (2005) have examined the potential impacts of climatic change on water resources in the Nile Basin and in particular the Abbay-Blue Nile and Tekeze-Atbara Sub-basins. The two main factors of interest in Nile river flows arising from global warming occasioned by increased emissions of greenhouse gases are increased rates of evaporation (evapo-transpiration) and changes (positive or negative) in precipitation.

All researchers caution against taking the results of their analyses as "predictions" given the paucity and quality of data, the lack of robustness of their models, runoff models and general circulation models (GCM's) given the many spatial and temporal scales involved and the poor state of knowledge of the complex relationships between global warming (atmostspheric and oceanic), circulatory patterns and changes in amounts and timing precipitation.

Estimations of the future rate and patterns of global warming, and the ensuing changes in other climatic parameters such as precipitation are currently made using GCM's. Two global climates are generated: current (i.e. 1 X CO_2) and forecasted (i.e. 2 X CO_2).

Gleick's (1991) study indicated a 50 percent reduction in runoff in the Blue Nile Sub-basin due to a 20 percent reduction in precipitation. Hulme (1994) reported on the use of a composite of 5 GCS's to forecast temperature and precipitation changes by 2030 over the Nile basin. The model indicated possible temperature rises between 2° and 4°C, which are slightly higher in the northern part of the Basin than the southern part. There was no clear signal about the magnitude or extent of precipitation changes. No runoff model was used, but with the inevitable increases in temperatures and actual evapotranspiration combined with estimated precipitation changes the best guess would be a reduction in Abbay-Blue Nile flows and a constant or slightly increase in White Nile flows. The magnitude of fluctuations in annual flows was not likely to lessen.

In a later study, Conway and Hulme (1996) used three GCM's: one indicating an increase in precipitation, one indicating a decrease and a third composite of 7 GCM's (that indicated a small increase in precipitation) together with a water balance model to generate estimates of runoff. Changes in precipitation over the Blue Nile Sub-basin ranged from an increase of +2.2 percent, a decrease of 1.9 percent and an increase of +7.4 percent for the composite, "dry" and "wet" GCM's respectively. Over Lake Victoria the projected changes were +5.0 percent, -1.0 percent and +5.0 percent for the same set of GCM's. In terms of runoff and Nile flows into Egypt the changed climate scenarios (i.e. changes in temperature and precipitation) for 2025 were as follows:

Current mean flow	= 55.5 km^3
Composite CRM	= 56.4 km^3 (+0.9 km^3)
"Dry" CRM	= 50.1 km^3 (-5.4 km^3)
"Wet" CRM	= 64.7 km^3 (+9.2 km^3)

Assuming no changes in precipitation but with the temperature changes (of approximately 1°C by 2030 the changes in Nile flow into Egypt are estimated to be as follows:

Composite CRM	= 51.5 km^3 (-4.0 km^3)
"Dry" CRM	= 52.7 km^3 (-2.8 km^3)
"Wet" CRM	= 52.7 km^3 (-2.8 km^3)

These changes take *no* account of increased evaporation and actual evapotranspiration in the irrigation schemes and reservoirs of Sudan or of the estimated increase of evaporation in Lake Nasser/Nubia 0.4 km^3 (assuming current losses are 10.0 km^3 and a 4 percent change in PET per 1°C). However, Conway and Hulme note that these scenarios are not predictions and that it is currently not possible to make accurate estimates of future Nile discharges. A range of possibilities should therefore be considered in any water resource planning. In a more recent paper, Conway (2004) considers that results from more recent GCM's make little difference to the results outlined in their 1996 paper.

Yates (1998) (reported in Young, 2004) examined 7 other GCM's and the potential impacts on Nile flows into Egypt. Six results indicate an increase in Nile flows and one a decrease. Johns (2003) using the latest data from the IPCC Third Assessment report estimates a 6 percent increase in Nile flows.

Egypt now has three resources to analyse the potential impacts of short and long term climatic changes on Nile flows. MWRI have developed the Nile Forecasting Centre (NFC) aimed at predicting inflows to Lake Nasser with as much lead time as possible. Originally confined to the Blue Nile it was later extended to cover the White Nile and uses satellite estimates of rainfall over the upper basin. There is also the Nile Basin Management Decision Support System (DSS) developed in conjunction with the Georgia Institute of Technology Development. This DSS is being used to explore climate and management scenarios in parts of the basin (Georgakakos, 2004). Additionally, there is the Dutch funded "Lake Nasser Flood Control and Drought Control project" in MWRI with the aim of analysing the impacts of flooding and also climatic change on the operation of Lake Nasser/Nubia.

3.3.2 Impact of Sea Level Rises on the Nile Delta

Paragraph 3.3.1 has outlined the impacts on the Nile delta and adjoining coastlines of the very substantial reductions in sediment in the Nile on the closure of the Aswan High Dam. Currently the coastal zone around the delta is subsiding at approximately 2-5 mm/yr. One of the predicted impacts of increasing global temperatures is a general rise in sea levels due to melting of the northern and southern ice caps. Agrawala et alia (2004) have examined the potential impacts of climatic change on Egypt's coastal resources and of the Nile. They used 8 of 17 GCM's tested for their ability to best simulate the current climate.

The analysis revealed that the potential impacts on coastal resources as being the most serious. Climatic change induced sea level rise (SLR) will exacerbate the existing land subsidence. Much of Egypt's infrastructure is along this coastal belt and the delta constitutes its prime agricultural land. Loss of land could take place due to inundation and also to saline intrusion.

The study used three estimates of SLR: 0.25 m, 0.5 m and 1.0 m and examined the impacts on the cities of Alexandria and Rosetta and the Alexandria Governorate. For an SLR of 0.5 m (and current subsidence of 2 mm/yr) about 30 percent of the city of Alexandria (19.0 km^2) will be lost to inundation and 1.5 million people (67 percent of the population) will have to be relocated. Other expected losses include 195,000 jobs as well as land, property and revenues in the range of US$ 30 billion. In Alexandria Governorate the most seriously impacted sectors would be industry and tourism. For the city of Rosetta and its region using the same SLR, the study estimated the loss of one third of employment and US$ 2.9 billion worth of property.

3.3.3 Issues and Implications for Future Research and Watershed Management Planning

The impacts of precipitation changes on the Nile flows over the past 100 years have been considerable. There is still considerable uncertainty on the future impacts of global warming on precipitation patterns over the Nile Basin. These factors clearly have important implications for watershed management (Howell and Allen, 1990). The existing vulnerability of rural populations in the Eastern Nile Basin to climatic shocks caused by rainfall variability is a major determinant in the incidence of poverty and insecure livelihoods. Any negative changes in precipitation and/or in evapotranspiration could have potential devastating impacts.

The effects of climatic change will increase the uncertainties in general development planning. There is a clear need to extend the future climatic scenario planning of water resources to encompass watershed, agricultural and poverty reduction and development planning to determine possible outcomes of climatic change in order to develop appropriate defensive measures. The GIS-based Food Early Warning System now has the capacity to forecast on an annual basis impacts on agricultural production and livelihoods as the season progresses. The system an be extended with little modifications to run potential scenarios based on the climatic change models such as those developed by the University of East Anglia for the Nile Basin (Conway and Hulme, 1993).

3.4 An Overview of the Direct and Supporting Interventions

The proposed interventions can be categorized into (i) Direct Interventions, and (ii) Supporting Interventions. The direct interventions are relatively specific to Development Domains and address the proximate causes of resource degradation whilst the supporting interventions seek to address the underlying policy, institutional and capacity constraints and establish an enabling environment for the implementation of the direct interventions. Both types are inextricably linked and comprise a holistic programme of interventions.

The programmes are outlined below.

3.4.1 Ethiopia

The direct interventions comprise seven broad sets:

- (i) Soil Conservation and Improved Soil Husbandry, (with cut-off drains and improved road drainage, gully stabilization and reclamation, and stream bank protection,
- (ii) Crop diversification and intensification,
- (iii) On-farm Tree production and Domestic Energy,
- (iv) On-farm Forage production,
- (v) Improved Animal Health,
- (vi) Area Closure: Communal lands, Community Woodlots,
- (vii) Water Conservation and Improved Utilization

Their cost items and direct, indirect and Regional/Global impacts are outlined in the matrix below.

INTERVENTIONS	TIME SCALE	COST ITEMS	DIRECT BENEFITS	INDIRECT BENEFITS	REGIONAL/GLOBAL BENEFITS
MATRIX 1a. ETHIOPIA					
A. DIRECT INTERVENTIONS					
1a. Soil conservation and improved soil husbandry. **Integrated with:** • Crop intensification & diversification • Area closure • Gully stabilization, stream bank protection • Cut-off drains, road drainage • Water conservation & improved utilization	Immediate	- Construction - Maintenance - Loss of land - labour: compost production & delivery to field - Broad-bed Maker (+ additional ox days)	- Soil erosion reduced - Suspended sediment reduced - Loss of moisture holding capacity reduced - loss of soil nutrients reduced - loss of crop productivity reduced - Improved Vertisol drainage & increased crop production	- Households: Increased access to food: Improved food security - Improved health and nutrition - Degradation of household natural resource capital asses significantly reduced - Vulnerability to natural shocks reduced - Reduced sedimentation dams & irrigation schemes (Ethiopia)	- Reduced sedimentation in reservoirs & Irrigation Schemes (Sudan, Egypt) - Increased soil organic carbon and sequestration - Increased groundwater recharge: prolonged dry season flows
1b. Gully stabilization & reclamation & Stream bank protection **Integrated with:** • Area closure • Community woodlots • Cut-off drains, road drainage • Cropland soil conservation	Immediate	- Labour: structures & tree planting - Labour: forage cut & carry	- Reduced runoff and sediment to streams - Increase wood and forage production	- Improved livestock health & productivity - Reduced sedimentation in dams & reservoirs (Ethiopia)	- Increased groundwater recharge & prolonged dry season flows - Reduced sedimentation in reservoirs & irrigation schemes (Sudan, Egypt)
1c. Cut off drains/Improved road drainage **Integrated with:** • Gully stabilization, stream bank protection • Area closures • Cropland Soil	Immediate	- Labour: construction of drainage structures	- Controlled runoff: reduced gully formation	- Reduced sedimentation in dams & reservoirs	- Increased groundwater recharge/prolonged dry season flows

conservation					
2. Crop intensification and diversification - Vegetables - Fruit trees - Organic coffee - Spices (Corrarima, ginger) - Improved Honey production & marketing **Integrated with:** • Soil conservation & improved soil husbandry • Feeder roads, Improved marketing Water conservation & improved utilization	Immediate	- Improved seed & chemical fertilizer, integrated pest control - Water harvesting structures - Small/micro dams and water delivery systems - Increased labour (irrigation, weeding, pest control, harvesting,) - transport, storage and marketing	- Households: Production of wider range of cash crops - Households: Increased cash incomes	- Households: Increased purchasing power: access to food/social services (education, health) - Improved health & nutrition - Vulnerability to natural and other shocks reduced	
3. On-farm tree production and Improved Household Energy Supply **Integrated with**: • On-farm forage production	Medium term	- Tree seedlings - Labour: planting & maintenance - Improved Mitad - Improved Stove	- Increased supply of wood fuel - Substitution of wood for dung and crop residues as fuel - Reduced fuel wood consumption - Increased forage production (multi-purpose trees)	- Reduced fuel collection time & Energy (Women & children) - Reduced smoke inhalation/ & improved health (Women & children) - Reduction in soil nutrient breaches: Increased crop production:	- Reduced degradation of woodland/shrubland & loss of biodiversity
4. On-farm Forage Production - Backyard forage (grasses, legumes, multi-purpose trees **Integrated with:** • **On-farm tree**	Immediate	- Seeds & seedlings - Labour: planting & maintenance - Labour: cut and carry	- Increase livestock feed supply - Improved animal health and productivity	- Increased livestock sales and household income (Improved access to education & health facilities) - More timely land preparation - Increased milk production & dairy products : Increased income	

production • **Area closures**				- Reduced pressure on open access Communal grazing lands	
5. Improved Animal health **Integrated with:** • On-farm forage production	Medium term	- Veterinary services - drug provision	- Improved animal health and productivity	- Increased livestock sales and income - More timely & efficient land preparation - Increased milk production and dairy products: Increased income	
6. Area closure: Communal Lands, & Community Woodlots **Integrated with:** • On-farm tree production • On-farm forage production	Medium term	- loss of forage/fuelwood supply in initial years - labour cut & carry of forage - purchase of forage - Seedlings - Labour: planting & maintenance - Labour: harvesting - Purchase of wood	- Increase livestock feed supply - Improved livestock health & productivity - Increased supply of wood (fuel & construction	- Increased livestock sales and income - More timely land preparation - Reduced pressure on open access Communal lands - Reduced time & effort fuelwood collection (women & children) Reduced pressure on Communal Woodlands & shrublands	- Increased vegetation cover: increased biodiversity - Increased soil, herbaceous and wood biomass: carbon sequestration - Increased groundwater recharge & prolonged dry season flows - Reduced sedimentation Reservoirs & Irrigation schemes (Sudan, Egypt) - Increased biodiversity & carbon sequestration in Communal Woodland - Increased groundwater recharge & prolonged dry season flows
7. Water Conservation & Improved Utilization **Integrated with:** • Soil conservation • Crop diversification • On-farm forage production • On-farm tree production	Immediate	- Labour construction of water harvesting structures; small/micro dams - Labour: Operations & maintenance -Malaria (e.g. nets) & Bilharzias (moluscides) prevention measures	- Increased availability of water for human & livestock water supplies - Availability of water for vegetation production	- Reduced time & effort for water collection (women & children) - Improved health	- Increased groundwater recharge/prolonged dry season flows

The supporting interventions form a sub-set of a much broader array of rural development and poverty reduction activities. In the Ethiopia these are well developed and clearly articulated in the country's Sustainable Development and Poverty Reduction Programme (SDPRP) and its successor the Plan for Accelerated and Sustainable Development to End Poverty (PASDEP). This has enabled the supporting interventions to be identified in some detail and to be costed. The PASDEP is also supplemented by the Poor Area Programme comprising a Safety Net Programme for the chronically poor and a Planned Resettlement programme.

Some nine broad sets of interventions are identified and include:

(i) Capacity Building
(ii) Strengthening Extension Service
(iii) Development of Community Assets
(iv) Support to Non-farm Income Generation and Small/Micro Enterprise Development
(v) Support to Micro Finance Institutions (MFI's)
(vi) Improved Market Systems and Linkages
(vii) Sustainable Management and Development: Baro-Akobo Highland Wetland Systems
(viii) Strategic Land Use Planning: High Forest Areas: Baro-Akobo and Abbay sub-basins
(ix) Community Forest Management Planning and Implementation

Their cost items and direct, indirect and Regional/Global impacts are outlined in the matrix below.

INTERVENTIONS	TIME SCALE	COST ITEMS	DIRECT BENEFITS	INDIRECT BENEFITS	REGIONAL/GLOBAL BENEFITS
MATRIX 1b. ETHIOPIA					
SUPPORTING INTERVENTIONS					
1. Capacity Building - Physical capacity development - Human capacity development - Support to land Registration - Wereda Database -Regional /National Park Development **Linkages to:** • All Interventions	Medium term	- Purchase equipment, vehicles, etc - Short & long term training - Training surveyors & equipment provision - Database equipment & training - Capacity building Park staff	- Federal, regional & wereda level staff trained & qualified - Land registration surveyors trained. - Wereda level databases established & utilized - Regional & National Park staff trained.	- Increased quality & intensity of Extension - Increased numbers of farms registered: - Increased perceptions of tenure security - Improved Programme Planning & Implementation - Improved National & Regional Park Management	- Enhanced Biodiversity conservation
2. Strengthening Extension **Linkages to:** • Capacity building	Immediate	- Farmer Training Centres (FTC's) - Training D.A.'s - Radio broadcasts	- Physical training facilities - Increased output of trained D.A.s - Increase access to information (technical, health, economic) by Farm families	- Increased extension quality and farmer contacts (focussed & locally appropriate technologies) - Increased farmer knowledge	
3. Development Community Assets **Linkages to:** • Strengthening extension • Support Non-farm employment/small-micro enterprise development • Support micro-finance institutions	Immediate	- Construction of Feeder roads constructed - Construction of Improved market facilities	- Improved access to markets, social services health., education), information, non-farm employment - Improved storage facilities for traders: reduced storage and spoilage costs: reduced marketing costs	- Increased market product prices - Reduced input (fertilizer, seed) prices - Increased market intelligence: better crop scheduling - Increased profitability for crop, livestock and tree production	
4. Support to Non-farm	Medium term	- Construction Vocational Training	- Increased levels of skills of rural/urban dwellers	- Increased non-farm employment a higher wage	

Income Generation & Small/micro Enterprise Development - Non-farm employment support - Small/micro enterprise support **Linkages to:** • Strengthening extension • Feeder road construction • Capacity building		Centres (VTC's) - Literacy/Vocational Training provision - Experience transfer (migratory employment - Managerial/enterprise capacity training - Provision of Market demand information	- Increased levels of entrepreneurial and managerial skills	levels - Increased development of small/micro enterprises - Strengthened backward & forward linkages and multipliers: - increased economic development of small/medium urban centres	
5. Support to Micro Finance Institutions (MFI's) **Linkages to:** • Improved markets & linkages • Support to Small/micro enterprise development • Development Community Assets	Medium term	- Needs assessment & curricula development - Training of trainers - Training MFI staff	- Trained MFI Staff - Improved efficiency & effectiveness of MFI's - Effective Management Information Systems in place	- Expansion of credit availability	
6. Improved Market Linkages **Linkages to:** • Development of Community Assets • Support Small/Micro Enterprise development	Medium term	- Training provision: Farmer Marketing Cooperatives (market intelligence, cooperation with traders)	- Strengthened market power of farmers - Improved producer prices	- Increased farm incomes - Increased marketed volume	
7. Sustainable management	Medium	- Detailed survey &	- Wetlands inventoried,	- Increased & sustainable	- Catchment hydrological

& development: Baro-Akobo Highland wetlands **Linkages to:** • Soil Conservation * improved soil husbandry • Area closures • Water conservation & improved utilization • Strategic Land Use Planning: High Forest areas • Feed road & market development • Support Small/micro enterprise development	term	assessment of Highland Wetlands Systems - Specialised training: Sustainable Wetland Management Systems (Wereda/Kebelle Extension Staff) - Establishment of Water User Groups (WUG's) - Farmer training - Formulation of M & E System	Surveyed & Assessed - Wetland User Groups established - Participatory wetland management systems developed - Monitoring & impact evaluation systems developed & operational	productivity of Highland wetlands increased - Household food security increased: vulnerability to natural shocks reduced - Wetland environmental services intact	systems integrity maintained - Biodiversity conserved - Soil organic carbon maintained & sequestered
8. Strategic land Use Planning: High Forest Areas: Abbay & Baro-Akobo Sub-basins **Linkages to:** • Soil Conservation * improved soil husbandry • Area closures • Water conservation & improved utilization • Strategic Land Use Planning: High Forest areas • Feed road & market development • Support Small/micro enterprise development •	Medium term	- Provision of remotely sensed images, interpretation & survey equipment - Field Survey & Assessment of remaining High Forest Areas -Inter-regional participatory Forest Land Use Zoning - Preparation of Forest Management Plans	- Environmental, Social and economic basis established for long-term watershed management & regional economic development planning - Technical & Legal Framework established for Community Forests & Commercial Logging Forests - Most ecologically/economically suitable areas for sustainable agricultural development & settlement defined	- Biodiversity (genetic, species & habitat) hotspot" areas protected - Most important areas of High Forest with key environmental services protected - Areas for sustainable smallholder & commercial agricultural development, Community Forests & Commercial Logging Forests defined & delineated based on social, ecological & economic criteria	- Essential catchment Hydrological & environmental services protected - Biodiversity Conserved - Substantial amounts of soil & biomass carbon retained & sequestered.
9. Community Forest	Medium	- Capacity building	- Community Forests managed	- Increased household incomes	- Essential catchment

Management Planning & Implementation **Linkages to:** • Strategic land Use Planning: High Forest • Soil Conservation & improved soil husbandry • Area closures • Feeder road & improved market linkages • Support Small/micro enterprise development	term	Extension Service: Participatory Community Forest Management Planning-Field level: Community Forest Management Planning	for protection of environmental services; shade for coffee & corrarima; sustainable supply of wild food plants & fruits; supply of medicinal plants; supply of fuelwood; and honey production.	(sales of NTFP's) - Reduced time & energy for fuelwood collection - Increased food security (wild plants, fruits)	Hydrological & environmental services protected - Biodiversity Conserved - Substantial amounts of soil & biomass carbon retained & sequestered. -

3.4.2 Sudan

There are ten sets of direct interventions. They include:

(i) Arresting Soil Degradation: Rainfed Semi-mechanized Farms
(ii) Improving Crop Production: Rainfed Traditional Farms:
(iii) Support to Rainfed Traditional Water Harvesting Systems
(iv) Reducing Degradation: Rangelands in Northern Drylands
(v) Improving Rangeland Productivity: Southern Flood retreat Grasslands
(vi) Kerib land Reclamation
(vii) Halting Shifting Sand Dunes
(viii) Reducing Drifting Sand onto Cropland
(ix) Reducing River Bank Erosion
(x) Survey and Assessment: Human induced salinity in Irrigated lands

Their cost items and direct, indirect and Regional/Global impacts are outlined in the matrix below.

INTERVENTIONS	TIME SCALE	COST ITEMS	DIRECT BENEFITS	INDIRECT BENEFITS	REGIONAL/GLOBAL BENEFITS
MATRIX 2a. SUDAN					
A. DIRECT INTERVENTIONS					
1. Arresting Soil Degradation: Rainfed: SMF's: - Increased crop production: -Expanded Gum Arabic production: - Increased Timber/fuelwood production	Immediate	- Sub-soiling (5 yr interval) - Tied ridging/Bunding - Improved Seed: Drought resistant crop varieties/High yielding varieties - Furrow planting - Acacia senegal seedlings, planting, maintenance - Shelterbelt establishment: (seedlings, planting, maintenance: contract – traditional rainfed crop households))	- Increased yields & production - Increased farm incomes: (crops, Gum Arabic; timber) - Increased employment: Crop production - Increased employment: Gum harvesting - Increased employment: Shelterbelt establishment, maintenance & harvesting (traditional rainfed sector)	- Soil degradation arrested - Wind erosion reduced - Reduced pressure on forests & woodlands for fuelwood/charcoal - Increased household incomes & improved livelihoods (hired labour) - Increased household incomes & improved livelihoods (traditional rainfed sector)	- Increased soil organic matter & Carbon sequestration.
2. Arresting Soil Degradation: Rainfed: Traditional Farms - Increased Crop production	Immediate	- Tied ridging Improved Seed: High Yielding Varieties	- Increased yields & production - Increased crop residues: livestock feed - Increased farm incomes: (crops, livestock)	- Increased farm incomes & improved livelihoods - Reduced vulnerability to natural shocks - Improved livestock productivity	- Increased soil organic matter & Carbon sequestration
3. Support to Rainfed: Traditional: Water harvesting: Semi arid areas (Kassala, N. Kordofan)	Immediate	- Improved seed: Drought resistant varieties (sorghum, sesame, vegetables) - Multiplication & supply of Vetiver grass - Research: Cost effective methods of *tera* construction/reconstruction	- Increased yields & production - Crop diversification to cash crops (okra, water melon) - reduced variability in yields - Increased production crop residues (livestock feed)	- Increased farm incomes & improved livelihoods - Reduced vulnerability to natural shocks - Improved livestock productivity	- Increased soil organic matter & Carbon sequestration
4. Reducing Degradation of Rangelands: Northern Drylands **Integrated with:** • Rainfed: traditional: Central Plains (Land	Immediate	- Delineation & demarcation of stock routes ("nomad paths") - provision of water points along stock routes - Improved forage seed: (On-farm forage development for agro-pastoralists)	- More equitable access to land and other natural resources - Relieving pressure on both dry and wet season rangelands would lead to improved and sustainable	- Reduced vulnerability to natural shocks, - increasing household assets and widening livelihood strategies.	- Arresting desertification: increasing herbaceous & soil organic matter & Carbon sequestration

Re-allocation) • Capacity Building: Extension Service • Research programme: small-scale rainfed crop sector • State-wide Strategic Land Use Planning • Community-level Land Use Planning		- Test feasibility of aerial sowing of rangelands - Establish Community-based Animal Health Worker (CAHW) Scheme - Sustainable Supply of drugs	management of these resources; - increased livestock productivity and off-take		
5. Improving Rangeland Productivity: Flood retreat grasslands of the South **Integrated with:** • Baro-Sobat-White Nile Integrated Wetlands Study • Community-level land Use Planning: South Sudan	Immediate	- Bunding shallow drainage lines on clay plains - Delineation & demarcation of stock routes - Provision of water points along stock routes - Establishing holding (quarantine) grounds for export animals - Improved forage seed: (On-farm forage development for agro-pastoralists) - Support existing Community-based Animal Health Worker (CAHW) Scheme - Sustainable supply of drugs	- Increasing productivity of seasonally flooded grasslands - Increased marketed off-take of animals - Increased export of animals to Kenya, Uganda & DRC. - Improved animal health & productivity - Improved forage supply for calves & cows in milk (on-farm forage)	- Increased household incomes & sustainable livelihoods - Reduced vulnerability to natural shocks	- Increasing herbaceous & soil organic matter & carbon sequestration
6. Kerib Land Reclamation: Atbara, Blue Nile, Rahad & Dinder Rivers	Immediate	- Establish 100m Zone of deep rooting trees: (seedlings, leguminous tree planting & maintenance) - Micro-catchments: Grass & leguminous tree planting (seed, seedlings, planting, maintenance)	- Arresting loss of cropland - Forage production - Fuelwood %/or charcoal production	- Increased livestock productivity - Reduced pressure on rangelands & woodlands	- Increasing herbaceous, wood & soil organic matter & carbon sequestration
7. Halting Shifting Sand Dunes (Main Nile, White Nile)	Immediate	- 10 kms Emergency shelter belt at Argi (seedlings, planting, maintenance) - 80 kms External shelterbelt (seedlings, water provision,	- Sand dune encroachment into croplands & Nile River arrested: - Sand source areas cut-off from dunes	- Increased tree cover within irrigated areas (5%): shade, fuelwood	- Increased wood & soil organic carbon & sequestration

		plantings, maintenance) - Tree planting within irrigation areas (5%) (seedlings, planting, maintenance)	- Current irrigation land (6,200 fed) protected - Potential irrigation land (33,000 fed) protected - Livelihoods of 43,000 people protected		
8. Reducing Drifting Sand onto Cropland (Atbara, Main Nile)	Immediate	- Tree planting on field boundary (seedlings, planting, maintenance) - Fencing (labour)	- Reduced sand cover on cropland - Reduced sedimentation in irrigation canals - Increased crop yields & production: (increased household incomes) - Increased water delivery efficiencies (increased crop yields & production: increased household incomes	- Increased tree cover within irrigation areas: shade, fuelwood supply	- Increased wood & soil organic carbon & sequestration
9. Reducing River bank Erosion (Blue Nile, Atbara, Main Nile)	Immediate	- Undertake survey & assessment of current bank erosion: - Establish bank erosion monitoring system - Encourage deep rooting crops near river edge - Construct revetments (in areas high land values)	- Reductions in loss of irrigated land - Reductions in sediment entering river	- Maintaining livelihood assets & reducing vulnerability to natural shocks - Reducing downstream sediment in reservoirs & irrigation systems	
10. Survey & Assessment: Human induced salinity in irrigated land (White Nile, Main Nile)	Immediate	- Undertake survey & assessment of salinized lands - Logistical support (Personnel, transport, equipment, analyses) - Assess remedial interventions required (drainage, gypsum application, etc) - Assess economics of remedial action (Need for credit?)	- Comprehensive data base on incidence & prevalence of salinity & impacts on crop production	- Basis established for programme of remedial actions to reduce soil salinity (drainage, soil amelioration)	

In Sudan development policy is currently in a state of considerable flux following the Comprehensive Peace Agreement (CPA). Outline proposals have been identified in the Joint Appraisal Mission's (JAM) Report in nine Cluster Reports but many details have yet to be determined and worked out.

The Supporting Interventions identified include:

(i) Capacity Building
(ii) Strengthening Extension Service
(iii) Support to Micro Finance Institutions (MFI's)
(iv) Improved Accessibility and Market Linkages
(v) Support to Traditional Rainfed Agriculture: Central Clay Plains, Ngessena Hills and Nuba Mountains
(vi) Sustainable Management and Development: Dinder-Rahad Wetlands
(vii) Sustainable Management and Development: Baro-Sobat-White Nile Wetlands
(viii) Sustainable Management and Development: Blue Nile Wetlands
(ix) Community Woodland Management Planning and Implementation
(x) Support to Establishment of Dinder-Alatish Transboundary Park
(xi) Transboundary Collaborative Wildlife Inventory and Habitat Assessment
(xii) Support to State-wide Strategic Land Use Planning: Northern Sudan
(xiii) Support to Southern Commission for Natural Resources
(xiv) Support to Community Level Land Use Planning: Northern Sudan
(xv) Support to Community Level Land Use Planning: Southern Sudan

Their cost items and direct, indirect and Regional/Global impacts are outlined in the matrix below.

INTERVENTIONS	TIME SCALE	COST ITEMS	DIRECT BENEFITS	INDIRECT BENEFITS	REGIONAL/GLOBAL BENEFITS
MATRIX 2b. SUDAN					
B. SUPPORTING INTERVENTIONS					
1. Capacity Building - Physical capacity development - Human capacity development **Linkages to:** • Strengthening Extension Service	Medium term	- Office Construction - Purchase equipment, vehicles, etc - Short (in-service) & long term (University) training	- Office facilities constructed - State, Locality staff trained & qualified	- Increased quality & intensity of Extension - Improved Programme Planning & Implementation	
2. Strengthening Extension Service **Linkages to:** • Capacity Building	Medium term	- Agricultural Agent Training centres - Farmer Training Centres (FTC's) - Training: Agricultural Agents - Radio broadcasts	- Physical training facilities for Agricultural Agents & Farmers - Increased output of trained Agricultural Agents - Increase access to information (technical, health, economic) by Farm families	- Increased extension quality and farmer contacts (focussed & locally appropriate technologies) - Increased farmer knowledge	
3. Support to Agricultural Research: Rainfed Cropping **Linkages to:** • Strengthening Extension Service • Capacity Building	Medium term	- Physical capacity development (Buildings, equipment, materials) - Human capacity development (short & long term training) - Operating & Maintenance Costs - Establish closer Research-Extension Linkages	- Physical research facilities constructed - Research staff trained & qualified - Adequate funding resources available - Close Research-Extension-Farmer linkages established	- Appropriate & improved soil, crop and animal husbandry recommendations communicated to farmers - Increased crop & livestock production: Improved Livelihoods & poverty reduction in traditional agricultural sector	
3. Support to Micro Finance Institutions (MFI's) **Linkages to:** • Improved markets & linkages • Support to Small/micro enterprise development •	Medium term	- Needs assessment & curricula development - Training of trainers - Training MFI staff	- Trained MFI Staff - Improved efficiency & effectiveness of MFI's - Effective Management Information Systems in place	- Increased availability of credit to small farmers & pastoralists	
4. Improved Accessibility &	Immediate	- Construction of Feeder	- Improved access to markets,	- Increased market product prices	

Market Linkages **Linkages to:** • Strengthening extension • Support micro-finance institutions		roads - Construction of Improved market facilities	social services health., education), information, non-farm employment - Improved storage facilities for traders: reduced storage and spoilage costs: reduced marketing costs	- Reduced input (fertilizer, seed) prices - Increased market intelligence: better crop scheduling - Increased profitability for crop, livestock and tree production	
5. Rainfed: Traditional: Central Clay Plains: Ngessena Hills & Nuba Mountains **Integrated with:** • Support Traditional Pastoral/Agro-pastoral Sector: Drylands of North • Capacity Building: • Strengthening Extension Service • Research programme: small-scale rainfed crop sector • State-wide Strategic Land Use Planning • Community-level Land Use Planning • Micro credit development	Medium term	- Survey of all land occupied by SMF leases & utilization status - Reversion back to State of abandoned/non utilized land - Land suitability assessment of reverted land - Land Use Zoning & re-allocation to Traditional agricultural sector	- More equitable access to land and other natural resources - Increasing fallow periods & restoration of soil fertility, organic matter & physical condition - Increased crop production - Improved & sustainable management & utilization of woodlands & pastures:	- Increased farms incomes & improved livelihoods - Reduced vulnerability to natural shocks	- Increased soil organic matter & Carbon sequestration
6. Sustainable management & development: Dinder-Rahad Wetlands **Linkages to:** • Kerib Land Reclamation • Support to Dinder-	Medium term	- Detailed Transboundary Survey & assessment of Dinder-Rahad Wetland Systems - Satellite Images/Air Photos, Survey Equipment - Develop Sustainable Wetlands Management Plan	- Wetlands inventoried, Surveyed & Assessed - Sustainable Wetlands Management Plan Developed	- Wetland Services (biodiversity, water supply, flood buffering, fish) maintained	- Catchment hydrological systems integrity maintained - Biodiversity conserved

Alatish Transboundary Park • State-wide Strategic Land Use Planning: • Community level land Use Planning • Rainfed: Traditional: Central Clay Plains					
7. Sustainable management & development: Baro-Sobat-White Nile Wetlands **Linkages to:** • Community level Land Use Planning (Southern Sudan) • Transboundary Collaborative Wildlife & Habitat Survey	Medium term	- Detailed Transboundary Hydro-ecological Survey & Assessment of Baro-Sobat-White Nile Wetlands System - Satellite Images/Air Photos, Survey Equipment	- A sound understanding of the inter-relationships between hydrology, ecology and livelihoods developed	- A basis for an effective impact assessment of existing and potential developments. established	- Catchment hydrological systems integrity maintained - Biodiversity conserved
8. Sustainable Management & Development of Blue Nile Wetlands	Medium term	- Assessment of conservation status of Blue Nile Wetlands (Logistics: personnel, transport, equipment & materials) - Identify areas for strict conservation & reservation - Designate as Forest Reserves	- Blue Nile wetlands conserved	- Integrity of wetlands services maintained (flood buffering, biodiversity)	- Biodiversity Conserved
9. Community Woodland Management Planning & Implementation **Linkages to:** • Strategic State-wide Land Use Planning • Community Level Land Use Planning • Rainfed: Traditional:	Medium term	- Capacity building Extension Service: (Participatory Community Woodland Management Planning- Field level: Community Forest Management Planning	- Establishment of Community Forest Management Institutions, - Sustainable forest access and use rules leading to sustainable use and management of forests and a reduction in the rates of deforestation. - Increased supply of fuelwood and charcoal for	- Increased household incomes (sales of fuelwood & charcoal) - Reduced time & energy for fuelwood collection	- Essential catchment Hydrological & environmental services protected - Biodiversity Conserved - Substantial amounts of soil & biomass carbon retained & sequestered.

Central Clay Plains			own use and sale, leading to increased incomes and livelihood capital assets and reduced vulnerability. - More equitable access to natural resources and reduction in resource conflicts.		
10. Support to Establishment of Dinder-Alatish Transboundary Park **Linkages to:** • Strategic State-wide Land Use Planning • Community Level Land Use Planning	Medium term	- Establishment of Permanent Joint Park Management Institution (Administrative expenses, travel) - Harmonization of Park Management Plans - Harmonization of Park Monitoring Systems	- Enhanced habitat and species conservation because of the larger protected area.	- Increased potential for "Eco-tourism" and increased employment opportunities for Park inhabitants.	- Biodiversity Conservation Enhanced
11. Transboundary Collaborative Wildlife & Habitat Survey & Assessment **Linkages to:** • Sustainable Wetlands Management: Baro-Sobat-White Nile	Immediate	- Establishment of Joint Steering Committee (Travel, Meetings) - Transboundary Inventory & Habitat Assessment (aircraft hire, vehicles, equipment)	- Detailed data on wildlife numbers, trends & habitat status - Experience gained in transboundary Biodiversity Conservation	- Basis established for developing management Plans for Boma & Gambella National parks & Buffer Zones - Increased potential for "Eco-tourism" and increased employment opportunities for Park inhabitants.	- Biodiversity Conservation Enhanced
12. Transboundary Biosphere Reserve: Wadi Allaqi Linkages to: • State-wide Strategic Planning: Northern Sudan • Egypt: Interventions Wadi Allaqi	Immediate	- Establishment of permanent Joint Management Organization - Harmonization of Conservation Activities - Harmonization of Development Activities	- Enhanced habitat and species conservation because of the larger protected area. - Wadi Allaqi one Livelihood Support System	- Increased potential for "Eco-tourism" and increased employment opportunities for Biosphere Reserve's inhabitants.	- Biodiversity Conservation Enhanced

13. State-wide Strategic Land Use Planning: Northern Sudan **Linkages to:** • Capacity building • Rainfed Traditional: Central Plains (SMF survey & assessment; Land re-allocation)	Immediate – Medium term	- Establish national-level Planning Guidelines & principles - Establish Institutional Framework: for collaborative planning (Identify relevant stakeholders: meetings, workshops) - Undertake Surveys (Natural Resource base, Resource Use Systems, Land access institutions (formal & informal) - Draft Strategic Land Plan - Logistics (Personnel equipment, remote sensing images transport, technical support)	- Agreed long-term Natural Resource use & management - Institutional procedures for resource allocation & utilization established - Integration of traditional * State land allocation procedures & institutions	- Clear set of principals established to guide future developments - Defusing resource access conflicts - More equitable access to natural resources - Strengthened State capacity to develop long-term economic development plans	
14. Support to Southern Commission for Natural Resources **Linkages to:** • Sustainable Management of Baro-Sobat-White Nile Wetlands (hydro-ecological & livelihoods survey)	Medium term	- Capacity Building (physical & human capacity) - Technical Support (in-service training, equipment)	- Increased capacity to undertake natural resources inventory and development strategy	- Natural resource base inventory, assessment & Strategic Natural Resource Use Plan	
15. Community Level land Use Planning: Northern Sudan **Linkages to:** • State-wide Strategic land Use Planning • Capacity Building • Rainfed Traditional:	Immediate – Medium term	- Link Traditional land allocation Institutions with Formal State Institutions - Capacity Building & Training: (Participatory planning techniques) - Logistic Support (Personnel, transport, equipment, technical support)	- Sustainable use of natural resource base - More equitable access to natural resources - Improved livelihoods (capital assets, livelihood strategies, reduced vulnerability to natural shocks)	- Reduced resource-based conflicts	

Central Plains (SMF survey & assessment; Land re-allocation) **16. Community Level land Use Planning: Southern Sudan** **Linkages to:** • Support to Southern Commission for Natural Resources	Immediate – medium term	- Link Traditional land allocation Institutions with Formal State Institutions - Capacity Building & Training: (Participatory planning techniques) - Logistic Support (Personnel, transport, equipment, technical support)	- Sustainable use of natural resource base - More equitable access to natural resources - Improved livelihoods (capital assets, livelihood strategies, reduced vulnerability to natural shocks)	- Reduced resource-based conflicts	

3.4.3 Egypt

In Egypt the supporting institutions and mechanisms required for the implementation of the proposed direct interventions are largely in place. The key supporting intervention identified in the Transboundary analysis is institutional strengthening of the linkages and information flows between agricultural research, extension and farmers.

The direct interventions include:

i. Livelihoods Support: Resettlement Schemes around Lake Nasser
ii. Livelihoods Support: Ababda and Bishari Communities

The supporting interventions include:

(i) Capacity Building High Dam Lake Development Authority (HDLDA), Ministry of Agriculture and Land Reclamation (MALR) and Settlers
(ii) Capacity Building: Ministry of Health (MOH)
(iii) Capacity Building: Community Development Associations (CDA's)
(iv) Support o Micro Finance Institutions (MFI's)
(v) Improved Accessibility and Market Linkages

Their cost items and direct, indirect and Regional/Global impacts are outlined in the matrices below.

INTERVENTIONS	TIME SCALE	COST ITEMS	DIRECT BENEFITS	INDIRECT BENEFITS	REGIONAL/GLOBAL BENEFITS
MATRIX 3a. EGYPT					
A. DIRECT INTERVENTIONS					
1. Livelihoods Support: Resettlement Schemes around Lake Nasser **Linkages to:** • Capacity Building: Extension & Research • Capacity Building: Community Associations	Immediate	- Extend research results (bio-fertilization, bio-pest control) to Settlers - Strengthen Research-Extension-Farmer linkages - Establish Micro-credit Facilities - Extend range of Social Services (Secondary Schools, Health Facilities) & Electricity - Construct Settlement-Market access roads: - Develop Market price Information Communications system - Undertake Salinity/alkalinity study on irrigated lands	- Increased adoption of Bio-fertilization & bio-pest control techniques - Enhanced crop research responsive to settlers needs and capacities - Well developed social & physical infrastructure: - Improved access to markets & market price information	- Adoption environmentally of sustainable irrigated cropping technologies as models for large-scale adoption - Elimination of seepage of agro-chemicals into Lake Nasser - Increased farm incomes & reduced vulnerability to low market prices - Access to social services, markets: reduced seasonal migration to home areas	
2. Livelihoods Support: Ababda & Bishari Communities: Wadi Allaqui	Immediate	- Develop open-canopy Acacia woodland in Wadi Allaqui (seedlings, planting & initial maintenance) - Switch to fodder crops (seeds, technical support)	- Sustainable supply of wood for charcoal production - Increased cash incomes (particularly resource poor & women headed households)	- Reduced pressure on Acacia trees in Red Sea Hills - Reduced vulnerability to market price shocks (for vegetables) - Enhanced livelihood assets for women-headed households	

MATRIX 3b. EGYPT

INTERVENTIONS	TIME SCALE	COST ITEMS	DIRECT BENEFITS	INDIRECT BENEFITS	REGIONAL/GLOBAL BENEFITS
A. SUPPORTING INTERVENTIONS					
1. Capacity Building (HDLDA, MALR & Settlers) **Linkages to:** • Capacity Building: MOH • Capacity Building: CDA's	Medium term	- Training: Agricultural Agents (Participatory Action Research & Extension) - Training: Settlers (Use of Bio-fertilizer & Bio-pest control measures) & Market planning - Radio broadcasts	- Increased output of trained Agricultural Agents - Improved communication & linkages between Settlers & Extension, and between Extension & Research - Increase access to information (technical, health, economic) by Farm families	- Increased extension quality and farmer contacts (focussed & locally appropriate technologies) - Increased farmer knowledge	
2. Capacity Building: MOH **Linkages to:** • Capacity Building: HDLDA, MALR, Settlers • Capacity Building: CDA's	Medium term	- Training Health Workers in Eco-system Health Surveys & Monitoring (Participatory Rural Appraisal, Focussed group discussions, Semi-structured interviews)	- Information base on Health problems in Settlement Schemes - Health monitoring system established	- Improved health status of Settlers	
3. Capacity Building: Community Development Associations (CDA's) **Linkages to:** • Capacity Building: HDLDA, MALR, Settlers • Capacity Building: MOH	Medium term	- Training CDA members (Project Management, Board Management, M &E, Proposal Writing, Financial Management, Inventory Control) - Basin training in new Bio-agricultural techniques	- Increased administrative & development effectiveness of CDA's.	-Increased Community participation in Settlement Scheme management - Environmental Integrity of Lake Nasser maintained.	

4. Support to Micro Finance Institutions (MFI's) **Linkages to:** • Improved markets & linkages • Support to Small/micro enterprise development	Medium term	- Needs assessment & curricula development - Training of trainers - Training MFI staff	- Trained MFI Staff - Improved efficiency & effectiveness of MFI's - Effective Management Information Systems in place	- Increased availability of credit to small farmers & pastoralists	
5. Improved Accessibility & Market Linkages **Linkages to:** • Strengthening extension • Support micro-finance institutions	Immediate	- Construction of Feeder roads constructed - Market price communication system installed	- Improved access to markets, social services health., education), information, non-farm employment	-- Increased market intelligence: better crop scheduling - Increased profitability for crop production	

4. COSTS, BENEFITS AND IMPACTS OF WATERSHED MANAGMENT INTERVENTIONS: ABBAY-BLUE NILE SUBBASIN

This chapter begins by looking at the benefits for the Abbay-Blue Nile Sub-basin deriving from the interventions of the programme as a whole. The analysis considers benefits at the local community level, the national, the Sub-basin/Regional and the global levels.

The rest of the chapter first considers Ethiopia and then Sudan. For each country the analysis first examines the costs of continued natural resource management practices and then analyses the impacts, costs and benefits of the direct interventions.

4.1 Benefits for the Abbay-Blue Nile Sub-basin of the Watershed Management Interventions of the Programme as a Whole

4.1.1 Household and Community Level: Local Rural-Urban Linkages

The results of the benefit-cost analysis of on-farm and community interventions demonstrate that there is significant potential for increasing household farm incomes, increasing food supply with improved levels of nutrition and health, reducing vulnerability to climate, social and economic shocks and improving the quality of the natural resource base. However, a key finding is that a number of the interventions have substantial costs in terms of labour for construction or establishment. For a number of the interventions it takes a number of years for benefits to be realized (on-farm and community tree planting) or benefits only slowly accrue (SWC measures).

In the areas of food deficits there are a number of programmes that support households and communities through food/cash for work and safety net support measures. However, there is an urgent need to extend support to households and communities in apparently more favourable areas where there is clear evidence that the high costs of initial labour requirements are an impediment to adoption of SWC measures on cropland.

The programme of interventions will have a substantial impact on arresting degradation of the natural resource base both on cropland and also on non-cropland. This is a vital entry point in breaking the cycle of poverty and resource degradation and attacks one of the root causes of poverty in the Abbay-Blue Nile Sub-basin. Conservation of the non-croplands through enclosure and tree enrichment planting will provide not only direct benefits to communities in terms of increased livestock feed and improved livestock productivity and increased supply of fuelwood and timber, but also an increase in wild plants of food and medicinal values that are of considerable importance to the most disadvantaged community members such as female headed households. The obvious regional and global benefits are enumerated below.

The SWC structures on cropland and the enclosed areas on non-cropland will reduce runoff and increase infiltration to groundwater. There is evidence (WFP, 2005) that where integrated watershed management measures have been implemented that groundwater levels have risen and long dormant springs have started to flow.

The supporting interventions will have substantial benefits to households and communities. Measures to increase market accessibility and integration such as feeder roads and extension of telecommunications will have positive impacts by reducing market transaction costs thus benefiting both producers and consumers. The interventions will enable an expansion of local economic multipliers. At the local level these will occur through increased incomes being spent on purchases of local non-tradable goods i.e. goods made locally rather than those imported. Work in an inaccessible area of Nigeria similar to many parts of rural Ethiopia and Sudan suggested a multiplier of 1.32 for the non-tradable sector (Hazell & Roell, 1983). In addition, there will be increased backward multipliers (from an increased demand for improved inputs) and forward multipliers (from an increase in marketed agricultural products. These in turn will increase employment opportunities in the many small urban centres for rural and urban households.

The capacity building interventions will have a number of positive benefits at the local level. Increased access to improved technologies (with increased support to extension and research services) combined with access to literacy and skills training have been shown to be strongly correlated with increased adoption of improved agronomic technologies. The support to the Extension Service with improved information linkages between farmers and research will increase the relevance of agricultural research to the traditional small-holder sector. Increased road accessibility and skills training will enable rural households to have better access to non-farm employment opportunities.

Increased access to micro credit will provide an important enabling environment for farmer adoption of improved technologies, in particular fertilizer and improved seeds. Credit together with support to small enterprise training will also enable the development of small enterprises in the small urban centres further increasing employment opportunities. It must emphasized that there a number important synergies between the various interventions most particularly in improving rural-urban linkages, the increasing economic development of small urban centres and increased agricultural production.

The support to Community Level Land Use Planning and Community Woodland Management Planning in Sudan will enable rural communities to better manage the natural resource base and sustainably harvest wood and other non-wood products. This will in turn assist in reducing local conflicts over natural resource use and increase access to all groups. Strategic Land Use Planning and Zoning in the High Forest areas of the Ethiopian Highlands will clearly delineate areas for small-holder and large-scale commercial agricultural development based on stakeholder participation and sustainable land suitability principals. Similarly, areas for Community Forests will also be clearly delineated on the same basis. Clear and transparently developed land use zoning will allow for sustainable development and management of the Forest and Land resources at the local level.

4.1.2 National Level

At the national level the interventions will increase the rate of poverty reduction and numbers of households needing safety net support. In both Ethiopia and Sudan the highest incidence of poverty is with the traditional agricultural smallholder sector. By targeting this sector (rather than the commercial agricultural sector) a proportionally greater impact will be achieved in reducing the numbers of households living below the poverty line.

A recent study by IFPRI and ASARECA[3] (Omamo et al., 2006) covering all the counties in the Region including Ethiopia and Sudan found that the largest poverty reductions will come not from growth in export sub-sectors but from growth in those sub-sectors for which demand is the greatest – such a crop staples, livestock products, oil seeds and fruits and vegetables. Another more detailed study for Ethiopia (Daio et al., 2006) confirms these findings. The studies also found that agricultural productivity growth alone is insufficient to meet the Millennium Development Goals (MDG) poverty reduction targets. Growth in non-agricultural sectors and improvements in market conditions are also required.

The interventions that increase the easily accessible supply of fuelwood (on-farm tree planting) and the reduction in its consumption (using fuel efficient stoves) will have consider impacts on reducing the work loads of women and children. In addition, there will positive impacts on their health and well-being through the reduction in smoke inhalation thus reducing the incidence of respiratory diseases.

The interventions to increase market accessibility and integration will have positive impacts across the Sub-basin in each country as market transaction costs are substantially reduced. Sub-regional multipliers: backward and forward as well as growth of tertiary and secondary urban centres will stimulate the sub-regional economies. It is difficult to predict the size of these

[3] The Association for Strengthening Agricultural Research in Eastern and Central Africa

multipliers. Bhattari et al., (2007) have examined irrigation development across India and irrigation multipliers to the economy as a whole. They found irrigation multiplier values of 3 to 4.5 suggesting that about two thirds of the irrigation benefits have accrued to the non-irrigation sector, with farmers receiving the other third. Whilst markets and the economy as a whole in India are better integrated and accessible, with increasing market integration in Ethiopia and Sudan Sub-regional economic multipliers will become increasingly important.

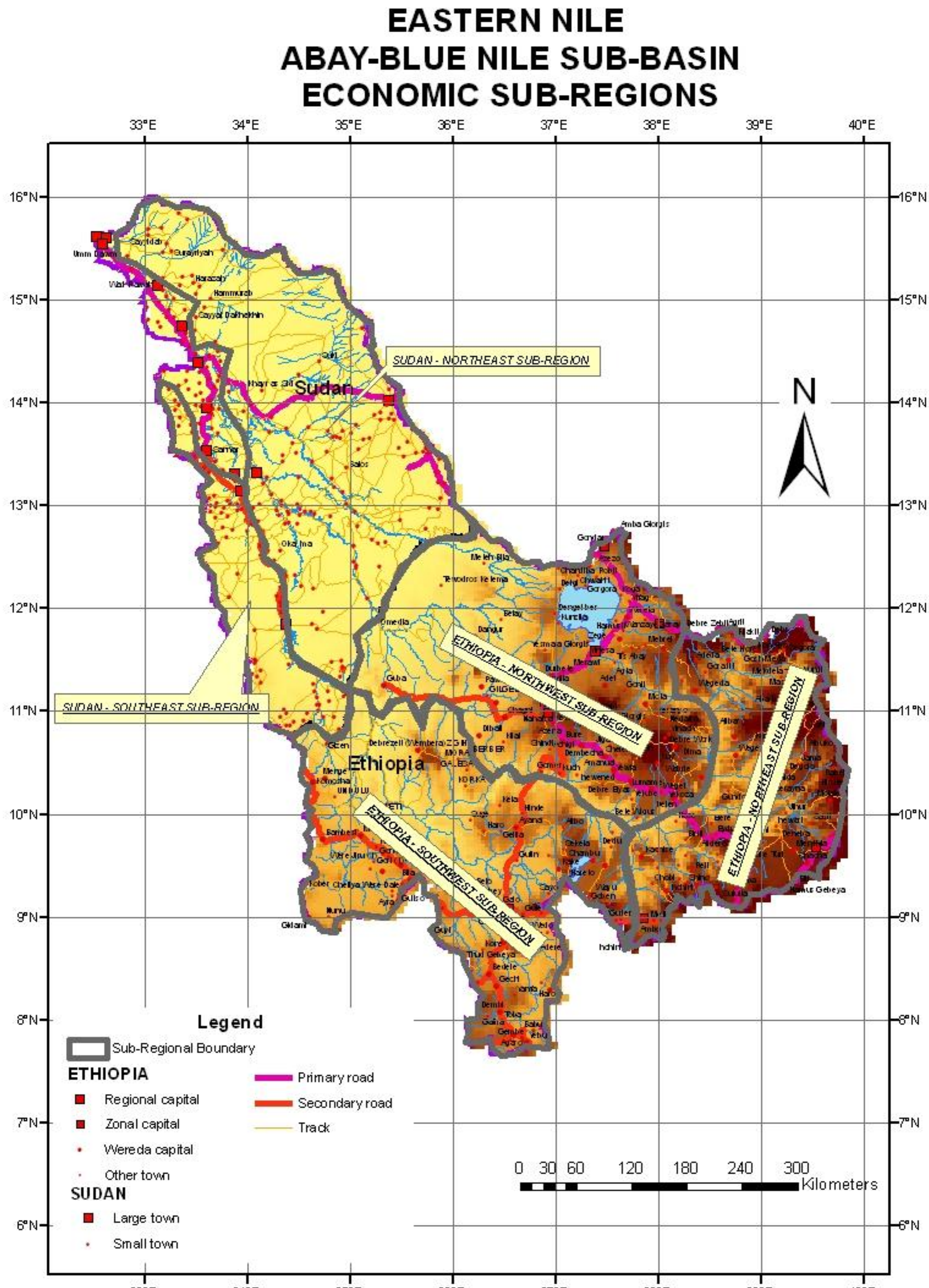
In Ethiopia within the Abbay Sub-basin three major Sub-regions[4] can be identified: the northwest encompassing Gojam and Gonder and the western Lowlands north of the Abbay; the northeast encompassing Wello and North Shewa east of the Abbay; and the Southwestern Sub-region encompassing East and West Wellega and the western lowlands south of the Abbay (Map 3). Two of these – the Northwestern and the Southwestern have been identified as potential "Growth Corridors" by the Poverty Reduction Strategy Plan.

The Northwestern Sub-region includes the surplus producing areas of the Highlands with the new area for irrigation development of the Tana-Beles Project and expansion of Commercial rain-fed crop production in the western Lowlands. It also includes a growing tourist attraction of Barhir Dar and its environs. The proposed intervention programme will substantially increase the net income of the Sub-region and thus contribute to the overall economic development. The growth of non-agricultural sectors (particularly services) should generate the increased demand for agricultural products required for significant agricultural growth.

The Northeast Sub-region encompasses the main food deficit areas of the Sub-basin and given the extreme variations in terrain the most inaccessible. However with the proposed interventions in feeder road construction, small-scale irrigation, water harvesting, improved small livestock production and diversification activities such as wool and honey production and the development of deciduous fruits, there are likely to significant benefits to the Sub-regional economy.

The Southwestern Sub-region includes relatively high potential agricultural areas with the main cash crop coffee. Improved primary road communications have reduced transport costs to the capital Addis Ababa. The recent increase in demand for organic coffee has seen a rise in demand and market prices. In those areas closest to Addis Ababa with its International Airport, there has been considerable development in cut flower production for the export market. The programme of WSM interventions thus will have significant positive impacts on the regional economy.

[4] "Sub-region" in this context refers to a broad area defined by physical relief features and by a degree of road inter-connectedness and thus economic integration. There are "core" and periphery areas within each Sub-region.



Map 3. **Abbay-Blue Nile Sub-Basin: Economic Sub-Regions**

In Sudan two main Sub-regions (Map 3) can be identified. The first is in the Northeast Sub-region, found north of the Blue Nile River and includes the Butana Plain, the Semi-mechanized farms and the traditional rainfed farms mainly to the east; the second is the Southeast Sub-region found south of the Blue Nile River and includes the SMF's and the traditional rainfed farms. Both Sub-regions and Sub-sectors will see substantial increases in incremental incomes deriving from the Direct Interventions.

In addition to the local multipliers there will be substantial Sub-regional multipliers deriving from increased market accessibility and integration. Improved access to the Butana Plains with the implementation of the stock routes and water points will substantial increase livestock productivity and increased domestic and export earnings. The increase use of crop residues from the SMF's by pastoralists, agro-pastoralists and livestock holders in the large irrigation schemes will also contribute to increased livestock productivity and the Sub-regions economies.

The interventions to support State-wide Strategic land Use Planning in Sudan have clear linkages to Sub-regional economic development. The Strategic Plans will be developed with full stakeholder participation and will assist in clarifying development objectives and strategies. The plans will contribute to the harmonization of sectoral development strategies and so developing the synergy between sector developments identified in the IFPRI/ASARECA Study as necessary for substantial poverty reduction.

The Capacity Building interventions will contribute to the increased effectiveness of the agricultural Extension and Research Services. In each country this increase in both the quantity and quality of human capital will impact on the quality of research outputs and on extension advice. The Land Policy reforms in Sudan will have far reaching effects in increasing access to natural resources by the most disadvantaged, reducing Sub-regional and regional conflicts over resource access and use, and in increasing crop and livestock productivity. These will further re-enforce Sub-regional economic growth and its attendant multipliers.

4.1.3 Sub-basin and Regional Level

Benefits at this level reach across the political boundary and accrue to the Abbay-Blue Sub-basin and Eastern Nile Basin as a whole. Currently there is little trans-boundary trade between Ethiopia and Sudan but the expansion of economic development in the Sub-basin on both sides of the border, coupled with an extension of cross-border road-links, the potential for increasing integration of the Sub-regional economies of both countries becomes possible.

This is particularly so for the Ethiopian Northwestern and the Sudan Northwestern Sub-regions. This would be further facilitated with the construction of the proposed rail link between Sudan and Ethiopia as well as the expansion of cross-border power transmission. Increased access to Port

Sudan for western Ethiopia would have a positive impact in reducing transport costs for both imports and exports. The expanding industrial sector in Sudan could provide off-farm employment opportunities for both Sudanese and Ethiopian households and so providing financial capital for investment in agriculture, agricultural processing and small-scale service sector enterprises in the small urban centres.

There are clear linkages and synergies that can be developed here to initiatives being developed under the Joint Multi-purpose Programme, and to the Transboundary Trade in Power, Irrigation and Drainage and Flood Control and managment CRA's.

Closer cooperation in crop early warning systems, establishing joint strategic grain reserves and purchase of grains for food relief either side of the border would enable faster responses to local food shortages to the mutual benefit of both countries. Increased food security on both sides of the border will contribute to overall food security for the region.

The quantifiable benefits to reduced erosion in the Ethiopian Highlands and sediment loads in the Abbay-Blue Nile river system on reducing costs within Sudan of dredging of power intakes and irrigation canals, loss of power generating potential due to the need for reservoir flushing are relatively small in comparison to the national benefits. Nevertheless, they will also contribute to a reduction in costs that it has not been possible to quantify: of pump and turbine damage and the removal of sediment for domestic and industrial water supplies. The reduced sediment loads in the Rahad and Dinder Rivers should reduce the siltation of the maya'a wetlands in Sudan and thus reduce the incidence and extent of flooding and the damage this causes to crop production. They will also contribute to a reduction in the sedimentation of the Meroe Dam and to an increase in its economic life. A reduction of Abbay-Blue Nile sediment load will also contribute to a reduction in the rate of loss of live storage in Lake Nasser/Nubia and the loss of potential irrigation water and power generation for Egypt.

Support to the establishment of the Dinder-Alatish Transboundary Park will facilitate the increased effectiveness of biodiversity conservation of this important area of fauna and flora. It will also increase the potential for eco-tourism and increased employment opportunities for people in and around the Park. It will also provide a tangible example of the benefits of trans-boundary cooperation between Sudan and Ethiopia. A similar example of trans-boundary cooperation is the proposed intervention to develop a plan for the sustainable management and development of the Rahad-Dinder Wetlands. This will require a cross-border study and the development of a catchment management plan. It also has clear linkages with the establishment of the Transboundary Park as much of the information on hydro-ecology will contribute to an effective Park management plan.

4.1.4 Global Level

The global benefits identified in the analysis relate to the increased amount of carbon sequestered in wood biomass, herbaceous biomass and soil carbon. In some cases it has been possible to quantify these and the results are provided below. In other cases such as improved pasture development in the Butana Plains this has not been possible because of the uncertainties in quantifying the amount of increased pasture that will result. Nevertheless, small-scale experiments have clearly demonstrated that increased herbaceous biomass will substantially increase the amount of carbon sequestered in the soil and that there is considerable untapped potential for increased carbon sequestration under improved pastures (FAO, 2003). This is notwithstanding that the increased herbaceous matter will be consumed by livestock – the carbon is stored in the soil. The small scale example of improved rangeland management supported by the GEF in Bara Province of North Kordofan described in chapter 8 indicates how this may be implemented at the local level.

Other global benefits accruing to the programme of interventions relate to the conservation of biodiversity. At the local level this is represented in the increase in native plant species in enclosed areas that have all but disappeared in the open access communal areas. Such an increase in species diversity will also be seen in the improved management of the pastures of the Butana Plains. Substantial conservation of genetic, species and habitat diversity will accrue to the supporting interventions to the Dinder and Alatish Parks and to the development of the management plan for the Dinder-Rahad Wetlands. The proximity of the Park to the desert and semi-desert makes it an important buffer zone for the vegetation cover of central Africa in addition to its significance in providing genetic material for the rehabilitation in the semi-arid and arid areas (ArabMAB (2006).

This area represents one of the last intact areas of the transition ecotone between two floristic regions: the Ethiopian High Plateau and the arid Saharan-Sudanian biomes. It also lies along the boundary of two major faunal Realms of the world: the Palearctic and the Ethiopian. It is also located along a major north-south flyway of migratory birds. The area is thus of considerable international importance in terms of biodiversity and has already attracted support from international and national conservation NGO's indicating that it has considerable environmental-economic value.

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. Thus, the interventions targeted at the traditional and the commercial farming sectors in Ethiopia and Sudan will generate these benefits.

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.

In Sudan a large number of natural selections of sorghum and millet have over millennia accrued a gene pool of considerable importance. In addition, the cultivation of *Acacia seyal* for its gum has also through centuries of natural selection accrued an important gene pool for this species.

The proposed interventions to support traditional agriculture will enable farm households to be buffered from natural shocks and allow them to maintain these important gene pools. The value of the Ethiopian coffee gene pool in terms of disease resistance, low caffeine content and improved production is outlined below.

4.2 Costs of Continued Natural Resource Management Practices: Ethiopia

It is emphasized again that the physical impacts and costs outlined below do not reveal to full extent of the social and economic costs to the rural (and urban) population in terms of those key elements in the downward spiral of poverty and a degrading resource base such as poor nutrition and health, poor access to social services (health and education) and restricted access to alternative livelihood strategies.

4.2.1 Agricultural production forgone

Agricultural production forgone is caused by soil erosion, dung/crop residue burning and crop removal through:

(i) Reduced moisture-holding capacity and nutrient loss from soil erosion.
(ii) Nutrient breaches due to the burning of dung and crop residues and grain removal.

The methodologies used to estimate soil loss rates on crop and non-crop land and nutrient breaches have been set out in the Transboundary Reports and are detailed in Annex 1 to this Report.

The total amount of soil eroded each year in the Abbay Sub-basin is estimated at 302.8 million tons of which 101.8 million tons is from cultivated land and 201 million tons is from mainly communal grazing and settlement areas. The area of cultivated land whose use is considered to be unsustainable[5] is estimated at 2.86 million ha (table 2).

Table 2. Affected Area Cropland (ha) Due to Soil Erosion in the Abbay Sub-basin by Percentage Annual Crop Yield Decline Class

REGION	Percent annual yield decline					Total affected area
	0.2%	0.4%	0.8%	1.4%	4.8%	
	ha	ha	ha	ha	ha	ha
Amhara	430,535	442,872	326,595	123,915	75,510	1,399,427
Beneshangul-Gumuz	31,962	52,716	29,357	8,775	13,178	135,988
Oromiya	367,030	498,675	300,935	102,386	54,923	1,323,950
Sub-basin	**829,527**	**994,263**	**656,887**	**235,076**	**143,611**	**2,859,364**

The impact on crop production due to the decline in soil-moisture holding capacity caused by soil erosion is the loss of 9,454 tons/yr. Each year this loss accumulates so that the loss of crop production in 25 years is 236,348 tons/yr. Soil erosion also causes a nutrient loss that decreases crop production annually and non-cumulatively by 31,126 tons/yr. Crop production lost as a proportion of total annual crop product is 1 percent in year 1 rising to 8 percent in year 25.

The breaches in soil nutrient cycling caused by dung/crop residue burning and crop removal reduce crop production annually and non-cumulatively by 159,270 tons and 586,688 tons respectively. The total crop production forgone is shown in Table 3 but it's important to note that soil nutrient loss prediction is based on limited data (Barber, 1985).

Table 3. Annual Crop Production Forgone Due to Soil Erosion, Dung/Crop Residue Burning and Crop Removal in Abbay Sub-basin (tons/yr)

Cause	Annual Crop Production Forgone (tons)		
	Year		
	1	10	25
Loss in soil moisture-holding capacity due to soil erosion	12,551	125,510	313,784
Nutrient loss due to soil erosion	36,785	36,785	36,785
Total due to soil erosion	**49,336**	**162,295**	**350,569**
Nutrient breach due to dung/crop residue burning for fuel	159,270	159,270	159,270
Nutrient breach due to crop removal	586,688	586,688	586,688
Total due to nutrient breach	**745,958**	**745,958**	**745,958**

Using the local price (ETB 1,880/ton) for wheat enables a monetary estimate to be made of these losses. Annual losses due to soil erosion are ETB 92.8 million/yr rising to ETB 659.1 million in 25 yrs or US$ 11.9 million rising to US$ 84.4 million.

Annual losses due to nutrient breaches are estimated at ETB 1,402 million or US$ 179.6 million.

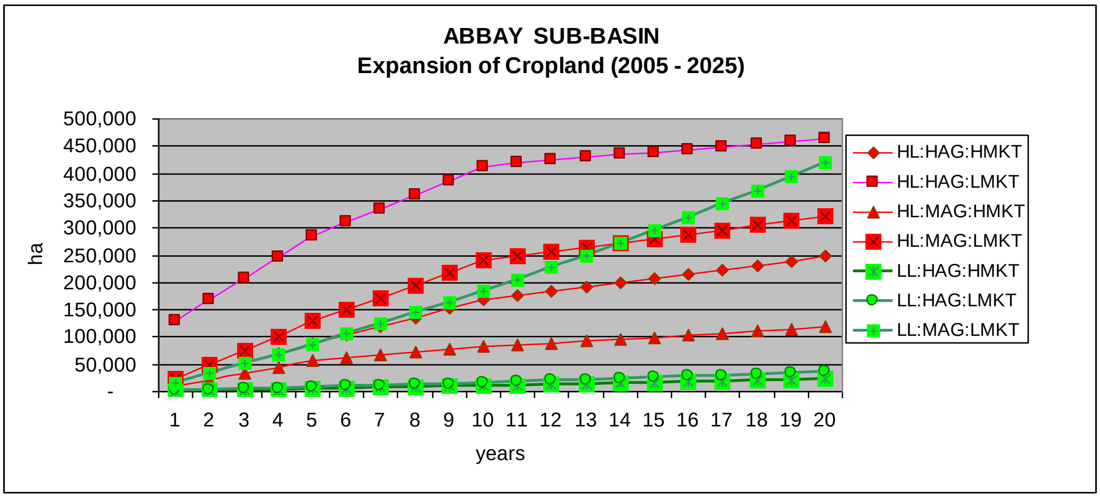
[5] Where the rate of soil loss exceeds that of soil formation of 9 t/ha per year.

4.2.2 Future Trends in Soil Erosion without WSM Programme

The background and methodology to determine future trends in soil erosion caused by expansion of agriculture due to population increase were outlined in the Transboundary Abbay-Blue Nile Sub-basin Report. The results of the analysis are shown in Chart form below for the Sub-basin.

In the Abbay Sub-basin the main expansion of cropland will take place in the two Highland domains with High Agricultural Potential and Poor market access and in the domain with Medium Agricultural Potential and Poor market access (figure 3). One Lowland Domain will also see a considerable expansion in cropland: the domain with Medium Agricultural Potential and poor market access. After ten years all Highland domains see a decline in the rate of expansion as weredas reached their population support capacities. The total expansion of cropland within the Sub-basin by the year 2025 is estimated to be 1.63 million ha or approximately 22 percent of the current area. Because inter-Regional resettlement is currently not permitted the potential for cropland expansion in the Lowlands (mainly Beneshangul-Gumuz regional State) is not realized.

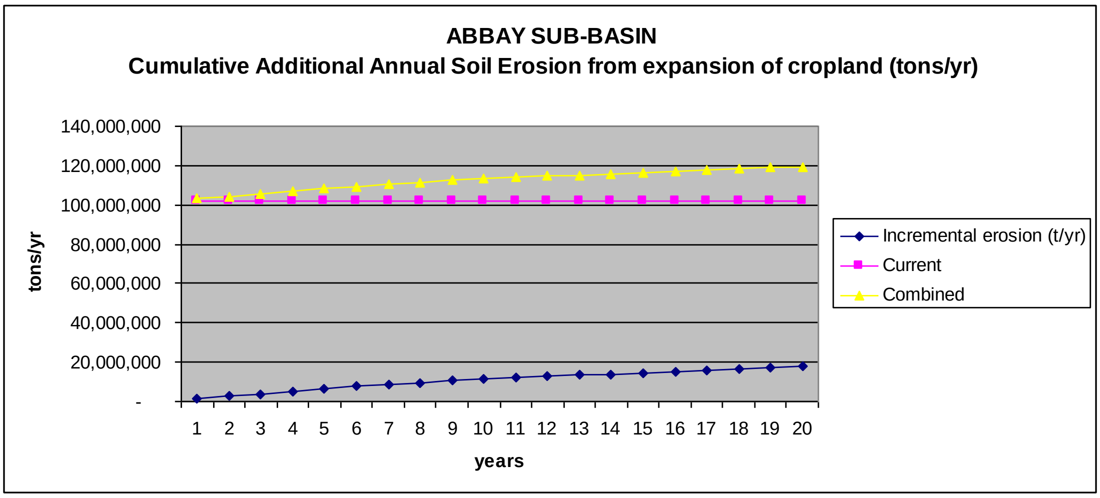
Figure 3. Abbay Sub-basin: Expansion of Cropland by Development Domain 2005 – 2025 (ha)



HL = Highland; LL= Lowland; HAH = High agricultural potential; MAG – Medium agricultural potential; HMKT + Good market access; LMKT = Poor market access.

The additional annual soil erosion by the year 2025 occasioned by the expansion of cropland is estimated to be 17.7 million tons or an increase of 17.4 percent of the current annual loss (figure 4).

Figure 4. Incremental annual soil erosion (tons/yr) from the expansion of cropland (2005 – 2025.)



Using the estimated Sub-basin wide sediment delivery ratio of 39 percent[6] this would indicate an additional 7 million tons/yr of suspended sediment at the border – a 7 percent increase on current rates.

4.2.3 Reservoir and irrigation system sedimentation: Ethiopia

With respect to water harvesting King and Leul Kasahay (2005) highlight the problem of excessive sediment due to the lack of integration of water harvesting with watershed management. In Amhara and Tigray Regions some 70,000 ponds and tanks were constructed in one year alone (Alemayehu Tafessa, 2005). In addition to siltation, excessive seepage is another key problem. It is often difficult to separate the problems of seepage, poor design and construction and sedimentation as in many cases it is a combination two or more of these.

At a larger scale, small dams for water supplies and irrigation have constituted a significant programme in the Abbay Sub-basin. Some 44 dams and diversion schemes have been constructed in Amhara and some 30 in Oromiya Region. An Interim Evaluation of the IFAD Special Country Programme Phase II (IFAD, 2005) which focused on small-scale irrigation schemes (mainly run-of-river diversion schemes) found that the soil conservation component of the project had not been undertaken in many schemes and that soil erosion was "threatening" the viability of a number of these. However, no quantitative data could be found on the physical or economic impacts of land degradation on small dams and irrigation schemes in the Abbay Sub-basin.

[6] Calculated in the Transboundary reports.

An *ex-post* evaluation of water-harvesting schemes in Tigray found that construction cost estimates for water harvesting ponds were "incomplete and inadequately monitored" (Irish Aid, 2004). It also found that estimates in the field guide manual were "unclear, incomplete and generally unsubstantiated". The Evaluation Report estimated the cost of PVC lining for each pond at ETB 1,516. Average costs of excavation were ETB 5,672 (unlined) to ETB 6,704 (clay lined with stone paving). Full costs were estimated to be from ETB 7,148 to ETB 8,220. Average pond capacity is 190 m^3 giving an average pond cost of between ETB 38/m^3 stored to ETB 43/ m^3 stored.

Approximately 700 m^2 can be irrigated from one pond with one filling. No estimates are available from the Evaluation Report for maintenance costs (cleaning silt traps, cleaning ponds). Negussie Haregeweyne et al., 2005 have estimated that (hand) dredging costs in Tigray are approximately ETB 40/m^3 of sediment. Assuming that an estimated 5 percent of pond capacity is lost to sedimentation annually this would give an estimate annual cleaning cost of ETB 380/yr.

Using cost and price data from Wagnew Ayalney (2004) for small-scale irrigation of onions in the Awash Valley the following plot (190 m2) budget estimate can be made (table 4). Market price of onions is the 2004 average for the Amhara Region (ETB 1.70/kg). However, it is important to note that an IFAD Evaluation Report on the IFAD supported Small Irrigation Project found that on many schemes prices received by farmers from iterant traders were often considerably less than the local market price.

Table 4. Estimated Gross margin: Plot (190 m2) Onions: 2 Crops/yr

Item	Cost	Benefit
Annualized cost of construction (i)	758	
Annual Input (incl. labour) costs	156	
Annual cleaning costs (5% siltation)	380	
Sub-total Costs	**1,294**	
Annual revenue (2 crops onions(ii) (iii)		**2,618**
Gross margin		**1,324**

(i) Using capital recovery factor at 10% for 30 years (0.106079)
(ii) 1 m^3 = 4.05kgs onions (77kgs onion/season)
(iii) 770kgs/plot @ ETB1.70/kg

In practice construction is undertaken using food for work and thus is not a "cost" to the farmer. However, annual cleaning costs due to sedimentation are borne by the farmer and can be seen to comprise a substantial proportion of total costs. Annual sedimentation (5% of live storage) losses amount to 29 percent (ETB 380/yr) of total costs.

An alternative method to estimate the cost of sedimentation is to use the irrigation water lost through loss of live storage capacity and equate that to crop production forgone (in the same way as estimating losses due to seepage). In this case some 9.5 m^3 are lost annually. This could produce 38 kgs of onions per crop or 77 kgs/yr. This is valued at ETB 312/yr. However, in the absence of cleaning this accumulates each year: thus after 25 years the annual loss is ETB 7,791.

In the absence of data on sedimentation and seepage for all ponds within the Abbay Sub-basin it is not possible to provide a firm estimate of total costs of sedimentation and seepage. However, assuming that some 100,000 ponds have been constructed and that 10 percent are subject to 5 percent annual sedimentation rates and using the cost of cleaning then this amounts to ETB 3.2 million /yr (US$ 0.35 million/yr).

Other potential costs are the increase in the incidence and prevalence of malaria and bilharzia in terms of medicine purchased by sufferers or the costs of prevention (impregnated nets, moluscicides).

"Benefits" of pond sedimentation relate to reductions in sediment loads downstream. Thus the annual retention of 9.5 m^3 of sediment in 10,000 ponds would reduce the sediment load in the Abbay-Blue Nile system by 100,940 tons/yr or 0.07 percent of the sediment load at the border with Sudan.

4.2.4 Deforestation and Degradation of Wood Biomass: Ethiopia

(i) Definitions

"**Deforestation"** is here defined (following Reitbergen, 1993) as:

> *The permanent conversion of "forest" to non forest land cover and land use.*

Trees cleared for agriculture involves a complete change in land cover from shrubland, woodland or forest to "non forest land" and an almost complete removal of wood in the area cleared. However, wood removed for fuel does not involve a complete and instant change in land cover. Shrubland, woodland or forest may remain as those land cover types for a number of years. Instead, there is a gradual erosion of wood stocks and "**degradation**" of land cover rather than "deforestation".

(ii) Deforestation

There has been no monitoring of land cover changes in response to the new resettlement and agricultural investment programmes. The WBISPP attempted to forecast future land cover changes resulting from natural population increase in Oromiya and BSG Regions, using 1990 and 2000 as the base years respectively[7]. Because of the ease of clearing, the land cover change model assumed that potentially arable land with shrubland would be

[7] Oromiya landcover was mapped using 1989 landsat imagery and BSG using 2000 imagery.

cleared first, followed by woodland and then forest (WBISPP, 2001, WBISPP, 2003).

The analysis was conducted at the wereda level using current population growth rates and crop, grazing and settlement land requirements of the existing farming systems. Full results are presented in the Transboundary Analysis – Ethiopia Country Report. By 2015 some 56 percent of forests, 61 percent of woodlands and 43 percent of shrublands will have been cleared for agriculture and settlement as a result of natural population increase. No account is taken of resettlement and migration, or of expansion of large-medium scale commercial agriculture. On average 6,300 ha of high forest and 76,300 ha of woodland are cleared annually. Using altitude the criteria (between 1,100 and 1900 masl) it is estimated that 5,200 ha of high forest that is ecologically suitable for wild coffee is cleared annually.

To obtain an estimation of the cost of deforestation in the Abbay Sub-basin three Direct Use and five Indirect Use values were estimated. Direct Use values included the sustainable supply of (i) timber, (ii) poles, and (iii) fuelwood. Indirect use values included (i) carbon sequestration and (ii) watershed services, (iii) potential pharmaceutical products, (iv) species and habitat biodiversity, and (v) wild coffee gene pool. The detailed methodologies and sources used are detailed in Annex 1.

A summary of values used is provided in table 5.

Table 5. Summary of Values used to Estimate Costs of Deforestation

Value	Unit	Unit Value (US$)
A. DIRECT USE COSTS		
Timber	m^3	35
Poles	m^3	5
Fuelwood	m^3	5
B. INDIRECT USE COSTS		
Carbon sequestration	ton Carbon	3
Watershed services	ha	42
Potential pharmaceutical products	ha	5
Species & habitat biodiversity	ha	5
Coffee gene pool	ha	280
D. BENEFITS		
- Agricultural production	ha	127
- 40% Watershed services retained	ha	16.80

See Annex 1 for sources.

It was assumed that clearing was for traditional agriculture. Thus to obtain the net value of forest lost the value of agricultural production replacing the forest was subtracted from the gross value of forest removed. In addition it was assumed that 40 percent of watershed services would continue to be provided by land under crop production (e.g. reduced evapotranspiration from trees and increased water yield; continued use of traditional soil conservation measures and reduced erosion and sedimentation).

In practice the annual rates of woodland and forest removal vary slightly due to different deforestation rates at the wereda level. The results presented below (table 6) are the average annual values. It is important to note that these costs are cumulative.

Table 6. Estimated costs of deforestation of (a) High Forest and (b) Woodland in the Abbay Sub-basin (US$/yr)

a. High Forest

VALUE	Unit	Amount	Cost (ETB million/yr)	Cost (US $ million/yr)
A. DIRECT USE				
Timber	m^3	251,900	79.35	8.82
Poles	m^3	62,980	2.83	0.31
Fuelwood	m^3	251,900	11.34	1.26
Sub-total			**93.52**	**10.39**
B. INDIRECT USE				
Carbon sequestration	ton Carbon	188,930	5.10	0.57
Watershed services	ha	6,300	2.38	0.26
Potential pharmaceutical products	ha	6,300	0.28	0.03
Species & habitat biodiversity (High forest)	ha	6,300	0.28	0.03
Coffee gene pool	ha	5,200	13.11	1.46
Sub-total			**21.15**	**2.35**
Less value of Agricultural production	ha	6,300	7.21	0.80
Less value of continued watershed services	ha	6,300	0.06	0.01
Sub-total			**7.27**	**0.81**
TOTAL NET COST			**95.20**	**11.93**

b. Woodland

VALUE	Unit	Amount	Cost (ETB million/yr)	Cost (US $ million/yr)
A. DIRECT USE				
Timber	m^3	0	0	0
Poles	m^3	0.31	13.73	1.53
Fuelwood	m^3	1.14	51.51	5.72
Sub-total			**65.24**	**7.25**
B. INDIRECT USE				
Carbon sequestration	ton Carbon	0.46	12.36	1.37
Watershed services	ha	76,300	28.84	3.20
Potential pharmaceutical products	ha	76,300	3.43	0.38
Species & habitat biodiversity	ha	76,300	3.43	0.38
Coffee gene pool	ha	0	0	0
Sub-total			**48.06**	**5.33**
Less value of Agricultural production	ha	76,300	87.41	9.71
Less value of continued watershed services	ha	76,300	11.54	1.28
Sub-total			**98.94**	**10.99**
TOTAL NET COST			**2.36**	**1.29**

c. Total

VALUE	Unit	Amount	Cost (ETB million/yr)	Cost (US $ million/yr)
A. Direct use value			158.76	17.64
B. Indirect use Values			69.21	8.68
TOTAL GROSS COSTS			**227.97**	**25.32**
Less value of benefits			106.21	11.80
TOTAL NET COSTS			**121.75**	**13.52**

The total net costs of deforestation of high forest and woodland in the Abbay Sub-basin are ETB 121.8 million (US$ 13.6 million/yr), which rises to 3,044 million/yr (US$ 338.2 million/yr) in 25 years time.

(iii) Degradation of Woody Biomass

Degradation of forest, woodland and shrubland is caused by harvesting of wood (mainly for fuel) in excess of the natural yield and results in a reduction in woody biomass. These have been calculated by the WBISPP (WBISPP-MARD, 2001, 2003). In the Abbay Sub-basin an estimated 14 million tons of wood are unsustainably harvested as fuelwood and charcoal each year. This represents an annual accumulating loss of sequestered carbon of approximately 7 million tons valued at ETB 189 million/yr (US$ 21 million/yr). Other unquantifiable losses are of non-timber forest products (fruits, medicinal products, gums and resins, etc) and biodiversity.

4.2.5 Wetland Degradation in Abbay Sub-basin: Ethiopia

(i) Benefits

Wood (2001) distinguishes between benefits deriving from (i) "natural" wetlands and (ii) from "converted" wetlands. The benefits of the natural wetlands all into three categories as follows:

a. Ecological benefits (Environmental Services):

- recharge of groundwater and maintenance of spring flow,
- moderation of stream flow and buffering flood peaks,
- maintaining dry season flows,
- water storage throughout out year,
- purification of water (through reed beds),
- filtration and sediment trapping.

b. Socio-economic Benefits from Environmental Services

- maintenance of domestic water supply,
- maintenance of water for hydro-power generation in dry season,

- reduced health problems from purification of drinking water,
- reduced sedimentation of dams and reservoirs.

c. Socio-economic Benefits from Wetland Products
- water for clothes washing,
- livestock watering,
- reeds: thatching, handicrafts, floor covering,
- medicinal plants,
- livestock forage,
- Food supply: fish

When converted to agriculture there are a number of additional benefits and also the loss of some environmental services and supply of wetland products. Thus, conversion involves a set of trade-offs between additional benefits and lost services and products. Additional benefits include:

- crop production: either early harvest In "hungry season") or 2nd crop,
- enable cultivation of cash crops (e.g. vegetables, sugar cane),
- forage production in wet season (upland fields are under crops).

(ii) Costs of Wetland Conversion

Conversion of wetlands for agriculture can involve one or more costs in terms of loss of environmental services and products. These can include:

- spring water supplies,
- clean water,
- flood buffering,
- sediment trapping,
- thatching reeds,
- palm products,
- medicinal plants,
- dry season grazing.

Experience in Ethiopia indicates that there is an optimum degree of drainage that will ensure an optimum level of agricultural production. Over-drainage[8] has in a number of cases damaged the wetland beyond recovery for agriculture as well as loosing many of the environmental services and products. Secondly, it has been found necessary to rest the wetland for one or more years to allow recovery of nutrients and soil organic matter.

[8] This is caused by constructing the central drainage channel too deep and lowering the water table below the rooting level of most plants.

(iii) Distribution of Benefits of Converted Wetland

Even where a wetland is optimally drained and sustainably managed the distribution of benefits is not necessarily equitable. Some people gain whilst others loose. People who gain benefits of conversion include those households with sufficient livelihood capital assets (labour, capital) to enable them to cultivate the wetland (Solomon Mulegeta, 2004). Households with large livestock holdings will gain more than those households with few or no livestock.

Large sections of the community will suffer losses if there are sever reductions in the availability of medicinal plants, thatching grass and domestic water supplies. Women in particular will be disadvantaged if springs dry up and they are required to travel greater distances for water. Downstream users may be adversely affected by increased levels of flooding, high sediment loads in streams and poor water quality and the loss of dry season flows,

The optimum conversion of a wetland seeks to provide the greatest number of socio-economic benefits from environmental services and products as well agricultural benefits to the greatest number of households in a sustainable manner. A conversion that focuses narrowly on crop production and grazing benefits only those households that command the largest livelihood capital resources (natural, human, financial and social).

An optimum solution (in terms of an equitable distribution of benefits) is that a portion of the wetland is not converted to agriculture but left under natural vegetation to ensure a sustainable supply of thatching materials. Additionally, certain plants of medicinal importance are also left in areas that are not converted. Leaving such areas under natural vegetation at intervals along the wetland helps to maintain many of the environmental services (e.g. filtration, sediment trapping, flood buffering). Rotation of cultivated fields with reed grasses enables full recovery of nutrients and organic matter.

Community wetland management institutions determine land allocation for cropping, frequency and length of fallow periods, grazing access, collection of medicinal plants and thatching material. Such institutional measures are necessary to ensure optimum management of the wetland and the sustainable supply of services and products.

(iv) Valuation of Costs and benefits of Wetland Conversion

Except for a small area around Metu in southwestern Ethiopia, no surveys have been undertaken in Ethiopia of the extent of the highland wetlands, their degree of conversion and the status of their environmental services and products (i.e. a comparison between unconverted and converted). Similarly, no detailed socio-economic surveys have been undertaken to determine in quantitative terms the various direct and indirect use values of wetland services and products.

Integrated hydro-ecological and socio-economic studies of individual wetlands are required to determine these values. Such studies would provide a basis for the environmentally and economically sustainable and socially equitable development and management of the Highland wetland systems in the Abbay and Baro-Akobo Basins.

4.2.6 Summary of Costs of Natural Resource Degradation in the Abbay-Blue Nile Sub-basin: Ethiopia

The various cost estimates of natural resource degradation in the Abbay-Blue Nile Sub-basin in Ethiopia are summarized in Table 7.

Table 7. Summary of Costs of Natural Resource Degradation in the Abbay-Blue Nile Sub-basin in Ethiopia.

Resource	Annual		25 years	
	ETB Million	**US$ million**	**ETB million**	**US$ million**
ETHIOPIA				
1. Soil Erosion/degradation				
- Erosion	92.8	11.9	659.1	84.4
- Nutrient breaches	1,402.0	179.6	1,402.0	179.6
2. Sedimentation (ponds)	3.2	0.4	3.2	0.4
3. Deforestation/degradation				
- Deforestation	228.0	25.3	3,044.0	338.2
- Degradation Wood Biomass	279.0	31.0	6,975.0	775.0
4. Wetland Conversion	n.d.	n.d.	n.d	n.d.
TOTAL GROSS COSTS	**2,005.0**	**248.2**	**9,083.3**	**1,377.6**
Value of Crop production: (deforestation)	**106.2**	**11.9**	**2,655.0**	**297.5**
TOTAL NET COSTS	**1,898.8**	**237.3**	**6,428.3**	**1,080.1**

n.d. = no data available

A comparison between degradation costs from soil erosion and soil nutrient breaches is not strictly comparable as the first are cumulative and the second are annual. Taken together after 25 years soil degradation accounts for 41 percent of costs and deforestation and degradation of wood biomass some 59 percent. Sedimentation costs and benefits constitute a very small proportion of the total. Regretfully, it has not been possible to quantify or value wetland conversion.

These costs have local/national, Regional (East Nile Basin) and Global implications. Table 8 provides a distribution of these costs into local/national, Regional and Global. Some 80 percent of the costs have local/national implications, 2 percent Regional and 16 percent global. An important though non-quantified Regional cost is wetland degradation and thus the 2 percent presented here is underestimated.

Table 8. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Abbay-Blue Nile Sub-basin in Ethiopia.

Resource	Annual			25 years	
	ETB million	US$ million	%	ETB million	US$ million
NATIONAL					
Soil Erosion	92.8	11.9		659.1	84.4
Nutrient breaches	1,402.0	179.6		1,402.0	179.6
Timber Value forgone	79.4	8.8		1,983.8	220.5
Pole Value forgone	16.6	1.8		414.0	46.0
Fuelwood Value forgone	62.9	7.0		1,571.3	174.5
Sedimentation (ponds)	3.2	0.4		3.2	0.4
Wetland Conversion	n.d.	n.d.		n.d.	n.d.
Sub-total	**1,656.8**	**209.5**	**84.0%**	**6,033.3**	**705.4**
REGIONAL					
Watershed Services (60%)	11.0	1.1		274.3	27.9
Wetland Conversion	n.d.	n.d.		n.d.	n.d.
Sub-total	**11.0**	**1.1**	**0.6%**	**274.3**	**27.9**
GLOBAL					
Carbon Sequestration : Deforrestation	17.5	1.9		436.5	48.5
Carbon Sequestration : Degradation	279.0	31.0		6,975.0	775.0
Pharmaceutical Value forgone	3.7	0.4		92.8	10.3
Coffee gene pool value forgone	3.7	0.4		92.8	10.3
Habitat/species Biodiveristy value forgone	0.9	1.5		22.8	36.5
Sub-total	**304.8**	**35.2**	**15.5%**	**7,619.8**	**880.5**
TOTAL GROSS COST	**1,972.5**	**245.9**		**13,927.4**	**1,613.8**
Less Crop production	**94.6**	**10.5**		**2,365.5**	**262.8**
TOTAL NET COST	**1,877.9**	**235.4**		**11,561.9**	**1,351.0**

4.3 Impacts, Costs and Benefits of the Direct Interventions: Ethiopia

4.3.1 Soil Conservation and Improved Soil Husbandry

(i) Reduced Soil Erosion on and Sedimentation from Cropland

(a) Grass Strips and Soil Bunds

There is currently a programme of watershed management interventions being undertaken in the Ethiopian Highlands of the Abbay Sub-basin. The structures are mainly soil bunds although more recently grass trips are being adopted.

In the higher rainfall areas of the west the up-take of soil conservation structures has been much slower. It is now recognized that vegetative measures such as grass strips are more likely to be adopted in these areas (GTZ, 2005). These have been shown to almost as effective as physical structures in Anjeni, Gojam (Herweg & Ludi, 1999). Similar findings have been found Central America and the Caribbean (Lutz et al., 1994). As with any

SWC structure (physical and biological) they must be protected from livestock. GTZ report that if this is done during the year of establishment the grass strips can withstand trampling by livestock thereafter.

(b) Adoption Rates

It has been assumed that 39 percent of the cropland can be treated over a 10 years period. The basis for this estimate is data extracted from the CSA Agricultural Census (2003) on the numbers of farmers adopting bunds on their cropland. For the Abbay Sub-basin this was 19 percent of all farmers. It was assumed that adoption had taken place over a ten year period and that this would continue for the next ten years. It is possible that with the rapid build-up of D.A.s in the field that this rate could be exceeded. The 19 percent estimate is thus conservative.

Because the labour requirements for biological measures are less than 10 percent of that required for soil bunds it was assumed that 20 percent of cropland with soil loss rates of less than 50 tons/ha could be treated with biological measures.

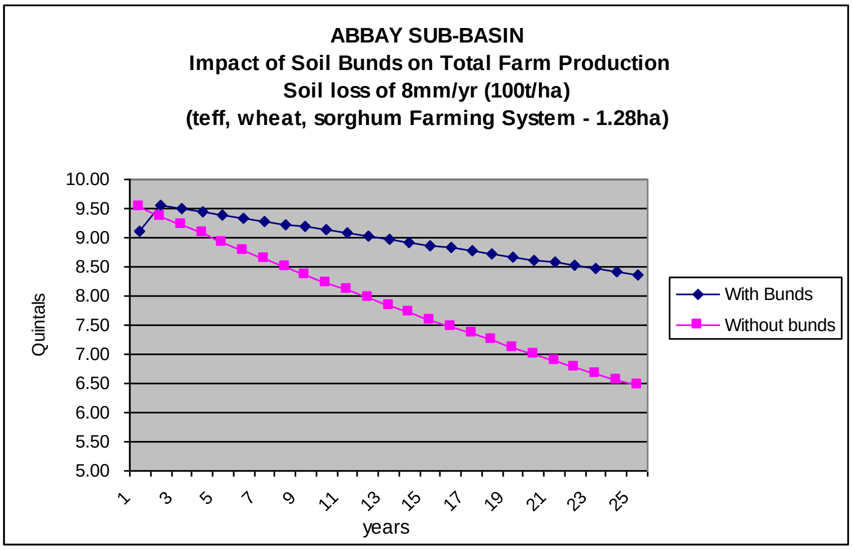
(ii) Reducing Declining Agricultural Production on Cropland

(a) Farm Level

The without and with SWC measures decline in total farm production for the teff-wheat-sorghum farming system in the western Abbay Sub-basin for a soil losing 8 mm of soil per year (100 tons/ha) are shown in figure 5. The without-bund annual production decline due to loss of soil moisture holding capacity is 1.6 percent and the with-bund annual yield decline is 0.57 percent. There is also an increase in yield from retained soil nutrients of 0.28Q/ha. Note also the initial drop in production due to the loss of land for crops taken up by the grass strips or bunds.

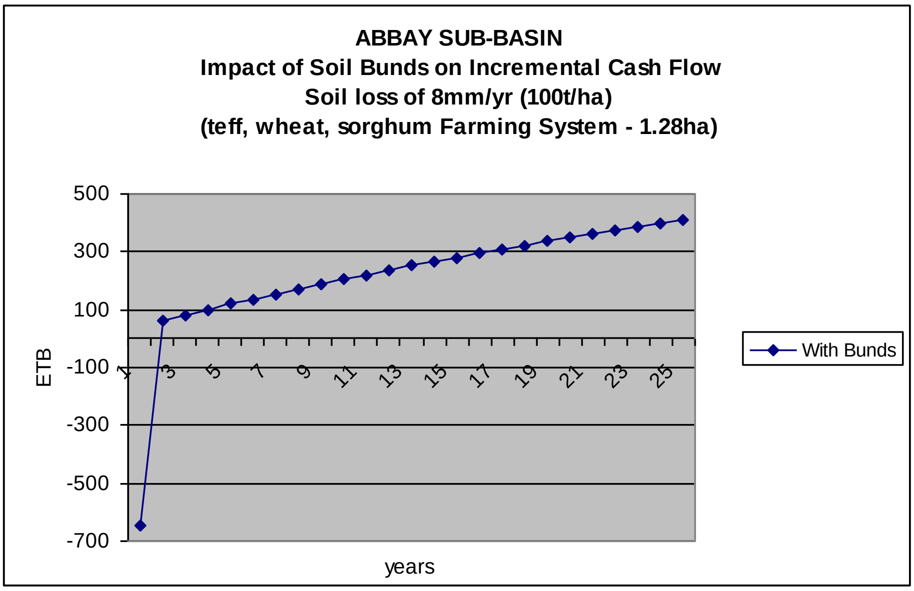
On a 1.28 ha farm losing 8 mm of soil/yr the net changes in farm production (excluding weight of grass on strips and bunds) in year 2 are 19 kgs per year. The accumulated yield changes at the end of 25 years are 241 kgs per yr (figure 6). Whilst significant in the longer term it can be seen that these are relatively small in the short term.

Figure 5. Changes in Farm production without and with soil bunds (25 years)



The net incremental value of farm production is ETB-647 in the year 1, which is a reflection of the costs of family labour (123 days at ETB 5/day) in constructing the bunds. However, from year 2 this changes to ETB +220 rising to ETB +487 by year 20. Although the internal rate of return (over 20 years) is 17%, the pay-back period for ETB -647 is 6 years.

Figure 6. Impact of Soil bunds on Incremental Cash Flow: Soil Loss Rate of 8 mm/yr (100t/ha/yr) for Teff-Wheat-Sorghum farming System: Western Abbay Sub-basin



In the Abbay Sub-basin 5 farming Systems for which crop area and yield data were available (WBISPP, 2001, WBISPP, 2003) were analyzed to determine the impact on farm income, pay back period on investment costs, the financial internal rate of return (IRR) and the discounted B:C ratio over 25 years at 20 and 10 percent discount rates. The results are presented in Table 9a for grass strips and 9b for soil bunds.

Table 9. Impact of Grass strips and Soil Bunds: Incremental farm income, Payback-back period (years), IRR (%) and B:C ratio at 20% and 10% discount rates: Abbay Sub-basin

(a) Grass Strips

Farming System	Incremental Annual; Farm income year 1 (ETB)	Incremental Annual Farm income year 25 (ETB/yr)	Payback period (yrs)	IRR (%)	B:C ratio (20% discount rate)	B:C ratio (10% discount rate))
3. Wheat, Barley	-174	+199	5	35%	0.6	4
4. Teff, wheat, sorghum	-30	+236	1	196%	7.0	17
5. Teff, Maize, Sorghum	-125	+269	3	42%	5.0	19
6. Maize, teff, sorghum	-128	+295	4	40%	3.3	8
7. Enset, maize, teff	-67	+309	1	82%	6.0	12

(b) Soil bunds

Farming System	Incremental Annual; Farm income year 1 (ETB)	Incremental Annual Farm income year 25 (ETB/yr)	Payback period (yrs)	IRR (%)	B:C ratio (20% discount rate)	B:C ratio (10% discount rate))
3. Wheat, Barley	-534	+373	6	24%	1.0	2.8
4. Teff, wheat, sorghum	-647	+409	6	21%	1.1	2.7
5. Teff, Maize, Sorghum	-966	+438	12	12%	0.5	1.2
6. Maize, teff, sorghum	-991	+519	10	14%	0.5	1.3
7. Enset, maize, teff	-630	+357	6	20%	1.0	1.9

There is a clear advantage of grass strips over soil bunds because of their extremely low labour costs for construction and maintenance and because they take up less area. The initial investment and the payback period for grass strips are significantly less than soil bunds. With both structures however there is need for farmer support to undertake the initial investment in bund construction. Using the higher discount rate substantially reduces the B:C ratio and explains why resource poor farmers with high discounbt rates are reluctant to adopt SWC measures.

Current measures such as food or cash for work being instituted under the Food Security and the Safety Net Programmes should be extended areas beyond the "food deficit" areas.

(b) Sub-basin Level: National

Across the Sub-basin the cumulative increase in crop production is shown in table 10 assuming that 40 percent of land that requires conservation measures is covered.

Table 10. Abbay-Blue Nile Sub-basin: Cumulative Increase in Grain production due SWC Measures (tons)

1 year	10 years	**25 years**
7,353	73,529	183,823

To examine the Direct Intervention SWC programme (Grass strips and Soil Bunds) on its own, the benefit-cost analysis was undertaken over 50 years to take account of the 10 years of investments and using the Government discount rate for public investments of 10 percent. The results at the farming System level were aggregated to the Development Domain. The results are shown in table 11.

Table 11. Financial Benefit-cost Analysis of the Proposed SWC Programme on Cropland for Grass Strips and Soil Bunds in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%: Results by Development Domain.

Financial Costs and Benefits of WSM Interventions by Development Domain in Abay Sub-Basin
40% ADOPTION RATE

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:HMKT	739,166	815,786	2,924,991	3,106,931	76,620	181,940	2.4
HL:HAG:LMKT	1,163,070	1,277,377	4,406,368	4,688,187	114,308	281,819	2.5
HL:MAG:HMKT	849,337	899,490	2,267,742	2,433,897	50,153	166,154	3.3
HL:MAG:LMKT	3,608,232	3,807,220	9,519,189	10,239,552	198,988	720,362	3.6
total	**6,359,804**	**6,799,873**	**19,118,291**	**20,468,566**	**440,069**	**1,350,275**	**3.1**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:HMKT	85.5	94.3	338.1	359.2	8.9	21.0	2.4
HL:HAG:LMKT	134.5	147.7	509.4	542.0	13.2	32.6	2.5
HL:MAG:HMKT	98.2	104.0	262.2	281.4	5.8	19.2	3.3
HL:MAG:LMKT	417.1	440.1	1,100.5	1,183.8	23.0	83.3	3.6
total	**735.2**	**786.1**	**2,210.2**	**2,366.3**	**50.9**	**156.1**	**3.1**

all costs and benefits are PVs over 50 years at 10% discount rate

Overall there is a benefit-cost ratio of 3.1. There is little difference in the B:C ratios between the Development Domains. When examined separately, grass strips and soil bunds exhibit the significant difference seen in the farm level analysis. These are shown in Table 12a and 12b.

Table12. Financial Benefit-cost Analysis of the Proposed SWC Programme on Cropland for Grass Strips and Soil Bunds in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%: Results by Development Domain.

(a) Grass Strips

Financial Costs and Benefits of WSM Interventions by Development Domain in Abay Sub-Basin
40% ADOPTION RATE
Grass strips

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:HMKT	514,855	517,782	1,515,035	1,575,934	2,927	60,899	21
HL:HAG:LMKT	784,431	789,572	2,282,329	2,377,546	5,141	95,217	19
HL:MAG:HMKT	485,183	487,891	1,183,406	1,241,075	2,708	57,669	21
HL:MAG:LMKT	1,982,863	1,997,197	4,955,144	5,207,286	14,334	252,143	18
total	**3,767,332**	**3,792,442**	**9,935,914**	**10,401,842**	**25,110**	**465,928**	**19**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:HMKT	59.5	59.9	175.1	182.2	0.3	7.0	21
HL:HAG:LMKT	90.7	91.3	263.9	274.9	0.6	11.0	19
HL:MAG:HMKT	56.1	56.4	136.8	143.5	0.3	6.7	21
HL:MAG:LMKT	229.2	230.9	572.8	602.0	1.7	29.1	18
total	**435.5**	**438.4**	**1,148.7**	**1,202.5**	**2.9**	**53.9**	**19**

(b) Soil Bunds

Financial Costs and Benefits of WSM Interventions by Development Domain in Abay Sub-Basin
40% ADOPTION RATE
Soil Bund

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:HMKT	224,311	298,004	1,409,956	1,530,997	73,693	121,041	1.6
HL:HAG:LMKT	378,638	487,805	2,124,039	2,310,641	109,167	186,602	1.7
HL:MAG:HMKT	364,154	411,599	1,084,337	1,192,821	47,445	108,485	2.3
HL:MAG:LMKT	1,625,369	1,810,023	4,564,045	5,032,265	184,654	468,220	2.5
total	**2,592,472**	**3,007,430**	**9,182,377**	**10,066,724**	**414,958**	**884,348**	**2.1**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:HMKT	25.93	34.45	163.00	176.99	8.52	13.99	1.6
HL:HAG:LMKT	43.77	56.39	245.55	267.13	12.62	21.57	1.7
HL:MAG:HMKT	42.10	47.58	125.36	137.90	5.48	12.54	2.3
HL:MAG:LMKT	187.90	209.25	527.64	581.76	21.35	54.13	2.5
total	**299.71**	**347.68**	**1,061.55**	**1,163.78**	**47.97**	**102.24**	**2.1**

(c) Sub-basin Level: Regional Level

With the assumptions outlined above soil movement on cropland could be reduced from 101.8 million to 75.3 million tons. Using the sediment delivery ratio of 39 percent calculated in the Transboundary reports then annual sediment to Abbay river system from cropland within Ethiopia could be reduced by 12.4 million tons (down from 43.8 million tons to 34.4 million t/yr). This contributes to the overall reduction in suspended sediment loads in the Abbay-Blue Nile River system. The Regional impacts (in Sudan and Egypt are considered in sections 4.3.4 (Sudan) and 7.3.1 (Egypt).

(d) Global Benefits

Soil carbon (SC) comprises the largest carbon pool of the terrestrial carbon cycle: three times more than vegetation and twice as much as the atmostsphere (FAO, 2004). Eroded soil contains 1.2 times more SC than is present in the soil being eroded. Soil carbon that is eroded very quickly becomes oxidized and is lost as CO_2 (FAO, 2004). Barber (1985) estimated the average SC content of Highland soils as 46 tons per ha. Using the same methodology to estimate the loss of nitrogen and a retention rate of 40 percent indicate that some 1.15 million tons of SC is being retained behind the structures that otherwise would be lost. Using US$ 3.00 per ton of carbon means that the value of carbon remaining sequestered is ETB 31.2 million/yr (US$ 3.47 million//yr). As this accumulates in 25 years the value of sequestered carbon is ETB 790.0 million/yr (US$ 86.8 million/yr).

(iii) Gully reclamation and stream bank protection

(a) Gully Reclamation

The proportion of stream sediment originating from gullies, as distinct from cropland and non-cropland is not known but based on research elsewhere it is estimated at 20 percent[9] of the total loss on cropland and non-cropland. Research in Tigray (Nyssen et al., 2005a) estimated long-term soil losses from gullies at approximately 5 to 6 tons/ha/yr, although many gullies are discontinuous and sediment is often deposited in a debris fan at the foot of the slope.

Three related approaches are used to stabilize and reclaim gullies: (i) soil conservation measures above the gulley (bunds, cut-off drains), and (ii) physical and biological structures (check dams) within the gully itself, and (iii) livestock exclusion (GTZ, 2005, MARD, 2005). Given the lack of data on the total distribution, length and slope of gullies in the Sub-basin it is not possible to place a cost of reclamation. It is estimated that reclaimed gullies can retain 85 percent of sediment that was previous lost (Nyssen et al. 2005b). At the Sub-basin level the sediment delivery ratio is estimated to be 43 percent (Transboundary Abbay-Blue Nile Sub-basin Report).

In the analysis is has been assumed that 40 percent of the gullies on cropland and on non-cropland can be reclaimed over a 10 years period. It is estimated that at the end of the programme some 2.05 million tons/yr can be retained on non-cropland reducing the current contribution of 6.03 million tons to 3.98 million tons. On cropland sediment retention would amount to 1.04 million tons/yr, reducing the current contribution from 3.05 million tons/yr to 2.02

[9] The loess Plateau in China, which comprises hundreds of meters of extremely soft and erodible aeolian dust, and where gullies contribute the bulk of stream sediment is not comparable with Ethiopia.

millions tons/yr. This amounts to a 2.2 percent reduction in the current sediment load of the Abbay-Blue Nile River of 140 million tons/yr at the border.

(b) Stream bank Erosion

Research into dam siltation in Tigray (Negussie Haregeweyn et al., 2005) determined that 65 percent of siltation was due to river bank erosion above the dam. This clearly points to the need to ensure that river banks are protected above dams. This could be effected by area closure a short distance from the bank.

4.3.2 Crop Intensification and Diversification

(i) Reduced Cropland Soil Nutrient Breaches Grain Removal and Increased Agricultural Production from Fertilizer

(a) Farm Level

Assuming 20 kgs of N per 1 ton of grain and average grain yield of 700 kgs/ha means a loss of 14 kgs of N/ha/yr. To replace this would require 78 kgs of DAP.

The replacement of 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 on 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 higher in the climatic environment of the eastern part of the Abbay Sub-basin and is a constraint to investment in chemical fertilizer for rainfed cropping, but less so in the high rainfall areas of the western part of the Sub-basin. For example 10 percent of farmer use fertilizer in North Wello compared with 70 percent in East Gojam.

Fertilizer use not in combination of improved seeds provides a 64 percent increase in yields using the results of fertilizer trials (NCC, 1983)[10]. This compares with 114 percent increase when used in combination (Diao et al., 2005). The analysis was conducted using both interventions to allow a comparison between the two technologies. In the analysis it has been assumed that farmers would use a rate of 100 kgs/ha of DAP on either wheat, teff or maize depending on which was the dominant crop in terms of area in the farming system.

[10] The NCC used a quadratic function Y = (7.1) + (0.038N + 0.086P – 0.0004N2 – 0.00038P2 – 0.00063NP (Y yield in Q/ha: DAP 18%N & 46P)

The percentage area application rates are close to the current application rates. However, current area of cropland using improved seeds is approximately 3 percent. The results are shown in Table 13.

Table 13. Financial Benefit-cost Analysis of the Proposed Fertilizer and Improved Seed Intervention in the Abbay Sub-basin

Farming system	Crop fertilized	Area (ha)	% farm area	B:C fert. only	B:C fert+seed	Inc. income (ETB/ha) fert only	Inc income (ETB/ha) fert+seed
Wheat, Barley	Wheat	0.29	23%	3.5	4	208	386
Teff, wheat, sorghum	Teff	0.49	38%	3.8	6	358	716
Teff, Maize, Sorghum	Teff	0.80	39%	3.0	5	476	1,028
Maize, teff, sorghum	Maize	0.76	38%	3.5	6	505	1,040
Enset, maize, teff	Maize	0.59	30%	3.7	6	435	829

For the fertilizer only intervention there is little difference between B:C ratios, although wheat has the lowest incremental income. When fertilizer is combined with improved seed, with the B:C ratios for maize and teff are higher than for wheat. This may be a reflection of the very high seed rate of wheat for wheat compared with teff and maize, with the incremental cost of improved seed depressing the B:C ratio. The difference in incremental income between the fertilizer only and the fertilizer with seed is biggest for maize, followed by teff and then wheat. The may explain why improved maize seed comprises by far the largest proportion of improved seed used in the Amhara and Oromiya Regions in Abbay Sub-basin.

(b) Sub-basin Level

For the analysis it was assumed that an additional 30 percent of farmers would adopt fertilizer (DAP) and improved seeds[11]. Thus some 102,200 tons of DAP would be used by 1.02 million farmers. The analysis was conducted over a period of 50 years given the 10 year period of investment. A discount rate of 10 percent was used.

The results for the fertilizer only intervention are shown in table 14a and those for the combined fertilizer and improved seed intervention in table 14b. The overall B:C ratio is 3.3 for the fertilizer only intervention and 5.6 for the combined intervention.

[11] Currently 26 percent of farmers in Amhara Region use chemical fertilizer (CSA, 2006).

Table 14. Financial Benefit-cost Analysis of the Proposed Fertilizer Intervention n the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

(a) Fertilizer Only

Financial Costs and Benefits of Fertilizer Only Intervention by Farming System in Abbay Sub-Basin

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:HMKT	2,830,601	3,578,676	8,849,668	11,210,338	748,075	2,360,670	3.2
HL:HAG:LMKT	4,388,604	5,534,441	13,684,203	17,379,503	1,145,837	3,695,301	3.2
HL:MAG:HMKT	1,906,865	2,304,591	4,922,439	6,211,419	397,726	1,288,980	3.2
HL:MAG:LMKT	7,251,567	8,725,150	19,806,736	24,829,181	1,473,582	5,022,445	3.4
total	**16,377,637**	**20,142,858**	**47,263,046**	**59,630,442**	**3,765,221**	**12,367,395**	**3.3**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:HMKT	314.5	397.6	983.3	1,245.6	83.1	262.3	3.2
HL:HAG:LMKT	487.6	614.9	1,520.5	1,931.1	127.3	410.6	3.2
HL:MAG:HMKT	211.9	256.1	546.9	690.2	44.2	143.2	3.2
HL:MAG:LMKT	805.7	969.5	2,200.7	2,758.8	163.7	558.0	3.4
total	**1,819.7**	**2,238.1**	**5,251.4**	**6,625.6**	**418.4**	**1,374.2**	**3.3**

all costs and benefits are PVs over 50 years at 10% discount rate

(b) Fertilizer and Improved Seed

Financial Costs and Benefits of Fertilizer & Imp. Seed Intervention by Farming System in Abbay Sub-Basin

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:HMKT	943,534	1,199,540	2,949,889	4,351,537	256,006	1,401,648	5.5
HL:HAG:LMKT	1,462,868	1,860,756	4,561,401	6,755,486	397,888	2,194,085	5.5
HL:MAG:HMKT	635,622	774,746	1,640,813	2,406,145	139,124	765,332	5.5
HL:MAG:LMKT	2,417,189	2,945,415	6,602,245	9,584,322	528,226	2,982,077	5.6
total	**5,459,212**	**6,780,457**	**15,754,349**	**23,097,490**	**1,321,244**	**7,343,141**	**5.6**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:HMKT	104.8	133.3	327.8	483.5	28.4	155.7	5.5
HL:HAG:LMKT	162.5	206.8	506.8	750.6	44.2	243.8	5.5
HL:MAG:HMKT	70.6	86.1	182.3	267.3	15.5	85.0	5.5
HL:MAG:LMKT	268.6	327.3	733.6	1,064.9	58.7	331.3	5.6
total	**606.6**	**753.4**	**1,750.5**	**2,566.4**	**146.8**	**815.9**	**5.6**

all costs and benefits are PVs over 50 years at 10% discount rate

(ii) Diversification of Agricultural Production

Diversification need not be confined to crop production and can include livestock fattening, sheep and goat rearing, improved honey production. In terms of crops a number of initiatives are now being promoted including: vegetables, fruit trees (apples and plums in the Highlands, Citrus and bananas in the Lowlands); organic coffee, and spices (corrarima, ginger). Quality control and effective marketing are essential elements of crop diversification. Integration with other elements of the farming system is also often essential such as on-farm forage production for livestock fattening and improved sheep and goat production. Water provision from micro-dams and water harvesting structures are an essential element of vegetable production. The key strategy with respect to diversification is to extend the range of livelihood strategies thus reducing vulnerability to natural and other shocks. Given the very wide range of these interventions it not possible to undertake a benefit:cost analysis.

4.3.3 On-farm Forage Production

(a) Patterns of Livestock Feed Deficit

Month on month feed balances will vary more than annual variations in both the Highlands and Lowlands. The Zebu bred of cattle can withstand seasonal deficits in livestock feed by utilizing body reserves of energy and suffering weight loss. As soon as feed balances become positive animals regain lost weight.

Two patterns of feed shortage were identified in the WBISPP Special Natural Grazing Lands Survey (WBISPP-MARD, 2003). The first pattern is found in the eastern Highlands of the Sub-basin. Feed deficits start in February-March as natural pastures are at their lowest with respect to dry matter, nutrients and digestibility, and the supply of stored crop residues is beginning to diminish. In addition some of the harvested cropland is beginning to be ploughed up ready for planting the next season’s crop, and thus aftermath grazing is also beginning to diminish. The deficits peak in May and June and rapidly decline as pastures increased in dry matter, nutrient status and digestibility.

The second pattern is found in the western Highlands. Here, the deficit builds up more slowly in March through to May as dry matter, nutrients and digestibility of the natural pastures are at their lowest, and the supply of aftermath grazing declines due to some of the cropland being ploughed up in readiness for the next season’s planting. The deficit starts to decline at the onset of rains in June with the increase in dry matter and digestibility of the natural pastures, only to increase again as much of the bottomland land grazing becomes waterlogged. Most upland well-drained areas have already been converted to cropland and thus during July through to September feed deficits become severe.

(b) Livestock Feed Requirements

The physical quantity of feed required by ruminant livestock is conditioned in the main by the quality of the feed and its metabolizable energy (ME) content. This in turn is strongly influenced by its crude protein (CP) content. A full grown zebu cow of 240 kgs requires some 44 mega joules (MJ) of ME per day. Lactating cows and work oxen require an additional 12 to 15 MJ ME per day.

Poor quality natural pasture has about 7.5 MJ M/E per kg., whilst high quality forage (improved grasses) has about 10.0 MJ ME per kg. The impact these differences have on the quantity of feed is as follows: to achieve the daily requirement of ME some 5.8 kgs of natural pasture is required compared with 4.4 kgs of improved grass. Over one year this translates into 2.1 tons of natural pasture and 1.6 tons of improved grass. Average yield of unimproved pasture in the Highlands is approximately 2.0 tons DM/ha whilst those of improved grasses are about 5 tons/ha for short grasses and up to 9 tons/ha for tall grasses (e.g. Napier grass). To feed one adult cow for one year on improved short grasses would require 0.32 ha and on long grasses 0.18 ha. This compares with the 1.1 ha of natural pasture to provide the same feed.

(c) On-farm Forage Strategies

A more realistic strategy for many small farmers would be to grow sufficient improved forage to meet three months supply at ploughing time or during lactation periods. This would reduce the improved forage area requirements to 0.11 ha (short grasses) and 0.06 ha (long grasses). This is possible within the homestead area (i.e. "backyard forage" strategy). An alternative strategy would be to grow the improved grasses on the grass strips during the period the crops are in the field and cut for hay or silage production.

(d) On-farm Financial Analysis

Benefits to the intervention include increased livestock productivity (increased calving, lower calf mortality, increased draught power). The difficulty in undertaking a financial comparison of unimproved pasture (as the without project) and improved on-farm forage is estimating a value for the two forage commodities. In North Wello teff straw commands a market price nearly double that of unimproved pasture grass. A bundle of teff straw (assumed to be 12 kgs) sells for ETB 10, which is ETB 833.33/ton compared with ETB 416.66/ton for unimproved grass. It is assumed that teff straw is equivalent to improved forage although it is likely that improved forage has a higher ME value than teff straw.

Using these relative prices and including costs of improved seed and fertilizer gave a B:C ratio of 3.6 for the on-farm intervention. The incremental return on cultivating 0.11 ha of improved forage was ETB 198.00.

(e) Sub-basin Wide Financial Analysis: National Benefits

In the Sub-basin wide analysis it was assumed that 40 percent of households would adopt improved on-farm forage production over 10 years. For the analysis the average area per farm was 0.11 ha or sufficient to feed one cow for 3 months. The results are presented in table 15. The overall B:C ratio is 3.6.

Table 15. Financial Benefit-cost Analysis of the Proposed On-farm Forage Intervention n the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of On-farm Forage Intervention by Farming System in Abbay Sub-Basin

Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
-	41,102	98,073	245,183	41,102	147,110	3.6

Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
-	4.8	11.3	28.3	4.8	17.0	3.6

all costs and benefits are PVs over 50 years at 10% discount rate

Unquantifiable benefits include reduced pressure on communal grazing areas leading to increased forage natural pasture production, lower erosion rates and reduced sedimentation in streams.

(f) Sub-basin Wide: Global Benefits

Global benefits to on-farm forage product result from reduced pressure on communal grazing areas leading to increased pasture production. This would have the impact of increasing soil organic matter. Given the wide variability of existing grazing pressures and the variations in the degree of relief provided it is very difficult to quantify the increase in soil carbon in soils of the communal grazing areas.

4.3.4 On-farm Tree production and Domestic Energy

(a) Farm Level

Supply-side Interventions: Fuel Substitution:

In the Abbay Sub-basin the process of fuel substitution is already underway (WBISPP/MARD, 2001). Per capita dung use as fuel has been declining at an annual rate of nearly 3 percent in the past 10 years. Some 40 percent of the dung used as fuel comes from cropland. Only this proportion is used in the analysis. Assuming that each household undertakes a full conversion to fuelwood of the dung from cropland and all residues burnt it is estimated that the each converting household would save some 30 kgs of available N. This is equivalent to 147 kgs of grain per converting household. In nutritional terms this is sufficient to feed one adult for 74 percent of the year. Using the average price for wheat (ETB 187/ton) in the Abbay Sub-basin this is equivalent to ETB 274.15 or 26 percent of the ETB 1,070/yr per capita poverty line.

In addition there is the value of the trees as fuelwood and/or poles. For the analysis it was assumed that each adopting farmer would plant 60 Eucalyptus trees a year for 5 years. This would provide a total of 300 trees. At a density of 1,500 trees/ha[12] this would require 0.15 ha. Household labour is costed at the reservation rural wage rate of ETB 5.00/day. Over 25 years and using a discount rate of 10 percent the financial rate of return is 36 percent and the discounted B:C ratio is 2.4. However, the payback period is 8 years.

Demand-side Interventions: Improved Stoves[13]:

Two improved stoves are available: the *lakech* (a charcoal stove) and the *gounziye* (a ceramic wood stove that mimics the traditional 3-stone fireplace). The *mirte* is an improved mitad stove (for baking injera). The *lakech* is already well established in urban areas where charcoal is a preferred fuel for wot cooking.

In rural areas in the Abbay Sub-basin little or no charcoal is used (WBISPP-MARD, 2003). The *mirte* mitad has a fuel saving of 50 percent and costs ETB 45 – 60. It also considerably reduces the amount of smoke generated. Average rural household fuelwood consumption in the Abbay Sub-basin is approximately 5,220 kgs/yr/family). Some 47 percent of wood is used for mitad cooking and 40 percent for other cooking (mainly *wot* cooking).

Adoption of the *mirte* and *gounziye* could generate household fuelwood savings of approximately 1,227 kgs/yr and 626 kgs/yr: a total of 1,853 kgs/yr. Approximately 30 hours (about 3.75 days) a week of family labour (women 20, children 9 and men 2 hours) are use in collecting and transporting 100 kgs of fuelwood. Using a average wage rate of ETB 4.00 as representative of the whole family labour (men, women and children), this would indicate a value for fuelwood of 0.15/kg. Total annual savings per family would thus amount to ETB 277. Assuming stoves are replaced after 5 years and using a discount rate of 10 percent the B:C ratio is 24.

Because burning biomass fuels on the traditional wood stove is inefficient and as much as 20 percent of fuel is not completely combusted, a number of toxic substances are released into the atmostsphere. In many Ethiopia households this often takes place in an enclosed kitchen. The toxic substances include small particles, carbon monoxide and nitrogen dioxide as well as formaldehyde, benzene and other pollutants. Detailed studies (Holden and Smith, 2000) have indicated the levels of pollutants from burning 1 kg of wood on a typical traditional wood stove in an enclosed space. These are indicated below in table 16 together with the WHO maximum permitted levels.

[12] In practice farmers plant at much higher densities (up to 30,000 trees/ha) although yields are lower than at wider spacing.

[13] Data from the "National Strategic Plan for the Biomass Energy Sector", (WBISPP-MARD, 2005)

Table 16. Indoor Concentrations of Health-Damaging Pollutants from a Burning 1 kg of Wood in 1 Hour on a typical Traditional Wood Stove in an Enclosed Kitchen of 40 cubic meters (mg/M3)

	Carbon monoxide mg/m3	Particles mg/m3	Benzene mg/m3	1,3-Butadiene mg/m3	Formaldehyde mg/m3
Level experienced	150	3.3	0.8	0.15	0.7
Maximum permitted level	10	0.1	0.002	0.0003	0.1

These pollutants are now known to have serious negative impacts on human health, in particular acute respiratory infections and respiratory diseases. Women and particularly children are affected. No detailed studies have been undertaken in Ethiopia, but detailed studies have been undertaken in India where 80 percent of households use biomass fuels. In India it estimated that about 5 percent of premature deaths in women and children under 5 are due to indoor smoke pollution. By way of comparison poor water and sanitation account for 6 percent and malnutrition 15 percent. In Ethiopia 95 percent of households use biomass fuels a substantial majority in enclosed spaces as fires are also used for heating and lighting.

(b) Sub-basin Level Benefits: National

Supply-side Interventions: Fuel Substitution:

At the Sub-basin level and assuming that 3 percent of households or some 109,035 households convert to fuelwood each year the annual saving of N would amount to 1,322 tons: a grain equivalent of 7,930 tons/yr. This is sufficient to provide food for 36,000 people. This amount would cumulate in the Sub-basin at 7,930 tons per yr. The annual accumulating value of grain saved is ETB 15.6 million (US$ 1.74 million/yr) reaching 156.0 million/yr (US$ 17.4 million/yr) after 10 years.

To examine the Direct Intervention of On-farm tree planting programme on its own, the benefit-cost analysis was undertaken over 50 years to take account of the 10 years of investments and using the Government discount rate for public investments of 10 percent. An annual adoption rate of 3 percent of households per year for 10 years was used in the analysis. The results are shown in table 17. The overall discounted B:C ratio is greater than unity at 2.4.

Table 17. Financial Benefit-cost Analysis of the Proposed On-farm Tree Planting Intervention in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of On-farm Tree Planting Interventions in Abbay Sub-Basin							
	Cost WOP (ETB'000)	**Cost WP (ETB'000)**	**Benefit WOP (ETB'000)**	**Benefit WP (ETB'000)**	**Incremental Cost (ETB'000)**	**Incremental Benefit (ETB'000)**	**B/C Ratio**
	-	1,576,925	-	3,826,937	1,576,925	3,826,937	2.4
total	**-**	**1,576,925**	**-**	**3,826,937**	**1,576,925**	**3,826,937**	**2.4**
Farming System	**Cost WOP ($US m)**	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	182.3	-	442.4	182.3	442.4	2.4
total	**-**	**182.3**	**-**	**442.4**	**182.3**	**442.4**	**2.4**
all costs and benefits are PVs over 50 years at 10% discount rate							

Demand-side Intervention: Improved Stoves

The GTZ Household Energy/Protection of Natural Resources Project (HENRP) working in Amhara, Tigray, SNNP and Oromiya regions report that in the first three years some 5 percent of mirte mitad stoves were being sold to rural households. Assuming that 10 percent of households (336,750) will adopt the mirte mitad and the gounziye stoves over a period of 10 years with the same assumptions above regarding fuel savings then incremental costs and benefits are shown in table 18. The overall B:C ratio is 15.

Table 18. Financial Benefit-cost Analysis of the Proposed Improved Stove Planting Intervention in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of Improved Stove Interventions in Abbay Sub-Basin							
	Cost WOP (ETB'000)	**Cost WP (ETB'000)**	**Benefit WOP (ETB'000)**	**Benefit WP (ETB'000)**	**Incremental Cost (ETB'000)**	**Incremental Benefit (ETB'000)**	**B/C Ratio**
	-	40,106	-	617,440	40,106	617,440	**15**
	Cost WOP ($US m)	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	4.6	-	71.4	4.6	71.4	**15**
all costs and benefits are PVs over 50 years at 10% discount rate							

(c) Global Benefits

Wood harvested and burnt does not contribute to the carbon pool, only wood used for construction and furniture will retain its carbon. It is assumed that the life of such wood is 10 years upon which it will be burnt or decay. After 10 years wood in such use would accumulate from 0.36 million tons to 3.64 million/yr over the next 10 years. Thus some 1.82 million tons/yr of carbon will be sequestered after a period of 20 years development. This has a value of ETB 49.3 million (US$ 5.5 million).

Using the improved stoves some 363,450 households will be saving 673,470 tons/yr or 336,736 tons of carbon. Valued at US$ 3/ton this represents a value of ETB 9.09 million/yr (US$ 1.0 million/yr).

4.3.5 Communal lands: Increased Pasture and Wood production

(i) Reduced Soil Erosion on Non-Cropland

(a) Background

It is estimated that some 201.0 million tons of soil per annum are eroded from non-cropland. An estimated 20 percent of additional soil is removed by gully erosion. "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 70 percent of the total area.

There has been a strong programme of reclamation of these degraded communal lands in the Abbay Sub-basin within the past decade. These areas are closed to livestock and managed for cut-and-carry forage, community and individual woodlots. However, there is no information for the Abbay Sub-basin of how much land has been already been closed. An assumption of 10 percent is used (less than the 15 percent reported for the Tekeze Sub-basin).

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

(b) Potential Increase in Forage and Tree production: Site Level

In the financial analysis it was assumed that 50 percent of the area would be under trees (i.e. at half the recommended planting density) and the whole area under grass. A ten year rotation of trees was used[14]. Grass yields reach a maximum after 5 years, decline with tree shading and increased after tree harvest. Trees are valued for poles and BLT[15]. Open pastures yields about 2

[14] Farmers follow much shorter rotations for Eucalyptus (10 years) than commercial plantations (15 – 20 years).
[15] BLT = Branches, leaves and twigs (20% of total volume).

tons DM/ha. After closure, forage yields increase up to 4 tons. Family labour for cut and carry of forage was costs at ETB 5/day for 10 days.

There are positive impacts on livestock health and productivity (milk, draught power, fecundity, reduced calf mortalities) with increases in feed supply. To capture these values grass was valued using the annualized value of an ox over 10 years at 10 percent discount rate multiplied by the ratio of 1 Q of grass dry matter to the annual feed requirements of 1 ox (18.25 Q of grass dry matter).

The financial analysis for 1 hectare of closed area produced a financial rate of return of 68 percent and a B:C ratio of 13. The payback period is short – 3 years.

The increase in wood supply for fuel and construction will relieve pressure on the remaining areas on non-cropland. Because of the very wide variation in the existing state of communal lands it is very difficult to quantify these potential impacts.

In a very detailed village study in Tigray Howard and Smith (2006) found that plants within the enclosed areas had considerable importance for traditional medicines (138 species), as wild food (30 species), as bee forage and for religious and cultural activities. Often there are gender differences in the value of these plants. The sale of some of these plants provides a vital source of livelihood for the most disadvantaged people in the community (e.g. female headed households). In the degraded areas many of these plants had disappeared. Clearly, these plants provide an important element in the broader livelihoods of rural (and urban) communities and their value has often not been recognized (Shackleton et al., 2000).

(c) Potential Increase in Forage and Tree production: Sub-basin Level

As indicated above it has been assumed that 40 percent of non-cropland would be enclosed over a 10 year period in equal proportions (i.e. 4 percent per year). This would amount to nearly 6.0 million ha. The analysis was conducted over a period of 50 years given the 10 year period of investment. A discount rate of 10 percent was used. The results are shown in table 19. The overall B:C ratio is 13 and the internal rate of return was 68 percent.

Table 19. Financial Benefit-cost Analysis of the Proposed Area Closure in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of Closed Area Interventions by Farming System in Abbay Sub-Basin

	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
	-	5,065,382	8,692,518	73,302,982	5,065,382	64,610,463	13
total	**-**	**5,065,382**	**8,692,518**	**73,302,982**	**5,065,382**	**64,610,463**	**13**
Farming System	**Cost WOP ($US m)**	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	562.8	965.8	8,144.8	562.8	7,178.9	13
total	**-**	**562.8**	**965.8**	**8,144.8**	**562.8**	**7,178.9**	**13**

all costs and benefits are PVs over 50 years at 10% discount rate

(d) Potential Regional Benefits and Costs

Benefits

The opportunities for significant reducing sediment delivery to the river system are very substantial. Assuming that 40 percent of the non-cropland could be brought under closure and sustainable forage or woodland management over a ten year period with a soil retention rate of 85 percent, this could reduce sediment delivery to the river system by approximately 28.22 million t/yr (from 90.45 million t/yr to 50.17 million t/yr). Gulley reclamation could add a further reduction of 2.05 million tons per annum. These contribute to the overall reduction in sediment load in the Abbay-Blue Nile River system passing into Sudan and onto Egypt. The benefits (and costs) of these reductions are considered in sections 4.5.4 (Sudan) and 7.3.1 (Egypt).

Potential Costs

In a study of the Chemoga Watershed, Bewket and Sterk (2005) examined the changes in stream flow patterns with reference to the dynamics of land cover. The results showed that between 1960 and 1999 annual stream flow decreased at a rate of 1.7 mm/yr whereas annual rainfall decreased only at a rate 0.29 mm/yr. Over the past four decades the major change in land cover was the increase in cultivated land from 60.4 to 66.6 percent. Closed canopy forest cover increased 2.4 to 3.6 percent. This was attributed to plantation (mainly Eucalyptus) activities during the Derg, and planting of trees by households since 1991 (again mainly Eucalyptus). Woodland and shrublands increased over the period 1982-1998. The increase in the second period was attributed to hillside closures. The significant change was in the amount of Eucalyptus that had been planted during the second period.

The changes in stream flow were ascribed to an increase in cropland, an increase in Eucalyptus planting and to overgrazing. Another cause was the increased abstraction of water due to the increase in population during the study period. The increase in Eucalyptus has led to an increase in evapotranspiration over the previous land cover. Local people confirmed that Eucalyptus dried out the land, but that the economic returns were substantial. Decreased dry season flows indicate a decline in groundwater resources.

The impacts of land cover change on the hydraulic characteristics of catchments and basins is very scale specific (Bruijnzeel, 1990). A particular impact at the small catchment scale may not be discernable at the basin scale. Thus, the potential negative impacts of Eucalyptus planting at the scale of the Abbay Sub-basin may not be detectable at the scale of the Chemoga Catchment. Much more research is required to determine these scale-specific impacts of land cover change.

(e) Global Benefits

Potential global benefits can accrue from increased carbon sequestered in wood and soil organic matter.

Sequestered Wood carbon

Most of the incremental above-ground herbaceous biomass will be consumed by livestock and thus there will be no increase in the carbon pool. Wood harvested and burnt will not contribute to the carbon pool. Only wood that is not burnt: e.g. construction and furniture will contribute. It has been assumed that 10 percent of wood harvested will be used for construction and furniture and will thus become part of the sequestered carbon pool. It assumed that this wood will last for 10 years before being burnt or decaying and releasing CO2 back to the atmostsphere.

Using the assumptions outlined above with tree planting at half the plantation density and using a factor of 10 percent, wood not burnt would rise from 3.4 million tons at 10 years to some 68 million tons/yr after 20 years development. This would sequester 34 million tons of carbon valued at ETB 917 million (US$ 101.6 million).

Sequestered Soil Carbon

However, the greatest potential for adding to the carbon pool is from an increase in soil carbon (SC) from the increased production of pasture as grasslands sequester double the amount carbon as croplands.

Descheemaeker et al., 2005 found that soil organic matter in an enclosed area in Tigray had increased from between 0.2 percent to 1.3 and 0.5 percent to 3.4 percent in areas that had been enclosed for 4 to 5 years. These would indicate increases from 17 to 45 tons/ha. It is likely in the higher rainfall areas of the Abbay Sub-basin that levels of SC are about 20 tons/ha on grassland (Barber, 1985). Using an increment of 31 tons/ha of soil carbon after 5 years of enclosure would increase total SC by 92.8 million tons. Using the same values as before this represents a value of ETB 2,506 million/yr (US$ 278 million/yr) accumulating over 10 years.

The medicinal, nutritional and other use-values of plants in the enclosed areas have been noted above. These plants also have a biodiversity value and provide a reservoir of genetic and species diversity that is being lost in the open access communal lands.

4.3.6 Water Conservation and Improved Utilization

The key activities related to water conservation and its improved utilization are small/micro dams and household-level water harvesting structures. Both can be used for domestic and livestock water supply and for small-scale irrigated cropping (integrating with the crop diversification intervention).

(i) Small/Micro Dams and Weirs (River diversions)

(a) Basic Data

Data from IFAD for the Amhara Region puts the average costs per hectare for weir irrigation systems at ETB 41,418/ha (US$ 4,602/ha). Average area irrigated is 72 ha giving total costs of each scheme of ETB 2.98 million (US$ 0.33 million). Average number of beneficiary households was 288 with an average holding of 0.25 ha. Average maintenance costs were estimated to be ETB 750/ha (US$ 8.33/ha).

Data for dam systems puts average costs per hectare at ETB 61,200/ha (US $6,800/ha). Average area irrigated is 160 ha giving total cost of each scheme as ETB 9.98 million (US$ 1.11 million). Maintenance costs are estimated to be 2.5 percent of construction costs (Hewitt and Semple, 1985). The average number of beneficiary households is 460 per scheme with an average area of 0.35 ha per household.

(b) Financial Analysis: Irrigation from Small dams: farm level

It assumed that the irrigated area cropped is 0.35 ha, and that 100 percent is cropped in the main season (green maize 35%, potatoes 50%, peppers 15%) and that 50 percent is cropped to onions in the 2nd season. In the without project situation is assumed that the 0.35 ha is rainfed cropped according to the crop mix of the local farming system. Family labour for cultivation, irrigation and transport to market is not included.

The B:C ratio is 7.5 and the incremental income is ETB 2,783/yr. The incremental return to family labour is ETB 25.80/day. When family labour is costed the incremental income is ETB 2,120 and the B:C ratio falls to 3.3. Nevertheless, clearly the small irrigation intervention is financially very attractive. Average Amhara Region market prices were used although an IFAD Evaluation Report on small scale irrigation schemes found that on some schemes prices received by farmers from itinerant traders were considerably below local market prices. There have also been problems with local gluts in markets with poor outside accessibility. Reducing market prices by 25 percent and 50 percent reduces the B:C ratio to 6.0 and 4.2 respectively. Incremental cash income declines to ETB 1,883 and ETB 1,156 respectively. Similar changes in costs produce almost identical results.

(c) Financial Analysis: Weir Diversion from Run-of River

In this analysis it is assumed that only one cropping season is possible because of lack of water during the 2nd season. The cropping mix is the same as the Main Season of the Small Dam schemes. The other assumptions remain the same.

The B:C ratio is 4 and the incremental income is ETB 589/yr. The returns to family labour are ETB 4.30/day. The absence of a second cropping season limits the incremental income. Reducing market prices by 25 percent and 50 percent reduces the B:C ratio to 3.1 and 2.3 respectively. Incremental cash income reduces to ETB 405 and ETB 221 respectively.

(d) Financial Analysis: Small scale irrigation Abbay Sub-Basin

Current rates of small dam construction in the Abbay Sub-basin have been about 12 per year and a similar number of weir diversion schemes have been implementation with IFAD's support. For the Sub-basin wide analysis it is assumed that 120 small dams and 120 weir diversion schemes can be implemented in the 10 year period. These would serve some 110,300 households irrigating a total area of 39,200 ha.

The analysis examined the costs and benefits of 120 dam schemes and 120 weir diversion schemes over a period of 50 years using 10 percent discount rate. Costs of watershed management interventions above the dam or weir have not been included, but are a vital element if problems of sedimentation are to be avoided. Clearly such watershed management interventions have many other benefits and the analysis would become protracted if a "total approach" were to be used. Nevertheless, these costs should be borne in mind when reviewing the results below.

The results are presented in table 20. The overall B:C ratio is 1.3. Changing the discount rate from 10 percent to 5 percent increases the B:C ratio to 1.9.

Table 20. Financial Benefit-cost Analysis of the Proposed Small-scale Irrigation Intervention in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of 240 Small-scale Irrigation Intervention in Abbay Sub-Basin

Farming System	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
Dam schemes (Construction)	-	736,062	-	-	736,062	-	-
Dam schemes (maintenance)	-	202,395	-	-	202,395	-	-
Wier Schemes Construction	-	219,884	-	-	219,884	-	-
Weir Schemes (Maintenance)	-	60,462	-	-	60,462	-	-
Dam schemes: Irrigation	110,484	260,853	167,337	1,298,951	150,369	1,131,614	7.53
Weir schemes: Irrigation	110,002	224,197	143,740	930,184	114,196	786,444	6.89
total	**220,485**	**1,703,853**	**311,077**	**2,229,135**	**1,483,367**	**1,918,057**	**1.29**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
Dam schemes (Construction)	-	85.1	-	-	85.1	-	-
Dam schemes (maintenance)	-	23.4	-	-	23.4	-	-
Wier Schemes Construction	-	25.4	-	-	25.4	-	-
Weir Schemes (Maintenance)	-	7.0	-	-	7.0	-	-
Dam schemes: Irrigation	12.8	30.2	19.3	150.2	17.4	130.8	7.53
Weir schemes: Irrigation	12.7	25.9	16.6	107.5	13.2	90.9	6.89
total	**25.5**	**197.0**	**36.0**	**257.7**	**171.5**	**221.7**	**1.29**

(e) Other Costs

Research in Tigray (Ersado, 2005) has revealed that whilst dams and small-scale irrigation increased farm incomes they also led to an increased incidence of malaria. This in turn led to reduced allocation of labour to non-farm activities and increased expenditure on medicines. These costs have not been quantified. However, they can be prevented by spraying in and around houses and/or with the provision of impregnated mosquito nets. The estimated cost of such a net is ETB 36.00 (US$ 4.00). Assuming 2 nets per household and 460 households in each Irrigation Scheme village would mean a four yearly cost of ETB 33,120/scheme (US$ 3,680). Assuming a replacement every 4th year and adding these costs to (i) household costs and (ii) Scheme costs has the following impact on B:C ratios:

Households

Dam schemes: B:C ratio: from 7.5 to 7.3:
Weir schemes: B:C ratio: from 3.9 to 3.7

Schemes
All schemes: B:C from 2.1 to 2.0

Clearly, including impregnated mosquito nets into the schemes "maintenance" costs makes very little difference to the household or the overall programme B:C ratios.

Potential health costs could also result from the introduction and spread of bilharzia through its host the *Bulinus* spp. snail. Preventative costs would be incurred from the use of moluscicides. Other potential health costs could be

incurred through the use of agro-chemicals and their effect on down-stream users of the river for human and livestock water supplies.

Increased use of water through increased evapotranspiration of irrigated crops in comparison with rainfed crops as well as evaporation from the reservoirs will reduce river flow downstream of the Schemes. This could have negative impacts on downstream users in terms of water use for domestic and livestock water supplies and for irrigation.

(f) Multiplier Benefits

Many dams are constructed to serve a number of uses. These include domestic and livestock water supplies. These in turn have secondary (multiplier) benefits in terms of enhanced human health, reduced time for water collection for women and children and increased livestock productivity.

Other multiplier effects include backward and forward linkages in the local economy. These include increased sales of inputs and increased products entering the market. Increased multiplier effects will also be felt with increased household purchases of local and "imported" (i.e. into the local area) goods. Purchases of locally produced non-food goods ("non-tradables) make a substantial contribution to the multiplier effect.

No information is available at the local level in Ethiopia but evidence from an area of poor accessibility in Nigeria (similar to many areas in Ethiopia) suggests that the marginal household budget share of non-tradable goods may be about 32 percent (Hazell and Roell, 1983). This means that every birr of additional household expenditure has a 32 percent stimulative first round effect on the local economy. The annual incremental household income for the small dam schemes is ETB 2,630/yr and that for the Weir Run-of-River schemes ETB 1,802/yr.

Assuming that 32 percent of this incremental income is spent on non-tradables by the 748 beneficiary households, this would indicate that an additional ETB 5.5 million/yr would enter the local economy of locations with a dam scheme and ETB 2.2 million/yr for the Weir Schemes. At the end of 0 years and across the 240 schemes in the Sub-basin this would amount to ETB 78.8 million/yr (US$ 8.8 million). This in turn would stimulate 2 and 3rd order multipliers within the local economy.

4.3.7 Summary of Financial analysis of the Measurable WSM Interventions

This section summarizes the financial analysis of the nine interventions that has preceded and outlines the results at the household level (table 21). The (discounted) costs of the supporting interventions have been included to determine an overall B:C ratio for the 10 year programme. All interventions indicate a B:C ratio in excess of unity and the overall B:C ratio is 7.0.

The largest incremental benefits accrue to the fertilizer/improved seed intervention, followed by the on-farm trees and the area enclosure interventions. For the cropland soil conservation measures a key factor affecting adoption/non-adoption is the length of the pay-back period of the initial negative returns because of the high labour requirements. This points to the need to extend the current support being provided in the food deficit weredas to all weredas. The very low requirements and substantial B:C ratios for grass strips indicate that this biological measure would prove attractive to farmers.

Table 21. Summary of Financial Analysis of the Programme of Direct Interventions for the Abbay Sub-basin: Ethiopia

Financial Costs and Benefits of WSM Interventions in the Abbay Sub-Basin

Intervention	Cost WOP (ETB'million)	Cost WP (ETB'million)	Benefit WOP (ETB'million)	Benefit WP (ETB'million)	Incremental Cost (ETB'million)	Incremental Benefit (ETB'million)	B/C Ratio
Soil conservation: Bunds	2,592	3,007	9,182	10,067	415.0	884	2.1
Soil conservation: Grass strips	3,767	3,792	9,936	10,402	25	466	18.6
Fertilizer/Improved seed	5,459	6,780	15,754	23,097	1,321	7,343	5.6
On-farm Forage	-	699	1,667	4,168	699	2,501	3.6
On-farm Trees	-	1,577	-	3,827	1,577	3,827	2.4
Improved stoves	-	40	-	617	40	617	15.4
Area enclosure	-	5,065	8,693	73,303	5,065	64,610	12.8
Small-scale Irrigation	220	1,704	311	2,229	1,483	1,918	1.3
Supporting Interventions	-	-	-	-	1,051	-	
TOTAL	**12,040**	**22,665**	**45,544**	**127,711**	**11,677**	**82,167**	**7.0**

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
Soil conservation: Bunds	299.7	347.7	1,061.5	1,163.8	48.0	102.2	2.1
Soil conservation: Grass strips	435.5	438.4	1,148.7	1,202.5	2.9	53.9	18.6
Fertilizer/Improved seed	631.1	783.9	1,821.3	2,670.2	152.7	848.9	5.6
On-farm Forage	-	80.8	192.8	481.9	80.8	289.1	3.6
On-farm Trees	-	182.3	-	442.4	182.3	442.4	2.4
Improved stoves	-	4.6	-	71.4	4.6	71.4	15.4
Area enclosure	-	585.6	1,004.9	8,474.3	585.6	7,469.4	12.8
Small-scale Irrigation	25.5	197.0	36.0	257.7	171.5	221.7	1.3
Supporting Interventions	-	-	-	-	121.5	-	
	1,391.8	**2,620.3**	**5,265.1**	**14,764.3**	**1,350.0**	**9,499.1**	**7.0**

all costs and benefits are PVs over 50 years at 10% discount rate

The relevant sections have pointed out the additional unquantifiable benefits accruing to these interventions. Thus, the analysis presented here represents a conservative estimate of the incremental benefits accruing to the programme.

The quantifiable National, Regional and Global benefits are presented at the end of the Chapter for Ethiopia and Sudan.

4.4 Estimated Budget - Direct and Supporting Interventions: Abbay Sub-basin - Ethiopia

The previous section has outlined some of the quantifiable costs and benefits accruing to the direct interventions. All of these depend to a greater or lesser extent on the implementation of the Supporting Interventions. These

Supporting Interventions will provide increased physical and human capacity to rural households and government implementing organizations and in particular the extension Service; support to assisting rural families to gain non-farm employment and to small enterprise development in both rural areas and small urban centers; improved road and market infrastructure and increased capacity of farmers in product marketing and with increased available and access to micro finance and credit. The details of these and their direct and indirect benefits are summarized Matrix 1b in Chapter 2.

This section provides a summary of the budget required to implement both the Direct and Supporting Interventions (table 22). A detailed breakdown with units and unit costs is provided in Annex 3. Given the very complex nature of the relationships between the Direct and the Indirect Interventions, in particular their short and long term impacts on human welfare and development in local, regional and National terms it would be extremely hazardous to attempt an overall benefit-cost analysis. However, it is submitted that the figures below provide a sense of the order of magnitude in implementing a programme of the interventions as outlined in Chapter 2.

Table 22. Summary 10 Year Budget: Abbay Sub-basin – Ethiopia: (a) Direct Interventions, (b) Supporting Interventions and (c) Total budget (ETB).

(a) Direct Interventions

Intervention	Total cost (ETB)	Total cost (US$)
1. Water Conservation & Improved Utilization	4,067,129,880	463,226,638
2. Crop Diversification & Intensification	1,129,637,422	128,660,299
3. Soil Conservation & Improved Soil Husbandry Measures	5,806,812,746	661,368,194
5. Livestock Development	408,682,198	46,546,947
Sub-total	**11,412,262,246**	**1,299,802,078**

(b) Supporting Interventions

Intervention	Total cost (ETB)	Total cost (US$)
1.. Capacity Building	417,077,360	47,503,116
2. Support to Agricultural Extension	141,445,000	16,109,909
3. Support to Non-farm Income Generation, Small/micro Enterprise development	289,283,740	32,948,034
4. Community Assets Development	848,260,000	96,612,756
5. Improved Marketing	7,323,000	851,139
6. Support to Micro-finance, Credit and Savings	7,473,000	851,139
Sub-total	**1,710,862,100**	**194,876,093**

TOTAL

Intervention	Total cost (ETB)	Total cost (US$)
(a) Direct Interventions	11,412,262,246	1,299,802,078
(b) Supporting Interventions	1,710,862,100	194,876,093
TOTAL	**13,123,124,346**	**1,494,678,172**

4.5 Costs of Continued Natural Resource Management Practices: Sudan

4.5.1 Agricultural production forgone from Soil Degradation – Blue Nile Sub-basin - Sudan

It is emphasized again that the physical impacts and costs outlined below do not reveal to full extent of the social and economic costs to the rural (and urban) population in terms of those key elements in the downward spiral of poverty and a degrading resource base such as poor nutrition and health, poor access to social services (health and education) and restricted access to alternative livelihood strategies.

(i) Loss of Agricultural land

Both *kerib* land formation and river bank erosion are resulting in the loss of cropland along the Dinder, Rahad and Blue Nile Rivers. However, there are no quantified estimates of these annual losses and thus it is not possible to place a value on them.

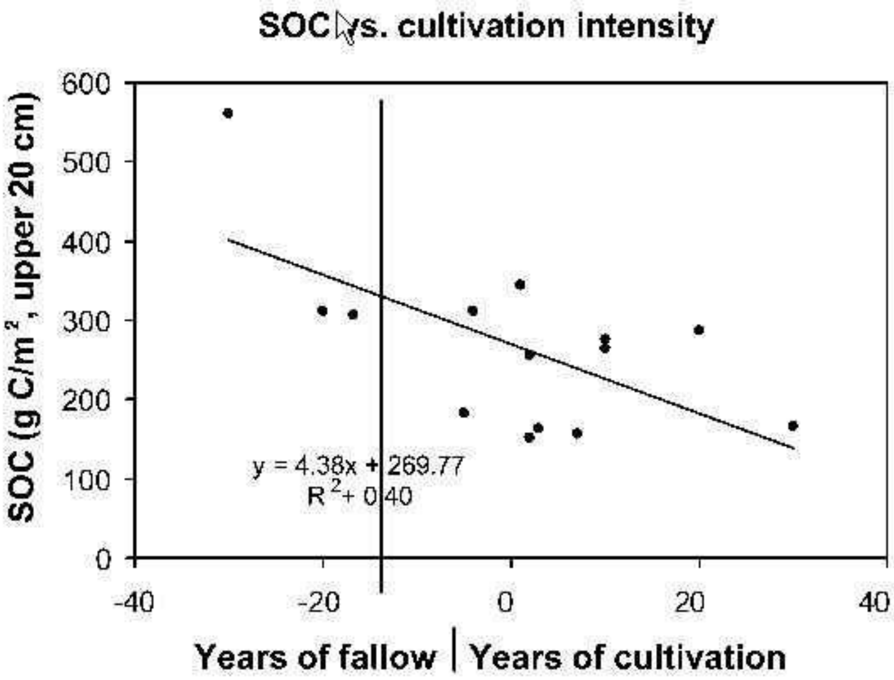
(ii) Decline of Soil Productivity on Semi Mechanized Farms

Annual decline in yields on the Semi mechanized Farms has been estimated between 2 and 5.1 percent per annum (World Bank, 2003). The conservative figure of 2 percent has been used in the analysis. This yield decline is attributed to declines in soil fertility caused by the lack of fallowing combined with loss of soil structure, sub-soil compaction and excessive weed growth (in particular the parasitic weed *striga*).

Whilst no long-term detailed and extensive soil fertility measurements have been made extensive surveys on crop yields have been made by MOA and FAO. The scientific consensus is that continuous cultivation in the absence of fallowing, subsequent weed growth coupled with soil compaction and soil structure destruction are responsible for the long term yield declines on both the Semi-mechanized Farms (Consultant Team discussions with Researchers at the Agricultural Research Corporation, Wad Medani, M.A.Latif, 2005, Caterson et al., 2005, Yagoub Abdalla, 2005).

In North Kordofan Olsson and Ardo (2002) have researched the relationship between the ratio of the years of fallow to years of cultivation and the levels of soil organic carbon, which is a good indicator of fertility. Their research demonstrated the very clear relationship between the increase in soil organic matter with increasing fallow periods (or decreasing the crop:fallow ratio). Thus a field that is cropped for 40 years with 1 year fallow has a ratio of 40. Measurements with a negative ratio indicate no crops and years of fallow. This is shown in figure 6.

Figure 6. Relationship between Soil Organic Carbon Content and the Crop:Fallow Ratio



Source: Olsson & Ardo (2002) in FAO, 2004.

Assuming that approximately 792,000 ha are cropped annually this represents an annual cumulative loss of production of 7,603 tons declining to 4,682 tons in 25 years time. At approximately SDD 43,000/ ton[16] this represents a loss of SDD 327 million (US$ 1.6 million) in the first year rising to SDD 6,482 million (US$ 32.4 million) after 25 years.

(iv) Decline in Soil Productivity on Traditional Rainfed farms

Approximately 1.05 million feddans (441,080 ha) of small-scale rainfed cropping has been mapped in the Blue Nile Sub-basin. The problem of soil nutrient depletion and degradation on traditional held land is not as severe as on the SMF land. This is because traditional farmers are to some extent able to fallow their land. In addition, they do not use heavy machinery to cultivate the land. Finally, most traditional farmers practice crop rotation with sorghum followed by sesame, which although does not increase soil fertility does reduce the build up of weeds (particularly striga).

Nevertheless, because of the encroachment of the SMF's the land available for fallowing has decreased leading to longer periods of cultivation. This in turn leads to declining soil fertility and an increase in weeds. Farmers' do not use manure on their fields as they say that it spreads weed seeds and leads to a build of weeds. Crop residues are removed from fields as livestock feed, construction material and to facilitate tractor operations.

[16] Price data from Ministry of Agriculture and Forests, 2006. In December 2006 the Government of Sudan announced a minimum price of SDD4,500/sack (SDD 50,000/ton)

The World Bank estimate for yield declines in the traditional rainfed farm sector is 1 percent/yr. This would indicate an annual cumulative loss production of 2,117 tons declining to 1,663 tons in 25 years time. At approximately SDD 43,000/ ton this represents a loss of SDD 91.0 million (US$ 0.5 million) in the first year rising to SDD 2,022.7 million (US$ 10.1 million) after 25 years.

4.5.2 Reservoir and Irrigation System Sedimentation: Sudan

Reservoir and irrigation system sedimentation may lead to reservoir storage loss. This in turn may lead to:

- (i) agricultural production forgone,
- (ii) higher irrigation-system operation and maintenance cost,
- (iii) increased dredging in front of turbines in-takes,
- (iv) higher cost of water purification,
- (v) pump damage,
- (vi) river bed aggradation[17].
- (vii) hydroelectricity production forgone.

This section values for Sudan the most important of these namely (i), (ii), (iii) and (vii).

(i) Downstream agricultural production forgone

Annual loss of storage in the Roseires and Senner Reservoirs is approximately 0.007 percent and 0 percent /yr[18]. At these storage loss rates there is little or no impact on loss of irrigation water.

(ii) Increased irrigation-system operation and maintenance cost

(a) Costs of Sedimentation

In 1991 some 9.78 million m^3 of silt entered the irrigation canal system of the Gezira-Managil which 62 percent is deposited in the canals with the remainder being deposited in the fields (World Bank, 2002). Desilting of the 17,244 kms of irrigation and 10,650 kms of drainage canals in the Gezira scheme alone is an enormous and expensive operation estimated in 1997-98 to cost SDD 1,366.8 million (US$ 6.83 million/yr) .

It is estimated that 0.70 million tons/yr enter the Rahad and other pump schemes along the Blue Nile River. Using the pro rata costs for cleaning the Rahad scheme estimated annual costs are SDD 85.6 million (US$ 0.4).

[17] Causing accelerated meandering and river bank erosion.
[18] Comments on 1st Draft of Distributive Analysis Report from Sudan Committee.

Some 38 percent of sediment reaches the fields as a deposit some 1.4 mm per year (M.A. Mohmoud, 1999). This will increasingly make it difficult to get water into the fields without raising the feeder canal (as has to be frequently done in the Gash Irrigation Scheme).

High sediment loads in the rivers used as sources for domestic and industrial water supplies cause problems and additional expenditures for water treatment plants.

(b) Benefits of Sedimentation

Some 38 percent of sediment is deposited in fields: 2.99 million tons in Gezira and 0.93 million tons in Rahad. No data is available for Sudan on the fertilizer equivalent of sediment deposited in fields. Some data is available from Egypt. Nixon (2004) estimated that prior to the construction of the Aswan High dam some 35 million tons of sediment were deposited in the fields. Abu Zied and El-Shibini (2004) estimate the nitrogen content of the sediment deposited was 0.13 percent of which one third was available for plant growth. This would indicate that the sediment contained 45,500 tons of N of which 15,165 tons N were available for plant growth. Urea fertilizer has an N content of 45 percent. The available N is thus equivalent to 32,970 tons of Urea. Thus for each ton of sediment there has 0.94 kgs of urea.

This would indicate that deposition of sediment in Gezira and Rahad is equivalent to 3,692 tons of urea fertilizer. With a price of urea at US$ 286 /ton the benefits accruing to sediment deposition amount to SDD 21.2 million (US$ 1.1 million) for the Gezira and Rahad schemes. The gains are annual and not cumulative due to nutrient uptake by crops, leaching and volatization losses. It is possible there is some residual accumulation of phosphorous although given the high P fixing properties of the Gezira soils the amount available to plants is likely to be negligible.

(iii) Costs of Dredging Turbine In-takes

The need to dredge in front of turbine in-takes occurs only at Roseires Dam. More than 100,000 m3 of sediment is annually removed from the in-takes prior to the flood season (Ahmed Musa Siyam et al., 2005). Costs of clearing the intake are said to be US$ 20 /m^3 at a total annual cost of SDD 400.0 million (US$ 2.0 million).

(iv) Downstream hydroelectricity production forgone

The loss of hydro-power generation due to the very small or zero sedimentation rates in Roseires and Senner reservoirs is negligible. Using data from the Sudan Electricity Corporation for the years 1965 to 2005 the average drop in power generation in the month of August when the dam is flushed compared with other months was 1.3 MWH with a value of SDD 26 million/yr (US$ 0.13 million/yr). Data for Rosieres is not available but assuming the same proportion of drop in total power output this would be equivalent to about 1.86 MWH with a value of SDD 37.1 million/yr (US$ 0.2 million/yr).

4.5.3 Deforestation and Degradation: Sudan

(i) Deforestation

Some 1.3 million ha of woodland and shrubland were cleared for the Semi mechanized farms. The complete removal of vegetation and the consequent removal of natural predators (snakes and cats) have led to an increase in rats and other vermin. Insect eating birds have disappeared leading to a big increase in the use of insecticides and insect damage. Because the land is totally cleared of all tree cover and combined with years of constant harrowing and disking the tree seed bank in the soil has been completely destroyed. The abandoned areas are a waste land with no tree cover. The quality of the grass cover is very poor because of the very low levels of soil fertility.

Pressure on the remaining woodlands is intense. This pressure is from wood removal for charcoal, fuelwood, construction, furniture and lime burning. Estimates are not available for the whole Sub-basin but in the Bau Locality of Blue Nile State it has been estimated using consumption data from ENTRO, (2005) and stocking data from Glen (1996) that some 224,180 ha of woodland are cleared annually. Some will have been cleared legally as part of a prescribed long-term rotation, but a substantial proportion is being cleared without permit. In the absence of definitive data it is difficult to place a value on this.

However, assuming that 50 percent is cut illegally with a stocking rate of 5.04 m3/ha (Groupe Poulin Theriault, 1984) and a stumpage value for charcoal/fuelwood of SDD 1,000/m^3 (US$ 5 /m^3)[19], this represents an annual loss of SDD 112.1 million (US$ 0.56 million/yr). In terms of the loss of CO2 sequestration this is an annual loss of 56,000 tons of carbon. Using a value of $US 3.00/ton C this represents a value of SDD 33.6 million (US$ 0.17 million). This is a total annual loss of SDD 145.7 million or US$ 0.73 million just for this locality.

In addition, closed woodland cover has a value for watershed services, NTFP's and potential pharmaceuticals and species and habitat biodiversity. Using the same values as those in Ethiopia's woodlands the annual net costs of these services are:

	(SDD million)	(US$ million)
Watershed management services:	941.6	4.71
NTFP's, Potential Pharmaceuticals:	112.1	0.56

[19] A UNDP/World Bank Wood Energy/Forestry Project appraisal report estimated the 1986 stumpage value for charcoal at £S8.0/m3 and fuelwood £S14.5/m3: a weighted value of £S9.6/m3. (US$5.80, US$3.25 and US$3.85 respectively @ £S2.50: US$1.00)

Species and Habitat Biodiversity:	179.3	0.90

(ii) Woodland Degradation

Not all woodland is clear felled. Fuelwood collection often reduces the woody biomass stocks without totally removing tree cover. In the Blue Nile Sub-basin approximately 11.8 million m^3 of wood fuel and charcoal (per capita consumption of 0.73 m^3)[20] are consumed forming about 80 percent of the total energy consumption. This represents some million tons of carbon lost. Using the same values as above this amounts to some SDD 1,674 million (US$ 8.4 million).

4.5.4 Degradation of Rahad-Dinder Wetlands

The Rahad-Dinder wetlands comprise a large number of ox-bow lakes and cutoff meanders along and between the Rahad and Dinder Rivers known as *mayas*. They are found at various stages of sedimentation: from pristine small lakes through to those completely filled with sediment. The sedimentation is due to the high sediment loads of the two rivers originating in the Ethiopian Highlands. It is reported (Salwah M. Abdelhameed et al., 1997) that the rate of sedimentation is the *mayas* is increasing.

These wetlands provide a number of environmental services and products. These include the following:

(i) Ecological benefits (Environmental Services):
- recharge of groundwater,
- moderation of stream flow and buffering flood peaks,
- sediment trapping.
- Biodiversity (species and habitats)
- pasture for wild animals

(ii) Socio-economic Benefits from Environmental Services
- reduced health problems from purification of drinking water,
- reduced sedimentation of downstream dams and reservoirs.

(iii) Socio-economic Benefits from Wetland Products
- human water supply,
- livestock watering,
- pasture for livestock
- medicinal plants,

[20] MEPD/HCENR (2003) "Sudan's First National Communications under the United Nations Framework Convention on Climatic Change: Volume I: Main Communications", Khartoum.

There is no information on the amount recharge of groundwater from the wetlands. Unlike the valley-bottom wetlands of the Ethiopian Highlands they are not cultivated. The numbers of people and livestock using the mayas as source of water are considerable. Also many people are using them as a source of medicinal plants. However, there is no quantitative data on the use of these wetland products.

The sediment trapping properties of the wetlands has both costs and benefits. Sediment trapped in the mayas reduces downstream sediment loads. On the other hand increasing rates of sedimentation of the *mayas* reduces their flood buffering capacity leading to higher flood peaks. The exact impact of accelerated *maya* sedimentation on reducing their buffering capacity is difficult to estimate without some detailed surveys and modeling. Bullock and Acreman (2003) examined 439 published papers on wetlands. Of these 23 out 28 studies found that floodplain wetlands reduce or delay floods.

The area between the Rahad and Dinder Rivers is subject to frequent flooding causing extensive damage to crops. Some reports show that about 40 percent of crops are destroyed every 3 to 4 years[21]. An examination of the Africover (2003) map of the area between the Rahad and Dinder Rivers indicates that there are some 414,180 ha of large-scale semi-mechanized farms (SMF's) and 46,000 ha of traditional farms: a total of 460,180 ha. Assuming that 40 percent of this area is flooded and crops destroyed every 4 years gives an estimated area of 165,700 ha of SMF's and 18,400 ha of traditional farms affected.

The net value of production on the semi-mechanized farms is SDD 825/ha (MOA, 2006a) and that on the traditional farms SDD 2,530/ha (MOA, 2006b). This translates into losses every 4 years of SDD 136.7 million (US$ 0.68 million) for the SMF's and SDD 183.3 million (US$ 0.23 million for the traditional farming sector: a total of SDD 183.3 million (US$ 0.92 million). On annual-basis this would be SDD 45.8 million (US$ 0.23). Using a social discount rate of 5 percent (see annex 1) and a time period of 50 years gives a net present value of these losses of SDD 1,624 million (US$ 8.1 million). This provides an indication of the value of the *maya* wetlands flood buffering services.

4.5.5 Summary of Costs of Natural Resource Degradation in the Abbay-Blue Nile Sub-basin: Sudan

The various cost estimates of natural resource degradation in the Abbay-Blue Nile Sub-basin in Sudan are summarized in Table 23.

[21] Sudan comment on 1st Draft Distributive Analysis Report.

Table 23. Summary of Costs of Natural Resource Degradation in the Abbay-Blue Nile Sub-basin: Sudan.

Resource	Annual		After 25 years	
	SDD million	US$ million	SDD million	US$ million
1. Soil productivity decline				
- SMF's	326.9	1.6	6,482.1	32.4
- Traditional rainfed Sector	91.0	0.5	2,022.7	10.1
2. Sedimentation				
- Irrigation area lost	-	-	0	-
- Dredging/Weed cleaning	1,452.4	7.3	1,452.4	7.3
- Dredging turbine in-takes	400.0	2.0	400.0	2.0
- Hydro-power lost: Flushing	63.1	0.3	63.1	0.3
3. Deforestation/degradation				
- Deforestation*	795.8	4.0	19,895.3	99.5
- Degradation	1,674.0	8.4	41,850.0	210.0
4. Wetlands: Flood buffering	45.8	0.2	45.8	0.2
TOTAL GROSS COSTS	**4,849.0**	**24.3**	**72,211.4**	**361.9**
Benefits: Sediment-Fertilizer	21.2	1.1	21.2	1.1
TOTAL NET COSTS	**4,827.8**	**23.2**	**72,190.2**	**360.8**

* One locality only

At the annual level the costs of sedimentation predominate but in the longer term the accumulating losses from soil degradation and deforestation predominate. Table 24 provides a distribution of these costs into local/national, Regional and Global. Some 48 percent of the costs have local/national implications, 11 percent Regional and 41 percent global.

Table 24. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Abbay-Blue Nile Sub-basin in Sudan

Resource	Annual			25 years	
	SDD million	US$ million	%	SDD million	US$ million
LOCAL/NATIONAL					
Soil fertility loss: SMF	326.9	1.6		6,482.1	32.4
Soil fertility loss: Traditional sector	91.0	0.5		2,022.7	10.1
Irrigation area lost	-	-	-	-	-
Dredging/Weed cleaning	1,452.4	7.3		1,452.4	7.3
Dredging turbine in-takes	400.0	2.0		400.0	2.0
Hydro-power lost: Flushing	63.1	0.3		63.1	0.3
Sub-total	**2,333.4**	**11.7**	**48%**	**10,420.3**	**52.1**
REGIONAL					
Watershed Services	470.8	2.4		11,769.5	58.8
Wetland sedimentation: Loss of flood buffering	45.8	0.2		45.8	0.2
Sub-total	**516.6**	**2.6**	**11%**	**11,815.3**	**59.0**
GLOBAL					
Carbon Sequestration: Deforestation	33.6	0.2		840.0	4.3
Carbon Sequestration: Degradation	1,674.0	8.4		41,850.0	210.0
Pharmaceutical Value forgone	112.1	0.6		2,802.3	14.0
Habitat/species Biodiveristy value forgone	179.3	0.9		4,483.6	22.4
Sub-total	**1,999.0**	**10.0**	**41%**	**49,975.9**	**250.7**
TOTAL GROSS COST	**4,849.0**	**24.3**		**72,211.4**	**361.9**
Less: Value of sediment as fertilizer	21.2	1.1		21.2	1.1
TOTAL NET COST	**4,827.8**	**23.2**		**72,190.2**	**360.8**

4.6 Impacts, Costs and Benefits of the Proposed Watershed Management Interventions: Sudan

4.6.1 Reduced Land Degradation and Increased Rainfed Semi-mechanized farms

The analysis uses the recently published MOA Economic Survey of Semi-mechanized Farms (MOA, 2006a) covering Gedarif, Kassala, Blue Nile, Sinnar, White Nile, Upper Nile, South and North Kordofan States. In the area covered by the Blue Nile Sub-basin the data for Blue Nile State was used. Crop prices were obtained from a second MOA study (MOA, 2006b) on the traditional rain-fed areas.

(i) Improved Technologies

Three main crops are cultivated: sorghum (58 % of the area), sesame (36 % of the area) and millet (6% of the area). Current yields are 480 kgs/ha, 233 kgs/ha and 157 kgs/ha for sorghum, sesame and millet respectively.

Improved technologies include 5 yearly sub-soiling to break the plough pan, in-furrow planting, high-yielding seed varieties and the use of *Acacia senagal* for Gum Arabic as the fallow. Yields are expected to increase over a three year period by 50 percent to 540 kgs/ha, 262 kgs/ha and 176 kgs/ha for sorghum, sesame and millet respectively.

A. senegal is cultivated on a 15 year cycle with gum harvesting commencing in year 5. Initially 10 percent of the farm in planted with a further 10 percent commencing in year 11. Thus, at 10 yearly intervals for a period of 5 years some 20 percent of the farm is under *A. senegal*. This is to ensure a constant supply of gum Arabic and to meet government requirements that at least 10 percent of the farm should be under trees. Gum yields in year 4 and 5 are 29 kgs/ha and 57 kgs/ha. From years 6 to 11 they are 115 kgs/ha declining in years 12 and 13 to 88 kgs/ha and 57 kgs/ha. In years 14 and 15 yields are 19 kgs/ha. The trees are felled and removed at the end of year 15. The wood has a residual value as charcoal which covers the cost of land clearing (Earl, 1985).

(ii) Farm analysis

The analysis was conducted over a 50 year time period using a discount rate of 10 percent. The discounted B:C ratio was 4. The mean annual incremental cash income is SDD 10,445/ha (US 52/ha). Sorghum accounted for 63 percent, sesame 35 percent, millet was negligible and gum 2 percent of incremental returns. At current market prices and using the MOA Survey costs the returns to millet are very low. The use of *A.sengal* as a fallow clearly has other benefits in terms of enhanced soil fertility, although these are difficult to quantify.

(iii) Sub-basin Analysis

Assuming that only 60 percent of the 3.14 million feddans (1.33 million ha) mapped as large farms is actually cropped in an average year, and that 60 percent of the land is improved there is the potential to improve crop production of 1.13 million feddans (475,200 ha).

The improved technology was assumed to be adopted over a 10 year period on some 1.13 million feddans (475,200 ha). The overall B:C ratio at 10 percent discount rate was 3.9. The B:C ratio increased to 4.9 using a 5 percent discount rate. The results are shown in table 25.

Table 25. Financial Analysis: Improved Technology – Semi-Mechanized Rainfed farms: Blue Nile Sub-basin

Financial Costs and Benefits of Improved Agronomy Interventions on SMF's in Blue Nile Sub-basin

	Cost WOP (SDD '000)	Cost WP (SDD '000)	Benefit WOP (SDD '000)	Benefit WP (SDD '000)	Incremental Cost (SDD '000)	Incremental Benefit (SDD '000)	B/C Ratio
SMF	46,462,905	54,028,182	55,148,417	85,002,230	7,565,277	29,853,812	3.9

	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
SMF	232.3	270.1	275.7	425.0	37.8	149.3	3.9

all costs and benefits are PVs over 50 years at 10% discount rate

(iv) Shelterbelt Planting on Semi-mechanized farms

(a) National

Opportunities for closer collaboration between the Semi-mechanized and Traditional Farming rainfed agricultural sectors exist. These involve the implementation of the government regulation for 10 percent tree planting on large government lease-hold farms through the provision of forestry services by communities to the large farms including supply of seedlings, planting and maintenance through to harvesting. Contracts for supply of seedlings, planting and care and maintenance could provide substantial contributions to households' financial assets as well as widening the range of the livelihood strategies.

Some 40 percent of the Semi-mechanized farms will not have *A. senegal* planted on them. Thus, there is the potential for re-forestation of some 76,000 feddans (31,920 ha) under these collaborative arrangements over a 10 year period. Assuming sustainable yield of 5 m^3/ha on a 15 year rotation then an annual cut of 159,600 m^3 would be possible. This could be converted to 28,730 tons/yr of charcoal. Charcoal production costs at site are estimated to be 87 percent of the site selling price (UNDP/World Bank, 1988). Current price of charcoal at site is SDD 70,000/ton. The total annual net revenue is estimated to be SDD 262 million/yr (US$ 1.3 million/yr).

However, when the opportunity costs of the crop production that is forgone are taken into account the long term (50 years) B:C ratio using a 10 percent discount rate is only 0.7. This rises to 0.84 and 0.91 when the rate is lower to 5 percent and zero percent respectively. This may explain why farmers are reluctant to plant shelter belts and point to the need for tax concessions to encourage their planting.

A second opportunity for collaboration is the utilization of the estimated 1.7 million tons of residues for livestock feed for transhumant pastoralists. This is sufficient to feed 920,000 tropical livestock units (250 kgs live-weight). Using the annualized value of a tropical livestock unit as a basis the value of residues as livestock feed is SDD 2,282/ton (US$ 11.40/ton). Assuming that 60 percent is available to livestock this gives an estimated value of the residues as livestock feed as SDD 2,328 million (US$ 11.6 million).

(b) Potential Global Benefits

Increased crop production increases the production of crop residues and if these are left after harvest can contribute to increasing soil organic matter. Research in a semi-arid zone in Kenya showed that an increase of just 0.3 tons/yr of residues left on the soil increased soil carbon by 20 percent over a 50 year period (FAO, 2004). Research in North Kordofan (Olsson and Ardo, 2002) indicates current levels of carbon in cultivated land to be 1.5 tons/ha. A 20 percent increase in soil carbon in the soils of the 1.13 million feddans (475,200 ha) of improved cropland would amount to 95,040 tons of carbon. Using a value of US$ 3/ton of carbon this amounts to SDD 57 million (US$ 0.29 million).

Putting 10 percent of the total cropped land under trees (either as *A. senegal* or Shelterbelts) would mean that there would an increase in soil carbon. Research in Northern Kordofan (Olsson and Ardo, 2002) suggests that converting cropland to woodland increases soil carbon from 1.5 tons/ha (under millet) to 2.5 tons/ha over a period of 50 years. Thus, total soil carbon would accumulate at the rate of 0.03 tons/ha/yr. Total soil carbon in the tree areas would increase from 1,426 tons in the first year rising to 36,640 tons after 25 years. This incremental soil carbon is valued at SDD 21.4 million (US$ 0.11 million).

4.6.2 Reduced Land Degradation and Increased Rainfed Traditional Agricultural and Pastoral Production

(ii) Specific Interventions to Improve Crop Productivity

Two specific interventions to raise crop productivity have been proven by Research: higher yields crop varieties for sorghum, sesame and groundnuts, and the use of tied ridging to increase soil moisture. It estimated that using both improved varieties and tied ridging yield increases of 50 percent are possible (Mekki Abdul Latif, 2005).

(iii) Farm Level Analysis

The analysis uses the recently published MOA Economic Survey of Traditional rainfed Areas (MOA, 2006b) covering Blue Nile, Sinnar, White Nile, South and North Kordofan States. In the area covered by the Blue Nile Sub-basin the data for Blue Nile State was used. Crop yields were assumed to increase by 25 percent in the first year and to 50 percent from year 2 on-wards. Increased family labour for tied ridging and additional time for harvesting and threshing and increased cost of improved seed varieties[22] were the main incremental costs.

The analysis was conducted over 50 years using a discount rate of 10 percent. The farm level B:C ratio is 2.6.

(iv) Sub-basin Level Analysis

An estimated 1.05 million feddans (411,080 ha) of traditional rainfed farms have been mapped in the Blue Nile Sub-basin, although because of their small size and the spatial resolution of the Landsat satellite imagery this may be an underestimate. Additionally, returning displaced people and natural migration into the area will lead to an increase in area cultivated.

The analysis assumes that 50 percent of the area will adopt the new technology over a period of 10 years. The discounted incremental benefits are SDD 106.5 million (US$ 532.7 million). The overall B:C ratio is 1.7. The results are shown in table 26.

Table 26. Financial Analysis: Improved Technology – Traditional Rainfed farms: Blue Nile Sub-basin

Financial Costs and Benefits of Improved Agronomy Interventions on Traditional Farms: Blue Nile Sub-basin

	Cost WOP (SDD '000)	Cost WP (SDD '000)	Benefit WOP (SDD '000)	Benefit WP (SDD '000)	Incremental Cost (SDD '000)	Incremental Benefit (SDD '000)	B/C Ratio
Trad. Farms	84,322,098	148,835,647	113,284,383	219,827,666	64,513,549	106,543,283	1.7

	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
Trad. Farms	421.6	744.2	566.4	1,099.1	322.6	532.7	1.7

all costs and benefits are PVs over 50 years at 10% discount rate

[22] Currently MOA are distributing improved seed free of charge.

(v) Global Benefits

The increase in crop residue production would be approximately 220 kgs are 70 percent of that on the Semi-mechanized farms. The increase in soil carbon would be slightly less – an estimated 1.4 percent increase. Over the 1.05 million feddans (411,080 ha) this would amount to an increase of 57,550 ton of carbon sequestered. Using the same value of carbon sequestered this would be valued at SDD 34.5 million (US$ 0.17 million).

Research on soil carbon in North Kordofan showed the value of fallow periods on soil carbon (Olsson and Atrdo, 2002). Under the current continuous cropping soil carbon will decline from 1 ton/ha to 0.68 tons in 100 years. Changing the crop:fallow ratio to 5:6, 5:10 and 5:20 would increase soil carbon content to 1.15, 1.28 and 1.70 tons/ha respectively. In the absence of data on possible future rates of change in the crop:fallow ratios it is difficult to place a value on these.

4.6.3 Reduced Sediment Load in the Abbay-Blue Nile

(i) New Sediment Budget of the Abbay-Blue Nile Sub-basin

The new sediment budget for the Abbay-Blue Nile Sub-basin is shown in table 27. The reductions in sedimentation are approximately 30 percent of current rates. It can be expected that there would be a commensurate reduction in costs of sedimentation (i) loss of irrigation water and crop production, (ii) reduction in operation and maintenance costs of irrigation schemes, (iii) lost hydro-power production. It is difficult to forecast the potential impact these reductions in suspended sediment load will have on the current dam operational procedures (i.e. waiting for the main sediment peak to pass before closing the gates) and so on lost potential to store water and the current hydro-power generation losses.

Table 27. Abbay-Blue Nile Sub-basin: Estimated Current Sediment Budget: With Watershed Management Programme and only Existing Dams.

	(1) NO WSM OR DAMS	(2) WSM ONLY	(1) - (2) REDUCTION
	M t/yr	M t/yr	M t/yr
SEDIMENT ENTERING KARADOBI	92.00	65.87	26.13
SEDIMENT RETAINED IN KARADOBI	0.00	0.00	
SEDIMENT THRU' KARADOBI	92.00	65.87	26.13
SEDIMENT ENTERING RIVER BELOW KARADOBI (EXCLUDING BELES)	46.81	31.56	15.25
SEDIMENT ABOVE BELES-ABBAY CONFLUENCE (M t/yr)	138.81	97.43	41.38
SEDIMENT ENETERING BELES	1.56	1.12	0.44
SEDIMENT RETAINED IN BELES RESERVOIR	0.00	0.00	
SEDIMENT THRU' BELES	1.56	1.12	0.44
SEDIMENT IN ABBAY AT BORDER	140.37	98.55	**41.82**
SEDIMENT ENTERING ROSIERES	140.37	98.55	41.82
SEDIMENT RETAINED IN ROSIERES (%)	15%	15%	
SEDIMENT RETAINED IN ROSIERES M t/yr	21.06	14.78	6.27
SEDIMENT THRU' ROSIERES	119.31	83.76	
SEDIMENT ENTERING RAHAD PUMP	119.31	83.76	35.55
SEDIMENT RETAINED IN RHAD PUMP (%)	1.88%		
SEDIMENT RETAINED IN RHAD PUMP (M t/yr)	2.24	1.57	0.67
SEDIMENT AFTER RAHAD PUMP	117.07	82.19	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	1.25%	1.25%	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	1.46	1.03	
SEDIMENT ENTERING SENNER	115.61	81.16	34.44
SEDIMENT RETAINED IN SENNER (%)	10%		
SEDIMENT RETAINED IN SENNER	11.56	8.12	3.44
SEDIMENT THU SENNER	104.05	73.05	
SEDIMENT AT GEZIRA/MANAGIL INTAKE	104.05	73.05	31.00
SEDIMENT RETAINED IN GEZIRA/MANAGIL (%)	7.5%		
SEDIMENT RETAINED IN GEZIRA/MANAGIL M t/yr	7.88	5.48	2.40
SEDIMENT AFTER GEZIRA	96.17	67.57	
SEDIMENT FROM RAHAD-DINDED	9.19	9.19	
SEDMENT BELOW RAHAD-DINDER CONFLUENCE	105.36	76.76	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	2.5%	2.5%	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	6.32	4.61	
BLUE NILE SEDIMENT AT KHARTOUM	99.04	72.15	26.89
SEDIMENT FROM WHITE NILE (3% OF 142mT/YR)	4.26	3.84	0.41
SEDIMENT MAIN NILE AT KHARTOUM (Mt/yr)	**103.30**	**76.00**	**27.30**

(ii) Lost irrigation water and Crop production

As there is currently no negative impact on irrigation water storage from sediment loads in the Blue Nile River.

(iii) Reduced Operation and Maintenance Costs of Rahad and Geizira-Managil Irrigation Schemes

In 1998 the Irrigation water Corporation annually removed some 6.9 million m^3 of silt from the Gezira Scheme at a cost of SDD 1,366.8 (US$ 5.87 million). Assuming a 30 percent reduction in these costs would indicate a benefit of SDD 410 million/yr (US$ 1.8 million). Savings in the Rahad Scheme are estimated at SDD 51.4 million/yr (US$ 0.26 million/yr).

Costs of damages caused to pumps and the additional costs of water purification for domestic water supplies by high sediment loads are not known. Thus, the impact of a 30 percent reduction in sediment load on these costs cannot be calculated but will be positive.

(iv) Lost Power Hydro-Production

There is no impact of river sediment loads affecting storage in Roseires and Senner Reservoirs and thus no saving due to reduced river sediment loads. It is not possible to forecast what, if any, changes will result in the flushing regimes of these two dams due to a 30 percent reduction in sediment load.

(v) Reduced costs of dredging Roseires Power Intakes

Current dredging costs are SDD 400 million/yr (US$ 2.0 million). These costs would reduced by SDD 120 million/yr (US 0.6 million).

(vi) Reduced Benefits for Sediment as Fertilizer

Currently 2.99 million tons/yr are deposited in fields in the Gezira Scheme and 0.93 million tons/yr in the Rahad Scheme. These would be reduced by approximately 30 percent reducing their benefits as fertilizer by SDD 63.4 million/yr (US$ 0.32 million/yr). This would require some 1,108 tons of urea as replacement.

(vii) Summary of Impacts of Reduced Sediment Load in the Abbay-Blue Nile River system.

Overall the benefits of reduced sediment loads are SDD 581.4 million/yr (US$ 2.7 million/yr) with un-measurable benefits to reductions in the damage to pumps and costs of water purification. Loss of benefits due to the fertilizer value is SDD 63.4 million/yr (US$ 0.32/yr). The net measurable net impacts are SDD 518.0 million/yr (2.38 million/yr).

4.6.4 Summary of Financial analysis of the Measurable WSM Interventions

This section summarizes the financial analysis of the two interventions that has preceded and outlines the resuts at the household level (table 28). The (discounted) costs of the supporting interventions have been included to determine an overall B:C ratio for the 10 year programme. The overall B:C ratio is 1.8, which indicates the costs of the supporting interventions are well covered by the incremental benefits from the two direct interventions. The greatest share of incremental benefits comes from the Traditional Rainfed Sector indicating its importance.

Table 28. Summary of Financial Analysis of the Programme of Direct Interventions for the Abbay Sub-basin: Ethiopia

Financial Costs and Benefits of WSM Interventions in the Blue Nile Sub-Basin

Intervention	Cost WOP (SDD'million)	Cost WP (SDD'million)	Benefit WOP (SDD'million)	Benefit WP (SDD'million)	Incremental Cost (SDD'million)	Incremental Benefit (SDD'million)	B/C Ratio
Arresting Soil Degradation: Traditional Farms	84,322	148,836	113,284	219,828	64,514	106,543	1.7
Arresting Soil Degradation: Semi-mechanized farms	46,463	54,028	55,148	85,002	7,565	29,854	3.9
Supporting Interventions	-	-	-	-	19,798	-	
TOTAL	**130,785**	**202,864**	**168,433**	**304,830**	**91,876**	**136,397**	**1.5**

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
Arresting Soil Degradation: Traditional Farms	9,748.2	17,206.4	13,096.5	25,413.6	7,458.2	12,317.1	1.7
Arresting Soil Degradation: Semi-mechanized farms	5,371.4	6,246.0	6,375.5	9,826.8	874.6	3,451.3	3.9
Supporting Interventions	-	-	-	-	2,288.7	-	
	15,119.7	**23,452.5**	**19,472.0**	**35,240.5**	**10,621.6**	**15,768.5**	**1.5**

all costs and benefits are PVs over 50 years at 10% discount rate

4.7 Estimated Budget - Direct and Supporting Interventions: Sudan

The previous section has outlined some of the quantifiable costs and benefits accruing to the direct interventions. All of these depend to a greater or lesser extent on the implementation of the Supporting Interventions. These Supporting Interventions will provide increased physical and human capacity to rural households and government implementing organizations and in particular the extension Service; support to assisting rural families to gain non-farm employment and to small enterprise development in both rural areas and small urban centers; improved road and market infrastructure and increased capacity of farmers in product marketing and with increased available and access to micro finance and credit. The details of these and their direct and indirect benefits are summarized Matrix 2 in Chapter 2.

This section provides a summary of the budget required to implement both Direct and Supporting Interventions. A detailed breakdown with units and unit costs is provided in Annex 3. A summary is provided in table 29. Given the very complex nature of the relationships between the Direct and the Supporting Interventions, in particular their short and long term impacts on human welfare and development in local, State and National terms it would be extremely hazardous to attempt an overall benefit-cost analysis. However, it is submitted that the figures below provide a sense of the orders of magnitude in implementing a programme of interventions as outlined in Chapter 2.

The 10 year costs of Direct Interventions are estimated at SDD 15,100 million (US$ 75.5 million) and those of the Supporting Interventions SDD 16,655 million (US$ 83.3). The total estimated budget is SDD 31,756 million (US$ 158.8) or SDD 575,960 /traditional farm household (US$ 2,880/farm household).

Table 29. Summary 10 Year Budget: Blue Nile Sub-basin – Sudan (a) Direct Interventions, (b) Supporting Interventions and (c) Total budget

(a) Direct Interventions

Intervention	SDD	US$
1. ARRESTING SOIL DEGRADATION CROP INTENSIFICIATION	2,980,830,000	14,904,150
2. LIVESTOCK DEVELOPMENT	11,739,700,000	58,698,500
4. REDUCING RIVER BANK EROSON	380,000,000	1,900,000
Sub-total	**15,100,530,000**	**75,502,650**

(b) Supporting Interventions

Intervention	Total cost (SDD)	Total cost (US$)
1. CAPACITY BUILDING	3,437,925,778	17,189,629
2. AGRICULTURAL EXTENSION	788,640,000	3,943,200
3. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT	576,482,000	2,882,410
4. COMMUNITY ASSETS DEVELOPMENT	11,739,700,000	58,698,500
5. IMPROVED MARKETING	55,800,000	282,750
6. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS	56,550,000	282,750
7. SUPPORT TO STRATEGIC LAND USE PLANNING	464,173,333	2,320,867
Sub-total	**17,119,271,111**	**85,600,106**

TOTAL

Intervention	Total cost (SDD)	Total cost (US$)
(a) Direct Interventions	15,100,530,000	75,502,650
(b) Supporting Interventions	17,119,271,111	85,600,106
TOTAL	**32,219,801,111**	**161,102,756**

SDD/Household	US$/Household
584,380	**2,922**
SDD/ha	**US$/ha**
146,095	**730**

The average cost per household in the traditional rainfed and pastoral sectors SDD 575,961 (US$ 2,880/household). Clearly non-farming members of the community will also benefit from the Direct and Supporting Interventions in terms of improved access to social services, employment and information. Costs per ha of rainfed cropland are SDD 146,095/ha (US$ 730/ha). Again areas of rangeland and forest will benefit from the Interventions. These per unit costs are presented only to provide a first estimate of unit costs when considering programme at the catchment or sub-catchment scale.

4.8 Economic Costs and Benefits at the Sub-basin Level

All costs and benefits for Ethiopia and Sudan broken down into national, regional and global are shown in table 30. The overall Sub-basin B:C ratio is 4.0. Measurable global benefits comprise approximately 5 percent of total benefits. Net Regional benefits are relatively small: comprising benefits from reduced sediment loads but with the offsetting costs of reduced fertilizer effect of sediment. In Ethiopia global benefits raise the B:C ratio from 4.4 to 4.7 but in Sudan there is only a slight increase.

Table 30. National, Regional and Global Benefits of WSM Interventions: Abbay-Blue Nile Sub-basin (US$ million)

Economic Costs and Benefits of WSM Interventions in the Abbay-Blue Nile Sub-Basin

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
ETHIOPIA							
National							
Soil conservation: Bunds	284.9	330.1	953.3	1,044.8	45.2	91.4	2.0
Soil conservation: Grass strips	550.9	556.1	1,034.1	1,082.2	5.2	48.1	9.2
Fertilizer/Improved seed	535.5	684.2	1,634.3	2,369.1	148.7	734.8	4.9
On-farm Forage	0.5	16.8	166.7	416.8	16.3	250.1	15.3
On-farm Trees: Fuelwood	0.9	22.4	170.1	382.7	21.5	212.6	9.9
On-farm Trees: Crop Production saved: Soil N retained	-	-	-	-	-	115.8	
Improved stoves	-	4.4	-	62.8	4.4	62.8	14.4
Area enclosure	436.0	809.2	869.3	7,330.3	373.2	6,461.0	17.3
Small-scale Irrigation	2.7	180.6	31.6	220.1	178.0	188.6	1.1
Small-scale Irrigation: Multiplier Impact	-	-	-	-	-	36.1	
Supporting Interventions	-	-	-	-	1,051.3	-	
Sub-total	**1,811.4**	**2,603.9**	**4,859.3**	**12,908.9**	**1,843.7**	**8,201.5**	**4.4**
Regional	-	-	-	-	-	-	
Global							
Soil conservation: Soil Carbon seq.	-	-	-	-	-	36.4	
On-farm Trees: Tree carbon seq.	-	-	-	-	-	15.2	
Improved Stoves: Fuel saving: Tree Carbon seq.						6.7	
Enclosed areas: Tree carbon seq.	-	-	-	-	-	282.6	
Enclosed areas: Soil carbon seq	-	-	-	-	-	126.2	
Sub-total	**-**	**-**	**-**	**-**	**-**	**467.1**	
TOTAL ETHIOPIA	**1,811.4**	**2,603.9**	**4,859.3**	**12,908.9**	**1,843.7**	**8,668.6**	**4.7**
SUDAN							
National							
Traditional Rainfed Farms: Crop production	326.7	804.5	441.1	1,186.6	477.9	745.5	1.6
Semi-mechanised farms: Crop production	157.8	190.9	331.7	513.9	33.2	182.2	5.5
Semi-mechanised farms: Charcoal production	-	23.8	-	14.0	23.8	14.0	0.6
Semi-mechanised farms: Residue: Livestock feed	-	-	-	-	-	10.0	
Supporting Interventions	-	-	-	-	52.6	-	
Sub-total	**484.4**	**1,019.2**	**772.9**	**1,714.5**	**587.4**	**951.7**	**1.6**
	-						
Regional							
Reduced OM Costs: Irrigation schemes	-	-	-	-	-	2.6	
Reduced Derdging Power intake	-	-	-	-	-	5.9	
Reduced fertilizer value: Sediment	-	-	-	-	-	(3.1)	
Sub-total	**-**	**-**	**-**	**-**	**-**	**5.4**	
Global							
Traditional Rainfed Farms: Soil carbon	-	-	-	-	-	1.7	
SMF's : Soil carbon	-	-	-	-	-	2.9	
SMF's : Tree Cover: Soil carbon	-	-	-	-	-	0.1	
Sub-total	**-**	**-**	**-**	**-**	**-**	**4.6**	
TOTAL: SUDAN	**484.4**	**1,019.2**	**772.9**	**1,714.5**	**587.4**	**961.7**	**1.6**
TOTAL: SUB-BASIN	**2,295.9**	**3,623.1**	**5,632.2**	**14,623.4**	**2,431.1**	**9,630.3**	**4.0**

all costs and benefits are PVs over 50 years at 10% discount rate

5. COSTS, BENEFITS AND IMPACTS OF WATERSHED MANAGMENT INTERVENTIONS: TEKEZE-ATBARA SUBBASIN

This chapter begins by looking at the benefits for the Tekeze-Atbara Sub-basin deriving from the interventions of the programme as a whole. The analysis considers benefits at the local community level, the national, the Sub-basin/Regional and the global levels.

The rest of the chapter first considers Ethiopia and then Sudan. For each country the analysis first examines the costs of continued natural resource management practices and then analyses the impacts, costs and benefits of the direct interventions.

5.1 Benefits for the Tekeze-Atbara Sub-basin of the Watershed Management Interventions of the Programme as a Whole

5.1.1 Household and Community Level: Local Rural-Urban Linkages

The results of the benefit-cost analysis of on-farm and community interventions demonstrate that notwithstanding the lower rainfed agricultural potential of the Tekeze-Atbara Sub-basin, there is significant potential for increasing household farm incomes, increasing food supply with improved levels of nutrition and health, reducing vulnerability to climate, social and economic shocks and improving the quality of the natural resource base. As with the Abbay-Blue Nile Sub-basin a key finding is that a number of the interventions have substantial costs in terms of labour for construction or establishment. For a number of the interventions it takes a number of years for benefits to be realized (on-farm and community tree planting) or benefits only slowly accrue (SWC measures).

The support to traditional water harvesting rainfed systems in the Kassala area will increase crop and residue production, increase crop diversification and thus have a positive impact on farm income. Vulnerability of households to natural shocks in this difficult environment will be reduced.

In the areas of food deficits there are a number of programmes that support households and communities through food/cash for work and safety net support measures. However, there is an urgent need to extend support to households and communities in apparently more favourable areas where there is clear evidence that the high costs of initial labour requirements are an impediment to adoption of SWC measures on cropland.

The programme of interventions will have a substantial impact on arresting degradation of the natural resource base both on cropland and also on non-cropland. This is a vital entry point in breaking the cycle of poverty and resource degradation and attacks one of the root causes of poverty in the Tekeze-Atbara Sub-basin. Conservation of the non-croplands through enclosure and tree enrichment planting will provide not only direct benefits to communities in terms of increased livestock feed and improved livestock productivity and increased supply of fuelwood and timber, but also an increase in wild plants of food and medicinal values that are of considerable importance to the most disadvantaged community members such as female headed households.

The interventions that increase the easily accessible supply of fuelwood (on-farm tree planting) and the reduction in its consumption (using fuel efficient stoves) will have consider impacts on reducing the work loads of women and children. In addition, there will positive impacts on their health and well-being through the reduction in smoke inhalation thus reducing the incidence of respiratory diseases.

The SWC structures on cropland and the enclosed areas on non-cropland will reduce runoff and increase infiltration to groundwater. There is evidence (WFP, 2005) that where integrated watershed management measures have been implemented that groundwater levels have risen and long dormant springs have started to flow.

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The supporting interventions will have substantial benefits to households and communities. Measures to increase market accessibility and integration such as feeder roads and extension of telecommunications will have positive impacts by reducing market transaction costs thus benefiting both producers and consumers. The interventions will enable an expansion of local economic multipliers. At the local level these will occur through increased incomes being spent on purchases of local non-tradable goods i.e. goods made locally rather than those imported. Work in an inaccessible area of Nigeria similar to many parts of rural Ethiopia and Sudan suggested a multiplier of 1.32 for the non-tradable sector (Hazell & Roell, 1983). In addition, there will be increased backward multipliers (from an increased demand for improved inputs) and forward multipliers (from an increase in marketed agricultural products. These in turn will increase employment opportunities in the many small urban centres for rural and urban households.

The capacity building interventions will have a number of positive benefits at the local level. Increased access to improved technologies (with increased support to extension and research services) combined with access to literacy and skills training have been shown to be strongly correlated with increased adoption of improved agronomic technologies. The support to the Extension Service with improved information linkages between farmers and research will increase the relevance of agricultural research to the traditional small-holder sector. Increased road accessibility and skills training will enable rural households to have better access to non-farm employment opportunities.

Increased access to micro credit will provide an important enabling environment for farmer adoption of improved technologies, in particular fertilizer and improved seeds. Credit together with support to small enterprise training will also enable the development of small enterprises in the small urban centres further increasing employment opportunities. It must emphasized that there a number important synergies between the various interventions most particularly in improving rural-urban linkages, the increasing economic development of small urban centres and increased agricultural production.

The support to Community Level Land Use Planning and Community Woodland Management Planning in Sudan will enable rural communities to better manage the natural resource base and sustainably harvest wood and other non-wood products. This will in turn assist in reducing local conflicts over natural resource use and increase access to all groups.

5.1.2 National Level

At the national level the interventions will increase the rate of poverty reduction and numbers of households needing safety net support. In both Ethiopia and Sudan the highest incidence of poverty is with the traditional agricultural smallholder sector. By targeting this sector (rather than the commercial agricultural sector) a proportionally greater impact will be achieved in reducing the numbers of households living below the poverty line.

A recent study by IFPRI and ASARECA[23] (Omamo,et al. 2006) covering all the counties in the Region including Ethiopia and Sudan found that the largest

[23] The Association for Strengthening Agricultural Research in Eastern and Central Africa

poverty reductions will come not from growth in export sub-sectors but from growth in those sub-sectors for which demand is the greatest – such a crop staples, livestock products, oil seeds and fruits and vegetables. Another more detailed study for Ethiopia (Daio et al., 2006) confirms these findings. The studies also found that agricultural productivity growth alone is insufficient to meet the Millennium Development Goals (MDG) poverty reduction targets. Growth in non-agricultural sectors and improvements in market conditions are also required.

The interventions to increase market accessibility and integration will have positive impacts across the Sub-basin in each country as market transaction costs are substantially reduced. Sub-regional multipliers: backward and forward as well as growth of tertiary and secondary urban centres will stimulate the sub-regional economies. It is difficult to predict the size of these multipliers. Bhattari et al., (2007) have examined irrigation development across India and irrigation multipliers to the economy as a whole. They found irrigation multiplier values of 3 to 4.5 suggesting that about two thirds of the irrigation benefits have accrued to the non-irrigation sector, with farmers receiving the other third. Whilst markets and the economy as a whole in India are better integrated and accessible, with increasing market integration in Ethiopia and Sudan Sub-regional economic multipliers will become increasingly important.

In Ethiopia within the Tekeze Sub-basin four "Economic Sub-regions" can be identified: the Northeastern Sub-region, Southeastern Sub-region, the Western Tekeze Sub-region and the Western Region (Map 4). An "Economic Sub-Region is here defined as an area well delineated by its physiography, its road communication network and markets. Regional multiplier effects will be strongest inside each Sub-Region because of minimal economic linkages between each Sub-Region.

The Northeastern Region encompasses the most densely part of the Tekeze Sub-region and is located in Tigray Regional State. It has a relatively well developed road system. All the major urban centres including the Regional capital are located in the Sub-region, with the Regional capital of Makelle being a centre of significant demand fore agricultural produce. "Core" areas follow the primary road along the higher and wetter parts of the Sub-region. "Periphery" areas are located in the lower lying drier areas towards the Tekeze River. The proposed SWC interventions will contribute to arresting the decline of the resource base and increase food security. Small-scale irrigation development and water harvesting schemes will make significant contributions to incremental incomes and economic activity. Current developments in the non-agricultural sector (services and light industry) will stimulate demand for staples, livestock products, fruits and vegetables.

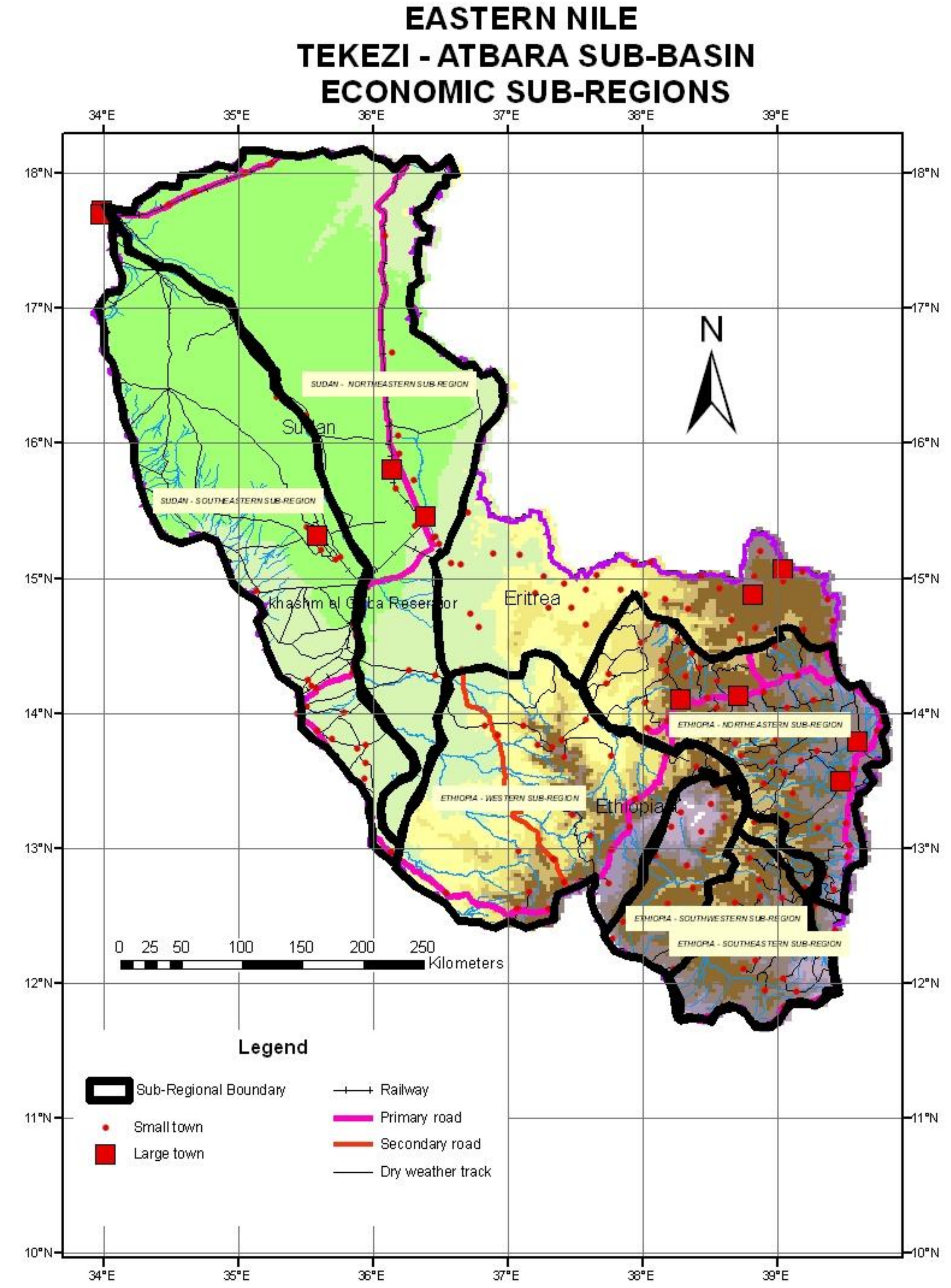
The Southeast Sub-region is located east of the Tekeze River within Amhara Regional State. It is relatively isolated from the regional capital of Barhir Dar although the Lalibela to Adua secondary road has increased accessibility. The area is subject to considerable low and variable rainfall and has a high proportion of its population classed as chronically vulnerable. The proposed programme of interventions will contribute to reducing vulnerability to natural shocks and increasing food security. The small-scale irrigation and water harvesting interventions will make a particularly significant contribution to reducing vulnerability and providing additional food security. The town of Lalibela with its rock-cut churches is developing as a tourist attraction and will provide a modest increase in demand for fruits and vegetables.

The Southwestern Sub-region is located on the opposite side of the Tekeze River to the east of the Simian Massif and is also in Amhara Regional State. This Sub-region is also relatively isolated from the relatively well-endowed Northwestern Sub-region of the Abbay Sub-basin as the primary roads are located along the ridges that form its periphery. Located in the rain shadow of the Simien Mountains the area also has low and variable rainfall. There are no medium sized towns. The interventions to increase market access and integration with the larger marketing system will have substantial positive impacts for this isolated Sub-region. The direct interventions for watershed management will contribute to reducing vulnerability and increasing food security.

The Western Sub-region encompasses the highland ridge on the western side of the Simien Mountains, the western escarpment and the western lowlands to the border with Sudan. The Highland areas are economically tied into the Northwestern Sub-region of the Abbay Sub-basin with the town of Gonder forming its "core". Although the western Lowlands are relatively sparsely populated it is served by the primary road to Metema and Sudan and a secondary road from Gonder to Humera. Humera is now linked by a secondary road to western Tigray and so into the Northeastern Sub-region's economy. Improved road conditions from Humera to Showak in Sudan will help to link the northern part of the western Lowlands into the Sudan economy. The programme of direct interventions will contribute to increasing incremental incomes in the Highland areas. Increased market accessibility and integration will contribute to linking the peripheral areas to substantial and growing market of Gonder. Much of the development of the Lowlands will come from commercial rainfed agricultural development and the proposed large scale irrigation at Humera.

In Sudan there are two main Sub-regions that will see positive impacts from the proposed programme of interventions. The first is in the Northeast Sub-region, found north of the Atbara River and includes the Gash delta and the rainfed water harvesting cropping systems, the Semi-mechanized farms and the traditional rainfed farms mainly to the east; the second is the Southeast Sub-Region found south of the Atbara River and includes the northern Butana Plain, the SMF's and the traditional rainfed farms. Both Sub-regions and Sub-sectors will see substantial increases in incremental incomes deriving from the Direct Interventions.

In addition to the local multipliers there will be substantial Sub-regional multipliers deriving from increased market accessibility and integration. Improved access to the Butana Plains with the implementation of the stock routes and water points will substantial increase livestock productivity and increased domestic and export earnings. The increase use of crop residues from the SMF's by pastoralists, agro-pastoralists and livestock holders in the large irrigation schemes will also contribute to increased livestock productivity and the Sub-regions economies.



Map 4. Tekeze-Atbara Sub-Basin: Economic Sub-Regions

The interventions to support State-wide Strategic land Use Planning in Sudan have clear linkages to Sub-regional economic development. The Strategic Plans will be developed with full stakeholder participation and will assist in clarifying development objectives and strategies. The plans will contribute to the harmonization of sectoral development strategies and so developing the synergy between sector developments identified in the IFPRI/ASARECA Study as necessary for substantial poverty reduction.

The Capacity Building interventions will contribute to the increased effectiveness of the agricultural Extension and Research Services. In each country this increase in both the quantity and quality of human capital will impact on the quality of research outputs and on extension advice. The Land Policy reforms in Sudan will have far reaching effects in increasing access to natural resources by the most disadvantaged, reducing Sub-regional and regional conflicts over resource access and use, and in increasing crop and livestock productivity. These will further re-enforce Sub-regional economic growth and its attendant multipliers.

5.1.3 Sub-basin and Regional Level

Benefits at this level reach across the political boundary and accrue to the Tekeze-Atbara Sub-basin and Eastern Nile Basin as a whole. Currently there is little trans-boundary trade between Ethiopia and Sudan but the expansion of economic development in the Sub-basin on both sides of the border, coupled with an extension of cross-border road-links, the potential for increasing integration of the Sub-regional economies of both countries becomes possible.

This is particularly so for the Ethiopian Western and the Sudan Southeastern Sub-regions. Increased access to Port Sudan for western Ethiopia would have a positive impact in reducing transport costs for both imports and exports. The expanding industrial sector in Sudan could provide off-farm employment opportunities for both Sudanese and Ethiopian households and so providing financial capital for investment in agriculture, agricultural processing and small-scale service sector enterprises in the small urban centres.

Closer cooperation in crop early warning systems, establishing joint strategic grain reserves and purchase of grains for food relief either side of the border would enable faster responses to local food shortages to the mutual benefit of both countries. Increased food security on both sides of the border will contribute to overall food security for the region.

The quantifiable benefits to reduced erosion in the Ethiopian Highlands and sediment loads in the Tekeze-Atbara river system on reducing costs within Sudan of dredging irrigation canals in the New Halfa Scheme, loss of power generating potential due to the need for reservoir flushing of the Kashm el Girba Dam are relatively small in comparison to the national benefits. Nevertheless, they will also contribute to a reduction in costs that it has not been possible to quantify: of pump and turbine damage and the removal of sediment for domestic and industrial water supplies. The reduced sediment load in the Atbara will also contribute to a reduction in the sedimentation of the Meroe Dam and to an increase in its economic life as well as contributing to a reduction in the rate of loss of live storage in Lake Nasser/Nubia and the loss of potential irrigation water and power generation for Egypt.

5.1.4 Global Level

The global benefits identified in the analysis relate to the increased amount of carbon sequestered in wood biomass, herbaceous biomass and soil carbon. In some cases it has been possible to quantify these and the results are provided below. In other cases such as improved pasture development in the Butana Plains this has not been possible because of the uncertainties in quantifying the amount of increased pasture that will result. Nevertheless, small-scale experiments have clearly demonstrated that increased herbaceous biomass will substantially increase the amount of carbon sequestered in the soil and that there is considerable untapped potential for increased carbon sequestration under improved pastures (FAO, 2003). This is notwithstanding that the increased herbaceous matter will be consumed by livestock – the carbon is stored in the soil. The small scale example of improved rangeland management supported by the GEF in Bara Province of North Kordofan described in chapter 8 indicates how this may be implemented at the local level.

Other global benefits accruing to the programme of interventions relate to the conservation of biodiversity. At the local level this is represented in the increase in native plant species in enclosed areas that have all but disappeared in the open access communal areas. Such an increase in species diversity will also be seen in the improved management of the pastures of the Butana Plains.

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. Thus, the interventions targeted at the traditional and the commercial farming sectors in Ethiopia and Sudan will generate these benefits.

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.

In Sudan a large number of natural selections of sorghum and millet have over millennia accrued a gene pool of considerable importance. In addition, the cultivation of *Acacia seyal* for its gum has also through centuries of natural selection accrued an important gene pool for this species.

The proposed interventions to support traditional agriculture will enable farm households to be buffered from natural shocks and allow them to maintain these important gene pools.

5.2 Costs of Continued Natural Resource Management Practices: Ethiopia

It is emphasized again that the physical impacts and costs outlined below do not reveal to full extent of the social and economic costs to the rural (and urban) population in terms of those key elements in the downward spiral of poverty and a degrading resource base such as poor nutrition and health, poor access to social services (health and education) and restricted access to alternative livelihood strategies.

5.2.1 Agricultural production forgone: Ethiopia

The soil erosion and nutrient breach rates were estimated and from them were derived the resulting agricultural production and income loss. The total quantity of soil eroded every year in the Tekeze Sub-basin is estimated at 100.5 million tons/yr of which 27.2 million tons/yr is from cultivated land and 73.3 million tons/yr is from mainly communal grazing and settlement areas. The cropland area with unsustainable soil loss rates is calculated to be 1.05 million ha comprising 0.53 million ha and 0.52 million ha in Tigray and Amhara Table 31).

Table 31. Percentage Annual Crop Yield Decline By Affected Area Due to Soil Erosion in the Tekeze Sub-basin

REGION	Percent annual yield decline					Total affected area
	0.2%	0.4%	0.8%	1.4%	4.8%	
	ha	ha	ha	ha	ha	ha
Tigray	255,633	193,572	59,348	15,700	6,778	531,032
Amhara	149,920	130,654	110,086	76,929	56,407	523,996
Sub-basin	**405,553**	**324,226**	**189,434**	**92,629**	**63,185**	**1,055,028**

The impact on crop production due to the decline in soil-moisture holding capacity caused by soil erosion is the loss of 2,396 tons/yr. Each year this loss accumulates so that the loss of crop production in 25 years is 59,891 tons/yr. Soil erosion also causes a nutrient loss that decreases crop production annually and non-cumulatively by 9,619 tons/yr. Crop production lost as a proportion of total annual crop product is 1.1 percent in year 1 rising to 6.5 percent in year 25.

The breaches in soil nutrient cycling caused by dung/crop residue burning and crop removal reduce crop production annually and non-cumulatively by 46,840 tons and 88,627 tons respectively. The total crop production forgone is shown in Table 32.

Table 32. Annual Crop Production Forgone Due to Soil Erosion, Dung/Crop Residue Burning and Crop Removal in Tekeze Sub-basin

Cause	Annual Crop Production Forgone (tons)		
	Year		
	1	10	25
Loss in soil moisture-holding capacity due to soil erosion	2,396	23,957	59,891
Nutrient loss due to soil erosion	9,619	9,619	9,619
Total due to soil erosion	**12,005**	**33,576**	**69,510**
Nutrient breach due to dung/crop residue burning for fuel	46,840	46,840	46,840
Nutrient breach due to crop removal	88,627	88,627	88,627
Total due to nutrient breach	**135,467**	**135,467**	**135,467**

Using the local price (ETB 1,880/ton) for wheat enables a monetary estimate to be made of these losses. Annual losses due to soil erosion are ETB 22.6 million/yr rising to ETB 130.7 million in 25 yrs or US$ 2.9 million rising to US 16.7 million.

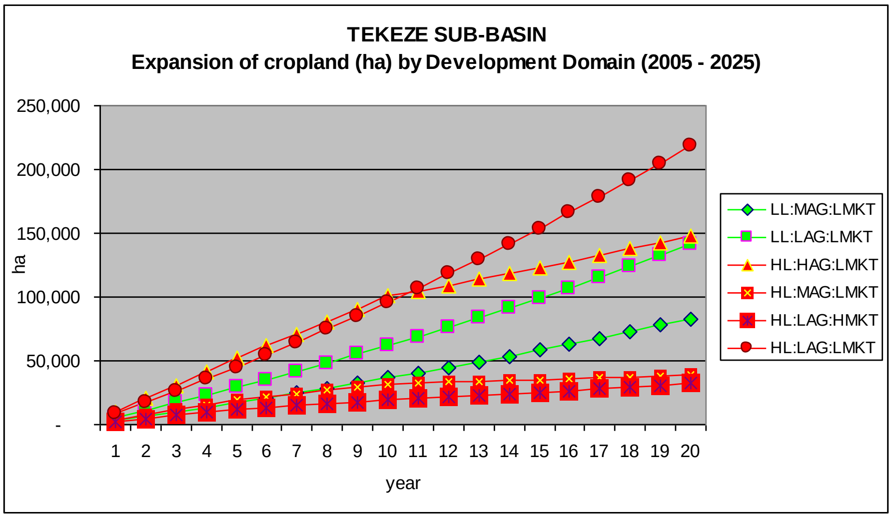
Annual losses due to nutrient breaches are estimated at ETB 254.7 million or US$ 32.67 million.

5.2.2 Future Trends in Soil Erosion without WSM Programme

The background and methodology to determine future trends in soil erosion caused by expansion of agriculture due to population increase were outlined in the Transboundary Tekeze-Atbara Sub-basin Report. The results of the analysis are shown in Chart form below for the Sub-basin.

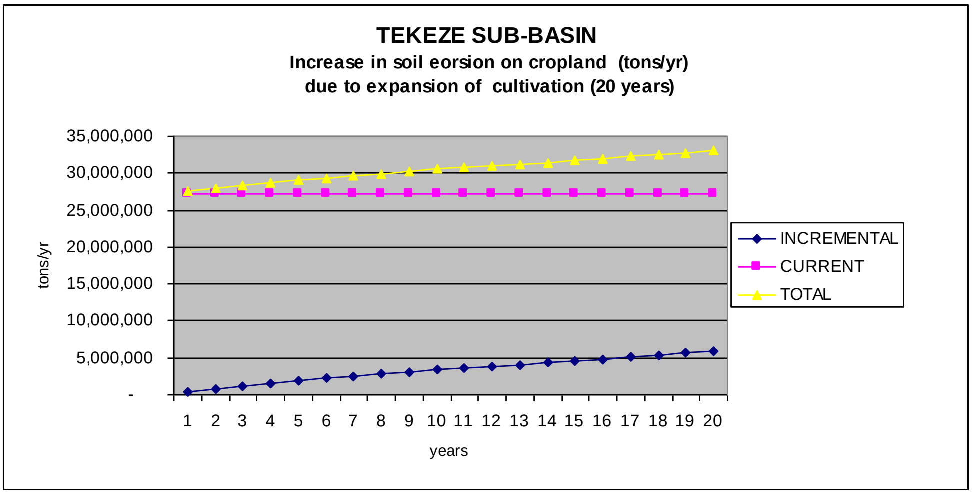
In the Tekeze Sub-basin the largest expansion of cropland will take place in the Highland Low Agricultural Potential-Poor Market Access Domain, followed by the two Lowland Domains (figure 7). The Highland Medium Agricultural Potential-Good Market Access domain has no potential and the Medium Potential-Poor 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.

Using the Sub-basin wide sediment delivery ratio of 60 percent[24] this would indicate an additional 4.3 million tons/yr of suspended sediment at the border – a 6 percent increase on current rates.

[24] Calculated in the Transboundary Report.

5.2.3 Reservoir and irrigation system sedimentation: Tekeze Sub-basin -Ethiopia

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). They studied 10 in detail. Of the 9 dams for which data was available 5 dams had between 15 and 50 percent of their design life remaining, 1 dam had 75 percent and the 3 remaining dams 100%.

The average sediment deposition in the 10 studied dams was 5,900 m^3/yr. Negussie Haregeweyne et al., 2005 estimate dredging costs at ETB 40/m^3 or ETB 236,000/yr (US$ 26,200/yr). Spread across 54 dams this would amount to ETB 12.7 million/yr (US$ 1.4 million/yr). These represent the annual damage avoidance costs of sedimentation in small dams in the Tekeze Sub-basin.

5.2.4 Deforestation and Wood Biomass Degradation

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. Over the past 5 years expansion is taking place in the Lowlands particularly in the area around Humera, which is a reception area for voluntary resettlement. The western Lowlands are also the location of some expansion of commercial agriculture. However, no data is available for land that has been cleared for resettlement or commercial agriculture.

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 the Tekeze Sub-basin 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.

In terms of carbon sequestration this represents a loss of some 635,000 tons of carbon. At the world price of US$ 3/ton C, this amount to a loss of ETB 17.1 million/yr (US$ 1.9 million/yr).

Other unquantifiable losses are of non-timber forest products (fruits, medicinal products, gums and resins, etc) and biodiversity.

5.2.5 Summary of Costs of Natural Resource Degradation in the Tekeze- Atbara Sub-basin: Ethiopia

The various cost estimates of natural resource degradation in the Tekeze-Atbara Sub-basin are summarized in Table 32.

Table 32. Summary of Costs of Natural Resource in the Tekeze-Atbara Sub-basin: Ethiopia

Resource	Annual		After 25 years	
	ETB million	US$ million	ETB million	US$ million
ETHIOPIA				
1. Soil Erosion/degradation				
- Erosion	22.6	2.9	130.7	16.7
- Nutrient breaches	254.7	32.6	254.7	32.6
2. Sedimentation	12.7	1.4	12.7	1.4
3. Deforestation/degradation				
- Deforestation	n.d.	n.d.	n.d.	n.d.
- Degradation Wood Biomass	17.1	1.9	17.1	1.9
TOTAL	**307.1**	**38.8**	**398.1**	**52.6**

n.d. = no data

Table 33 provides a distribution of these costs into local/national, Regional and Global. Some 94 percent of the costs have local/national implications, 8 percent Regional and 6 percent global.

Table 33. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Tekeze-Atbara Sub-basin in Ethiopia

Resource	Annual			25 years	
	ETB	US$	%	ETB	US$
LOCAL/NATIONAL					
Soil Erosion	22.6	2.9		130.7	16.7
Nutrient breaches	254.7	32.6		254.7	32.6
Sedimentation	12.7	1.4		12.7	1.4
Sub-total	**290.0**	**36.9**	**94%**	**398.1**	**50.7**
REGIONAL					
Sub-total	**-**	**-**	**0%**	**-**	**-**
GLOBAL					
Carbon Sequestration: Degradation	17.1	1.9		17.1	1.9
Sub-total	**17.1**	**1.9**	**6%**	**-**	**1.9**
TOTAL NET COST	**307.1**	**38.8**		**398.1**	**52.6**

5.3 Impacts, Costs and Benefits of the Proposed Direct Watershed Management Interventions

5.3.1 Soil Conservation and Improved Soil Husbandry

(i) Reduced Soil Erosion on and Sedimentation from Cropland

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 (Vancampenhout et al., 2005).

(b) Adoption Rates

All cropland with slopes exceeding 5 percent were assumed to require SWC measures. Results from the CSA Agricultural census indicate that 50 percent of land that requires SWC measures has already been treated. At the current rates of implementation it is possible to complete the remaining 50 percent within the next 10 years.

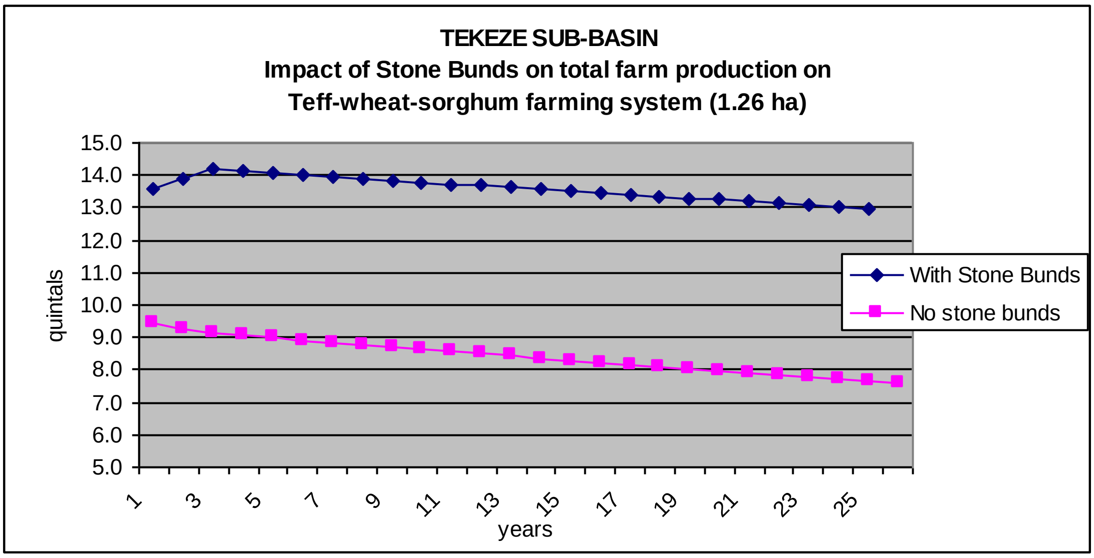
(ii) Reducing Declining Agricultural Production on Cropland

(a) Farm Level

The without and with SWC measures decline in total farm production for the teff-wheat-sorghum farming system in the Tekeze Sub-basin for a soil losing 8 mm of soil per year (100 tons/ha) are shown in figure 9. The without-bund annual production decline due to loss of soil moisture holding capacity is 1.6 percent and the with-bund annual yield decline is 0.57 percent. There is also a yield increase of 7 percent due to increased soil moisture and an increase in yield from retained soil nutrients of 0.28Q/ha. Note also the buildup of yields as the effectiveness of the stone bunds increases.

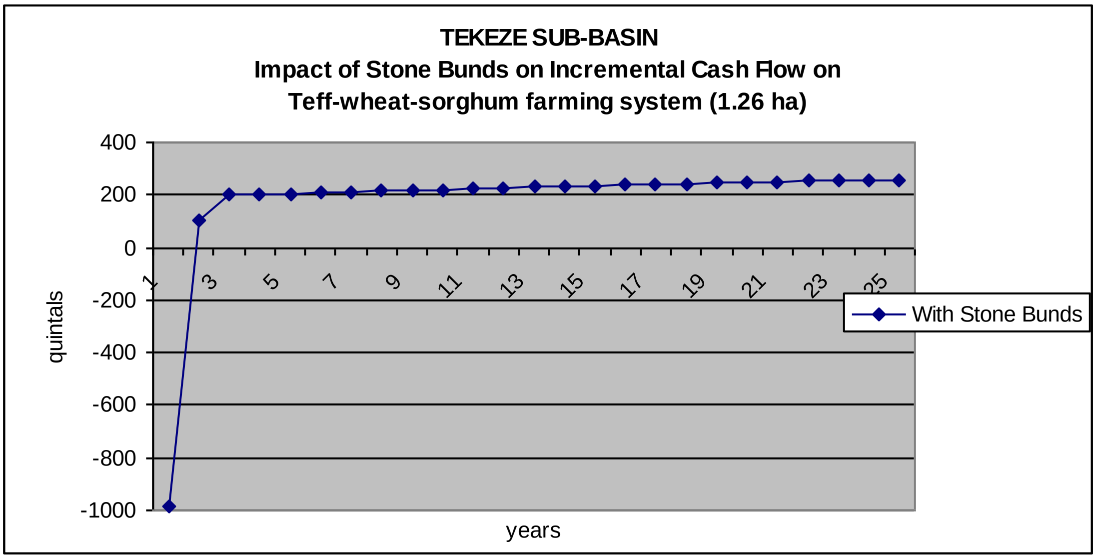
On a 1.26 ha farm with a soil loss rate of 8 mm/yr (100 tons/yr) the initial net change in farm production is 412 kgs per year building up to 534 kgs.

Figure 9. Changes in Farm production without and with soil bunds (25 years)



The net incremental value of farm production is ETB -986 in the year 1, which is a reflection of the costs of family labour (167 days at ETB 5/day) in constructing the bunds (figure 10). However, from year 2 this changes to ETB +105 rising to ETB +259 by year 25. Although the internal rate of return (over 25 years) is 20%, the pay-back period for ETB -986 is 5 years.

Figure 10. Impact of Stone bunds on Incremental Cash Flow: Soil Loss Rate of 8 mm/yr (100t/ha/yr) for Teff-Wheat-Sorghum farming System: Tekeze Sub-basin



In the Tekeze Sub-basin 3 farming Systems for which crop area and yield data were available (WBISPP, 2001, WBISPP, 2003) were analyzed to determine the impact on farm income, pay back period on investment costs, the financial internal rate of return (IRR) and the discounted B:C ratio over 25 years at 20 and 10 percent discount rates. The results are presented in

Tables 34a, 34b and 34c for soil loss rates of 2 mm/yr, 4 mm/yr and 8 mm/yr (25 tons/yr, 50 tons/yr and 100 tons/yr) respectively.

Table 34. Impact of Stone Bunds: Incremental farm income, Payback-back period (years), IRR (%) and B:C ratio at 20% and 10% discount rates: Tekeze Sub-basin

(a) 2 mm/yr (25 tons/yr) Soil loss

Farming System	Incremental Annual; Farm income year 1 (ETB)	Incremental Annual Farm income year 25 (ETB/yr)	Payback period (yrs)	IRR (%)	B:C ratio (20% discount rate)	B:C ratio (10% discount rate))
Sorghum,millet,teff	-1,215	236	14	10%	0.5	1.0
Teff, wheat, sorghum	-632	206	6	19%	0.9	1.8
Teff, barley, wheat	-599	175	6	17%	0.9	1.7

(b) 4 mm (50 tons/ha) Soil Loss

Farming System	Incremental Annual; Farm income year 1 (ETB)	Incremental Annual Farm income year 25 (ETB/yr)	Payback period (yrs)	IRR (%)	B:C ratio (20% discount rate)	B:C ratio (10% discount rate))
Sorghum,millet,teff	-2,005	257	15	9%	0.54	0.9
Teff, wheat, sorghum	-1,044	255	9	11%	1.2	1.5
Teff, barley, wheat	-989	240	8	12%	0.6	1.2

(c) 8 mm/yr (100 tons/yr)

Farming System	Incremental Annual; Farm income year 1 (ETB)	Incremental Annual Farm income year 25 (ETB/yr)	Payback period (yrs)	IRR (%)	B:C ratio (20% discount rate)	B:C ratio (10% discount rate))
Sorghum,millet,teff	-1,886	763	6	16%	0.8	1.3
Teff, wheat, sorghum	-986	259	5	20%	1.0	1.8
Teff, barley, wheat	-134	730	5	23%	1.1	2.2

The higher negative cash flows in year 1 for the 4 mm/yr and 8 mm/yr loss rates are due to the need to have closer spacing of the stone bunds and thus an increase in the labour requirement. The sorghum-millet-teff farm sizes are larger than the other two farming systems and thus require greater length of bunds and thus labour. At the 10 percent discount rate all but one case have B:C ratios greater than 1 and IRR's greater than 10%. At the 20 percent discount rate only 2 cases have B:C ratios great than 1. The key problems facing farmer adoption is the initial high labour requirements and the long payback period. For resource poor farmers with high personal discount rates clearly the financial benefits are not attractive. This clearly supports the case for support in constructing bunds either through cash or food for work.

(b) Sub-basin Level

Across the Sub-basin the cumulative increase in crop production is shown in table 35 assuming that 40 percent of land that requires conservation measures is covered.

Table 35. Tekeze Blue Nile Sub-basin: Cumulative Increase in Grain production due SWC Measures (tons)

1 year	10 years	**25 years**
1,785	17,854	44,635

To examine the Direct Intervention SWC programme (Stone Bunds) on its own, the benefit-cost analysis was undertaken over 50 years to take account of the 10 years of investments and using the Government discount rate for public investments of 10 percent. The results at the farming System level were aggregated to the Development Domain. The results are shown in table 36.

Table 36. Financial Benefit-cost Analysis of the Proposed SWC Programme on Cropland for Stone Bunds in the Tekeze Sub-basin over a 50 year time-frame and a Discount Rate of 10%: Results by Development Domain.

Financial Costs and Benefits of WSM Interventions by Development Domain in Tekeze Sub-Basin

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	332,895	380,705	676,749	741,992	47,810	65,243	1.4
HL:MAG:HMKT	243,055	284,886	695,246	749,156	41,831	53,910	1.3
HL:MAG:LMKT	296,576	339,882	623,605	682,375	43,306	58,770	1.4
HL:LAG:HMKT	77,304	91,073	171,527	189,321	13,770	17,793	1.3
HL:LAG:LMKT	271,344	312,553	616,676	671,885	41,210	55,209	1.3
LL:MAG:LMKT	89,496	132,205	430,201	481,869	42,709	51,668	1.2
total	**1,310,669**	**1,541,305**	**3,214,004**	**3,516,598**	**230,635**	**302,594**	**1.3**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	38	44	78	86	5.5	7.5	1.4
HL:MAG:HMKT	28	33	80	87	4.8	6.2	1.3
HL:MAG:LMKT	34	39	72	79	5.0	6.8	1.4
HL:LAG:HMKT	9	11	20	22	1.6	2.1	1.3
HL:LAG:LMKT	31	36	71	78	4.8	6.4	1.3
LL:MAG:LMKT	10	15	50	56	4.9	6.0	1.2
total	**151.5**	**178.2**	**371.6**	**406.5**	**26.7**	**35.0**	**1.3**

all costs and benefits are PVs over 50 years at 10% discount rate

Overall there is a benefit-cost ratio of 1.3. There is little difference in the B:C ratios between the Development Domains, except that the Lowland Domain has a slightly lower B:C ratio than the Highland Domains.

(c) Sub-basin Level: Regional Benefits

With the assumptions outlined above soil movement on cropland could be reduced from 27.2 million to 9.8 million tons. Using the sediment delivery ratio of 60 percent calculated in the Transboundary reports then annual sediment to Tekeze river system within Ethiopia could be reduced by 10.4 million tons (down from 16.3 million tons to 5.9 million t/yr).

The Regional impacts (in Sudan and Egypt are considered in sections 5.3.4 (Sudan) and 7.3.1 (Egypt).

(d) Global Benefits

Using the same methodology to estimate the loss of soil carbon in the Abbay Sub-basin indicates that some 1.15 million tons of SC is being retained behind the structures that otherwise would be lost. Using US$ 3.00 per ton of carbon means that the value of sequestered carbon not lost to erosion is ETB 15.6 million/yr (US$ 1.74 million/yr). As this accumulates in 25 years the value of sequestered carbon is ETB 390.5 million/yr (US$ 43.4 million/yr).

(iii) Gully reclamation and stream bank protection

(a) Gully Reclamation

The proportion of stream sediment originating from gullies, as distinct from cropland and non-cropland is not known but based on research elsewhere it is estimated at 20 percent[25] of the total loss on cropland and non-cropland. Research in Tigray (Nyssen et al., 2005a) estimated long-term soil losses from gullies at approximately 5 to 6 tons/ha/yr, although many gullies are discontinuous and sediment is often deposited in a debris fan at the foot of the slope.

In the analysis is has been assumed that 40 percent of the gullies on cropland and on non-cropland can be reclaimed over a 10 years period. It is estimated that at the end of the programme some 5.0 million tons/yr can be retained on non-cropland reducing the current contribution of 5.4 million tons to 2.7 million tons. On cropland sediment retention would amount to 2.7 million tons/yr, reducing the current contribution from 0.8 million tons/yr to 0.4 millions tons/yr. This amounts to a 1.5 percent reduction in the current sediment load of the Tekeze River of 76 million tons/yr at the border.

[25] The loess Plateau in China, which comprises hundreds of meters of extremely soft and erodible aeolian dust, and where gullies contribute the bulk of stream sediment is not comparable with Ethiopia.

(b) Stream bank Erosion

Research into dam siltation in Tigray (Negussie Haregeweyn et al., 2005) determined that 65 percent of siltation was due to river bank erosion above the dam. This clearly points to the need to ensure that river banks are protected above dams. This could be effected by area closure a short distance from the bank.

5.3.2 Crop Intensification and Diversification

(i) Reduced Cropland Soil Nutrient Breaches Grain Removal and Increased Agricultural Production from Fertilizer

(a) Farm Level

Assuming 20 kgs of N per 1 ton of grain and average grain yield of 700 kgs/ha means a loss of 14 kgs of N/ha/yr. To replace this would require 78 kgs of DAP.

The replacement of 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 on 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 higher in the climatic environment of the Tekeze Sub-basin and is a constraint to investment in chemical fertilizer for rainfed cropping. Nevertheless, some 32 percent of farmers in Tigray use chemical fertilizer at an average rate of 95 kgs/ha.

Fertilizer use not in combination of improved seeds provides a 64 percent increase in yield using the results of fertilizer trials (NCC, 1983). This compares with 114 percent increase when used in combination (Diao et al., 2005). The analysis was conducted using both interventions to allow a comparison between the two technologies. In the analysis it has been assumed that would use a rate of 100 kgs/ha of DAP on either teff or sorghum depending on which was the dominant crop in terms of area in the farming system.

The analysis was conducted using both interventions to allow a comparison between the two technologies. In the analysis it has been assumed that would use a rate of 100 kgs/ha of urea on either teff or finger millet depending on which was the dominant crop in terms of area in the farming system. However, sorghum is the dominant crop in the sorghum, millet, teff system but little fertilizer is applied to sorghum (CSA, 2006) but is applied to finger millet.

The percentage area fertilizer application rates are close to the current application rates. However, current area of cropland using improved seeds is approximately 3 percent. The results are shown in Table 37.

Table 37. Financial Benefit-cost Analysis of the Proposed Fertilizer and Improved Seed Intervention in the Tekeze Sub-basin

Farming system	Crop fertilized	Area (ha)	% farm area	B:C fert. only	B:C fert+seed	Inc. income (ETB/ha) fert only	Inc income (ETB/ha) fert+seed
1. Sorghum, millet, teff	Finger millet	1.00	41%	3.0	4.6	207	429
3. Teff, wheat, sorghum	Teff	0.46	37%	3.6	5.6	336	674
4. Teff, barley, wheat	Teff	0.36	30%	3.0	4.6	201	416

There is little difference between finger millet and teff in terms of the B:C ratios and incremental income for both the fertilizer only nor for the fertilizer and improved seed intervention. The teff-wheat-sorghum farming system has higher B:C ratios and incremental income because of the higher yield of teff over the other teff farming system.

(b) Sub-basin Level

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.

For the analysis it was assumed that an additional 20 percent of farmers would adopt fertilizer and improved seeds. Thus some 51,100 tons of urea would be used by 1.02 million farmers producing an additional 87,160 tons of grain. The analysis was conducted over a period of 50 years given the 10 year period of investment. A discount rate of 10 percent was used.

The results for the fertilizer only intervention are shown in table 38a and those for the combined fertilizer and improved seed intervention in table 38b. The overall B:C ratio is 3.2 for the fertilizer only intervention and 4.9 for the combined intervention.

Table 38. Financial Benefit-cost Analysis of the Proposed Fertilizer Intervention n the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

(a) Fertilizer Only

Financial Costs and Benefits of Fertilizer Only Intervention by Farming System in Tekezi Sub-Basin

Farming System	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
Sorghum, millet, teff	5,269	6,600	35,369	39,310	1,331	3,941	3.0
Teff, wheat, sorghum	15,923	20,348	67,351	83,139	4,425	15,788	3.6
Teff, barley, wheat	27,476	33,376	94,267	111,599	5,900	17,333	2.9
total	**48,668**	**60,324**	**196,987**	**234,048**	**11,656**	**37,062**	**3.2**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
Sorghum, millet, teff	0.6	0.8	4.1	4.5	0.2	0.5	3.0
Teff, wheat, sorghum	1.8	2.4	7.8	9.6	0.5	1.8	3.6
Teff, barley, wheat	3.2	3.9	10.9	12.9	0.7	2.0	2.9
total	**5.6**	**7.0**	**22.8**	**27.1**	**1.3**	**4.3**	**3.2**

all costs and benefits are PVs over 50 years at 10% discount rate

(b) Fertilizer and Improved Seed

Financial Costs and Benefits of Fertilizer + Improved Seedby Development Domain in Tekeze Sub-Basin

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	7,916	9,937	27,922	37,431	2,021	9,509	4.7
HL:MAG:HMKT	5,838	7,699	24,695	35,007	1,860	10,312	5.5
HL:MAG:LMKT	7,058	8,899	25,319	34,137	1,840	8,818	4.8
HL:LAG:HMKT	1,965	2,463	7,778	10,052	499	2,274	4.6
HL:LAG:LMKT	6,471	8,243	24,153	32,993	1,772	8,840	5.0
LL:MAG:LMKT	3,197	4,128	21,457	25,716	931	4,259	4.6
total	**32,445**	**41,369**	**131,324**	**175,335**	**8,924**	**44,011**	**4.9**

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	0.9	1.1	3.2	4.3	0.2	1.1	4.7
HL:MAG:HMKT	0.7	0.9	2.9	4.0	0.2	1.2	5.5
HL:MAG:LMKT	0.8	1.0	2.9	3.9	0.2	1.0	4.8
HL:LAG:HMKT	0.2	0.3	0.9	1.2	0.1	0.3	4.6
HL:LAG:LMKT	0.7	1.0	2.8	3.8	0.2	1.0	5.0
LL:MAG:LMKT	0.4	0.5	2.5	3.0	0.1	0.5	4.6
total	**3.8**	**4.8**	**15.2**	**20.3**	**1.0**	**5.1**	**4.9**

all costs and benefits are PVs over 50 years at 10% discount rate

(ii) Diversification of Agricultural Production

Diversification need not be confined to crop production and can include livestock fattening, sheep and goat rearing, improved honey production. In terms of crops a number of initiatives are now being promoted including: vegetables, fruit trees (apples and plums in the Highlands, Citrus and bananas in the Lowlands); organic coffee, and spices (corrarima, ginger). Quality control and effective marketing are essential elements of crop diversification. Integration with other elements of the farming system is also often essential such as on-farm forage production for livestock fattening and improved sheep and goat production. Water provision from micro-dams and water harvesting structures are an essential element of vegetable production.

The key strategy with respect to diversification is to extend the range of livelihood strategies thus reducing vulnerability to natural and other shocks. Given the very wide range of these interventions it not possible to undertake a benefit:cost analysis.

5.3.3 On-farm Forage Production

(a) Patterns of Livestock Feed Deficit

Month on month feed balances will vary more than annual variations in both the Highlands and Lowlands. The Zebu bred of cattle can withstand seasonal deficits in livestock feed by utilizing body reserves of energy and suffering weight loss. As soon as feed balances become positive animals regain lost weight.

Two livestock feed deficit patterns are found in the Tekeze Sub-Basin: the first is located in the western Lowlands and the second in the Highlands.

In the western Lowlands feed deficits start in February-March as natural pastures are at their lowest quantity with respect to dry matter, nutrients and digestibility, and the supply of stored crop residues is beginning to diminish. In addition some of the harvested cropland is beginning to be ploughed up ready for planting the next season’s crop, and thus aftermath grazing is also beginning to diminish. Because the rains arrive earlier in this farming system, deficits quickly decline in May to zero in June.

The second pattern is in the Highlands. Here, the deficit builds up first in the drier Eastern Zone, followed by Southern Zone and the wetter Central Zone. Deficits last through to June as dry matter, nutrients and digestibility of the natural pastures are at their lowest, and the supply of aftermath grazing declines due to some of the cropland being ploughed up in readiness for the next season’s planting. The deficit starts to decline in June in reverse order: firstly in central Zone, then Southern and finally Eastern Zone with increases in dry matter and digestibility of the natural pastures. In Eastern and Southern Zones most upland well-drained areas have already been converted to cropland and where there is a shortage of grazing land deficits continue through to October at a low level.

(b) On-farm Forage Strategies

Average yield of unimproved pasture in the Highlands is approximately 1.5 tons DM/ha (lower than Abbay Sub-basin because of lower rainfall) whilst those of improved grasses are about 5 tons/ha for short grasses.

Rather than aiming for a full year's livestock feed supply a more realistic strategy for many small farmers would be to grow sufficient improved forage to meet three months supply at ploughing time or during lactation periods. This would reduce the forage area requirements to 0.11 ha, which is possible within the homestead area (i.e. "backyard forage" strategy).

(c) On-farm Financial Analysis

Benefits to the intervention include increased livestock productivity (increased calving, lower calf mortality, increased draught power). The difficulty in undertaking a financial comparison of unimproved pasture (as the without project) and improved on-farm forage is estimating a value for the two forage commodities. Using the prices from the Abbay Sub-basin and including costs of improved seed and fertilizer gave a B:C ratio of 4.2 for the intervention. The incremental return on cultivating 0.11 ha of improved forage was ETB 244.

(d) Sub-basin Wide Financial Analysis

In the Sub-basin wide analysis it was assumed that 40 percent of households would adopt improved on-farm forage production. For the analysis the average area per farm was 0.11 ha. The results are presented in table 39. The overall B:C ratio is 4.2.

Table 39. Financial Benefit-cost Analysis of the Proposed On-farm Forage Intervention in the Tekeze Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of On-farm Forage Intervention by Farming System in Tekeze Sub-Basin

Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
-	192,141	343,845	1,146,152	192,141	802,306	4.2

Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
-	22.2	39.8	132.5	22.2	92.8	4.2

all costs and benefits are PVs over 50 years at 10% discount rate

Unquantifiable benefits include reduced pressure on communal grazing areas leading to increased forage natural pasture production, lower erosion rates and reduced sedimentation in streams.

(e) Global Benefits

Global benefits to on-farm forage product result from reduced pressure on communal grazing areas leading to increased pasture production. This would have the impact of increasing soil organic matter. Given the wide variability of existing grazing pressures and the variations in the degree of relief provided it is very difficult to quantify the increase in SC in soils of the communal grazing areas.

5.3.4 On-farm Tree Production and Domestic Energy

(a) Farm Level

Supply-side Interventions: Fuel Substitution:

Unlike the Abbay Sub-basin, in the Tekeze Sub-basin the process of fuel substitution is only just starting (WBISPP/MARD, 2001). If the substitution rate follows that of the Abbay Sub-basin per capita dung use as fuel should decline at an annual rate of nearly 3 percent. Some 40 percent of the dung used as fuel comes from cropland. Only this proportion is used in the analysis. Assuming that each household undertakes a full conversion to fuelwood of the dung from cropland and all residues burnt it is estimated that the each converting household would save some 10 kgs of available N. This is equivalent to 50 kgs of grain per converting household. In nutritional terms this is sufficient to feed one adult for 25 percent of the year. Using the average price for wheat (ETB 1880/ton) in the Tekeze Sub-basin this is equivalent to ETB 94 or 9 percent of the ETB 1,070/yr per capita poverty line.

In addition there is the value of the trees as fuelwood and/or poles. For the analysis it was assumed that each adopting farmer would plant 45 Eucalyptus trees a year for 5 years. This would provide a total of 225 trees. At a density of 1,500 trees/ha[26] this would require 0.15 ha. Trees are harvested from year 8 to 10. Over 25 years and using a discount rate of 10 percent the financial rate of return is 35 percent and the discounted B:C ratio is 2.1 However, the payback period is 8 years.

Unquantifiable benefits include reduced pressure on communal grazing areas leading to increased trees, natural pasture production, lower erosion rates and reduced sedimentation in streams.

Demand-side Interventions: Improved Stoves[27]:

Two improved stoves are available: the *lakech* (a charcoal stove) and the *gounziye* (a ceramic wood stove that mimics the traditional 3-stone fireplace). The *mirte* is an improved mitad stove (for baking injera). The *lakech* is becoming established in urban areas where charcoal is a preferred fuel for wot cooking. However, in Tigray there already exists an efficient traditional stove, a reflection of fuelwood scarcity over a long period. Adoption of the

[26] In practice farmers plant at much higher densities (up to 30,000 trees/ha) although yields are lower than at wider spacing.
[27] Data from the "National Strategic Plan for the Biomass energy Sector", (WBISPP-MARD, 2005)

gounziye is therefore unlikely. However, for injera cooking the traditional 3-stone "stove" is still used.

In rural areas in the Tekeze Sub-basin some charcoal is used (WBISPP-MARD, 2003) but not in sufficient quantities to warrant the change to the *lakech*. The *mirte* mitad has a fuel saving of 50 percent and costs ETB 45 – 60. It also considerably reduces the amount of smoke generated. Average rural household fuelwood consumption in the Tekeze Sub-basin is approximately 3,330 kgs/yr/family). Some 56 percent of wood is used for mitad cooking and 39 percent for other (mainly *wot* cooking).

Adoption of the *mirte* could effect household fuelwood savings of approximately 783 kgs/yr. Approximately 30 hours (about 3.75 days) a week of family labour (women 20, children 9 and men 2 hours) are use in collecting and transporting 100 kgs of fuelwood. Using a wage rate of ETB 4.00 as representative of the whole family labour (men, women and children), this would place a value of 0.15/kg. Total annual savings per family would thus amount to ETB 183.30. Assuming stoves are replaced after 5 years and using a discount rate of 10 percent the B:C ratio is 7.3.

Because burning biomass fuels on the traditional wood stove is inefficient and as much as 20 percent of fuel is not completely combusted, a number of toxic substances are released into the atmostsphere. In many Ethiopia households this often takes place in an enclosed kitchen. The toxic substances include small particles, carbon monoxide and nitrogen dioxide as well as formaldehyde, benzene and other pollutants.

These pollutants are now known to have serious negative impacts on human health, in particular acute respiratory infections and respiratory diseases. Women and particularly children are affected. No detailed studies have been undertaken in Ethiopia, but detailed studies have been undertaken in India where 80 percent of households use biomass fuels (a lower proportion than in Ethiopia). In India it estimated that about 5 percent of premature deaths in women and children under 5 are due to indoor smoke pollution. By way of comparison poor water and sanitation account for 6 percent and malnutrition 15 percent.

(b) Sub-basin Level

Supply-side Interventions: Fuel Substitution:

At the Sub-basin level and assuming that 3 percent of households or some 28,100 households convert to fuelwood each year the annual saving of N would amount to 281 tons: a grain equivalent of 1,686 tons/yr. This is sufficient to provide food for 8,450 people. This would accumulate each year for 10 years. The value of grain saved is ETB 3.3 million/yr (US$ 0.01 million/yr) rising to ETB 33.0 million/yr (US$ 0.1 million/yr) after 10 years.

To examine the Direct Intervention on-farm tree planting programme on its own, the benefit-cost analysis was undertaken over 50 years to take account of the 10 years of investments and using the Government discount rate for public investments of 10 percent. An annual adoption rate of 3 percent of households per year for 10 years was used in the analysis. The results are shown in table 40. The overall discounted B:C ratio is 2.1.

Table 40. Financial Benefit-cost Analysis of the Proposed On-farm Tree Planting Intervention in the Tekeze Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of On-farm Tree Planting Interventions in Tekeze Sub-Basin							
	Cost WOP (ETB'000)	**Cost WP (ETB'000)**	**Benefit WOP (ETB'000)**	**Benefit WP (ETB'000)**	**Incremental Cost (ETB'000)**	**Incremental Benefit (ETB'000)**	**B/C Ratio**
	-	348,115	-	738,170	348,115	738,170	2.1
total	**-**	**348,115**	**-**	**738,170**	**348,115**	**738,170**	**2.1**
Farming System	**Cost WOP ($US m)**	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	38.7	-	82.0	38.7	82.0	2.1
total	**-**	**38.7**	**-**	**82.0**	**38.7**	**82.0**	**2.1**
all costs and benefits are PVs over 50 years at 10% discount rate							

Demand-side Intervention: Improved Stoves

The GTZ Household Energy/Protection of Natural Resources Project (HENRP) working in Amhara, Tigray, SNNP and Oromiya regions report that in the first three years some 5 percent of mirte mitad stoves were being sold to rural households. Assuming that 10 percent of households (93,675) will adopt the mirte mitad over a period of 10 years with the same assumptions above regarding fuel savings then incremental costs and benefits are shown in table 41. The overall B:C ratio is 15.

Table 41. Financial Benefit-cost Analysis of the Proposed Improved Stove Intervention in the Tekeze Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of Improved Stove Interventions in Tekeze Sub-Basin							
	Cost WOP (ETB'000)	**Cost WP (ETB'000)**	**Benefit WOP (ETB'000)**	**Benefit WP (ETB'000)**	**Incremental Cost (ETB'000)**	**Incremental Benefit (ETB'000)**	**B/C Ratio**
	-	10,337	-	125,518	10,337	125,518	**12**
	Cost WOP ($US m)	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	1.2	-	14.5	1.2	14.5	**12**
all costs and benefits are PVs over 50 years at 10% discount rate							

c) Global Benefits

Only wood that is not burnt and is used for furniture making or construction will form part of sequestered carbon. It assumed that this will last at least 10 years before decomposing or being burnt. .The analysis assumes that after 10 years the average wood going to construction and furniture is will accumulate at 0.26 million tons/yr. Thus some 0.13 million tons/yr of carbon will be sequestered. This has a value of ETB 7.0 million/yr (US$ 0.8 million/yr).

At the end of 10 years some 93,675 households will be saving 1.665 tons of wood fuel a year by using improved stoves. This is equivalent to 78,000 tons carbon/yr. Using a value of US$ 3/tons this amounts to ETB 2.1 million/yr (US$ 0.23 million).

5.3.5 Communal lands: Increased Pasture and Wood production

(i) Reduced Soil Erosion on Non-Cropland

(a) Background

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 totaling some 87.96 million t/yr.

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.

(b) Potential Increase in Forage and Tree production: Site Level

In the financial analysis it was assumed that 50 percent of the area would be under trees (i.e. at half the recommended planting density) and the whole area under grass. A ten year rotation of trees was used[28]. Unimproved pasture yields are lower in the Tekeze Sub-basin compared with the Abbay Sub-basin at an estimated 1.4 tons/ha. Grass yields reach a maximum after 5 years of 3.6 tons/ha, decline with tree shading to 1.44 and increased after tree harvest. Trees are valued for poles and BLT[29].

There are positive impacts on livestock health and productivity (milk, draught power, fecundity, reduced calf mortalities) with increases in feed supply. To

[28] Farmers follow much shorter rotations for Eucalyptus (10 years) than commercial plantations (15 – 20 years).
[29] BLT = Branches, leaves and twigs (20% of total volume).

capture these values grass was valued using the annualized value of an ox over 10 years at 10 percent discount rate multiplied by the ratio of 1 Q of grass dry matter to the annual feed requirements of 1 ox (22.50 Q of grass dry matter).

The financial analysis for 1 hectare of closed area produced a financial rate of return of 57 percent and a B:C ratio of 12. The payback period is short – 3 years. The net value of increased livestock production is ETB 213/ha/yr.

The increase in wood supply for fuel and construction will relieve pressure on the remaining areas on non-cropland. It has not been possible to quantify this impact.

(c) Potential Increase in Forage and Tree production: Sub-basin Level

As indicated above it has been assumed that 40 percent of non-cropland would be enclosed over a 10 year period in equal proportions (i.e. 4 percent per year). The analysis was conducted over a period of 50 years given the 10 year period of investment. A discount rate of 10 percent was used. The results are shown in table 42. The overall B:C ratio is 10 and the internal rate of return was 62 percent.

Table 42. Financial Benefit-cost Analysis of the Proposed Area Closure in the Tekeze Sub-basin over a 50 year time-frame and a Discount Rate of 10%

Financial Costs and Benefits of Area Closure in Tekeze Sub-Basin

Cost WOP ETB $'000)	Cost WP ETB $'000)	Benefit WOP ETB $'000)	Benefit WP ETB $'000)	Incremental Cost ETB $'000)	Incremental Benefit ETB $'000)	B/C Ratio
-	1,125,400	1,769,208	16,225,676	1,125,400	14,456,468	**13**
Cost WOP (US$'000)	**Cost WP (US$'000)**	**Benefit WOP (US$'000)**	**Benefit WP (US$'000)**	**Incremental Cost (US$'000)**	**Incremental Benefit (US$'000)**	**B/C Ratio**
-	125,044	196,579	1,802,853	125,044	1,606,274	**13**

all costs and benefits are PVs over 50 years at 10% discount rate

(d) Potential Regional Benefits and Costs

Benefits

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.

These contribute to the overall reduction in sediment load in the Tekeze-Atbara-Main Nile River system passing through Sudan and onto Egypt. The benefits (and costs) of these reductions are considered in sections 5.3.4 (Sudan) and 7.3.1 (Egypt).

Potential Costs

The potential impacts of large-scale Eucalyptus planting have outlined in section 4.1.5 and the same comments apply to the Tekeze-Atbara Sub-basin.

(e) Global Benefits

Potential global benefits can accrue from increased carbon sequestered in wood and soil organic matter.

Wood carbon Sequestration

Most of the incremental above-ground herbaceous biomass will be consumed by livestock and thus there will be no increase in the carbon pool from herbaceous growth.

Wood that is not burnt and is used for permanent products or uses such as construction and furniture will contribute to the carbon pool for at least 10 years.

Using the assumptions outlined in para. (b) and (c) above with Eucalyptus planting at half the plantation density wood being used for construction and furniture would reach to some 52 million tons/yr after 20 years development. This would sequester 26 million tons/yr of carbon at annual value of ETB 698 million/yr (US$ 73 million/yr). The present value of this over 50 years using a10 percent discount rate is ETB 1,660 million (US$ 184 million).

Soil Carbon Sequestration

However, the greatest potential for adding to the carbon pool is from an increase in soil carbon (SC) from the increased production of pasture as grasslands sequester double the amount carbon as croplands.

Using the research results of Descheemaeker et al., 2005 in Tigray an increment of 31 tons/ha of SC after 5 years of enclosure would increase total SC by 5.1 million tons/yr accumulating over a period of 10 years. Using the same values as before this represents a value of ETB 138.8 million/yr (US$ 15.4 million/yr).

Other Global Values

The medicinal, nutritional and other use values of plants in the enclosed have been noted above. These plants also have a biodiversity value and provide a reservoir of genetic and species diversity that is being lost in the open access communal lands.

5.3.6 Water Conservation and Improved Utilization

The key activities related to water conservation and its improved utilization are small/micro dams and household-level water harvesting structures. Both can be used for domestic and livestock water supply and for small-scale irrigated cropping (integrating with the crop diversification intervention).

(i) Small/Micro Dams and Weirs (River Diversions)

(a) Basic Data

Data from the Tigray Region puts the average costs per dam at ETB 1.274 million (US$ 141,617) with an average irrigated area of 74 ha. This gives an average cost of irrigated land of ETB 17,362/ha (US$ 1,929/ha). Maintenance costs are estimated to be 2.5 percent of construction costs (Hewitt and Semple, 1984). There is no data of the average number of beneficiary households per scheme. The average area of 0.35 ha per household from Amhara Region is assumed, which gives the number of beneficiary households per scheme as 210.

Data from IFAD's river diversion programme in Tigray have average costs per hectare of ETB 39,715 ha (US$ 4,602/ha). Average size of the schemes is 72 ha which gives an average cost per scheme of ETB 2.86 million (US$ 0.32 million). The average number of beneficiaries is 227 with an average holding of 0.32 ha. Estimated maintenance costs are ETB 750/ha.

(b) Financial Analysis: Irrigation from Small dams: farm level

It assumed that the irrigated area cropped is 0.35 ha, and that 100 percent is cropped in the main season (green maize 35%, potatoes 50%, peppers 15%) and that 50 percent is cropped to onions in the 2nd season. In the without project situation is assumed that the 0.35 ha is rainfed cropped according to the crop mix of the local farming system. Family labour for cultivation, irrigation and transport to market is not included.

The B:C ratio is 9 and the incremental income is ETB 4,723/yr. The incremental return to family labour is ETB 46.30/day. When family labour is costed the incremental income is ETB 4,212 and the B:C ratio falls to 5. Nevertheless, clearly the small irrigation intervention is financially very attractive. Average Tigray Region market prices were used although an IFAD Evaluation Report on small scale irrigation schemes found that on some schemes prices received by farmers from itinerant traders were considerably below local market prices. There have also been problems with local gluts in markets with poor outside accessibility. Reducing market prices by 25 percent and 50 percent reduces the B:C ratio to 7.9 and 6.0 respectively. Incremental cash income declines to ETB 3,463 and ETB 2,202 respectively. Similar changes in costs produce almost identical results.

(c) Financial Analysis: Weir Diversion from Run-of River

In this analysis it is assumed that only one cropping season is possible because of lack of water during the 2nd season. The cropping mix is the same as the Main Season of the Small Dam schemes. The other assumptions remain the same.

The B:C ratio is 7 and the incremental income is ETB 1,802/yr. The returns to family labour are ETB 13.20/day. The absence of a second cropping season limits the incremental income. Reducing market prices by 25 percent and 50 percent reduces the B:C ratio to 6 and 5 respectively. Incremental cash income reduces to ETB 1,315/yr and ETB 827/yr respectively.

(d) Financial Analysis: Small scale Irrigation Tekeze Sub-Basin

Currently there is a moratorium of small dam construction in Tigray whilst modalities of integrating watershed management measures are determined. Previous rates of small dam construction in the Tekeze Sub-basin have been about 5 per year and an average of 7 weir diversion schemes have been implementation with IFAD's support. Assuming dam construction will recommence, for the Sub-basin wide analysis it is assumed that 50 small dams and 70 weir diversion schemes can be implemented in the 10 year period. These would serve some 26,390 households irrigating a total area of 8,740 ha.

The analysis examined the costs and benefits of 50 dam schemes and 70 weir diversion schemes over a period of 50 years using 10 percent discount rate. Costs of watershed management interventions above the dam or weir have not been included, but are a vital element if problems of sedimentation are to be avoided. Clearly such watershed management interventions have many other benefits and the analysis would become protracted if a "total approach" were to be used. Nevertheless, these costs should be borne in mind when reviewing the results below.

The results are presented in table 43. The overall B:C ratio is 0.8. Changing the discount rate from 10 percent to 5 percent increases the B:C ratio to 1.1. The financial rate of return is 6 percent.

Table 43. Financial Benefit-cost Analysis of the Proposed Small-scale Irrigation Intervention in the Tekeze Sub-basin over a 50 year time-frame and a Discount Rate of 10%

Financial Costs and Benefits of 120 Small-scale Irrigation Schemes in Tekeze Sub-Basin

Farming System	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
Dam schemes (Construction)	-	39,141	-	-	39,141	-	-
Dam schemes (maintenance)	-	10,628	-	-	10,628	-	-
Wier Schemes Construction	-	123,014	-	-	123,014	-	-
Wier Schemes (Maintenance)	-	33,403	-	-	33,403	-	-
Dam schemes: Irrigation	20,753	41,343	31,433	111,452	20,589	80,019	-
Wier schemes: Irrigation	31,407	62,565	47,568	168,664	31,159	121,096	-
total	**52,160**	**310,094**	**79,001**	**280,116**	**257,934**	**201,115**	**0.8**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
Dam schemes (Construction)	-	4.5	-	-	4.5	-	-
Dam schemes (maintenance)	-	1.2	-	-	1.2	-	-
Wier Schemes Construction	-	14.2	-	-	14.2	-	-
Wier Schemes (Maintenance)	-	3.9	-	-	3.9	-	-
Dam schemes: Irrigation	2.4	4.8	3.6	12.9	2.4	9.3	-
Wier schemes: Irrigation	3.6	7.2	5.5	19.5	3.6	14.0	-
total	**6.0**	**35.8**	**9.1**	**32.4**	**29.8**	**23.3**	**0.8**

all costs and benefits are PVs over 50 years at 10% discount rate

(e) Other Costs

Research in Tigray (Ersado, 2005) has revealed that whilst dams and small-scale irrigation increased farm incomes they also led to an increased incidence of malaria. This in turn led to reduced allocation of labour to non-farm activities and increased expenditure on medicines. These costs have not been quantified. However, they can be prevented by spraying in and around houses and/or with the provision of impregnated mosquito nets. The estimated cost of such a net is ETB 36.00 (US$ 4.00). Assuming 1 net per household and 200 households in each Irrigation Scheme village would mean an initial cost of ETB 7,200/scheme (US$ 800). Assuming a replacement every 4th year and adding these costs to (i) household costs and (ii) Scheme costs has the following impact on B:C ratios:

Households

Dam schemes: B:C ratio: from 9.4 to 9.2
Weir schemes: B:C ratio: from 4.6 to 4.4

Schemes
All schemes: B:C from 0.8 (1.1) to 0.8 (1.0)

Potential health costs could also result from the introduction and spread of bilharzia through its host the *Bulinus* spp. snail. Preventative costs would be incurred from the use of moluscicides. Other potential health costs could be

incurred through the use of agro-chemicals and their effect on down-stream users of the river for human and livestock water supplies.

Increased use of water through increased evapotranspiration of irrigated crops in comparison with rainfed crops as well as evaporation from the reservoirs will reduce river flow downstream of the Schemes. This could have negative impacts on downstream users in terms of water use for domestic and livestock water supplies and for irrigation.

(f) Other Benefits

Many dams are constructed to serve a number of uses. These include domestic and livestock water supplies. These in turn have secondary (multiplier) benefits in terms of enhanced human health, reduced time for water collection for women and children and increased livestock productivity.

(g) Multiplier Benefits

Other multiplier effects include backward and forward linkages in the local economy. These include increased sales of inputs and increased products entering the market. Increased multiplier effects will also be felt with increased household purchases of local and "imported" (i.e. into the local area) goods. Purchases of locally produced non-food goods ("non-tradables) make a substantial contribution to the multiplier effect.

The same assumptions used in the multiplier analysis in the Abbay Sub-basin analysis are used. The annual incremental household income for the small dam schemes is ETB 2,630/yr and ETB 1,802/yr for the Weir Schemes. Assuming that 32 percent of this incremental income is spent on non-tradables by the beneficiary households, this would indicate that an additional ETB 991,856/yr would enter the local economy of locations with a dam scheme and ETB 192,516/yr for the Weir Schemes. Across the 50 dam and the 70 weir schemes in the Sub-basin this would amount to ETB 20.2 million/yr (US$ 2.24 million/yr). This in turn would stimulate 2 and 3rd order multipliers within the local economy.

5.3.7 Summary of Financial analysis of the Measurable WSM Interventions

This section summarizes the financial analysis of the nine interventions that has preceded and outlines the resuts at the household level (table 44). The (discounted) costs of the supporting interventions have been included to determine an overall B:C ratio for the 10 year programme. All interventions indicate an overall B:C ratio of 6.5.

The largest incremental benefits accrue to the area enclosure intervention, followed by the on-farm trees and the on-farm forage interventions. For the cropland soil conservation measures a key factor affecting adoption/non-adoption is the length of the pay-back period of the initial negative returns because of the high labour requirements. This indicates the need to extend the current support being provided in the food deficit weredas to all weredas.

Table 44. Summary of Financial Analysis of the Programme of Direct Interventions for the Abbay Sub-basin: Ethiopia

Financial Costs and Benefits of WSM Interventions in the Tekeze Sub-Basin

Intervention	Cost WOP (ETB'million)	Cost WP (ETB'million)	Benefit WOP (ETB'million)	Benefit WP (ETB'million)	Incremental Cost (ETB'million)	Incremental Benefit (ETB'million)	B/C Ratio
Soil conservation: Stone Bunds	1,311	1,541	3,214	3,517	231	303	1.3
Fertilizer/Improved seed	32	41	131	175	9	44	4.9
On-farm Forage	-	192	344	1,146	192	802	4.2
On-farm Trees: Fuelwood	-	348	-	738	348	738	2.1
Improved stoves	-	8	-	137	8	137	16.5
Area enclosure	-	1,125	1,769	16,226	1,125	14,456	12.8
Small-scale Irrigation	52	310	79	280	258	201	0.8
Supporting Interventions	-	-	-	-	395	-	
TOTAL	**1,395**	**3,567**	**5,537**	**22,219**	**2,567**	**16,681**	**6.5**

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
Soil conservation: Stone Bunds	145.6	171.3	357.1	390.7	25.6	33.6	1.3
Fertilizer/Improved seed	3.6	4.6	14.6	19.5	1.0	4.9	4.9
On-farm Forage	-	21.3	38.2	127.4	21.3	89.1	4.2
On-farm Trees: Fuelwood	-	38.7	-	82.0	38.7	82.0	2.1
Improved stoves	-	0.9	-	15.2	0.9	15.2	16.5
Area enclosure	-	125.0	196.6	1,802.9	125.0	1,606.3	12.8
Small-scale Irrigation	5.8	34.5	8.8	31.1	28.7	22.3	0.8
Supporting Interventions	-	-	-	-	43.9	-	
	155.0	**396.3**	**615.3**	**2,468.7**	**285.2**	**1,853.5**	**6.5**

all costs and benefits are PVs over 50 years at 10% discount rate

The relevant sections have pointed out the additional unquantifiable benefits accruing to these interventions. Thus, the analysis presented here represents a conservative estimate of the incremental benefits accruing to the programme.

The quantifiable National, Regional and Global benefits are presented at the end of the Chapter for Ethiopia and Sudan.

5.4 Estimated Budget - Direct and Supporting Interventions: Tekeze Sub-basin - Ethiopia

The previous section has outlined some of the quantifiable costs and benefits accruing to the direct interventions. All of these depend to a greater or lesser extent on the implementation of the Supporting Interventions. These Supporting Interventions will provide increased physical and human capacity to rural households and government implementing organizations and in particular the extension Service; support to assisting rural families to gain non-farm employment and to small enterprise development in both rural areas and small urban centers; improved road and market infrastructure and increased capacity of farmers in product marketing and with increased available and access to micro finance and credit. The details of these and their direct and indirect benefits are summarized Matrix 2b in Chapter 2.

This section provides a summary of the budget required to implement both the Direct and Supporting Interventions. A detailed breakdown with units and unit costs is provided in Annex 3. A summary is provided in table 45. Given the very complex nature of the relationships between the Direct and the Indirect Interventions, in particular their short and long term impacts on human welfare and development in local, regional and National terms it would be extremely hazardous to attempt an overall benefit-cost analysis. However, it is submitted that the figures below provide a sense of the order of magnitude in implementing a programme of the interventions as outlined in Chapter 3.

Table 45. Summary 10 Year Budget: Tekeze Sub-basin – Ethiopia: (a) Direct Interventions, (b) Supporting Interventions and (c) Total budget (ETB).

(a) Direct Interventions

Intervention	Total cost (ETB)	Total cost (US$)
1. Water Conservation & Improved Utilization	4,067,129,880	463,226,638
2. Crop Diversification & Intensification	1,129,637,422	128,660,299
3. Soil Conservation & Improved Soil Husbandry Measures	5,806,812,746	661,368,194
5. Livestock Development	408,682,198	46,546,947
Sub-total	**11,412,262,246**	**1,299,802,078**

(b) Supporting Interventions

Intervention	Total cost (ETB)	Total cost (US$)
1.. Capacity Building	417,077,360	47,503,116
2. Support to Agricultural Extension	141,445,000	16,109,909
3. Support to Non-farm Income Generation, Small/micro Enterprise development	289,283,740	32,948,034
4. Community Assets Development	848,260,000	96,612,756
5. Improved Marketing	7,323,000	851,139
6. Support to Micro-finance, Credit and Savings	7,473,000	851,139
Sub-total	**1,710,862,100**	**194,876,093**

TOTAL

Intervention	Total cost (ETB)	Total cost (US$)
(a) Direct Interventions	11,412,262,246	1,299,802,078
(b) Supporting Interventions	1,710,862,100	194,876,093
TOTAL	**13,123,124,346**	**1,494,678,172**

The unit area costs are ETB 5,554/ha (US$ 633) of cropland treated[30]. Very clearly there are many benefits accruing to the Direct and Indirect Interventions beyond the area and households involved in the overall programme. The figure is noted as a preliminary estimate of the programme the costs at the Catchment or Sub-catchment level.

[30] The figure for the Abbay Sub-basin is ETB 5,875/ha (US$ 669/ha).

5.5 Costs of Continued Natural Resource Management Practices: Sudan

It is emphasized again that the physical impacts and costs outlined below do not reveal to full extent of the social and economic costs to the rural (and urban) population in terms of those key elements in the downward spiral of poverty and a degrading resource base such as poor nutrition and health, poor access to social services (health and education) and restricted access to alternative livelihood strategies.

5.5.1 Agricultural production forgone from Soil Degradation – Atbara Sub-basin

(i) Loss of Agricultural land: Gulley Erosion

Extensive *kerib* land is located along the Atbara-Setit River. It is estimated that some 3,000 ha of land are lost each year – some 40 percent above and 60 percent below the Kashm el Girba dam. The land above the dam is under traditional rainfed cropping, whilst that below the dam is rangeland used for extensive grazing. The estimated net returns per feddan for the traditional rainfed sector is SDD 1,062/feddan (SDD 6,020/ha) (MOA, 2006b). To obtain an estimated long term value of land a discount rate of 10 percent is used with an infinite time horizon. This gives a value of SDD 60,200/ha or US$ 301/ha[31]. The value of the annual loss of agricultural land above the dam is estimated to be SDD 72.2 million/yr or US$ 0.4 million/yr.

(ii) Decline of Soil Productivity on Semi Mechanized Farms

Annual decline in yields on the Semi mechanized Farms has been estimated at 2 percent per annum (World Bank, 2003). Assuming that approximately 505,020 ha are cropped annually with average yield of 480 kgs/ha (MOA, 2006a) this represents an annual cumulative loss of production of 4,848 tons declining to 2,985 tons in 25 years time. At approximately SDD 43,000/ ton this represents a loss of SDD 208.5 million (US$ 1.0 million) in the first year rising to SDD 4,133.3 million (US$ 20.7 million) after 25 years.

(iii) Decline in Soil Productivity on Traditional Rainfed farms

Approximately 60,250 feddans (31,330 ha) of small-scale rainfed cropping has been mapped in the Atbara Sub-basin. Assuming the same yields as the SMF's but with half the rate of yield decline (i.e. 1 percent/yr) this would indicate an annual cumulative loss production of 150 tons declining to 118

[31] This compares with an MOA (2006a) estimate of the annual average rental value of SMF land of SDD 4,144 /fd (SDD9,867 /ha). The PV over 50 years at 10% discount rate is SDD 97,826/ha (US$ 489/ha)

tons in 25 years time. At approximately SDD 43,000/ ton this represents a loss of SDD 6.5 million (US$ 0.03 million) in the first year rising to SDD 143.7 million (US$ 0.7 million) after 25 years.

(iv) Drifting Sand and Reduction in Land productivity: Lower Atbara

Drifting sand in the Lower Atbara area reduces crop production in two major ways: (i) damage to growing plants through sand coverage and leaf stripping, and (ii) through sedimentation in irrigation canals and reduced water delivery efficiencies and costs of dredging. Mekdi M. Latif (2005) estimated approximately 30 percent of cropland was affected by sand in the Lower Atbara. These led to the need to increase irrigation frequencies because of the high infiltration rates.

No detailed survey data is available on estimated crop damage and costs of cleaning canals. It is therefore not possible to place a monetary cost on the impact of drifting sand on crop productivity.

5.5.2 Reservoir and irrigation system sedimentation: Atbara Sub-basin Sudan

Reservoir and irrigation system sedimentation may lead to:

(i) agricultural production forgone.
(ii) higher irrigation-system operation and maintenance cost.
(iii) increased dredging and turbine-replacement cost.
(iv) higher cost of water purification.
(v) pump damage.
(vi) river bed aggradation[1].
(vii) Hydroelectricity production forgone.
(viii) Loss of fisheries production due to reservoir flushing.

This section values the most important of these namely (i), (ii), (viii) and (viii).

(i) Downstream agricultural production forgone

Annual loss of storage in the Kashm El Girba Reservoir is approximately 1.54 percent /yr. Sedimentation is leading to downstream agricultural production forgone due to the loss of water for irrigation. Assuming a water duty of 8,140 m^3/ha, the annual area of irrigated land lost is 2,457 ha. Note that these losses are cumulative. The estimated net returns of US$ 61 per hectare for Acala cotton were used to estimate the financial value of production forgone (World Bank, 2000). These are shown in Table 46.

[1] Causing accelerated meandering and river bank erosion.

Table 46. Irrigated Crop Production Forgone Caused by Sedimentation of Kashm El Girba Dam and Loss of Irrigation Water

SDD million/yr	$US million)	SDD million/yr	$US million)
1 year	1 year		25 years
29.97	0.15	749.38	3.75

NB: 2005 prices

(iv) Sedimentation in irrigation-system

(a) Costs

It is estimated that 6.08 million tons/yr enter the New Halfa Scheme or some 77 percent of that entering the Gezira Scheme. Based on the costs incurred in the Gezira-Managil Scheme the annual costs of clearing would be approximately SDD 906 million (US$ 4.53 million). With an increase in sediment of 22 percent over the next 10 years these are likely to rise to SDD 1,102.6 million/yr (US$ 5.5 million/yr)

(b) Benefits

Assuming that 38 percent of 6.08 million tons/yr of sediment entering the system is deposited in the fields and that 1 ton of sediment is equivalent to 0.94 kgs of fertilizer, this would indicate that deposition of sediment in New Halfa Scheme is equivalent to 67,000 tons of fertilizer. Assuming the fertilizer is urea and that the price of urea is US$ 286 /ton the benefits accruing to sediment deposition amounts to SDD 327.6 million (US$ 1.64 million). The gains are annual and not cumulative due to nutrient uptake by crops, leaching and volatization losses. It is possible there is some residual accumulation of phosphorous although given the high P fixing properties of the New Halfa soils the amount available to plants is likely to be negligible.

(v) Downstream hydroelectricity production forgone

Sedimentation also leads to hydroelectricity production forgone and its estimated value is shown in Table 47. It is important to note that this loss is also cumulative and the total value of electricity production forgone in 25 years will be US$ 49.3 million/yr.

Table 47. `Hydroelectricity Production Forgone Due To Sedimentation

Kashm El Girba	
Installed capacity (MW)	12
Mean annual output (MWH)	68.2
Annual loss of storage capacity (%)	1.54
Cost of electricity (US$/kwh)	0.1
Annual hydroelectricity production forgone	**SDD million 20.980 (US$ million 0.105)**

Using data from the Sudan Electricity Corporation for Senner Dam for the years 1965 to 2005 the average drop in power generation in the month of August when the dam is flushed compared with other months was 1.53 percent of mean annual output. Data for Kasm El Girba not available but assuming the same proportion of drop in total power output this would be equivalent to about 0.11 MWH with a value of SDD million 2.1 (US$ million 0.01 million/yr.

(vi) Fisheries Production Lost due to Reservoir Flushing

Flushing of the Kashm El Girba Reservoir causes an annual mass kill of fish[32]. The estimated annual fish catch in the reservoir is 500 tons/yr out of an estimated 840 tons/yr potential (FAO, 2004). The exact proportion of fish stocks that are killed each is not known. However, to make an estimate of the value of fish killed each year the following assumptions were made:

- Potential sustainable catch of 840 tons is 25 percent of total stocks: total fish stocks in the reservoir are approximately 3.360 tons.
- Annual fish kill is 20 percent of total stocks which represents a loss of some 672 tons of fish/yr.
- Khartoum market price of fresh fish is SDD 462/kg: transport and marketing costs are 60 percent of Khartoum market price: Landed price of fresh fish is SDD 184,800/ton.

The analysis assumes that all the fish lost are marketable, which is most certainly not correct. However, they have a future marketable value when mature. Using the above assumptions gives the value of the annual fish kill caused by the flushing regime as SDD 124.2 million (US$ 620,900).

5.5.3 Deforestation and Degradation: Sudan

(i) Deforestation

Some 841,700 ha of woodland and shrubland were cleared for the Semi mechanized farms. As in the Blue Nile Sub-basin the complete removal of vegetation and the consequent and the consequent removal of natural predators (snakes and cats) have led to an increase in rats and other vermin. Insect eating birds have disappeared leading to a big increase in the use of insecticides and insect damage. Because the land is totally cleared of all tree cover and combined with years of constant harrowing and disking the tree seed bank in the soil has been completely destroyed. The abandoned areas are a waste land with no tree cover. The quality of the grass cover is very poor because of the very low levels of soil fertility.

[32] Comments on 1st Draft of Distributive Analysis: Sudan Committee.

The current levels of permanent woodland removal are not available and thus a valuation can not be made.

(ii) Degradation of Woody Biomass Stocks

Pressure on the remaining woodlands is intense. This pressure is from wood removal for charcoal, fuelwood, construction, furniture and lime burning. In Sudan in the Tekeze-Atbara Sub-basin approximately 1.56 million m^3 of wood fuel and charcoal: a per capita consumption of 0.73 m^3 (MEPD/HCENR (2003) are consumed forming about 80 percent of the total energy consumption. This represents some 782,100 tons of sequestered carbon. Using the value of US$ 3 per ton of carbon this approximates to some SDD 469 million (US$ 2.3 million).

5.5.4 Summary of Costs of Natural Resource Degradation in the Tekeze- Atbara Sub-basin

The various cost estimates of natural resource degradation in the Tekeze-Atbara Sub-basin are summarized in Table 48.

Table 48. Summary of Costs of Natural Resource Loss and Degradation in the Tekeze-Atbara Sub-basin: Sudan

Resource	Annual		25 years	
	SDD million	US$ million	SDD million	US$ million
1. Soil productivity decline				
- Kerib land formation	72.2	1.0	1,805.0	20.7
- SMF's	208.5	0.03	7,607.0	0.7
- Traditional rainfed Sector	6.5	0.1	303.0	1.5
2. Sedimentation				
- Irrigation area lost	30.0	0.2	740.0	3.7
- Dredging/Weed cleaning	906.0	4.5	1,102.0	5.5
- Hydro-power lost: Lost storage	21.0	0.1	525.0	2.8
- Hydro-power lost: Sediment flushing	2.1	0.0	2.1	0.0
- Fish Kill: Sediment flushing	124.2	0.6	124.2	0.6
3. Deforestation/degradation				
- Deforestation	n.d.	n.d.	n.d.	n.d.
- Degradation	469.0	2.3	469.0	2.3
TOTAL GROSS COSTS	**1,839.5**	**8.9**	**12,677.3**	**37.8**
Benefits from Sediment in Fields	14.5	(0.1)	14.5	(0.1)
TOTAL NET COSTS	**1,825.0**	**9.0**	**12,662.8**	**37.9**

n.d. = no data

At the annual level the largest share of the costs are from the impacts of downstream sedimentation. Looking at the longer term the accumulating losses from soil degradation and deforestation predominate.

Table 49 provides a distribution of these costs into local/national, Regional and Global. Some 75 percent of the costs have local/national implications, no Regional and 25 percent global.

Table 49. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Tekeze-Atbara Sub-basin in Sudan

Resource	Annual			25 years	
	SDD million	US$ million	%	SDD million	US$ million
LOCAL/NATIONAL					
Soil fertility loss: SMF	208.5	1.0		4,133.3	20.7
Soil fertility loss: Traditional sector	6.5	0.03		143.7	0.7
Irrigation area lost	30.0	0.2		740.0	3.7
Dredging/Weed cleaning	906.0	4.5		1,102.0	5.5
Hydro-power lost: Storage	21.0	0.1		525.0	2.8
Hydro-power lost: Flushing	2.1	0.0		2.1	0.0
Kerib Land formation: Lost cropland	72.2	1.0		1,805.0	20.7
Fish Kill: Reservoir Flushing	124.2	0.6		124.2	0.6
Sub-total	**1,370.5**	**7.5**	**75%**	**8,575.3**	**54.7**
REGIONAL					
Sub-total	**-**	**-**	**0%**	**-**	**-**
GLOBAL					
Carbon Sequestration: Deforestation	n.d.	n.d.		n.d.	n.d.
Carbon Sequestration: Degradation	469.0	2.3		469.0	2.3
Sub-total	**469.0**	**2.3**	**25%**	**469.0**	**2.3**
TOTAL GROSS COST	**1,839.5**	**9.8**		**9,044.3**	**57.0**
Less: Value of sediment as fertilizer	(14.5)	(0.1)		(14.5)	(0.1)
TOTAL NET COST	**1,854.0**	**9.9**		**9,058.8**	**57.0**

5.6 Impacts, Costs and Benefits of the Proposed Direct Watershed Management Interventions

5.6.1 Reduced Land Degradation and Increased Rainfed Semi-mechanized farms

The analysis uses the recently published MOA Economic Survey of Semi-mechanized Farms (MOA, 2006a) covering Gedarif, Kassala, Blue Nile, Sinnar, White Nile, Upper Nile, South and North Kordofan States. In the area covered by the Atbara Sub-basin the data for Gedarif State was used. Crop prices were obtained from a second MOA study (MOA, 2006b) on the traditional rain-fed areas.

(i) Improved Technologies

Three main crops are cultivated: sorghum (91 % of the area), sesame (8 % of the area) and millet (1% of the area). Current yields are 725 kgs/ha, 842 kgs/ha and 607 kgs/ha for sorghum, sesame and millet respectively.

Improved technologies include 5 yearly sub-soiling to break the plough pan, in-furrow planting, drought-resistant seed varieties and the use of *Acacia senagal* for Gum Arabic as the fallow. Yields are expected to increase over a three year period to 1,087 kgs/ha, 1,053 kgs/ha and 911 kgs/ha for sorghum, sesame and millet respectively.

A. senegal is cultivated on a 15 year cycle with gum harvesting commencing in year 5. Initially 10 percent of the farm in planted with a further 10 percent commencing in year 11. Thus, at 10 yearly intervals for a period of 5 years some 20 percent of the farm is under *A. senegal*. This is to ensure a constant supply of gum Arabic and to meet government requirements that at least 10 percent of the farm should be under trees. Gum yields in year 4 and 5 are 29 kgs/ha and 57 kgs/ha. From years 6 to 11 they are 115 kgs/ha declining in years 12 and 13 to 88 kgs/ha and 57 kgs/ha. In years 14 and 15 yields are 19 kgs/ha. The trees are felled and removed at the end of year 15. The wood has a residual value as charcoal which covers the cost of land clearing (Earl, 1985).

(ii) Farm analysis

The analysis was conducted over a 25 year time period using a discount rate of 10 percent. The discounted B:C ratio was 34. The mean annual incremental cash income is SDD 25,738/ha (US 129/ha). These very high returns explains in part why rent charges in Gederif State are the highest in Sudan – SDD 23,172/feddan (US$ 119/ha) (MOA, 2006a). With a land tax of only SDD 200/yr (US$ 1.00/yr) this implies a substantial subsidy. Costing this rental value of land into the analysis reduces the B:C ratio to 2 and the average returns per hectare per year to SDD 17,180 (US$ 86/ha/yr).

Sorghum accounts for 78 percent of the incremental income, sesame 19 percent, millet 2 percent and gum arabic 1 percent. At current market prices and using the MOA Survey costs, the returns to millet are very low. The use of *A.sengal* as a fallow clearly has benefits in terms of enhanced soil fertility, although these are difficult to quantify.

(iii) Sub-basin Analysis

Assuming that only 60 percent of the 2.0 million feddans (841,700 ha) mapped as large farms is actually cropped in an average year, and that 60 percent of the land is improved there is the potential to improve crop production of 721,460 feddans (303,000 ha).

The improved technology was assumed to be adopted over a 10 year period. The overall B:C ratio at 10 percent discount rate was 23.

The results are shown in table 50.

Table 50. Financial Analysis: Improved Technology – Semi-Mechanized Rainfed farms: Atbara Sub-basin

Financial Costs and Benefits of Improved Agronomy Interventions on SMF's in the Atbara Sub-Basin

	Cost WOP (SDD '000)	Cost WP (SDD '000)	Benefit WOP (SDD '000)	Benefit WP (SDD '000)	Incremental Cost (SDD '000)	Incremental Benefit (SDD '000)	B/C Ratio
	40,331,795	41,262,308	60,519,293	91,362,830	930,513	30,843,537	33
total	**40,331,795**	**41,262,308**	**60,519,293**	**91,362,830**	**930,513**	**30,843,537**	**33**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
	201.7	206.3	302.6	456.8	4.7	154.2	33
total	**201.7**	**206.3**	**302.6**	**456.8**	**4.7**	**154.2**	**33**

all costs and benefits are PVs over 50 years at 10% discount rate

(iv) Shelterbelt Planting on Semi-mechanized farms

(a) National

Some 40 percent of the Semi-mechanized farms will not have A.senegal planted on them. Thus, there is the potential for re-forestation of some 48,100 feddans (20,200 ha) under these collaborative arrangements over a 10 year period. Contracts to traditional rainfed farmers for supply of seedlings, planting and care and maintenance could provide substantial contributions to households' financial assets as well as widening the range of the livelihood strategies.
Assuming sustainable yield of 5 m^3/ha on a 15 year rotation then an annual cut of 101,000 m^3 would be possible. This could be converted to 18,180 tons/yr of charcoal. Charcoal site production costs are estimated to be 87 percent of the site price (UNDP/World Bank, 1988). The current price of charcoal is SDD 70,000/ton. The total annual net revenue is estimated to be SDD 167 million/yr (US$ 0.8 million/yr).

However, when the opportunity costs of the crop production that is forgone are taken into account the long term (50 years) B:C ratio using a 10 percent discount rate is only 0.64. This rises to 0.8 and 0.9 when the rate is lower to 5 percent and zero percent respectively. This may explain why farmers are reluctant to plant shelter belts and point to the need for tax concessions to encourage their planting.

A second opportunity for collaboration is the utilization of the estimated existing production of 606,000 tons of residues for livestock feed for transhumant pastoralists. Using the annualized value of a tropical livestock unit as a basis the value of residues as livestock feed is SDD 2,282/ton (US$ 11.40/ton). Assuming that 60 percent is available to livestock this gives an estimated value of the residues as livestock feed as SDD 830.0 million (US$ 4.2 million).

(b) Potential Global Benefits

Increased crop production increases the production of crop residues and if these are left after harvest can contribute to increasing soil organic matter. The incremental production of crop residues on the improved cropland would be approximately 0.3 tons/ha/yr.

Research in a semi-arid zone in Kenya showed that an increase of just 0.3 tons/yr of residues left on the soil increased soil carbon by 20 percent over a 50 year period or at a rate of 0.01 tons/ha/yr (FAO, 2004). Research in North Kordofan (Olsson and Ardo, 2002) indicates current levels of carbon in cultivated land to be 1.5 tons/ha. A 20 percent increase in soil carbon in the soils of the 721,460 feddans (303,012 ha) of improved cropland from the incremental production of crop residues would amount to 90,900 tons of carbon. Using a value of US$ 3/ton of carbon this amounts to SDD 54.5 million (US$ 0.27 million).

Putting 10 percent of the total cropped land under trees (either as A. senegal or Shelterbelts) would mean that the soil carbon would increase. Research in Northern Kordofan suggests that converting cropland to woodland accumulates soil carbon at the rate of 1,010 tons/ha/yr. Thus, total soil carbon would have increased by 25,250 tons after 25 years. This is valued at SDD 15.2 million (US$ 0.075 million).

5.6.2 Reduced Land Degradation and Increased Rainfed Traditional Agricultural and Pastoral Production

(i) Supporting Interventions

The broad strategies to address the problems of land degradation and declining agricultural production in the traditional rainfed farming systems have been outline in chapter 3 of this Report and in the Transboundary reports.

At a more specific level the opportunities for closer collaboration between the two rainfed agricultural sectors exist. These involve the implementation of the government regulation for 10 percent tree planting on large government lease-hold farms through the provision of forestry services by communities to the large farms including supply of seedlings, planting and maintenance through to harvesting.

A constraint would be that many farms are considerable distance from traditional communities and establishing relationship and providing service would be difficult. Nevertheless, assuming 60 percent is being farmed then there is the potential for re-forestation of some 120,240 feddans (50,500 ha) under these collaborative arrangements. Assuming sustainable yield of 5 m^3/ha on a 20 year rotation then an annual cut of 252,000 m^3 would be possible.

Contracts for supply of seedlings, planting and care and maintenance could provide substantial contributions to households' financial assets as well as widening the range of the livelihood strategies.

A second opportunity for collaboration is the utilization of the estimated 425,000 tons of residues for livestock feed for transhumant pastoralists. This is sufficient to feed 229,300 tropical livestock units (250 kgs live-weight).

(ii) Specific Interventions to Improve Crop Productivity

Two specific interventions to raise crop productivity have been proven by Research: drought-resistant crop varieties for sorghum, sesame and groundnuts, and the use of tied ridging to increase soil moisture. It estimated that using both improved varieties and tied ridging yield increases of 50 percent are possible (Mekki Abdul Latif, 2005).

(iii) Farm Level Analysis

The analysis uses the recently published MOA Economic Survey of Traditional rainfed Areas (MOA, 2006b) covering Blue Nile, Sinnar, White Nile, South and North Kordofan States. In the area covered by the Blue Nile Sub-basin the data for Blue Nile State was used. Crop yields were assumed to increase by 25 percent in the first year and to 50 percent from year 2 on-wards. Increased family labour for tied ridging and additional time for harvesting and threshing and increased cost of improved seed varieties[33] were the main incremental costs.

The analysis was conducted over 50 years using a discount rate of 10 percent. The farm level B:C ratio is 2.6.

[33] Currently MOA are distributing improved seed free of charge.

(iv) Sub-basin Level Analysis

An estimated 75,000 feddans (31,330 ha) of traditional rainfed farms have been mapped in the Atbara Sub-basin, although because of their small size and the spatial resolution of the Landsat satellite imagery this may be an underestimate. Additionally, returning displaced people and natural migration into the area will lead to an increase in area cultivated.

The analysis assumes that 50 percent of the area will adopt the new technology over a period of 10 years. The discounted incremental benefits are SDD 4.6 million (US$ 23.1 million). The overall B:C ratio is 2.4. The results are shown in table 51.

Table 51. Financial Analysis: Improved Technology – Traditional Rainfed farms: Atbara Sub-basin

Financial Costs and Benefits of Improved Agronomy Interventions on Traditional Farms: AtbaraSub-basin							
	Cost WOP (SDD '000)	Cost WP (SDD '000)	Benefit WOP (SDD '000)	Benefit WP (SDD '000)	Incremental Cost (SDD '000)	Incremental Benefit (SDD '000)	B/C Ratio
Trad. Farms	5,989,415	8,046,612	10,571,826	15,614,403	2,057,197	5,042,577	2.5
	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
Trad. Farms	29.9	40.2	52.9	78.1	10.3	25.2	2.5
all costs and benefits are PVs over 50 years at 10% discount rate							

(v) Global Benefits

The increase in crop residue production would be approximately 220 kgs are 70 percent of that on the Semi-mechanized farms. The increase in soil carbon would be slightly less – an estimated 14 percent increase. Over the 37,300 feddans (15,665 ha) this would amount to an increase of 57,550 ton of carbon sequestered. Using the same value of carbon sequestered this would be valued at SDD 34.5 million (US$ 0.17 million).

Research on soil carbon in North Kordofan showed the value of fallow periods on soil carbon (Olsson and Atrdo, 2002). Under the current continuous cropping soil carbon will decline from 1 ton/ha to 0.68 tons in 100 years. Changing the crop:fallow ratio to 5:6, 5:10 and 5:20 would increase soil carbon content to 1.15, 1.28 and 1.70 tons/ha respectively. In the absence of data on possible future rates of change in the crop:fallow ratios it is difficult to place a value on these.

5.6.3 Benefits from arresting Kerib Land formation and Restoration of Existing Kerib Land

(i) Background

There is the potential to reclaim nearly 192,860 feddans (81,000 ha) of kerib land above the Kashm El Girba dam. In the analysis it is assumed that 40 percent of this – some 77,140 feddans (32,400 ha) can be reclaimed over a period of 10 years.

The kerib land has an average distance from the river to the edge of 1,000 meters. Thus each 1 km reach of river encompasses some 200 ha of kerib land both sides of the river. Each 100 meters reach of river encompasses 24 feddans (10 hectares) kerib land. The 32,400 ha proposed reclamation cover some 162 kms of river.

An exclusion zone some 100 meters from the edge of the gullying is required to prevent gully extension. This would require that some 7,720 feddans (3,240 ha) of cropland be enclosed over the 10 year period – 772 feddans (324 ha) per year.

Currently, some 2,860 feddans (1,200 ha) of rainfed cropland are being lost each year above the dam[34]. By reclaiming 40 percent of the kerib land some 1,145 feddans (480 ha) of cropland can be saved – 115 feddans (48 ha) per year. Thus, there is a net gain of cropland of 760 feddans (328 ha).

(ii) Unit Area Analysis

The analysis assumes a mix of multi-purpose trees and herbaceous forage. Annual forage production is estimated to reach after 4 years of closure a sustainable yield of 400 kgs of herbaceous biomass per hectare per year over 40 percent of the area. Tree planting at a density of 300 trees/ha would produce 9 tons/ha after 15 years. This could produce 2.7 tons/ha of charcoal every 15 years. The net saving of cropland due to reclamation is approximately 1.5 percent of the area reclaimed (0.035 feddan or 0.015 ha). The value of cropland is SDD 60,200/ha (US$ 301/ha)[35].

The financial analysis was conducted over a 50 year period using a discount rate of 10 percent. At the 1 hectare level the intervention has a B:C ratio of 2.0. Annual incremental returns for forage are SDD 5,065/ha (US$ 25/ha) and for charcoal SDD 26,964/ha (US$ 135/ha) every 15 years.

[34] There is no rainfed cropland below the dam,.
[35] See para. 3.2.6 (i) for calculation.

(iii) Programme-level Analysis

The analysis at the programme-level assumed that 10 percent of the 32,400 ha will be reclaimed each year for 10 years. The total reclaimed area would produce forage of 13,000 tons/yr sufficient to feed 7,000 TLU's. Trees planted over the total reclaimed area could produce some 8,750 tons/yr of charcoal from year 15 onwards.

The land to be enclosed is traditional rainfed cropland with an annual net return of SDD 6,348/ha. After enclosure it could produce forage grass at of 1 tons/ha valued at SDD 2,282/ha. The net loss of income from the enclosed cropland as well as the prevention of the cropland lost to gully erosion was taken into account. The B:C ratio is 3.0 (table 52).

Table 52. Financial Costs and Benefits of Reclaimed kerib land in the Atbara Sub-basin.

Financial Costs and Benefits of Reclaimed Kerib Land Interventions in Atbara Sub-Basin

	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
	18,815	637,061	1,288	1,877,283	618,246	1,875,994	3.0
total	**18,815**	**637,061**	**1,288**	**1,877,283**	**618,246**	**1,875,994**	**3.0**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
	0.1	3.2	0.0	9.4	3.1	9.4	3.0
total	**0.1**	**3.2**	**0.0**	**9.4**	**3.1**	**9.4**	**3.0**

all costs and benefits are PVs over 50 years at 10% discount rate

(iv) Regional Benefits

It estimated that currently gully erosion on the kerib land contributes approximately 3.14 million tons of sediment per year to the Atbara River. The proposed programme will reclaim 40 percent of the kerib land, reducing the sediment contribution by 1.26 million tons/yr or a reduction of 1.2 percent/yr. This will have a small positive impact on sediment reduction in the Kashm el Girba Reservoir and the New Halfa Irrigation scheme. The increased benefits of reductions in costs of lost irrigation water, canal cleaning and lost power production are SDD 10.6 million/yr (US$ 0.05 million/yr). These benefits are offset by the loss of fertilizer properties of the sediment of SDD 42.0 million/yr (US$ 0.21 million/yr).

(v) Global Benefits

The current SC content of the soils in the kerib land are likely to be very low indeed and the parent material is partially weathered Quaternary colluvial/alluvial sediments, and is probably not more than 0.5 tons/ha. Assuming a 20 percent increase in SC over 50 years soil carbon would accumulate over the reclaimed area at a rate of 65 tons/yr. After 25 years total incremental soil carbon would be 1,620 tons valued at SDD 0.97 million (US$ 0.048 million).

5.6.4 Impacts of Reduced Sedimentation in Reservoirs and Irrigation Systems

(i) New Sediment Budget of the Tekeze-Atbara Sub-basin

These reductions were based on a 40 percent adoption of WSM interventions on cropland and 40 percent of non-cropland. The main impacts of a reduction in sediment load of the Tekeze-Atbara River will be felt in the Kashm El-Girba Reservoir and in the New Halfa Irrigation Scheme. The new sediment budget for the Tekeze-Atbara Sub-basin is shown in table 53.

Table 53. Tekeze-Atbara Sub-basin: Estimated Current Sediment Budget: With Watershed Management Programme and only Existing Dams.

SEDIMENT BUDGET: TEKEZE-ATBARA SUB-BASIN	(1) NO WSM+ NO DAM	(2) WSM ONLY (NO DAM)	(2) - (1) REDUCTION
SEDIMENT ENTERING TEKEZE TK5	31.10	21.34	9.76
SEDIMENT RETAINED IN TEKEZE TK5	0.00	0.00	
SEDIMENT THRU' TEKEZE TK5	31.10	21.34	9.76
SEDIMENT ENTERING RIVER BELOW TEKEZE TK5	37.51	25.74	11.77
TOTAL SEDIMENT TEKEZE-SETIT AT BORDER M t/yr	68.61	47.08	**21.53**
SEDIMENT FROM UPPER ATBARA/ANGEREB Mt/yr	7.37	5.06	2.31
TOTAL SEDIMENT AT BORDER M t/yr	**75.98**	**52.14**	**23.84**
MILLION TONS/YR SUSPENDED LOAD AT BORDER: KERIB LAND	3.23	3.23	
TOTAL SEDIMENT IN ATBARA IN SUDAN (M t/yr)	79.21	55.37	
SEDIMENT ENTERING KASHM EL GIRBA	79.21	55.37	23.84
SEDIMENT RETAINED IN KASHM EL GIRBA	10.30	7.20	3.10
SEDIMENT THRU' KASHM EL GIRBA	68.91	48.17	
SEDIMENT ENTERING NEW HALFA IRRIGATION SCHEME	68.91	48.17	20.74
SEDIMENT RETAINED IN NEW HALFA IRRIGATION SCHEME	6.08	4.25	1.83
SEDIMENT THRU' NEW HALFA IRRIGATION SCHEME	62.83	43.92	
MILLION TONS/YR FROM KERIB LAND BELOW KHASM EL GIRBA DAM	0.00	0.00	
SEDIMENT STORAGE RATE ON RIVER BED AND ALLUVIAL PLAINS	7%	7%	
MILLION TONS LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS	4.40	3.07	
MILLION TONS/YR TO WHITE NILE	**58.43**	**40.85**	

The reductions in sedimentation are approximately 31 percent of current rates. It can be expected that there would be a commensurate reduction in costs of sedimentation (i) loss of irrigation water and crop production, (ii) reduction in operation and maintenance costs, (iii) dredging turbine intakes. It is difficult to forecast the potential impact these reductions in suspended sediment load will have on the current dam operational procedures (i.e. waiting for the main sediment peak to pass before closing the gates) and so on lost potential to store water.

(ii) Reductions in Lost Irrigation Water and Crop production

The estimated annual costs of reservoir sediment in Kashm El-Girba Reservoir and its impacts on lost irrigated water were SDD 29.97 million/yr (US$ 0.15 million) accumulating to SDD 749.4 million/yr (US$ 3.75 million/yr) after 25 years.

With a 31 percent reduction in sediment load these would be reduced to an accumulating annual loss of SDD 20.68 million/yr (US$ 0.10 million/yr).

(iii) Reduced Operation and Maintenance Costs of the New Halfa Irrigation Scheme

(a) Cost Reductions

Sediment cleaning costs in the New Halfa scheme are estimated to be SDD 906.0 million/yr (US$ 4.53 million/yr). These would be reduced to SDD 625.1 million/yr (US$ 3.13 million/yr).

(b) Benefit Reductions

Current benefits accruing to the value of the sediments as fertilizer are SDD 3832.5 million/yr (US$ 19.2 million/yr). These benefits would be reduced by SDD 101.6 million/yr (US$ 0.51 million/yr).

(iv) Lost Power Hydro-Production

Current hydro-power losses due reservoir sedimentation are estimated to be an accumulating SDD 20.98 million/yr (US$ 0.011 million/yr). The losses would be reduced to SDD 14.5 million/yr (US$ 0.07 million/yr).

It is difficult to predict what a 31 percent reduction in sediment load would have on the flushing regime of the Kashm el Girba dam, thus no assessment is made.

5.7 Estimated Budget - Direct and Supporting Interventions: Atbara Sub-basin - Sudan

The previous section has outlined some of the quantifiable costs and benefits accruing to the direct interventions. All of these depend to a greater or lesser extent on the implementation of the Supporting Interventions. These Supporting Interventions will provide increased physical and human capacity to rural households and government implementing organizations and in particular the extension Service; support to assisting rural families to gain non-farm employment and to small enterprise development in both rural areas and small urban centers; improved road and market infrastructure and increased capacity of farmers in product marketing and with increased available and access to micro finance and credit. The details of these and their direct and indirect benefits are summarized Matrix 2b in Chapter 2.

This section provides a summary of the budget required to implement both the Direct and Supporting Interventions. A detailed breakdown with units and unit costs is provided in Annex 3. A summary is provided in table 54. Given the very complex nature of the relationships between the Direct and the Indirect Interventions, in particular their short and long term impacts on human welfare and development in local, regional and National terms it would be extremely hazardous to attempt an overall benefit-cost analysis. However, it is submitted that the figures below provide a sense of the order of magnitude in implementing a programme of the interventions as outlined in Chapter 3.

Table 54. Summary 10 Year Budget: Atbara Sub-basin – Sudan: (a) Direct Interventions, (b) Supporting Interventions and (c) Total budget (SDD).

(a) Direct Interventions

Intervention	SDD	US$
1. ARRESTING SOIL DEGRADATION CROP INTENSIFICIATION	2,884,630,000	14,423,150
2. LIVESTOCK DEVELOPMENT	4,733,750,000	23,668,750
3. REDUCING RIVER BANK EROSON	380,000,000	1,900,000
4. KERIB LAND RECLAMATION	3,920,400,000	19,602,000
5. REDUCING DRIFTING SAND	300,000,000	1,500,000
Sub-total	**12,218,780,000**	**61,093,900**

(b) Supporting Interventions

Intervention	Total cost (SDD)	Total cost (US$)
1. CAPACITY BUILDING	1,501,805,556	7,509,028
2. AGRICULTURAL EXTENSION	318,000,000	1,590,000
3. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT	174,855,000	874,275
4. COMMUNITY ASSETS DEVELOPMENT	4,733,750,000	23,668,750
5. IMPROVED MARKETING	22,500,000	116,250
6. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS	23,250,000	116,250
7. SUPPORT TO STRATEGIC LAND USE PLANNING	187,166,667	935,833
Sub-total	**6,961,327,222**	**34,810,386**

TOTAL

Intervention	Total cost (SDD)	Total cost (US$)
(a) Direct Interventions	12,218,780,000	61,093,900
(b) Supporting Interventions	6,961,327,222	34,810,386
TOTAL	**19,180,107,222**	**95,904,286**

The average cost per household in the traditional rainfed and pastoral sectors SDD 2.45 million (US$ 12,244/household). These costs are higher than the Blue Nile Sub-basin because the population density is much lower. Clearly non-farming members of the community will also benefit from the Direct and Supporting Interventions in terms of improved access to social services, employment and information. Costs per ha of rainfed cropland are SDD 612,196/ha (US$ 3,061/ha). Again areas of rangeland and forest will benefit from the Interventions. These per unit costs are presented only to provide a first approximation of unit costs when considering programme at the catchment or sub-catchment scale.

5.8 Costs and Benefits: the Tekeze-Atbara Sub-basin

All costs and benefits for Ethiopia and Sudan broken down into national, regional and global are shown in table 56. The overall Sub-basin B:C ratio is 5.4. Global benefits comprise approximately 6 percent of total benefits. Net Regional impacts are just over 1 percent of total benefits comprising benefits from reduced sediment loads and the greater offsetting costs of reduced fertilizer effect of sediment. The B:C ratio for Ethiopia increases from 6.2 to 6.7 with global benefits, and that of Sudan from 1.1 to 1.5 with the inclusion of the Regional and Global benefits.

Table 56. National, Regional and Global Benefits of WSM Interventions: Tekeze-Atbara Sub-basin

Economic Costs and Benefits of WSM Interventions in the Tekeze-Atbara Sub-Basin

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
ETHIOPIA							
National							
Soil conservation: Bunds	127.5	153.1	330.0	360.8	25.6	30.8	1.2
Fertilizer/Improved seed	3.0	4.0	13.3	17.7	1.0	4.4	4.5
On-farm Forage	0.1	4.8	34.4	114.6	4.6	80.2	17.3
On-farm Trees: Fuelwood	0.2	4.3	37.6	73.8	4.1	36.2	8.9
On-farm Trees: Crop Production saved: Soil N retained						24.7	
Improved stoves	-	0.9	-	12.5	0.9	12.5	13.8
Area enclosure	120.7	277.3	176.9	1,698.4	156.6	1,521.4	9.7
Small-scale Irrigation	45.9	173.7	78.8	565.7	127.9	486.9	3.8
Small-scale Irrigation: Multiplier Impacts						72.7	
Supporting Interventions	-	-	-	-	45.0	-	
Sub-total	**297.6**	**618.2**	**671.0**	**2,843.4**	**365.7**	**2,269.8**	**6.2**
Regional	-	-	-	-	-	-	
Global							
-	-	-	-	-	-	18.2	
On-farm Trees: Tree carbon	-	-	-	-	-	33.1	
Improved Stoves: Fuel saving: Tree Carbon seq.	-	-	-	-	-	1.6	
Enclosed areas: tree carbon	-	-	-	-	-	74.1	
Enclosed areas: Soil carbon	-	-	-	-	-	34.9	
Sub-total	**-**	**-**	**-**	**-**	**-**	**162.0**	
TOTAL	**297.6**	**618.2**	**671.0**	**2,843.4**	**365.7**	**2,431.8**	**6.7**
SUDAN							
National							
Traditional Rainfed Farms: Crop production	25.2	34.1	62.2	91.8	8.8	29.7	3.4
Semi-mechanised farms: Crop production	57.1	60.7	198.0	258.7	3.6	60.7	16.8
Semi-mechanised farms: Charcoal production		22.5	-	16.2	22.5	16.2	0.7
Semi-mechanised farms: Residue: Livestock feed						5.7	
Reclamation: Kerib land	0.0	3.2	0.0	8.1	3.2	8.1	2.5
Supporting Interventions					52.6		
Sub-total	**82.3**	**120.5**	**260.2**	**374.8**	**90.8**	**120.4**	**1.3**
	-						
Regional							
Increased irrigation water	-	-	-	-	-	10.5	
Reduced OM Costs: Irrigation schemes	-	-	-	-	-	31.0	
Reduced fertilizer value: Sediment	-	-	-	-	-	(5.0)	
Kerib land: Reduced sediment load Atbara						0.1	
Kerib land: Reduced fert. Value						(0.0)	
Sub-total	**-**	**-**	**-**	**-**	**-**	**36.5**	
Global							
Traditional Rainfed Farms: Soil carbon	-	-	-	-	-	0.0	
SMF's : Soil carbon	-	-	-	-	-	5.7	
SMF's : Tree Cover: Soil carbon	-	-	-	-	-	0.5	
Kerib land: Soil carbon	-	-	-	-	-	0.5	
Sub-total	**-**	**-**	**-**	**-**	**-**	**5.7**	
TOTAL: SUDAN	**82.3**	**120.5**	**260.2**	**374.8**	**90.8**	**162.6**	**1.8**
TOTAL: SUB-BASIN	**379.9**	**738.7**	**931.1**	**3,218.2**	**456.5**	**2,594.4**	**5.7**

all costs and benefits are PVs over 50 years at 10% discount rate

6. COSTS, BENEFITS AND IMPACTS OF WATERSHED MANAGMENT INTERVENTIONS BARO-SOBAT-WHITE NILE SUB-BASIN

This chapter begins by looking at the benefits for the Baro-Sobat-White Nile Sub-basin deriving from the interventions of the programme as a whole. The analysis considers benefits at the local community level, the national, the Sub-basin/Regional and the global levels.

The rest of the chapter first considers Ethiopia and then Sudan. For each country the analysis first examines the costs of continued natural resource management practices and then analyses the impacts, costs and benefits of the direct interventions.

6.1 Benefits for the Baro-Sobat-White Nile Sub-basin of the Watershed Management Interventions of the Programme as a Whole

6.1.1 Household and Community Level: Local Rural-Urban Linkages

The results of the benefit-cost analysis of on-farm and community interventions demonstrate that there is significant potential for increasing household farm incomes, increasing food supply with improved levels of nutrition and health, reducing vulnerability to climate, social and economic shocks and improving the quality of the natural resource base. As with the Abbay-Blue Nile Sub-basin a key finding is that a number of the interventions have substantial costs in terms of labour for construction or establishment. For a number of the interventions it takes a number of years for benefits to be realized (on-farm and community tree planting) or benefits only slowly accrue (SWC measures).

In the areas of food deficits there are a number of programmes that support households and communities through food/cash for work and safety net support measures. However, there is an urgent need to extend support to households and communities in apparently more favourable areas where there is clear evidence that the high costs of initial labour requirements are an impediment to adoption of SWC measures on cropland.

The programme of interventions will have a substantial impact on arresting degradation of the natural resource base both on cropland and also on non-cropland. This is a vital entry point in breaking the cycle of poverty and resource degradation and attacks one of the root causes of poverty in the Baro-Sobat-White Nile Sub-basin. Conservation of the non-croplands through enclosure and tree enrichment planting will provide not only direct benefits to communities in terms of increased livestock feed and improved livestock productivity and increased supply of fuelwood and timber, but also an increase in wild plants of food and medicinal values that are of considerable importance to the most disadvantaged community members such as female headed households.

The interventions that increase the easily accessible supply of fuelwood (on-farm tree planting) and the reduction in its consumption (using fuel efficient stoves) will have consider impacts on reducing the work loads of women and children. In addition, there will positive impacts on their health and well-being through the reduction in smoke inhalation thus reducing the incidence of respiratory diseases.

The supporting interventions will have substantial benefits to households and communities. Measures to increase market accessibility and integration such as feeder roads and extension of telecommunications will have positive impacts by reducing market transaction costs thus benefiting both producers and consumers. The interventions will enable an expansion of local economic multipliers. At the local level these will occur through increased incomes being spent on purchases of local non-tradable goods i.e. goods made locally rather than those imported. Work in an inaccessible area of Nigeria similar to many parts of rural Ethiopia and Sudan suggested a multiplier of 1.32 for the non-tradable sector (Hazell & Roell, 1983). In addition, there will be increased backward multipliers (from an increased demand for improved inputs) and forward multipliers (from an increase in marketed agricultural products. These in turn will increase employment opportunities in the many small urban centres for rural and urban households.

The capacity building interventions will have a number of positive benefits at the local level. Increased access to improved technologies (with increased support to extension and research services) combined with access to literacy and skills training have been shown to be strongly correlated with increased adoption of improved agronomic technologies. The support to the Extension Service with improved information linkages between farmers and research will increase the relevance of agricultural research to the traditional small-holder sector. Increased road accessibility and skills training will enable rural households to have better access to non-farm employment opportunities.

Increased access to micro credit will provide an important enabling environment for farmer adoption of improved technologies, in particular fertilizer and improved seeds. Credit together with support to small enterprise training will also enable the development of small enterprises in the small urban centres further increasing employment opportunities. It must emphasized that there a number important synergies between the various interventions most particularly in improving rural-urban linkages, the increasing economic development of small urban centres and increased agricultural production.

The support to Community Level Land Use Planning in Sudan will enable rural communities to better manage the natural resource base and sustainably harvest wood and other non-wood products. This will in turn assist in reducing local conflicts over natural resource use and increase access to all groups.

Strategic Land Use Planning and Zoning in the High Forest areas of the Ethiopian Highlands will clearly delineate areas for small-holder and large-scale commercial agricultural development based on stakeholder participation and sustainable land suitability principals. Similarly, areas for Community Forests will also be clearly delineated on the same basis. Clear and transparently developed land use zoning will allow for sustainable development and management of the Forest and Land resources at the local level.

6.1.2 National and Sub-National Levels

At the national level the interventions will increase the rate of poverty reduction and numbers of households needing safety net support. In both Ethiopia and Sudan the highest incidence of poverty is with the traditional agricultural smallholder sector. By targeting this sector (rather than the commercial agricultural sector) a proportionally greater impact will be achieved in reducing the numbers of households living below the poverty line.

A recent study by IFPRI and ASARECA[36] (Omamo,et al. 2006) covering all the counties in the Region including Ethiopia and Sudan found that the largest poverty reductions will come not from growth in export sub-sectors but from growth in those sub-sectors for which demand is the greatest – such a crop staples, livestock products, oil seeds and fruits and vegetables. Another more detailed study for Ethiopia (Daio et al., 2006) confirms these findings. The studies also found that agricultural productivity growth alone is insufficient to meet the Millennium Development Goals (MDG) poverty reduction targets. Growth in non-agricultural sectors and improvements in market conditions are also required.

The interventions to increase market accessibility and integration will have positive impacts across the Sub-basin in each country as market transaction costs are substantially reduced. Sub-regional multipliers: backward and forward as well as growth of tertiary and secondary urban centres will stimulate the sub-regional economies. It is difficult to predict the size of these multipliers. Bhattari et al., (2007) have examined irrigation development across India and irrigation multipliers to the economy as a whole. They found irrigation multiplier values of 3 to 4.5 suggesting that about two thirds of the irrigation benefits have accrued to the non-irrigation sector, with farmers receiving the other third. Whilst markets and the economy as a whole in India are better integrated and accessible, with increasing market integration in Ethiopia and Sudan Sub-regional economic multipliers will become increasingly important.

[36] The Association for Strengthening Agricultural Research in Eastern and Central Africa

In Ethiopia within the Baro-Akobo Sub-basin three Economic Sub-Regions can be identified: the Northeastern Sub-Region, Southeastern Sub-Region, the Gambella Lowlands Sub-Region (Map 5).

The Northeastern Region is located in the Highlands in the upper reaches of the Baro River. Although in a high rainfall area there are increasing signs of food insecurity. It is linked by a primary road to from Metu to Nekempte and to Addis Ababa, although it is a two day vehicle journey to Addis Ababa and thus relatively remote. This Sub-Region has large areas of intact High Forest to the south. It also has many valley-bottom wetlands which are being drained for crop production. The proposed direct interventions will support the establishment of sustainable wetland production systems, thus increasing food security and diversifying crop production. The Land Use Zoning of the High Forest areas will contribute to reducing conflict over the use of forest and land resources between traditional farmers and large commercial estates and support the legal establishment of Community Forests. Support to improved quality control and marketing for organic coffee, honey and the spice corrorima (all products from the Community Forests) will have a substantial impact on the economy of the Sub-Region.

The Southeastern Sub-Region is located in the Highlands in the upper reaches of the Akobo River and its tributaries. It is linked by a primary road from Mizen Teferi to Jimma and to Addis Ababa, which is also a 2 day vehicle journey. There is a large area of intact forest to the north. Valley-bottom wetlands are relative sparse as the terrain is more dissected. There are already two large State owned coffee estates and there are proposal to establish a rubber plantation. The recent clearing of a large area of forest for a commercial tea estate has caused considerable conflict with traditional farmers. The Land Use Zoning of the High Forest will contribute to reducing such conflict and enable the legal establishment of Community Forests. As with the Sub-Region to the north support to quality control and improved marketing of organic coffee, corrorima and honey will have a considerable impact on the economy of the Sub-Region.

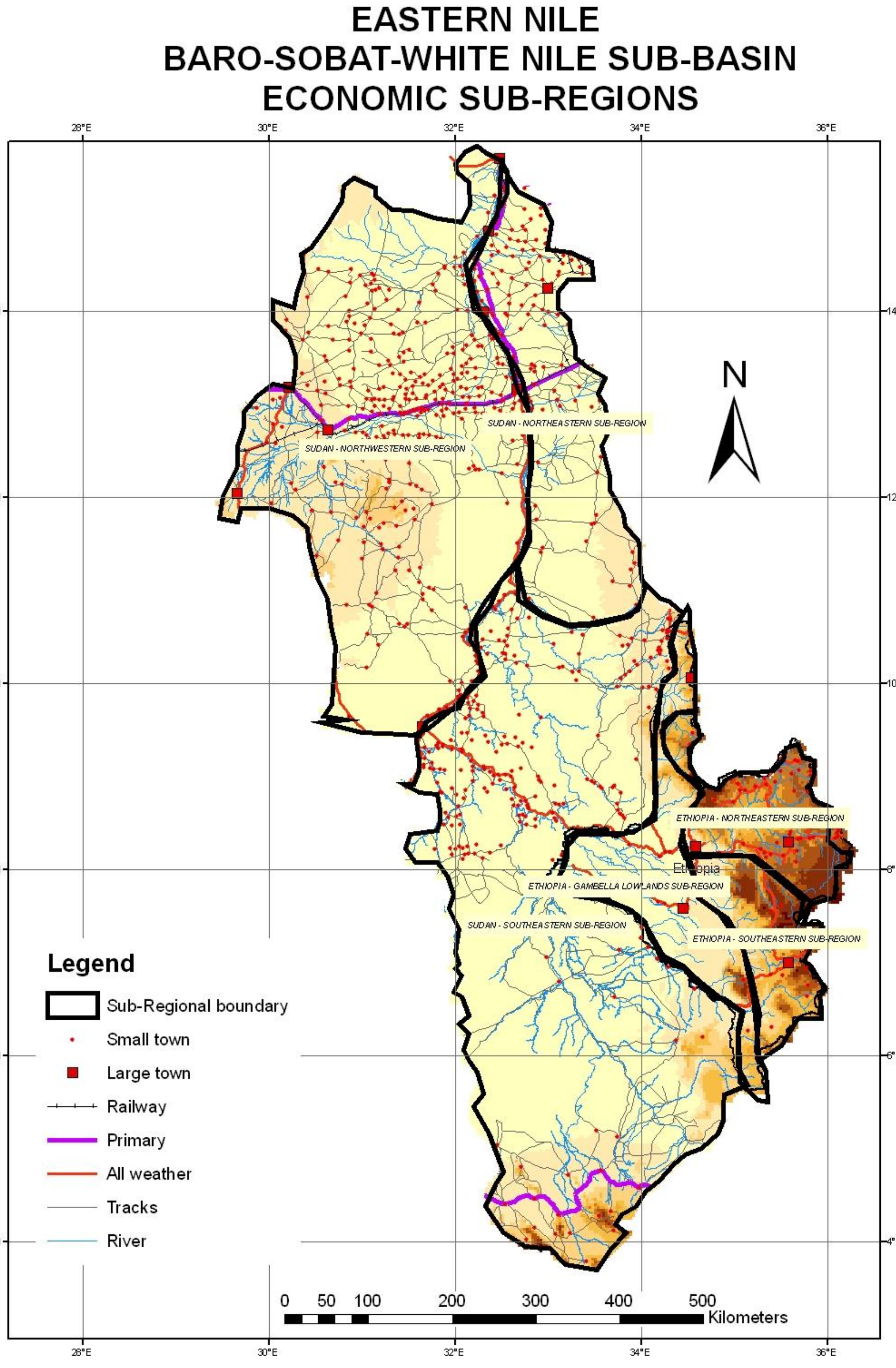
The Gambella Lowlands Sub-Region is located in the west and comprises the salient of Lowlands between the Baro and Akobo Rivers. It is linked by an all-weather road to Metu, and thence to Nekempte and to Addis Ababa. There is a 5 times a week air service to Addis Ababa. The area is relatively food secure although excessive flooding of the Baro and Akobo rivers can cause considerable crop damage. There is one large State cotton farm and plans for a large-scale irrigation scheme. There is a large area of intact Lowland Forest in the east and the Gambella National Park in the centre of the Sub-Region. The proposed interventions will have a number of positive impacts. Land Use Zoning of the forest will reduce conflicts between local and commercial interests. Support to the development of the Gambella National Park will create a valuable eco-tourism attraction, which could make an important contribution to the local economy.

In Sudan there are three Economic Sub-regions are defined. The first is in the Southeast Sub-Region encompassing the catchment of the Sobat River - East Equatoria, Jongoli and the southern half of Upper Nile States; the second is the Northeastern Sub-Region found east of the White Nile – the northern part of Upper Nile, Blue Nile and Sinner States; and thirdly Northwestern Sub-Region found west of the White Nile – North and South Kordofan.

The Southeastern Economic Sub-Region is very isolated with very poor road communications and comprises a vast area of seasonally flooded clay plains. On the west the White Nile provides a transport artery to the north to Khartoum and south to Juba. During the floods the Sobat can also be used. Much of the physical and social infrastructure has been destroyed during the civil war. The proposed detailed hydro-ecological and livelihoods survey of this Sub-Region will provide a sound understanding of these complex inter-relationships. The results of the study will be used as a basis for developing detailed sustainable development programmes for agriculture and social welfare. The support to the Southern Commission for Natural Resources will include physical and human capacity building and technical support. This will enable the effective planning, and sustainable development and management of the natural resource base of the Sub-region. The livestock interventions covering animal health and improved marketing will increase production and increase off-take. The increased income from an expanding livestock export sector will make an important contribution to the Sub-Regional economy.

The Northeastern Economic Sub-Region has good road connections to Khartoum from Renk and to Port Sudan through Senner and Wad Madeni. The proposed interventions to arrest soil degradation and improve crop yields will have a substantial impact on incomes. In addition to the local multipliers there will be substantial Sub-regional multipliers deriving from increased market accessibility and integration. Improved access to pastures north of the Machar marshes with the implementation of the stock routes and water points will substantial increase livestock productivity and increased domestic and export earnings. The increase use of crop residues from the SMF's by pastoralists, agro-pastoralists and livestock holders in the large irrigation schemes will also contribute to increased livestock productivity and the Sub-regions economies.

The Northwestern Economic Sub-Region is well connected to Khartoum in the northern part with the primary road from El Obeid through Kosti. However to the south of Kosti the road network is sparse. The proposed inventions to increase market access and integration will have a very positive impact on reducing market transaction costs. The proposed interventions to arrest soil degradation and improve crop yields will have a substantial impact on incomes. In addition to the local multipliers there will be substantial Sub-regional multipliers deriving from increased market accessibility and integration.



Map 5. **Baro-Sobat-White Nile: Economic Sub-Regions**

The interventions to support State-wide Strategic land Use Planning in Sudan have clear linkages to Sub-regional economic development. The Strategic Plans will be developed with full stakeholder participation and will assist in clarifying development objectives and strategies. The plans will contribute to the harmonization of sectoral development strategies and so developing the synergy between sector developments identified in the IFPRI/ASARECA Study as necessary for substantial poverty reduction.

The Capacity Building interventions will contribute to the increased effectiveness of the agricultural Extension and Research Services. In each country this increase in both the quantity and quality of human capital will impact on the quality of research outputs and on extension advice. The Land Policy reforms in Sudan will have far reaching effects in increasing access to natural resources by the most disadvantaged, reducing Sub-regional and regional conflicts over resource access and use, and in increasing crop and livestock productivity. These will further re-enforce Sub-regional economic growth and its attendant multipliers.

6.1.3 Sub-basin and Regional Level

Benefits at this level reach across the political boundary and accrue to the Baro-Sobat-White Nile Sub-basin and Eastern Nile Basin as a whole. Currently there is little trans-boundary trade between Ethiopia and Sudan. On both sides of the border there are no road links and the border area is extremely periferal in both countries. However, there are strong cultural ties with the Anuak and the Nuer peoples who live in both countries. Good road access from Gambella town to the Juba – Lokichokia road to Kenya would open both the Boma area in Sudan and the Gambella area in Ethiopia to markets in Kenya, Uganda and the Democratic Republic of Congo.

Closer cooperation in crop early warning systems, establishing joint strategic grain reserves and purchase of grains for food relief either side of the border would enable faster responses to local food shortages to the mutual benefit of both countries. Increased food security on both sides of the border will contribute to overall food security for the region.

The quantifiable benefits to reduced erosion in the Ethiopian Highlands and sediment loads in the Baro-Sobat-White Nile are very small. However, the rapid and uncontrolled loss of forest cover in the Ethiopian Highlands could have significant impacts of the hydrology of the Baro-Sobat River system. At the small catchment level these are likely to result in increased flood and given the relatively small size of the Baro-Akobo catchment area would impact on the flooded grasslands of both Ethiopia and Sudan. As these are vital components in the livelihood systems of both the Anuak cultivators and the Nuer pastoralists sever disruption to their economies could result. The proposed Strategic Land use Zoning of the high forest together with the watershed management components will contribute to reducing any potential negative impacts of increased flooding.

The support to the trans-boundary collaborative wildlife and habitat survey and assessment of the areas encompassing the Gambella and the Boma National Parks will contribute to enhanced wildlife and habitat conservation. It will also establish the institutional mechanisms for continuing cooperative measures. The basis will be established for developing Park Management Plans that complement each other. There would be increased potential for "Eco-tourism and thus increased employment opportunities for Park inhabitants on both sides of the border. It will also provide a tangible example of the benefits of trans-boundary cooperation between Sudan and Ethiopia.

6.1.4 Global Level

The global benefits identified in the analysis relate to the increased amount of carbon sequestered in wood biomass, herbaceous biomass and soil carbon. In some cases it has been possible to quantify these and the results are provided below. In other cases such as improved pasture development in the seasonally flooded grasslands this has not been possible because of the uncertainties in quantifying the amount of increased pasture that will result.

Nevertheless, small-scale experiments have clearly demonstrated that increased herbaceous biomass wills substantially increase the amount of carbon sequestered in the soil and that there is considerable untapped potential for increased carbon sequestration under improved pastures (FAO, 2003). This is notwithstanding that the increased herbaceous matter will be consumed by livestock – the carbon is stored in the soil. The small scale example of improved rangeland management supported by the GEF in Bara Province of North Kordofan described in chapter 8 indicates how this may be implemented at the local level.

Other global benefits accruing to the programme of interventions relate to the conservation of biodiversity. At the local level this is represented in the increase in native plant species in enclosed areas that have all but disappeared in the open access communal areas. Such an increase in species diversity will also be seen in the improved management of the pastures of the seasonally flooded grasslands.

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. Thus, the interventions targeted at the traditional and the commercial farming sectors in Ethiopia and Sudan will generate these benefits.

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$. In situ conservation of the barley, teff and wheat gene pools are of global significance. The value of the coffee pool of US$ 420 million (at 10 percent discount rate) has been demonstrated by Hein and Gatzweiller (2006).

In Sudan a large number of natural selections of sorghum and millet have over millennia accrued a gene pool of considerable importance. In addition, the cultivation of *Acacia seyal* for its gum has also through centuries of natural selection accrued an important gene pool for this species.

The proposed interventions to support traditional agriculture will enable farm households to be buffered from natural shocks and allow them to maintain these important gene pools.

6.2 Costs of Continued Natural Resource Management Practices in Ethiopia

It is emphasized again that the physical impacts and costs outlined below do not reveal to full extent of the social and economic costs to the rural (and urban) population in terms of those key elements in the downward spiral of poverty and a degrading resource base such as poor nutrition and health, poor access to social services (health and education) and restricted access to alternative livelihood strategies.

6.2.1 Agricultural production forgone

The total amount of soil eroded annually in the Baro-Akobo Sub-basin is estimated to be 43.7 million tons/yr of which 21.5 million tons/yr (50 percent) is from cultivated land. This is a higher proportion than that in the Tekeze and Abbay Sub-basins owing to higher communal-land vegetative cover.

The impact on crop production due to the decline in soil-moisture holding capacity caused by soil erosion is the loss of 3,716 tons/yr. Each year this loss accumulates so that the loss of crop production in 25 years is 92,908 tons/yr. Soil erosion also causes a nutrient loss that decreases crop production annually and non-cumulatively by 7,162 tons/yr. Crop production lost as a proportion of total annual crop product is 1.3 percent in year 1 rising to 12 percent in year 25.

The breaches in soil nutrient cycling caused by dung/crop residue burning and crop removal reduce crop production annually and non-cumulatively by 1,866 tons and 5,941 tons respectively. The total crop production forgone is shown in Table 57 but it's important to note that soil nutrient loss prediction is dubious and precarious based on limited data and many estimates (Barber, 1985).

Table 57. Annual Crop Production Forgone Due to Soil Erosion, Dung/Crop Residue Burning and Crop Removal in Baro-Akobo Sub-basin

Cause	Annual Crop Production Forgone (t)		
	Year		
	1	10	25
Loss in soil moisture-holding capacity due to soil erosion	3,716	37,163	92,908
Nutrient loss due to soil erosion	7,162	7,162	7,162
Total due to soil erosion	**10,878**	**44,325**	**100,070**
Nutrient breach due to dung/crop residue burning for fuel	1,753	1,753	1,753
Nutrient breach due to crop removal	2,152	2,152	2,152
Total due to nutrient breach	**3,905**	**3,905**	**3,905**

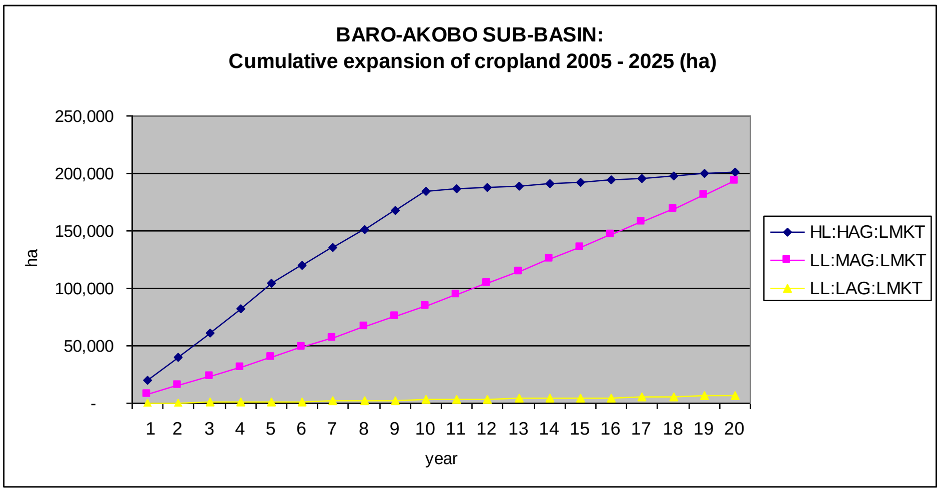
Using the local (ETB 1,880/ton) and the import parity (US$ 240.80/ton) price for wheat enables a monetary estimate to be made of these losses. Annual losses due to soil erosion are ETB 20.4 million/yr rising to ETB 188.1 million in 25 yrs or US$ 2.6 million rising to US 24.1 million. Annual losses due to nutrient breaches are estimated at ETB 7.3 million or US$ 0.9 million.

6.2.2 Future Trends in Soil Erosion without WSM Programme

The background and methodology to determine future trends in soil erosion caused by expansion of agriculture due to population increase were outlined in the Transboundary Baro-Sobat-White Sub-basin Report. The results of the analysis are shown in Chart form below for the Sub-basin.

In the Baro-Akobo Sub-basin the main expansion of cropland takes place in the Highland domain. However except for weredas in the high Forest areas most reach capacity within 10 years and expansion slows down (Figure 10).

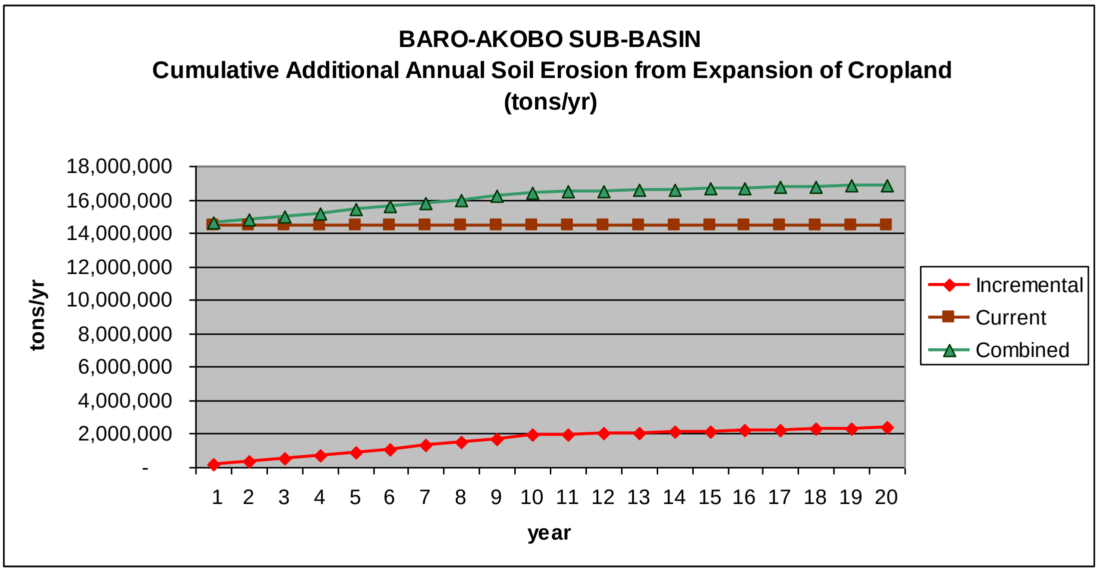
Figure 10. Baro-Akobo Sub-basin: Expansion of Cropland by Development Domain 2005 – 2025 (ha)



HL = Highland; LL= Lowland; HAG = High agricultural potential; MAG – Medium agricultural potential; LAG = Low agricultural potential; HMKT + Good market access; LMKT = Poor market access.

The additional soil erosion after 20 years from cropland is estimated to be 2.38 million tons/yr or approximately 16 percent of current erosion on cropland (Figure 11).

Figure 11. Baro-Akobo Sub-basin: Incremental annual soil erosion (tons/yr) from the expansion of cropland (2005 – 2025.)



Using the Sub-basin wide sediment delivery ratio of 22 percent this would indicate an additional 0.52 million tons/yr of suspended sediment at the border – a 6 percent increase on current rates.

6.2.3 Deforestation and Degradation:

The terms deforestation and degradation are defined as in para. 3.1.4 (i).

(i) Deforestation

The method of determining deforestation rates have been described in para. 3.1.4 (ii). Full results are presented in the Transboundary Analysis – Ethiopia Country Report. By 2015 some 33 percent of forests, 23 percent of woodlands and 15 percent of shrublands will have been cleared for agriculture and settlement as a result of natural population increase. No account is taken of resettlement and migration, or of expansion of large-medium scale commercial agriculture. On average 28,916 ha of high forest and 30,890 ha of woodland are cleared annually. Using altitude as a criterion (between 1,100 and 1900 masl) it is estimated that 23,884 ha of high forest that is ecologically suitable for wild coffee is cleared annually.

To obtain an estimated of the cost of deforestation in the Baro-Akobo Sub-basin three Direct Use and five Indirect Use values were estimated. Direct Use values included (i) timber, (ii) poles, and (iii) fuelwood. Indirect use values included (i) carbon sequestration, (ii) watershed services, (iii) potential pharmaceutical products, (iv) species and habitat biodiversity, and (v) wild coffee gene pool. The detailed methodologies and sources used are detailed in Annex 1.

A summary of values used is provided in table 5.

It was assumed that clearing was for agriculture. Thus to obtain the net value of forest lost the value of agricultural production replacing the forest was subtracted from the gross value of forest removed. In addition it was assumed that 40 percent of watershed services would be retained under the new agricultural land use.

In practice the annual rates of woodland and forest removal vary slightly due to different deforestation rates at the wereda level. The results presented below (table 58) are the average annual values. It is important to note that these costs are cumulative.

Table 58. Estimated Annual Costs of Deforestation of (a) High Forest and (b) Woodland in the Baro-Akobo Sub-basin (US$/yr)

a. High Forest

VALUE	Unit	Amount	Cost (ETB million/yr)	Cost (US $ million/yr)
A. DIRECT USE				
Timber	m^3	1,156,652	364.3	40.5
Poles	m^3	289,163	13.0	1.4
Fuelwood	m^3	1,156,652	52.1	5.8
Sub-total			**429.4**	**47.7**
B. INDIRECT USE				
Carbon sequestration	ton Carbon	867,489	23.4	2.6
Watershed services	ha	28,916	10.9	1.2
Potential pharmaceutical products	ha	28,916	1.3	0.1
Species & habitat biodiversity (High forest)	ha	28,916	1.3	0.1
Coffee gene pool	ha	23,884	54.1	6.0
Sub-total			**91.0**	**10.0**

C. BENEFITS				
Less value of Agricultural production	ha	28,916	33.1	3.7
Less value of continued watershed services	ha	28,916	4.4	0.5
Sub-total			**37.5**	**4.2**
TOTAL NET COST			**482.9**	**53.5**

b. Woodland

VALUE	Unit	Amount	Cost (ETB million/yr)	Cost (US $ million/yr)
A. DIRECT USE				
Timber	m^3	0	0	0
Poles	m^3	123,563	5.6	0.6
Fuelwood	m^3	463,362	20.9	2.3
Sub-total			**26.5**	**2.9**
B. INDIRECT USE				
Carbon sequestration	ton Carbon	185,345	5.0	0.6
Watershed services	ha	30,891	5.8	0.7
Potential pharmaceutical products	ha	30,891	1.4	0.2
Species & habitat biodiversity (High forest)	ha	30,891	1.4	0.2
Coffee gene pool	ha	0	0	0
Sub-total			**13.6**	**1.9**
C. BENEFITS				
Less value of Agricultural production	ha	30,891	35.4	3.9
Less value of continued watershed services	ha	30,891	4.7	0.5
Sub-total			**40.1**	**4.4**
TOTAL NET COST			**0.0**	**0.0**

c. Total

VALUE		Cost (ETB million/yr)	Cost (US $ million/yr)
A. Direct use value		455.9	50.6
B. Indirect use Values		104.6	11.8
Less value of agricultural production		77.2	8.4
TOTAL NET COSTS		**482.9**	**53.8**

The total net costs of deforestation of high forest and woodland in the Baro-Akobo Sub-basin are ETB 482.9 million/yr (US$ 53.8 million/yr), which rises to ETB 12,072 million/yr (US$ 1,345 million/yr) in 25 years time.

(iii) Degradation of Woody Biomass

Degradation of forest, woodland and shrubland is caused by harvesting of wood (mainly for fuel) in excess of the natural yield and results in a reduction in woody biomass. These have been calculated by the WBISPP (WBISPP-MARD, 2001, 2003). In the Baro-Akobo Sub-basin an estimated 4.7 million tons of wood are unsustainably harvested each year. This represents a loss of sequestered carbon of approximately 2.4 million tons valued at ETB 64.4 million/yr (US$ 7.2 million/yr). Other unquantifiable losses are of non-timber forest products (fruits, medicinal products, gums and resins, etc) and biodiversity.

6.2.4 Degradation of Wetlands in the Ethiopian Highlands of the Baro-Akobo Sub-basin

This has been covered in the section on Highland wetlands in the Abbay Sub-basin in paragraph 4.1.5.

6.2.5 Summary of Costs of Natural Resource Degradation in the Baro-Sobat-White Nile Sub-basin: Ethiopia

The various cost estimates of natural resource degradation in the Baro-Sobat-White Nile Sub-basin in Ethiopia are summarized in Table 59.

Table 59. Summary of Costs of Natural Resource Degradation in the Baro-Sobat-White Nile Sub-basin in Ethiopia

Resource	Annual		After 25 years	
	ETB million	US$ million	ETB million	US$ million
1. Soil Erosion/degradation				
- Erosion	20.4	2.6	188.1	24.1
- Nutrient breaches	7.3	0.9	7.3	0.9
2. Sedimentation	-	-	-	-
3. Deforestation/degradation				
- Deforestation	565.0	54.8	12,311.0	1,368.0
- Degradation Wood Biomass	64.4	7.2	64.4	7.2
TOTAL GROSS COSTS	**657.1**	**65.5**	**12,570.8**	**1,400.2**
Benefits: Crop production	68.5	7.6	68.5	7.6
TOTAL	**588.6**	**57.9**	**12,502.3**	**1,392.6**

Costs are dominated by deforestation and degradation of wood biomass, with losses from soil erosion and nutrient losses comprising only 4 percent of total costs.

Table 60 provides a distribution of these costs into local/national, Regional and Global. Some 74 percent of the costs have local/national implications, 2 percent Regional and 24 percent global. The costs with regional implications are underestimated as it has not been possible to value costs of unsustainable Highland wetland conversion.

Table 60. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Baro-Sobat-White Nile Sub-basin in Ethiopia

Resource	Annual			25 years	
	ETB million	US$ million	%	ETB million	US$ million
NATIONAL					
Soil Erosion	20.4	2.6		659.1	84.4
Nutrient breaches	7.3	0.9		1,402.0	179.6
Timber Value forgone	364.3	40.5		9,108.6	1,012.1
Pole Value forgone	33.9	3.8		846.6	94.1
Fuelwood Value forgone	57.6	6.4		1,440.2	160.0
Wetland Conversion	n.d.	n.d.		n.d.	n.d.
Sub-total	**483.5**	**54.1**	**74.9%**	**13,456.6**	**1,530.2**
REGIONAL					
Watershed Services (60%)	10.1	1.1		251.5	27.9
Wetland Conversion	n.d.	n.d.		n.d.	n.d.
Sub-total	**10.1**	**1.1**	**1.6%**	**251.5**	**27.9**
GLOBAL					
Carbon Sequestration : Deforrestation	28.4	3.2		710.7	79.0
Carbon Sequestration : Degradation	64.4	7.2		1,610.0	180.0
NTFP's, Pharmaceutical Value forgone	2.7	0.3		67.3	7.5
Coffee gene pool value forgone	54.1	6.0		1,351.5	150.2
Habitat/species Biodiveristy value forgone	2.7	0.3		67.3	7.5
Sub-total	**152.3**	**17.0**	**23.6%**	**3,806.8**	**424.1**
TOTAL GROSS COST	**645.9**	**72.2**		**17,514.9**	**1,982.2**
Less Crop production	**68.5**	**7.6**		**68.5**	**7.6**
TOTAL NET COST	**577.3**	**64.6**		**17,446.3**	**1,974.6**

6.3 Impacts, Costs and Benefits of Direct Watershed Management Interventions

6.3.1 Soil Conservation and Improved Soil Husbandry

(i) Reduced Soil Erosion on and Sedimentation from Cropland

In these high rainfall areas the up-take of soil conservation structures has been much slower than in the Abay or Tekeze Sub-basins. It is now recognized that vegetative measures such as grass strips are more likely to be adopted in these areas (Wood - personal communication) with soil bunds used for the steeper slopes: above 15 percent slope with soil loss rates approximately 20 t/ha.

However, these measures are only likely to be adopted in areas that have always been (e.g. in Oromiya Region) or have evolved (e.g. in SNNP Region) into a system which is dominated by cereal cropping with no fallowing. In other areas where there is still considerable soil depth and high organic matter levels farmers are unlikely to change from their traditional methods (e.g. contour trash lines). In these areas enset and root crops are important components of the farming system. Although no research has been done of the efficiency of these soil conservation methods and so their soil retention rates are not known but must be positive. The GIS soil erosion hazard analysis indicates that the weredas where these systems are still operating also have relatively low proportions of their cultivated area with a moderate to high soil erosion hazard.

(b) Adoption Rates

The areas with higher proportions of cultivated land with a moderate to high erosion hazard occur in two areas in the Sub-basin: both where cereals tend to dominate and fallowing has generally ceased. The first is in the south-east in the upper Akobo Sub-catchment in SNNP Region (4 weredas), and the second is located on the steeper slopes of the Upper Baro catchment in Oromiya (17 weredas). It is estimated that 279,509 ha or 22 percent of the cropped area should be treated.

In the high rainfall area of the Amhara Region, research showed that after land taken up by the structures had been taken into account, crop yield increases of 14 percent were recorded on 12 percent slopes and no increase on 28 percent slopes. It has been estimated that grass strips trap between 57 (on 12% slopes) and 72 percent (on 28% slopes) of soil moved, with the remaining 28 to 43 percent passing through. Vetiver grass has long been used in the Bebeka Coffee Estate to demarcate blocks of coffee trees and grows vigorously in the area. With soil bunds and after land taken up by the structures is taken into account crop yield increases of 7 percent were recorded. It has been estimated that soil bunds trap 64 percent of soil moved. To estimate the impacts of both grass strips and soil bunds an average trapping efficiency of 65 percent was used.

With 22 percent of cultivated land covered with grass strips and soil bunds and assuming an average of 65% trapping efficiency, soil movement on cropland could be reduced from 14.5 million to 12.43 million tons and sediment delivery to the river from 3.15 million t/yr to 2.70 million t/yr.

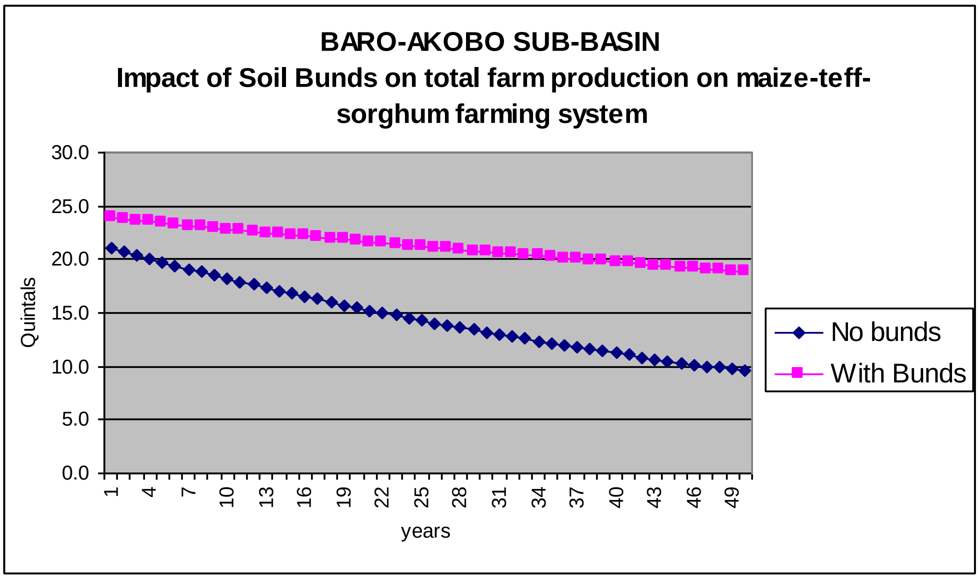
(ii) Reducing Declining Agricultural Production on Cropland

(a) Farm Level

The without and with SWC measures decline in total farm production for the maize-teff-sorghum farming system in the Baro-Akobo Sub-basin for a soil losing 8 mm of soil per year (100 tons/ha) are shown in figure 12. The without-bund annual production decline due to loss of soil moisture holding capacity is 1.6 percent and the with-bund annual yield decline is 0.57 percent. There is also an increase in yield from retained soil nutrients of 0.28Q/ha.

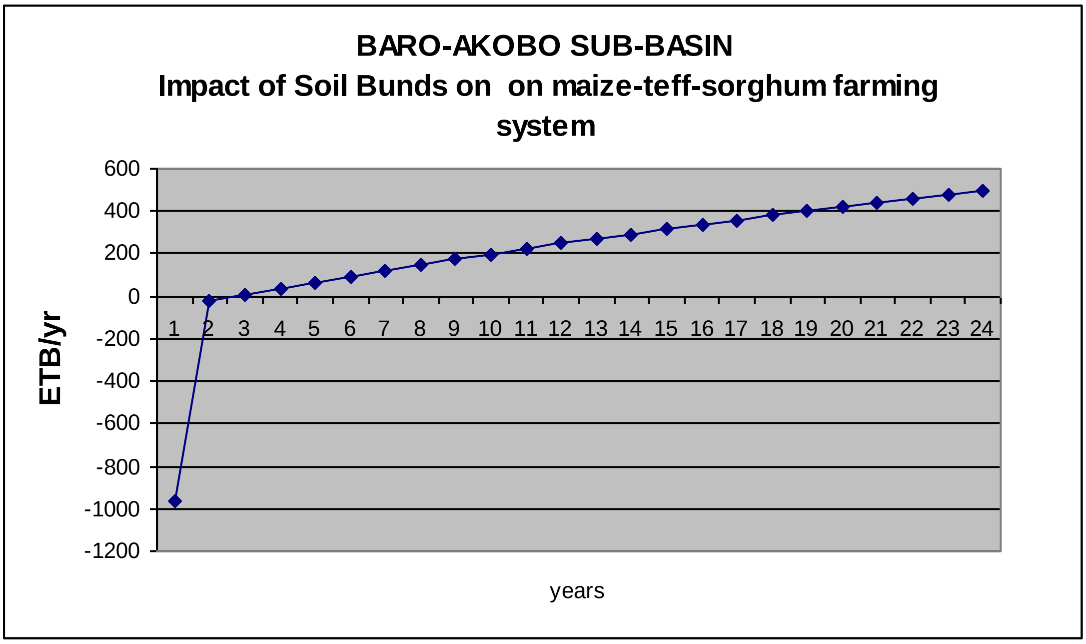
On a 2.00 ha farm with a soil loss rate of 8 mm/yr (100 tons/yr) the initial net change in farm production is 281 kgs per year building up to 692 kgs after 25 years.

Figure 12. Changes in Farm production without and with soil bunds (25 years)



The net incremental value of farm production is ETB -964 in the year 1, which is a reflection of the costs of family labour (192 days at ETB 5/day) in constructing the bunds (figure 13). However, this rises to ETB +513 by year 25. Although the internal rate of return (over 25 years) is 14%, the pay-back period for ETB -964 is 9 years.

Figure 13. Impact of Stone bunds on Incremental Cash Flow: Soil Loss Rate of 8 mm/yr (100t/ha/yr) for maize-teff-sorghum farming System: Baro-Akobo Sub-basin



The financial internal rate of return (IRR) and the discounted B:C ratio over 25 years at 20 and 10 percent discount rates were calculated. The results are presented in Table 61 for soil loss rates of 2 mm/yr, 4 mm/yr and 8 mm/yr (25 tons/yr, 50 tons/yr and 100 tons/yr) respectively.

Table 61. Impact of Grass strips and Soil Bunds: Incremental farm income, Payback-back period (years), IRR (%) and B:C ratio at 20% and 10% discount rates: Baro-Akobo Sub-basin

Farming System	Incremental Annual; Farm income year 1 (ETB)	Incremental Annual Farm income year 25 (ETB/yr)	Payback period (yrs)	IRR (%)	B:C ratio (20% discount rate)	B:C ratio (10% discount rate))
i. 2mm/yr (25 tons/ha/yr): Grass Strips	-63	+165	3	49%	3.3	7.5
ii. 4 mm/yr (50 tons/ha): Grass strips	-115	+295	3	43%	3.2	7.6
iii. 8 mm/yr (100tons/yr) Soil bunds	-964	+513	9	14%	0.6	1.5

The higher negative cash flows in year 1 for the 4 mm/yr and 8 mm/yr loss rates are due to the need to have closer spacing of the strips and bunds and thus an increase in the labour requirement. At the 10 percent discount rate all have B:C ratios greater than 1 and with a 20 percent discount rate the B:C ratio for bunds falls below unity. The IRR's greater than 10% but for bunds less than 20 percent. The key problem for farmer adoption of bunds is the initial high labour requirements and the long payback period. This clearly supports the case for support in constructing bunds either through cash or food for work.

(b) Sub-basin Level

Across the Sub-basin the cumulative increase in crop production is shown in table 62 assuming that 22 percent of land that requires conservation measures is covered.

Table 62. Baro-Akobo Sub-basin - Ethiopia: Cumulative Increase in Grain production due SWC Measures (tons)

1 year	10 years	**25 years**
1,367	13,672	34,179

To examine the Direct Intervention SWC programme (grass strips and soil bunds) on its own, the benefit-cost analysis was undertaken over 50 years to take account of the 10 years of investments and using the Government discount rate for public investments of 10 percent. The results at the farming System level were aggregated to the Development Domain. The results are shown in table 63.

Table 63. Financial Benefit-cost Analysis of the Proposed SWC Programme on Cropland for Grass Strips and Soil Bunds in the Baro-Akobo Sub-basin over a 50 year time-frame and a Discount Rate of 10%: Results by Development Domain.

Financial Costs and Benefits of WSM Interventions by Development Domain in Baro-Akobo Sub-Basin

GRASS STRIPS Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	24,329	24,821	106,755	111,641	492	4,886	9.9

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	2.81	2.87	12.34	12.91	0.06	0.56	9.9

BUNDS Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	102,249	120,257	415,460	450,529	18,007	35,070	1.9

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	11.82	13.90	48.03	52.08	2.08	4.05	1.9

TOTAL PROGRAMME Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	126,578	145,077	522,214	562,171	18,499	39,956	2.2

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	14.63	16.77	60.37	64.99	2.14	4.62	2.2

all costs are PVs over 50 years at 10% discount rate

Overall there is a benefit-cost ratio of 2.2 with grass strips with a ratio of 9.9 and soils bunds 1.9. The overall internal rate of return is 17 percent.

(c) Sub-basin Level: Regional Benefits

With the assumptions outlined above soil movement on cropland could be reduced from 15.5 million to 12.4 million tons. Using the sediment delivery ratio of 22 percent calculated in the Transboundary reports then annual sediment to Baro-Akobo river system within Ethiopia could be reduced by 0.45 million tons (down from 3.15 million tons to 2.70 million t/yr).

The Regional impacts (in Sudan and Egypt are considered in sections 6.5.4 (Sudan) and 7.3.1 (Egypt).

(d) Global Benefits

Using the same methodology to estimate the loss of soil carbon in the Abbay Sub-basin indicates that some 375,440 tons of SC is being retained behind the structures that otherwise would be lost. Using US$ 3.00 per ton of carbon indicates that the value of sequestered carbon not lost to erosion is ETB 10.1 million/yr (US$ 1.12 million/yr). As this accumulates in 25 years the value of sequestered carbon is ETB 253.4 million/yr (US$ 28.2 million/yr).

6.3.2 Crop Intensification and Diversification

(i) Reduced Cropland Soil Nutrient Breaches Grain Removal and Increased Agricultural Production from Fertilizer

(a) Farm Level

Assuming 20 kgs of N per 1 ton of grain and average grain yield of 700 kgs/ha means a loss of 14 kgs of N/ha/yr. To replace this would require 78 kgs of DAP.

The replacement of 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 on 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. Overall some 23 percent of farmers in the Highlands in the Baro-Akobo Sub-basin use chemical fertilizer at an average rate of 170 kgs/ha mainly on maize or teff on approximately 9 percent of the cereal area (CSA, 2006). No fertilizer is used in the lowlands of Gambella or Beneshangul-Gumuz. Some 22 percent of farmers are using improved seed: nearly all maize seed. This is much higher than the national average of 3 percent.

Fertilizer use not in combination of improved seeds provides a 64 percent increase in yield using the results of fertilizer trials (NCC, 1983)[37]. This compares with 114 percent increase when used in combination (Diao et al., 2005). The analysis was conducted using both interventions to allow a comparison between the two technologies. In the analysis it has been assumed that farmers would use fertilizer at a rate of 100 kgs/ha of DAP on maize.

The results are shown in Table 64.

[37] The NCC used a quadratic function Y = (base yield) + (0.038N + 0.086P – 0.0004N2 – 0.00038P2 – 0.00063NP (Y yield in Q/ha: DAP 18%N & 46P)

Table 64. Financial Benefit-cost Analysis of the Proposed Fertilizer and Improved Seed Intervention in the Tekeze Sub-basin

Farming system	Crop fertilized	Area (ha)	% farm area	B:C fert. only	B:C fert+seed	Inc. income (ETB/ha) fert only	Inc income (ETB/ha) fert+seed
Maize, teff, sorghum	Maize	0.76	38%	3.4	5.8	502	1,042

(b) Sub-basin Level

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.

For the analysis it was assumed that an additional 20 percent of farmers would adopt fertilizer and improved seeds. Thus some 8,670 tons of DAP would be used by 86,700 farmers producing an additional 30,000 tons of maize. The analysis was conducted over a period of 50 years given the 10 year period of investment. A discount rate of 10 percent was used.

The results for the fertilizer only intervention are shown in table 65a and those for the combined fertilizer and improved seed intervention in table 65b. The overall B:C ratio is 3.3 for the fertilizer only intervention and 5.8 for the combined intervention.

Table 65. Financial Benefit-cost Analysis of the Proposed Fertilizer Intervention n the Baro-Akobo Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

(a) Fertilizer Only

Financial Costs and Benefits of fertilizer only Intervention in Baro-Akobo Sub-Basin

Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	206,968	320,279	1,565,615	1,940,819	113,312	375,204	3.31

Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	23.00	35.59	173.96	215.65	12.59	41.69	3.31

all costs and benefits are PVs over 50 years at 10% discount rate

(b) Fertilizer and Improved Seed

Financial Costs and Benefits of Fertilizer Imp. Seed Intervention in Baro-Akobo Sub-Basin							
Development Domain	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
HL:HAG:LMKT	206,968	323,092	1,565,615	2,233,947	116,124	668,332	5.76
Development Domain	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
HL:HAG:LMKT	23.00	35.90	173.96	248.22	12.90	74.26	5.76

all costs and benefits are PVs over 50 years at 10% discount rate

(ii) Diversification of Agricultural Production

Diversification need not be confined to crop production and can include livestock fattening, sheep and goat rearing, improved honey production. In terms of crops a number of initiatives are now being promoted including: vegetables, fruit trees (apples and plums in the Highlands, Citrus and bananas in the Lowlands); organic coffee, and spices (corrarima, ginger). Quality control and effective marketing are essential elements of crop diversification. Integration with other elements of the farming system is also often essential such as on-farm forage production for livestock fattening and improved sheep and goat production. Water provision from micro-dams and water harvesting structures are an essential element of vegetable production. This is considered in section 6.1.6.

The key strategy with respect to diversification is to extend the range of livelihood strategies thus reducing vulnerability to natural and other shocks.

6.3.3 On-farm Forage Production

(a) Patterns of Livestock Feed Deficit

In the Baro-Akobo Sub-basin tsetse fly and trypanosomiasis prevent livestock production in the shrublands and woodlands below 1,500 masl in Gambella and Beneshangul-Gumuz Regions. Only the far western grasslands of Gambella are relatively tsetse free and here the Nuer pastoralists utilize the flood-retreat grasslands along the Baro and Akobo Rivers. In the Highlands the main feed deficits occur in West Wellega and to a lesser degree in the densely populated areas of Illubabor and Jimma. These areas are the target weredas for the on-farm forage development programme.

Livestock feed deficits occur towards the end of the dry season when crop residues are finished and natural pastures are heavily grazed. Enset leaves and valley-bottom swamp grazing provide some respite.

(b) On-farm Forage Strategies

In this high rainfall area average yield of unimproved pasture in the Highlands is approximately 2.4 tons DM/ha whilst those of improved grasses are about 5 tons/ha for short grasses.

Rather than aiming for a full year's livestock feed supply a more realistic strategy for many small farmers would be to grow sufficient improved forage to meet three months supply at ploughing time or during lactation periods. This would reduce the forage area requirements to 0.11 ha, which is possible within the homestead area (i.e. "backyard forage" strategy).

(c) On-farm Financial Analysis

Benefits to the intervention include increased livestock productivity (increased calving, lower calf mortality, increased draught power). Using the teff and grass prices from the North Wello in the Abbay Sub-basin and including costs of improved seed and fertilizer gave a B:C ratio of 3.1 for the intervention. The incremental return on cultivating 0.11 ha of improved forage was ETB 161/yr.

(d) Sub-basin Wide Financial Analysis

In the Sub-basin wide analysis it was assumed that 30 percent of households in the Highlands would adopt improved on-farm forage production. For the analysis the average area per farm was 0.11 ha. The results are presented in table 66. The overall B:C ratio is 3.1.

Table 66. Financial Benefit-cost Analysis of the Proposed On-farm Forage Intervention n the Baro-Akobo Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of On-farm Forage Intervention by Farming System in Baro-Akobo Sub-Basin

Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
-	56,637	162,167	337,848	56,637	175,681	3.1

Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
-	6.5	18.7	39.1	6.5	20.3	3.1

all costs and benefits are PVs over 50 years at 10% discount rate

Unquantifiable local benefits include reduced pressure on communal grazing areas leading to increased forage natural pasture production, lower erosion rates and reduced sedimentation in streams.

(e) Sub-basin Wide: Global Benefits

Global benefits to on-farm forage product result from reduced pressure on communal grazing areas leading to increased pasture production. This would have the impact of increasing soil organic matter. Given the wide variability of existing grazing pressures and the variations in the degree of relief provided it is very difficult to quantify the increase in soil carbon in soils of the communal grazing areas.

6.3.4 On-farm Tree Production and Domestic Energy

(i) Farm Level

(a) Supply-side Interventions: Fuel Substitution:

Overall in the Sub-basin there is a net gain of nitrogen due mineralization. However, in those weredas whose soils are derived from acidic basement complex rocks (gneisses, granites) the mineralization rates are likely to be one fifth of those on basalts. The nutrient losses from burning dung and residues in these weredas would be almost total. Currently each family is experiencing an annual net loss of 2.5 kgs of available N, equivalent to 15 kgs of grain/yr. These rates are lower than the Abbay or Tekeze Sub-basins because residues dominate the fuel type, which have a much lower nutrient content. However, crop residues are increasing in value as livestock feed as grazing becomes in increasingly short-supply due to the expansion of cropland. In addition there is the value of the trees as fuelwood and/or poles.

For the analysis it was assumed that each adopting farmer would plant 30 Eucalyptus trees a year for 5 years[38]. This would provide a total of 150 trees. At a density of 1,500 trees/ha this would require 0.10 ha. Household labour is costed at the reservation rural wage rate of ETB 5.00/day. Over 25 years and using a discount rate of 10 percent the financial rate of return is 51 percent and the discounted B:C ratio is 3.7. However, the payback period is 8 years. Reducing the price of fuelwood by 75 percent and 50 percent reduces the internal rate of return to 44 and 32 percent respectively and the B:C ratio to 2.8 and 1.9 respectively. The average annual incremental cash income (if fuelwood is sold) is ETB 594/yr.

Unquantifiable benefits include reduced pressure on communal grazing areas leading to increased trees, natural pasture production, lower erosion rates and reduced sedimentation in streams.

[38] This is a lower rate than in the Abbay and Tekeze Sub-basins as fuelwood deficits are not as severe in the Baro-Akobo Sub-basin. However, mean annual growth and final wood biomass will be higher in this high rainfall area.

Demand-side Interventions: Improved Stoves[39]:

Three improved stoves are available: the *lakech* (a charcoal stove) and the *gounziye* (a ceramic wood stove that mimics the traditional 3-stone fireplace). The *mirte* is an improved mitad stove (for baking injera). Charcoal is not used in rural areas and thus only the gounziye and mirte are likely to be adopted in rural areas.

The *mirte* mitad has a fuel saving of 50 percent and costs ETB 45 – 60. The gounziye saves about 30 percent and costs ETB15. They both considerably reduce the amount of smoke generated. Average rural household fuelwood consumption in the Baro-Akobo Sub-basin is approximately 6,160 kgs/yr/family). Some 43 percent of wood is used for mitad cooking and 37 percent for other (mainly *wot* cooking).

Adoption of the *mirte* and the gounziye could effect household fuelwood savings of approximately 2,008 kgs/yr. Approximately 30 hours (about 3.75 days) a week of family labour (women 20, children 9 and men 2 hours) are use in collecting and transporting 100 kgs of fuelwood. Using a wage rate of ETB 4.00 as representative of the whole family labour (men, women and children), this would place a value of 0.13/kg. Total annual savings per family would thus amount to ETB 254.58/yr. Assuming stoves are replaced after 5 years and using a discount rate of 10 percent the B:C ratio is 22.

Pollutants from domestic biomass fires are now known to have serious negative impacts on human health, in particular acute respiratory infections and respiratory diseases. Women and particularly children are affected. No detailed studies have been undertaken in Ethiopia, but detailed studies have been undertaken in India where 80 percent of households use biomass fuels (a lower proportion than in Ethiopia). In India it estimated that about 5 percent of premature deaths in women and children under 5 are due to indoor smoke pollution. By way of comparison poor water and sanitation account for 6 percent and malnutrition 15 percent.

(ii) Sub-basin Level

(a) Supply-side Interventions: Fuel Substitution:

At the Sub-basin level and assuming that 3 percent of households in the 31 weredas (out of 50), which are exceeding their sustainable supply substitute dung and residues for fuelwood each year the annual saving of N would amount to 31 tons: a grain equivalent of 187 tons/yr. This amount would accumulate at 3 percent per yr for the 10 year programme. At local market prices this is valued at ETB 0.3 million (US$ 0.03 million).

[39] Data from the "National Strategic Plan for the Biomass Energy Sector", (WBISPP-MARD, 2005)

To examine the Direct Intervention on-farm tree planting programme on its own, the benefit-cost analysis was undertaken over 50 years to take account of the 10 years of investments and using the Government discount rate for public investments of 10 percent. An annual adoption rate of 3 percent of households per year for 10 years was used in the analysis. The results are shown in table 67. The overall discounted B:C ratio is 2.9.

Table 67. Financial Benefit-cost Analysis of the Proposed On-farm Tree Planting Intervention in the Baro-Akobo Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of On-farm Tree Planting Interventions in the Baro-Akobo Sub-Basin							
	Cost WOP (ETB'000)	**Cost WP (ETB'000)**	**Benefit WOP (ETB'000)**	**Benefit WP (ETB'000)**	**Incremental Cost (ETB'000)**	**Incremental Benefit (ETB'000)**	**B/C Ratio**
	-	108,235	-	413,202	108,235	413,202	3.8
total	**-**	**108,235**	**-**	**413,202**	**108,235**	**413,202**	**3.8**
Farming System	**Cost WOP ($US m)**	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	12.0	-	45.9	12.0	45.9	3.8
total	**-**	**12.0**	**-**	**45.9**	**12.0**	**45.9**	**3.8**
all costs and benefits are PVs over 50 years at 10% discount rate							

(b) Demand-side Intervention: Improved Stoves

The GTZ Household Energy/Protection of Natural Resources Project (HENRP) working in Amhara, Tigray, SNNP and Oromiya regions report that in the first three years some 5 percent of mirte mitad stoves were being sold to rural households. Assuming that 10 percent of households (41,650) will adopt the *mirte* mitad and the *gounziye* over a period of 10 years with the same assumptions above regarding fuel savings then incremental costs and benefits are shown in table 68. The overall B:C ratio is 15.

Table 68. Financial Benefit-cost Analysis of the Proposed Improved Stove Intervention in the Baro-Akobo Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of Improved Stove Interventions in Baro-Akobo Sub-Basin							
	Cost WOP (ETB'000)	**Cost WP (ETB'000)**	**Benefit WOP (ETB'000)**	**Benefit WP (ETB'000)**	**Incremental Cost (ETB'000)**	**Incremental Benefit (ETB'000)**	**B/C Ratio**
	-	4,596	-	64,973	4,596	64,973	**14**
	Cost WOP ($US m)	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
	-	0.5	-	7.5	0.5	7.5	**14**
all costs and benefits are PVs over 50 years at 10% discount rate							

(iii) Global Benefits

Wood harvested and burnt does not contribute to the carbon pool, only wood used for construction and furniture will retain its carbon. It is assumed that the life of such wood is 10 years upon which it will be burnt or decay. After 10 years wood in such use would accumulate from 0.04 million tons to 0.48 million/yr over the next 10 years. Thus some 0.24 million tons/yr of carbon will be sequestered after a period of 20 years development. This has a value of ETB 6.6 million (US$ 0.7 million).

Using the improved stoves some 4,165 households will be saving 2.0 tons of fuelwood per year accumulating over a period of 10 years: at a rate of 8,364 tons/yr. After 10 years this is equivalent to the sequestration of 41,820 tons of carbon/yr from year 10. At the US$ 3/ton of carbon this amounts to ETB 0.11 million/yr (US$ 1,254/yr).

6.3.5 Communal lands: Increased Pasture and Wood production

(a) Reduced Soil Erosion on Non-Cropland

It is estimated that some 28.64 million tons of soil per annum are moved from non-cropland. "Non-cropland" is essentially communal lands that are used for grazing and fuelwood collection and include the under-utilized degraded lands. In the Baro-Akobo Sub-basin it also includes 1.77 million ha of high Montane and Lowland Forest. Generally, in this high rainfall environment vegetation cover is dense.

It is considered that the opportunities for significantly reducing erosion on non-cropland are much less in the Baro-Akobo than the Tekeze and Abay Sub-basins. The two main production objectives for area closure are fodder and fuelwood/poles. The opportunities for area closures are restricted to the north-eastern highlands in West and East Wellega where grazing and fuelwood are becoming in short supply (6 weredas). In the remaining areas fuelwood is not short supply, livestock feed is generally not in short supply or livestock are not kept. In these areas the demand for area closure would be low to nothing.

(b) Potential Increase in Forage and Tree production: Site Level

In the financial analysis it was assumed that 50 percent of the area would be under trees (i.e. at half the recommended planting density) and the whole area under grass. A ten year rotation of trees was used[40]. Unimproved pasture yields are estimated to be 2.00 tons/ha. Grass yields reach a

[40] Farmers follow much shorter rotations for Eucalyptus (10 years) than commercial plantations (15 – 20 years).

maximum after 5 years of 3.6 tons/ha, decline with tree shading to 1.44 and increased after tree harvest. Trees are valued for poles and BLT[41].

There are positive impacts on livestock health and productivity (milk, draught power, fecundity, reduced calf mortalities) with increases in feed supply. To capture these values grass was valued using the annualized value of an ox over 10 years at 10 percent discount rate multiplied by the ratio of 1 Q of grass dry matter to the annual feed requirements of 1 ox (22.50 Q of grass dry matter).

The financial analysis for 1 hectare of closed area produced a financial rate of return of 73 percent and a B:C ratio of 24. The payback period is short – 3 years. The net value of increased livestock production is ETB 238/ha/yr.

The increase in wood supply for fuel and construction will relieve pressure on the remaining areas on non-cropland. It has not been possible to quantify this impact.

(c) Potential Increase in Forage and Tree production: Sub-basin Level

As indicated above it has been assumed that 30 percent of non-cropland would be enclosed over a 10 year period in equal proportions (i.e. 3 percent per year). The analysis was conducted over a period of 50 years given the 10 year period of investment. A discount rate of 10 percent was used. The results are shown in table 69. The overall B:C ratio is 5 and the internal rate of return was 73 percent. The net present value of the benefits to livestock and wood production are ETB 315 million (US$ 36.5 million).

Table 69. Financial Benefit-cost Analysis of the Proposed Area Closure in the Baro-Akobo Sub-basin over a 50 year time-frame and a Discount Rate of 10%

Financial Costs and Benefits of Area Closure Interventions by Farming System in Baro-Akobo Sub-Basin

	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
	-	255,900	393,683	1,654,746	255,900	1,261,064	4.9
total	**-**	**255,900**	**393,683**	**1,654,746**	**255,900**	**1,261,064**	**4.9**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
	-	29.6	45.5	191.3	29.6	145.8	4.9
total	**-**	**29.6**	**45.5**	**191.3**	**29.6**	**145.8**	**4.9**

all costs and benefits are PVs over 10 years at 10% discount rate

[41] BLT = Branches, leaves and twigs (20% of total volume).

(d) Potential Regional Benefits and Costs

Benefits

Total soil loss in the target weredas is 1.18 million tons/yr. Assuming 30 percent of the non-cultivated land is enclosed with a trapping efficiency of 90 percent, a catchment to enclosure ratio of 3.0 and a sediment delivery ratio of 22 percent, then 49,520 tons/yr will be delivered to the river system, a reduction of 211,122 tons/yr or 81 percent of the sediment load before treatment.

These contribute to the overall reduction in sediment load in the Sobat-White Nile River system passing through Sudan and onto Egypt. The benefits (and costs) of these reductions are considered in sections 6.3.4 (Sudan) and 7.3.1 (Egypt).

Potential Costs

The potential impacts of large-scale Eucalyptus planting have outlined in section 4.1.5 and the same comments apply to the Baro-Akobo Sub-basin.

(e) Global Benefits

Sequestration of Wood Carbon

Wood harvested and burnt does not contribute to the carbon pool, only wood used for construction and furniture will retain its carbon. It is assumed that the life of such wood is 10 years upon which it will be burnt or decay. After 10 years wood in such use would accumulate from 1.6 million tons to 7.3 million/yr over the next 10 years. Thus some 3.65 million tons/yr of carbon will be sequestered after a period of 20 years development. This has a value of ETB 98.5 million (US$ 11.0 million).

Sequestration of Soil Carbon

However, the greatest potential for adding to the carbon pool is from an increase in soil carbon (SC) from the increased production of pasture as grasslands sequester double the amount carbon as croplands.

Descheemaeker et al., 2005 found that soil organic matter in an enclosed area in Tigray had increased from between 0.2 percent and 0.5 percent in the open areas to between 1.3 and 3.4 percent in areas that had been enclosed for 4 to 5 years. These would indicate an increase from 9 tons/ha (0.5% SC) to 64 tons/ha (3.4%), an increase of 55 tons/ha. It is likely in the higher rainfall areas of the Abbay Sub-basin that levels of SC are about 20 tons/ha on grassland (Barber, 1985). Using an increment of 44 tons/ha of soil carbon after 5 years of enclosure would increase total SC by 132 million tons. Using the same values as before this represents a value of ETB 3,564 million (US$ 396 million).

The medicinal, nutritional and other use values of plants in the enclosed areas have been noted above. These plants also have a biodiversity value and provide a reservoir of genetic and species diversity that is being lost in the open access communal lands.

6.3.6 Water Conservation and Improved Utilization

The key activities related to water conservation and its improved utilization are small/micro dams and household-level water harvesting structures. Both can be used for domestic and livestock water supply and for small-scale irrigated cropping (integrating with the crop diversification intervention).

(i) Small/Micro Dams and Weirs (River diversions)

(a) Basic Data

Data from IFAD for the Amhara Region puts the average costs per hectare for weir irrigation systems at ETB 41,418/ha (US$ 4,602/ha). Average area irrigated is 72 ha giving total costs of ETB 2.98 million (US$ 0.33 million). Average number of beneficiary households was 288 with an average holding of 0.25 ha. Average maintenance costs were estimated to be ETB 750/ha (US$ 8.33/ha).

Data for dam systems puts average costs per hectare at ETB 61,200/ha (US $6,800/ha). Average area irrigated is 160 ha giving total cost ETB 9.98 million (US$ 1.11 million). Maintenance costs are estimated to be 2.5 percent of construction costs (Hewitt and Semple, 1984). The average number of beneficiary households is 460 per scheme with an average area of 0.35 ha per household.

(b) Financial Analysis: Irrigation from Small dams: farm level

It assumed that the irrigated area cropped is 0.35 ha, and that 100 percent is cropped in the main season (green maize 35%, potatoes 50%, peppers 15%) and that 50 percent is cropped to onions in the 2nd season. In the without project situation is assumed that the 0.35 ha is rainfed cropped according to the crop mix of the local farming system. Family labour for cultivation, irrigation and transport to market is not included.

The B:C ratio is 11 and the incremental income is ETB 4,408/yr. The incremental return to family labour is ETB 43.20/day. When family labour is costed the incremental income is ETB 3,897 and the B:C ratio falls to 5. Nevertheless, clearly the small irrigation intervention is financially very attractive. Average West Wellega market prices were used although an IFAD Evaluation Report on small scale irrigation schemes found that on some schemes prices received by farmers from itinerant traders were considerably below local market prices. There have also been problems with local gluts in markets with poor outside accessibility.

Reducing market prices by 25 percent and 50 percent reduces the B:C ratio to 8.8 and 6.3 respectively. Incremental cash income declines to ETB 3,226 and ETB 2,044 respectively. Similar changes in costs produce almost identical results.

(c) Financial Analysis: Weir Diversion from Run-of River

In this analysis it is assumed that only one cropping season is possible because of lack of water during the 2nd season. The cropping mix is the same as the Main Season of the Small Dam schemes. The other assumptions remain the same.

The B:C ratio is 5 and the incremental income is ETB 882/yr. The returns to family labour are ETB 6.50/day. The absence of a second cropping season limits the incremental income. Reducing market prices by 25 percent and 50 percent reduces the B:C ratio to 4 and 3 respectively. Incremental cash income reduces to ETB 625 and ETB 367 respectively.

(d) Financial Analysis: Small scale irrigation in the Baro-Akobo Sub-Basin

Current rates of small dam construction in Oromiya and SNNP Regions have been about 5 per year and a similar number of weir diversion schemes have been implementation with IFAD's support. For the Sub-basin wide analysis it is assumed that 50 small dams and 50 weir diversion schemes can be implemented in the 10 year period. These would serve some 37,400 households irrigating a total area of 11,650 ha.

The analysis examined the costs and benefits of 50 dam schemes and 50 weir diversion schemes over a period of 50 years using 10 percent discount rate. Costs of watershed management interventions above the dam or weir have not been included, but are a vital element if problems of sedimentation are to be avoided. Clearly such watershed management interventions have many other benefits and the analysis would become protracted if a "total approach" were to be used. Nevertheless, these costs should be borne in mind when reviewing the results below.

The results are presented in table 70. The overall B:C ratio is 2.1. Changing the discount rate from 10 percent to 5 percent increases the B:C ratio to 2.5

Table 70. Financial Benefit-cost Analysis of the Proposed Small-scale Irrigation Intervention in the Abbay Sub-basin over a 50 year time-frame and a Discount Rate of 10%:

Financial Costs and Benefits of 24 Small-scale Irrigation Schemes in Abbay Sub-Basin

Farming System	Cost WOP (ETB'000)	Cost WP (ETB'000)	Benefit WOP (ETB'000)	Benefit WP (ETB'000)	Incremental Cost (ETB'000)	Incremental Benefit (ETB'000)	B/C Ratio
Dam schemes (Construction)	-	114,086	-	-	114,086	-	-
Dam schemes (maintenance)	-	433,390	-	-	433,390	-	-
Wier Schemes Construction	-	68,787	-	-	68,787	-	-
Wier Schemes (Maintenance)	-	261,308	-	-	261,308	-	-
Dam schemes: Irrigation	236,579	558,565	358,319	2,781,448	321,986	2,423,129	-
Wier schemes: Irrigation	222,021	403,298	153,896	995,903	181,277	842,007	-
total	**458,600**	**1,839,435**	**512,215**	**3,777,351**	**1,380,835**	**3,265,136**	**2.4**

Farming System	Cost WOP ($US m)	Cost WP ($US m)	Benefit WOP ($US m)	Benefit WP ($US m)	Incremental Cost ($US m)	Incremental Benefit ($US m)	B/C Ratio
Dam schemes (Construction)	-	13.2	-	-	13.2	-	-
Dam schemes (maintenance)	-	50.1	-	-	50.1	-	-
Wier Schemes Construction	-	8.0	-	-	8.0	-	-
Wier Schemes (Maintenance)	-	30.2	-	-	30.2	-	-
Dam schemes: Irrigation	27.4	64.6	41.4	321.6	37.2	280.1	-
Wier schemes: Irrigation	25.7	46.6	17.8	115.1	21.0	97.3	-
total	**53.0**	**212.7**	**59.2**	**436.7**	**159.6**	**377.5**	**2.4**

(e) Other Costs

Research in Tigray (Ersado, 2005) has revealed that whilst dams and small-scale irrigation increased farm incomes they also led to an increased incidence of malaria. This in turn led to reduced allocation of labour to non-farm activities and increased expenditure on medicines. These costs have not been quantified. However, they can be prevented by spraying in and around houses and/or with the provision of impregnated mosquito nets. The estimated cost of such a net is ETB 36.00 (US$ 4.00). Assuming 2 nets per household and 460 households in each Irrigation Scheme village would mean a four yearly cost of ETB 33,120/scheme (US$ 3,680). Assuming a replacement every 4th year and adding these costs to (i) household costs and (ii) Scheme costs has the following impact on B:C ratios:

Households

Dam schemes: B:C ratio: from 7.5 to 7.3:
Weir schemes: B:C ratio: from 3.9 to 3.7

Schemes
All schemes: B:C from 2.1 to 2.0

Clearly, including impregnated mosquito nets into the schemes "maintenance" costs makes very little difference to the household or the overall programme B:C ratios.

Potential health costs could also result from the introduction and spread of bilharzia through its host the *Bulinus* spp. snail. Preventative costs would be incurred from the use of moluscicides. Other potential health costs could be

incurred through the use of agro-chemicals and their effect on down-stream users of the river for human and livestock water supplies.

Increased use of water through increased evapotranspiration of irrigated crops in comparison with rainfed crops as well as evaporation from the reservoirs will reduce river flow downstream of the Schemes. This could have negative impacts on downstream users in terms of water use for domestic and livestock water supplies and for irrigation.

(f) Multiplier Benefits

Other multiplier effects include backward and forward linkages in the local economy. These include increased sales of inputs and increased products entering the market. Increased multiplier effects will also be felt with increased household purchases of local and "imported" (i.e. into the local area) goods. Purchases of locally produced non-food goods ("non-tradables) make a substantial contribution to the multiplier effect.

The same assumptions used in the multiplier analysis in the Abbay Sub-basin analysis are used. The annual incremental household income for the small dam schemes is ETB 4,723/yr and ETB 848/yr for the Weir Schemes. Assuming that 32 percent of this incremental income is spent on non-tradables by the beneficiary households, this would indicate that an additional ETB 317,394/yr would enter the local economy of locations with a dam scheme and ETB 61,600/yr for the Weir Schemes. Across the 50 dam and the 70 weir schemes in the Sub-basin this would amount to ETB 199.9 million/yr (US$ 22.2). This in turn would stimulate 2 and 3^{rd} order multipliers within the local economy.

6.4 Estimated Budget - Direct and Supporting Interventions: Baro-Akobo Sub-basin - Ethiopia

The previous section has outlined some of the quantifiable costs and benefits accruing to the direct interventions. All of these depend to a greater or lesser extent on the implementation of the Supporting Interventions. These Supporting Interventions will provide increased physical and human capacity to rural households and government implementing organizations and in particular the extension Service; support to assisting rural families to gain non-farm employment and to small enterprise development in both rural areas and small urban centers; improved road and market infrastructure and increased capacity of farmers in product marketing and with increased available and access to micro finance and credit. The details of these and their direct and indirect benefits are summarized Matrix 2b in Chapter 2.

This section provides a summary of the budget required to implement both the Direct and Supporting Interventions. A detailed breakdown with units and unit costs is provided in Annex 3. A summary is provided in table 71. Given the very complex nature of the relationships between the Direct and the Indirect Interventions, in particular their short and long term impacts on human welfare and development in local, regional and National terms it would be extremely hazardous to attempt an overall benefit-cost analysis. However, it is submitted that the figures below provide a sense of the order of magnitude in implementing a programme of the interventions as outlined in Chapter 3.

Table 71. Summary 10 Year Budget: Baro-Akobo Sub-basin – Ethiopia: (a) Direct Interventions, (b) Supporting Interventions and (c) Total budget (ETB).

(a) Direct Interventions

Intervention	Total cost (ETB)	Total cost (US$)
1. Water Conservation & Improved Utilization	1,287,470,098	146,636,685
2. Crop Diversification & Intensification	335,143,172	38,171,204
3. Soil Conservation & Improved Soil Husbandry Measures	359,241,777	40,915,920
4. Livestock Development	109,908,230	12,518,022
5. Forest Planning & Sustainable Managment	175,595,000	19,999,431
Sub-total	**2,267,358,277**	**258,241,262**

(b) Supporting Interventions

Intervention	Total cost (ETB)	Total cost (US$)
1.. Capacity Building	138,154,040	15,735,084
2. Support to Agricultural Extension	114,827,500	13,078,303
3. Support to Non-farm Income Generation, Small/micro Enterprise development	79,112,218	9,010,503
4. Community Assets Development	250,390,000	28,518,223
5. Improved Marketing	2,584,500	311,446
6. Support to Micro-finance, Credit and Savings	2,734,500	311,446
Sub-total	**587,802,758**	**66,965,007**

TOTAL

Intervention	Total cost (ETB)	Total cost (US$)
(a) Direct Interventions	2,267,358,277	258,241,262
(b) Supporting Interventions	587,802,758	66,965,007
TOTAL	**2,855,161,035**	**325,206,268**

ETB/HA	**US$/HA**
20,430	**2,327**
ETB/HH	**US$/HH**
6,586	**750**

The average cost per household in the traditional rainfed and pastoral sectors is ETB 6,181 (US$ 704/household). Clearly non-farming members of the community will also benefit from the Direct and Supporting Interventions in terms of improved access to social services, employment and information. Costs per ha of cropland are ETB 19,173/ha (US$ 2,184/ha). Again areas of rangeland and forest will benefit from the Interventions. These per unit costs are presented only to provide a first approximation of unit costs when considering programme at the catchment or sub-catchment scale.

6.5 Costs of Continued Natural Resource Management Practices in Sudan

6.5.1 Agricultural production forgone from Soil Degradation – Sobat-White Nile Sub-basin - Sudan

(i) Decline of Soil Productivity on Semi Mechanized Farms

Annual decline in yields on the Semi mechanized Farms has been estimated at 2 percent per annum (World Bank, 2003). Assuming that approximately 2.29 million ha are cropped annually this represents an annual cumulative loss of production of 21,984 tons declining to 13,537 tons in 25 years time. At approximately SDD 43,000/ ton this represents a loss of SDD 945.3 million (US$ 4.7 million) in the first year rising to SDD 18,742.5 million (US$ 93.7 million) after 25 years.

(iii) Decline in Soil Productivity on Traditional Rainfed farms

Approximately 476,190 feddans (200,000 ha) of small-scale rainfed cropping has been mapped in the Sobat-White Nile Sub-basin. Assuming the same yields as the SMF's but with half the rate of yield decline (i.e. 1 percent/yr) this would indicate an annual cumulative loss production of 960 tons declining to 754 tons in 25 years time. At approximately SDD 43,000/ ton this represents a loss of SDD 41.3 million (US$ 0.2 million) in the first year rising to SDD 917.2 million (US$ 4.6 million) after 25 years.

6.5.2 Irrigation system sedimentation: White Nile Sub-basin Sudan

(i) Costs

The only major irrigation scheme on the White Nile is the Kenana Sugar Scheme. It is estimated that 0.27 million m^3/yr enter the Kenana scheme along the White Nile River. Using the pro rata costs for cleaning the Rahad scheme estimated annual costs are SDD 49.8 million (US$ 0.2 million).

(ii) Benefits

Assuming that 38 percent of sediment entering the system is deposited in the fields and that 1 ton of sediment is equivalent to 0.98 kgs of fertilizer; this would indicate that deposition of sediment in Scheme is equivalent to 254 tons of fertilizer. Assuming the fertilizer is urea and that the price of urea is US$ 286 /ton the benefits accruing to sediment deposition amounts to SDD 14.5 million (US$ 0.07 million).

The gains are annual and not cumulative due to nutrient uptake by crops, leaching and volatization losses. It is possible there is some residual accumulation of phosphorous although given the high P fixing properties of the Kenana soils the amount available to plants is likely to be negligible.

6.5.3 Deforestation and Degradation

(i) Deforestation

Some 3.8 million ha of woodland and shrubland were cleared for the Semi mechanized farms. As in the Blue Nile Sub-basin the complete removal of vegetation and the consequent and the consequent removal of natural predators (snakes and cats) have led to an increase in rats and other vermin. Insect eating birds have disappeared leading to a big increase in the use of insecticides and insect damage. Because the land is totally cleared of all tree cover and combined with years of constant harrowing and disking the tree seed bank in the soil has been completely destroyed. The abandoned areas are a waste land with no tree cover. The quality of the grass cover is very poor because of the very low levels of soil fertility.

Data on the current levels of permanent woodland removal are not available and thus a valuation can not be made.

(ii) Degradation of Woody Biomass Stocks

Pressure on the remaining woodlands is intense. This pressure is from wood removal for charcoal, fuelwood, construction, furniture and lime burning. In Sudan in the Sobat-White Nile Sub-basin approximately 4.6 million m^3 of wood fuel and charcoal (per capita consumption of 0.73 m^3) are consumed forming about 80 percent of the total energy consumption. This represents some 2.3 million tons of sequestered carbon. Using the value of US$ 3 per ton of carbon this approximates to some SDD 1,376 million (US$ 6.9 million).

6.5.4 Summary of Costs of Natural Resource Degradation in the Baro-Sobat-White Nile Sub-basin

The various cost estimates of natural resource degradation in the Baro-Sobat-White Nile Sub-basin are summarized in Table 72.

Table 72. Summary of Costs of Natural Resource Degradation in the Baro-Sobat-White Nile Sub basin

Resource	Annual		After 25 years	
	SDD million	US$ million	SDD million	US$ million
1. Soil productivity decline				
- SMF's	945.3	4.7	18,742.5	93.7
- Traditional rainfed Sector	41.3	0.2	917.2	4.6
2. Sedimentation				
- Dredging/Weed cleaning	49.8	0.2	49.8	0.2
3. Deforestation/degradation				
- Deforestation	n.d	n.d.	n.d.	n.d
- Degradation	1,376.0	6.9	34,400.0	193.2
TOTAL GROSS COSTS	**2,412.4**	**12.0**	**54,109.5**	**291.7**
Benefits: Sediment - Fertilizer	14.5	0.1	14.5	0.1
TOTAL NET COSTS	**2,397.9**	**12.0**	**54,095.0**	**291.6**

n.d. = no data

The costs are dominated by the declines in soil productivity in the Semi-mechanized farms and degradation of wood biomass. As it has not been possible to quantify the annual rate of deforestation for the Sub-basin the costs of "deforestation/degradation" are under estimated.

Table 73 provides a distribution of these costs into local/national, Regional and Global. Some 43 percent of the costs have local/national implications, no Regional and 57 percent global.

Table 73. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Baro-Sobat-White Nile Sub-basin in Sudan

Resource	Annual			After 25 years	
	SDD million	US$ million	%	SDD million	US$ million
LOCAL/NATIONAL					
Soil fertility loss: SMF	945.3	4.7		18,742.5	93.7
Soil fertility loss: Traditional sector	41.3	0.2		917.2	4.6
Dredging/Weed cleaning	49.8	0.2		49.8	0.2
Sub-total	**1,036.4**	**5.1**	**43%**	**19,709.5**	**98.5**
REGIONAL					
Sub-total	**-**	**-**	**0%**	**-**	**-**
GLOBAL					
Carbon Sequestration: Deforestation	n.d.	n.d.		n.d.	n.d.
Carbon Sequestration: Degradation	1,376.0	6.9		34,400.0	193.2
Sub-total	**1,376.0**	**6.9**	**57%**	**34,400.0**	**193.2**
TOTAL GROSS COST	**2,412.4**	**12.0**		**54,109.5**	**291.7**
Less: Value of sediment as fertilizer	14.5	0.1		14.5	0.1
TOTAL NET COST	**2,397.9**	**12.0**		**54,095.0**	**291.6**

6.6 Impacts, Costs and Benefits of the Proposed Watershed Management Direct Interventions

6.6.1 Reduced Land Degradation and Increased Rainfed Semi-mechanized farms

The analysis uses the recently published MOA Economic Survey of Semi-mechanized Farms (MOA, 2006a) covering Gedarif, Kassala, Blue Nile, Sinnar, White Nile, Upper Nile, South and North Kordofan States. In the area covered by the Sobat-White Nile Sub-basin the data for White Nile State was used. Crop prices were obtained from a second MOA study (MOA, 2006b) on the traditional rain-fed areas.

(i) Improved Technologies

Three main crops are cultivated: sorghum (69 % of the area), sesame (28 % of the area) and millet (3% of the area). Current yields are 323 kgs/ha, 213 kgs/ha and 679 kgs/ha for sorghum, sesame and millet respectively.

Improved technologies include 5 yearly sub-soiling to break the plough pan, in-furrow planting, drought-resistant seed varieties and the use of *Acacia senagal* for Gum Arabic as the fallow. Yields are expected to increase over a three year period by 75 percent to 565 kgs/ha, 373 kgs/ha and 1,188 kgs/ha for sorghum, sesame and millet respectively.

A. senegal is cultivated on a 15 year cycle with gum harvesting commencing in year 5. Initially 10 percent of the farm in planted with a further 10 percent commencing in year 11. Thus, at 10 yearly intervals for a period of 5 years some 20 percent of the farm is under *A. senegal*. This is to ensure a constant supply of gum Arabic and to meet government requirements that at least 10 percent of the farm should be under trees. Gum yields in year 4 and 5 are 29 kgs/ha and 57 kgs/ha. From years 6 to 11 they are 115 kgs/ha declining in years 12 and 13 to 88 kgs/ha and 57 kgs/ha. In years 14 and 15 yields are 19 kgs/ha. The trees are felled and removed at the end of year 15. The wood has a residual value as charcoal which covers the cost of land clearing (Earl, 1985).

(ii) Farm analysis

The analysis was conducted over a 50 year time period using a discount rate of 10 percent. The discounted B:C ratio was 7.8. The mean annual incremental cash income is SDD 13,571/ha (US 68/ha). Rent charges in White Nile State are SDD 2,884/feddan (US$ 34/ha) (MOA, 2006a). With a land tax of only SDD 200/yr (US$ 1.00/yr) this implies a substantial subsidy (although not as high as Gederef State). Costing this rental value of land into the analysis reduces the B:C ratio to 2.8 and the average returns per hectare per year to SDD 11,096 (US$ 55/ha/yr). Reducing the increase in crop yield to only 25 percent reduces the B:C ratio to 1.7.

Sorghum accounts for 39 percent of the incremental income, sesame 10 percent, millet 44 percent and gum arabic 7 percent. The very high proportion accruing to millet is because of its high yield and high market price. This is in direct contrast to the Atbara Sub-basin where millet returns were very low. The use of *A.sengal* as a fallow clearly has benefits in terms of enhanced soil fertility, although these are difficult to quantify.

(iii) Sub-basin Analysis

Assuming that 60 percent of the 9.1 million feddans (3.8 million ha) mapped as large farms is actually cropped in an average year, and that 60 percent of the land is improved over a 10 year period there is the potential to improve crop production on 3.3 million feddans (1.4 million ha). The overall B:C ratio at 10 percent discount rate was 7.4. The results are shown in table 74.

Table 74. Financial Analysis: Improved Technology – Semi-Mechanized Rainfed farms: White Nile Sub-basin

Financial Costs and Benefits of Improved Agronomy Interventions on SMF's in White Nile Sub-basin

Cost WOP (SDD '000)	Cost WP (SDD '000)	Benefit WOP (SDD '000)	Benefit WP (SDD '000)	Incremental Cost (SDD '000)	Incremental Benefit (SDD '000)	B/C Ratio
136,378,149	149,448,148	168,826,055	266,025,714	13,070,000	97,199,659	7.4
Cost WOP ($US m)	**Cost WP ($US m)**	**Benefit WOP ($US m)**	**Benefit WP ($US m)**	**Incremental Cost ($US m)**	**Incremental Benefit ($US m)**	**B/C Ratio**
681.9	747.2	844.1	1,330.1	65.3	486.0	7.4

all costs and benefits are PVs over 50 years at 10% discount rate

(iv) Shelterbelt Planting on Semi-mechanized farms

(a) National

Some 40 percent of the Semi-mechanized farms will not have A.senegal planted on them. Thus, there is the potential for re-forestation of some 218,286 feddans (91,680 ha) over a 10 year period. Contracts to traditional rainfed farmers for supply of seedlings, planting and care and maintenance could provide substantial contributions to households' financial assets as well as widening the range of the livelihood strategies.

Assuming sustainable yield of 5 m^3/ha on a 20 year rotation then an annual cut of 458,400 m^3 would be possible. This could be converted to 82,512 tons/yr of charcoal. Charcoal site production costs are estimated to be 87 percent of the site price (UNDP/World Bank, 1988). The current price of charcoal is SDD 70,000/ton. The total annual net revenue is estimated to be SDD 759 million/yr (US$ 3.8 million/yr).

However, when the opportunity costs of the crop production that is forgone are taken into account the long term (50 years) B:C ratio using a 10 percent discount rate is only 0.6. This rises to 0.76 and 0.87 when the rate is lower to 5 percent and zero percent respectively. This may explain why farmers are reluctant to plant shelter belts and point to the need for tax concessions to encourage their planting.

A second opportunity for collaboration is the utilization of the estimated existing production of 606,000 tons of residues for livestock feed for transhumant pastoralists. Using the annualized value of a tropical livestock unit as a basis the value of residues as livestock feed is SDD 2,282/ton (US$ 11.40/ton). Assuming that 60 percent is available to livestock this gives an estimated value of the residues as livestock feed as SDD 830.0 million (US$ 4.2 million).

(b) Potential Global Benefits

Increased crop production increases the production of crop residues and if these are left after harvest can contribute to increasing soil organic matter. The incremental production of crop residues on the improved cropland would be approximately 0.3 tons/ha/yr.

Research in a semi-arid zone in Kenya showed that an increase of just 0.3 tons/yr of residues left on the soil increased soil carbon by 20 percent over a 50 year period or at a rate of 0.01 tons/ha/yr (FAO, 2004). Research in North Kordofan (Olsson and Ardo, 2002) indicates current levels of carbon in cultivated land to be 1.5 tons/ha. A 20 percent increase in soil carbon in the soils of the 721,460 feddans (303,012 ha) of improved cropland from the incremental production of crop residues would amount to 90,900 tons of carbon. Using a value of US$ 3/ton of carbon this amounts to SDD 54.5 million (US$ 0.27 million).

Putting 10 percent of the total cropped land under trees (either as A. senegal or Shelterbelts) would mean that the soil carbon would increase. Research in Northern Kordofan suggests that converting cropland to woodland accumulates soil carbon at the rate of 1,010 tons/ha/yr. Thus, total soil carbon would have increased by 25,250 tons after 25 years. This is valued at SDD 15.2 million (US$ 0.075 million).

6.6.2 Reduced Land Degradation and Increased Rainfed Traditional Agricultural and Pastoral Production

(i) Supporting Interventions

The broad strategies to address the problems of land degradation and declining agricultural production in the traditional rainfed farming systems have been outline in Chapter 3 of this Report and in the Transboundary Reports.

At a more specific level the opportunities for closer collaboration between the two rainfed agricultural sectors exist. These involve the implementation of the government regulation for 10 percent tree planting on large government lease-hold farms through the provision of forestry services by communities to the large farms including supply of seedlings, planting and maintenance through to harvesting.

A constraint would be that many farms are considerable distance from traditional communities and establishing relationship and providing service would be difficult. Nevertheless, assuming 60 percent is being farmed then there is the potential for re-forestation of some 545,700 feddans (229,200 ha) under these collaborative arrangements. Assuming sustainable yield of 5 m^3/ha on a 20 year rotation then an annual cut after 20 years of 1.15 million m^3 would be possible.

Contracts for supply of seedlings, planting and care and maintenance could provide substantial contributions to households' financial assets as well as widening the range of the livelihood strategies.

A second opportunity for collaboration is the utilization of the estimated 2.1 million tons of residues for livestock feed for transhumant pastoralists. This is sufficient to feed 1.1 million tropical livestock units (250 kgs live-weight).

(ii) Specific Interventions to Improve Crop Productivity

Two specific interventions to raise crop productivity have been proven by Research: drought-resistant crop varieties for sorghum, sesame and groundnuts, and the use of tied ridging to increase soil moisture. It estimated that using both improved varieties and tied ridging yield increases of 50 percent are possible (Mekki Abdul Latif, 2005).

(iii) Farm Level Analysis

The analysis uses the recently published MOA Economic Survey of Traditional rainfed Areas (MOA, 2006b) covering Blue Nile, Sinnar, White Nile, South and North Kordofan States. In the area covered by the White Nile Sub-basin the data for White Nile State was used. Crop yields were assumed to increase by 25 percent in the first year and to 50 percent from year 2 on-wards. Increased family labour for tied ridging and additional time for harvesting and threshing and increased cost of improved seed varieties[42] were the main incremental costs.

The analysis was conducted over 50 years using a discount rate of 10 percent. The farm level B:C ratio is 20, which fell to 10.4 when yields increased only 25 percent. Annual incremental cash income was SDD 349,482/yr (US$ 1,747/yr). Income per hectare was SDD 304/ha (US$ 1.52/ha).

(iv) Sub-basin Level Analysis

An estimated 476,190 feddans (200,000 ha) of traditional rainfed farms have been mapped in the Atbara Sub-basin, although because of their small size and the spatial resolution of the Landsat satellite imagery this may be an underestimate. Additionally, returning displaced people and natural migration into the area will lead to an increase in area cultivated.

The analysis assumes that 50 percent of the area will adopt the new technology over a period of 10 years. The discounted incremental benefits are SDD 233744 million (US$ 1,168.7 million). The overall B:C ratio is 20 (table 75).

Table 75. Financial Analysis: Improved Technology – Traditional Rainfed farms: White Nile Sub-basin

Financial Costs and Benefits of Improved Agronomy Interventions on Traditional Farms: White Nile Sub-basin

	Cost WOP (SDD '000)	Cost WP (SDD '000)	Benefit WOP (SDD '000)	Benefit WP (SDD '000)	Incremental Cost (SDD '000)	Incremental Benefit (SDD '000)	B/C Ratio
Trad. Farms	51,480,447	63,266,097	490,048,476	723,793,090	11,785,650	233,744,613	19.8

	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
Trad. Farms	257.4	316.3	2,450.2	3,619.0	58.9	1,168.7	19.8

all costs and benefits are PVs over 50 years at 10% discount rate

6.6.3 Reduced Sedimentation in Reservoirs and Irrigation Systems

(i) New Sediment Budget of the Baro-Sobat-White Nile Sub-basin

These reductions were based on a 22 percent adoption of WSM interventions on cropland and 30 percent of non-cropland in the Ethiopian Highlands. The main impacts of a reduction in sediment load of the Baro-Sobat-White Nile will be felt in the pump schemes and the Kenena Sugar Estate along the White

[42] Currently MOA are distributing improved seed free of charge.

Nile. The new sediment budget for the Baro-Sobat-White Nile Sub-basin is shown in table 76.

Table 76. Baro-Sobat-White Nile Sub-basin: Estimated Current Sediment Budget: With Watershed Management Programme and only Existing Dams.

	(1) NO WSM OR DAMS M t/yr	(2) WSM ONLY M t/yr	(1) - (2) REDUCTION M t/yr
SEDIMENT ENTERING BARO 1& 2 (M t/yr)			
SEDIMENT RETAINED IN BARO 1& 2 (%)			
SEDIMENT RETAINED IN BARO 1 & 2 (M t/yr)			
SEDIMENT THRU' BARO 1&2I (M t/yr)			
SEDIMENT IN AKOBO (M t/yr)	3.94	3.76	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	3%	3%	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (M t/yr)	0.12	0.11	
SEDIMENT IN AKOBO AT BARO CONFLUENCE(M t/yr)	3.83	3.65	
SEDIMENT IN BARO (M t/yr)	4.65	3.99	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS : GAMBELA -(%)	3%	3%	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (M t/yr)	0.14	0.12	
% OF MAIN RIVER FLOW TO KHOR MACHAR	8%	8%	
% OF ANNUAL SEDIMENT LOAD DURING TIME OF SPILL	50%	50%	
% SEDIMENT LOST TO VIA KHOR MACHAR	4%	4%	
SEDIMENT LOST TO VIA KHOR MACHAR (M t/yr)	0.18	0.15	
SEDIMENT IN BARO AT AKOBO CONFLUENCE(M t/yr)	4.33	3.72	
SEDIMENT AT SOBAT HEAD (M t/yr)	**8.15**	**7.36**	**0.79**
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	3%	3%	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (M t/yr)	0.24	0.22	
% OF MAIN RIVER OVERBANK FLOW TO MACHAR MARSHES	17%	17%	
% OF ANNUAL SEDIMENT LOAD DURING TIME OF OVERFLOW	50%	50%	
% SEDIMENT LOST TO MACHAR MARSHES FROM OVERFLOW	9%	9%	
SEDIMENT LOST TO MACHAR MARSHES (M t/yr)	0.70	0.63	
SEDIMENT AT SOBAT- WHITE NILE CONFLUENCE (M t/yr)	**7.21**	**6.51**	**0.70**
SEDIMENT FROM WHITE NILE (M t/yr)	0	0	
SEDIMENT IN WHITE NILE BELOW SOBAT CONFLUENCE (M t/yr)	7.21	6.51	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	3%	3%	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (M t/yr)	0.22	0.20	
SEDIMENT AT KENENA INTAKE (M t/yr)	7.00	6.32	
% of WHITE NILE FLOW TO IRRIGATION SCHMES	7%	7%	
% OF ANNUAL SEDIMENT LOAD	90%	90%	
% OF ANNUAL SEDIMENT LOAD	6%	6%	
SEDIMENT TO IRRIGATION SCHEMES (M t/yr)	0.43	0.38	**0.04**
SEDIMENT TO IRRIGATION SCHEMES (M m3/yr)	0.40	0.36	
SEDIMENT TO JEBEL AULIA RESERVOIR (M t/yr)	6.57	5.93	**0.64**
SEDIMENT RETENTION RATE (%)	37%	37%	
SEDIMENT RETAINED (M t/yr)	2.46	2.22	**0.24**
SEDIMENT RETAINED (M m3t/yr)	2.31	2.09	**0.23**
SEDIMENT TO MAIN NILE AT BLUE NILE CONFLUENCE (m t/yr)	**4.26**	**3.84**	**0.41**

The reductions in sedimentation are approximately 10 percent of current rates, which is considerable less than those for the Abbay-Blue Nile and the Tekeze-Atbara Sub-basins.

(ii) Lost irrigation water and Crop production

As the Schemes along the White Nile are pump schemes there is no loss of irrigation water storage

(iii) Reduced Operation and Maintenance Costs of the Kenana and other Pump Irrigation Schemes

It can be expected that there would be a commensurate reduction in costs of sedimentation in the reduction in operation and maintenance costs of the pump schemes along the White Nile. However, given the low sediment loads already in the White Nile and the very small reduction the benefits are negligible compared with those accruing in the Rahad, Gezira-Rahad and New Halfa Schemes. It estimated that with just 5 percent of the sediment entering the Kenana Scheme and with only a 10 percent reduction in sediment, savings would be SDD 5.0 million (US$ 0.0.02 million).

There would be a reduction in the benefits from the fertilizer value of the sediments. This would reduce by SDD 0.22 million/yr (US$ 1,000/yr)

6.7 Estimated Budget - Direct and Supporting Interventions: Sobat-White Nile Sub-basin - Sudan

The previous section has outlined some of the quantifiable costs and benefits accruing to the direct interventions. All of these depend to a greater or lesser extent on the implementation of the Supporting Interventions. These Supporting Interventions will provide increased physical and human capacity to rural households and government implementing organizations and in particular the extension Service; support to assisting rural families to gain non-farm employment and to small enterprise development in both rural areas and small urban centers; improved road and market infrastructure and increased capacity of farmers in product marketing and with increased available and access to micro finance and credit. The details of these and their direct and indirect benefits are summarized Matrix 2b in Chapter 2.

This section provides a summary of the budget required to implement both the Direct and Supporting Interventions. A detailed breakdown with units and unit costs is provided in Annex 3. A summary is provided in table 77. Given the very complex nature of the relationships between the Direct and the Indirect Interventions, in particular their short and long term impacts on human welfare and development in local, regional and National terms it would be extremely hazardous to attempt an overall benefit-cost analysis. However, it is submitted that the figures below provide a sense of the order of magnitude in implementing a programme of the interventions as outlined in Chapter 3.

Table 77. Summary 10 Year Budget: Atbara Sub-basin – Sudan: (a) Direct Interventions, (b) Supporting Interventions and (c) Total budget (SDD).

(a) Direct Interventions

Intervention	SDD	US$
1. ARRESTING SOIL DEGRADATION: CROP INTENSIFICIATION	2,252,900,000	11,264,500
2. LIVESTOCK DEVELOPMENT	3,123,830,000	15,619,150
Sub-total	**5,376,730,000**	**26,883,650**

(b) Supporting Interventions

Intervention	Total cost (SDD)	Total cost (US$)
1. CAPACITY BUILDING	6,098,618,000	30,493,090
2. SUPPORT TO AGRICULTURAL EXTENSION	1,488,240,000	7,441,200
3. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT	871,697,000	4,358,485
4. COMMUNITY ASSETS DEVELOPMENT (INFRASTRUCTURE)	22,153,950,000	110,769,750
5. IMPROVED MARKETING	105,300,000	530,250
6. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS	106,050,000	530,250
7. SUPPORT TO STRATEGIC LAND USE PLANNING	875,940,000	4,379,700
Sub-total	**31,699,795,000**	**158,502,725**

TOTAL

Intervention	Total cost (SDD)	Total cost (US$)
(a) Direct Interventions	5,376,730,000	26,883,650
(b) Supporting Interventions	31,699,795,000	158,502,725
TOTAL	**37,076,525,000**	**185,386,375**

SDD/Household	US$/Household
741,531	**3,708**
SDD/ha	**US$/ha**
185,383	**927**

The average cost per household in the traditional rainfed and pastoral sectors SDD 741,531 million (US$ 3,708/household). Clearly non-farming members of the community will also benefit from the Direct and Supporting Interventions in terms of improved access to social services, employment and information. Costs per ha of rainfed cropland are SDD 185,383/ha (US$ 927/ha). Again areas of rangeland and forest will benefit from the Interventions. These per unit costs are presented only to provide a first approximation of unit costs when considering programme at the catchment or sub-catchment scale.

6.8 Economic Costs and Benefits: the Baro-Sobat-White Nile Sub-basin

All economic and environmental costs and benefits for Ethiopia and Sudan broken down into national, regional and global are shown in table 78. The overall Sub-basin B:C ratio is 2.0. Global benefits comprise approximately 4 percent of total benefits. Net Regional impacts are negligible comprising benefits from reduced sediment loads and the greater offsetting costs of reduced fertilizer effect of sediment. The B:C ratio for Ethiopia increases from 1.8 to 2.1 with global benefits, and that of Sudan increases only very slightly with the inclusion of the Regional and Global benefits.

Table 78. National, Regional and Global Benefits of WSM Interventions: Baro-Sobat-White Nile Sub-basin

Economic Costs and Benefits of WSM Interventions in the Baro-Sobat-White Nile Sub-Basin

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
ETHIOPIA							
National							
Soil conservation: Bunds	30.6	36.7	131.6	142.7	6.1	11.1	1.8
Soil conservation: Grass strips	25.8	26.8	121.6	126.3	1.0	4.7	4.9
Fertilizer/Improved seed	20.0	32.8	162.6	229.5	12.7	66.8	5.2
On-farm Forage	0.0	1.4	16.2	33.8	1.3	17.6	13.3
On-farm Trees	0.1	2.1	11.7	41.3	2.0	29.6	14.6
On-farm Trees: Crop Production saved: Soil N retained	-	-	-	-	-	0.30	
Improved stoves: time saved	-	0.5	-	7.7	0.5	7.7	15.4
Area enclosure	19.7	75.0	39.4	109.5	55.2	70.1	1.3
Small-scale Irrigation	0.9	61.2	10.3	95.2	60.3	84.9	1.4
Small-scale Irrigation: Multiplier Impacts						25.7	
Supporting Interventions					41.1		
Sub-total	**97.2**	**236.5**	**493.4**	**786.0**	**180.4**	**318.5**	**1.8**
Regional	-	-	-	-	-	-	
Global							
Soil conservation: Soil Carbon seq.	-	-	-	-	-	11.8	
On-farm Trees: Tree carbon						2.0	
Improved Stoves: Fuel saving: Tree Carbon seq.						0.1	
Enclosed areas: Tree carbon						33.8	
Enclosed areas: Soil carbon						9.0	
Sub-total	-	-	-	-	-	**56.7**	
TOTAL ETHIOPIA	**97.2**	**236.5**	**493.4**	**786.0**	**180.4**	**375.2**	**2.1**
SUDAN							
National							
Traditional Rainfed Farms: Crop production	214.6	265.3	2,712.9	4,007.0	50.7	1,294.0	25.5
Semi-mechanised farms: Crop production	456.8	472.4	835.0	1,281.7	15.6	446.7	28.6
Semi-mechanised farms: Charcoal production	-	185.8	-	117.8	185.8	117.8	0.6
Semi-mechanised farms: Residue: Livestock feed						18.8	
Supporting Interventions					695.0		
Sub-total	**671.4**	**923.4**	**3,547.9**	**5,406.5**	**947.0**	**1,877.4**	**2.0**
Regional							
Reduced OM Costs: Irrigation schemes	-	-	-	-	-	0.2	
Reduced fertilizer value: Sediment	-	-	-	-	-	(0.01)	
Sub-total	-	-	-	-	-	**0.2**	
Global							
Traditional Rainfed Farms: Soil carbon						14.7	
SMF's : Soil carbon						21.0	
SMF's : Tree Cover: Soil carbon	-	-	-	-	-	3.1	
Sub-total	-	-	-	-	-	**38.8**	
TOTAL: SUDAN	**671.4**	**923.4**	**3,547.9**	**5,406.5**	**947.0**	**1,916.3**	**2.0**
TOTAL: SUB-BASIN	**768.6**	**1,159.9**	**4,041.3**	**6,192.4**	**1,127.4**	**2,291.6**	**2.0**

all costs and benefits are PVs over 50 years at 10% discount rate

7. COSTS, BENEFITS AND IMPACTS OF WATERSHED MANAGMENT INTERVENTIONS: MAIN NILE SUB-BASIN

7.1 Costs (and Benefits) of Continued Natural Resource Management Practices in Sudan

7.1.1 Moving Sand Dunes

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

Two of the 14 dune fields abut the river, each with a front of about 2.6 kms. However, in the absence of any measurements it is difficult to estimate the amount of sand tipping into the River. In addition to increased sediment suspended and bed load the sand tipped into the river causes point bars to form and these in turn cause accelerated river bank erosion.

Currently the dunes threaten three villages of Argi, Abkar and Afaad, some 4,000 feddans (2,240 ha) of existing irrigated cropland and 17,000 feddans (9,520 ha) of potential cropland (10,000 beneficiaries).

The cropping pattern on the irrigated land is winter wheat and summer sorghum, vegetables and forage crops, together with permanent stands of date palm. Assuming net returns to irrigated summer sorghum and winter wheat of SDD 24,140/ha (US$ 33.07/ha) and SDD 6,614/ha (US$ 120.69/ha) and a discount rate of 10 percent and an infinite time horizon gives an estimated value of irrigated land of SDD 307,525 /ha (US$ 1,538/ha).

Thus the loss of existing irrigated land to dune encroachment would represent a cost of SDD 689 million (US$ 3.4 million) and that of the potential cropland of SDD 2,928 million (US$ 14.6 million). The total potential cost of dune encroachment onto existing and potential cropland is SDD 3,616 million (US$ 18.1 million).

7.1.2 River Bank Erosion: Sudan

Abdalla A.S. Ahamed at el., 2005 have reviewed the available data and information on river bank erosion in Sudan and Egypt. In the Main Nile in Sudan most river bank erosion occurs in the first and third of four reaches.

The first reach being between Khartoum and the 5th Cataract and the third between 3rd and 4th Cataracts, with the third reach experiencing the most severe erosion. The large and rapid changes in water level and high river velocities together with induced flow shear on the outer banks acting on the sandy layer which underlies a cohesive clayey bank material.

Whilst certain information exists for certain reaches or a specific irrigation scheme there is no in formation on annual rates of bank erosion. Surveys undertaken by the Sudan Hydraulics Research Station over a period 1989 – 1999 in the Northern State Reach of the Main Nile estimated that some 19,400 feddans had been lost or severely affected by river erosion.

Assuming an estimated value of irrigated land of SDD 307,525 /ha (US$ 1,538/ha) this would indicate that the cost of river bank erosion for those areas that have been surveyed as SDD 2,506 million (US$ 12.5 million).

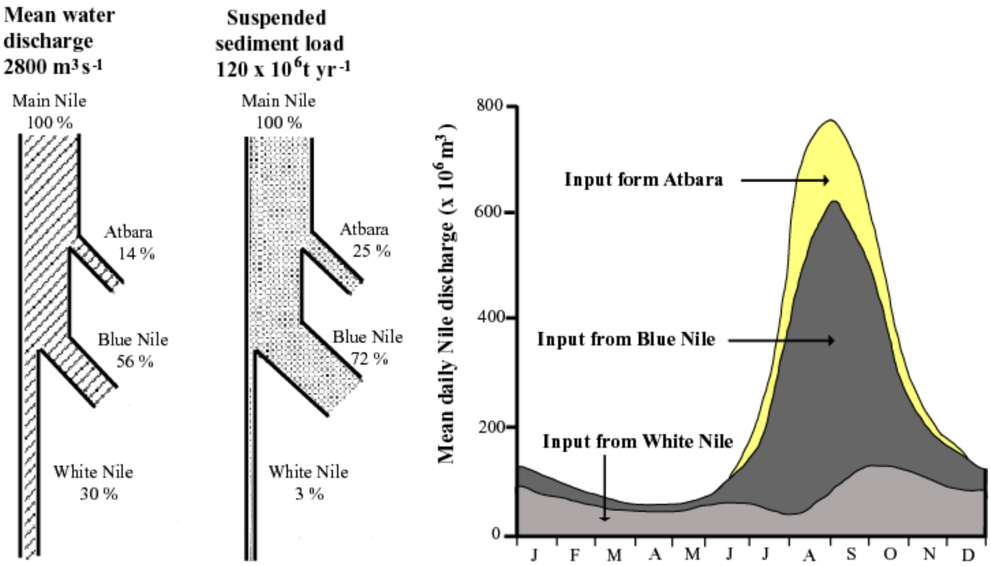
7.1.3 Sedimentation in Lake Nubia/Nasser

(i) Origins and Rates of Sedimentation

The suspended sediment load entering Lake Nubia is almost entirely from the Ethiopian Highlands (Figure 14). Some 97 percent is derived from the Blue Nile (72%) and the remainder from the Atbara (25%). The mean water discharge differs considerably with the White Nile contributing 30 percent and the Blue Nile and the Atbara 72 and 25 percent respectively.

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

Figure 14. Mean Discharge and Suspended Sediment Load for the Nile Basin.



Shalash (1982) estimated the total annual inflow as 142 million tons, the average rate of outflow as 6 million tons with a net sedimentation within the Lake of 136 million tons. Using an average sediment density of 1.56 g cm^{-3} and corrected for compaction (dry weight density of 2.6 g cm^{-3} and a porosity of 40 %), the amount of annually retained sediment of 136 million tons of suspended sediment corresponds to an accumulated volume of 87 million m^3 per yr (Shalash, 1982). However, it is important to note that there is considerable annual variation in sediment load, ranging from 50 and 228 million tons.

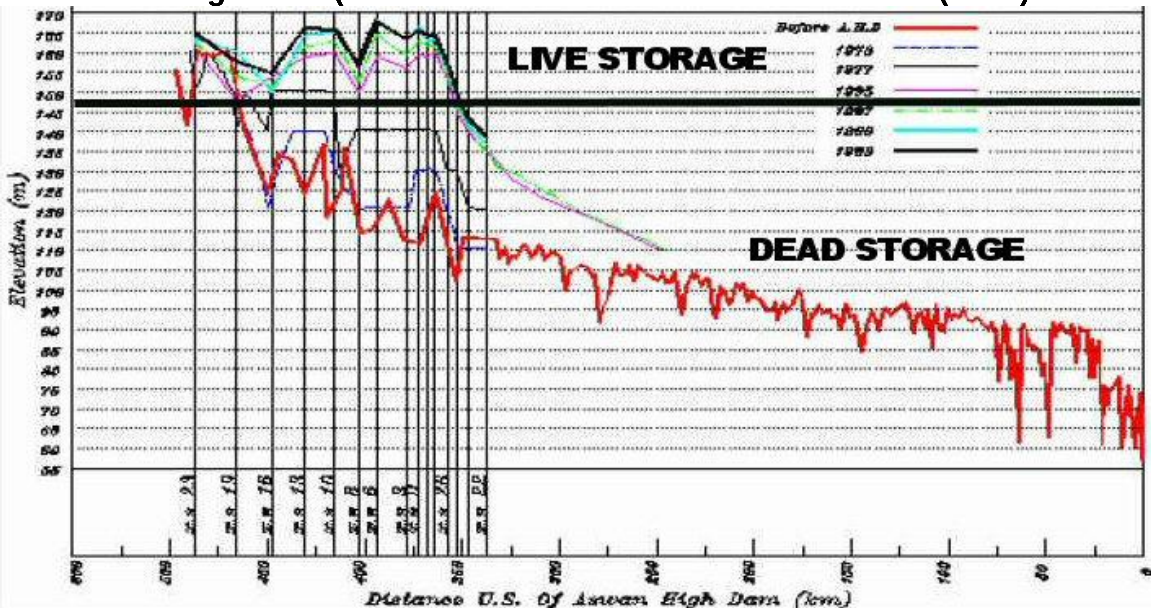
(ii) Spatial and Volumetric Extent of Sedimentation

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

The extent of the sediment has been measured by Mohamed El-Moattassem et al, 2005). The sediment deposition is concentrated at the head of the Lake mainly in the Sudan. Figure 4 describes the longitudinal section of the lowest bed elevation of Aswan High Dam Reservoir (AHDR) from year 1964 to 2003 using bathymetric data collected by the Nile Research Institute (NRI). The reservoir was designed with 31.6 km^3 of dead storage to accommodate the sediment being retained in the reservoir. In 1982 the Research Institute to Study Effects of the High Dam estimated that the reservoir would function unimpeded by sediment for approximately 362 years (Smith, 1990).

However, it can be seen in figure 15 that 360 kms from the dam to 500 kms from the dam the sediment is filling up the live storage as well as the dead storage. This is having an immediate impact on the useful storage capacity of the reservoir and thus is reducing the amount of water available for hydro power generation and for irrigation.

Figure 15. Longitudinal bed elevation profiles in meters above sea level from pre-dam to 1999 for Aswan High Dam Reservoir showing dead and live storage level (Source: Mohamed El-Moattassem et al (2005)



(iii) Costs and Benefits to Sudan

(a) Costs of Sedimentation in Lake Nubia

Sudan does not use Lake Nubia for hydro-power generation or irrigation. Thus the sedimentation in Lake Nubia does not currently incur a cost to Sudan.

(b) Potential Benefits of Sediments Deposited in Lake Nasser

As the sediment appears above the low Lake levels it will be possible to utilize this land for crop irrigated production, either by pumping directly from the Lake or from shallow groundwater or for recession cropping on residual moisture. Currently, no data is available as to the extent of this new land and its annual rate of formation. Thus it is not possible to place a monetary value on it.

El-Moattassem (2005) has outlined potential industrial and agricultural uses of the sediments that are under investigation by the Nile Research Institute (NRI). Potential materials that can be extracted include radio-active materials and metallic minerals, whilst potential processed materials include fertilizer and ceramics. The sediments also have a use in the manufacture of bricks and building sand. To date no detailed cost-benefit has been undertaken.

7.1.4 Summary of Costs of Natural Resource Degradation in the Main Nile Sub-basin: Sudan

The various cost estimates of natural resource degradation in the Main Nile Sub-basin in Sudan are summarized in Table 79. As annual rates of cropland loss are not known, the costs indicated represent the total potential losses (dune encroachment) and surveyed losses over a 10 period (river bank erosion).

Table 79. Summary of Costs of Natural Resource Degradation in the Main Nile Sub basin: Sudan

Resource	SDD million	US$ million
Dune encroachment: Existing crop land	689.0	3.4
Dune encroachment: Potential crop land	2,928.0	14.6
River bank erosion	2,506.0	12.5
TOTAL GROSS COSTS	**6,123.0**	**30.5**
Benefits from Sediment in Lake Nubia	n.d.	n.d.
TOTAL NET COSTS	**6,123.0**	**30.5**

n.d. = no data

Table 80 provides a distribution of these costs into local/national, Regional and Global. All costs have local/national implications, there being no Regional or global.

Table 80. Distribution of Natural Resource Loss and Degradation Costs into Local/National, Regional (East Nile Basin) and Global. Baro-Sobat-White Nile Sub-basin in Sudan

Resource	SDD million	US$ million	%
LOCAL/NATIONAL			
Dune encroachment: Existing crop land	689.0	3.4	
Dune encroachment: Potential crop land	2,928.0	14.6	
River bank erosion	2,506.0	12.5	
Sub-total	**6,123.0**	**30.5**	**100%**
REGIONAL			
Sub-total	**-**	**-**	**0%**
GLOBAL			
Sub-total	**-**	**-**	**0%**
TOTAL GROSS COST	**6,123.0**	**30.5**	
Less value of Sediments: Lake Nubia	n.d.	n.d.	
TOTAL NET COST	**6,123.0**	**30.5**	

7.2 Impacts, Costs and benefits of the Proposed Watershed Management Direct Interventions

7.2.1 Halting Shifting Sand Dunes

In the absence of data on the annual rate of loss of irrigation land a dynamic analysis is not possible. The value of irrigated land is estimated to be SDD 307,525/ha (US$ 1,538/ha) (see chapter 3). In static terms the potential total costs of the destruction of existing and potential irrigated land in the Dongola reach is estimated at SDD 3,616.5 million (US$ 18.1 million). An 80 km shelterbelt costing SDD 10.0 million/km (US$ 50,000/km) would cost some SDD 800 million (US$ 4 million). The B:C ratio is 5. Other costs would be involved such as the loss of housing and other infrastructure (wells, pumps stations) as well as increased river bank erosion caused by sand bar formation. Thus, the actual B:C ratio would be higher.

7.2.2 River Bank Erosion

The costs of river bank erosion along the Main Nile have been estimated to be SDD 2,505.7 million (US$ 12.5 million). Assuming that river bank erosion affects land up to 200 meters from the river edge then each kilometer reach of river has a potential 20 ha of land on each bank that can be affected. Loss of land due to river bank erosion has been estimated at 8,148 ha. This would indicate that some 407 kms of river bank are affected.

The experience in Egypt has been to avoid using spurs but to use revetments for bank protection with stone and compacted back-fill using local material (Moattassem, 2005). No costs are available but using the above figures the cost per kilometer should not exceed SDD 6.2 million/km (US$ 30,783/km) for the financial B:C ratio to less than unity.

7.2.3 New Sediment Budget of the Main Nile Sub-basin with WSM Programme in the Upstream Sub-basins

Reductions in sediment load in the Main Nile were based on the assumptions set out in the Watershed Management Programme in the Ethiopian Highlands and in restoration of the *kerib* lands along the Atbara. Given the lack of data on sediment entering the Main Nile from bank erosion and sand tipping from moving dunes it is not possible to say in quantitative terms what positive impact remedial measures (bank revetments, land use changes and shelterbelts) will have in reducing sediment load.

The main impacts of a reduction in sediment load of the Main Nile will be felt in the pump schemes along the White Nile, in the reduction in sedimentation in Lake Nubia/Nasser and the reductions in the sediment in the Meroe Dam currently under construction and due for completion on 2008 (table 81).

The new sediment budget for the Eastern Nile Basin is shown in table 70. The two key points along the Main Nile for reductions in sediments are the entrance to the Meroe Reservoir and to Lake Nubia/Nasser where there are approximate reductions of 28 percent. Unquantifiable but positive impacts will be experienced in reduced wear and tear to equipment in the pumping schemes.

Nevertheless, there will some negative impacts in terms of increased bed scour and river bank erosion. The current costs of river bank erosion are stated in paragraph 7.1. These costs are likely to increase but it is not possible to predict by how much. Compounding factors are likely to be the change in flood regime following completion of the Tekeze 5 and Meroe dams. Current causes of bank erosion are related to the considerable annual rise and fall in river levels.

Table 81. Eastern Nile Basin: Estimated Current Sediment Budget: With Watershed Management Programme and only Existing Dams.

LOCATION	WSM ONLY	REDUCTION
	M t/yr	M t/yr
SEDIMENT ENTERING KARADOBI	65.87	26.13
SEDIMENT RETAINED IN KARADOBI	-	
SEDIMENT THRU' KARADOBI	65.87	26.13
SEDIMENT ENTERING RIVER BELOW KARADOBI (EXCLUDING BELES)	30.98	15.83
SEDIMENT ABOVE BELES-ABBAY CONFLUENCE (M t/yr)	96.85	41.96
SEDIMENT ENTERING BELES	1.12	0.44
SEDIMENT RETAINED IN BELES RESERVOIR	-	
SEDIMENT THRU' BELES	1.12	0.44
SEDIMENT IN ABBAY AT BORDER	97.97	42.40
SEDIMENT ENTERING ROSIERES	97.97	42.40
SEDIMENT RETAINED IN ROSIERES (%)	0.15	
SEDIMENT RETAINED IN ROSIERES M t/yr	14.70	6.36
SEDIMENT THRU' ROSIERES	83.27	
SEDIMENT ENTERING RAHAD PUMP	83.27	36.04
SEDIMENT RETAINED IN RAHAD PUMP (%)		
SEDIMENT RETAINED IN RAHAD PUMP (M t/yr)	1.57	0.68
SEDIMENT AFTER RAHAD PUMP	81.71	

LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	0.01	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	1.02	
SEDIMENT ENTERING SENNER	80.69	34.92
SEDIMENT RETAINED IN SENNER (%)		
SEDIMENT RETAINED IN SENNER	8.07	3.49
SEDIMENT THU SENNER	72.62	
SEDIMENT AT GEZIRA/MANAGIL INTAKE	72.62	31.43
SEDIMENT RETAINED IN GEZIRA/MANAGIL (%)		
SEDIMENT RETAINED IN GEZIRA/MANAGIL M t/yr	5.45	2.43
SEDIMENT AFTER GEZIRA	67.17	
SEDIMENT FROM RAHAD-DINDER	9.19	
SEDIMENT BELOW RAHAD-DINDER CONFLUENCE	76.36	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	0.03	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	4.58	
BLUE NILE SEDIMENT AT KHARTOUM	71.78	27.26
SEDIMENT FROM WHITE NILE (3% OF 142mT/YR)	3.84	0.41
SEDIMENT MAIN NILE AT KHARTOUM (Mt/yr)	**75.62**	**27.67**
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	0.04	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	3.02	
	2.85	
SEDIMENT MAIN NILE ABOVE ATBARA	72.60	
SEDIMENT FROM ATBARA	40.85	
SEDIMENT MAIN NILE BELOW ATBARA CONFLUENCE	**113.45**	**44.15**
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	0.04	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	4.54	
	4.27	
SEDIMENT ENTERING MEROE RESERVOIR (M t/yr)	**108.91**	**42.39**
SEDIMENT RETAINED IN MEROE RESERVOIR (%)		
SEDIMENT RETAINED IN MEROE RESERVOIR (M t/yr)	-	
SEDIMENT BELOW MEROE DAM (M t/yr)	108.91	

LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (%)	0.06	
LOST TO PERMANENT STORAGE IN RIVER BED/ALLUVIAL PLAINS (Mt/yr)	6.53	
	6.15	
SEDIMENT ENTERING LAKE NASSER/NUBIA (M t/yr)	**102.37**	**39.84**
SEDIMENT ENTERING LAKE NASSER/NUBIA (M M3/yr)	**96.35**	**37.50**
SEDIMENT RETAINED IN LAKE NASSER/NUBIA (%)		
SEDIMENT RETAINED IN LAKE NASSER/NUBIA (M t/yr)	98.28	38.25
SEDIMENT RETAINED IN LAKE NASSER/NUBIA (M m3/yr)	92.50	36.00
% REDUCTION IN SEDIMENTATION IN LAKE NASSER/NUBIA		**28%**
SEDIMENT THRU LAKE NASSER	4.09	1.59

7.2.4 Impact of Reduced Sediment Load: Basin and Flood-plain Irrigation

The area of irrigation along the floodplain of the Main Nile is approximately 340,848 feddans (143,156 ha) (Africover – Sudan, 2003). Some 24 percent are field crops (wheat, vegetables, etc) and 76 percent date palm. The amount of sediment being deposited on the flood plain and river bed is estimated at 19.5 million tons/yr (table 70). Assuming that 50 percent enters the schemes and that 30 percent of this sediment is deposited in irrigated fields then 2.9 million tons/yr of sediment reach the fields. This is equivalent to 84,883 tons of fertilizer. This has a total value of SDD 4,855 million/yr (US$ 24.3 million/yr).

It estimated that there will be a 28 percent reduction in sediment load in the Main Nile at full completion of the WSM programme in Ethiopia. This reduction will incur a cost in terms of fertilizer lost (23,767 tons/yr) of SDD 1,360 million/yr (US$ 6.8 million/yr).

7.2.5 Impact of Reduced Sediment Load: Lake Nubia/Nasser - Sudan

Currently, Sudan incurs no costs due to sediment deposition in Lake Nubia. The build-up of sediment above the low water level at the in-land delta has potential benefits to be used for flood retreat and pump irrigated cropping.

Thus any reduction in sediment will reduce the build-up of this material and may also cause down-cutting into the existing sediment. It is difficult to predict the exact nature of the erosion as reductions in sediment load will also occur because of the trapping of sediment in the Tekeze 5 and Meroe Dams.

The joint Sudan-Egypt programme of sediment monitoring will provide quantitative estimates of the impacts of reductions in sediment loads on the delta formation.

7.3 Costs of Continued Natural Resource Management Practices in the East Nile Basin: Egypt

7.3.1 Sedimentation in Lake Nubia/Nasser: Egypt

(i) Loss of Live Storage

From figure 15 it can be seen that from 360 kms to 500 kms from the dam the sediment is filling up the live storage as well as the dead storage. Live storage is estimated at 89.7 billion m^3. It is estimated[43] that the live storage lost to date is between 2.5 and 2.8 billion m3. To calculate the annual rate resource was made to figure 9. This indicates that live storage started to be lost sometime between 1977 and 1995. Taking the half way point this indicates that the total live storage loss has occurred over a period of 19 years. This gives an estimated annual rate of loss of between 0.132 and 0.147 billion m^3. Taking the half way point this would indicate that the average annual live storage loss is 0.139 billion m3 or 0.155 percent. This has implications for power generation and for irrigation below the Aswan High Dam (AHD).

(ii) Impact on Hydro-power generation

The AHD has an installed hydro-power generating capacity of 2.1 million MW capable of generating 10,000 MkWh annually. Production is currently at about 8,000 MkWh/yr (Abu-Zeid & El-Shibini, 1997). With annual (cumulative) loss of live storage of 0.155 percent this represents an annual cumulating loss of approximately 12.4 GWh. Using a value of LE 0.58/kWh (S$ 0.10 /kWh) this represents an annual accumulating loss of LE 6.9 million (US$ 1.2 million) rising to LE 172.7 million (US$ 30.0 million) after 25 years.

[43] Reference is Professor El- Moattassem: Communication from Chairman – Egypt Steering Committee.

(iii) Impact on Irrigation

The value of water in Egypt for irrigation is estimated[44] to be LE 0.64/m3 (US$ 0.11/m^3). The annual loss of live storage is 0.139 billion m^3, which represents an annual accumulating cost of LE 89.3 million (US$ 15.5 million) rising to LE 2,232.0 million (US$ 387.5 million) after 25 years.

(iv) Potential Benefits of Sediments Deposited in Lake Nasser

As mentioned above the sediments have a number of potential industrial and agricultural uses. This requires more detailed financial cost-benefit analysis.

7.3.2 Summary of Costs of Natural Resource Degradation in the Main Nile Sub-basin: Egypt

The various cost estimates of natural resource degradation in the Main Nile Sub-basin in Egypt are summarized in Table 82. The most significant cost is the loss of irrigation due to the loss of the live storage. All the costs are local/national, there being no regional or Global costs. A potential global cost would be incurred if the lost hydro-power was replaced by electricity generated by oil or gas fired power stations. If costed this way then it would replace the estimate in table 82 (to avoid double-counting).

Table 82. Summary of Costs of Natural Resource Degradation in the Main Nile Sub basin: Egypt

Resource	Annual		After 25 years	
	LE million	US$ million	LE million	US$ million
1. Lost hydro-power generation	7.2	1.2	179	31.1
2. Lost Irrigation	89.3	15.5	2,231.00	387.6
TOTAL GROSS COSTS	**96.5**	**16.7**	**2,410.00**	**418.7**
Benefits from Sediment in Lake Nubia	n.d.	n.d.	n.d.	n.d.
TOTAL NET COSTS	**96.5**	**16.7**	**2,410.00**	**418.7**

n.d. = No data

[44] From table of Indicator Values for Egypt (1997) received from Egypt Steering Committee.

7.4 Impacts of the Proposed Watershed Management Direct Interventions

7.4.1 Impact of Reduced Sediment in Lake Nubia/Nasser - Egypt

Currently, the annual loss of live storage is incurring annual accumulating costs of LE 6.9 million/yr (US$ 1.2 million) for lost power generation and LE 2,232 million/yr (US$ 387.3 million) in lost irrigation water (chapter 3).

It estimated that there will be a 28 percent reduction (37.2 million tons/yr) in sediment entering Lake Nubia/Nasser on completion of the WSM programme in the Ethiopian Highlands. The reductions in these costs due to reduced rate of live storage losses are LE 1.9 million/yr (US$ 0.3 million/yr) for power generation and LE 24.8 million/yr (US$ 4.3 million/yr): a total of LE 26.7 million/yr (US$ 4.6 million). These reductions are accumulating.

7.5 Economic Costs and Benefits: the Main Nile Sub-basin

All costs and benefits for Sudan and Egypt are broken down into national, regional and global are shown in table 82. Net Regional impacts comprise 96 percent and national benefits 4 percent. There are no measurable global benefits. The B:C ratio for decreases from 4.4 to 3.7 because of the losses of fertilizer value of the reduced sedimentation. Clearly the incremental benefits to Egypt are considerable.

Table 82. National, Regional and Global Benefits of WSM Interventions: Baro-Sobat-White Nile Sub-basin

Economic Costs and Benefits of WSM Interventions in the Main Nile Sub-Basin

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
SUDAN							
National							
Arresting Sand Dunes	-	-	-	-	2.5	11.2	4.4
River Bank Protection					9.5	9.5	1.0
Sub-total	**-** -	**-**	**-**	**-**	**2.5**	**11.2**	**4.4**
Regional							
Reduced fertilizer value: Sediment	-	-	-	-	-	(1.8)	
Sub-total	**-**	**-**	**-**	**-**	**-**	**(1.8)**	
Global	-	-	-	-	-	-	
TOTAL: SUDAN	**-**	**-**	**-**	**-**	**2.5**	**9.4**	**3.7**
EGYPT							
Regional							
Reductions in lost Power Generation	-	-	-	-	-	16	
Reductions in lost Irrigation Water	-	-	-	-	-	243	
	-	**-**	**-**	**-**	**-**	**259**	
TOTAL: EQYPT	**-**	**-**	**-**	**-**	**-**	**258.6**	
TOTAL: SUB-BASIN	**-**	**-**	**-**	**-**	**2.5**	**268.0**	
all costs and benefits are PVs over 50 years at 10% discount rate							

7.6 Aggregated Economic Costs and Benefits: Eastern Nile Basin

The economic costs and benefits for the whole Eastern Nile Basin have been aggregated into National, Regional and Global estimates. It must be noted again that these figures only capture those costs and benefits that it has been possible in the time and with the resources available. The first section in chapters 4, 5 and 6 have attempted to set out the many benefits not captured in the benefit:cost analysis and those that accrue to the synergistic effects of direct and supporting interventions.

The aggregated results are present in table 83. The overall B:C ratio is 2.8. The incremental benefits comprise 92 percent national, 2 percent regional and 5 percent global. The overall net present value of the benefits using a real discount rate of 10 percent over 50 years is US$ 8,510 million.

Table 83. Aggregated Economic Costs and Benefits (US$ millions) for the Eastern Nile Basin.

Economic Costs and Benefits of WSM Interventions in the Eastern Nile Sub-Basin

Intervention	Cost WOP ($US million)	Cost WP ($US million)	Benefit WOP ($US million)	Benefit WP ($US million)	Incremental Cost ($US million)	Incremental Benefit ($US million)	B/C Ratio
ETHIOPIA							
National							
Soil conservation: Bunds	443.0	519.9	1,414.9	1,548.3	76.9	133.3	1.7
Soil conservation: Grass strips	576.8	582.9	1,155.8	1,208.6	6.2	52.8	8.6
Fertilizer/Improved seed	558.5	721.0	1,810.3	2,616.3	162.4	-	0.0
On-farm Forage	0.7	23.0	217.3	565.2	22.2	347.9	15.6
On-farm Trees: Fuelwood	1.3	28.9	219.3	497.8	27.6	278.5	10.1
On-farm Trees: Crop Production saved: Soil N retained	-	-	-			140.8	
Improved stoves	-	5.8	-	83.0	5.8	83.0	14.4
Area enclosure	576.5	1,161.5	1,085.5	9,138.1	585.0	8,052.6	13.8
Small-scale Irrigation	49.4	415.6	120.6	881.0	366.2	760.4	2.1
Small-scale Irrigation: Multiplier Impacts	-	-	-	-	-	134.5	
Supporting Interventions					1,137.4		0.0
Sub-total	**2,206.2**	**3,458.6**	**6,023.7**	**16,538.3**	**2,389.8**	**9,983.8**	**4.2**
Regional	-	-	-	-	-	-	
Global							
Soil conservation: Soil Carbon seq.	-	-	-	-	-	66.4	
On-farm Trees: Tree carbon	-	-	-	-	-	19.1	
Improved Stoves: Fuel saving: Tree Carbon seq.	-	-	-	-	-	8.4	
Enclosed areas: tree carbon	-	-	-	-	-	394.9	
Enclosed areas: Soil carbon	-	-	-	-	-	170.1	
Sub-total	**-**	**-**	**-**	**-**	**-**	**658.8**	
TOTAL ETHIOPIA	**2,206.2**	**3,458.6**	**6,023.7**	**16,538.3**	**2,389.8**	**10,642.6**	**4.5**
SUDAN							
National							
Traditional Rainfed Farms: Crop production	808.7	1,311.0	1,338.3	2,560.2	502.3	1,221.9	2.4
Semi-mechanised farms: Crop production	351.9	1,024.4	503.3	1,396.2	672.5	892.9	1.3
Semi-mechanised farms: Charcoal production	-	46.3	-	30.2	46.3	49.0	1.1
Semi-mechanised farms: Residue: Livestock feed						15.7	
Reclamation: Kerib land	0.0	3.2	0.0	8.1	3.2	8.1	2.5
Supporting Interventions					1,052.2		
Sub-total	**1,160.6**	**2,384.8**	**1,841.6**	**3,994.6**	**2,276.5**	**2,187.6**	**1.0**
	-						
Regional							
Increased irrigation water	-	-	-	-	-	10.5	
Reduced OM Costs: Irrigation schemes	-	-	-	-	-	33.6	
Reduced fertilizer value: Sediment	-	-	-	-	-	(9.8)	
Kerib land: Reduced sediment load Atbara						0.1	
Kerib land: Reduced fert. Value Sediment						(0.0)	
Sub-total	**-**	**-**	**-**	**-**	**-**	**34.3**	
Global							
Traditional Rainfed Farms: Soil carbon	-	-	-	-	-	22.7	
SMF's : Soil carbon	-	-	-	-	-	11.7	
SMF's : Tree Cover: Soil carbon	-	-	-	-	-	39.3	
Kerib land: Soil carbon	-	-	-	-	-	0.5	
Sub-total	**-**	**-**	**-**	**-**	**-**	**34.4**	
TOTAL: SUDAN	**1,160.6**	**2,384.8**	**1,841.6**	**3,994.6**	**2,276.5**	**2,256.3**	**1.0**
EQYPT							
Regional							
Reductions in lost Power Generation						16	
Reductions in lost Irrigation Water						243	
TOTAL: EGYPT	**-**	**-**	**-**	**-**	**-**	**277.0**	
TOTAL: SUB-BASIN	**3,366.8**	**5,843.4**	**7,865.3**	**20,532.9**	**4,666.3**	**13,175.9**	**2.8**

all costs and benefits are PVs over 50 years at 10% discount rate

National	92.4%
Regional	2.4%
Global	5.3%

8. OPTIONS FOR ALTERNATIVE DISTRIBUTIONS OF COSTS AND BENEFITS

8.1 Options to Redistribute Costs between Beneficiaries of Interventions – Payment for Environmental Services

Benefits like costs that accrue to recipients that have not been responsible for causing them are generally referred to as "externalities". This section examines how costs that are incurred by one party that provides not only benefits to that party, but also provides benefits to a another party. In watershed terms: activities in upper parts of the watershed can also benefit (and harm!) people and activities in the downstream part of the watershed.

Methods of redistributing costs among all beneficiaries of an intervention come under the rubric "Payment for Environmental Services" and are not confined only to Watershed Management activities.

8.1.1 Characteristics of Payment for Environment Schemes

Watersheds provide environmental services as mentioned earlier but these may ignore since landowners often receive no compensation for providing them. Payments for Environmental Services PESs are innovative instruments for the financing of sustainable watershed management and typically involve the payment of a user fee by downstream entities to upstream landowners for the provision of environmental services. The latter may include planting degraded mountain slopes and the up-rooting of invasive plants and vegetation.

PES offers the prospect of simultaneously diminishing land degradation and reducing income poverty with typical schemes relying on legal, government and financial institutions to function well. There are however examples that show that PES is adaptable and may function well under atypical conditions.

This sections looks at:

- definition and scope of PES in watersheds,
- design of PES schemes,
- execution of PES schemes,
- impacts of PES schemes,
- PES, sensitization and awareness raising, and
- PES and legislation

The challenges are service monitoring and appraisal as well as payment-mechanism sustainability. PES implementation in the Eastern Nile Basin would be possible provided that it is well thought through including anti-poverty targeting and adapted to site. It may be an option to start implementing PES at local level through NGOs if there is an absence of strong official institutions but it is important to give the PES legitimacy in the community eyes in order to help sustainability and compliance.

The monitoring of services as already mentioned may be a problem because there is often controversy on their direction, extent, distribution and cost-benefit distribution mechanism. Land use's effects vary according to local conditions but their assessment is difficult due to long delays between cause and effect and to interference between anthropogenic and natural impacts caused by factors such as climatic change although some experience shows that WSM's sedimentation impact may be observed more clearly in small watersheds[3].

Data collection on land use-watershed service interaction is also expensive and may be obtained only in the long term although some generalizations may be derived from extrapolation of farm and watershed experimental results.

This underlines the need for careful assessment, monitoring and evaluation of land-water relations for watershed PES implementation. The IBRD is working in many tropical countries to develop environmental-service markets and has so far drawn the following lessons:

The watershed service must be identified and quantified. This depends on the environment and the user. Hydroelectricity producers for instance use water differently to the municipal provider of drinking-water supply. A key obstacle faced by PES is the lack of establishment of a linkage between the service provider and user.

Most introduce mechanisms to ensure that user payments compensate the service provider such as the landowner. Forest owner compensation has generally been ignored although effort has been made to collect user payments.

Future research should include an assessment of where these markets can be developed. This requires knowing which forests are essential to which watersheds, if they are at risk or not, and the quality and quantity of service demand by downstream users. This also means identifying forests which could be preserved through means other than PES such as through policy change. These will require mandated protection or continuous payment from federal or international funding sources.

PES options include (i) payment of the opportunity cost for forest at risk (ii) flat payment scheme with a cap on allowable hectares and (iii) opportunity cost payment for forest at risk that maximizes the services per dollar paid. The last may be the most efficient and the second the most egalitarian. Larger and

[3] Measuring tens of km2.

more remote communities receive most of the budget but that payments to them are not necessarily more efficient. This scheme results in more though smaller payments to poor and indigenous communities and these payments are more efficient than those to non-poor and non-indigenous forest communities.

WSM provides principles for PES including payment differentiation according to land use and location and permanent payments instead of one-time ones. The PES also involves issues such as assurance of the Poor's benefit and potentially high transaction costs.

8.1.2 Aspects of Successful Watershed PES Systems

Watershed PES development initiatives have mainly focused on identification of potential buyers and payment collection mechanisms. The latter depend on trust in the efficacy of actions to ensure to consumers the provision of and access to watershed services even though they may have public goods characteristics. The key efficiency aspects are:

- Integrity of environmental functions which maintain service provision.
- Efficient institutions ensuring service provision.
- Knowing whether biophysical impact is economically significant.

Management effectiveness is uncertain and depends on location-specific factors given the long period between the watershed’s multiple causes and effects. Continuous evaluation is therefore critical but often absent from watershed PESs.

A good definition of watershed services is therefore necessary in order to provide the foundation for the selection of threat-response and monitoring and evaluation. Initiatives are often based on myths or inadequate generalization in the absence of good evaluation.

A high NPV for WSM that includes regional and global public good benefits would provide a strong justification for it and it could be financed by one or a combination of the following:

The market players for environmental services may include:

- Potential buyers: o Government: MOA, Treasury, MOWR; Firms; Households; International firms; Multilateral organizations: UN, WB, OECD and International donors: DFID, GTZ, Ford foundation.
- Potential certification authorities: Commercial Bank of Ethiopia, NBS (National Bank of Sudan)

- Potential certification specialist: Edinburgh Centre for Carbon Management

Government needs to take projects from their specific focus to a higher level of national interest but without losing unique identity. Government needs to decide to make environmental services market a strategic focus area. Need to establish a certification authority with all the required legal and institutional links. There is a need to establish verification process that takes account of the ethical as well as equity considerations. Need to establish risk insurance mechanism.

8.1.3 Financing Mechanisms[45]

(i) Process Financing

An excellent example of the process-orientated approach is the Nile Basin Initiative (NBI). Two characteristics of the NBI are that has taken some years to develop the shared vision and commitment. The World Bank has taken an important facilitating role leading to donor confidence in the sustainability and effectiveness of the NBI.

The ODI/Arcadis Study advocates process financing to support four key stages of developing the institutional mechanisms:

1. **Initiating process**: Financing support to establish the Transboundary Institutions.

2. **Institutional management**: Joint (Riparian countries and external donors) Financing support to the management costs.

3. **Programme Implementation**: Development of data base; planning, monitoring (Trust Fund financing by Bi-lateral donors, UN Agencies)

4. **Investment in Shared Water Management Works**: Development of Regional investments in water related infrastructure (Coordinated national and/or regional investment; Risk financing Regional Development Banks; private sector)

Other examples of process financing include the Indus Basin (by the World Bank) and the Mekong Basin (by UNDP). Other potential initiatives can assist not only with financing but also policy coordination and sustainable development at the local level. Examples of these include the Global Water

[45] This section relies on ODI/Arcadis Euroconsult (2001); Nicol et al. (2002); M.P. Wells (2005) and James (2005)

Partnership (GWP) which promotes integrated water management; the Transboundary River basin initiative (TRIB) and the Global water Alliance.

(ii) Trust Funds

Trust funds can be used in stages 1 to 3 to allow continuity of shared watershed management programmes. A shared level of confidence is required in the shared programme to shift from project funding to trust funding. Other advantages include the empowering of stake holders to operate funds, leveraging additional resources and allowing for capacity building.

(iii) Revolving Funds to engage private investors in projects with positive transboundary externalities (Regional benefits)

Although the private sector has had only limited engagement in transboundary water management it has played a significant role in other sectors with regional or global implications. One example is the role of the private sector in Ozone depletion and Climatic Change. A revolving fund has been set by the GEF in Thailand to introduce cleaner refrigerators.

It is suggested that similar revolving funds could be set up at the transboundary level to promote private sector investments with regional and global benefits such as watershed management, water treatment and pollution abatement by providing grants, technical assistance and loans to the private sector. One such example in the eastern Nile Basin could be a revolving fund to establish a Transboundary National Park incorporating the Dinder national park and Alatish Regional Park. In Ethiopia one National park (the Nechisar National park) is now operated by a private company.

(iv) Risk Financing and Public-Private Partnerships

The advantages of public-private partnerships is that they help to minimize political risks and provide contract stability by locking private investment into transboundary agreements and having river basin organizations a party to the contract.

An example of this is the public-private partnership in the Senegal River basin. Cooperation between the countries sharing the Senegal River (Mali, Mauritania and Senegal) resulted in the signing of the Convention of the establishment of the Senegal River Development Organization in 1972. One result was the Manatali Dam completed in the 2990's. The project used donor contributions and loans (US$ 620 million) guaranteed by export credit agencies. By 1997 transboundary legal and institutional arrangements were reinforced by the establishment of an Inter-state Public Company – SOGEM – for the management and the exploitation of the Manantali dam. SOGEM awarded Escom of South Africa the contract to operate and maintain the power generating unit.

Public-private partnerships can be supplemented by political risk insurance and investment guarantees such as those provided by the Multilateral Investment Guarantee Agency (MIGA) that is part of the World Bank Group and the Lloyds Syndicate in the private sector.

(v) Inter-riparian Financing by Public means

Currently investments in transboundary waters are soly on a national basis though often with prior notice or agreement. Inter-riparian financing requires countries to finance investments beyond their borders. Examples of such financing include the dredging of the Westerschelde estuary undertaken by the Dutch but funded by Belgium. Pre-requisites for such financing arrangements include an obvious benefit to the financing country that exceeds the financial (and political) costs of implementation; a definition of the scope of works that is precise as possible; defined responsibilities for cost over-runs and a joint management structure to oversee the works.

Conclusions:

Currently the NBI and ENSAP's IDEN projects are part of the process financing mechanisms outlined in (i) above. Process financing has a much loner history than the more innovative financing mechanisms indicated above. The NBI process financing also includes a trust fund mechanism for financing particular projects. It would appear from the above that a continuation of the process financing mechanism would the most advantageous process in the short to medium term.

However, investments in shared water management infrastructure will require a shift from Trust Funds to regional cooperative financing either through public-private partnerships as in the case of the Senegal basin or Inter-riparian financing.

The Watershed Management interventions proposed in the present report or a sub-set of these could well form a component in such a shared infrastructure. An obvious case is the proposed Karadobi Dam on the Abbay River in Ethiopia currently under consideration in the Joint Multi-Purpose (JMP) programme. If the watershed management interventions were incorporated into the overall design of the dam it would have benefits in terms increased sustainability of livelihoods of the inhabitants in the catchment area, but also reduced sediment loads in the Abbay and the conservation of biodiversity and increased sequestration of soil and wood carbon.

The benefit-cost calculations for the WSM intervention in the Abbay Sub-basin in the present report clearly indicate that the total sum of incremental benefits exceed the incremental costs.

8.2 Options for Alternative Distributions at the Global Level

Many of the interventions proposed in this Watershed Management Framework have significant costs to farmers, pastoralists and rural communities that have private benefits (increased fuelwood) but also have significant Global benefits. Prominent among these are (i) carbon sequestration and its positive impact in reducing global warming, and (ii) conservation and an increase in genetic, species and habitat biodiversity. For former a number of initiatives are now available for communities to secure carbon credits. For the latter the Global Environmental Fund is a major source of "redistributing" costs although there are other sources. These are now examined below.

8.2.1 Carbon Fund

This Includes:

- Prototype Carbon Fund (PCF),
- BioCarbon Fund,
- Community Development Carbon Fund (CDCF),
- OECD Country Funds, and Technical Assistance Facilities).

(i) Carbon Financing

The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) introduced in 1997 flexible trade instruments comprising Emission Trading (ET), Joint Implementation (JI) and Clean Development Mechanism (CDM) in order to help achieve greenhouse gas emission reduction objectives.

The CDM enables emissions from Developed Countries to be offset in Least Developed Countries LDCs in which emissions reduction accruing to specific projects is quantified relative to baseline scenarios. These are supposed to represent the probable emissions in the absence of intervention. Forestry measures are not yet included under the CDM but given the significance of forests of the LDC's within the global carbon cycle and the importance of terrestrial carbon fluxes within the national emission inventories of most LDCs, its seems likely that forestry provision will soon be included.

The role of forests within such trading systems could be important as a means of providing a cap to the cost of emission reduction at least in the medium term. Assessment of pilot projects around the world indicates that large amounts of carbon may be sequestered by forestry at costs in the range of US$ 10 - 30 /ton C. The global potential for enhancing forest carbon storage may reach 60 - 90 G t C through decreasing the deforestation rate and increasing the reforestation rate.

This section focuses on the CDM since it is geographically eligible for Ethiopia, Sudan and Egypt. Its purpose is to help less developed countries (LDCs) achieve sustainable development and assist developed countries (DCs) to attain compliance with their quantified emission limitation. The carbon funds work as agents buying carbon credit on behalf of government and large corporations to help them offset their emissions with one carbon credit equivalent to 1 ton of greenhouse gas including carbon dioxide. These credits are issued if the government meets the CDM standards of additionally, quantification, permanence, leakage, monitoring and verification.

Terracing, agroforestry, afforestation, reforestation, grazing regulation and area protection are WSM interventions that may be eligible for carbon funding with the most frequently quoted activities being water, wind, sun, biomass and hydropower. But carbon funds are reluctant to fund sink projects where carbon is sequestered through land use, land use change and forestry (LULUCF) including afforestation and reforestation because of the problems of verification and leakage.

Only reforestation appears to be eligible for financing under recent rules agreed to under Kyoto Protocol. Carbon funds are also unsuitable to finance incremental costs because they are only available at the project-cycle’s end. The BioCarbon Fund and the Finnish JI/CDM Pilot Programme are interested in afforestation/reforestation CDM projects even though the BioCarbon Fund is currently oversubscribed.

Currently there are two Projects in the Eastern Nile Basin using carbon sequestration to obtain financing: one in Ethiopia and the Other in Sudan (Box 1 and Box 2.)

Box 1. The Humbo Project, Soddo, SNNP Regional State, Ethiopia

The project is funded by carbon fund purchases to the sum of US$ 7.5 million. The objectives are the sequestration of 2 million tons of CO_2 by 2012 in a biodiverse forest and the simultaneous reduction of poverty in the Humbo and Soddo weredas with support to education, health and food security financed by carbon funds. Some 15,000 ha of biodiverse natural forest would be restored and conserved. The stock of carbon would be monitored and verified over time.

In addition the project would pilot community ownership and management of public land within a framework of broad core values (carbon sequestration, biodiversity enhancement, natural resource management, poverty reduction. In addition the habitat would be restored for a number of threatened species including the Ethiopian Banana Frog, the Ethiopian Thicket Rat and the Nechisar Nightjar.

Both the BioCarbon Fund and the CDCF are interested to purchase at a price of US$ 3.75.

Source: World Bank Project Information Document (PID), 2005.

Box 2. Community-based Rangelands Rehabilitation Project: Bara Province, North Kordofan State, Sudan.

This project is funded by the Global Environmental Facility (GEF) is testing a simple model of community-based natural resource management using participatory techniques with short-term economic and long-term environmental objectives.

The project is seeking to reverse the negative environmental trends through participatory activities such as planting trees and grass to stabilize sand dunes by creating kilometers of windbreaks comprising two rows of trees, improving the rangeland by planting native perennial species of grasses, and developing land use and rangeland management plans.

The project activities have resulted in much of the area being re-seeded with reduced wind erosion, increased soil organic matter, greater carbon sequestration and increased plant species diversity. There have been significant positive impacts in livestock production, livelihoods, in particular among the poor and women.

Source: Near east Foundation, posted June 1st, 2001.

8.2.2 Global Environmental facility (GEF)

Many interventions produce benefits that are a "global" nature. The GEF is a useful mechanism to redistribute the costs incurred by communities is helping to produce these benefits. Environmental and biodiversity are the main areas it provides assistance. The GEF typically only funds any "incremental" costs but also assists in leveraging other funding sources.
The GEF has two specific programmes of relevance to watershed management (i) the Waterbody Based programme and (ii) the Integrated Land and water Multiple Focal Area Programme. The latter is broader in scope than the former.

In the Waterbody Based programme the GEF plays a catalytic role in assisting groups of countries to:

- conduct transboundary diagnostic exercises to identify priority transboundary environmental concerns;
- Formulate a Strategic Action Programme of actions each country needs to take to address priority transboundary environmental concerns;
- support the incremental cost of technical assistance, capacity building, limited demonstrations and certain investments ;
- encourage the use of sound science and technological innovations for transboundary water management.

The Integrated Land and Water Multiple Focal Area programme is broader in scope and takes an integrated approach to better use of land and water resources management on an area-wide basis. The goal of the programme is to help groups of countries utilize the full range of technical, economic, financial, regulatory, and institutional measures needed to operationalize sustainable development strategies for transboundary waters and their basins. Global benefits in other GEF focal areas (e.g. biodiversity) are often produced in these area wide projects and the cross-cutting issue of land degradation is a cross-cutting issue. In addition projects addressing linkages to climatic change are also included. Linkages with other GEF Operational programmes such as Arid and Semi-arid Zone Ecosystems and Wetlands are also important.

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ANNEX 1. METHODOLOGY

1. SOIL DEGRADATION AND AGRICULTURAL PRODUCTIVITY

1.1 Soil Erosion and Crop Yield

1.1.1 Background

Agricultural soil is usually treated as a potentially depletable resource and it is assumed that many farming practices result in erosion rates that exceed the natural rate. Soil erosion may reduce actual and potential land productivity by decreasing soil depth and plant-available moisture-holding capacity, removing nutrient and altering soil's physical properties. This Annex will use the word erosion and soil erosion interchangeably.

Information on soil degradation and land productivity decline is sometimes extrapolated from limited data and may therefore exaggerate the problem. Many analysts for example consider moved-soil as lost-soil even though much of it may be (i) deposited on other agricultural land (ii) trapped by soil-harvesting structures and (iii) redistributed to fields as inexpensive fertilizer. Inaccurate results may therefore be generated by the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) because they do not account for soil deposition. Many of the other simulation models also fail to represent fundamental hydrological and erosion processes.

Physical soil loss is only a rough proxy for soil-fertility decline and it's difficult to attribute crop yield decline to past erosion-rate differences. Even high erosion rates may affect crop yields marginally if soils are deep with favourable subsoil characteristics. It's also hard to accurately quantify the erosion-soil productivity relationship using time series data because irrigation water, fertilizer and improved crop variety may mask erosion's cumulative production effects.
Recent methods to estimate crop yield decline for different erosion scenarios are shown in Table 1 and range from informal expert judgment to complex plant-growth simulation models. The latter found more widespread acceptance with Nelson et al. (1996a) for example distinguishing (i) statistical or empirical models of inferred soil loss-yield decline functions (Bojö, 1996) (ii) productivity index (PI) models (iii) component process models and (iv) cropping system or soil plant models (Bojö, 1996).

Table A1.1 Recent Methods to Quantify Erosion-Crop Yield Relationship

Author, Year and Location	Method	Comments
Wiggins and Palma, 1980, El Salvador	Estimates based on US experimental data	2% crop-yield decline for each cm of topsoil lost
Attaviroj, 1986, Thailand	Estimates based on regression analysis	Assumes no soil-conservation positive impact
Cruz *et al*., 1988, Philippines	None	Use RCA
Bishop and Allen, 1989, Mali	Inferred erosion-crop yield decline	Exponentially declining function with annual 2-10% productivity loss
Magrath and Arens, 1989, Java, Indonesia	Estimates based on three earlier studies	Annual 0-12% productivity loss
Ehui et al., 1990, Western Nigeria	Regression analysis relating maize yield to cumulative soil loss	IITA model developed by Lal (cited in Ehui *et al*., 1990)
Grohs, 1994, Zimbabwe	Plant growth simulation models EPIC and CERES; inferred erosion-crop yield decline function.	Models produce different results but reveal similar trends; annual 0.3-1% productivity loss
Bishop, 1995, Mali and Malawi	Regression analysis relating crop yield to cumulative soil loss	IITA model developed by Lal (1981, cited in Bishop, 1995)
Barbier, B., 1996, Central America	Proposes EPIC use	Unavailable
Eaton, 1996, Malawi	Combines existing data with adapted data from Ehui *et al*., 1990	Calculates economic productive soil-life
Nelson *et al*., 1996a, Philippines	APSIM	Simulates erosion's effects on daily soil-water/nitrogen-stock available for plant-uptake

Source: Enters 1998

Soil erosion is seen to have two on-site impacts related to crop yield:

(i) A reduction in soil moisture holding capacity and the moisture available for plant growth,

(ii) The loss of organic matter and soil nutrients in the eroded soil.

The following sections describe the methodologies used to estimate these in the present analysis.

1.1.2 Impact of on crop yield with no soil and water conservation measures

(i) Loss of Soil Moisture Holding Capacity

To determine the impact of reductions in soil moisture holding capacity the concept of the "Soil Life" model was used and combined with a "water requirements satisfaction index" (WRSI) developed by FAO as part of its crop early warning system (FAO, 1986). The "soil life" model derives from work by Stocking and Pain (1983) and a comprehensive review by Stocking (1984) of the literature of studies on soil loss and its impact on crop production conduced throughout the world. The main conclusion from Stocking's and other work is that "erosion reduces productivity first and foremost through the loss of plant available soil water capacity" by reducing soil depth.

To use the WRSI, available soil moisture is tracked on a 10 day basis. Any moisture deficits (as a percent of total plant requirements) are then related through empirical relationships to a reduction in crop yield. The model uses the following factors in calculating the impact of declining soil depth on crop yield:

-rainfall (by month)
-potential evapotranspiration (PET) (by month)
-actual evapotranspiration(AT)(by month)
-crop coefficients (by month)
-crop water requirements (by month)
-soil water reserves
-excess/deficit

A **Water Requirements Satisfaction Index** was calculated as follows. In the month prior to planting the index was set at 100. Subsequent deficits as a fraction of total crop water requirements (multiplied by 100) were deducted from the previous month's index. The index of the last month of the crop growing period represented the cumulative water deficit. The index was correlated with decline in crop yields as follows:

Index	**% of average yield**
95-99	80-100
80-94	50-79
60-79	20-49
<60	crop failure

The correspondence between the index and crop yield has been calculated by FAO from information from many test sites and projects.

The model was formatted in Lotus 123 and soil depth was progressively lowered and the depth at which crop yield was affected recorded. Decline in yield was assumed to linear and was calculated by dividing 100 percentage units by the number of years taken to reach the minimum depth. Yield declines set in at about 95 cms and reached 30 percent of normal yield at about 30 cms. The following average annual yield declines for various soil loss rates were obtained:

Table A1.2 Soil loss rates (tons/ha/yr and mm/yr) and the corresponding yield declines

Soil Loss rate (tons/ha/yr)	Soil loss rate (mm/yr)	Yield decline
12.5	1	0.2%
25.0	2	0.4%
50.0	4	0.8%
100.0	8	1.6%
300.0	24	4.8%

Work by Hurni (1983) describes the relationship between barley yields on a Nitisol in North Shewa and soil depth by the equation:

Y = 0.38 + 0.032* tons per hectare (R=0.7=66)
where * = soil depth in cm.

This equation gives the following yield declines per mm of soil lost at various soil depths as shown below.

Table A1.3 Relationship between Yield Decline and Soil depth from the Hurni equation.

depth (cms)	Yield (t/ha)	Yield difference	% yield decline/mm soil loss
120	4.22		
110	3.9	0.0032	0.08%
100	3.58	0.0032	0.08%
90	3.26	0.0032	0.09%
80	2.94	0.0032	0.10%
70	2.62	0.0032	0.11%
60	2.3	0.0032	0.12%
50	1.98	0.0032	0.14%
40	1.66	0.0032	0.16%
30	1.34	0.0032	0.19%

Ludi (21998) also using data in a regression analysis from the Ethiopian SCRP estimated yield decline due to soil erosion to be 0.062 percent per mm of soil lost, although the R^2 of her regression analysis was very low. The EHRS estimated the average soil loss on cropland as 40 tons/ha with an annual yield decline of 3 percent/annum. This gives a yield decline of 0.9 percent considerably higher than the Hurni or Soil Life Model results.

The estimate of 0.2 percent per mm of soil loss estimated in soil life-WRSI model analysis accords well with the Hurni estimate and has been used in the subsequent analysis.

(ii) Loss of Soil Nutrients from Soil Erosion and Impact on Crop Yields

The amount of soil nutrients lost through soil erosion 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 2 known as the nutrient enrichment ratio (Barber, 1985). The dynamics of nitrogen (N) mineralization and availability are relatively simpler to model than those of phosphorous and thus N was chosen to assess the impact on crop production. Total N refers to the soil's total N content of which only about 2 percent is in a form available to plants (available N). Barber's mid-range of total N contents in Ethiopian soils was used in the analysis: 0.0025% by weight in the topsoil. This gave an estimated 32.5 kgs/ha of total N per mm of topsoil (15 cms) deep) or 6.5 kgs of available N. With an enrichment ratio of 2 this means that for every mm of soil removed by erosion there is a loss of 13 kgs of available N.

The FAO Ethiopian fertilizer project (FAO, 198?) estimated an grain yield increment coefficient of 6 for available N. Thus, 1 kg of available N produces a yield increment of 6 kgs. Put another way 1 kgs of N is equivalent to 0.46 kgs of urea (with 46 percent N content).

Relating these to the four soil loss rates of 1 mm/yr, 2 mm/yr, 4 mm/yr and 8 mm/yr the estimated losses in available N are 3, 5, 10 and 18 kgs/ha/yr respectively. These losses are not cumulative as they are an annual event. It is therefore not possible to make a direct comparison with the yield losses due to a cumulative reduction in soil moisture holding capacity and those due to the loss of nutrients in the soil removed.

1.1.3 Impact of on crop yields with soil and water conservation measures

Three cropland soil conservation measures were assessed: stone bunds (in the Tekeze Sub-basin), soil bunds and grass strips in the Abbay and Baro-Akobo Sub-basins. These correspond to current practices in these areas. Three potential positive impacts of soil and water conservation structures on crop yields are possible: (i) reduced soil loss and thus loss of soil water holding capacity , (ii) reduced nutrient loss from the field, and (iii) increased soil moisture from reduced runoff. The last impact can also be negative in high rainfall areas where conservation structures can (and do) cause waterlogging.

Herweg & Ludi, 1999 have assessed the impact of a number of soil conservation structures at the six SCRP Research sites on soil retention. It has been estimated that grass strips trap between 57 (on 12% slopes) and 72 percent (on 28% slopes) of soil moved, with the remaining 28 to 43 percent passing through. It has been estimated that soil and stone bunds trap 64 percent of soil moved. To estimate the impacts of both grass strips and soil bunds an average trapping efficiency of 65 percent was used.

In moisture deficit areas there is a positive impact on crop yields due to increased soil water due to reduced runoff. Vancampenhout et al., (2005) in their research into the impacts of stone bunds on crop yield in Tigray found that after land taken up by the structures is taken into account stone bunds crop yield increases of 7 percent were recorded.

Thus, SWC structures are only 60 percent effective – soil erosion and thus soil depth and moisture holding capacity continues to decline but at a rate 40 percent of the previous rate. The changes are shown below:

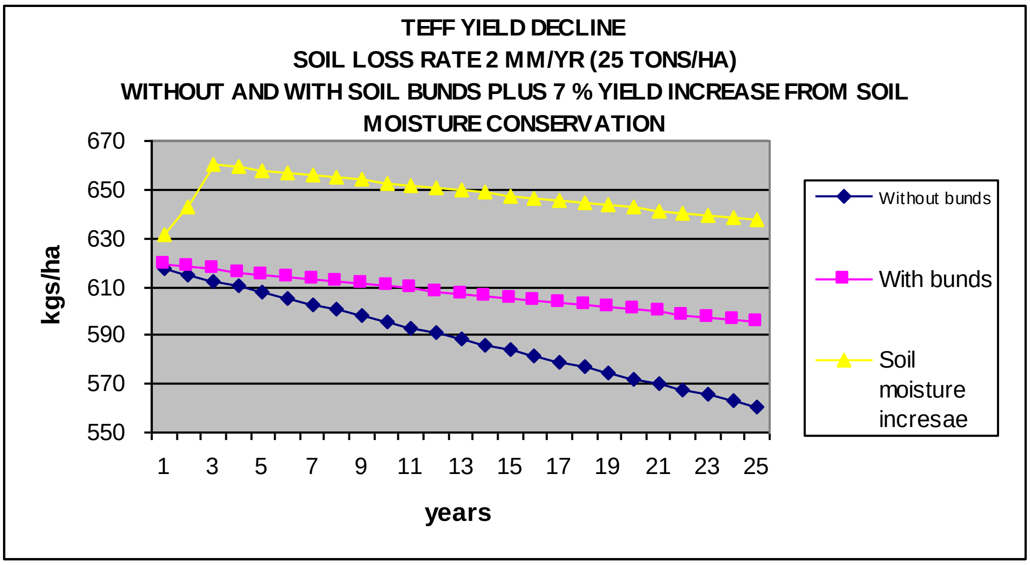
Table A1.4 Impact of SWC Structures on reducing yield decline.

Soil Loss rate (tons/ha/yr)	Soil loss rate (mm/yr)	Without SWC yield decline	With SWC yield decline
12.5	1	0.2%	0.08%
25.0	2	0.4%	0.16%
50.0	4	0.8%	0.32%
87.5	7	1.4%	0.56%

The without and with SWC measures yield declines for a soil losing 2 mm of soil per year (25 tons/ha) are shown in figure 1. The without-bund annual yield decline is 0.4 percent and the with-bund annual yield decline is 0.16 percent. On a per hectare basis the net changes in yield (assuming a mean teff yield of 620 kgs/ha) are 0.7, 1.5, 3 and 5 kgs per year. The accumulated yield changes at the end of 25 years are 18, 35, 65, and 103 kgs per ha for the various soil loss rates.

In the Tekeze Sub-basin an additional yield increase of 9 percent will occur because of increased soil moisture conservation combined with better soil nutrient uptake. To provide a visual picture of these various rates of decline and increase an example using the case of teff is given. This is shown in Figure A1.1 with the decline with and with out bunds and also with the 7 percent increase due to increased soil moisture staggered over three years.

Figure A1.1 Crop (teff) Yield Decline without and with soil bunds (25 years)



1.2 Estimation of Soil Loss rates at the Sub-basin Level

The RUSLE equation modified for Ethiopia was used to generate a map of potential soil loss rates using a formula:

A = R*K*L*S*C*P; where

A = Total soil loss (t/ha/yr)

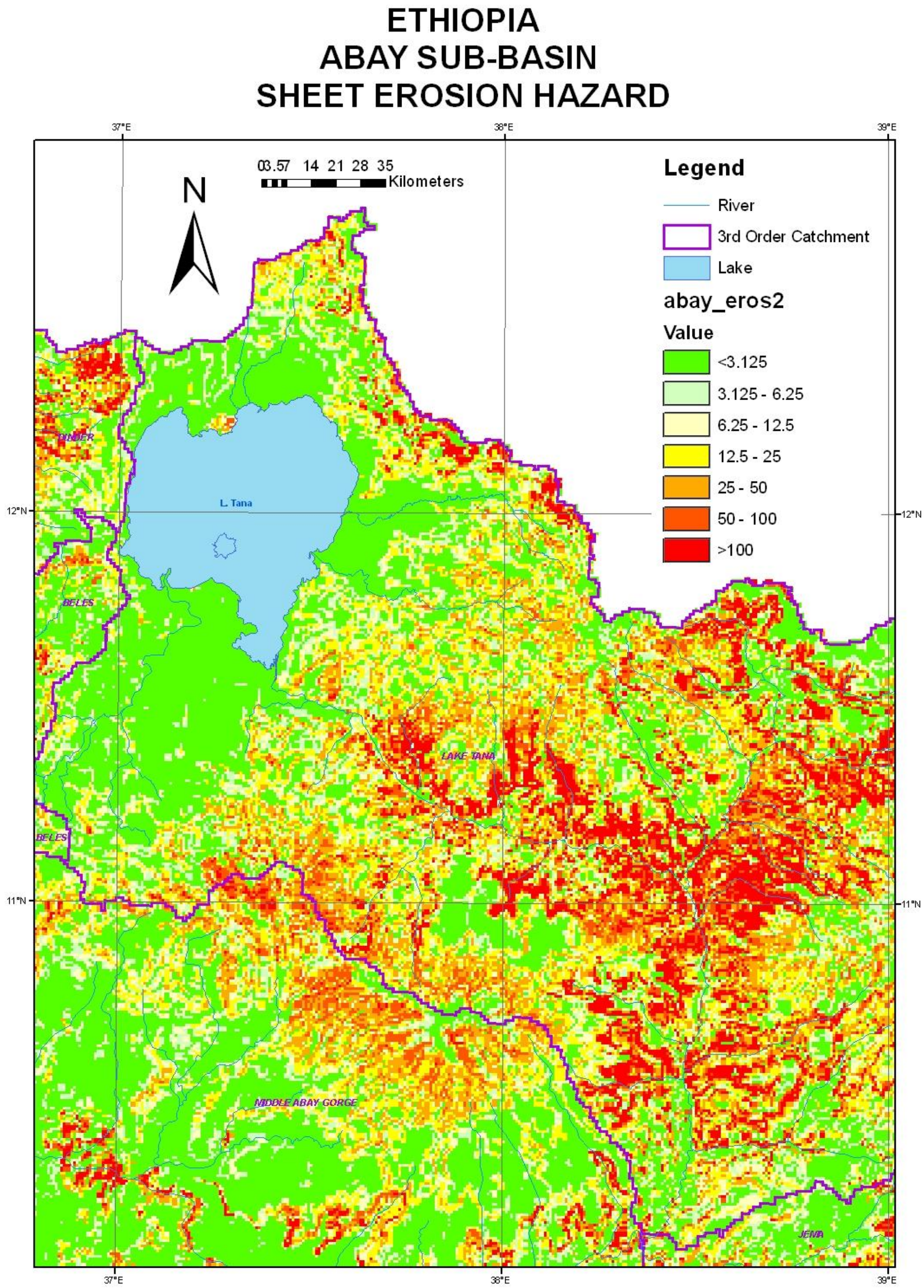
R = Rainfall Erosivity factor,
K = Soil Erodibility Factor, a classified soil surface cover according to a pre-defined norms for each soil type.
L = Slope length factor, is a classified raw slope surface level according to a pre-defined norms for different slope classes.
S = Slope gradient, is a classified raw slope surface level according to a pre defines norms for different slope classes
C = Land cover factor, is a surface level converted from a land cover polygon based on each land cover's erosion factor
P = Management factor

Six overlay maps were used in the GIS to undertake the calculation.

The rainfall erosivity factors for Ethiopia have been calculated by the Ethiopian SCRP (199?) of the Ethiopian SCRP. The map was digitized and entered into the GIS database. Slope gradients were derived from a digital elevation model (DEM) obtained by the Shuttle Radar Mission (SRM). Slope length was correlated with slope using formula used by FAO (1985).

The soil erosivity factors for various FAO soils types were derived from Hurni (1985). The FAO (1985) national Soil and geomorphology Map portrayed relatively large spatial mapping units of defined Geomorphological Units at a scale of 1:1 million. The accompanying report provided a detailed break down of each mapping unit into three or more smaller "Land Facets. For each Land Facet the Report provided details on slope percent, soil sub- type (FAO Classification and some 15 soil properties. To generate a map of the Land Facets the relevant slope and soils data was entered into the database of the digitized Soil and Geomorphology Map. By correlating the slope range of each Land Facet with the Slope Map it was possible for the GIS to locate and assign each facet to its correct location. The resulting Soils Map was considerably more detailed than the original Soils and Geomorphology Map. The soil erosivity rating for each Soil type was also entered into the Land facet database enabling the generation of the Soil Erosivity map.

The Land Cover Map was primary data obtained by the Woody Biomass Inventory and Strategic planning Project at a scale of 1:250,000. By using a two stage visual interpretation and ground-truthing of the Landsat TM image followed by a ground-truthed Unsupervised Classification of the same image an extremely fine detailed land cover map was produced. The Land Management Factors followed those of Hurni (1985) for Ethiopia.



Map A1.1 Detail of the Sheet Erosion Hazard map of the Abbay Sub-basin.

The resulting potential soil loss map enabled a number of secondary data sets to be produced. By overlaying the land cover map with the soil loss map soil loss rates for each land cover type were calculated enabling soil loss rates for cultivated and non-cultivated land to be separated. By overlaying the wereda map with the soil loss rate map and the land cover map enabled the soil loss rates for cultivated and non-cultivated land for every wereda to be calculated. Further overlaying of the Sub-basin Maps enabled for the same data to be tabulated by wereda by Sub-basin. The soil loss rates were grouped into five classes for the purpose of the impact and benefit cost analysis. By correlating the 5 soil loss rates with the yield decline rates in table 2 enabled the tabulation of areas of cropland by yield decline by wereda. The aggregated results for the Abbay Sub-basin are shown in table A1.5 below.

Table A1.5 Areas (ha) of cropland by Yield Decline Class for the Abbay Sub-basin

ABAY SUB-BASIN: ANNUAL (CUMULATIVE) YIELD REDUCTIONS - SOIL EROSION (HA OF CULTIVATED AREA)						
	0.02%	**0.04%**	**0.08%**	**1.40%**	**4.80%**	
ABAY - AMAHARA	430,535	442,872	326,595	123,915	75,510	**1,399,427**
ABAY - BSG	31,962	52,716	29,357	8,775	13,178	**135,988**
ABAY - OROMIYA	367,030	498,675	300,935	102,386	54,923	**1,323,950**
ABAY BASIN	**829,527**	**994,263**	**656,887**	**235,076**	**143,611**	**2,859,364**
ABAY SUB-BASIN: ANNUAL (CUMULATIVE) YIELD REDUCTIONS - SOIL EROSION (% OF CULTIVATED AREA)						
	0.02%	**0.04%**	**0.08%**	**1.40%**	**4.80%**	
ABAY - AMAHARA	31%	32%	23%	9%	5%	
ABAY - BSG	24%	39%	22%	6%	10%	
ABAY - OROMIYA	28%	38%	23%	8%	4%	
ABAY BASIN	**0**	**0**	**0**	**0**	**0**	

For each wereda data on the number of farm families was available. Using the simple assumption that the percent of area of yield decline equated with the percent of farmers provided a rough estimate of the numbers of farmers affected by the various rates of soil erosion and yield decline.

2. FINANCIAL AND ECONOMIC ANALYSIS

2.1 Introduction

A financial analysis and economic analysis were conducted by taking the viewpoint of individual participants and society respectively. These analyses are complementary but there are three distinctions between them that must be remembered:

Economic analysis treats taxes and subsidies as transfers and not as resource costs and benefits whereas financial analysis usually treats taxes as a cost and subsidies as a benefit.

Financial analysis uses market prices that take account of taxes and subsidies while economic analysis may change some of these prices in order to reflect more accurately social or economic values. The latter are called shadow, accounting or economic prices.

2.2 Prices

Costs and benefits were broken down into traded and non-traded. Traded prices are the export parity for gum arabic and or import parity for sorghum and wheat. They were derived from the local currency CIF and fob prices adjusted for transport and handling costs. Taxes, subsidies and other transfer payments were eliminated. The conversion factors for non-tradables in Ethiopia were taken from WFP's benefit cost analysis of their Soil and water Conservation Programme (WFP, 2005) and are as follows:

Conversion factors: Ethiopia - Non-tradables	
Exchange rate (ETB/US$1.00)	9.00
Non-traded agricultural products (except wheat	0.9
Labour	0.98

The import parity price for wheat, urea and DAP in Ethiopia were calculated as in table A1.6.

Table A1.6 Derivation of Import Parity prices for Wheat, Urea and DAP: Ethiopia

Derivation of Import Parity Price	Wheat financial	Wheat economic	Urea financial	Urea economic	DAP financial	DAP economic
FOB (USA)	$141.70	$141.70	$269.80	$269.80	$267.60	267.60
Add freight & insurance	$32.30	$32.30	$32.30	$32.30	$32.30	32.30
CIF ($) Djibouti	$174.00	$174.00	$302.10	$302.10	$299.90	299.90
CIF (Birr) Djibouti	ETB 1,566.00	ETB 1,409.40	ETB 2,718.90	ETB 2,447.01	ETB 2,699.10	ETB 2,699.10
Add port handling (2.5% CIF)	39.15	35.24	67.97	61.18	67.48	60.73
Add inland transport	643.60	579.24	643.60	579.24	643.60	579.24
Add transhipment costs	38.80	34.92	38.80	34.92	38.80	34.92
Distributor Costs	16.60	14.94	16.60	14.94	16.60	14.94
Price at point of Distribution	**ETB 2,304.15**	**ETB 2,073.74**	**ETB 3,485.87**	**ETB 3,439.39**	**ETB 3,765.48**	**ETB 3,688.83**
Price in US$ in US$	**$256.02**	**$230.42**	**$387.32**	**$382.15**	**$418.39**	**$409.87**
Exchange rate (ETB = US$1.00)	9.00					
Standard conversion factor	0.90					
All prices 2006 constant						

The conversion factors for non-tradables in Sudan were taken from the World Bank's domestic resource costs calculations for their assessment of the Gezira Scheme (World Bank, 2003). These are shown below:

Conversion factors: Sudan Non-tradables	
Exchange rate (SDD/US$1.00)	200.00
Non-traded agricultural products	0.86
Labour	0.60
Transport, machinery use	0.72
Seeds	0.86
Sacks, etc	0.82

The import parity price for sorghum and the export parity price for gum arabic were calculated as in table A1.7.

Table A1.7 Derivation of Import Parity prices for Wheat, Urea and DAP: Ethiopia

Derivation of Import Parity Price	Sorghum financial	Sorghum economic		Gum arabic financial	Gum arabic economic
FOB (USA)	$175.20	$175.20			
Add freight	$32.30	$32.30			
Add insurance					
CIF ($) Port Sudan	$207.50	$207.50	FOB (US$) Port Sudan	$1,959	$1,958.88
CIF (SDD) Port Sudan	SDD 41,500.00	SDD 41,500.00	FOB (SDD) Port Sudan	SDD 391,776.00	SDD 391,776.00
Add port handling (2.5% CIF)	1,037.50	747.00	Less port handling (2.5% CIF)	7,836	5,641.57
Add inland transport (50%)	20,750.00	14,940.00	Less inland transport (50%)	195,888	141,039.36
Add transhipment costs	3,918.58	2,821.38	Less transhipment costs (1%)	3,918	2,820.79
Add Distributor Costs	3,918.58	2,821.38	Less Collection Costs (1%)	3,918	2,820.79
Price at point of Distribution	**SDD 71,124.67**	**SDD 63,037.26**	Price at point of Collection	**SDD 180,216.96**	**SDD 239,453.49**
Price in US$	**$355.62**	**$315.19**		**$901.08**	**$1,197.27**
Exchange rate (ETB = US$1.00)	200				
Transport conversion factor =	0.72				

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Non-traded crop prices were market-determined and obtained from Government surveys. Averages for various months were used for highly seasonal crops.

Inputs were divided into tradable and non-tradable and their economic prices were determined from import parity calculations (fertilizer) or using the conversion factors for non-tradables. The financial prices for seeds, seedlings and cuttings were assumed to be (i) zero for those produced by the farmer as a by-product of normal cultivation and (ii) based on the market price when purchased. The financial price of seedlings obtained from nurseries is that charged by the nursery.

Fertilizer and plant protection chemicals are sold at cost price and this has been used as the financial price. The economic price was obtained using an SCF. Economic prices were estimated for seeds and seedlings provided by nurseries from analysis of seed and seedling production costs of current nurseries.

Improved seeds have been treated as non-tradable and a premium of 50 percent added on the market price of the crop concerned. The cost of bags and packing materials in Sudan were obtained from the MOA farm surveys for the SMF's and the Traditional Rainfed Sector.

In Ethiopia the daily agricultural wage rate of ETB 5.0 has been taken as representative of the financial hired labour cost while the economic labour cost was estimated based on a conversion factor of 0.98. In Sudan the hired labour rates cited in the MOA SMF and Traditional Rainfed Farm Surveys were used. Economic costs were obtained using the labour conversion factor of 0.6.

2.3 Spatial and Time Frames

Four spatial time frames were used in the analysis. The lowest level was the farm or a unit area (1 hectare) of Communal land. Where site specific data on impacts was not available (e.g. specific locations of deforestation or shelterbelt establishment in the Semi-mechanized Farms) a more aggregated level of analysis was used. In the case of deforestation the area estimates were available at the wereda and thus Sub-basin level, and for the Semi-mechanized farms from the area data available at the Sub-basin level.

The time frame for the financial local level analysis was 25 years to represent one generation of time. The programme is scheduled to be implemented over 10 years. This was taken as it was considered that this would be the time required to undertake a programme of the magnitude that would be sufficient to have any discernable impact at the spatial scale of the Eastern Nile basin. Because many of the interventions have a negative return in the first year or more, with an investment programme of 10 years many benefits would not start to have an impact on the overall programme until after 10 or more years.

For this reason a time scale of 50 years was used for the national/Sub-basin level and Sub-basin/Basin level analyses.

The financial and economic CBA was conducted for the without-WSM and the with-WSM in the Abbay, Tekeze and Baro-Akobo Sub-basins. It was assumed that land degradation would continue at the 2006 rate without-WSM but at a lower rate with-WSM. The proposed WSM interventions would include SWC or subsidy provision or both.

SWC refers to stone bunding, soil bunding or the adoption of grass strips. The impact of these interventions would be:

Farm Models

The WSM's potential farm-level impact may be illustrated by the formulation of farm models. The latter represent a simplification of a complex and varied situation and are based on data on land use, agro-ecological zone and crop area (Table A1.8).

Table A1.8 Farming Systems in Ethiopia's Abbay, Tekeze and Baro-Akobo Sub-basins

Sub-basin	Farming System
Abbay	T1 Lowland - Sorghum + Maize (including shifting sorghum)
	T2 Lowland - Finger Millet + Sorghum + Maize
	T3 Highland - Wheat + Barley
	T4 Highland - Teff + Wheat/Teff + Wheat + Maize
	T5 Highland - Teff + Maize + Sorghum
	T6 Highland - Maize + Teff (Coffee/Wheat)
	T7 Highland - Enset + Maize/Wheat
Tekeze	T1 Lowland - Sorghum + Millet + Teff (including shifting sorghum)
	T2 Highland - Teff + Maize + Sorghum
	T3 Highland - Teff + Wheat + Sorghum
	T4 Highland - Teff + Wheat + Barley (+ Wheat + Barley)
Baro - Akobo	T1 Lowland - Shifting Sorghum + Maize
	T2 Lowland - Riverbank Cultivation of Anuak
	T3 Lowland - AgroPastoral Nuer
	T4 Highland - Maize + Teff + Sorghum + Coffee
	T5 Highland - Sorghum + Maize + Coffee

The analysis in Ethiopia assumes that the cropping pattern would remain the same for rainfed agriculture but would change for irrigated agriculture owing to the introduction of the production of high-value fruit and vegetables such as tomato and onion.

Most of the poor households do not hire ploughing animals since each household owns at least one animal and there is a well established system of sharing oxen ("*mekanado*"). Animal labour days were therefore not costed in the financial analysis. Family labour was also not costed in the financial analysis according to convention while hired labour was treated as a financial cash cost to the farmer. The exception to this was that the incremental labour required to construct and maintain the SWC structures was costed at the daily agricultural rate of ETB 5.00/day. This was done to demonstrate the considerable impact this has on farmers' decisions to invest or not invest, most particularly with the construction of soil and stone bunds.

The without-WSM situation assumes no SWC, unimproved planting material and no fertilizer, pesticide, herbicide or fungicide while the with-WSM situation assumes only SWC.

Ten farming systems were used in the analysis as representative of the three Sub-basins. In the Tekeze Sub-basin there were 4 farming systems, one SWC structure – stone bunds, and the three yield decline rates (0.4%, 0.8% and 1.6%) making 12 models. In the Abbay Sub-basin there were 5 farming systems, two SWC structures: grass strips (2 yield declines) and soil bunds (1 yield decline) making 15 farm models. In the Baro-Akobo Sub-basin there was 1 farming system and two SWC structures: grass strips (2 yield declines) and soil bunds (1 yield decline) making 3 farm models. Thus the analysis comprised some 30 farms models.

The most useful measure of the potential financial viability of individual SWC interventions is the undiscounted or discounted net returns to family labour day. Farm production models were formulated based on per hectare crop models in the without-WSM and with-WSM situations.

2.4 Discount Rates

There is a vast and voluminous literature on the use of discount rates in benefit-cost analysis. In the present analysis for both the financial and the economic-environmental analysis a real rate of 10 percent was used. For the financial analysis this represents the farmers/community's own discount rate. In the economic analysis this is the rate that government uses for its own investment evaluation. In most cases the benefit-cost ration exceeded unity by a considerable order of magnitude. In these cases sensitivity analysis was undertaken by adjusting the market prices to determine if this would adversely affect the benefit-cost ratio. It is recognized that many smallholder farmers in Ethiopia and Sudan have high personal discount rates because of their vulnerability to shocks and risk-averse nature (Shiferew and Holden, 2005). In these cases the discount rate was increased. Where the B:C ratio was close to or less than unity (e.g. the establishment of shelterbelts on the Semi-mechanized farms) a lower rate of 5 percent was used to determine the relative impact on the B:C ratio.

3. ENVIRONMENTAL BENEFIT-COST ANALYSIS

3.1 Introduction

As well as local costs and benefits the impacts of current resource management practices and those of the proposed interventions have regional and global costs and benefits (James, 2005, Pagiola et al., 2004). Total economic value comprises three values:

- **Use values**: divided into direct, indirect use and option or bequest values: Examples of direct use values include timber harvesting and sustainable harvesting of non-timber forest products (NTFP's) maintained and of indirect use values include watershed services (flood dampening, low flows maintained) and carbon sequestration. Option values include preserving an "option" to use environmental goods or services in the future - either by oneself – an "option" value or by other people - a "bequest" value.

- **Non-Use Values**: represent the enjoyment people have simply knowing that a resource exists (e.g. montane forests, whales) even if they never expect to use that resource themselves.

Regional costs and benefits include downstream reservoir sedimentation and loss of storage capacity (or the reduction in sedimentation as a result of a comprehensive upstream watershed management programme). Global costs include the loss of biodiversity caused by deforestation and global benefits include the increase in soil carbon sequestration (and reduction of atmostspheric carbon dioxide) caused by improved soil management practices.

Two methods of valuation are possible: market-based and survey-based methods. Market based methods use actual costs involved (cleaning sediment from irrigation canals. Where markets do not exist then surrogate or proxy market prices may be used. For example no market exists for soil nitrogen. In the present analysis its value in increasing crop yield and the market value of the increased crop is used.

Survey-based methods can be used to "construct" markets where neither markets nor surrogate markets exist. These include surveys to ascertain how much people have spent to visit a National Park (travel cost method); to measure peoples' willingness to pay for a good or service or their willingness to accept compensation for the loss of a good or service; or to ask people to rank their preference for a non-monetary good or service (e.g. forest products) and "anchoring these to a good that can be valued (e.g. a bore-hole) (IIED, 1994).

Because of time and resource constraints the present analysis has not undertaken any survey-based methods of valuation. However, it has taken advantage of such surveys that have been undertaken in Kenya (Wass, 1995) and Eritrea (Emerton and Asrat (1998) to obtain values for some of the forest services that are deemed to be very similar to those in Ethiopia. Where other values (for biodiversity) resource was made to the literature.

3.2 Regional Costs and Benefits

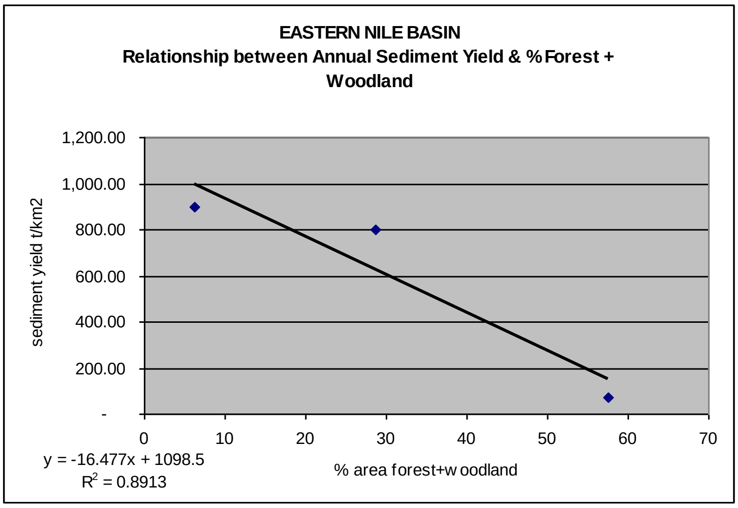
3.2.1 Watershed Services of Forests and Woodlands

The indirect values of forests and woodlands include watershed services. Chomitz and Kumari (1998) and Calder 2005) have warned that these benefits can be over estimated. However there is general agreement that they have the capacity to protect land from soil erosion and thus their removal can increase sediment loads in rivers.

The sediment delivery ratios (SDR) of the Tekeze-Atbara, Abbay-Blue Nile and Baro-Sobat Sub-basins (60%, 43% and 22% respectively) are indicative of the value of forest and woodland cover. These were calculated as follows: the total amount of soil eroded in each of the three sub-basins within Ethiopia were determined from the GIS analysis (see below). The average sediment load of the Baro-Akobo, Abbay and Tekezi at the border was obtained. The SDR was calculating by dividing the average annual sediment load by the annual total soil loss in the Sub-basin. The Sediment Yield was obtained by dividing the total annual sediment load at the border by the area (km2) of the Sub-basins upstream of the border. The area of woodland and forest in each of the Sub-basins was obtained from the WBISPP land Cover maps.

Figure A1.2 shows the sediment yield in tons/km2 in relation to the percent area of forest and woodland for the three catchments. For every 1 percent increase in forest-woodland cover there is a reduction of 16.5 tons/km2 in sediment yield. Related to reduced sediment is the improved quality of water.

Figure A1.2 Relationship between Annual Sediment Yield and Percentage Forest and Woodland Cover for the Tekeze-Atbara, Abbay-Blue Nile and Baro-Sobat Sub-basins.



Flood dampening at the catchment or sub-catchment scale is another service provided by woodland and forest cover, although this is not likely to occur at the Sub-basin level.

Placing values of these services requires considerable time and resources that are not available in the present study. Very detailed work has been carried in Kenya on the watershed values of the Mau forests that are very similar floristically to the Southwest montane forests of Ethiopia (Wass, 1995). This study estimated these values as US$ 42 per ha. Emerton and Arat (1998) valued the watershed services of vegetation cover using the replacement cost method – that is the cost of replacing vegetation with tree planting. Their value was 7,602 Nfa[46]/ha or US 844/ha, which is considerably higher than the Kenya value. The value of US$ 42/ha was used in the present analysis.

3.2.2 Sedimentation

Sedimentation in reservoirs and irrigation systems incurs costs in terms of lost reservoir storage and its potential impacts on the reduction of water available for irrigation and hydro power generation. Sediment in irrigation canals incurs costs in dredging and removing the sediment and the weed growth that accompanies it.

The average costs of sediment removal from the Gezira Scheme were used as a basis for valuing the costs of sedimentation in canals, although the World Bank study of the scheme considered that these were insufficient to clear all the sediment. It is reported[47] some of the dredged sediment is used in brick making and thus this is an off-setting benefit. In addition some 34 percent of the sediment is deposited in the fields. The sediment being derived mainly from the basalt derived soils of the Ethiopian Highlands has long been recognized as having a value as nutrient for plant growth.

No research into the fertilizer value of this sediment has been found in the literature for Sudan. However, some data is available from Egypt. Nixon (2004) estimated that prior to the construction of the Aswan High dam some 35 million tons of sediment were deposited in the fields. Abu Zied and El-Shibini (2004) estimate the nitrogen content of the sediment deposited was 0.13 percent of which one third was available for plant growth. This would indicate that the sediment contained 45,500 tons of N of which 15,165 tons N were available for plant growth. Urea fertilizer has an N content of 45 percent. The available N is thus equivalent to 32,970 tons of Urea. Thus for each ton of sediment there has 0.94 kgs of urea.

The three dams in Sudan (Roseires, Senner and Kashm el Girba) try to mitigate sedimentation in their reservoirs by opening the sluices at the time of

[46] Nafka – Eritrean currency: Exchange rate Nfa9.00/US$1,00
[47] Comments from the Sudan Committee on the 1st Draft of the Distribution Analysis Report.

the heaviest sediment loads (August) and "flushing" the sediment through the dam. Although reducing sedimentation in the reservoir flushing incurs a cost in terms of reduced power generation because of the loss of head – an important factor for these relatively low dams. The average reduction in power generation during the month of August was available for Roseires Dam and this was used in the calculation of the cost of lost power due to opening the sluices.

3.3 Global Costs and Benefits

3.3.1 Carbon Sequestration

Two modes of long term carbon sequestration are possible in the present context: carbon sequestered in wood biomass and carbon sequestered in the soil. The relationship between wood biomass and its carbon content is approximately 50%. Wood biomass in standing stocks of natural forest and woodland and of plantation species were obtained from the WBISPP inventory results for Ethiopia and from the FAO (2004) and the Blue Nile Inventory (Poulin Theriault, 1995).

Soil carbon as measured in soil chemical analysis gives values of pure carbon. The average soil carbon content of soils in Ethiopia and Sudan were obtained from the literature. FAO (2003) provide details of studies undertaken in Sudan and Kenya on the values of leaving crop residues on the field in increase levels of soil carbon. Barber (1995) has assessed the annual losses of soil carbon in Ethiopian soils due to soil erosion, and his median value for soil carbon content was used to determine soil carbon losses due to soil erosion. Research (Sanches, 1976) indicates that nearly all soil carbon is lost when exposed to the air following erosion.

Carbon sequestered can be traded in the carbon market. Purchase prices vary widely. In Ethiopia the Humbo Woodland Conservation project is receive US$ 3.75 per ton of carbon permanently sequestered. In the present analysis a more conservative value of US$ 3.00/ton C has been used.

3.3.2 Non timber forest Products (Including Penitential Pharmaceutical Products)

Estimates of the option value of potential pharmaceutical products vary from US$ 0.9 to US$ 6.3 per ha (World Bank, 2005). The value of NTFP's in Kenya's forests has been valued at US$ 17/ha although the study estimated that 30 percent of this was unsustainable. In the present valuation a conservative estimate of US$ 5/ha was used.

3.3.3 Coffee Gene Pool

Hein and Gatzweiler (2006) have estimated the total value of Ethiopia's coffee gene pool to be between US$ 1,458 million (5 % discount rate) and US$ 420 million (10 percent discount rate). The breakdown of this value is shown in table A5. The valuation was based on an assessment of the potential benefits and costs of the use of *C. arabica* genetic information in breeding programmes for enhanced coffee cultivars. The study considered there types of enhanced cultivars: increased pest and disease resistance, low caffeine content and increased yield potential. Costs and benefits were compared for a 30 years discounting period using 10 percent and 5 percent discount rates (table A1.9).

Table A1.9 Economic Value of Ethiopian Coffee Genetic Resources

Characteristic	NPV (US$ million) at discount rate	
	5 %	10%
Disease resistance of which	617	169
CBD	61	11
Meloidogyne spp.	232	65
Coffee rust	323	94
Decaffeinated coffee	576	175
Yield increase	266	75
TOTAL VALUE	**1,458**	**420**

Source: Hein & Gatzweiler (2006)

The lower value of US$ 420 million was taken and divided by the number of hectares of high forest that was within the ecological limits (1,100 – 1,900 masl) for *C. aribica* to obtain the value of US$ 280/ha. It is difficult to estimate what the minimum continuous area of forest is required to maintain the genetic diversity.

3.3.4 Biodiversity Values

Biodiversity values cover all other genetic, species and habitat resources. A World Bank cost assessment of environmental degradation of Iran placed a value US$ 16/ha on the value of biodiversity conservation of the Caspian forests. Akpalu and Parks (2007) used an estimate of US$ 23/ha for the value of biodiversity in Ghana's forests. Pearce (1996) in a review of a number of estimates for biodiversity value came to the conclusion that US$ 5/ha would be the most appropriate value. In the absence of estimates from Ethiopia or East Africa the value of US$ 5/ha was used in the analysis.

ANNEX 2. TARGETING INTERVENTIONS

1. Framework of Interventions

1.1 Basic Considerations

This section enumerates and briefly describes the watershed management interventions identified in the Transboundary Analysis and provides information on their most appropriate locations and countries together with an assessment of their associated impacts. However, it is important to note that watershed management is a system-orientated concept with a holistic approach to problems and potentials. For this reason the implementation of many of the individual interventions outlined here will form part of sets of interventions that complement each other and where possible, in a synergistic way.

Considerable experience has been built up in the Eastern Nile Region and elsewhere in the world on the technological aspects of integrated watershed management. In particular there has been an increasing emphasis on biological measures using where possible locally available materials and away from physical structures. National and international collaborative watershed management research is adopting new methodologies that go beyond analysis of farm level productivity constraints to a problem diagnosis that seeks an understanding of the different types of landscape-level watershed management problems and the linkages of components (crops, water, livestock, trees and soil) to user groups (German et al., 2005). This also includes trans-boundary interactions and common property resource management.

Thus, 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 take 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. The proposed interventions range beyond soil and water conservation technologies and include inter-linked technologies related to crop, animal and tree husbandry.

1.2 Targeting Interventions

Given the wide range of agricultural/pastoral systems in terms of their technology and environmental, social and economic circumstances, it is necessary to stratify these land use systems into some form of spatial unit. These spatial units have similar environmental, socio-economic (including market access) conditions and related problems and potentials. These form the basis of "**Development Domains**". These have a common set of interventions, impacts, costs and benefits. They can be seen as a "first order" filter to assess the general magnitude of rural development gaps and opportunities (Chamberlin et al., 2006, Onamo et al., 2005).

There is an extremely wide range of agro-ecological, socio-cultural and economic conditions existing across the Eastern Nile Basin. Many of these are country-specific. For this reason different criteria have been used to define the Domains in Ethiopia, Sudan and Egypt.

1.2.1 Ethiopia

(i) Current Spatial Development Frameworks

The new poverty Reduction Strategy Programme ("Plan for Accelerated and Sustainable Development to End Poverty" – PASDEP), unlike its predecessor ("Sustainable Development and Poverty Reduction Programme" – SDPRP) recognizes the need to tailor agricultural interventions according to specific economic and agro-ecological conditions. It recognized three different Zones ("Three Ethiopia's") as a framework for identifying appropriate strategies. The World Bank has its own version under the label "Four Ethiopias" (World Bank, 2005), which provides the basis for its Country Economic Memorandum. The traditional Ethiopia agro-ecological zonation and the more recent agro-ecological zonation system adopted by the MARD both use temperature with the latter incorporating potential evapotranspiration. Demographic or economic criteria are not used.

(ii) Development Domains (IFPRI)

The International Food Policy Research Institute (IFPRI) has used three criteria to define "Development Domains": (i) agricultural potential, (ii) accessibility to markets, and (iii) population density. This schema has some 12 Development Zones (Pender at al., 1999). A comprehensive household socio-economic survey was based in this classification and a substantial amount of research into poverty and land degradation conducted based on this survey (Onamo et al., 2006, Diao et al., 2004). No other classification provides the level of detail nor the empirical research based upon it. For this reason the Development Domain as defined below has been selected as the framework

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

A number of studies (Benin, 2006, Pender at al., 2001, Tefera et al., 2000, Gebremedin et al., 2003, 2004, Kruseman et al., 2006) have examined a range of measurable variables to capture "market accessibility including (i) distance/walking time to nearest wereda town or market, to all weather road, to seasonal road, to bus service, to development agent, to input supply shop, to grain mill; (ii) whether access to a road had improved in the recent past; (iii) whether an all-weather road passes through the wereda; and (iv) road density in the wereda. A consensus is emerging that localized market access is probably of greater importance to most rural households (Hoddinot and Dercon, 2005). Pender et al. 1999 defined "Good market accessibility" is defined as being within 50kms to a town of >50,000.

Pender at al (1999) used population density as their third criterion with "High" population density defined as =>100 persons/km2 and "Low" population density as <100 persons/km2. This was found to almost coincide with the distinction between "Highland" and "Lowland" areas, with "highland" defined as land over 1,500 masl and "Lowland" land <1,500 masl. Because the Highland/Lowland distinction in Ethiopia covers not only population density but also a range of socio-cultural and environmental factors this was selected as the third criteria.

The Highland High Agricultural Potential Domain has been sub-dived into three Sub-Domains based on current farming systems. These Sub-domains are as follows:

i. Teff-Maize-Sorghum: Western Highlands north of Abbay River: Abbay Sub-basin: Surplus Cereal (teff) producing area. No potential for agricultural expansion.
ii. Maize-Sorghum-Teff: Western Highlands south of the Abbay: Abbay Sub-basin: Main maize producing area. Some potential for agricultural expansion.
iii. Enset-Roots-Cereal-Coffee: Baro-Akobo Sub-basin: Main coffee producing area. Agricultural expansion into High Forests.

1.2.2 Sudan

In Sudan three criteria have been used to define six major agricultural systems or development domains. These are (i) rainfed or irrigated cropping, (ii) scale of enterprise (large/small) and (iii) whether predominantly crops and livestock. Thus, the major systems are (i) large-scale semi-mechanized rainfed crop production, (ii) small-scale traditional rainfed crop production, (iii) pastoral/agro-pastoral livestock production, (iv) large-scale irrigated cropping (mainly sugar cane), (v) small-scale (tenant) irrigated cropping on large schemes, (vi) small-scale (freehold/tenant) irrigated cropping on small schemes or individual farms (White, Blue, and Main Niles, Atbara, shores Lake Nubia).

The semi-mechanized rainfed cropping systems has been further sub-divided into (a) those located in areas with a mean annual rainfall of less than 600 mm and (b) those receiving above 600 mm. The Traditional Rainfed Systems have been further subdivided into (a) the rainfed water-harvesting systems of the north (Northern Kordofan, Kassala) , (b) the rain fed systems of the central plains, Ngessena Hills and Nuba Mountains, and the (c) the Flood retreat systems of the Shilluk and Anuak along the Baro-Sobat-White Nile rivers. The pastoral/agro-pastoral systems have also been divided into (a) the dryland systems of the north (predominantly Camels), (b) the dryland systems of the north (predominantly cattle, sheep and goats) and the flood retreat systems of the south.

Table A2.1. Development Domains - Sudan

Main Development Domain	Subsidiary Domain
1. Rainfed: Large-scale: Semi-mechanized	a. < 600 mm mean annual rainfall b. > 600 mm mean annual rainfall
2. Rainfed: Small-scale: Traditional: Crop production	a. Water harvesting Systems (Kassala, North Kordofan b. Central Clay Plains, Ngessena Hills, Nuba Mountains c. Flood retreat Systems (Shilluk, Anuak)
3. Pastoral/Agro-pastoral Extensive Livestock Production	a. Predominantly Camels (Drylands of north) b. Mixed Cattle and Small Stock: (Central Clay Plains and Goz sands) c. Mixed cattle and Small Stock (Southern flood retreat grasslands)
4. Irrigated: Large scheme: Large-scale mono-cropping	a. Dam b. Pump
5. Irrigated: Large scheme: Small-scale (Tennant)	a. Dam b. Pump
6. Irrigated: Small scheme: Small-scale (Tennant, Freehold)	a. Basin (Flood) b. Basin (Pump) c. Pump d. Recession (+pump)

1.2.3 Egypt

In Egypt similar criteria to those in Sudan have been used except that rainfed cropping does not occur and only scale (large/small) and crop/livestock have been used, except that an additional natural resource use system, charcoal production is identified. Thus the domains in and around Lake Nasser are (i) large-scale irrigated cropping in the Tushka Depression and on the Lake shore, (ii) small-scale irrigated cropping on the lake shore and in the Wadi Alaqui, (iii) Camel herding in the Red Sea Hills and (iv) Charcoal production in the Wadi Allaqui and the Red Sea Hills.

ANNEX 3: PROGRAMME BUDGETS

ETHIOPIA: ABBAY SUB-BASIN

Intervention	Beneficiary wereda/household	Unit	No./wereda or HH	Total number	Unit Cost (ETB)	Total cost (ETB)	Total cost (US$)
1. WATER CONSERVATION AND IMPROVED UTILIZATION							
1.1 Water harvesting							
- Pond/cistern construction (35% hh)	479,291	unit	1	479,291	4,200	2,013,023,880	223,669,320
- Hand dug wells (10% hh)	136,940	unit	1	136,940	2,500	342,351,000	38,039,000
- Springs+night storage (5% hh)	68,470	unit	1	68,470	5,000	342,351,000	38,039,000
1.2 Small/micro scale irrigation (10% hh)	136,940	unit	0.25	34,235	40,000	1,369,404,000	152,156,000
Sub-total						**4,067,129,880**	**451,903,320**
2. CROP DIVERISTIFICATION AND INTENSIFICIATION							
2.1 Improved seeds							
- Cereal seeds (45% hh)	616,232	Q	0.75	462,174	275	127,097,809	14,121,979
- Vegetables (water harvesting) (50% hh)	684,702	kg	0.15	102,705	55	5,648,792	627,644
- Vegetatbles (small-scale irrigation((10% hh)	136,940	kg	0.3	41,082	55	2,259,517	251,057
2.2 Fertilizer (30% hh)	410,821	Q	0.5	205,411	275	56,487,915	6,276,435
2.3 Oxen (30% hh)	410,821	OX	1	410,821	1,000	410,821,200	45,646,800
2.4 Implements (30% hh)	410,821	SET	1	410,821	75	30,811,590	3,423,510
2.5 Post-harvest technology							
- Threshing floor/storage) (15% hh)	205,411	unit	1	205,411	1,000	205,410,600	22,823,400
- Threshing machines, mills, shellers. (100% weredas)	142	unit	40	5,680	50,000	284,000,000	31,555,556
2.6 Adaoptive Research (50% weredas)	71		1	71	100,000	7,100,000	788,889
Sub-total						**1,129,637,422**	**125,515,269**
3. SOIL CONSERVATION AND IMPROVED HUSBANDRY MEASURES							
3.1 Physical	1,116,864	ha		1,116,864	4,200	4,690,830,451	521,203,383
3.2 Biological	1,116,864	ha		1,116,864	933	1,042,034,479	115,781,609
3.3 Compost pits (40% hh)	547,762	unit	1	547,762	60	32,865,696	3,651,744
3.4 Agro-forestry (40% hh)	547,762	seedlings	100	54,776,160	0.50	27,388,080	3,043,120
3.5 Improved stoves (10% hh)	136,940	unit	1	136,940	100	13,694,040	1,521,560
Sub-total						**5,806,812,746**	**645,201,416**
4. EXTENSION							
4.1 Wereda experts Training	166	wereda	12	1,992	1,750	3,486,000	387,333
4.2 D.A. Training	166	wereda	30	4,980	4,800	23,904,000	2,656,000
4.3 Contact Farmer Training	360	wereda	360	129,600	800	103,680,000	11,520,000
4.4 Stregnthen Farmer Training Centres (FTC's)	166	wereda	10	1,660	2,200	3,652,000	405,778
4.5 Radio Extension							
- Establishment of radio reception centres	166	wereda	3	498	10,000	4,980,000	553,333
- Cost prog. Development/broadcasting	166	wereda	3	498	3,500	1,743,000	193,667
Sub-total						**141,445,000**	**15,716,111**
5. LIVESTOCK DEVELOPMENT							
5.1 Improved Forage Development (40% hh)	547,762	kg	1	547,762	50	27,388,080	3,043,120
5.2 Livestock Diversificiation							
- Poultry (35% hh)	479,291	number	6	2,875,748	15	43,136,226	4,792,914
- Sheep/goat rearing (5% hh)	68,470	number	4	273,881	120	32,865,696	3,651,744
- Cattle fattening (5% hh)	68,470	number	1	68,470	600	41,082,120	4,564,680
- Sheep/goat fattening (5% hh)	68,470	number	2	136,940	70	9,585,828	1,065,092
- Bee keeping (10% hh)	136,940	set	2	273,881	675	184,869,540	20,541,060
- Dairy production (5% hh)	68,470	number	1	68,470	1,000	68,470,200	7,607,800
5.3 Strengthen Livestock Extension							
- Train paravets	166	wereda	6	996	1,044	1,039,824	115,536
- Equipment + drugs	166	set	1	166	1,474	244,684	27,187
Sub-total						**408,682,198**	**45,409,133**
6. COMMUNITY ASSETS DEVELOPMENT							
6.1 Feeder Raods	166	km	180	29,880	27,000	806,760,000	89,640,000
6.2 Upgrade Market Places (weredas)							
- Construction shades/shlters	166	number	4	664	30,000	19,920,000	2,213,333
- Construction stores	166	number	2	332	50,000	16,600,000	1,844,444
- Construction VIP Latrines	166	number	2	332	15,000	4,980,000	553,333
Sub-total						**848,260,000**	**94,251,111**
7. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT							
7.1 Vocational Training Centres (VTC's)	166	number	1	166	250,000	41,500,000	4,611,111
7.2 Vocational Training Farmers (10% hh)	136,940	number		136,940	1,800	246,492,720	27,388,080
7.3 Samll/micro Entrerprise Training: (wereda capital)	166	town	30	4,980	150	747,000	83,000
7.4 Trainers	166	town	3	498	490	244,020	27,113
7.5 Labour mobility experience sharing	3	Region		3	100,000	300,000	33,333
Sub-total						**289,283,740**	**32,142,638**
8. IMPROVED MARKETING							
8.1 Market chain analysis (Consultancy)						600,000	66,667
8.2 Cooperative Training	166	number	90	14,940	450	6,723,000	747,000
8.3 Improved access (see 6.1)							
Sub-total						**7,323,000**	**813,667**
9. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS							
9.1 Review MFI's operations (Consultancy)						750,000	83,333
9.2 Training: local savings, credit institutions	166	number	90	14,940	450	6,723,000	747,000
Sub-total						**7,473,000**	**830,333**
10. CAPACITY BUILDING							
10.1 Physical capacity development							
- Vehicles: 4wd S/W	1	federal	3	3	500,000	1,500,000	166,667
- Vehicles: 4wd d-cab p/u	3	region	2	6	250,000	1,500,000	166,667
- Vehicles: s-cab p/u	166	wereda	1	166	25,000	4,150,000	461,111
- Vehicles: m/c	166	wereda	3	498	28,000	13,944,000	1,549,333
- Cycles (DA's)	166	wereda	5	830	1,000	830,000	92,222
- Hand tools (labour-based works)	166	wereda	400	66,400	120	7,968,000	885,333
- Computers, Copiers	166	wereda	2	332	30,000	9,960,000	1,106,667
- Office equipment	166	wereda	1	166	100,000	16,600,000	1,844,444
10.2 Human capacity development							
- Short-term Training: Computers	166	wereda	12	1,992	2,000	3,984,000	442,667
- Short-term Training: In-country study tours	166	wereda	30	4,980	2,000	9,960,000	1,106,667
- Short-term Training: Overseas Study tours	166	wereda	2	332	60,000	19,920,000	2,213,333
- Long-term Training: Certificates/Diploma	166	wereda	20	3,320	20,000	66,400,000	7,377,778
- Long-term Training: Dimploma to Degree level	166	wereda	30	4,980	31,000	154,380,000	17,153,333
- Long-term Training: Degree to M.Sc. Level	3	region	30	90	200,000	18,000,000	2,000,000
10.3 Support to Land Registration							
- Training local surveyors	166	wereda	44	7,304	250	1,826,000	202,889
- Trainers	166	wereda	4	664	490	325,360	36,151
- Daily Allowances	166	wereda	44	7,304	4,500	32,868,000	3,652,000
- Materials, equipment	166	wereda	44	7,304	500	3,652,000	405,778
-Support: Land Administration	166	wereda	1	166	285,000	47,310,000	5,256,667
10.4 Establish Databse	166	wereda	1	166	10,000	1,660,000	184,444
10.5 National Park: Management	1	site		1	340,000	340,000	37,778
						417,077,360	**46,341,929**
TOTAL						**13,123,124,346**	**1,458,124,927**

SUDAN: BLUE NILE SUB-BASIN

Intervention	Beneficiaries	Unit	No	Total number	Unit Cost (SDD)	Total cost (SDD)	Total cost (US$)
1. ARRESTING SOIL DEGRADATION CROP INTENSIFICIATION							
2.1 Improved seeds							
- Foundation seed production		tons	1	2,500	45,000	112,500,000	562,500
- Cereal seeds (50% traditional farms)	110,270	Pack	1	110,270	15,000	1,654,050,000	8,270,250
- Tied ridging implements (50% hh)	27,568	unit	1	27,568	20,000	551,350,000	2,756,750
2.2 Adaptive Research (50% localities)	31	loality	1	31	2,400,000	74,400,000	372,000
Sub-total						**2,392,300,000**	**11,961,500**
2. EXTENSION							
2.1 Locality Experts Training	62	locality	12	744	40,000	29,760,000	148,800
2.2 Agric. Agent . Training	62	locality	30	1,860	110,000	204,600,000	1,023,000
2.3 Contact Farmer Training	62	locality	360	22,320	20,000	446,400,000	2,232,000
2.4 Farmer Training Centres (FTC's)	62	locality	15	930	50,000	46,500,000	232,500
2.5 Radio Extension					-		
- Establishment of radio reception centres	62	locality	3	186	250,000	46,500,000	232,500
- Cost prog. Development/broadcasting	62	locality	3	186	80,000	14,880,000	74,400
Sub-total						**788,640,000**	**3,943,200**
3. LIVESTOCK DEVELOPMENT							
3.1 Improved On-farm Forage Development (50% hh)	27,568	kg	1	1,500	1,200	1,800,000	9,000
3.2 On-farm Livestock Diversificiation							
- Poultry (35% hh)	27,568	number	6	400	350	140,000	700
- Sheep/goat rearing (5% hh)	27,568	number	4	3,200	2,750	8,800,000	44,000
- Cattle fattening (5% hh)	27,568	number	1	16,000	14,000	224,000,000	1,120,000
- Sheep/goat fattening (5% hh)	27,568	number	2	1,900	1,600	3,040,000	15,200
- Dairy production (5% hh)	27,568	number	1	27,000	23,000	621,000,000	3,105,000
3.3 Reducing Rangeland Degradation							
- Demarcating stock routes	62	kms	50	3,100	40,000	124,000,000	620,000
- Provision of water points	62	number	5	310	120,000	37,200,000	186,000
- Test feasibility: aerial sowing	5	site	1	5	250,000	1,250,000	6,250
3.4 Strengthen Livestock Extension							
- Train paravets	62	locality	6	28,000	23,200	649,600,000	3,248,000
- Equipment + drugs	62	locality	6	40,000	32,750	1,310,000,000	6,550,000
Sub-total						**2,980,830,000**	**14,904,150**
4. REDUCING RIVER BANK EROSON							
- Survey & Asssessment Current Erosion sites			1	1	10,000,000	10,000,000	50,000
- Establish Bank erosion monitoring system			1	1	20,000,000	20,000,000	100,000
- Construct revetments: High land value areas: Stone-filled gabions		m3	100	50	7,000,000	350,000,000	1,750,000
Sub-total						**380,000,000**	**1,900,000**
5. COMMUNITY ASSETS DEVELOPMENT							
5.1 Feeder Raods	62	km	300	18,600	600,000	11,160,000,000	55,800,000
5.2 Upgrade Market Places (localities							
- Construction shades/shlters	62	number	5	310	670,000	207,700,000	1,038,500
- Construction stores	62	number	5	310	1,200,000	372,000,000	1,860,000
Sub-total						**11,739,700,000**	**58,698,500**
6. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT							
6.1 Vocational Training Centres (VTC's)	62	number	1	62	5,600,000	347,200,000	1,736,000
6.2 Vocational Training Farmers (10% hh)	5,514	number	1	5,514	40,000	220,540,000	1,102,700
6.3 Samll/micro Entrerprise Training: (locality capital)	62	town	30	1,860	3,500	6,510,000	32,550
6.4 Trainers	62	town	3	186	12,000	2,232,000	11,160
Sub-total						**576,482,000**	**2,882,410**
7. IMPROVED MARKETING							
7.1 Farmers' Union Training	62	number	90	5,580	10,000	55,800,000	279,000
7.3 Improved access (see 6.1)							
Sub-total						**55,800,000**	**279,000**
8. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS							
8.1 Review MFI's operations				1	25,000	750,000	3,750
8.2 Training: local savings, credit institutions	62	number	90	5,580	10000	55,800,000	279,000
Sub-total						**56,550,000**	**282,750**
9. SUPPORT TO STRATEGIC LAND USE PLANNING							
9.1 Materials (air photos, satelite images, maps, etc)	62	locality	1	62	200,000	12,400,000	62,000
9.2 Equipment (computers, GPS, etc)	62	locality	1	62	666,667	41,333,333	206,667
9.3 Technical Training	62	locality	10	620	12,000	7,440,000	37,200
9.4 Daily allowances	62	locality	1	62	100,000	6,200,000	31,000
9.5 Support to Local Administration	62	locality	1	62	6,400,000	396,800,000	1,984,000
						464,173,333	**2,320,867**
9. CAPACITY BUILDING							
9.1 Physical capacity development							
- Vehicles: 4wd d-cab p/u	3	State	2	6	5,600,000	33,600,000	168,000
- Vehicles: s-cab p/u	62	locality	1	62	560,000	34,720,000	173,600
- Vehicles: m/c	62	locality	3	186	625,000	116,250,000	581,250
- Hand tools (labour-based works)	62	locality	400	24,800	2,667	66,133,333	330,667
- Computers, Copiers	62	locality	2	124	666,667	82,666,667	413,333
- Office equipment	62	locality	1	62	2,222,222	137,777,778	688,889
9..2 Human capacity development					-		
- Short-term Training: Computers	62	locality	12	744	45,000	33,480,000	167,400
- Short-term Training: In-country study tours	-	locality	30	-	45,000	-	-
- Short-term Training: Overseas Study tours	62	locality	2	124	150,000	18,600,000	93,000
- Long-term Training: Certificates/Diploma	-	locality	20	-	450,000	-	-
- Long-term Training: Dimploma to Degree level	62	locality	30	1,860	700,000	1,302,000,000	6,510,000
- Long-term Training: Degree to M.Sc. Level	3	State	30	90	4,500,000	405,000,000	2,025,000
9.3 Support to SMF Survey							
- Training local surveyors	62	locality	44	2,728	5,750	15,686,000	78,430
- Trainers	62	locality	4	248	12,000	2,976,000	14,880
- Daily Allowances	62	locality	44	2,728	100,000	272,800,000	1,364,000
- Materials, equipment	62	locality	44	2,728	12,000	32,736,000	163,680
-Support: Land Administration	62	locality	1	62	6,400,000	396,800,000	1,984,000
9.4 Establish Databse	62	locality	1	62	250,000	15,500,000	77,500
9.5 National Park: Management	62	site		62	7,600,000	471,200,000	2,356,000
						3,437,925,778	**17,189,629**
TOTAL						**22,872,401,111**	**114,362,006**

ETHIOPIA: TEKEZE SUB-BASIN

Intervention	Beneficiary wereda/household	Unit	No./wereda or HH	Total number	Unit Cost (ETB)	Total cost (ETB)	Total cost (US$)
1. WATER CONSERVATION AND IMPROVED UTILIZATION							
1.1 Water harvesting							
- Pond/cistern construction (35% hh)	104,768	unit	1	104,768	4,200	440,024,851	50,116,726
- Hand dug wells (10% hh)	29,934	unit	1	29,934	2,500	74,834,158	8,523,253
- Springs+night storage (5% hh)	14,967	unit	1	14,967	5,000	74,834,158	8,523,253
1.2 Small/micro scale irrigation (10% hh)	29,934	unit	0.25	7,483	40,000	299,336,634	34,093,011
Sub-total						**889,029,802**	**101,256,242**
2. CROP DIVERISTIFICATION AND INTENSIFICIATION							
2.1 Improved seeds							
- Cereal seeds (45% hh)	134,701	Q	0.75	101,026	275	27,782,181	3,164,258
- Vegetables (water harvesting) (50% hh)	149,668	kg	0.15	22,450	55	1,234,764	140,634
- Vegetatbles (small-scale irrigation((10% hh)	29,934	kg	0.3	8,980	55	493,905	56,253
2.2 Fertilizer (30% hh)	89,801	Q	0.5	44,900	275	12,347,636	1,406,337
2.3 Oxen (30% hh)	89,801	OX	1	89,801	1,000	89,800,990	10,227,903
2.4 Implements (30% hh)	89,801	SET	1	89,801	75	6,735,074	767,093
2.5 Post-harvest technology							
- Threshing floor/storage) (15% hh)	44,900	unit	1	44,900	1,000	44,900,495	5,113,952
- Threshing machines, mills, shellers. (100% weredas)	51	unit	40	2,040	50,000	102,000,000	11,617,312
2.6 Adaoptive Research (50% weredas)	26		1	26	100,000	2,550,000	290,433
Sub-total						**287,845,046**	**32,784,174**
3. SOIL CONSERVATION AND IMPROVED HUSBANDRY MEASURES							
3.1 Physical	-	ha		-	4,200	-	-
3.2 Biological	414,912	ha		414,912	933	387,113,206	44,090,342
3.3 Compost pits (40% hh)	109,703	unit	1	109,703	60	6,582,196	749,681
3.4 Agro-forestry (40% hh)	109,703	seedlings	100	10,970,327	0.50	5,485,164	624,734
3.5 Improved stoves (10% hh)	27,426	unit	1	27,426	100	2,742,582	312,367
Sub-total						**401,923,148**	**45,777,124**
4. EXTENSION							
4.1 Wereda experts Training	58	wereda	12	696	1,750	1,218,000	138,724
4.2 D.A. Training	58	wereda	30	1,740	4,800	8,352,000	951,253
4.3 Contact Farmer Training	360	wereda	360	129,600	800	103,680,000	11,808,656
4.4 Stregnthen Farmer Training Centres (FTC's)	58	wereda	10	580	2,200	1,276,000	145,330
4.5 Radio Extension							
- Establishment of radio reception centres	58	wereda	3	174	10,000	1,740,000	198,178
- Cost prog. Development/broadcasting	58	wereda	3	174	3,500	609,000	69,362
Sub-total						**116,875,000**	**13,311,503**
5. LIVESTOCK DEVELOPMENT							
5.1 Improved Forage Development (40% hh)	109,703	kg	1	109,703	50	5,485,164	624,734
5.2 Livestock Diversificiation							
- Poultry (35% hh)	95,990	number	6	575,942	15	8,639,133	983,956
- Sheep/goat rearing (5% hh)	13,713	number	4	54,852	120	6,582,196	749,681
- Cattle fattening (5% hh)	13,713	number	1	13,713	600	8,227,746	937,101
- Sheep/goat fattening (5% hh)	13,713	number	2	27,426	70	1,919,807	218,657
- Bee keeping (10% hh)	27,426	set	2	54,852	675	37,024,855	4,216,954
- Dairy production (5% hh)	13,713	number	1	13,713	1,000	13,712,909	1,561,835
5.3 Strengthen Livestock Extension							
- Train paravets	58	wereda	6	348	1,044	363,312	41,379
- Equipment + drugs	58	set	1	58	1,474	85,492	9,737
Sub-total						**82,040,614**	**9,344,034**
6. COMMUNITY ASSETS DEVELOPMENT							
6.1 Feeder Raods	58	km	180	10,440	27,000	281,880,000	32,104,784
6.2 Upgrade Market Places (weredas)							
- Construction shades/shlters	58	number	4	232	30,000	6,960,000	792,711
- Construction stores	58	number	2	116	50,000	5,800,000	660,592
- Construction VIP Latrines	58	number	2	116	15,000	1,740,000	198,178
Sub-total						**296,380,000**	**33,756,264**
7. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT							
7.1 Vocational Training Centres (VTC's)	58	number	1	58	250,000	14,500,000	1,651,481
7.2 Vocational Training Farmers (10% hh)	27,426	number		27,426	1,800	49,366,473	5,622,605
7.3 Samll/micro Entrerprise Training: (wereda capital)	58	town	30	1,740	150	261,000	29,727
7.4 Trainers	58	town	3	174	490	85,260	9,711
7.5 Labour mobility experience sharing	3	Region		3	100,000	300,000	34,169
Sub-total						**64,512,733**	**7,347,692**
8. IMPROVED MARKETING							
8.1 Market chain analysis (Consultancy)						600,000	68,337
8.2 Cooperative Training	58	number	90	5,220	450	2,349,000	267,540
8.3 Improved access (see 6.1)							
Sub-total						**2,949,000**	**335,877**
9. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS							
9.1 Review MFI's operations (Consultancy)						750,000	85,421
9.2 Training: local savings, credit institutions	58	number	90	5,220	450	2,349,000	267,540
Sub-total						**3,099,000**	**352,961**
10. CAPACITY BUILDING							
10.1 Physical capacity development							
- Vehicles: 4wd S/W	1	federal	3	3	500,000	1,500,000	170,843
- Vehicles: 4wd d-cab p/u	3	region	2	6	250,000	1,500,000	170,843
- Vehicles: s-cab p/u	58	wereda	1	58	25,000	1,450,000	165,148
- Vehicles: m/c	58	wereda	3	174	28,000	4,872,000	554,897
- Cycles (DA's)	58	wereda	5	290	1,000	290,000	33,030
- Hand tools (labour-based works)	58	wereda	400	23,200	120	2,784,000	317,084
- Computers, Copiers	58	wereda	2	116	30,000	3,480,000	396,355
- Office equipment	58	wereda	1	58	100,000	5,800,000	660,592
10.2 Human capacity development							
- Short-term Training: Computers	58	wereda	12	696	2,000	1,392,000	158,542
- Short-term Training: In-country study tours	58	wereda	30	1,740	2,000	3,480,000	396,355
- Short-term Training: Overseas Study tours	58	wereda	2	116	60,000	6,960,000	792,711
- Long-term Training: Certificates/Diploma	58	wereda	20	1,160	20,000	23,200,000	2,642,369
- Long-term Training: Dimploma to Degree level	58	wereda	30	1,740	31,000	53,940,000	6,143,508
- Long-term Training: Degree to M.Sc. Level	3	region	30	90	200,000	18,000,000	2,050,114
10.3 Support to Land Registration							
- Training local surveyors	58	wereda	44	2,552	250	638,000	72,665
- Trainers	58	wereda	4	232	490	113,680	12,948
- Daily Allowances	58	wereda	44	2,552	4,500	11,484,000	1,307,973
- Materials, equipment	58	wereda	44	2,552	500	1,276,000	145,330
-Support: Land Administration	58	wereda	1	58	285,000	16,530,000	1,882,688
10.4 Establish Databse	58	wereda	1	58	10,000	580,000	66,059
10.5 National Park: Management	1	site		1	340,000	340,000	38,724
						159,609,680	**18,178,779**
TOTAL						**2,304,264,023**	**262,444,650**

SUDAN: ATBARA SUB-BASIN

Intervention	Beneficiaries	Unit	No	Total number	Unit Cost (SDD)	Total cost (SDD)	Total cost (US$)
1. ARRESTING SOIL DEGRADATION CROP INTENSIFICIATION							
2.1 Improved seeds							
- Foundation seed production		tons	1	2,500	45,000	112,500,000	562,500
- Cereal seeds (50% traditional farms)	110,270	Pack	1	110,270	15,000	1,654,050,000	8,270,250
- Tied ridging implements (50% hh)	27,568	unit	1	27,568	20,000	551,350,000	2,756,750
2.2 Adaptive Research (50% localities)	31	loality	1	31	2,400,000	74,400,000	372,000
Sub-total						**2,392,300,000**	**11,961,500**
2. EXTENSION							
2.1 Locality Experts Training	62	locality	12	744	40,000	29,760,000	148,800
2.2 Agric. Agent . Training	62	locality	30	1,860	110,000	204,600,000	1,023,000
2.3 Contact Farmer Training	62	locality	360	22,320	20,000	446,400,000	2,232,000
2.4 Farmer Training Centres (FTC's)	62	locality	15	930	50,000	46,500,000	232,500
2.5 Radio Extension					-		
- Establishment of radio reception centres	62	locality	3	186	250,000	46,500,000	232,500
- Cost prog. Development/broadcasting	62	locality	3	186	80,000	14,880,000	74,400
Sub-total						**788,640,000**	**3,943,200**
3. LIVESTOCK DEVELOPMENT							
3.1 Improved On-farm Forage Development (50% hh)	27,568	kg	1	1,500	1,200	1,800,000	9,000
3.2 On-farm Livestock Diversificiation							
- Poultry (35% hh)	27,568	number	6	400	350	140,000	700
- Sheep/goat rearing (5% hh)	27,568	number	4	3,200	2,750	8,800,000	44,000
- Cattle fattening (5% hh)	27,568	number	1	16,000	14,000	224,000,000	1,120,000
- Sheep/goat fattening (5% hh)	27,568	number	2	1,900	1,600	3,040,000	15,200
- Dairy production (5% hh)	27,568	number	1	27,000	23,000	621,000,000	3,105,000
3.3 Reducing Rangeland Degradation							
- Demarcating stock routes	62	kms	50	3,100	40,000	124,000,000	620,000
- Provision of water points	62	number	5	310	120,000	37,200,000	186,000
- Test feasibility: aerial sowing	5	site	1	5	250,000	1,250,000	6,250
3.4 Strengthen Livestock Extension							
- Train paravets	62	locality	6	28,000	23,200	649,600,000	3,248,000
- Equipment + drugs	62	locality	6	40,000	32,750	1,310,000,000	6,550,000
Sub-total						**2,980,830,000**	**14,904,150**
4. REDUCING RIVER BANK EROSON							
- Survey & Asssessment Current Erosion sites			1	1	10,000,000	10,000,000	50,000
- Establish Bank erosion monitoring system			1	1	20,000,000	20,000,000	100,000
- Construct revetments: High land value areas: Stone-filled gabions		m3	100	50	7,000,000	350,000,000	1,750,000
Sub-total						**380,000,000**	**1,900,000**
5. COMMUNITY ASSETS DEVELOPMENT							
5.1 Feeder Raods	62	km	300	18,600	600,000	11,160,000,000	55,800,000
5.2 Upgrade Market Places (localities							
- Construction shades/shlters	62	number	5	310	670,000	207,700,000	1,038,500
- Construction stores	62	number	5	310	1,200,000	372,000,000	1,860,000
Sub-total						**11,739,700,000**	**58,698,500**
6. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT							
6.1 Vocational Training Centres (VTC's)	62	number	1	62	5,600,000	347,200,000	1,736,000
6.2 Vocational Training Farmers (10% hh)	5,514	number	1	5,514	40,000	220,540,000	1,102,700
6.3 Samll/micro Entrerprise Training: (locality capital)	62	town	30	1,860	3,500	6,510,000	32,550
6.4 Trainers	62	town	3	186	12,000	2,232,000	11,160
Sub-total						**576,482,000**	**2,882,410**
7. IMPROVED MARKETING							
7.1 Farmers' Union Training	62	number	90	5,580	10,000	55,800,000	279,000
7.3 Improved access (see 6.1)							
Sub-total						**55,800,000**	**279,000**
8. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS							
8.1 Review MFI's operations				1	25,000	750,000	3,750
8.2 Training: local savings, credit institutions	62	number	90	5,580	10000	55,800,000	279,000
Sub-total						**56,550,000**	**282,750**
9. SUPPORT TO STRATEGIC LAND USE PLANNING							
9.1 Materials (air photos, satelite images, maps, etc)	62	locality	1	62	200,000	12,400,000	62,000
9.2 Equipment (computers, GPS, etc)	62	locality	1	62	666,667	41,333,333	206,667
9.3 Technical Training	62	locality	10	620	12,000	7,440,000	37,200
9.4 Daily allowances	62	locality	1	62	100,000	6,200,000	31,000
9.5 Support to Local Administration	62	locality	1	62	6,400,000	396,800,000	1,984,000
						464,173,333	**2,320,867**
9. CAPACITY BUILDING							
9.1 Physical capacity development							
- Vehicles: 4wd d-cab p/u	3	State	2	6	5,600,000	33,600,000	168,000
- Vehicles: s-cab p/u	62	locality	1	62	560,000	34,720,000	173,600
- Vehicles: m/c	62	locality	3	186	625,000	116,250,000	581,250
- Hand tools (labour-based works)	62	locality	400	24,800	2,667	66,133,333	330,667
- Computers, Copiers	62	locality	2	124	666,667	82,666,667	413,333
- Office equipment	62	locality	1	62	2,222,222	137,777,778	688,889
9..2 Human capacity development					-		
- Short-term Training: Computers	62	locality	12	744	45,000	33,480,000	167,400
- Short-term Training: In-country study tours	-	locality	30	-	45,000	-	-
- Short-term Training: Overseas Study tours	62	locality	2	124	150,000	18,600,000	93,000
- Long-term Training: Certificates/Diploma	-	locality	20	-	450,000	-	-
- Long-term Training: Dimploma to Degree level	62	locality	30	1,860	700,000	1,302,000,000	6,510,000
- Long-term Training: Degree to M.Sc. Level	3	State	30	90	4,500,000	405,000,000	2,025,000
9.3 Support to SMF Survey							
- Training local surveyors	62	locality	44	2,728	5,750	15,686,000	78,430
- Trainers	62	locality	4	248	12,000	2,976,000	14,880
- Daily Allowances	62	locality	44	2,728	100,000	272,800,000	1,364,000
- Materials, equipment	62	locality	44	2,728	12,000	32,736,000	163,680
-Support: Land Administration	62	locality	1	62	6,400,000	396,800,000	1,984,000
9.4 Establish Databse	62	locality	1	62	250,000	15,500,000	77,500
9.5 National Park: Management	62	site		62	7,600,000	471,200,000	2,356,000
						3,437,925,778	**17,189,629**
TOTAL						**22,872,401,111**	**114,362,006**

ETHIOPIA: BARO-AKOBO SUB-BASIN

Intervention	Beneficiary wereda/household	Unit	No./wereda or HH	Total number	Unit Cost (ETB)	Total cost (ETB)	Total cost (US$)
1. WATER CONSERVATION AND IMPROVED UTILIZATION							
1.1 Water harvesting							
- Pond/cistern construction (35% hh)	151,722	unit	1	151,722	4,200	637,232,675	72,577,753
- Hand dug wells (10% hh)	43,349	unit	1	43,349	2,500	108,372,904	12,343,155
- Springs+night storage (5% hh)	21,675	unit	1	21,675	5,000	108,372,904	12,343,155
1.2 Small/micro scale irrigation (10% hh)	43,349	unit	0.25	10,837	40,000	433,491,616	49,372,621
Sub-total						**1,287,470,098**	**146,636,685**
2. CROP DIVERISTIFICATION AND INTENSIFICIATION							
2.1 Improved seeds							
- Cereal seeds (45% hh)	195,071	Q	0.75	146,303	275	40,233,441	4,582,396
- Vegetables (water harvesting) (50% hh)	216,746	kg	0.15	32,512	55	1,788,153	203,662
- Vegetatbles (small-scale irrigation((10% hh)	43,349	kg	0.3	13,005	55	715,261	81,465
2.2 Fertilizer (30% hh)	130,047	Q	0.5	65,024	275	17,881,529	2,036,621
2.3 Oxen (30% hh)	130,047	OX	1	130,047	1,000	130,047,485	14,811,786
2.4 Implements (30% hh)	130,047	SET	1	130,047	75	9,753,561	1,110,884
2.5 Post-harvest technology							
- Threshing floor/storage) (15% hh)	65,024	unit	1	65,024	1,000	65,023,742	7,405,893
- Threshing machines, mills, shellers. (100% weredas)	34	unit	40	1,360	50,000	68,000,000	7,744,875
2.6 Adaoptive Research (50% weredas)	17		1	17	100,000	1,700,000	193,622
Sub-total						**335,143,172**	**38,171,204**
3. SOIL CONSERVATION AND IMPROVED HUSBANDRY MEASURES							
3.1 Physical	63,964	ha		63,964	4,200	268,648,800	30,597,813
3.2 Biological	75,790	ha		75,790	933	70,712,070	8,053,767
3.3 Compost pits (40% hh)	147,266	unit	1	147,266	60	8,835,958	1,006,373
3.4 Agro-forestry (40% hh)	147,266	seedlings	100	14,726,597	0.50	7,363,299	838,644
3.5 Improved stoves (10% hh)	36,816	unit	1	36,816	100	3,681,649	419,322
Sub-total						**359,241,777**	**40,915,920**
4. EXTENSION							
4.1 Wereda experts Training	49	wereda	12	588	1,750	1,029,000	117,198
4.2 D.A. Training	49	wereda	30	1,470	4,800	7,056,000	803,645
4.3 Contact Farmer Training	360	wereda	360	129,600	800	103,680,000	11,808,656
4.4 Stregnthen Farmer Training Centres (FTC's)	49	wereda	10	490	2,200	1,078,000	122,779
4.5 Radio Extension							
- Establishment of radio reception centres	49	wereda	3	147	10,000	1,470,000	167,426
- Cost prog. Development/broadcasting	49	wereda	3	147	3,500	514,500	58,599
Sub-total						**114,827,500**	**13,078,303**
5. LIVESTOCK DEVELOPMENT							
5.1 Improved Forage Development (40% hh)	147,266	kg	1	147,266	50	7,363,299	838,644
5.2 Livestock Diversificiation							
- Poultry (35% hh)	128,858	number	6	773,146	15	11,597,195	1,320,865
- Sheep/goat rearing (5% hh)	18,408	number	4	73,633	120	8,835,958	1,006,373
- Cattle fattening (5% hh)	18,408	number	1	18,408	600	11,044,948	1,257,967
- Sheep/goat fattening (5% hh)	18,408	number	2	36,816	70	2,577,155	293,526
- Bee keeping (10% hh)	36,816	set	2	73,633	675	49,702,266	5,660,850
- Dairy production (5% hh)	18,408	number	1	18,408	1,000	18,408,247	2,096,611
5.3 Strengthen Livestock Extension							
- Train paravets	49	wereda	6	294	1,044	306,936	34,959
- Equipment + drugs	49	set	1	49	1,474	72,226	8,226
Sub-total						**109,908,230**	**12,518,022**
6. FOREST PLANNING AND SUSTAINABLE MANAGEMENT							
6.1 Forest Mapping	1,771,000	ha	1	1,771,000	10	17,710,000	2,017,084
6.2 Collaborative Strategic Planning	1,771,000	ha	1	1,771,000	25	44,275,000	5,042,711
6.3 Community Forest Management Plans	49	wereda	1	49	150,000	7,350,000	837,130
6.4 Forest Management Plans	1,771,000	ha	1	1,771,000	60	106,260,000	12,102,506
Sub-total						**175,595,000**	**19,999,431**
6. COMMUNITY ASSETS DEVELOPMENT							
6.1 Feeder Raods	49	km	180	8,820	27,000	238,140,000	27,123,007
6.2 Upgrade Market Places (weredas)							
- Construction shades/shlters	49	number	4	196	30,000	5,880,000	669,704
- Construction stores	49	number	2	98	50,000	4,900,000	558,087
- Construction VIP Latrines	49	number	2	98	15,000	1,470,000	167,426
Sub-total						**250,390,000**	**28,518,223**
7. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT							
7.1 Vocational Training Centres (VTC's)	49	number	1	49	250,000	12,250,000	1,395,216
7.2 Vocational Training Farmers (10% hh)	36,816	number		36,816	1,800	66,269,688	7,547,800
7.3 Samll/micro Entrerprise Training: (wereda capital)	49	town	30	1,470	150	220,500	25,114
7.4 Trainers	49	town	3	147	490	72,030	8,204
7.5 Labour mobility experience sharing	3	Region		3	100,000	300,000	34,169
Sub-total						**79,112,218**	**9,010,503**
8. IMPROVED MARKETING							
8.1 Market chain analysis (Consultancy)						600,000	68,337
8.2 Cooperative Training	49	number	90	4,410	450	1,984,500	226,025
8.3 Improved access (see 6.1)							
Sub-total						**2,584,500**	**294,362**
9. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS							
9.1 Review MFI's operations (Consultancy)						750,000	85,421
9.2 Training: local savings, credit institutions	49	number	90	4,410	450	1,984,500	226,025
Sub-total						**2,734,500**	**311,446**
10. CAPACITY BUILDING							
10.1 Physical capacity development							
- Vehicles: 4wd S/W	1	federal	3	3	500,000	1,500,000	170,843
- Vehicles: 4wd d-cab p/u	3	region	2	6	250,000	1,500,000	170,843
- Vehicles: s-cab p/u	49	wereda	1	49	25,000	1,225,000	139,522
- Vehicles: m/c	49	wereda	3	147	28,000	4,116,000	468,793
- Cycles (DA's)	49	wereda	5	245	1,000	245,000	27,904
- Hand tools (labour-based works)	49	wereda	400	19,600	120	2,352,000	267,882
- Computers, Copiers	49	wereda	2	98	30,000	2,940,000	334,852
- Office equipment	49	wereda	1	49	100,000	4,900,000	558,087
10.2 Human capacity development							
- Short-term Training: Computers	49	wereda	12	588	2,000	1,176,000	133,941
- Short-term Training: In-country study tours	49	wereda	30	1,470	2,000	2,940,000	334,852
- Short-term Training: Overseas Study tours	49	wereda	2	98	60,000	5,880,000	669,704
- Long-term Training: Certificates/Diploma	49	wereda	20	980	20,000	19,600,000	2,232,346
- Long-term Training: Dimploma to Degree level	49	wereda	30	1,470	31,000	45,570,000	5,190,205
- Long-term Training: Degree to M.Sc. Level	3	region	30	90	200,000	18,000,000	2,050,114
10.3 Support to Land Registration							
- Training local surveyors	49	wereda	44	2,156	250	539,000	61,390
- Trainers	49	wereda	4	196	490	96,040	10,938
- Daily Allowances	49	wereda	44	2,156	4,500	9,702,000	1,105,011
- Materials, equipment	49	wereda	44	2,156	500	1,078,000	122,779
-Support: Land Administration	49	wereda	1	49	285,000	13,965,000	1,590,547
10.4 Establish Databse	49	wereda	1	49	10,000	490,000	55,809
10.5 National Park: Management	1	site		1	340,000	340,000	38,724
						138,154,040	**15,735,084**
TOTAL						**2,855,161,035**	**325,189,184**

SUDAN: SOBAT-WHITE NILE SUB-BASIN

Intervention	Beneficiaries	Unit	No	Total number	Unit Cost (SDD)	Total cost (SDD)	Total cost (US$)
1. ARRESTING SOIL DEGRADATION CROP INTENSIFICIATION							
2.1 Improved seeds							
- Foundation seed production		tons	1	2,500	45,000	112,500,000	562,500
- Cereal seeds (50% traditional farms)	100,000	Pack	1	100,000	15,000	1,500,000,000	7,500,000
- Tied ridging implements (50% hh)	25,000	unit	1	25,000	20,000	500,000,000	2,500,000
2.2 Adaptive Research (50% localities)	59	loality	1	59	2,400,000	140,400,000	702,000
Sub-total						**2,252,900,000**	**11,264,500**
2. EXTENSION							
2.1 Locality Experts Training	117	locality	12	1,404	40,000	56,160,000	280,800
2.2 Agric. Agent . Training	117	locality	30	3,510	110,000	386,100,000	1,930,500
2.3 Contact Farmer Training	117	locality	360	42,120	20,000	842,400,000	4,212,000
2.4 Farmer Training Centres (FTC's)	117	locality	15	1,755	50,000	87,750,000	438,750
2.5 Radio Extension					-		
- Establishment of radio reception centres	117	locality	3	351	250,000	87,750,000	438,750
- Cost prog. Development/broadcasting	117	locality	3	351	80,000	28,080,000	140,400
Sub-total						**1,488,240,000**	**7,441,200**
3. LIVESTOCK DEVELOPMENT							
3.1 Improved On-farm Forage Development (50% hh)	25,000	kg	1	1,500	1,200	1,800,000	9,000
3.2 On-farm Livestock Diversificiation							
- Poultry (35% hh)	25,000	number	6	400	350	140,000	700
- Sheep/goat rearing (5% hh)	25,000	number	4	3,200	2,750	8,800,000	44,000
- Cattle fattening (5% hh)	25,000	number	1	16,000	14,000	224,000,000	1,120,000
- Sheep/goat fattening (5% hh)	25,000	number	2	1,900	1,600	3,040,000	15,200
- Dairy production (5% hh)	25,000	number	1	27,000	23,000	621,000,000	3,105,000
3.3 Reducing Rangeland Degradation							
- Demarcating stock routes	117	kms	50	5,850	40,000	234,000,000	1,170,000
- Provision of water points	117	number	5	585	120,000	70,200,000	351,000
- Test feasibility: aerial sowing	5	site	1	5	250,000	1,250,000	6,250
3.4 Strengthen Livestock Extension							
- Train paravets	117	locality	6	28,000	23,200	649,600,000	3,248,000
- Equipment + drugs	117	locality	6	40,000	32,750	1,310,000,000	6,550,000
Sub-total						**3,123,830,000**	**15,619,150**
4. COMMUNITY ASSETS DEVELOPMENT							
5.1 Feeder Raods	117	km	300	35,100	600,000	21,060,000,000	105,300,000
5.2 Upgrade Market Places (localities							
- Construction shades/shlters	117	number	5	585	670,000	391,950,000	1,959,750
- Construction stores	117	number	5	585	1,200,000	702,000,000	3,510,000
Sub-total						**22,153,950,000**	**110,769,750**
5. SUPPORT TO NON-FARM INCOME GENERATION, SMALL/MICRO ENTERPRISE DEVELOPMENT							
6.1 Vocational Training Centres (VTC's)	117	number	1	117	5,600,000	655,200,000	3,276,000
6.2 Vocational Training Farmers (10% hh)	5,000	number	1	5,000	40,000	200,000,000	1,000,000
6.3 Samll/micro Entrerprise Training: (locality capital)	117	town	30	3,510	3,500	12,285,000	61,425
6.4 Trainers	117	town	3	351	12,000	4,212,000	21,060
Sub-total						**871,697,000**	**4,358,485**
6. IMPROVED MARKETING							
7.1 Farmers' Union Training	117	number	90	10,530	10,000	105,300,000	526,500
7.3 Improved access (see 6.1)							
Sub-total						**105,300,000**	**526,500**
7. SUPPORT TO MICRO FINANCE, CREDIT AND SAVINGS							
8.1 Review MFI's operations				1	25,000	750,000	3,750
8.2 Training: local savings, credit institutions	117	number	90	10,530	10000	105,300,000	526,500
Sub-total						**106,050,000**	**530,250**
8. SUPPORT TO STRATEGIC LAND USE PLANNING							
9.1 Materials (air photos, satelite images, maps, etc)	117	locality	1	117	200,000	23,400,000	117,000
9.2 Equipment (computers, GPS, etc)	117	locality	1	117	666,667	78,000,000	390,000
9.3 Technical Training	117	locality	10	1,170	12,000	14,040,000	70,200
9.4 Daily allowances	117	locality	1	117	100,000	11,700,000	58,500
9.5 Support to Local Administration	117	locality	1	117	6,400,000	748,800,000	3,744,000
						875,940,000	**4,379,700**
9. CAPACITY BUILDING							
9.1 Physical capacity development							
- Vehicles: 4wd d-cab p/u	3	State	2	6	5,600,000	33,600,000	168,000
- Vehicles: s-cab p/u	117	locality	1	117	560,000	65,520,000	327,600
- Vehicles: m/c	117	locality	3	351	625,000	219,375,000	1,096,875
- Hand tools (labour-based works)	117	locality	400	46,800	2,667	124,800,000	624,000
- Computers, Copiers	117	locality	2	234	666,667	156,000,000	780,000
- Office equipment	117	locality	1	117	2,222,222	260,000,000	1,300,000
9..2 Human capacity development					-		
- Short-term Training: Computers	117	locality	12	1,404	45,000	63,180,000	315,900
- Short-term Training: In-country study tours	-	locality	30	-	45,000	-	-
- Short-term Training: Overseas Study tours	117	locality	2	234	150,000	35,100,000	175,500
- Long-term Training: Certificates/Diploma	-	locality	20	-	450,000	-	-
- Long-term Training: Dimploma to Degree level	117	locality	30	3,510	700,000	2,457,000,000	12,285,000
- Long-term Training: Degree to M.Sc. Level	3	State	30	90	4,500,000	405,000,000	2,025,000
9.3 Support to SMF Survey							
- Training local surveyors	117	locality	44	5,148	5,750	29,601,000	148,005
- Trainers	117	locality	4	468	12,000	5,616,000	28,080
- Daily Allowances	117	locality	44	5,148	100,000	514,800,000	2,574,000
- Materials, equipment	117	locality	44	5,148	12,000	61,776,000	308,880
-Support: Land Administration	117	locality	1	117	6,400,000	748,800,000	3,744,000
9.4 Establish Database	117	locality	1	117	250,000	29,250,000	146,250
9.5 National Park: Management	117	site		117	7,600,000	889,200,000	4,446,000
						6,098,618,000	**30,493,090**
TOTAL						**37,076,525,000**	**185,382,625**

ANNEX 4. GLOSSARY

Afforestation	Planting trees on land that has not been covered with forest historically.
Biodiversity	Biodiversity or biological diversity refers to the variety of species of plants, animals and micro-organisms and the ecosystems and ecological processes of which they are part. Diversity does not refer to the number of individuals within species.
Carbon finance business	The World Bank Group's carbon fund activities including their own carbon funds as well as the carbon funds they manage for other organizations.
Carbon dioxide sink	A carbon dioxide (CO_2) sink is a carbon reservoir that is increasing in size and is the opposite of a carbon "source". The main natural sinks are the oceans and plants and other organisms that use photosynthesis to remove carbon from the atmosphere by incorporating it into biomass. This concept of CO_2 sink has become more widely known because of its role in the Kyoto Protocol. Natural CO_2 sinks are Soil and Forest. (i) Soil: Carbon as plant organic matter is sequestered in soils: Soils contain more carbon than is contained in vegetation and the atmosphere combined. Soils' organic carbon (humus) levels in many agricultural areas have been severely depleted Grasslands contribute to soil organic matter, mostly in the form of roots, and much of this organic matter can remain unoxidized for long periods. (ii) Forest: Carbon is incorporated into forests and forest soils by trees and other plants. Through photosynthesis, plants absorb carbon dioxide from the atmosphere, store the carbon in sugars, starch and cellulose, and release the oxygen into the atmosphere. A young forest, composed of growing trees, absorbs carbon dioxide and acts as a sink. Mature forests, made up of a mix of various aged trees as well as dead and decaying matter, may be carbon neutral above ground. In the soil, however, the gradual buildup of slowly decaying organic material will continue to accumulate carbon, but at a slower rate than an immature forest. The forest eco-system may eventually become carbon neutral. Forest fires release absorbed carbon back into the atmosphere. The dead trees, plants, and moss in peat

	bogs undergo slow anaerobic decomposition below the surface of the bog. This process is slow enough that in many cases the bog grows rapidly and fixes more carbon from the atmosphere than is released. Over time, the peat grows deeper. Peat bogs inter approximately one-quarter of the carbon stored in land plants and soils. Under some conditions, forests and peat bogs may become sources of CO_2, such as when a forest is flooded by the construction of a hydroelectric dam. Unless the forests and peat are harvested before flooding, the rotting vegetation is a source of CO_2 and methane comparable in magnitude to the amount of carbon released by a fossil-fuel powered plant of equivalent power.
Carbon sequestration	The uptake and storage of carbon. Trees and plants for example absorb carbon dioxide, release the oxygen and store the carbon. Fossil fuels were at one time biomass and continue to store the carbon until burned. Carbon sequestration is the term describing processes that remove carbon from the atmosphere. To help mitigate global warming, a variety of means of artificially capturing and storing carbon -- as well as of enhancing natural sequestration processes -- are being explored.
Certified emission reduction	A carbon credit generated by a Clean Development Mechanism carbon project.
Clean development mechanism	One of the flexible mechanisms under the Kyoto Protocol for trading with carbon credits.
Gini coefficient	An aggregate numerical measure of income inequality ranging from 0 (perfect equality) to 1 (perfect inequality).
Headcount ratio	Usually refers to the proportion of individuals, households or families that falls under the poverty line. Divides the number of people identified as poor by the total number of people in the community. The headcount ratio H ranges from 0% (nobody is poor) to 100% (everybody is poor).
Income[1] poverty	Poverty defined with respect to a money-based poverty line for income or expenditure. The distinction is made between this and other concepts that emphasize the many dimensions of poverty. The income poverty line is set internationally at one dollar a day.
Incremental net benefit	The net benefit of a project investment is equal to the gross benefit minus the cost. It is a residual that is available to recover the investment (return of capital) and to compensate for the use of the resources invested in the project (return to capital). Deducting

[1] Or consumption.

the without-project net benefit from the net benefit gives the incremental net benefit.

Internal rate of return (IRR)

The internal rate of return is a discounted measure of project worth and may be defined as the discount rate that makes the NPV of the incremental net benefit or incremental cash flow equal to zero. The internal rate of return may also be defined as the maximum interest rate that an investment project can pay for the resources used if the project is to recover its investment and operating costs and still just break even. The selection criterion is to accept all independent investment projects with an IRR greater than the cut-off rate which generally is the opportunity cost of capital.

Kyoto protocol

Because growing vegetation absorbs carbon dioxide, the Kyoto Protocol allows countries that have large areas of forest (or other vegetation) to deduct a certain amount from their emissions thus making it easier for them to achieve the desired net emission levels.

Some countries want to be able to trade in emission rights in carbon emission markets to make it possible for one country to buy the benefit of carbon dioxide sinks in another country. If overall limits on greenhouse gas emission are put into place, such a "cap-and-trade" market mechanism will tend to find cost-effective ways to reduce emissions. There is as yet no carbon audit regime for all such markets globally and none is specified in the Kyoto Protocol. Each nation is on its own to verify actual carbon emission reductions and to account for carbon sequestration using some less formal method. In the Clean Development Mechanism, only afforestation and reforestation are eligible to produce CERs in the first commitment period of the Kyoto Protocol (2008–2012). Forest conservation activities or activities avoiding deforestation which would result in emission reduction through the conservation of existing carbon stocks, are not eligible at this time. Also agricultural carbon sequestration is not possible yet.

Land degradation

Reduction of the capacity of the land – together with factors such as climate, topography, soils, hydrology, and vegetation - to produce goods and services. It is more than just a physical or environmental process. Ultimately it is a social problem with economic costs attached as it consumes the product of labour and capital inputs into production.

National poverty line

Poverty lines drawn by national governments or national statistical offices to measure poverty. It is not possible to make comparisons between countries using national poverty lines as each is calculated on the basis of criteria specific to that country.

Net present value

The net present value is a discounted measure of project worth and may be defined as the present worth of the incremental net benefit or incremental cash flow. The selection criterion is to accept all independent investment projects with an NPV greater than zero when discounted at the opportunity cost of capital.

Poverty correlates

The characteristics that are closely associated with being poor such as living in a rural area or having a large number of children. These can be used to target public expenditure in the absence of detailed information relating to every household of the individual.

Poverty gap

A measure of the average distance of poor individuals or households below the income poverty line.

Poverty line

Represents the level of income or consumption necessary to meet a set of minimum requirements to feed oneself and one's family adequately and/or to meet other basic requirements such as clothing, housing and healthcare. Those with incomes or expenditure equal to or above the line are not poor. While what the minimum should be has an important subjective element, poverty lines are typically anchored to minimum nutritional requirements plus a modest allowance for non-food needs.

Public good

A public good is one that benefits a lot of people at the same time and the benefit to any one person is not affected by the benefit to another (joint consumption). It is also difficult to prevent anyone from enjoying benefit once it is provided (Appropriation problem). When local benefits have no market such as those of indirect use values like watershed protection, they are local public goods. When environmental benefits are global making if difficult for countries to appropriate benefits, the latter are called global public goods.

Risk

Probability of a hazard occurring.

Risk Analysis

Risk analysis refers to a methodology by which the uncertainty associated with critical variables such as the exchange rate or world sugar price is expressed in terms of probability distributions and allowed through a simulation process to register its impact on the NPV. Risk analysis estimates the variability in NPV or IRR. This variability is more realistic and easier to interpret than that from sensitivity analysis. This is because of the ceteris paribus assumptions in relation to other variables and particularly because of the inability to handle year-by-year variations in production estimates. What meaning can be attached to changes in NPV or IRR in responses to movements in 1 key variable when dozens and perhaps hundreds of others must be held constant is not clear. Risk analysis which involves attaching probabilities to NPV, FRR and ERR estimates can overcome these shortcomings.

Sensitivity analysis — Sensitivity analysis illustrates the impact on the NPV, FRR or ERR of a given percentage change in a key variable. It highlights the most critical variables that might need more careful specification but has limited value in assessing the confidence placed on the NPV, FRR or ERR estimates.

Soil degradation — A broader term for declining soil quality encompassing the deterioration in physical, chemical, and biological attributes of the soil. Soil degradation is a long-term process. Both erosion and nutrient breach are part of soil degradation.

Soil erosion — A physical process referring to the wearing away of the land surface by water and/or wind as well as to the reduction in soil productivity due to physical loss of topsoil, reduction in rooting depth, removal of plant nutrients, and loss of water. Soil erosion events are quick processes.

Standard conversion factor — A standard conversion factor is a number usually less than 1 that can be multiplied by the domestic financial market price, opportunity cost or value in use of a non-traded item to convert it into an equivalent economic border price that reflects the effect of trade distortions on domestic prices of that good or service.

Targeting — The process by which expenditure is directed to specific groups of the population defined as poor or disadvantaged in order to increase the efficiency of the use of resources.

Vulnerable — Vulnerability defined by combination of exposure to risk, sensitivity to shock (i.e. impact when a shock happens) and level of resilience and often referring to persons with an income poverty equal to 0.75 - 1.25 times the income poverty line.