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Proposal for a Cost-Benefit Framework to Support Pro-SLM Decision-Making in Ethiopia

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Abstract

The Cost Benefit Framework for pro-SLM Decision Making in Sub-Saharan Africa is an initiative by TerrAfrica at the World Bank to provide analytical contributions to the mobilization of additional financial resources for Sustainable Land Management in Sub-Saharan Africa. Two countries, Ethiopia and Ghana, have been chosen as pilots in the development of the framework.

The framework will compile relevant physical and economic information and make it available for policy analysis in a consistent manner. This will increase the reliability and availability of information on land degradation as well as its costs both on agricultural lands and downstream. It will also make use of existing research, and future research can fairly easily be incorporated, on the effectiveness of various SLM treatments so that this information can be used to calculate the returns from such treatments, taking into consideration both physical characteristics and economic factors. This is expected to be a valuable support to up-scaling of promising SLM technologies. Finally, since the CBF will be able to provide simulations of on- and off-site returns from treatments, this information can be used to both scale the size of investments in SLM and prioritize the use of these investments to areas with highest expected returns to society.

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List of acronyms

AEZ	Agro-Ecological Zones
CBF	Cost-Benefit Framework
CPA	Chane in productivity approach
DEM	Digital Elevation Model
ECPSLM	Ethiopia Country Program on Sustainable Land Management
EDRI	Ethiopian Development Research Institute
EIAR	Ethiopian Institute for Agricultural Research
EPA	Environmental Protection Agency
GAIL	Gross Annual Immediate Loss
GDCL	Gross Discounted Cumulative Loss
GDFL	Gross Deflated Future Loss
GEF	Global Environment Facility
GIS	Geographical Information System
HRU	Hydrologic Response Units
IRR	Internal Rate of Return
LGP	Length of Growing Period
MoARD	Ministry of Agriculture and Rural Development
MSP	Medium-Sized Project (supported by GEF funds)
NAIG	Net Annual Income Gain (or loss)
NDCIG	Net Discounted Cumulative Income Gain or Loss
NDIG	Net Discounted Income Gain or Loss
NPV	Net Present Value
RCA	Replacement Cost Approach
SCRP	Soil Conservation Research Project
SLM	Sustainable Land Management
SSA	Sub-Saharan Africa
SWAT	Soil and Water Assessment Tool
SWC	Soil and Water Conservation
UNCCD	United Nations Convention to Combat Desertification
USLE	Universal Soil Loss Equation

1 Introduction

1.1 Background

Land degradation is a major factor in the low agricultural productivity of Sub-Saharan Africa (SSA) and is estimated to be responsible for 2 to 3% loss in the agricultural GDP[1]. Although land degradation is recognized as a major development issue, sustainable land management (SLM) has not however received desired attention in the development agenda of SSA countries due to the existence of a number of critical barriers, including an unorganized body of knowledge, and weak analytical underpinnings to support decision-making processes. As a result, the scale and scope of investments in SLM programs continue to be limited. In the case of Ethiopia, for example, only USD 15 million of government spending was allocated to agriculture and natural resources conservation during the 1990's. This amounts to less than 3% of government spending during this period (EPA, 2005). According to the DAG, only about 7% of overseas development assistance goes to the agricultural sector.

A prerequisite for addressing these barriers, and promoting the adoption and scaling-up of SLM practices is to acquire a better understanding of the impact of land degradation and the related benefits of SLM. A better understanding of the negative impact of land degradation and positive effects of SLM would in fact provide evidence to decision-makers of the magnitude of the problem and of the benefits from implementing SLM policies and practices. Decision-making processes would thus be better driven, and based on a better understanding of the problem. In addition, by involving stakeholders (particularly key decision-makers) in the development of the framework this is expected to strengthen and focus the policy dialogue regarding this important sector.

1.2 TerrAfrica and the process leading to the CBF

TerrAfrica has been adopted as a multi-donor initiative hosted by the World Bank. It is part of a long-term programmatic commitment to support SLM through a collaborative and coordinated effort. TerrAfrica aims to foster immediate results on the ground, while putting in place a strong enabling framework for longer term, more predictable investments and lasting results. It offers opportunities to enhance the capacity and to scale up investments in SLM programs as a way to improve the

[1] This estimate is based on a recent review of cost of land degradation in Ethiopia which is part of the ESW phase I work on poverty and land degradation in Ethiopia.

contribution of natural resource management to economic growth and poverty reduction.

A prerequisite for the adoption of SLM programs is that policy makers are provided with reliable estimates of the magnitude of the land degradation problem, and that there are convincing evidences that the benefits from implementing policies, instruments, and SLM initiatives such as TerrAfrica, are greater than the costs. Under the activity line 2 – knowledge generation and management – TerrAfrica is developing a set of analytical tools to strengthen the knowledge of land degradation and its effects with the objective of mainstreaming SLM into the development agenda of Sub-Saharan countries.

In this context, the World Bank initiated an activity under the Africa project line on ”Costs and Benefits of SLM in African countries” to develop a pilot initiative on mainstreaming and partnership building in SLM, and providing analytical contributions to the mobilization of additional financial resources for SLM. The initiative was to contribute towards analytical work on the costs of land degradation and the barriers to the mainstreaming of SLM.

The objective of the Medium-Sized Project (MSP) expected to result from this initiative is “to increase in-country awareness of the true costs to livelihoods, growth and the environment, of land degradation.” It should further “clarify the potential benefits associated with increasing the scale and scope of SLM investments and related activities.” The SLM project should “complement existing systems in that it will strengthen the analytical assessment in dealing with not only economic costs but also environmental costs of first and second order as well as related benefits within a system of Natural Resources Accounting”.

The initiative, that was undertaken as a project by a Swedish team in 2004, resulted among others in reports on “Methods for Assessing the Impacts and Costs of Land Degradation and the Net Benefits of Prevention and Mitigation Measures” (Brismar-Björklund-Klintenberg-Christiansson, 2004), “Strategies to overcome barriers for sustainable land management in Africa” (Björklund-Brismar-Rudengren, 2004), a Concept paper: “A decision framework for accounting costs and benefits of land degradation and sustainable land management” (Vadnjal-Rudengren-Björklund, 2004), and a draft GEF/MSP Project Brief “Costs and Benefits of SLM in African Countries”.

The current initiative to design a CBF to support pro-SLM decision-making in SSA is a continuation of this process. The documents now produced under the current phase will result in a more detailed and specific proposal for a GEF/MSP which is to be implemented in some Sub-Saharan countries, including, as a priority, Ethiopia. There is an ambition that, based on the Ethiopian experience, the framework will later be applicable to other SSA countries.

1.3 Overview of land degradation processes and importance of SLM for Ethiopia

It has been said time and again that land degradation is one of the major problems affecting livelihoods of millions in Ethiopia. Although, comprehensive estimates of costs of land degradation is lacking in the country, it significantly affects agricultural production, with an estimated costs ranging from 2 to 6.75% of AGDP per annum (Yesuf et al. 2005, citing estimates by FAO (1986), Hurni (1988), Sutcliffe (1993), Bojo and Cassells (1995), and Sonneveld (2002). The Environmental Protection Authority (EPA) (1997) also estimated that approximately 17% of the potential annual agricultural GDP of the country was permanently lost because of physical and biological soil degradation. Moreover, the country also suffers from off-site effects of land degradation of various forms, although no detailed study has been done on this issue (Yesuf et al, 2005). These effects include siltation of dams, reservoirs, wetlands, lakes rich in biodiversity, and productive farm lands at foot slope areas. Such level of impact in a country where nearly 85% of the total population depends on subsistence agriculture is alarming.

The causes of land degradation are complex and have diverse nature and dimensions, depending on peculiarities of different countries, influenced as it is by a combination of natural and socio-economic-cultural factors. In Ethiopia, the heavy reliance of some 85 percent of Ethiopia's growing population on an exploitative kind of subsistence agriculture is a major reason behind the current state of land degradation. Moreover, land degradation is a long-term process in which the effect and steady expansion is hardly noticed until it manifests itself with disastrous drought and famine (Zeleke et al, 2006). That is why the policy attention to the problem was very little until the 1974 drought, although it has not still received policy support commensurate to the high risk it poses to the security of current and future livelihoods. Often land degradation is only associated to the tonnage of soil loss per hectare. It is in fact, the loss of productivity, which is more damaging as erosion removes the most fertile top soil, along with soil nutrients, organic matter, reduced soil depth and soil moisture holding capacity.

Although the country is endowed with enormous biophysical potential, it has been affected by the interlinked and reinforcing problems of land degradation and extreme poverty. This is further aggravated by high population pressure (currently about 72 million with annual growth rate of 2.5%), climatic variability, top-down planning systems, lack of appropriate and/or poor implementation of polices and strategies, limited use of sustainable land management practices, limited capacity of planners, researchers and land users as well as frequent organizational restructuring.

Moreover, the exploitative nature of the farming system also contributed to the high rate of deforestation that exposed the fragile landscape to erosive tropical rainfall and resulted in high and fast land degradation levels in many places. Deforestation results principally from: (i) the conversion of forests and woodland to cropland, and (ii) the harvesting of forests for fuel wood to meet the energy needs of a rapidly growing population. As a result, currently the high forest cover of the country is said to be reduced to about 2.4% of the total area as compared to the estimated 40% initial coverage (Tedla and Lemma, 1998). Even now, the remaining forest is being depleted at an alarming rate. This is partly due to the fact that nearly 95% of the total energy consumption originates from biomass fuels such as fuel wood, cow dung and crop residue. Burning of cow dung as a source of fuel, instead of using it as a soil conditioner, is considered to cause a reduction in grain production by some 550 thousand tonnes annually (EPA, 1997).

In addition to this, scarcity of grazing land and shortage of livestock feed has forced widespread use of crop residues as a source of livestock feed and in some parts as supplemental source of energy. The removal of crop residue for livestock feed, source of fuel and use of cow dung as a source of fuel results in subsequent loss of humus and soil nutrients from the soil that would otherwise have found their way back into the soil. This makes the nutrient cycle almost open and leads to a serious loss of soil quality, increased soil erosion and ultimately reduction in soil productivity.

According to Zeleke et al. (2006), the process of land degradation--which is a result of long history of agricultural activity combined with high level of population pressure and exploitative trends of agricultural practices--has led to the existing depletion of natural vegetative cover and over-utilisation of land resources in many parts of the country, and ultimately serious land degradation problems and intensified poverty.

Considering the above complex and interwoven problems of land degradation and poverty, it is evident that for Ethiopia, characterized by subsistence agriculture, extensive land degradation and chronic food insecurity, agricultural development with the application of sustainable land management (SLM) practices cannot be an option, but rather is an indispensable element of all development efforts (Zeleke et al, 2006). As demonstrated by different projects in the country, land degradation problems can be effectively addressed if SLM practices are properly planned in consultation with communities and implemented accordingly. Moreover, proper application of SLM practices with their proper quality, standard and integration requirements are key actions for effective results. Often, this is neglected and highly aggravates the current level of land degradation in the country.

1.4 Working definition of LD and selected LD processes to be addressed

Land degradation is a complex phenomenon influenced by natural and socio-economic factors. Most cost estimates of land degradation do not distinguish between soil erosion, soil degradation and land degradation in their analyses (see Mahmud et al., 2005 for definitional clarification of different components of land degradation).

Broadly defined, land degradation is a "reduction or loss … of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from … processes … such as (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, biological or economic properties of the soil; and (iii) long-term loss of natural vegetation" (Pagiola, 1999). Soil degradation is a narrower term for declining soil quality, encompassing the deterioration in physical, chemical and biological attributes of the soil (Enters, 1998). Soil erosion is a particular physical process that causes land and soil degradation, and refers 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 (Ibid.). Other forms of soil degradation include other types of physical degradation, such as compaction, surface sealing and crusting, waterlogging and aridification; chemical degradation, including depletion of soil nutrients, acidification, salinization, and pollution; and biological degradation, including loss of soil organic matter (which also affects physical and chemical properties of the soil), flora and fauna populations or species in the soil (e.g., earthworms, termites and microorganisms) (Scherr, 1999).

In Ethiopia, among others, removal of top soil through water erosion, nutrient depletion through the removal of dung and crop residues, off-site costs through sedimentation of water storages and lakes are believed to be major land degradation problems. Therefore, the framework focuses on estimating only these components of land degradation.

1.5 Brief review of past cost estimation information and gaps of knowledge of cost of land degradation

In Ethiopia, severe land degradation problems and negative productivity impacts have been observed both in low and high potential areas of the country (e.g. Desta, et al., 2001; Shiferaw and Holden 2001; Tefera, et al., 2002; Zeleke and Hurni, 2002; Okumu et al. 2002; Sonneveld, 2002). Over the last few decades, there have been several efforts to evaluate the on-site cost of land degradation in Ethiopia. These studies have reached widely varying conclusions concerning the nature, extent and economic cost of the land degradation problem. The diversity in methodological approaches and underlying assumptions used by these studies, contributes to this diversity of conclusions. This, together with the fact that the costs reported by different studies are not always reported in a manner that allows comparisons across them to be made, limits the ability to draw clear implications for policy and program decisions related to sustainable land management (Yesuf et al, 2005). In addition, some studies (e.g. Sonneveld, 2002) were based on earlier assessments of land degradation; however, the situation may have changed markedly in the past few decades. Despite the problems mentioned above, the range of on-site costs of land degradation estimated (2% to 6.75% of agricultural GDP) by the various studies for Ethiopia is not unreasonable as an order of magnitude estimate compared to the range of estimates of the cost of land degradation in several other African countries (Yesuf, et al., 2005). Bishop (1995) estimated costs of erosion to be 3% to 13% of agricultural GDP in Mali and 17% to 55% of agricultural GDP in Malawi. By contrast, Grohs (1994) estimated the costs of erosion in Zimbabwe to be less than 0.4% of agricultural GDP.

Table 1 summarizes the basic assumptions, methods, production losses due to erosion and weaknesses of past studies of the cost of land degradation in Ethiopia and other Sub-Saharan African countries. For a detailed critical review of various studies of cost of land degradation in Ethiopia, see Yesuf et al. (2005).

Table 1: On-site cost of soil erosion estimates from Ethiopia and other Sub-Saharan African countries.

Authors	Method used to compute soil erosion rate	Approach used to quantify erosion-yield relationship	Methods used to evaluate cost of soil erosion	Discount rate and (time horizon)	On site cost of soil erosion (% of AGDP)	Measure of cost
EHRS, 1986	USLE-like approach (not clearly specified)	No formal model but guesstimates based on international estimates	Change of productivity (CP)	9 (25 years)	2.2	Annual average of cumulative costs over 25 years (similar to GDFL)
SCRP, Hurni, 1988	USLE: modified for Ethiopian conditions	Experimental observations (52 sample plots of barley production)	CP	Only immediate losses are computed	2 (Bojö & Cassells, 1995)	Annual decrease in productivity
Sutcliffe, 1993	Used estimates from Hurni (1988). In addition to soil losses, nutrient losses from residues & dung was considered	Soil life model of Stocking & Pain (1983)	CP	Discount rate: not reported Time horizon: 25 years.	6.75 (including loss due to erosion & burning of dung and crop residues)	GAIL of nutrient losses, plus GDFL of erosion losses (GDFL < 1%)
Bojö & Cassells, 1995	Same as Sutcliffe	Followed approach of Sutcliffe, but adjusted for assumed effects of re-deposition of soil	CP	10 (100)	3 (including loss due to erosion and burning of dung)	GAIL and GDFL (GFFL < 1%)
Sonneveld (2002)	Empirical approach(EA): Map units based on UNEP/GRID, 1992 and for engineering approach(ENA) USLE, Expert and Accessible data models	EA: Non-parametric regression model & graphs where yield expressed as function of soil degradation index, ENA: calibration (empirical) relations. Yield reduction specified as a function of loss of soil fertility & water holding capacity within each map unit. Soil fertility classified into three based on their susceptibility to erosion and percentage of yield reduction assigned for each class. Similarly water-holding capacity was related to other soil characteristics.	CP	Not indicated (10 years for EA and 10 & 30 years for ENA but we consider 10 (2000 to 2010 to be comparable to other studies)	2.93	

Source: Yesuf et al. (2005)

Previous studies on cost of land degradation in Ethiopia have hardly been able to estimate the off-site costs and to show empirically the costs and benefits of sustainable land management (SLM) interventions to mitigate land degradation and improve productivity Cost of land degradation, no matter how well done, will only take us a little way towards deciding what to do about it. Decision makers need to know what actions can be taken that are socially profitable. That requires investigating off-site effects where those are likely to be important, as well as on-site costs and benefits of land management options. This is important to fill the knowledge gaps on SLM practices (e.g. see Zeleke et al., 2006), in scaling-up SLM technologies/practices and in designing policies and programs to address land degradation and sustainable land management in Ethiopia.

The proposed Cost-Benefit Framework is intended among other things to address these issues. By organizing the current information in a way that makes it useful for planning and implementation, it is expected that the impact of past research will be improved. The CBF could also be used to target the design of new applied research on SLM technologies so that this research can support future successful up scaling of the technology. Ideally, the CBF could be a unifying framework that would be constantly updated based on the latest findings on SLM not only from Ethiopia but from the whole region.

1.6 Barriers to and enabling conditions required for the mainstreaming of SLM

Strategies for promoting, mainstreaming and implementing SLM strategies may include government policies, market regulations or deregulations, different taxation systems, capacity enhancement and applied research programmes, etc. They may also imply different types of incentives, at district level or at farmers' level, including measures for handling of off-site effects of SLM. Such strategies may address potential barriers for implementing SLM practices.

More specifically, mainstreaming of SLM requires three development components, i) use of different technologies/practices and integration among them to solve ecological and socio-economic constraints, ii) the need for participatory land management planning to meet community needs and use of the renewable natural resources sustainably without compromising their environmental functions, iii) and the need for an appropriate policy environment to undertake the above major tasks on an equitable basis.

Along this line, Zeleke et al., (2006) foresee a number of requirements to improve the quality of intervention and to scale-up SLM practices successfully. These include intraand interdisciplinary linkages, effective integration of practices/technologies, flexibility in addressing community needs and priorities, participation of communities in the decision making process, existence of appropriate capacity and resources, appropriate policy environments and, most important of all, efficient utilization of available manpower and resources. Blanket recommendations and approaches cannot address specific local situations and hence cannot ensure SLM in general. Therefore, implementation of SLM should be seen within the specific local context. Moreover, SLM also aims to harmonize the potentially complementary but often conflicting goals of production and environmental protection. Hence, the need for balancing between economic feasibility and ecological soundness of SLM practices has paramount importance.

These being the major requirements of SLM, the barriers to SLM within the Ethiopian context are numerous. The most important barrier is the lack of proper awareness among policy makers of the extent and impacts of land degradation. This has emanated from gaps in relevant empirical evidence and the inability to present the existing facts about land degradation in a way that is useful to decision making bodies. Further barriers are the lack of awareness of the nature and technical requirements of SLM practices; a top-down planning approach to technical assistance combined with limited capacity to plan and implement SLM practices at all levels (including communities); weak linkages between technology generation and dissemination (inter- and intra-discipline); limited availability and poor networking of information on SLM; lack of appropriate policies and strategies for SLM and weak implementation of those that exist; institutional instability; lack of up a mechanism to scale up successful SLM practices; the existence of extreme poverty with its implications for risk aversion and short planning horizons hampering the adoption of long-term investments; and shortage of resources and incentives. These key barriers significantly hinder successful implementation and mainstreaming of SLM in the country (see also Zeleke et al., 2006 for a more detail description of barriers of SLM).

Despite the above mentioned barriers, there are many significant enabling conditions from which one could capitalize to properly mainstream and implement SLM practices in the country. Most importantly, the government has made commendable efforts to establish a number of good environmental policies and strategies, although the implementation leaves much to be desired. One of the most important umbrella polices is the Environmental Policy of Ethiopia. This policy was approved by the Council of Ministers in 1997 and addresses a wide variety of sectoral and cross-sectoral environmental concerns in a comprehensive manner (for details see Zeleke et al, 2006).

There is also a rich experience on participatory watershed management in the country, which is one of the key requirements for successful implementation of SLM. The organizational setup of the MoARD and the National Research System, which has significant presence at grassroots level, has high potential for effective implementation of SLM. Moreover, the availability of both indigenous and scientific knowledge on SLM and the country's ecological diversity emanating from its geological formation give great opportunities to test a wide array of SLM technologies and practices in different combinations. It is not only the availability of SLM technologies and knowledge, as mentioned above, but also the fact that there are areas in different parts of the country where pockets of successful SLM practices are visible that give potential to learn from and scale-up to wider areas. The existence of many global and regional environment initiatives and the willingness, despite some conceptual limitations, to arrest land degradation by the decision making body at all levels are the other enabling conditions that need to be properly exploited.

1.7 Outline of policy uses of a cost benefit framework

In brief, the picture that has emerged from the preceding sections is (i) that land degradation leads to substantial welfare losses for poor people in rural areas of Ethiopia, and that these are particularly serious in the mid- and long-term on agricultural lands while the downstream impacts are much less documented but potentially serious; (ii) that a fair amount of research on land degradation and SLM technologies have been carried out in the past but that it is non-trivial to base extension advice and scaling-up policies on this research since it is not compiled in a way that is conducive to policy analysis; finally (iii) that there is a need to prioritize SLM interventions, particularly in the light of greater international interest to support large scale SLM interventions in Ethiopia, such as the proposed Ethiopian Country Program on Sustainable Land Management (ECPSLM). The Stakeholder Analysis (Zeleke et al., 2006) also indicated that the government extension system for natural resource management could benefit from an improved knowledge system to base its priorities on.

It is in this perspective that the proposed CBF is expected to play an important role. The framework will compile relevant physical and economic information and make it available for policy analysis in a consistent manner. This will increase the reliability and availability of information on land degradation as well as its costs both on agricultural lands and downstream. It will also make use of existing research, and future research can fairly easily be incorporated, on the effectiveness of various SLM treatments so that this information can be used to calculate the returns from such treatments, taking into consideration both physical characteristics and economic factors. This is expected to be a valuable support to up-scaling of promising SLM technologies. Finally, since the CBF will be able to provide simulations of on- and off-site returns from treatments, this information can be used to both scale the size of investments in SLM and prioritize the use of these investments to areas with highest expected returns to society. But before we return to these potential policy uses of the framework in Section 3.4 we need to elaborate on the methodological steps required to assess land degradation, the productivity implications of treatments and the economic evaluation of these changes. The physical assessment is dealt with in Section 2, while the economic assessment is described in Section 3.

2 Methodologies for assessing land degradation and SLM practices

2.1 Classification and identification of recommendation domains for the CBF

Previous attempts to quantify land degradation processes in Ethiopia were highly constrained by lack of relevant reliable data sets. Most of them use USLE and ranges of parameters that were developed for the conditions of USA. In this study we are attempting to use the data sets of the Soil Conservation Research Project's (SCRP) gauged stations and extrapolate their results to homogenous land units represented by each station. We, however, are not claming that our approach is free from errors but at least we will try to minimize these errors by extrapolating results of each station to areas that have similar agro-climatic conditions to that of the stations. This classification will be used to predict both the on-site and off-site processes of land degradation. Attempts will be made to calibrate both empirical and process-based erosion models using gauged data sets of SCRP and extrapolate the result to the identified recommendation domains. It is, however, found important to characterize stations and find domain areas that can be represented by each station. Given that data is only available for 6 stations, the whole country will unfortunately not be covered with the existing data.

An attempt was made to use the already existing 18 major AEZs that are basically partitioned based on moisture availability related to rainfall condition, evapo-transpiration, and other factors that are used to delineate Length-of-Growing Period (LGP) zones, and thermal zones which result from temperature and altitude. Although altitude, temperature and moisture regimes determine much of agricultural activity, this classification may not fully capture the soil nature, current status of land degradation and local specific farming systems. Even if we attempted the possibility of representing one or two of the major AEZs by a station, we found it difficult given the location of the six research stations and the current classification of AEZs.

Instead we propose the development of simple criteria based on major characteristics of SCRP stations. Since land degradation is closely linked to land management, which is in turn a function of current farming systems, slope, climatic conditions, soil and current level of degradation, we propose to classify the highlands into representative recommendation areas similar to that of SCRP stations. The following broader classification procedures are recommended:

i) <u>Characterize SCRP stations:</u> the initial step to be done is to identify major biophysical and farming systems characters that could be presented by each of the SCRP research stations. Even though the altitudinal belt could be the same for some stations, their biophysical and farming system conditions may not necessarily be similar depending on their location in the country. As indicated in Appendix 1, altitude, rainfall, major crops, level of soil degradation and LGP are used to characterize SCRP stations. The criteria for classification and the ranges of some of the biophysical elements should be further checked and refined based on field observation.

ii) <u>Develop national layers for each factor:</u> for the major factors used to characterize each station a national map (focusing on the highlands) should be developed at a scale of 1:250,000. Although the models suggested in the following sections can be applied at different scales, we feel that 1:250,000 is a fair size to determine costs of land degradation at national level. Except from soil and related factors other factors can be generated from existing studies and GIS modelling at this scale. However, different mechanisms can also be used to reduce additional data collection at this scale.

iii) <u>Define homogenous recommendation domains:</u> by overlaying the different factors selected to characterize research stations it is possible to identify homogenous units that can be represented by the different SCRP research centers. However, there will be some areas that may not be represented by any of the stations. Further work is needed to characterize and quantify the soil loss of these areas.

2.2 Assessment of SLM practices: past country experience and possible scenarios

We tried to see SLM measures that have been applied to control land degradation in different forms in the past and possible scenarios of improvement in three major land use/land cover classes, i.e., cultivated land, woodlots (mainly on hilly areas) and degraded hillsides. We will try to quantify their ecological impacts in reducing land degradation (mainly soil loss) and costs and benefits of applying the different options. Overall we will have three broadly classified scenarios for cultivated lands, two for afforestation and two for degraded land rehabilitation and they are briefly discussed as follows.

2.2.1 Selected SLM practices on cultivated land

The major SLM practices, and combination of practices, that have been used on cultivated lands can be broadly classified into three levels and they are presented as follow:

i) Only physical soil and water conservation structures (Conventional)

The use of physical soil and water conservation measures (SWC) to halt land degradation has been the most commonly practiced treatment in many parts of Ethiopia. Although there are other physical SWC measures, Fanyajuu, soil and stone bunds were the three most important conservation measures that have been used across the country. Depending on the rainfall situation they can be designed as level (in moisture deficit areas) and graded (in high rainfall areas). Though they are effective in reducing soil erosion in many parts, they cannot give desired results by themselves in terms of improving land productivity in the short run, particularly in high rainfall areas. In this study we will try to quantify the costs and benefits of applying these measures on identified domain areas using SCRP research findings.

ii) Physical SWC measures combined with soil fertility and moisture management (Standard)

As mentioned above, the use of physical SWC measures only may not yield desired results in halting land degradation and improving land productivity. To get better results, at a minimum, such physical SWC measures should be integrated with soil fertility management (such as composting, farmyard manuring, cover crops, fertilizer application etc.) and moisture management (such as mulching, deep ploughing, tie-ridging, etc) is essential. This scenario has not been seriously monitored in the country and exhaustive data is not available. However, efforts should be made to collect the relevant information, including direct field measurements, to include this treatment in the framework by using existing experience in some project sites with the above set of interventions.

iii) A combination of all best land management practices (Progressive)

This is the kind of treatments where physical SWC measures combined with soil fertility management, moisture management, and agroforestry (including above, on and below bund plantation, in-between terrace plantation, etc.). The planted materials are expected to have multiple purposes such as improving soil fertility, source of fodder, food (fruits, pulses, etc), and fuel wood. Therefore, the farmer will get income not only as a result of soil conservation but from the vegetative materials themselves. Like that of the second scenario there is no experimental data available for this scenario in the country. The same approach as discussed above will need to be used to quantify costs and benefits of this combination, with particular consideration to marketable products and long-term investments in terms e.g. fruit trees.

2.2.2 Afforestation

State, community and individual woodlot development of various sizes has been one of the major actions taken by the government, communities and non-state actors in the country. With the exception of recently developed eucalyptus woodlots (often on fertile and flat areas), most of the past afforestation efforts have been on steep and mainly degraded areas. Under this we will try to quantify woodlot development and their possible impacts in reducing land degradation in two scenarios: i.e., with and without moisture conservation practices.

2.2.3 Rehabilitation of degraded hillsides

Like that of woodlot development efforts, large area, mainly degraded hillsides, has been closed to enhance regeneration of the ecosystem in many parts of the country. Although the speed of regeneration and quality of vegetation varies from place to place depending on the level of degradation and aridity (keeping management constant), moisture management is essential. Therefore we will try to quantify impacts of area closure in halting land degradation with and without moisture conservation measures.

2.3 Quantifying major impacts of land degradation[2]

2.3.1 On site impacts

There have been a number of studies and estimates in the past to quantify the on-site impacts of land degradation. Studies by EHRS, (1984), Hurni (1988), Sutcliffe (1993) and Sonneveld (2002) are some of the studies that have tried to closely investigate the impacts of land degradation at national level. Most of them recognize that sheet and rill erosion by water, and burning of dung and crop residue are the major components of land degradation

[2] The full set of methods and procedures of estimating land degradation processes for the biophysical component are presented on Appendix 1.

that affects on-site land productivity. The approach proposed for the CBF will draw on the previous research in this area by estimating, predicting and quantifying the biophysical processes for the identified recommendation domain areas.

2.3.1.1 Determining soil loss using Universal Soil Loss equation (USLE)

Although it is possible to apply other soil loss models, which are more precise in modelling soil erosion processes, the applicability is always a question. Therefore, we propose the use of the USLE, but with proper model calibration and identification of model parameters based on actual measurements at SCRP stations. The application of the USLE and model parameters will not represent the whole country, but only the areas that can be represented by research stations as discussed in Section 2.1.

The USLE is an empirical overland flow or sheet-rill erosion equation (Wischmeier-Smith, 1978). It is a regression equation developed based on information from large data sets and lumps inter-rill and rill erosion together in order to estimate average soil loss over an extended period, e.g., average annual soil loss (Foster, 1982). The limitations of the model are: i) it is not designed to estimate soil loss from single storm events; ii) it is an erosion equation, and consequently does not estimate deposition; iii) it does not estimate gulley or channel erosion. Sonneveld (2002) also mentioned various model limitations based on his own detailed analysis of the model and works of Risse et al., (1993) and Nearing (1998).

Apart from the above limitations, the model gives fair estimates provided that its model parameters are carefully generated based on local information. Since we are not interested in single storm erosion events and not specifically interested in estimating gulley and channel erosion, the limitations may not affect the intended framework very much except for the lack of a deposition element. A fair assumption will be made to account for the latter limitation (see section 2.3.1.1).

Sonneveld (2002) did a comprehensive analysis of the applicability of USLE for Ethiopian conditions using the SCRP database. We propose that the CBF builds on the regression work he did with only one exception. He extrapolated the results from SCRP stations to the whole nation but we propose extrapolation of results only to the areas that have similar conditions to that of the relevant SCRP stations. Moreover, for some of the parameters he applied literature values. We are of the opinion that attempts should be made to estimate model parameters based on specific local conditions.

Accordingly, to quantify soil loss using USLE the following three important actions are proposed: i) develop coefficients for USLE based on SCRP data sets (which means adapted to stations biophysical and management conditions, some parameters can be directly taken form the work of Sonneveld (2002) and Hurni, (1985), ii) classify the highlands into different recommendation domains (AEZs) similar to that of SCRP stations and apply the same USLE coefficients to these areas, iii) develop layers for major variables for each recommendation domain (i.e., soil, land use, climate, management, and slope). Then determine soil loss using the following equation:

$$A = R * K * SL * C * P \tag{1}$$

Where *A* represents the soil loss expressed in tons/ha/year; *R* refers to the rainfall erosivity factor[3]; *K* is the soil erodibility factor reflecting the susceptibility of a soil type to erosion.[4]. *SL* is the topographic factor expressed as the expected ratio of soil loss per unit area from a field slope to that from a unit plot under otherwise identical conditions. *C* is cover-management factor expressed as the ratio of soil loss with a given management practice to that from a unit slope. It is an index for the protective coverage of canopy and dead plant materials (residue) in contact with the ground. The support practice factor, *P*, is defined as the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down slope culture. Support practices include contour tillage, strip-cropping on the contour, and various terrace systems that are applied to control erosion. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

Although part of the sediment detached from the land mass is deposited downstream, it is often on depressions and channels of streams and rivers where it is difficult to reuse the deposited sediment. However, 10-15% of the sediment is assumed to be deposited on part of the landscape that can be reused for production purposes. This assumption is developed based on results of SCRP research stations.

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[3] Calculated by the summation of the erosion index EI30 over the evaluation period, often average annual. EI30 is a compound function of the kinetic energy of a storm and its 30 minutes maximum intensity (for details refer to Sonneveld, (2002), Wischmeier and Smith, (1978), Neitsch, S.L., et al, (2002).

[4] Wischmeier and Smith (1978) defined it as the soil loss rate per erosion index unit (R) for a specified soil as measured on a unit plot. A unit plot is 22.1-m (72.6-ft) long, with a uniform length-wise slope of 9-percent, in continuous fallow, tilled up and down the slope. Continuous fallow is defined as land that has been tilled and kept free of vegetation for more than 2 years (Wischmeier and Smith 1978).

2.3.1.1.1 Procedures of model parameter development

Although the parameters required for the model are six and they look simple, probably USLE is one of the most data demanding empirical models. Moreover, since the mathematical form of the equation which is a multiplication of six lumped parameters leads to larger errors (Wischmeier, 1976), the development of model parameters requires careful analysis of situations in each center and available data sets. Taking this into consideration, the parameter generation could benefit a lot from the work of Sonneveld (2002), Hurni (1985b) and Zeleke (2000) as indicated under each specific parameter, i.e., *R, K, SL, C* and *P*. Detail procedures of parameter estimation and options are presented in Appendix 1.

2.3.1.1.2 Procedures of extrapolation and calculation of soil loss for recommendation domains

Once the model parameters for each center are developed and refinement of parameters, using different techniques including calibration (if found necessary) is done, the next step is determining soil loss for the recommendation domain represented by the specific SCRP centers. Before this, however, the following actions should be undertaken for each recommendation domain area:

i. <u>Preparation of land use/land cover map:</u> land degradation is strongly associated to land use and land management conditions. Therefore, preparation of this component with fair accuracy is an essential element of the whole exercise. However, the task could be very expensive and demanding if one attempts to do it from zero at national level. Luckily, the Woody Biomass project has recently finalized a land use/land cover map of the country at 1:250,000 scale, this data can be directly used for this purpose with some field observation after the draft map is prepared. What is important is that this map should be clipped by the boundaries of the identified recommendation domain areas.

ii. <u>Preparation of soil map:</u> As indicated in Section 2.2 and Appendix 3, this is one of the oldest and most coarse data sets available in the country. However, appropriate information on soil is highly important in determining costs of land degradation and other actions in the country. Full national coverage soil map is available only at a scale of 1:1,000,000. However, there are many soil databases at scale of 1:250,000, particularly basin studies, which can be used for this purpose with fair adjustment (Abayneh Esayas, 2006, personal communication). Therefore, the soil map should be prepared for each domain area by bringing together the entire available (and reliable) soil database (map) at the scale of 1:250,000 and filling identified gaps using fair and quick survey techniques. However, this shall not be done at the expense of quality and care should be taken in defining the methodology and undertaking the task. Producing the soil map with all associated soil quality (chemical and physical including soil depth) at the scale mentioned above is one of the major tasks to be undertaken as part of the implementation of the CBF.

iii. Prepare topographic map: A digital elevation model (DEM) can be prepared from available satellite images or directly taken from already released DEM by different international research agencies. The 90x90 m^2 pixel DEM is freely available but since this is a bit coarse efforts should be applied to acquire the recent 30x30 m^2 pixel DEM. Using this, it is possible to extract topographic factors that could be reclassified afterwards.

iv. Reclassification work: Once the above three products are made available one would need to perform reclassification work to develop model parameter layers, for the parameters *C*, *K*, and *SL*. The following are the reclassification tasks:

  a. *Developing the C factor map:* the land use/land cover map can be converted to a *C* factor map by assigning selected *C* coefficients to each land use type. Since the cultivated land will not show crop based divisions but rather percentages of dominant crop covers for each recommendation domain, the *C* factor for the cultivated land will be calculated as the weighted average of the crop specific *C* factors: Once this is determined and the *C* factors for all land use units have been calculated, these coefficients can be assigned to each land use unit to create a *C* factor map.
  b. *Developing the K factor map:* based on the methods suggested in Appendix 1, the *K* factor can be calculated for each soil unit or if the user has a predetermined *K* factor for each soil type, then the factors can be assigned to each soil unit and can be converted to a *K* factor map.
  c. *Developing the SL factor map:* the DEM should be reclassified with the identified *SL* classes (factors) and a *SL* factor map can be produced.
  d. *Develop a P factor map:* assign a *P* factor for each land use unit based on management options exercised in the recommendation domain and produce a *P* factor map.
  e. *Define annual R value* for the recommendation zone (it could be a single or average value of major stations).
  f. Then overlay the four reclassified maps and calculate soil loss using the following equation for each map unit:

$$A_i = R_{aez}\left(K_i * C_i * P_i * SL_i\right) \tag{2}$$

Where A_i is soil loss for the map unit '*i*' with specific *C*, *P*, *SL* and *K* values as extracted from previous map overlays (see Appendix 1 for details of calculating each parameter).

v. <u>Calculate Gross Soil loss using the following equation:</u>

$$A^g = \sum_{i=1}^{n} A_i \tag{3}$$

Where A^g is gross soil loss for the recommendation domain or for a major land use unit within the domain.

vi. Determine soil formation rates, S^f , for each domain area using the following equation proposed by Hurni, (1983),

$$S^f = S^{mf} * t * r \cdot l * u * d * s * c \tag{4}$$

Where, *t* is mean annual temperature, *r* is mean annual rainfall, *l* is length of growing period, *d* is soil depth, *s* is slope gradient, *c* is land cover and land use. S^{fm} is maximum soil formation factor for tropical zone and its suggested value is 24 tonnes/ha/year.

vii. Assign the proposed soil deposition amount for the domain area, *D;*

viii. Calculate net soil loss for the recommendation domain using the following equation (this can also be done for a specific map unit *i*):

$$A^n = A^g - S^f - D \tag{5}$$

Where A^n is net soil loss for a recommendation domain or for the selected land use unit within the recommendation domain.

To account for annual reduction of soil depth as a result of soil loss use the following equation (modified after Mantel and van Engelen (2000) cited in Ephraim Nkonya, et al., (2006))

$$\Delta S = \left(\frac{A^n}{B}\right) * 0.01 \tag{6}$$

Where ΔS is loss of soil depth (in cm), A^n is net soil loss in Kg/ha/yr, and B is bulk density of top soil in kg m^{-3}. The net soil loss and the change in soil depth will be used when estimating the crop specific production function in order to establish the impact of soil erosion on productivity, see Section 3.3.

2.3.1.2 Determining nutrient loss

The other key component that needs to be determined to assess the on-site effects of land degradation is nutrient loss. Although there are a number of ways for nutrient to leave the soil, we only consider three major types of possible nutrient flows out of the soil, i.e., dung and crop residue burning and crop grain produced and removed.

2.3.1.2.1 Estimating nutrient loss due to dung and crop residue burning

This is the aggregated amount of dung and crop residue burnt at household level and sold in market by each household. The intensity of dung and crop residue utilization as a source of fuel varies depending on the level of fuel wood availability and agro climatic conditions. Communities use dung as a source of energy in many parts of the country where the climate is cold and fuelwood availability is scarce. The best method to know the amount of dung and residue utilization is through comprehensive household survey. So far there are three surveys done along this line, i.e., by Newcombe (1989) and ENEC (1986). Sutcliffe (1993) compared the two studies and use the results of ENEC because of its comprehensiveness and nationwide coverage. This information was then updated by a comprehensive survey carried out as part of the Woody Biomass Inventory, under the leadership of Sutcliffe. Removal of dung us thus available for the whole country but only at Woreda level. This will be the basis for calculation of gross nutrient loss due to dung and crop residue removal. However, the loss needs to be decomposed into the loss in nitrogen (N) and phosphoros (P), based on dung and crop specific factors (see table in Appendix 1). N^{db} and N^{cb} are loss of nitrogen as a result of dung burning and crop residue burning respectively; N^A is addition as a result of fixation, weathering and addition of fertilizer and/manure. Similarly, loss of phosphoros, ΔP, is a result of P^{db} and P^{cb} dung burning and crop residue burning, respectively, where P^A is the net addition as a result of weathering and addition of fertilizer and/or manure, respectively. The nutrient balance will then be merged with the loss from grain removal and is shown in equations 7 and 8.

However, only a proportion of the dung burnt would actually be available for refertilization of agricultural lands. A leakage factor, α, is therefore introduced. This leakage factor could be estimated from detailed household surveys such as the Ethiopian Environmental Household Survey, carried out by AAU/Göteborg University in Amhara Region.

2.3.1.2.2 *Estimating nutrient loss due to removal of produced grain*

Every part of the plant is made of soil nutrients and water. Removal of crop grain or other edible parts of plant is another way for depleting soil nutrient. This is often neglected but we are trying to incorporate this in the nutrient balance calculation and see its impact in affecting soil productivity in general.

We will only focus on the production of dominant crops in each of the identified recommendation domains. Based on the land use data we can roughly estimate the amount of grain production using average values on hectare basis.[5] The conversion of grain yield into major nutrient losses can be calculated using the crop specific conversion factors indicated in Appendix 1. The resulting loss of nitrogen and phosphorus due to grain removal is given by N^{gr} and P^{gr}, respectively. The total change in nitrogen and phosphorus is the sum of these, as indicated in equations and the following series of equations 7 and 8:

$$\Delta N = \alpha N^{db} + N^{cb} + N^{gr} + N^{A} \qquad (7)$$

$$\Delta P = \alpha P^{db} + P^{cb} + P^{gr} + P^{A} \qquad (8)$$

The evaluation of these changes in the nutrient balance of the soil will be discussed further in Sections 3.2 and 3.3. One possibility is to include them in the crop production function in order to estimate the loss directly in crop production. Another approach, proposed in Section 3.3 is to use the replacement cost method and calculate the cost of replacing the lost nutrients. The value of these changes in nutrients is included as η_t in Section 3.3.

2.3.1.3 Estimating impacts of SLM practices

2.3.1.3.1 *On cultivated lands*

a) 1st scenario: Only physical SWC measures.

For each treatment it is essential to have field or experimental data in order to relate the treatment to changes in land degradation and impacts on productivity of various crops. With regards to physical SWC measures, it is recommended to use existing SCRP data set (results of experimental plots). These data sets have rich information on the impact of treatment in reducing soil loss. It has also been used to estimate production changes (see e.g. Shefiraw and Holden (2001). For those areas that are not represented by SCRP some

[5] The nation-wide agricultural census can prove to useful in predicting dominant crop for each area under analysis.

literature values representing the situations of these areas could be used to calculate impacts of the above selected measures.

b) **2nd scenario: Physical SWC measures with soil fertility and moisture management practices**

To determine the impact of this scenario, there is no well organized data at national level. Therefore, there are two possible ways to determine its impacts: i) conduct a minimum measurement by developing simple methodology to undertake on selected recommendation domains. ii) Modelling can also be used to determine the impact of these combinations. The WEPP model profile version, which was adapted to the Ethiopian condition (Zeleke, 2000), or SWAT model can be used to determine the impact of such interventions.

c) 3rd scenario: All best management practices:

We also do not have well organized data for this scenario like that of the second scenario. Similar approaches can be followed like mentioned on scenario 2 but the measurement part might require more time. Possible measurements could be done on already well established project sites. In any case careful methodology development and model parameter development is required to get better results.

2.3.1.3.2 Afforestation

To determine the impacts of afforestation as one SLM practice in reducing land degradation and its economic benefits, the following two scenarios are recommended to be seen:

a. Afforestation with moisture conservation measures

This includes afforestation trenches, eyebrow basin, and micro-basin structures. It is known that survival and growth rate is high when plantation is done with moisture conservation structures. The above recommended structures have also their own costs and positive impacts. Therefore, it is recommended to quantify the impacts of afforestation through use of these measures either through measurement or using some literature values. Data from ARARI could help to develop the relations for specific recommendation domain areas.

b. Afforestation without moisture conservation measures

For the last many years afforestation has been undertaken using plantation pits only. In areas where moisture is limiting and high temperature areas, survival rate has been very low. Which means both the biophysical and economic benefits of plantation has been very low. This can be directly measured or taken from existing research results. Data from ARARI can also be used for this purpose.

2.3.1.3.3 Rehabilitation of degraded lands (area closure)

Area closure has been one of the major SLM activities that have been undertaken by the government and local communities for the last many years. This has been the case in many degraded parts of the country. Depending on many factors, very successful results have been registered in the past. The past experience shows that area closure can be done with and without moisture conservation measures. These are discussed below.

a. <u>Area closure with moisture conservation structures</u>

Many experiences in the country showed that area closure with moisture conservation structures, i.e., hillside terrace (widely spaced) combined with either trench, eyebrow basin or micro-basin give better results. The regeneration speed and capacity is very high. This should be investigated either through simple measurements or using literature values. The additional costs of these structures would also need to be carefully recorded.

b. Area closure without moisture conservation structures

This has been the major action by the government and local communities in the past. The impacts of these measures need to be investigating using available data or direct measurement like that of afforestation.

2.3.2 Off-site impacts

Offsite impacts of land degradation have been neglected in previous studies in Ethiopia. This is not due to its lack of importance but it is mainly related to lack of appropriate tools to quantify offsite impacts of land degradation and the complexity to capture major features. We, however, feel that this is an important component of land degradation in Ethiopia and foresee possible work to quantify at least three major offsite impacts on selected parts of the country, i.e. siltation of dams and reservoirs that reduces storage capacity for power generation and irrigation (Koka, Sendafa, Angereb and Adwa dams), siltation of lakes that affects biodiversity (Lake Tana and Zewai) and deposition on downstream agricultural lands that reduces cultivated land and grasslands (Ambassel Area, Wollo). We will therefore focus on presenting the methodology and tools to quantify the off-site impacts that we propose for the CBF.

To quantify siltation and related problems on reservoirs and lakes, we choose the Soil and Water Assessment Tool (SWAT) basin/watershed model. We found that SWAT has much potential to estimate the above two offsite impacts. Main features, components and functions of the model and application procedures are described in the following sections.

2.3.2.1 Quantifying siltation of dams and lakes using SWAT model

2.3.2.1.1 The SWAT Model and its capabilities

The Soil and Water Assessment Tool (SWAT) is a river basin, or watershed, scale model developed by the USDA Agricultural Research Service. It is a continuous time, physically based and distributed watershed model (Tolson and Shoemaker, 2004). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical movements in large complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2001a; 2001b). To satisfy this objective, the model is physically based. This means, rather than incorporating regression equations to describe the relationship between input and output variables, SWAT requires specific information about weather, soil properties, topography, vegetation, and land management practices occurring in the watershed (Neitsch et al., 2001a; 2001b).

Accordingly, the physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modeled by SWAT using the above mentioned input data sets. Benefits of this approach are: i) watersheds with no monitoring data (e.g. stream gauge data) can be modeled; ii) the relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, etc.) on water quality or other variables of interest can be quantified; iii) uses readily available inputs; iv) is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money; v) enables users to study long-term impacts.

SWAT allows a number of different physical processes to be simulated in a watershed, i.e., hydrology, crop growth, soil erosion, nutrient and pesticide movement within the soil. The other potential of SWAT is its capability to take point source pollutants as an input and simulate their downstream impact. It also shows the impact of different management options on soil, water and nutrient flow balances. This means that the user can apply the recommended SLM practices indicated on Section 2.2, on major land use units and could see their downstream impacts.

The model simulates processes at three levels: i) at Hydrologic Response Units (HRU), ii) sub-basin and iii) watershed level. HRU are sub-components of the sub-basin that are comprised of unique land cover, soil and management combinations. Simulation of processes at HRU level allows the user to locate where in the watershed major processes happened, in other words it allows locating hotspots within the watershed. Depending on the requirements of the user the model generates outputs for the three levels mentioned above. Therefore it is essentially a very powerful tool to predict both on-site and off-site land degradation process.

The model has a weather generator that generates daily values from monthly average values. It generates daily precipitation, air temperature, solar radiation, wind speed and relative humidity. Since the weather generator is developed for the US weather database system, it needs minor adjustment to adapt it to other countries weather databases.

Apart from the weather generator it has also a GIS interface. The interface allows classifying the watershed or basin into sub-basins (sub-watersheds) following drainage networks and the sub-basins into HRUs based on user defined criteria (i.e., soil, land cover and management options). The user can also run the model through this interface and this allows viewing results on map display.

The GIS interface software is called AVSWAT-2000 (version 1.0) (Di Luzio et al., 2002) which is an ArcView extension and a graphical user interface for the SWAT model (Arnold et al., 1998).

According to Di Luzio et al., 2002), the AVSWAT-2000 ArcView extension evolved from AVSWAT, an ArcView extension developed for an earlier version of SWAT. In its current version, important functional components and the analytical capability of ArcView GIS are implemented in several sets of customized and user friendly tools designed to: (1) generate specific parameters from user-specified GIS coverages; (2) create SWAT input data files; (3) establish agricultural management scenarios; (4) control and calibrate SWAT simulations; (5) extract and organize SWAT model output data for charting and display. The most relevant components of the system are: (1) a complete and advanced watershed delineator, (2) a tool for the definition of the Hydrologic Response Units, and (3) the latest version of the SWAT model with a relative interface (for details see Di Luzio et al., 2002).

The only limitations of the model are its data requirements, a need of some data readjustment to fit the models data structure, and good professional capacity.

Therefore, apart from the limitations mentioned above it is a powerful tool to predict off-site impacts of land degradation mainly on lakes and storage dams (reservoirs). In general, the SWAT model can be used to predict the off-site impacts of land degradation (biophysical processes) in selected watersheds in Ethiopia.

2.3.2.1.2 Procedures of model application

Prior to the application of the model there are a number of steps that need to be taken. First and foremost, the user should try to understand what the model could do and what the requirements are of the model as well as its limitations. Following this sensitivity analysis, preliminary model parameter generation, model calibration, parameter adjustment, model validation and application are subsequent steps in the model adaptation processes (for details on process-based model adaptation see Zeleke, 2000).

Before site-specific data is collected the model should be calibrated and validated using SCRP research stations. Anjeni research station is a perfect site for this purpose because it is possible to benefit from the modeling experience and data filtering steps from Zeleke (2000). Once the model is calibrated and adapted using measured values of SCRP stations, parameter generation of selected test watersheds or basins should follow. Efforts should be applied to derive model parameters from existing datasets. However, the available soil data layer is rather coarse and one might need to conduct a detailed soil survey on selected watersheds at a scale of 1:100,000 or 1:250,000. Most other parameters can be derived from satellite images (land use, DEM, slope, etc), from agencies (such as climate data) and applying different transfer functions and modules as well as generic values from literature (see also Di Luzio et al., 2002).

2.3.2.1.3 Procedures of translating model outputs to impacts

The SWAT model produces a number of outputs, such as sediment yield, key nutrients, pesticide, pollutants, and other climate, crop and soil specific outputs. For our purpose we will focus on the sediment yield, nutrient balance, pesticide and pollutant balances. The sediment yield should be converted into volume and loss of storage capacity in reservoirs. This information will then be used for economic analysis, see Section 3.2.

Moreover, the impact of siltation, nutrient, pesticide and pollutant flows on biodiversity in selected lakes including on fishery, will be quantified using existing data sets from Bahir Dar Fishery Research Center and other sources. It is expected that substantial additional work is needed in defining the complex dose – response relationships between these flows and the affected biotopes.

2.3.2.2 Quantifying land lost as a result of gravel deposition

Although pure sediment deposition can be a positive impact of land degradation like that of the Nile Delta, it can also negatively affect downstream areas when the structure of the sediment is too coarse. The latter is the case in many parts of the country, particularly in the eastern escarpments of Ambasel, Sirinka, Kobo, and Alamata areas. Huge fertile cultivated lands in downstream areas of Ambassel hill are now out of production due to heavy gravel deposition. In some places it displaces farmers. We don't find any model that can simulate gravel movement and estimate level of deposition. Therefore, we propose a simple survey to quantify amount of land taken out of production in these areas and this can be converted into cost of land degradation using an alternative cost approach that would include the net value of the crop yields and other benefits that the land used to serve.

3 Economic approaches to assess land degradation and SLM practices

The previous sections looked at the bio-physical dimensions of the effects of soil erosion to both private land users and society at large. In this section an economic framework is presented that attaches economic values to the effects of soil erosion and efforts of soil conservation.

3.1 Scope of the framework

Following the biophysical description of land management practices in Section 2.1, in this economic framework, four management practices, including the base line scenario of no conservation measure, would be considered. These are:[6]

1. *No conservation measure* (base line scenario)
2. "*Physical*" conservation measures (such as soil and stone bunds and *fanya juu*)
3. "*Physical with moisture management*" conservation measures (such as physical structures combined with moisture and fertility management measures such as mulching, application of green manure, and other cover crop for soil fertility improvement)
4. "*Progressive"* conservation measures (such as standard conservation measures combined with soil management (fertility and moisture), plantation of fruits, grasses, and other trees on, above or below the bunds, including agroforestry between the bunds. This measure could also include bee-keeping integrated with bee forage plantation and can also be combined with small-scale fattening)

The stream of net benefits/losses of the second, the third and the fourth conservation scenarios will be computed in reference to the base line scenario of no conservation measure for each recommendation domains described in Section 2.1.

[6] For a more detailed description, see Section 2.2.1.

Furthermore, only three forms of on-site damage of soil erosion would be considered, i.e. crop production loss due to movements of top soil, crop production loss due to nutrient cycle breaches (removal of dung and crop residues), and livestock production loss due to the burning of crop residues. However, at later stage efforts will be made to quantify impacts of unwise deforestation, mainly outside the carrying capacity and overgrazing. The on site costs would be assessed only in reference to the dominant crop in each domain. Of the different off-site damages, only damages caused by sediment loads to water storages (both hydroelectric dams and irrigation water storages), and sediment loads to lakes mainly used for fish production and loss of downstream productive lands as a result of gravel deposition will be assessed. However, the methodology that is proposed is so general so that with increased information (data and research) more treatments and off-site impacts can be incorporated.

The whole exercise of attaching economic values to both on- and off-site costs of soil erosion, and subsequently conducting the full cost-benefit analysis of SLM practices involves the following steps:

- Estimating the soil erosion rates for each recommendation domain.
- Estimating production responses to erosion and treatments for each recommendation domain.
- Translating soil erosion into income losses using different economic valuation techniques.
- Computing the net present value (NPV) of each treatment for each development domain.

The first point is addressed in Section 2 and Appendix 1. In what follows, we will describe issues involved in the remaining three steps.

3.2 Translating soil erosion into income losses

Two valuation techniques are commonly used to assess both the on-site and off-site economic costs of soil erosion under different conservation scenarios. These are change of productivity (CPA) and replacement cost (RCA) approaches[7],[8].

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[7] For a more extended discussion of these two approaches in light of their applications to soil erosion, please refer to Enters, 1998; Yesuf et al, 2005.

8 Other methods of valuation include contingent valuation and hedonic pricing (Enters, 1998). Contingent valuation involves asking individuals about their willingness to accept compensation for the negative effects of erosion or their willingness to pay for the benefits of conservation. This approach can also be used to assess off-site costs of land degradation. Hedonic pricing uses land prices to assess the economic value of land degradation. This approach depends upon well functioning land markets, which is a doubtful proposition in Ethiopia since land sales are prohibited.

The CPA values changes in the agricultural production caused by erosion damage with conventional market prices.[9] Under the change of productivity approach, the value of on-site cost of soil erosion (mainly referring to the movements of or removal of top soil) equals the value of the lost crop production valued at market prices (with future losses discounted by market interest rates). Likewise, the off-site cost of soil erosion equals the income forgone from not being able to irrigate fields or generate electricity caused by the reduction in the dam yield, increased operation and maintenance costs of irrigation or power supply schemes, and the higher operating costs for removing sediments through dredging or increased cost of fishing and reduced fish harvest due to eutrophication of lakes. As a physical measurement, it relies on projected yields with and without soil erosion or with or without soil conservation measures. Differences in crop or other yields are then multiplied by their unit price to get the value of lost production due to soil erosion damage.[10]

The replacement cost approach calculates the costs that would have to be incurred in order to replace a damaged asset (soil). Under the replacement cost approach, the on- site cost of soil erosion (referring mainly to nutrient depletion due to the removal of dung and crop residues) equals the annual marginal costs of fertilizer applications to compensate for the loss of soil nutrients due to breaching of nutrient cycles. The inter-temporal value would then equal the capitalized annual costs of replacing lost nutrients or soil cover over a defined period of time. Likewise, following Grohs (1994), the off-site costs of soil erosion (referring mainly to siltation of water storages) would become the cost of replacing the live storage lost annually or in terms of defensive expenditure (a concept very much related to replacement cost approach) would be the costs of constructing dead storage to anticipate the accumulation of sediments[11]. In terms of eutrophication of lakes, the replacement cost would become the costs of removing water hyacinth in the lake.

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[9] In CPA, the opportunity costs of the erosion induced decline in production are the costs of purchasing an equivalent amount of goods from another source (same region, country or other country). It can therefore be argued that the CPA is based on the weak sustainability criteria when used to evaluate the costs of erosion because the level of substitution is the consumption stream. Equally, it can be theoretically argued that the replacement cost approach is based on the strong sustainability constraint because it uses substitutes at the production input level to value the cost of erosion. Practically, replacing nutrients is not sufficient to restore all soil functions because losses of organic matter, reduction of soil rooting depth and water-holding capacity equally reduces soil productivity.

[10] This is under the extreme case of no additional cost of production. In most cases, a slightly more elaborate approach needs to be taken involving supply and demand considerations.

[11] According to Grohs, 1994, the storage capacity of reservoirs is divided into live and dead storage. The dead storage capacity lies at the bottom of the reservoir and the live storage capacity on the top; the latter supplies the water for hydro-electricity generation and irrigation. Sediment deposition can occur in both the live and dead storage capacity and its distribution between the two is specific to the characteristics of the individual reservoir. Sedimentation first affects the dead storage, and when the dead storage is used up the life storage, and thus production capacity of the dam, becomes affected.

In our framework, both the change of productivity and replacement cost approaches would be used to estimate the on-site and off-site costs of soil erosion or the stream of net benefits of different conservation measures in different domains (see fig 1 for the summary of impacts and the respective economic approaches).

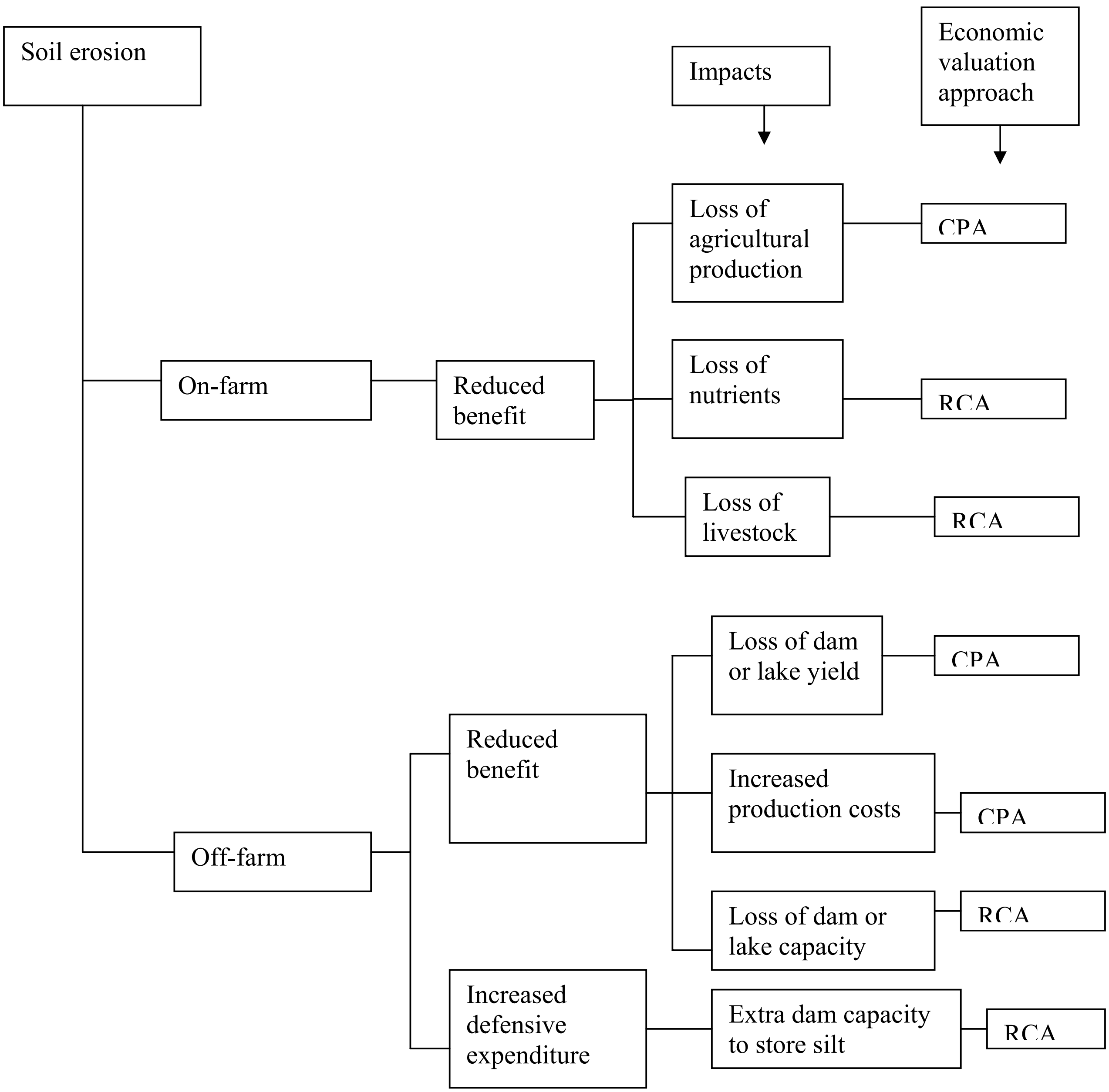

Fig. 1: Soil erosion, its impacts and valuation methods to be used to quantify the impacts

3.3 Estimating profitability of treatments over time

CBA of sustainable land management interventions relies on estimates obtained using the preceding economic approaches to impute costs to soil erosion (both on- and offsite) or benefits to soil conservation. The two yardsticks that are commonly used to determine whether a conservation measure in a given domain is profitable are the Net Present Value (NPV) and Internal Rate of Returns (IRR). NPV is the future stream of benefits and costs converted into discounted values today. IRR is the discount (interest) rate at which the present value of investments (costs) is equal to the present value of streams of returns. Farmers will find it profitable to adopt SLM practices if NPV>0. However, farmers' decision to adopt SLM practices does not take into account the offsite costs and benefits that result from the adoption or non-adoption of SLM practices[12]. Hence a distinction need to be made between a private CBA that takes into account only on-site effects, and a social CBA that includes off-site impacts such as siltation of dams, and water storages, eutrophication of lakes, and other global impacts such as carbon sequestration[13].

At an individual household level, the private net cost/benefits (mainly through crop yield changes) of adopting a SLM is nothing but the difference between farm profit with and without SLM practices. The profit functions with (*c*)[14] and without (*0*) SLM are given by equations 17 and 18 respectively[15].

$$\pi_t^c = P_{it} f_t \ (x_t^c, q_t^c, A_t^c, S_t^c, C_t^c) - \left(\sum_{i=1}^{n} e_{it} x_{it}^c - MC_t \right) \tag{9}$$

$$\pi_t^0 = P_{it} f_t \ (x_t^0, q_t^0, A_t^0, S_t^0, C_t^0) - \sum_{i=1}^{n} e_{it} x_{it}^0 \tag{10}$$

[12] Here NPV also does not take into account risk considerations, credit constraints, and irreversibility of investments. Hence profitability is a necessary but not a sufficient condition for adoption. For a discussion of NPV that takes all these factors into account, please refer to Mahmud & Pender, 2005.

13 Land degradation such as bush and crop burning is often directly correlated to with increased carbon dioxide emissions and reduced ability to store carbon. On the other hand, soil erosion reduces soil carbon as it takes away SOM. Hence the relationship between land degradation and carbon emission is very complex (see Pagiola, 1999 for further details). Recently, the World Bank has carried out a pre-feasibility assessment of the Humbo (Wolayita Sodo) reforestation carbon project in Ethiopia to assess carbon sequestration effect of a reforestration program. Because of its complex nature and lack of data, carbon effects are not included as part of off-site impacts in our framework.

[14] The treatments are for example those outlined in Section 2.2.1, provided data availability.

[15] This part of the model estimates the on-site effect of soil erosion that comes through the movement of top soil due to water. The other elements of on-site costs such as nutrient depletion and loss of livestock due to burning of crop residue could be included but is here proposed to be estimated using a replacement cost approach and hence will be reported separately as η_t in equation 11 (see Sutcliff, 1993 on how these costs could be estimated for Ethiopia).

where x_t is production inputs (labour and capital), q_t plot characteristics other than soil depth (e.g. slope, altitude, soil type) and C_t climate factors (e.g. rainfall, evapo-transpiration). MC_t, P_t *and* e_t, are conservation maintenance (management) costs, unit price of output, and inputs, respectively. Net soil loss (which was denoted by A^n in section 2.3.1.1) enters both directly into the production function and indirectly through changes in soil depth. As indicated in section 2.3.1.1, net soil loss at any point in time would be transformed into a reduction (Δ) in soil depth, which in our production function is captured by a separate variable called soil depth (S_t). This means that both the short-term and long-term implications of erosion will be captured in the model. This is important for the long-term simulations that the model will form the basis for. At farm household level, the above production functions can be adjusted by controlling for the decisions to adopt a given SLM practices (see Kassie and Holden (2005); Shively, 1998). Depending on the level of the analysis (experimental plots versus farm household level) endogeneity test will be carried out for some of the explanatory variables.

The functional form of the production function is an empirical issue. We propose that the analyst estimate the production function using different functional forms and estimation methods (linear and non-linear production functions) and choose the one that fits the data best[16].

The production functions will be estimated separately for each recommendation domain (based on the SCRP data). Specific coefficients will be estimated for each treatment and each major crop. These estimated coefficients will then be the basis for the simulations of impacts of treatments in the various mapping units *i*. For each unit, the generated explanatory variables from the GIS layers will be used (such as slope, soil, rainfall etc). These will be combined with the coefficients estimated based on the SCRP data in order to predict crop yield change due to a particular treatment.

The private NPV of adopting SLM practices is then given by

$$NPV^{p} = \sum_{t=0}^{T} \left[\left(\pi_t^0 - \pi_t^c \right) + \eta_t \right] (1+r)^{-t} \tag{11}$$

[16] Shiferaw and Holden (2001) used Polynomial and translog production function for Andit Tid and Anjene (SCRP sites) respectively. Wagayehu used Cobb-Douglas production function for Hunde-lafto SCRP site.

where η_t is nutrient depletion (which is computed through the RCA based on the nutrient balance calculation described in Section 2.3.1.2.1 and 2) and r is the farmer's private discount rate[17].

Adding off-site costs/benefits (ω_t) to equation (19) yields the social NPV of adopting SLM practice in a given domain. In the social NPV (NPV^s), shadow prices, instead of market prices would be used to correct for any kind of price distortions.

$$NPV^s = \sum_{t=0}^{T} \left[\left(\pi_t^0 - \pi_t^c \right) + \eta_t + \omega_t \right] (1+r)^{-t} \tag{12}$$

Following Bojö's (1991) classification of measures of costs of soil erosion, we use three types of measures to evaluate the economic costs of soil erosion which is equivalent to the economic benefits of conservation measures:

$$\text{Net Annual Income Gain or Loss (NAIG)} = \sum_{i=1}^{N} \left[\left(\pi_{it}^c - \pi_{it}^0 \right) + \eta_t + \omega_{it} \right] \tag{13}$$

$$\text{Net Discounted Income Gain or Loss (NDIG)} = \frac{\sum_{i=1}^{N} NAIG_{it}}{(1+r)^t} \tag{14}$$

$$\text{Net Discounted Cumulative Income Gain or Loss (NDCIG)} = \frac{\sum_{i=1}^{N} \sum_{t=1}^{T} NAIG_{it}}{(1+r)^t} \tag{15}$$

NAIG is only a first step to illustrate the immediate costs of soil erosion or benefits of conservation measures. NDIG measures the present value of the stream of NAIG. The NDIG can be used for national resource accounting to integrate environmental degradation into national accounts. The NDIG represents the loss in potential income over a number of years due to effects of one year of erosion. NDCIG not only includes the capitalized value of an annual loss but the cumulative impact of erosion over several years. It reflects the present value of the cumulative costs of erosion over a defined period of time. This measure is intended for use by policy makers to compare the costs of erosion with the investment and annual costs of conservation measures. Classification of economic costs of

[17] Following earlier definition, the IRR is given by $\sum_{t=1}^{T} \left(\frac{1}{1+IRR} \right) \left(\pi_t^c - \pi_t^0 \right) = 0$

soil erosion, both the private and social NPV of adopting SLM in each domain would be reported.

Sensitivity Analysis

- Both NPV and IRR measures are dependent on the price of input and output prices, and the choice of discount rate. In the framework, we propose to test the sensitivity of these measures to different possible levels of both input and output prices and discount rates.

- In our framework, the NPV would be first calculated based on the assumption that all the fixed investments are being made at the initial period (single shot investments). However, this assumption would be unrealistic, particularly for resource constrained small farm households where investments are staggered over several periods of time. Staggering of investment delays both the costs and benefits but it increases the feasibility of adopting lumpy technologies. Therefore, in our framework, we will conduct sensitivity of NPV and IRR results to investments that are staggered over several periods.

- NPV and IRR of adopting an SLM practice differ between areas practicing a mixed crop-livestock farming system and only a crop farming system. Profitability of SLM practices depends heavily on synergetic benefits of SLM practices with the livestock sector. For example, marginal benefits of grasses grown on the bunds are limited if the livestock sector is absent in the system. In our framework, we propose to conduct sensitivity analysis of NPV and IRR results to the presence and absence of diary production.

3.4 Potential uses of the CBF

With an unconstrained budget, it would be rational to invest in SLM in all areas where the net present value of such investment is greater than 0. However, funds (both from donors and local sources) available for research and extension in soil conservation are limited. Therefore, it would be economically rational to target funds more specifically to areas where the highest return on these investments can be expected. It is an increasingly common opinion that money invested for environmental protection should achieve a maximum benefit for the environment and the welfare of the population.

One of the most important strategies that has been and is negatively affecting the implementation of SLM practices is the old dichotomy of the country into two broad categories, i.e., “high potential” and “low potential”[18] areas and the associated biased actions in implementing SLM practices (Zeleke et al, 2006). This approach has been recognized by the different stakeholder to have played a detrimental role in targeting SLM intervention, as it focuses mainly on bio-physical criteria, ignoring economic comparative advantages. Mahmud and Pender (2005) suggested a simple way of characterizing regions in terms of comparative advantages based on differences in agricultural potential, market access and population density. Their classification however has also very limited use to target soil conservation intervention based on the severity of soil erosion problem, and returns from possible SLM intervention. It focuses more on economic factors, ignoring bio-physical elements. In the framework, we propose the use of the following combination of both biophysical and economic criteria to target interventions on SLM.

- The rate of soil erosion (EROSION)
- Net Annual Income Gain (NAIG) from intervention
- Net Discounted Cumulative Income Gain (NDCIG) from intervention

NAIG and NDCIG captures both the short term and long term benefits of SLM intervention in a given community or domain. If each criteria is crudely divided into “high” and “low”, eight possible combinations of EROSION, NAIG and NDCIG are logically possible[19] (see the decision matrix on table 2). However, only 5 of them are realistic. For example, it is very unlikely to find areas where the soil erosion rates are very low but NAIG and NDCIG from SLM interventions are high. Similarly, it is very unlikely to find areas experiencing low soil erosion rate but SLM interventions resulting in low NAIG but high NDCIG. Hence these two possibilities are excluded in the decision matrix.
Areas with high soil erosion rates and high NAIG and NDCIG should be the top priorities of interventions, not only because these areas are at high risk of soil erosion but also because the maximum short term and long term benefits from SLM intervention can be obtained. These are more likely areas with high agricultural potential but shallow soil depth and high moisture stress.

Next priority are areas with high risk of soil erosion, low short term returns from SLM intervention but high long term returns from intervention. These are more likely areas with high agricultural potential and deep soil depth. In these areas, it takes some time before the effect of soil erosion is felt. Furthermore, in these areas, use of soil conditioning inputs such as fertilizers could mask the effect of soil erosion for a long period of time. Hence

18 High potential areas also referred as food secure, non-moisture stressed and surplus producing areas. Similarly low potential areas are also called food insecure, moisture stressed and non-surplus producing areas.
[19] The “high” and “ low” cutoffs could be further disaggregated during implementation.

short term returns from conservation are smaller, or even negative, but the long term returns higher.

Table 2 Decision matrix to prioritize SLM intervention on economic grounds

High returns from soil conservation	Low returns from soil conservation	Unlikely cases
Case 1: Erosion: High NAIG: High NDCIG: High	Case 4: Erosion: Low NAIG: Low NDCIG: Low	Case 7: Erosion: Low NAIG: High NDCIG: High
Case 2: Erosion: High NAIG: Low NDCIG: High	Case 5: Erosion: Low NAIG: High NDCIG: Low	Case 8: Erosion: Low NAIG: Low NDCIG: High
Case 3: Erosion: High NAIG: High NDCIG: Low	Case 6: Erosion: High NAIG: Low NDCIG: Low	

The third priority would be areas with high soil erosion risk, with high short term returns but small long term gains. These are more likely areas with low agricultural potential and high moisture stress. The short term returns are higher as the SLM practices could help conserving the soil moisture and hence better yield returns in the short term.

Areas under cases 4 and 5 are not at risk of soil erosion and hence returns from SLM intervention are smaller. Investments in SLM in the already degraded area such as case 6, can not be recommended on economic grounds, even though erosion rates are high. Since agricultural potential has already reached to the point of no return, both short term and long term returns from SLM intervention are bound to be low. Area closure or alternative livelihood strategies should be sought to these areas.

Since all the necessary information to identify these different categories will be available for the selected geographical areas in the Ethiopia case, it will be possible to identify those with the highest potential for short- and long-term returns from SLM interventions. This information will then be combined with information about the reduction in off-site effects due to the increased conservation. The combined returns from treatment will be the basis for selection of areas to be treated – until the budget is finished.

3.5 Implications for intervention

If the dissemination of the appropriate SLM technologies is carried out with project funding (local or external or a combination of the two), one would need to estimate the expected diffusion rate of each conservation measure in each domain in order to compute total expected gain of each SLM intervention for each recommendation domain area.

In order to estimate the expected diffusion rate, we use the following logistics diffusion model (see Nkonya et al, 2006 for further details on logistics diffusion model):

$$d_t = \frac{1}{1 + \left(\frac{1}{d_0} - 1\right) e^{-mt}} \qquad (16)$$

where d_t is the rate of adoption at time t; d_0 the initial rate of adoption (adoption rate before intervention), and m is the maximum diffusion rate. Equation (16) assumes full diffusion at the end of the period. But if there are non adopters even at the full extent of adoption, the diffusion model takes the following form:

$$d_t = \frac{1}{\frac{1}{d_{\max}} + \left(\frac{1}{d_{\min}} - \frac{1}{d_{\max}}\right) e^{-mt}} \qquad (16)$$

where $d_t = d_{\min}$ when $t=0$, and $d_T \rightarrow d_{\max}$ when $t \rightarrow \infty$

Given the diffusion rate d_t^i in domain i, the social NPV of adopting a given SLM (say x) in domain i (NPV_x^i) is given by:

$$NPV_x^i = NPV_x^s * d_t^i * L^i \qquad (17)$$

where NPV_x^s is the social NPV of adopting SLM x at the experimental plot level, and L^i is total cultivable land in domain i.

Theoretically, the total intervention cost in domain i should not exceed NPV_x^i. But one could equally argue for the minimal intervention since unless there are other binding constraints (other than profitability), a rational farm household has enough incentive to control the soil erosion problem through appropriate conservation measures on own farms as long as the $NPV^p>0$. In that case, the maximum limit of intervention should not exceed ω_t, which is the off-site costs/benefits. This is true in countries where capital markets are perfectly functioning and land tenure is properly secured. But in countries like Ethiopia, where the capital markets are poorly functioning or sometimes missing, and tenure issues are not properly addressed, a government intervention beyond ω_t, to relieve some of the non-profit constraints, is justified. Following these two lines of argument the cost of intervention lies between ω_t and NPV_x^i.

In order to identify better instruments to allocate money budgeted for interventions, we propose the adoption of the so-called "triage" approach of intervention proposed in Yesuf and Pender (2005) in targeting any form of intervention. In areas where available technologies are highly profitable with high NAIG and NDCIG (such as case 1 in the decision matrix table 2), the focus should be on identifying the most binding constraints limiting their adoption, and the strategies that can most effectively relax these constraints (such as low cost credit provision). In areas where available technologies are only marginally profitable or close to profitability with high NAIG but low NDCIG and vice versa (such as cases 2 and 3 in table 2), the strategy should focus initially on the most feasible means of improving profitability such as improving the market environment (such as construction of roads) and institutions, or both. In areas where available technologies are far from profitability with low NAIG and low NDCIG, despite high risk of soil erosion (such as case 6 in table 2), the strategy should focus more on opportunities for alternative livelihood strategies that are less dependent on intensive land use. In these areas, since the technology is far from profitable, other constraints to adoption are irrelevant.

4 Potential scopes, dimensions and geographical delimitations of the framework

4.1 Overview of data availability and identification of data gaps

The estimation of the income gains due to adoption of SLM treatments are mainly expected to be made on experimental data obtained from the Soil Conservation Research Project (SCRP) that has been operating in Ethiopia since the mid 1980s. This data set will be used to capture both the short- and long-term responses of crop yield to SLM (mainly the conventional SLM practices) as the data are collected continuously for more than 15 years. Therefore, the SCRP data set, supplemented by other studies, could be the core of such an analysis. Out of the six research sites of SCRP, the following five could be used because of their representation of major parts of the highlands of Ethiopia: Anjeni (Gojam, representing high rainfall, intensively cultivated (mostly cereals), highly weathered and better soil depth but currently under high rate of degradation), Maybar (Wollo, representing the bimodal rainfall areas in the country with high rainfall variability but with moderate to severe land degradation), Gunnuno (Wolaita, representing densely populated and intensively cultivated areas in the South with high rates of degradation), Dizi (South Oromia, representing recently cleared areas), Hundelafto (Harergea, representing densely populated Chercher highlands, mainly sorghum growing with inter cropping culture, with moderate moisture stress and moderate to sever land degradation levels). Taking these smaller watersheds as nuclei, it is possible to investigate larger watersheds around them to design the frame.

Unfortunately, these SCRP centers did not collect data on other types ("physical with soil management (standard)" and "Bio-physical or all best management practices") of SLM measures. Hence, further data collection is required to estimate our production function parameters also for these SLM treatments. The impacts of the physical SWC measures on yield is only collected for initial stages of terrace development and cannot be taken as ultimate result. However, it is possible to translate the soil conserved to production gains.

The other major data source is the Woody Biomass Inventory and Strategic Planning Project which has been operating in Ethiopia for nearly a decade since the mid 1990s. The project collected data on woody biomass, as well as use of dung and crop residues at *wereda* level. This particular data set could be used in our framework to estimate the nutrient depletion component of on-site cost of land degradation.

In order to estimate the off-site costs of soil erosion, experimental data are required to compute the amount of soil erosion that contributes to sediment loading in water storages and lakes under different SLM alternatives. Part of this information could be extracted from 30 years of data collected on major rivers and basins by the Ministry of Water Resources. The difficult part of this exercise is identifying the share of SDR coming from crop lands. Information on eutrophication and hyacinths and their impacts on fish harvests and catch effort is partly available from Fishery department of MoRAD and Bahir Dar Fishery Research Center.

4.2 Prerequisites for and delimitations for implementation of the framework

The CBF is a tool for policy and implementation priorities and should act as an interface between applied research and extension related to SLM. This means that it is essential that there is an active interest and participation in the implementation of the CBF from these two groups, otherwise the initiative will lose momentum and ultimately disappear. A pragmatic approach to ensure this involvement from the implementing agencies' point of view is to gear the design and focus of the CBF to their current needs.

The proposed implementation of the Ethiopian Country Program for Sustainable Land Management (ECPSLM) has been identified as such a prioritized initiative that could benefit from synergies with the CBF, by the main stakeholders MoARD, that has the overriding responsibility for the implementation, and EPA, that will monitor the implementation. The **objectives** of the proposed ECPSLM are to: (a) Increase and sustain agricultural productivity through improved integrated land and water management practices; (b) Promote the development of non-farm livelihoods to minimize pressure over the long term on already fragile agricultural landscapes; and (c) Protect or restore ecosystem integrity and functions in agricultural landscapes. (WB, 2006). These objectives are to be reached by the implementation of the following proposed program components:

1: Policy and Administration of Land tenure. Investment in sustainable land management requires a supportive policy environment, especially secure land tenure. The objective of this component is to strengthen land use planning, land certification and administration by extending coverage of successful piloting work. Tentative interventions include, among many other things, strengthening of information management systems to support land use planning, certification, and administration.

2: Scaling up of Best Management Practices. This component is aimed at providing financial and technical support to implement on a wider scale land management practices and technologies selected by the intended beneficiaries to achieve on-the-ground results, i.e. financial, economic and environmental benefits at the farm, community, watershed, and higher levels. Program interventions would be based on the watershed/micro-watershed approach. This component would be implemented through a "cooperative extension program" established with a competitively selected university or research institution. Such a program would help to optimize the benefits of efforts to strengthen demand-driven applied research, technology transfer, and agricultural support services and would comprise the following for sub-programs:

(a) *Capacity building for integrated land and water management* to integrate sustainable land use into kebele, woreda, and regional development plans through participatory processes and to successfully implement sustainable land management sub-projects. (b) *Investments in best land and water management practices* providing beneficiaries access to best management practices and technologies on SLM by identifying those most suitable to local conditions, and implementing them. (c) *Diversification of rural livelihoods* providing assistance to develop non-farm livelihoods. (d) *Investments in environmentally safe rural energy sources* encouraging use of higher-efficiency woodstoves, alternative fuels, etc. and increasing wood supply through area enclosures and replanting on communal lands.

3: Land monitoring system. Integrating various existing GIS and other data systems into a more coordinated system to produce reports to guide policy makers, resource managers, local communities, and other decision makers. Information from such a system could also be used for regional/national environmental monitoring and reporting to monitor land use and land use changes, identify ecological hot spots, etc.

As can be seen in this brief description of the ECPSLM, there are a number of areas where the CBF could support the implementation of the ECPSLM. In particular there could be synergies regarding the land use planning in program component 1; Identification of profitable management practices for scaling-up in component 2; and a very high degree of overlap in component 3 that deals with land monitoring.

However, close synergies with the ECPSLM would also imply that the geographical focus of the two programs would need to overlap. It is therefore proposed that the CBF is implemented in tandem with the ECPSLM, sharing its geographical delimitations, taking into consideration the data needs and analytical focus of the CBF.

4.3 Implementation of CBF – preparations, capacity and training needs

4.3.1 Planning process

The TerrAfrica aims at presenting a GEF/ Medium Sized Project for a CBF process, in which Ethiopia and Ghana would be pilot countries. In order to be considered for funding under the GEF ‘Land degradation’ focal area, such a project would need to: demonstrate “global environmental benefits”; be replicable; demonstrate environmental, socio-economic and financial sustainability; and through its activities support capacity to address barriers towards introducing sustainable land management investments.

The MSP project proposal will need to be approved by the respective governments and will then be processed through the different project cycle steps in the World Bank and the GEF. This report and the recommendations from the stakeholder workshop, to be convened in Addis Ababa in May 2005 will, together with a general project document and a similar report from Ghana, be important documents in this process.

4.3.2 Implementation modalities and capacity

The implementation of the suggested GEF/MSP where the Cost-Benefit Framework is an important instrument for improved implementation of SLM, would need certain institutional arrangements. Such arrangements would need to span the different levels associated with the different functions in the process.

The government, being the contracting partner with the World Bank/GEF, and the main user of the outcome of the CBF analysis, would need to establish some kind of a governing board or body, where all major stakeholders should be represented. This body could e.g. be or be associated with the National Coordinating Body for the implementation of the UNCCD/NAP.

The governing board, or the government directly, should also designate some body, who would be responsible for executing the whole program. The one in charge of the program execution could be a person or a secretariat, or an existing structure, but should be accountable to the governing board.

The organization/s to undertake the CBF analysis would need to consist of a highly committed group of professional scientists that can bridge both the physical and the economic aspects of the analytical framework. These professionals need to be able to conduct and promote high quality and objective policy research and to develop policy research responsive to the needs of policy makers. This organization should act upon ordering from the programme executor, preferably in a cooperative arrangement to ensure best possible applicability.

In the process, both in implementing the CBF, and in undertaking a barrier analysis including deciding on measures to address the barriers, stakeholder participation is essential. This could be done by establishing reference groups or by having stakeholder consultations. To achieve true stakeholder participation, an analysis of the different levels of stakeholders and their respective roles should be done. There may be a need to formalize stakeholder involvement in order to fully ensure that at different levels.

The implementation of the CBF in Ethiopia would need to draw on large parts of the existing SLM capacity in Ethiopia and involve all the major stakeholders. As major stakeholders should be seen organizations that will utilize the framework (Departments of Extension and Natural Resource Development of MoARD; Regional Bureaus of Agriculture; Federal and Regional EPAs, major donors); organizations that will contribute to the framework (EDRI, EIAR, regional agricultural research institutes and universities), and organizations that have an interest in applying the framework in other countries (World Bank, UNCCD) as well as those who would need to respond to strategies and policies resulting from the implementation of the CBF and who would also be beneficiaries namely the farmers and land users. The organisational structure needs to be agreed with the stakeholders.

4.3.3 Capacity and training needs

The basic analytical capacity to implement the framework is already available in Ethiopia. However, the design, implementation and dissemination of the results could be improved if relevant **international expertise** is utilized, for example from CGIAR-centers such as IFPRI, ILRI, World Agroforestry Center and ICRISAT.

For the development of the framework in the longer term, it would be of great value if an **academic network** was formed that both contributed to and used the framework. For this to happen, sufficient resources need to be allocated to inform about the framework, support research that contributes to the framework and facilitate discussions about the framework, for example at annual workshops where soil scientists, economists, GIS experts and extension experts meet. This is one important way to secure the CBF as a unifying framework for applied research on SLM. Another is to secure active participation by the Ethiopian Agricultural Research System.

The most important capacity for the success of the CBF is that of planning and implementing officers at the regions. This is also where the greatest training needs are. ESSP has already trained a number of regional staff in GIS analysis. Targeted training that improves the regional capacity to utilize information within the CBF should therefore be part of the implementation. For the longer term, it would be important that a critical mass of federal and regional staff are well equipped to combine both physical and economic information in planning SLM interventions. These skills, and the underlying scientific basis of the CBF, should therefore be taught at MSc level programs. This could currently be done at AAU and Alemaya University, and with some support also at regional universities.

5 Summary and conclusion

The Cost Benefit Framework for pro-SLM Decision Making in Sub-Saharan Africa is an initiative by TerrAfrica at the World Bank to provide analytical contributions to the mobilization of additional financial resources for SLM in Sub-Saharan Africa. Two countries, Ethiopia and Ghana, have been chosen to act as pilots in the development of the framework. For Ethiopia this is a unique opportunity to increase the awareness of the cost of land degradation and the potential benefits of investments in sustainable land management in Ethiopia. The framework would be based on relevant research on land degradation and soil conservation, particularly from the Soil Conservation Research Project. It would include the following methodological steps:

- Identification of recommendation domains that share the same conditions for applications of treatments.
- Estimation the soil erosion rates for each recommendation domain based on explanatory factors proposed in the USLE.
- Estimation of production responses to erosion and treatments for each recommendation domain.
- Translation of soil erosion and nutrient depletion into income losses using different economic valuation techniques.
- Computing the net present value (NPV) of each treatment for each development domain.
- Mapping on- and off-site returns from treatment.
- Prioritizing areas with highest return according to budget constraint.
- Dissemination of this information to the relevant users, particularly land use planners and extension staff at regional level and below

The framework would thus act as an interface between applied research on SLM and the agencies involved in implementation of SLM initiatives. It is expected that it would be particularly useful if synergies are sought with the implementation of the proposed Ethiopian Country Program on Sustainable Land Management.

The CBF could thus fulfill a number of important functions. If properly implemented and managed, the CBF should be able to:

- Compile and utilize much of the existing relevant data and research on land degradation and various SLM treatments in Ethiopia and elsewhere.
- Provide information on the areas facing largest short- and long-term costs from land degradation.

- Show how SLM treatments could prevent losses in productivity in hydro- and irrigation dams as well as fisheries in affected lakes.
- Indicate the relevant size of investments in SLM.
- Prioritize areas and treatments in order to maximize the returns to society from these investments.
- Act as a unifying framework for the design and dissemination of applied research on SLM practices to further improve on the framework by better describing physical processes in various areas in Ethiopia and impacts of new combinations of treatments.
- Support the up-scaling of promising SLM practices.

The CBF is proposed to be implemented with the support of GEF-funding and World Bank/TerrAfrica back-stopping. The implementation requires active participation of a range of Ethiopian stakeholder. In particular, it is expected that MoARD and EPA will utilize the implemented framework while EDRI, Federal and Regional Agricultural Research Institutes and universities are expected to contribute to the implementation.

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Appendix 1: Quantifying methods and approaches of bio-physical process (on-site and off-site processes)

1. Quantifying On site impacts

There have been a number of studies and estimates in the past to quantify the on-site impacts of land degradation. Studies by EHRS, (1984), Hurni (1988), Suitcliff (1993) and Ben Sonneveld (2002) are some of the studies tried to closely investigate the impacts of land degradation at national level. Most of them recognize that sheet and rill erosion by water, and burning of dung and crop residue are the major components of land degradation that affects on-site land productivity. Although all of them tried to quantify the results of the biophysical processes and their impacts, the methods used were different and this makes it difficult to compare the results (Mahmud Yesuf, et al 2005) and also suffered from lack of local research based model parameters. Apart from this some of the methods used to quantify the cost of land degradation suffer from assumptions in the production function models.

The methods used for this study will not be fully free from sources errors mentioned above but will attempt to reduce them by using measured model parameters and a different set of production functions. Before we develop the production function we try to predict and quantify the biophysical processes for the identified recommendation domain areas.

1.2. Determining soil loss using Universal Soil Loss equation (USLE)

Although it is possible to apply different models, which are more precise in modelling soil erosion processes, the applicability is always a question. Therefore, we decided to use USLE but with proper model calibration and identification of model parameters based on measured data sets of SCRP stations. The application of USLE and model parameters will not include the whole country but only on identified areas that can be represented by research stations as discussed on section 2.2.

USLE is an empirical overland flow or sheet-rill erosion equation (Wischmeier-Smith, 1978). It is a regression equation developed based on information form large data sets and lumps inter-rill and rill erosion together and made to estimate average soil loss over extended period, e.g., average annual soil loss (Foster, G.R., 1982). The limitations of the model are: i) it is not designed to estimate soil loss from single storm events; ii) it is an erosion equation, and consequently does not estimate deposition; iii) it does not estimate gulley or channel erosion. Sonneveld (2002) also mentioned various model limitations based on is own detailed analysis of the model and works of Risse et al., (1993) and Nearing, (1998).

Apart from the above limitations, the model gives fair estimates provided that its model parameters are carefully generated based on local information. Since we are not interested on single storm erosion events and also estimating gulley and channel erosion, the limitations may not affect our intended work except the deposition element.

Sonneveld B., 2002, did a comprehensive analysis of applicability of USLE for Ethiopian conditions using SCRP database. We are intending to build on the regress work he did with only one exception. He extrapolated the results from SCRP stations to the whole nation but we will extrapolate the results to the areas that have similar conditions to that of the different SCRP stations. Moreover, for some of the parameters he applied literature values. We are of the opinion that attempts should be made to generate model parameters based on specific local conditions.

Accordingly, to quantify soil loss using USLE the following three important actions are proposed: i) develop coefficients for USLE based on SCRP data sets (which means adapted to stations biophysical and management conditions, some parameters can be directly taken form the work of Sonneveld B., 2002 and Hurni, 1987), ii) classify the highlands into different recommendation domains (AEZs) similar to that of SCRP stations and apply the same USLE coefficients to these areas, iii) develop layers for major variables for each recommendation domain (i.e., soil, land use, climate, management, and slope). Then determine soil loss using the following equation:

$$A = R * K * SL * C * P \qquad (A\ 1)$$

Where A represents the soil loss expressed in tons.ha^{-1}.$year^{-1}$. R refers to the rainfall erosivity factor, calculated by the summation of the erosion index EI30 over the evaluation period, often average annual. EI30 is a compound function of the kinetic energy of a storm and its 30 minutes maximum intensity (for details refer to Sonneveld, (2002), Wischmeier and Smith, (1978), Neitsch, S.L., et al, (2002). K is the soil erodibility factor reflecting the susceptibility of a soil type to erosion. It is defined by Wischmeier and Smith (1978) as the soil loss rate per erosion index unit (R) for a specified soil as measured on a unit plot[20]. LS is the topographic factor expressed as the expected ratio of soil loss per unit area from a field slope to that from a unit plot under otherwise identical conditions. C is cover-management factor expressed as the ratio of soil loss with a given management practice to that from a unit slope. It is an index for the protective coverage of canopy and dead plant

[20] A unit plot is 22.1-m (72.6-ft) long, with a uniform length-wise slope of 9-percent, in continuous fallow, tilled up and down the slope. Continuous fallow is defined as land that has been tilled and kept free of vegetation for more than 2 years (Wischmeier and Smith 1978).

materials (residue) in contact with the ground. The support practice factor, P, is defined as the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down slope culture. Support practices include contour tillage, strip-cropping on the contour, and various terrace systems that are applied to control erosion. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

Although part of the sediment detached from the land mass is deposited downstream, it is often on depressions and channels of streams, rivers that are difficult to reuse the deposited sediment. However, 10-15% of the sediment is assumed to be deposited on part of the landscape that can be reused for production purposes (personal estimate). This assumption is developed based on results of SCRP research stations.

1.2.1. Procedures of model parameter development

Since the mathematical form of the equation which is a multiplication of six lumped parameters leads to larger errors (Wischmeier, 1976), the development of model parameters requires careful analysis of situations in each center and available data sets. Taking this into consideration, the parameter generation could benefit a lot from the work of Sonneveld (2002) as indicated under each specific parameter in the following sections.

1.2.1.1. Developing R factor

We need to develop the R factor based on rainfall information for each center and extrapolate it to the represented recommendation domain. R for each center has been calculated using the following Wischmeier and Smith (1978) standard equation :

$$R = E * I_{30} \tag{A2}$$

Where R is erosivity (J/mh) and E is total energy of the rainfall and I_{30} is the maximum 30 minute intensity (mm/hr).

$$E = \frac{R_{day}}{1000}\left(12.1 + 8.9 * \left(\log_{10}\left[i_{mx}\right] - 0.434\right)\right) \tag{A3}$$

where R_{day} is the amount of precipitation falling on a given day (mm), and i_{mx} is the maximum rainfall intensity (mm/hr).

$$i_{mx} = -2 * R_{day} * \ln\left(1 - \alpha_{0.5}\right) \tag{A4}$$

Where $\alpha_{0.5}$ is the maximum half-hour rainfall expressed as a fraction of daily rainfall.

and

$$I_{30} = 2 * \alpha_{0.5} * R_{day} \qquad (A5)$$

Table…… R factor for each SCRP research stations

Since R is based on rainfall and related factors, taking the average value of R of all meteorological stations found in the recommendation domain might increase accuracy instead of using R values from one station, i.e., only from SCRP stations and apply it to the identified homogenous areas. This is because rainfall is highly variable within short distances and the average value can capture this variability. The calculation of R using the above equation for stations other than the SCRP might be cumbersome, because it requires interpretation of the rain gauge chart roll and other desk works which are time consuming and sometimes unavailable. Therefore, the following alternative equation suggested by Krauer (1988) can be used:

$$R = -124.485 + (4.828 * P) \qquad (A6)$$

Where R is expressed in SI units ($Jcm.m^{-2}h^{-1}$) and P the annual rainfall in cm. Sonneveld (2002) also use this regression equation for his work.

Note: conversion of R to $N.h^{-1}$ is essential.

Therefore, to calculate R for the recommendation domain the following equation is proposed:

$$R_{aez} = \frac{\sum (R_{SCRP_x} + R_{S_1} + R_{S_2} + \cdots R_{S_n})}{n} \qquad (A7)$$

Where R_{aez} is the average erosivity for the selected recommendation domain (AEZ), R_{SCRPx} is the erosivity for the representative SCRP station within the zone, R_{s1}….R_{sn}, are erosivity for other meteorological stations within the zone.

1.2.1.2. Developing the K factor:

The K factor is probably one of the factors that require extensive field data collection in the future. Sonneveld (2002) made lots of assumptions and extrapolations to calculate K for a nationwide scale. This exercise will adapt some of his assumptions provided that the gaps cannot be filled by data collection or are expensive to collect. This being the case we propose the following procedure for K factor calculation:

i. Using the soil survey data of each center develop K for major soil types identified in each center using the following three equations and one empirical relations:

a) The standard equation by Wischmeier and Smith (1978)

$$K = \frac{00021 * M^{1.14} * (12 - OM) + 3.25 * (S_{str} - 2) + 2.5 * (S_{per} - 3)}{100} \quad (A8)$$

Where K is the soil erodibility factor, M is the particle-size parameter, OM is the percent organic matter (%), S_{str} is the soil structure code used in soil
classification, and S_{per} is the profile permeability class.

The particle size parameter, M, is calculated by:

$$M = (M_{silt} + M_{vfs}) * (100 - M_c) \quad (A9)$$

Where M_{silt} is the percent silt content (0.002-0.05 mm diameter particles), M_{vfs} is the percent very fine sand content (0.05-0.10 mm diameter particles), and M_c is the percent clay content (< 0.002 mm diameter particles). In the absence of M_{vfs} data in the soil survey database suggestions by Sonneveld (2002) can be used.

The percent organic matter content, OM, of a layer can be calculated:

$$OM = 1.72 * orgC \quad (A10)$$

Where orgC is the percent organic carbon content of the layer (%)

Particle size distribution, size classes of soil structure and soil permeability classes of USDA soil survey Manual (1962), are presented on Table …. and the user is advised to check the applicability of this classification to the Ethiopian condition.

b. by Williams (1995)

$$K = f_{csand} * f_{cl-si} * f_{org} * f_{hisand} \quad (A11)$$

Where f_{csand} is factors for high coarse-sand contents, f_{cl-si} is a factor for clay to silt ratio, f_{orgc} is a factor organic carbon content, and f_{hisand} is a factor for soils with extremely high sand contents. The factors are calculated:

$$f_{csand} = \left[0.2 + 0.3 * \exp\left(-0.256 * M_s * \left(1 - \frac{M_{silt}}{100}\right)\right)\right] \quad (A12)$$

$$f_{cl-si} = \left(\frac{M_{silt}}{M_c + M_{silt}}\right)^{0.3} \quad (A13)$$

$$f_{org} = \left(1 - \frac{0.25 * orgC}{orgC + \exp[3.72 - 2.95 * orgC]}\right) \quad (A14)$$

$$f_{hisand} = \left[1 - \frac{0.7 * \left(1 - \frac{M_s}{100}\right)}{\left(1 - \frac{M_s}{100}\right) + \exp\left[-5.51 + 22.9 * \left(1 - \frac{M_s}{100}\right)\right]}\right] \quad (A15)$$

Where M_s is the percent sand content (0.05-2.00 mm diameter particles), M_{silt} is the percent silt content (0.002-0.05 mm diameter particles), M_c is the percent clay content (< 0.002 mm diameter particles), and *orgC* is the percent organic carbon content of the layer (%).

Table …… Particle size distribution

c. by Romkens et al., 1997 cited in Sonneveld (2002):

$$K = 7.594\left[0.0034 + 0.0405 * \exp\left(-0.5\left(\frac{\log(D_g) + 1.659}{0.7101}\right)^2\right)\right] \quad (A16)$$

Where

$$D_g = \exp\left[0.01 \sum f_i \ln(m_i)\right] \quad (A17)$$

Where Dg is the geometric mean particle diameter, fi corresponds to the primary particle size fraction in a percentage (for major particles), and mi is the arithmetic mean of soil particle size limits. According to Sonneveld (2002) this equation was developed by relating K values with texture information for all available (225) global data.

d) Suggestions by Hurni, (1987)

Hurni, (1987) tried to relate K with soil colour on his adoption of USLE for Ethiopian condition.

Soil Colour	Black	Brown	Red	Yellow
K factor	0.15	0.2	0.25	0.3

ii. The user should check the validity of each equation against measured values in each station and select the best fit equation to calculate K factor.
iii. After this there are two options: i) use the K coefficient for each soil type (as identified in the stations) and directly apply to the recommendation domain soil map, which means one would go on developing K factor map or, ii) take the soil information and calculate K factor for each mapping unit in the recommendation domain and then develop K factor map. The user of the framework is free to choose the best alternative.

1.2.1.3. Developing SL coefficient:

The topographic factor can be calculated or determined using two possibilities:

a) using Wischmeier and Smiths (1978) equation

$$SL = \left(\frac{L_{hill}}{22.1}\right)^m * \left(65.41 * Sin^2 * (\alpha_{hill}) + 4.56 * \sin \alpha_{hill} + 0.065\right) \quad (A18)$$

Where L_{hill} is the slope length (m), *m* is the exponential term, and α_{hill} is the angle of the slope. The exponential term, *m*, is calculated:

$$m = 0.6 * (1 - \exp[-35.835 * slp]) \quad (A19)$$

Where *slp* is the slope of the HRU expressed as rise over run (m/m). The relationship between α_{hill} and *slp* is:

$$slp = \tan \alpha_{hill} \tag{A20}$$

b) Using Hurni, 1987 approximations:

Slope Length in M	5	10	20	40	80	160	240	320
L factor	0.5	0.7	1.0	1.4	1.9	2.7	3.2	3.8

Slope (%)	5	10	15	20	30	40	50	60
S factor	0.4	1.0	1.6	2.2	3.0	3.8	4.3	4.8

Note that: the validity of each method or equation should be checked using measured values from SCRP stations then the user need to select the best one for further analysis. Using approximations by Kassam et al, (1991) cited in Sonneveld (2002) could also be one possibility.

1.2.1.4. Developing the C factor:

Since the production function will take major crops into consideration the development of the C factor on cultivated lands will seriously consider dominant crops grown within and the vicinity of the SCRP research stations and the recommendation domain represented by each station. It is also worth to consider the variability of the cover condition in accordance to location. Similar crops cannot give the same ground cover in different areas. The SCRP results show this clearly (see Table 1). For other land use/cover classes other than grass and fallow land, such as forest, bare land, etc, use values recommended by Hurni, (1987). In general, the following options are recommended:

a. Directly use SCRP station C values for selected crops (see Table 1 below). However, if the crop under consideration is identified in the recommendation domain but not in the research station, use average values derived from station data (Table 2).

Table 1: C values developed for SCRP stations and major crops grown in each station.

Station	Crop	C value	Station	Crop	C value
Afdeyu	Barley	0.077	Gununo	Barley	0.323
	Wheat	0.222		Teff	0.601
	Field Pea	0.106		Haricot bean	0.532
	Horse bean	0.291		Haricot b./Barley	0.226
	Fallow	0.252		Sweet Potato	0.389
	Grass	0.06		Fallow	0.174
Anjeni	Barley	0.239		Grass	0.001
	Wheat	0.188	Hunde Lafto	Maize/Sorghum	0.03
	Teff	0.315		Maize/Hricot Bean	0.155
	Field Pea	0.561		Sorghum/maize/bean	0.066
	Horse Bean	0.142		Sorghum	0.068
	Fallow	0.472		Haricot bean	0.053
	Grass	0.006		Fallow	0.00
Andit Tid	Barley	0.139		Grass	0.01
	Wheat	0.096	Maybar	Emmer Wheat (Barley)	0.018
	Lentils	0.207		Maize	0.104
	Linseed	0.455		Horse bean	0.042
	Fallow	0.108		Haricot bean	0.45
Dizi	Maize	0.096		Fallow	0.016
	Teff	0.054		Grass	0.006
	Sorghum	0.441			
	Coffee	0.066			
	Fallow	0.02			
	Grass	0.004			

Source: adapted from Sonneveld 2002

b. Use average values of major crops derived from SCRP stations across the identified recommendation domains (Table 2). This will shadow site specific values but since it is average value of national research findings some of the errors could be diluted.

Table 2: Average values of C factor for major crops based on SCRP database

Crop/cover type	Average C Factor calculated from SCRP stations	Remark
Barley	0.159	
Wheat	0.168	
Teff	0.323	
Maize	0.10	
Sorghum	0.254	
Horse Bean	0.158	
Field Pea	0.333	
Haricot Bean	0.158	
Lentils	0.207	
Fallow (ploughed)	0.15	
Grass	0.0145	
Coffee	0.066	

c. Use Hurni, (1987) approximations as an alternative but defiantly for some specific land use systems such as forest, bare land, etc, that are not treated under SCRP work Hurni's values are recommended. Since these values are recommended for nationwide application, caution need to be made in applying this factor for specific local conditions.

Table 3: C factor suggested by Hurni, 1987.

Cover type	C value	Remark
Dense forest	0.001	
Other forest (with modest ground cover)	0.01	The remark on bracket is personal interpretation of Hurni's value
Bad land hard	0.05	
Bad land soft	0.4	
Sorghum-maize	0.1	
Cereals, pulses	0.15	
Teff	0.25	
Dense grass	0.01	
Degraded grass	0.05	
Fallow hard	0.05	
Fallow ploughed	0.6	
Continuous fallow (without cover)	1.0	

d. Results from Mount Kenya region (Ephraim Nkonya, et. al., 2006) for comparison (table 4).

Table 4: C factor suggested by Ephraim Nkonya, et. al., 2006

Crop	C values	Remark
Maize	0.25	
Beans	0.10	
Wheat	0.10	
Sorghum	0.60	
Irish potato	0.33	
Sweet Potato	0.30	
Tea	0.36	

1.2.1.5. Developing P (management) factor

By closely investigating the dominant farming system within the Centers and the represented AEZ, ranges of P values can be developed in accordance to the different management options. Combinations of the following two options are recommended:

i. Hurni's approximation (1987): although not complete especially with regard to SWC measures, Hurni, (1987) recommended P factors for various management options. This can be directly used depending on the type of management selected in each recommendation area.

Table 5: P factor suggested by Hurni, 1987

Management options	P factor	Remark
Ploughing up and down	1.0	
Ploughing along contour	0.9	
Strip cropping	0.8	
Intercropping	0.8	
Dense intercropping	0.7	
Applying mulch	0.6	
Stone cover (80%)	0.5	
Stone cover (40%)	0.8	

Remark: some of the values of this table seem on the high side, particularly for contour ploughing, strip and intercropping. Therefore, care must be taken to extrapolate these values.

ii. P values taken from Ephraim Nkonya et al., (2006). The results used are for different land management scenarios and we found it reasonable and fits our initial intention of looking SLM practices into three scenarios (see section 2.2). Therefore, this can be directly applied for the three scenarios selected for this study.

Table 6: P-factor suggested by Ephraim Nkonya, et. al., (2006)

Management options	P values	Remark
Ploughing along the contour	0.45	A little on the low side for Ethiopian conditions, especially in high rainfall areas.
Terrace only	0.45	
Terrace+ agroforestry	0.25	Averaged
Terrace + soil fertility and moisture management	0.20	Extrapolated
All best management practices *	0.001	

* This includes Terraces, soil fertility management and agroforestry.

1.2.2. Procedures of extrapolation and calculation of soil loss for recommendation areas

Once the model parameters for each center are developed and possible refinement of parameters using different techniques, including calibration (if found necessary) is done, the next step is determining soil loss for the recommendation domain represented by the specific SCRP centers. Before this, however, the following actions should be undertaken for each recommendation domain area:

i. Preparation of land use/land cover map: land degradation is strongly associated to land use and land management conditions. Therefore, preparation of this component with fair accuracy is an essential element of the whole exercise. However, the task could be very expensive and demanding if one attempts to do it from zero at national level. Luckily, the Woody Biomass project has recently finalized a land use/land cover map of the country at 1:250,000 scale, this data can be directly used for this purpose with some field observation after the draft map is prepared. What is important is that this map should be (for that matter all maps) clipped by the boundaries of the identified recommendation domain areas.

ii. Preparation of soil map: As indicated on (section 2.1), probably this is one of the coarse and very old data set available in the country. However, appropriate information on soil is highly important in determining costs of land degradation and other actions in the country. Full national coverage soil map is available only at a scale of 1:1,000,000. However, there are many soil databases at scale of

1:250,000, particularly basin studies, which can be used for this purpose with fair adjustment (Abayneh Esayas, 2006, personal communication). Therefore, the soil map should be prepared for each domain area by bringing together the entire available (and reliable) soil database (map) at the scale of 1:250,000 and filling identified gaps using fair and quick survey techniques. However, this shall not be done at the expense of quality and care should be taken in defining the methodology and undertaking the task. Producing the soil map with all associated soil quality (chemical and physical including soil depth) at the scale mentioned above is one of the major tasks to be undertaken as part of the implementation of the CBF.

iii. Prepare topographic map: A digital elevation model (DEM) can be prepared from available satellite images or directly taken from already released DEM by different international research agencies. The 90x90 M^2 pixels DEM is freely available but since this is a bit coarse efforts should be applied to acquire the recent 30x30 M^2 pixel DEM. Using this it is possible to extract topographic factors and could be reclassified afterwards.

iv. Reclassification work: Once the above three products are made available perform the following reclassification work to develop model parameter layers, i.e., C, K, and LS. The following are the reclassification tasks:

g. Developing the C factor map: the land use/land cover map can be converted to C factor map by assigning selected C coefficients to each land use type. Since the cultivated land will not show crop based divisions but rather percentages of dominant crop covers for each recommendation domain, the C factor for the cultivated land will be calculated using the following equation:

$$C_{cuz1} = X_1 * C_1 + X_2 * C_2 + \cdots X_n * C_n \qquad (A21)$$

Where C_{cuz1} is C factor for cultivated land in recommendation domain (Z_1), X_n is percentage of the land unit covered by crop n and C_n is C factor for crop n.

Once this is determined and the C factors for all land use units identified assign this coefficient to the land use unit to convert it to a C factor map.

h. Developing K factor map: based on the methods suggested on section 2.3, the K factor can be calculated for each soil unit or if the user has predetermined K factor for each soil type, then the factors can be assigned to each soil unit and can be converted to K factor map.

i. Developing LS factor map: the DEM should be reclassified with the identified LS classes (factors) and LS factor map can be produced.

j. Develop a P factor map: assign a P factor for each land use unit based on management options exercised in the recommendation domain and produce P factor map.

ix. Define annual R value for the recommendation zone (it could be single or average value of major stations)

x. Then overlay the four reclassified maps and calculate soil loss using the following equation for each map unit:

$$A_i = R_{aez} * \left(K_i * C_i * P_i * SL_i\right) \qquad (A22)$$

Where A_i is soil loss for the map unit 'i' with specific C, P, SL and K values as extracted from previous map overlays.

xi. Calculate Gross Soil loss using the following equation:

$$A_g = \sum_{i=1}^{n} A_i \qquad (A23)$$

Where A_g is gross soil loss for the recommendation domain or major land use unit within the domain.

xii. Determine soil formation rates for the domain area using the following equation proposed by Hurni, (1983), S_f;

$$S_f = S_{mf} * t * r \cdot l * u * d * s * c \qquad (A23)$$

Where, t is mean annual temperature, r is mean annual rainfall, l is length of growing period, d is soil depth, s is slope gradient, c is land cover and land use. S_{fm} is maximum soil formation factor for tropical zone and is suggested value is 24 tones ha^{-1} $year^{-1}$

Alternatively the following values suggested by Hurni (1984) can be used to determine S_f for the domain area (see Table 7)

Table 7: Soil formation rates suggested by Hurni

Location in the country	**Specific sites**	**Soil formation ranges (tones ha^{-1} $year^{-1}$)**	**Remark**
Northern areas	Around Adigrat and the rest of Tigray and Wag, Belessa	2-6	Modified by author (sites added)
	Around Gonder, North Shewa, Part of Wollo	6-10	Modified by author (sites added)
North West	Around Gojam and part of South Gonder	10-14	Modified by author (sites added)
	Benshangul and Northern Wollega	14-18	Modified by author (sites added)
South West	Gambella	6-10	
	Keffa, Welega, Ilubabur, Bale	13-22	Modified by author (sites added)
South	Gamgofa	10-14	
	Borena	6-10	Modified by author (sites added)
Central	Southern Shewa	14-18	
	Rift valley	6-10	
	Arisi	10-14	
Eastern	Hararge highlands	6-10	
	Wollo area	6-10	Modified by author (sites added)
	Afar - Somali	<2	Modified by author (sites added)

xiii. Assign the proposed soil deposition amount for the domain area, *D;*

xiv. Calculate net soil loss for the recommendation domain using the following equation:

$$A_{net} = A_g - S_f - D \qquad A25)$$

Where A_{net} is net soil loss for recommendation domain or for the selected major land use unit within the recommendation domain.

To account for annual reduction of soil depth as a result of soil loss use the following equation (modified after Mantel and van Engelen (2000) cited in Ephraim Nkonya, et al., (2006))

$$X = \left(\frac{A_{net}}{10^4} * \frac{T}{B} \right) * 100 \qquad (A26)$$

Where X is loss of soil depth (cm), A_{net} is net soil loss in Kg ha^{-1} yr^{-1}, T is number of years in the planning horizon, and B is bulk density of top soil in kg m^{-3}.

1.3. Determining nutrient loss

The other key component that needs to be determined to assess the on-site effects of land degradation is nutrient loss. Although there are a number of ways for nutrient to leave the soil, we only consider three major types of possible nutrient flows out of the soil, i.e., dung and crop residue burning and crop grain produced and removed. The total loss of yield as result of the above three selected ways of nutrient loss from the soil is calculated as follow:

1.3.1. Estimating nutrient loss due to dung and crop residue burning

This is the aggregated amount of dung and crop residue burned at household level and sold in market by each household. The intensity of dung and crop residue utilization as a source of fuel varies depending on the level of fuel wood availability and agro climatic conditions. Communities use dung as a source of energy in many parts of the country where the climate is cold and fuel wood availability is scarce. The best method to know the amount of dung and residue utilization is through comprehensive household survey. So far there are two surveys done along this line, i.e., by Newcombe (1989) and ENEC (1986). Sutcliffe (1993) compared the two studies and use the results of ENEC because of its comprehensiveness and nationwide coverage. The team acknowledges that much has been changed since the ENEC study was conducted in favour of increased consumption of dung and crop residue as a source of fuel in many parts of the country. However, by using the current population number for the final calculation the error might be reduced, though this has to be verified by sample surveys. Therefore, the team recommends verification of this value with focussed sample survey in each of the recommendation domains during the implementation of the CBF.

We proposed two possible ways of determining dung and crop residue utilization as a source of fuel:

i) Directly apply the conversion table suggested by ENEC (1986)

This value can be converted into annual utilization of dung and crop residue using the average value of $0.9M^3$ fuel wood consumption per person per year (Sutcliff, 1993, extracted from Newcombe, (1989)). Moreover, the nutrient loss as a result of burning dung and crop residue can be calculated using the conversion table suggested below (Table 8, 9, 10 and 11). Finally the costs of land degradation due to nutrient losses can be arithmetically calculated by combining the results from the different tables (see table 12). The following simple equation is used to calculate productivity loss due to loss of key soil nutrients as a result of dung and crop residue burning:
and

$$N_{lb} = N_{ldb} + N_{lcrb} \qquad (A29)$$

and

$$P_{lb} = P_{ldb} + P_{lcrb} \qquad (A30)$$

and

$$N_{A} = N_{afi} + N_{aw} + N_{afr/m} \qquad (A31)$$

and

$$P_{A} = P_{aw} + P_{afr/m} \qquad (A32)$$

Where Y_{lb} is yield loss due to net nutrient losses as a result of dung and crop residue burning; C_n and C_p are coefficients N and P to convert nutrient to equivalent yield respectively; N_{lb} and N_A are loss of nitrogen due to burning and Nitrogen addition to the soil due to various processes respectively; N_{ldb} and N_{lcrb} are loss of Nitrogen as a result of dung burning and crop residue burning respectively; P_{ldb} and P_{lcrb} are loss of P as a result of dung burning and crop residue burning, respectively; N_{afi}, N_{aw} and $N_{afr/m}$ are N addition as a result of fixation, weathering and addition of fertilizer and/manure respectively; P_{aw}

and $P_{afr/m}$ are P addition as a result of weathering and addition of fertilizer and/or manure, respectively.

Table 8: Household annual use suggested by ENEC (1986) and Newcombe (1989)

Energy source	% consumption suggested ENEC	% consumption suggested by Newcombe	
Fuelwood	78	36	
Dung	10	33	
Crop residue	9	23	
Charcoal	1	1	
Non-biomass	2	7	

Table 9: Annual use of dung and crop residue extrapolated from ENEC percentage, population number and conversion factors suggested by Newcombe

Energy source	% consumption	Equivalent to Fuelwood P^{-1} $Year^{-1}$	* Converted to tone of dung and crop residue P^{-1} $Year^{-1}$	Total population (national or zone)	Total annual consumption (tonnes)	Remark
Dung	10	9	6.21			
Crop residue	9	8.1	5.16			

* the following conversion factor from Newcombe, (1989) was used: 1 tonne of dung is equivalent to 1.45 M3 of wood and 1 tonne of crop residue is equivalent to 1.57 M3 wood.

Table 10: conversion table for dung and crop residue burned to nutrient loss

Energy source		Nutrient content by weight (%)		Total dung and crop residue consumed	Total nutrient loss due to burning of Dung and crop residue (N_{ldb}, N_{lcrb} & P_{ldb}, P_{lcrb})		Remark
		N	P		N	P	
Dung	Fresh	0.7	0.2				
	Dry (15% moisture content)	1.46	1.3				
Crop residue	Fresh	?	?				
	Dry	?	?				

Table 11: annual nutrient addition to the soil mass due to different processes

Nutrients	Addition to the soil				Remark
	Due to fixation from atmosphere (N_{afi})	Due to weathering (N_{aw} & P_{aw})	Due to fertilizer and manure application ($N_{afr/m}$& $P_{afr/m}$)	Total nutrient added to the soil (N_A & P_A)	
N					
P					

Table 12: net annual nutrient loss converted into production loss

Major nutrients	Nutrient loss due to burning of dung and crop residue	Nutrient added to the soil due to various factors	Net annual nutrient loss	Loss converted in production*	Remark
N					
P					

** taking all other factors at optimum level 1 Kg N is equivalent to ……. Kg grain and 1 Kg of P is equivalent to …….. Kg of grain (……………)*

ii) Following step-wise calculation using fuelwood deficit data per recommendation zone or identified unit

This could be done by considering the fuelwood deficit for identified recommendation domain and converting it to crop residue and dung following the procedures and conversion tables suggested above. Therefore, instead of using old survey results, we can translate the fuelwood deficit into equivalent dung and crop residue using the proportion suggested by ENEC (1986). It could be also possible to make very quick survey in each of the identified zones to come up with acceptable and representative proportion of household energy sources.

1.3.2. Estimating nutrient loss due to removal of produced grain

Every part of the plant is made of soil nutrients and water. Removal of crop grain or other edible parts of plant is another way for depleting soil nutrient. This is often neglected but we are trying to incorporate this in the nutrient balance calculation and see its impact in affecting soil productivity in general.

We will only focus on the production of dominant crops in each of the identified recommendation domains. Based on the land use data we can roughly estimate the amount of grain production using average values on hectare basis. The conversion of grain yield into major nutrient losses can be calculated using the conversion factors indicated on Table……. and the following series of equations:

$$N_{zi} = \sum_{i=1}^{n} \left(N_1 + N_2 + N_3 + \ldots..N_n \right), \text{ i=1-n} \qquad (A35)$$

where

$$P_{zi} = \sum_{i=1}^{n} \left(P_1 + P_2 + P_3 + \ldots..P_n \right), \text{ i=1-n} \qquad (A36)$$

Where

$$N_i = N_g * Y_i \qquad (A37)$$

Where

$$P_i = P_g * Y_i \qquad (A38)$$

N_{zi} and P_{zi} are total nitrogen and phosphorus removal from recommendation zone 'i', respectively; N_i and P_i are nitrogen and phosphorus contents of crop 'i' selected for the recommendation domain 'i', respectively; and Y_i is total yield of crop 'i' for recommendation domain 'i'.

Table 13: Nutrient content of major crop grains

Crop type	Nutrient content		Remark
	N	P	
Barley			
Wheat			
Teff			
Maize			
Sorghum			
Beans			

1.4. Estimating impacts of SLM practices

1.4.1. On cultivated lands

a. 1st scenario: Only physical SWC measures.

It is recommended to use existing SCRP data set (results of experimental plots) particularly their impact in reducing soil loss. This will also help to use the same production functions proposed on Appendix 4 the result can also be compared to yield data collected from EPs. For those areas that are not represented by SCRP some literature values representing the situations of these areas could be used to calculate impacts of the above selected measures.

b. **2nd scenario: Physical SWC measures with soil fertility and moisture management practices**

To determine the impact of this scenario, there is no well organized data at national level. Therefore, there are two possible ways to determine its impacts: i) conduct a minimum measurement by developing simple methodology to undertake on selected recommendation domains. ii) Modelling can also be used to determine the impact of these combinations. The WEPP model profile version, which was adapted to the Ethiopian condition (Gete Zeleke, (2000), or SWAT model can be used to determine the impact of such interventions.

c. 3rd scenario: All best management practices:

We also do not have well organized data for this scenario like that of the second scenario. Similar approaches can be followed like mentioned on scenario 2 but the measurement part might require more time. Possible measurements could be done on already well established project sites. In any case careful methodology development and model parameter development is required to get better results.

1.4.2. Afforestation

To determine the impacts of afforestation as one SLM practice in reducing land degradation and its economic benefits, the following two scenarios are recommended to be seen:

a. Afforestation with moisture conservation measures

This includes afforestation trenches, eyebrow basin, and micro-basin structures. It is known that survival and growth rate is high when plantation is done with moisture conservation structures. The above recommended structures have also their own costs and positive impacts. Therefore, it is recommended to quantify the impacts of afforestation through use of these measures either through measurement or using some literature values. Data from ARARI could help to develop the relations for specific recommendation domain areas.

b. Afforestation without moisture conservation measures

For the last many years afforestation has been undertaken using plantation pits only. In areas where moisture is limiting and high temperature areas, survival rate has been very low. Which means both the biophysical and economic benefits of plantation has been very low. This can be directly measured or taken from existing research results. Data from ARARI can also be used for this purpose.

1.4.3. Rehabilitation of degraded lands (area closure)

Area closure has been one of the major SLM activities that have been undertaken by the government and local communities for the last many years. This has been the case in many degraded parts of the country. Depending on many factors, very successful results have been registered in the past. The past experience showed that area closure can be done with and without moisture conservation measures. These are discussed below.

a. Area closure with moisture conservation structures

Many experiences in the country showed that area closure with moisture conservation structures, i.e., hillside terrace (widely spaced) combined with either with trench, eyebrow basin or micro-basin gives better results. The regeneration speed and capacity is very high. This should be investigated either through simple measurements or using literature values.

b. Area closure without moisture conservation structures

This has been the major action by the government and local communities in the past. The impacts of these measures need to be investigating using available data or direct measurement like that of afforestation.

2. Estimating off-site impacts:

Offsite impacts of land degradation have been neglected from previously done studies in Ethiopia. This is not due to its lack of importance but it is mainly related to lack of appropriate tools to quantify offsite impacts of land degradation and the complexity to capture major features. We, however, feel that this is important component of land degradation in Ethiopia and foresee possible work to quantify at least three major offsite impacts on selected parts of the country, i.e., siltation of dams and reservoirs that reduces storage capacity for power generation and irrigation (Koka, Sendafa, Angereb and Adwa dams), siltation of lakes that affects biodiversity (Lake Tana and Zewai) and deposition on downstream agricultural lands that reduces cultivated and grasslands (Ambassel Area, Wollo). We will focus on designing the methodology and applying the tools to quantify the off-site impacts but the full extent of offsite impacts of land degradation can be done afterwards.

To quantify siltation and related problems on reservoirs and lakes, we choose the Soil and Water Assessment Tool (SWAT) basin/watershed model. We found that SWAT has much potential to estimate the above two offsite impacts. Main features components and functions of the model and application procedures are described in the following sections.

2.1. Quantifying siltation of dams and lakes using SWAT model

2.1.1. The SWAT Model and its capabilities

The Soil and Water Assessment Tool (SWAT) is a river basin, or watershed, scale model developed by the USDA Agricultural Research Service (ARS). It is a continuous time, physically based and distributed watershed model (Tolson B.A., and Shoemaker, C.A., 2004). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2001a; 2001b). To satisfy this objective, the model is physically based. Which means, rather than incorporating regression equations to describe the relationship between input and output variables, SWAT requires specific information about weather, soil properties, and topography, vegetation, and land management practices occurring in the watershed (Neitsch et al., 2001a; 2001b).

Accordingly, the physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc. are directly modeled by SWAT using the above mentioned input data sets. Benefits of this approach are: i) watersheds with no monitoring data (e.g. stream gauge data) can be modeled; ii) the relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, etc.) on water quality or other variables of interest can be quantified; iii) uses readily available inputs; iv) is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money; v) enables users to study long-term impacts.

SWAT allows a number of different physical processes to be simulated in a watershed, i.e., hydrology, crop growth, soil erosion, nutrient and pesticide movement within the soil. The other potential of SWAT is its capability to take point source pollutants as an input and simulate their downstream impact. It also shows the impact of different management options on soil, water and nutrient flow balances. Which means the user can apply the recommended SM practices indicated on Section 2.2, on major land use units and could see their downstream impacts.

The model simulates processes at three levels: i) at Hydrologic Response Units (HRU), ii) sub-basin and iii) watershed level. HRU are sub-components of the sub-basin that are comprised of unique land cover, soil and management combinations. Simulation of processes at HRU level allows the user to locate where in the watershed major processes happened, in other words it allows locating hotspots within the watershed. Depending on the requirements of the user the model generates outputs for the three levels mentioned above. Therefore it is essentially a very powerful tool to predict both on-site and off-site land degradation process.

The model has weather generator that generates daily values from monthly average values. It generates daily precipitation, air temperature, solar radiation, wind speed and relative humidity. Since the weather generator is developed for the US weather database system, it needs minor adjustment to adapt it to other countries weather databases.

Apart from the weather generator it has also GIS interface. The interface allows classifying the watershed or basin into sub-basins (sub-watersheds) following drainage networks and the sub-basins into HRUs based on user defined criteria (i.e., soil, land cover and management options). The user can also run the model through this interface and this allows viewing results on map display.

The GIS interface software is called AVSWAT-2000 (version 1.0) (Di Luzio et al., 2002) which is an ArcView extension and a graphical user interface for the SWAT (Soil and Water Assessment Tool) model (Arnold et al., 1998).

According to Di Luzio et al., 2002), the AVSWAT-2000 ArcView extension evolved from AVSWAT, an ArcView extension developed for an earlier version of SWAT. In its current version, important functional components and the analytical capability of ArcView GIS are implemented in several sets of customized and user friendly tools designed to: (1) generate specific parameters from user-specified GIS coverages; (2) create SWAT input data files; (3) establish agricultural management scenarios; (4) control and calibrate SWAT simulations; (5) extract and organize SWAT model output data for charting and display. The most relevant components of the system are: (1) a complete and advanced watershed delineator, (2) a tool for the definition of the Hydrologic Response Units, and (3) the latest version of the SWAT model with a relative interface (for details see Di Luzio et al., 2002).

The only limitations of the model are its data requirements, needs of some data readjustment to fit the models data structure, and good professional capacity.

Therefore, apart from the limitations mentioned above it is a powerful tool to predict off-site impacts of land degradation mainly on lakes and storage dams (reservoirs). In general, the SWAT model can be used to predict the off-site impacts of land degradation (biophysical processes) in selected watersheds in Ethiopia.

2.1.2. Procedures of model application

Understanding, parameter generation (climate, soil, land use, management…., sensitivity analysis, model calibration using SCRP sites, model validation using SCRP data, develop site specific data or model parameter, apply model and analyse results (for details see Gete Zeleke, 2000).

Prior to the application of the model there are a number of steps that need to be taken. First and for most the user should try to understand what the model could do and what are the requirements as well as limitations. Following this sensitivity analysis, preliminary model parameter generation, model calibration, parameter adjustment, model validation and application are subsequent steps in model adaptation processes (for details on process-based model adaptation see Gete Zeleke, 2000).

Before site specific data is colleted the model should be calibrated and validated using SCRP research stations. Anjeni research station is a perfect site for this purpose because it is possible to benefit from the modelling experience and data filtering steps from Gete Zeleke (2000) work. Once the model is calibrated and adapted using measured values of SCRP stations, parameter generation of selected test watersheds or basins should follow. Efforts should be applied to derive model parameters from existing datasets. However, the available soil data layer is rather coarse and might need to conduct detailed soil survey on selected watersheds at a scale of 1:100,000 or 1:250,000. Most other parameters can be derived from satellite images (land use, DEM, slope, etc), from agencies (such as climate data) and applying different transfer functions and modules s well as generic values from literature (see also Di Luzio et al., 2002).

2.1.3. Procedures of translating model outputs to impacts

The SWAT model produce a number of outputs, such as sediment yield, key nutrients, pesticide, pollutants, and other climate, crop and soil specific outputs. For our purpose we will focus on the sediment yield, nutrient balance, pesticide and pollutant balances. The sediment yield should be converted into volume and loss of storage capacity in reservoirs. Reservoirs are used for three main purposes, i.e., to generate hydroelectricity, irrigation and water supply. The reduction in storage capacity can be translated into costs in different forms, such as loss of energy, reduction in water supply and reduction in irrigation water, cleaning costs to remove the sediment, and purification costs (mainly for water supply), etc. (see section 3). Ephraim Nkonya et al, (2006) use purification costs as major indicator of offsite impacts of land degradation in Kenya. Apart from this the amount of sediment leaving the landscape can also be translated into production forgone.

Moreover, the impact of siltation, nutrient, pesticide and pollutant flows on biodiversity in selected lakes including on fishery, will be quantified using existing data sets form Bahir Dar Fishery Research center and other sources.

2.1.4. Quantifying land lost as a result of gravel deposition

Although pure sediment deposition can be a positive impact of land degradation like that of the Nile Delta, it can also negatively affect downstream areas when the nature of the sediment becomes coarser. The latter is the case in many parts of the country, particularly in the eastern escarpments of Ambasel, Sirinka, Kobo, and Alamata areas. Huge fertile cultivated lands in downstream areas of Ambassel hill are now out of production due to heavy gravel deposition. In some places it displaces farmers. We don't find any model that can simulate gravel movement and estimate level of deposition. Therefore, we propose a simple survey to quantify amount of land taken out of production in these areas and this can be very easily converted into cost of land degradation using possible crop yield and other benefits the land used to serve.

Appendix 2: Crop production and SLM budget sheet for Economic Cost Benefit Framework

Cost types	Proposed SLM measure			
	No conservation measure	Conventional measures	Standard measures	Progressive measures
On-site costs/benefits	**Loss of production due to removal of top soil:** • Crop output per ha from untreated lands • Initial soil depth, slope, rainfall • Soil erosion rate • Standard production costs (cost of labor and capital used for production) **Cost of nutrient depletion:** • Dung removed from own farm (in tons/ha/year) • Crop residue burnt or sold from own farm (tons/ha/year)	**Loss of production due to removal of top soil:** • Crop output per ha from treated lands • Initial soil depth, slope, rainfall • Soil erosion rate • Standard production costs (cost of labor and capital used for production) • *Construction and maintenance cost the physical structures per ha.* • *Area used up by the structures* **Cost of nutrient depletion:** • Dung removed from own farm (in tons/ha/year) • Crop residue burnt or sold from own farm	**Loss of production due to removal of top soil:** • Crop output per ha from treated lands • Soil depth, slope, rainfall • Soil erosion rate • Standard production costs (cost of labor and capital used for production) • Construction and maintenance cost the physical structures per	**Loss of production due to removal of top soil:** • Crop output per ha from treated lands • Initial soil depth, slope, rainfall • Soil erosion rate • Standard production costs (cost of labor and capital used for production) • Construction and maintenance cost the physical structures per ha. • Area used up by the structures • Area used up by the grasses

Cost types	Proposed SLM measure			
	No conservation measure	Conventional measures	Standard measures	Progressive measures
		(tons/ha/year)	ha. • Area used up by the structures • *Area used up by the grasses* • *Capital and labor costs of producing the grasses* • *Imputed value of grasses used for livestock fodder* • *Reduced maintenance costs of the structures due to the stabilization effect of the grasses and other biomasses*	• Capital and labor costs of producing the grasses • Imputed value of grasses used for livestock fodder • Reduced maintenance costs of the structures due to the stabilization effect of the grasses and other biomasses • *Additional capital and labor costs of producing fruits, other trees and related income generating activities (both initial fixed costs, and average*

Cost types	Proposed SLM measure			
	No conservation measure	Conventional measures	Standard measures	Progressive measures
			Cost of nutrient depletion: • Dung removed from own farm (in tons/ha/year) • Crop residue burnt or sold from own farm (tons/ha/year)	*variable costs over time).* • *Area used up the fruits and other trees.* • *Average income collected from the sale of fruits, trees and related income generating activities* • *Average gestation period of fruits and other trees.* **Cost of nutrient depletion:** • Dung removed from own farm (in tons/ha/year) • Crop residue burnt or sold from own farm (tons/ha/year)

Cost types	Proposed SLM measure			
	No conservation measure	Conventional measures	Standard measures	Progressive measures
Off-site costs/benefits	**Costs of sedimentation on water storage:** • Sediment delivery ratio (SDR) to water reserviours. • Share of SDR coming from crop lands • Loss of energy production per unit loss of reservoir depth • Area of unirrigated land due to loss of water through siltation. • Additional operating costs for removing sediments through dredging per ha/year • Average cost of constructing dead storage per m^3. **Costs due to eutrophication of lakes** • Proportion of SDR to lakes that comes from crop lands • Average annual fish catch in the lake • Reduction in fish catches per	**Costs of sedimentation on water storage:** • Sediment delivery ratio (SDR) to water reserviours. • Share of SDR coming from crop lands • Loss of energy production per unit loss of reservoir depth • Area of unirrigated land due to loss of water through siltation. • Additional operating costs for removing sediments through dredging per ha/year • Average cost of constructing dead storage per m^3. **Costs due to eutrophication of**	**Costs of sedimentation on water storage:** • Sediment delivery ratio (SDR) to water reserviours. • Share of SDR coming from crop lands • Loss of energy production per unit loss of reservoir depth • Area of unirrigated land due to loss of water through siltation. • Additional operating costs	**Costs of sedimentation on water storage:** • Sediment delivery ratio (SDR) to water reserviours. • Share of SDR coming from crop lands • Loss of energy production per unit loss of reservoir depth • Area of unirrigated land due to loss of water through siltation. • Additional operating costs for removing sediments through dredging per

Cost types	Proposed SLM measure			
	No conservation measure	Conventional measures	Standard measures	Progressive measures
	year due to eutrophication and the resulting water hyacinth.	**lakes** • Proportion of SDR to lakes that comes from crop lands • Average annual fish catch in the lake • Reduction in fish catches per year due to eutrophication and the resulting water hyacinth.	for removing sediments through dredging per ha/year • Average cost of constructing dead storage per m^3. **Costs due to eutrophication of lakes** • Proportion of SDR to lakes that comes from crop lands • Average annual fish catch in the lake • Reduction in fish catches per year due to	ha/year • Average cost of constructing dead storage per m^3. **Costs due to eutrophication of lakes** • Proportion of SDR to lakes that comes from crop lands • Average annual fish catch in the lake • Reduction in fish catches per year due to eutrophication and the resulting water hyacinth.

Cost types	Proposed SLM measure			
	No conservation measure	Conventional measures	Standard measures	Progressive measures
			eutrophication and the resulting water hyacinth.	
Other info.	• Crop output prices, • fertilizer prices, • average wage rate • Average initial diffusion rate in each domain area.	• Crop output prices, • fertilizer prices, • average wage rate • Average initial diffusion rate in each domain area.	• Crop output prices, • fertilizer prices, • average wage rate • Average initial diffusion rate in each • *Price of livestock fodder per m^3.*	• Crop output prices, • fertilizer prices, • average wage rate • Average initial diffusion rate in each • Price of livestock fodder per m^3. • *Price of fruits, trees and other related outputs*

Appendix 3: Data needs and inventory of existing data for application of the framework

Existing data:

1. **Topographical Data**
   Agro ecological map: A recently made agro ecological map is available in MoA with a scale of 1:1M

2. **Soil Type and Geomorphology:**
   A map in a 1:1M scale is available in the MoA. The map was made in 1986 g.c

3. **Erosion Map:**
   A map in a 1:1M scale is available in the MoA. The map was made in 1986 g.c

4. **Hydrological Data:**
   Data on River flow: About 30 years data is available in the MoWR on major rivers of the country
   Data on Sediment Load: About 30 years data is available in the MoWR on major rivers of the country
   Basin Data: Data and maps on AEZ, land cover, soil type and erosion is available for about 6 major basins of Ethiopia

5. **Rainfall Data:**
   A complete country wide data is available in ESSP GIS-Lab
   Collected from metrology agency.

6. **Land Cover:**
   A recently (2002) prepared map on land cover is available in the (Woody Biomass) MoA in a 1:0.25M scale. Land use map is unavailable.

7. **Socio-economic data:**
   A complete woreda level socio-economic data for the overall country collected from CSA is available in the ESSP GOS-Lab

8. Data availability for the economic CBF (both for on and off site costs/benefits)

A. On-site costs and benefits

8.1. Scenario 1: No conservation measure

8.1.1. Loss of production due to removal of topsoil:

- Crop output per ha from untreated lands (Available in SCRP)
- Soil depth, slope, rainfall (Available in SCRP)
- Soil erosion rate (Available in SCRP)
- Standard production costs (cost of labor and capital used for production) (not available but the amount of labor and it's cost can be estimated from the demographic information in the SCRP)

8.1.2. Cost of nutrient depletion:

- Dung removed from own farm (in tons/ha/year) (Available in WBISPP but on Woreda basis)
- Crop residue burnt or sold from own farm (tons/ha/year) (Available in WBISPP but on Woreda basis)

8.2. Scenario 2: conventional conservation measures

8.2.1. Loss of production due to removal of topsoil:

- Crop output per ha from untreated lands (Available in SCRP)
- Soil depth, slope, rainfall (Available in SCRP)
- Soil erosion rate (Available in SCRP)
- Standard production costs (cost of labor and capital used for production) (not available but labor cost can be estimated from the demographic information in the SCRP)
- Construction and maintenance cost the physical structures per ha. (Not available but can be estimated from information in the SCRP data)
- Area used up by the structures (Available in SCRP)

8.2.2. Cost of nutrient depletion:

- Dung removed from own farm (in tons/ha/year) (Not available)
- Crop residue burnt or sold from own farm (tons/ha/year) (Not available)

8.2. Scenario 3: standard conservation measures

(no data from SCRP but fragmented cross section and limited data on different projects such as MERET at WFP and EARO)

8.3. Scenario 4: Progressive conservation measures

(no data from SCRP but fragmented limited period data on different projects such as MERET at WFP)

B . Off-site costs/benefits

Costs of sedimentation on water storage:

- Sediment delivery ratio (SDR) to water reserviours. (Available in EELC)
- Share of SDR coming from crop lands (Not available)
- Loss of energy production per unit loss of reservoir depth (Available in EELC)
- Area of unirrigated land due to loss of water through siltation (Not available)
- Additional operating costs for removing sediments through dredging per ha/year (Available in EELC)
- Average cost of constructing dead storage per m^3. (Available in EELC)

Costs due to eutrophication of lakes

- Proportion of SDR to lakes that comes from crop lands (Not available)
- Average annual fish catch in the lake (Available in Amara Fisheries Dept.)
- Reduction in fish catches per year due to eutrophication and the resulting water hyacinth. (Available in Amara Fisheries Dept.)

Other Information needed

- Crop output prices, (Available in CSA)
- Fertilizer prices, (Available in CSA)
- Average wage rate (Available in CSA)
- Average initial diffusion rate in each domain area. (Available)

Appendix 4: ToR for Cost-Benefit Framework for Ethiopia

Preparatory work in support of the application of a Cost-Benefit Framework to support pro-SLM decision-making in Ethiopia

ToR for national consultants

Background

Land degradation is a major factor in the low agricultural productivity of Sub-Saharan Africa and is estimated to be responsible for 2 to 3% loss in the agricultural GDP[21]. Although land degradation is recognized as a major development issue, sustainable land management (SLM) has however not received desired attention in the development agenda of SSA countries due to the existence of a number of critical barriers, including an unorganized body of knowledge, and weak analytical underpinnings to support decision-making processes. As a result, the scale and scope of investments in SLM programs continue to be limited. A prerequisite for addressing these barriers, and promoting the adoption and scaling-up of SLM practices is to acquire a better understanding of the impact of land degradation and the related benefits of SLM. A better understanding of the negative impact/positive effects of LD/SLM would in fact provide evidence to decision-makers of the magnitude of the problem and of the benefits from implementing SLM policies and practices. Decision-making processes would thus be better driven, as based on a better understanding of the problem. In addition, by involving stakeholders (particularly key decision-makers) in the development of the framework this is expected to strengthen the policy dialogue in the country.

In this framework, TerrAfrica - a multi-stakeholder partnership which seeks to enable the scaling-up of mainstreaming and financing of SLM - is developing a set of analytical tools to strengthen the knowledge of land degradation and of its effects, with the objective of mainstreaming SLM in the development agenda of Sub-Saharan Africa. Among these tools, TerrAfrica is supporting the development of a framework to assess the impact of land degradation and the benefits of SLM: the *"Cost-Benefit Framework for pro-SLM decision-making in Sub-Saharan Africa"*. The framework is intended to present the extent, severity and impact of land degradation, in order to provide information on the costs of degradation, benefits of SLM practices, and trade-

[21] This estimate is based on a recent review of cost of land degradation in Ethiopia which is part of the ESW phase I work on poverty and land degradation in Ethiopia.

offs involved in policy choices that could guide decision-making, with the aim of supporting the mainstreaming of SLM.

During FY05 a decision-framework for accounting the costs and benefits of land degradation and SLM[22] was developed to support the World Bank SLM product line. This decision-framework provides some guiding principles for assessing the impact, the costs and the benefits of land degradation and SLM practices. Based on that decision-framework, this consultancy aims at identifying the necessary data, capacity, conditions etc. to apply the framework to the specific context of Ethiopia.

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

Activities

Introduction: The consultancy will build upon previous assessments and methodological frameworks already available, including in the concept paper "A Decision Framework for Accounting Costs and Benefits of Land Degradation and Sustainable Land Management" produced by D. Vadnjal, J. Rudengren and G. Björklund under the previous phase of this project. The consultancy will also take into account guidance from the World Bank provided through, e.g. the "Framework for Economic Analysis of Land Degradation and Assessment of Priorities for Sustainable Land Management in Sub Saharan Africa" drafted by Rama Reddy, and through documentation on TerrAfrica. In addition, in Ethiopia, the consultancy will be complemented and guided by the outcomes of the first phase of the World

[22] D. Vadnjal, J. Rudengren and G. Björklund (2004)

Bank/IFPRI analytical work on poverty and land degradation that has so far produced two deliverables (a review of determinants and impacts of land management technologies, and a critical review of previous studies on cost of land degradation in Ethiopia). A third deliverable from this ESW will be a stakeholders' analysis, which is currently under way. Much of the findings of the World Bank/IFPRI analyses could provide a basis for further fact finding work that will be undertaken by the consultancy, and for defining the information needed to apply the Cost-Benefit Framework that this consultancy will contribute to prepare. The fact that EEPFE is the lead investigator for the World Bank/IFPRI work and the consultancy makes the potential for synergies much stronger. These synergies would also be further strengthened by a back-to-back workshop that will possibly discuss the fact finding work of the consultancy and the three deliverables of ESW phase I. The comments from the workshop are expected to provide important inputs for the final design of the Cost-Benefit Framework.

The guiding principle for the consultancy is to provide important inputs for a Cost-Benefit Framework that can be applied to assess costs and benefits of SLM interventions in Ethiopia and elsewhere. The lessons learnt and the knowledge generated through this Cost-Benefit Framework will be in fact shared and possibly replicated regionally. It should thus be simple enough to be applied in a situation with limited access to data, fairly low technical capacity and high staff turn-over. It should, most likely, have a staggered approach that sequentially takes into account the severity of off-site effects and thus prioritizes areas for intervention and then identifies the most effective treatments of these areas (e.g. basin, catchment or micro-catchment).

Specific Activities: Activities to be carried out by the consultants in cooperation with the Swedish Technical team (Gunnar Köhlin[23] and Gunilla Björklund) and the World Bank during the work include:

(1) Fact-finding work (to be guided by a conceptual note by the Swedish team) and consultation with key stakeholders and project/research implementers:

a) The fact finding work should include an analysis of the baseline situation in Ethiopia that will include the definition of the geographical area for the work, and the assessment of the availability, typology and quality of the

[23] In particularly Gunnar Köhlin will contribute actively in this work.

existing data. Since the framework should include both off-site and on-site effects of land degradation, the fact finding will be organized accordingly:

i. **Off-site effects of land degradation and benefits of applying SLM**

The concept note prepared by the Swedish Team outlines a number of potentially economically important off-site effects of land degradation. The relative importance of such effects will be one guiding principle in the prioritization of SLM interventions. The fact finding should therefore start with an inventory of existing GIS databases on topography, hydrology and soil maps. The IFPRI/ESSP GIS lab at EDRI is a natural starting point for this work. The next step is to interact with federal and regional agencies to identify potentially critical catchments with substantial documented off-site problems. In line with the concept note prepared by the Swedish Team the consultancy should focus on three types of off-site impacts, i.e., impact on biodiversity (eg Lake Tana has plenty of information including historical sediment records of the lake, and possibly Lake Zeway could be added); impact on reservoir capacity (eg Borkena and Koka dams); impact on downstream plain areas (eg Ambasel plain areas in the eastern parts of the country). For such catchments all available data should be identified relating to physical dose – response functions and their potential economic impacts. In addition the consultancy should identify and describe the relevant soil and catchment models that have been applied on Ethiopia (eg by the SCRP/Bern University; Wageningen University; Norwegian University of Life Sciences).

ii. **On-site effects of land degradation and benefits of applying SLM**

A natural starting point for this part of the consultancy is to draw on the reviews made in the ESW on Poverty and land degradation. These reviews identify a number of the existing studies and research projects that have studied (i) the incidence of land degradation (ii) impacts on productivity (iii) economic impacts. The next step would be to identify whether there is an empirical basis for a more general mapping of cost of land degradation. For this purpose biophysical data should be sought for sites from representative areas. For example, SCRP data set, supplemented by other studies, could be the center of such an analysis. Out of the six research sites of SCRP, the following five could be used because of their representation of major parts of the highlands of Ethiopia. Anjeni (Gojam, representing high rainfall, intensively cultivated (mostly cereals), highly weathered and better soil depth but areas currently under high rate of degradation), Maybar (Wollo, representing the bimodal rainfall areas in the country with high rainfall variability but with moderate to sever land degradation level), Gunnuno (Wolaita, representing densely populated and intensively cultivated areas of the south with high rate of degradation), Dizi (South Oromia, representing recently cleared areas), Hundelafto (Harergea, representing densely populated Chercher highlands, mainly sorghum growing with inter cropping culture, with moderate moisture stress and moderate to sever land degradation levels). Taking these smaller watersheds as nuclei, the possibility to use them as a base for extrapolating to the larger watersheds around them to design the Cost-Benefit Framework should be studied.

By identifying the data that are available for the representative sites it should be possible to assess (i) the level of analytical ambition that can be achieved for the proposed Cost-Benefit Framework on the basis of exiting data and (ii) the need for further primary data collection to be able to design useful Cost-Benefit Framework.

b) dialogue with project/research implementers currently working in Ethiopia to identify relevant research gaps, lessons learnt, best practices, possible synergies and areas for cooperation. This could be largely drawn from the stakeholder analysis carried out under the ESW I, but selected stakeholders that were not consulted during the stakeholder analysis will be consulted.

c) consultation with key stakeholders, including national, regional and local governments, to acquire critical information to develop the framework.

d) control at field level of the expected costs and benefits at some selected sites, for example those indicated under ‘a’ above.

(2) Adaptation of the cost-benefit framework to the context of Ethiopia:

Based on work already done (i.e. the decision-framework for accounting the costs and benefits of land degradation and SLM, the concept note prepared by the Swedish Team), the fact-finding work carried out under deliverable 1, and on gap analysis, the consultancy should propose the most appropriate empirical approach for an application of this decision framework to Ethiopia. The selected geographic units mentioned under a) above shall be used as a basis for the proposed methodology.

The Cost-Benefit Framework, once confirmed with the country and the Bank team, should be able to be used for: (1) assessing the impacts of land degradation on land use, productivity and ecosystem services, trying to quantify them, and, whenever possible, to translate them into economic terms, (2) considering, and if possible quantify, the economic, social and environmental impacts of land degradation, (3) assessing the off-site effects of land degradation (externalities), (4) prioritizing SLM activities. It should also be responsive to the administrative constraints identified in the abovementioned stakeholder analysis. Given the current organization of SLM activities in Ethiopia it is expected that the Natural Resources Management Section (at State Minster level) of MoARD and Regional BoARD will implement the cost benefit framework. The land proclamation and EPA's guidelines will provide the legal basis for the application. In addition, the ultimate implementation process can be expected to be supported by EDRI (EEPFE and the GIS helpdesk of ESSP), the Natural Resources Management Directorate of EARO and the Regional Agricultural Research Institutes (RARAIs).

Expected outputs

Deliverable 1: Detailed work plan, within a week from signing the contract:
The Ethiopian team should provide a detailed work plan with an outline of the final report for consideration by the Swedish team and the World Bank.

Deliverable 2: Fact finding, due February 15, 2006:

a) A fact-finding report that includes an analysis of the baseline situation in Ethiopia, including identification and an assessment of the availability, typology and quality of the existing data, as well as an identification of data needed but not existing for the purpose of implementing a Cost-Benefit Framework.
b) Recommendations regarding the definition of the geographical area that the consultancy will focus on based (i) on the available data, (ii) the identified degradation processes and impacts, (iii) the potential for relevant welfare analysis (outlining costs in terms of dose-response functions of degradation)

and (iv) representativity of study areas of major land degradation processes in the country, since the processes in the South are different from the North of the country.

Deliverable 3: Workshop, due late March 2006:

Workshop with relevant stakeholders at federal and regional levels to discuss the findings in deliverable 1 and the draft outline of the Cost-Benefit Framework (deliverable 3). In order to maximize synergies with the World Bank/IFPRI work the cost of land degradation and stakeholder analysis from the "Poverty and Land degradation" project could also be presented, at the condition that the agenda of the workshop provides enough time and space to properly discuss each issue.

Deliverable 4: Cost of land degradation framework, due March 30, 2006

Based on the framework developed by the Swedish team, the consultancy should provide a report describing the potential application of such a Cost-Benefit Framework for assessing land degradation in Ethiopia. The report and framework should be made considering its implementation under an MSP. A first draft is to be prepared by March 1. The Framework should be developed with the active involvement of different stakeholders (at different levels and in different sectors) The Framework should meet the requirements mentioned above and include, among other things:

- The expected/required preparation process for implementation of the framework.
- The methodologies to be used, explicitly considering the trade-offs between quality and cost of the analysis.
- The required data and existing availability or cost of data collection.
- Geographical limitations of implementation based on lack of data or focus on certain impacts.