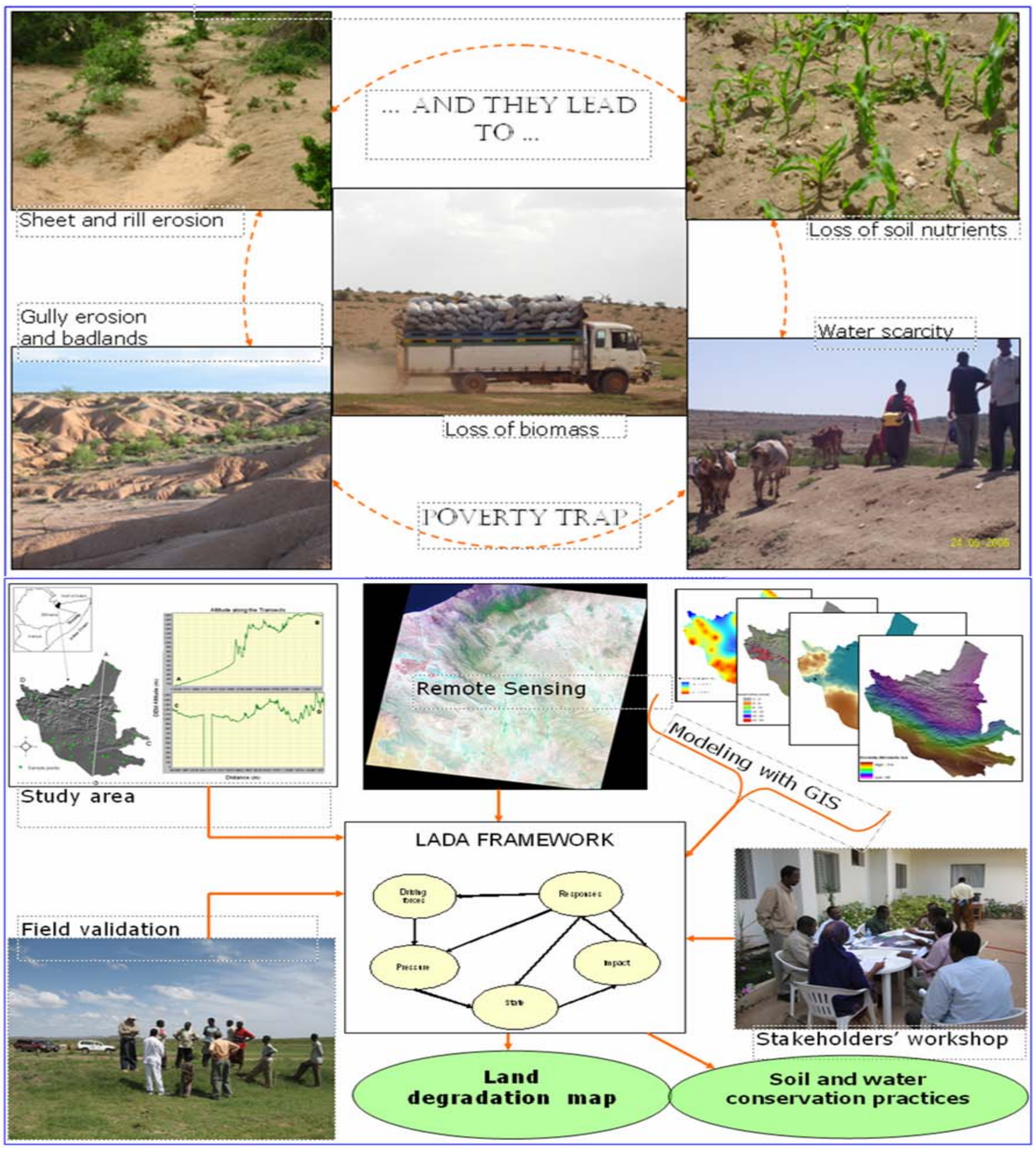
SWALIM

Land Degradation Assessment of a Selected Study Area in Somaliland: Application of Lada-Wocat Approach



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Somalia Water and Land Information Management
Ngecha Road, Lake View. P.O Box 30470-00100, Nairobi, Kenya.
Tel +254 020 4000300 - Fax +254 020 4000333,
Email: enquiries@faoswalim.org Website: http//www.faoswalim.org.

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Table of contents

List of Figures

List of Tables

List of acronyms

ADO	- Agricultural Development Organization
AEZ	- Agro-Ecological Zones
ASTER	- Advanced Space borne Thermal Emission and Reflection Radiometer
AVHRR	- Advance Very High Resolution Radiometer
BVO	- Barwaaqo Voluntary Organization
CART	- Classification and Regression Trees
CBO	- Community Based Organization
CTA	- Chief technical Advisor
DEM	- Digital Elevation Model
FAO	- Food and Agriculture Organization
FSAU	- Food Security and Assessment Unit
GAA	- German Agro Action
GLADA	- Global Land Degradation Assessment
IFAD	- International Fund for Agricultural Development
LADA	- Land Degradation Assessment
LUS	- Land Use System
MODIS	- Moderate-Resolution Imaging Spectrometer
NDVI	- Normalized Difference Vegetation Index
PENHA	- Pastoral and Environmental Network in the Horn of Africa
PRA	- Participatory Rural Appraisal
RUSLE	- Revised Universal Soil Loss Equation
SAR	- Synthetic Aperture Radar
SLM	- Sustainable Land Management
SPOT	- Satellite Probatoire d'Observation de la Terre (The French Remote Sensing Satellite)
SRTM	- Shuttle Radar Topography Mission
SWALIM	- Somalia Land and Water Information Management
SWC	- Soil and Water Conservation
UN	- United Nations
UNEP	- United Nations Environment Program
UNOPS	- United Nations Office for Project Services
WFP	- World Food Program

1. INTRODUCTION

1.1 Background

Land degradation assessment carried out in Somaliland was in response to numerous reports and suggestions about on going different types of degradation (e.g. soil erosion, loss of vegetation due to charcoal production, nutrient decline, etc), which affect implementation of development programs in Somaliland. The assessment was done to identify affected areas, the major causes, and quantify land degradation in a way that can support accurate and sustainable implementation of necessary control measures.

Before carrying out the assessment, it is important to understand the concept of land degradation: its definition, types, and characteristics. There are a number of definitions in the literature for land degradation. However, they all revolve around reduction of land resource potential by one or a combination of processes such as accelerated soil erosion by water or wind erosion, sedimentation, long-term reduction of the amount or diversity of natural vegetation, reduction of soil nutrients, increase of aridity, and salinization and sodification [28]. Recently, LADA [11] defined land degradation as reduction of the capacity of land to perform ecosystem functions and services (including those of agro-ecosystems and urban systems) which support society and development.

Land degradation is a gradual negative environmental process which can be accelerated by human activities. Due to its gradual nature, it takes some time (e.g. from a rainy season to several years) before manifesting observable symptoms in the field and is therefore often unnoticed until it is quite advanced. During its development, it leaves a trail of destruction which may be difficult and costly to eradicate should the responses to control the degradation be delayed. Examples of such destructions include inhibition of root-zone supply of water and nutrient for plant growth and subsequent reduction of food production, loss of vegetation and consequent loss of livestock pasture, interference with hydrologic cycle through decimation of trees and siltation of surface water reservoirs, destruction of road network by gully erosion, among others. These negative effects generally touch on food security, economic well-being, and environmental conditions; thus, explaining the reason behind much attention given to land degradation worldwide.

Since land degradation is a process and involves human activities, its assessment and monitoring should involve space and time dimensions as well as human activities. Inclusion of human activities in the assessment and monitoring is important because some human activities exacerbate negative environmental processes so that the land resources are not able to recover by themselves; thus leading to human-induced land degradation. Therefore, a meaningful assessment of human-induced land degradation should include land use patterns [16]. Space and time are also important aspects of land degradation assessment. They should be incorporated through proper establishment of a good baseline data and subsequent measurements. The baseline data serves to quantify the status of land resources at the start of land degradation assessment and monitoring process so that comparison with future measurements can lead to objective quantification of whether the land is degradation or improving.

In the current study of land degradation in Somaliland, attempts were made to include the above aspects of land degradation.

1.2 Definition of some common types of land degradation

There are three main groups of types of land degradation in Somaliland: soil degradation, biological degradation, and water degradation.

1.2.1 Soil degradation

Soil degradation occurs when the soil chemical or physical conditions have been negatively altered. Examples of soil degradation include acidification, salinization, organic matter depletion, compaction, nutrient depletion, structural deterioration, loss of topsoil, gully erosion, chemical contamination. In Somaliland, the most common soil degradation types identified by experts are loss of topsoil, nutrient depletion, and gully erosion (Table 1.1).

1.2.2 Biological degradation

Biological degradation includes loss of biomass, biodiversity, and loss of soil life. The most common types of biological degradation in Somaliland are loss of vegetation cover, loss of vegetation species, loss of habitat, and reduction of biomass (Table 1.1).

1.2.3 Water degradation

Water degradation includes processes such as aridification, change in quantity of surface water, change in ground water level, decline in surface/ground water quality, and reduction of the buffering capacity of wetlands [13]. During expert assessment of land degradation in Somaliland, the experts identified aridification and decline in surface water quality as the main types of water degradation (Table 1.1).

Table 1.1: Common types of land degradation in Somaliland

Type	Definition
Soil erosion by water	Implies the removal and transport of soil particles by water. Different types of soil erosion by water can be identified: loss of topsoil, gulley erosion, riverbank erosion, etc.
Soil erosion by wind	Where wind has direct access to bare dry soil and causes soil detachment and removal. The forms of it are: loss of topsoil, deflation and deposition, offsite degradation effects
Soil chemical deterioration	Refers to the negative change of the chemical properties of soil. Fertility decline in agriculture productive areas is the most common type of chemical degradation.
Water degradation	Water degradation includes processes such as aridification, change in quantity and quality of surface water, and drop in ground water level.
Biological degradation	Reduction of the vegetation cover, loss of vegetation species and habitats, and decline of biomass

1.3 Methods for assessing land degradation

Many methods have been developed in the literature for assessing land degradation. They range from field measurements, laboratory measurements of samples taken from the field, remote sensing applications and specifically the use of NDVI signals, expert assessment, and observations on changes in land productivity [5, 6, 18, 13, 19, 26].

In the last few years, the United Nations Environment Program (UNEP) and Food and Agriculture Organization (FAO) developed a Land Degradation Assessment in Drylands (LADA) framework, which attempted a holistic approach towards effective assessment of land degradation [7]. This framework is currently being debated and improved to effectively capture driving forces of land degradation, status and impacts, and what can be done to combat the degradation. It has numerous advantages including accommodation of a variety of practical steps for assessing and monitoring different aspects of land degradation. Exhaustive description of this framework, its methodological steps, and a set of activities to guide the assessment process can be found in online documents by the LADA project (http://lada.virtualcentre.org/pagedisplay/userguide.htm).

1.4 Land degradation in Somaliland

In Somaliland, many aspects of advancing land degradation have been reported in various literatures [8, 10, 17, 33]. The reports show evidences of loss of vegetation, gully erosion, loss of topsoil, siltation of surface dams and irrigation canals, invasive non-palatable plant species, and loss of plant nutrients in agriculture potential areas. These land degradation types affect pasture availability and consequently affecting livestock production. They also have negative influence on crop production in agriculture productive areas. In general, it can be said that land degradation is potentially affecting the traditional pastoral production systems which is the mainstay of Somaliland. The need for its assessment to support policy formulation and implementation of control measures can therefore not be overemphasized.

FAO-SWALIM successfully carried out a study of national and local level assessment of prevalent types and extent of land degradation in Somaliland. The objective of the study was to clearly identify the main types of land degradation, goods and services affected, the root causes, and potential ways for combating land degradation in Somaliland. The study also identified measurable indicators for monitoring land degradation. This technical report documents the methods, main findings from the study and proposed a monitoring framework.

1.4.1 Historical perspective of land degradation in Somaliland

The environmental and socio-economic characteristics of Somaliland are those that represent dryland ecosystem. It is characterized by low annual rainfall (below 200 mm) in most parts except in the western region and on the Golis Mountains (with about 300 – 500 mm). The soil is mainly sandy in the coast, silty loam in the piedmonts and clayey in the plateaus. Low rainfall amounts and the dominant soil types support rich dryland vegetation, which make pastoral livestock production a key economic activity in Somaliland. However, due to changes in climate, human and livestock population, and changes in national and global economy, the people of Somaliland have changed their land use patterns and economic activities in the last few decades. It is important to note however that even though the land use patterns have been changing, land resources (e.g. soil, water, vegetation) have not changed commensurate with the land use changes. In fact, in most cases the use of land resources has been stretched beyond the land's ability to recover; hence leading to land degradation.

The history of land use changes which has contributed to the present degradation problems in Somaliland can be traced back to 1890s. Between 1890 and 1900, the onset of land degradation was due to legislations introduced by the colonial government with regard to land use patterns. It has been reported that the colonial government introduced legislation for demarcation of some parts of western Somaliland for crop cultivation and later altered land ownership rights in these areas from communal to individual [8, 24]. These changes later triggered the onset of land degradation in Somaliland. For example, after the collapse of the central government in 1990s, the demarcated areas were later slowly and illegally increased up to steep slopes by the neighbouring clans who wanted to benefit from crop production. Since Somaliland is largely pastoralist society, the introduction of crop production without proper extension services on land management was more or less the incipient cause of some common types of land degradation (e.g. nutrient decline, gully erosion, loss of vegetation, etc). In some other places, the land subdivision policy for individual ownership as implemented by the post-colonial government was done in a way which promoted soil erosion. For example, there are cases where the sub-divisions were done such that the longest side of the sub-divided land was along the general slope of the land. During land preparation, the land users in trying to maximize ploughing efficiency (e.g. by reducing the number of turns with their oxen) ploughed along the slope instead of across the slope. Consequently, their ploughing practice led to accelerated soil erosion by water as is evidenced by gullies at the bottom of some farmlands. Still there are cases where the change of land ownership from communal to individuals altered the original livestock movement between wet and dry-season grazing patterns. The subsequent lack of original grazing pattern led to concentrated grazing and which has since contributed to over-grazing [24].

Apart from the contribution of bad policy and policy implementation towards land degradation, there are also reports of charcoal trade as a historical problem exacerbating land degradation in Somaliland. Charcoal trade is one of the traditional economic activities in Somaliland [24]. During the reign of the central government, it was regularized by acts of parliament and co-operative societies. After the collapse of the central government in early 1990s, the controls were never adhered to and to date many tree species have been cut for commercial charcoal production [1, 17].

Not only has this occasioned loss of vegetation but also removed the protective cover of the fragile soil; thus, leading to loss of topsoil and gully erosion in many parts of Somaliland.

Another historical factor which has contributed to the current state of land degradation in Somaliland is the invasive and non-palatable *Prosopis juliflora* plant specie. This plant was introduced into western Somaliland around refugee camps by humanitarian agencies after 1977 war between Somalia and Ethiopia [4, 24]. It was introduced partly to supplement the demand for fuelwood and partly to check the rising soil erosion at that time due to the removal of vegetation by the refugees around their settlement camps. The plant has since rapidly expanded and colonized many parts of western, sub-coastal and coastal zone, Somaliland.

The socio-political upheavals in Somalia cannot also be ignored in terms of their contribution to land degradation. Since the onset of civil unrest in early 1990s in Somalia, there have been problems with policy development and implementation in Somaliland with respect to use and management of land resources. Consequently, there are many cases of overuse of natural vegetation and mismanagement of soil and water resources as the population try to eke out livelihood from the environment. In this situation, the land resources definitely cannot sustain their capacity to effectively perform their ecosystem functions.

1.4.2 Approach for assessing land degradation in Somaliland

In view of the historical perspective of land degradation in Somaliland, an ideal assessment of land degradation would require data on land resources going back as early as 1900. However, this was not possible due to lack of reliable and accessible historical data. In this study, assessment of land degradation in Somaliland was done using the LADA-WOCAT framework [13]. Four different tools were used within this framework for assessing different types of land degradation; GIS and remote sensing applications, expert assessment using local experts, statistical modelling, and field surveys. These tools were used to try to overcome constraints of ideal land degradation assessment by integrating different sources of information, comparing limited historical data with current data layers, and producing spatial representation of different land degradation types and problems in Somaliland.

Two levels of assessment were carried out: national and local level. National level assessment was done for the whole Somaliland and aimed at identifying local spots to target for comprehensive assessment. This assessment is useful in guiding policy decision on areas to prioritize for controlling land degradation. Local level assessment was done in a selected area in western Somaliland in detail. Its aim was to quantify the prevalent types and degree of land degradation. The assessment will be useful in guiding the kind of effort needed to combat land degradation at the local level.

This report documents the results from the above two levels of assessment in Somaliland. The report is divided into two parts: Part (I) and Part (II). Part (I) documents national level assessment and Part (II) documents the local level assessment of land degradation. The major sources of data for land degradation assessment were those collected between 1982 and 2008. Therefore, the results contained in this document must be viewed in the context of this time frame.

PART I: NATIONAL ASSESSMENT OF LAND DEGRADATION

2. METHODOLOGY

National land degradation assessment was done using the LADA-WOCAT method [13] and remote sensing (mainly NDVI) analysis [5] (Figure 2.1). They were used as a basis for identifying local spots for detailed assessment. Their input requirements, application procedures, and integrated results are explained below.

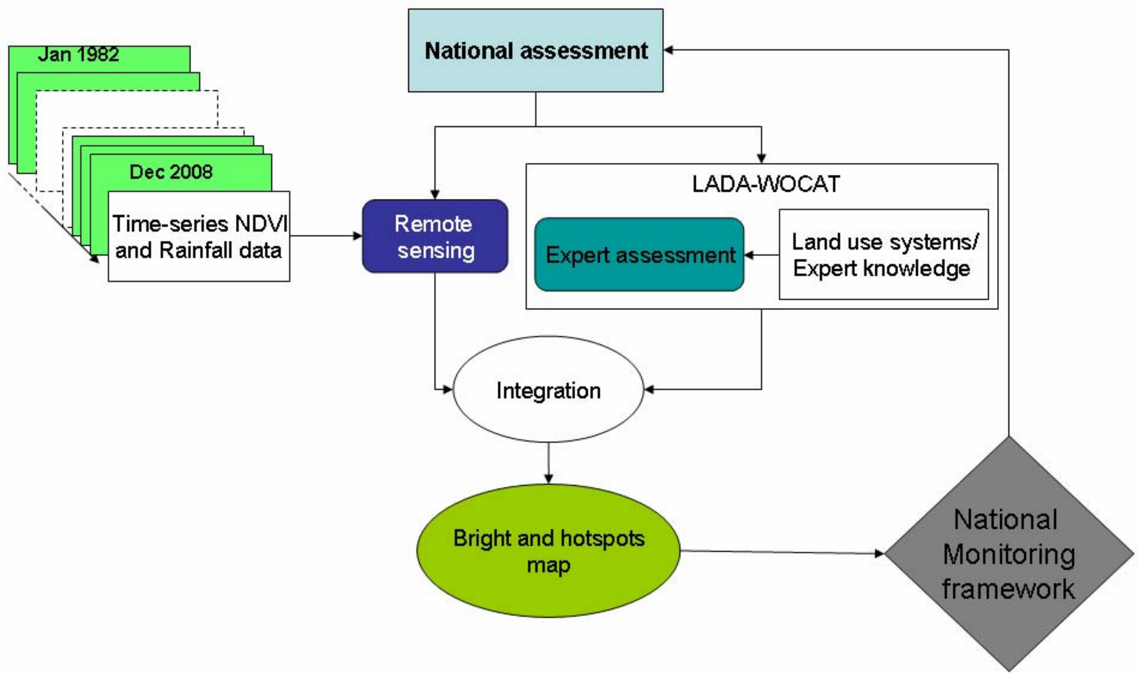


Figure 2.1: National assessment and monitoring of land degradation in Somaliland

2.1 National assessment of land degradation using LADA-WOCAT method

National assessment of land degradation using LADA-WOCAT involved: development of a land use systems map, validation of the LUS map, expert assessment of land degradation, and development of land degradation map from the expert assessment.

2.1.1 Land use systems map

Land use, is defined as the sequence of operations carried out with the purpose to obtain goods and services from the land. It is generally determined by socio-economic market forces and the biophysical constraints and potentials imposed by the ecosystems where they occur [16]. Land use systems map is a map of homogeneous areas of human activities and the resources base. It was proposed by the Land Degradation Assessment in Drylands (LADA) Project to guide global and regional assessment of land degradation because it attempts to incorporate the main drivers of land degradation [13].

The data used in this study for deriving land use systems (LUS) map were: land cover map, land use map, Digital Elevation Model (DEM), livestock distribution map, and livelihoods map. All these datasets were available at FAO-SWALIM. The methodology provided by Nachtergaele and Petri [16] was used in producing the LUS map for Somaliland (Figure 2.2).

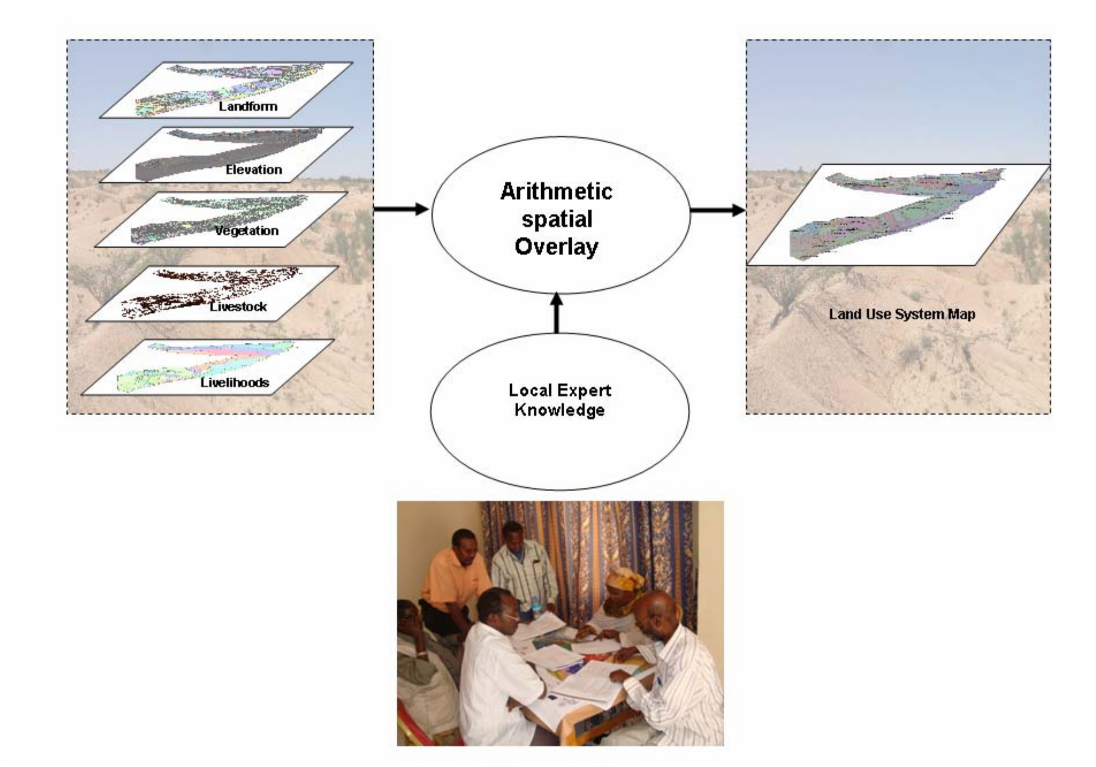


Figure 2.2: Development of land use systems map for Somaliland

2.1.2 Validation of LUS map and expert assessment using Questionnaire

A three-day expert assessment meeting between 17th and 19th January 2009 was organized to validate the LUS map and to use it in national assessment of land degradation. 14 Somali experts (Figure 2.3) from Somaliland government ministries, local and international NGO's, Universities, UN organizations, and freelance consultants attended the meeting.

Figure 2.3: Somali experts during a land degradation assessment meeting

Before validation of the LUS map and assessment of land degradation, the experts were given a short appraisal of the need for land degradation assessment in Somaliland, development of a land use systems map, and the procedure for assessing land degradation using the questionnaires. The experts were then grouped according to their geographic regions of knowledge and each group selected a leader to guide the process and to report their output.

All the units of the LUS map were verified in terms of their boundaries and description of their classes. The experts also verified if all actual land use systems were included at the mapping scale and adjusted the map accordingly. Thereafter, the map was adjusted and used to guide the filling of questionnaires.

Filling of the questionnaires was done using the LADA-WOCAT guidelines (http://www.wocat.org/QUEST/mape.pdf) and entailed: a) identifying the area and intensity trend of each land use system (for example if rainfed farms were expanding in area and intensity in terms of inputs in an Agro-pastoral LUS unit); b) assessing the types of land degradation in each LUS unit, then the extent, degree and rate of degradation. Complexities of land degradation (direct causes, indirect causes and impact on ecosystem services) were also identified; c) identifying and characterizing the sustainable land management practices that were in place, specifying the name of the practice, type of measure, the purpose, percent of the LUS unit that this measure occupied, the type of degradation addressed by the sustainable Land Management (SLM) practice, the effectiveness and trend of the SLM measure, the impact on ecosystem services and the period in which they were established; d) finally the experts were asked to provide expert recommendation in terms of how to address the land degradation problems in each LUS unit. Towards the end of the meeting, a final plenary discussion was established in which the experts discussed the main issues regarding the pros and cons of the assessment approach, the land degradation main findings, and the way forward. A sample of the filled questionnaire during the meeting can be found in Appendix 1.

2.1.3 Mapping land degradation and sustainable land management using outputs from expert assessment

Information from the questionnaires were first entered into a database and statistically analyzed to determine the prevalent land degradation types, their causes, and extent of the affected areas. Sustainable land management practices and impacts on ecosystem services were also obtained at this stage.

After analyzing the response from the questionnaires, the LUS codes in the database were linked to the same codes in LUS map in order to translate the responses into maps of land degradation types, their causes, and conservation measures in Somaliland. Since there were cases of more than one land degradation type in some LUS codes, more than two maps of land degradation types were necessary. However, for simplicity, this study only produced the prevalent types which were given first priority by the experts.

For representing the extent, severity and trends of different land degradation types per LUS codes, the degradation and conservation indices developed by Lindeque [12] were adopted and adjusted in this study. The indices were degradation index (DI) and sustainable land management practices index (SLMI) as given in Equation (1) and (2).

$$\mathbf{DI = \%\ Area * (Degree + Rate) / 2} \quad (1)$$

where %Area is the area affected by land degradation, degree is the mean intensity of the degradation processes within a LUS unit, and rate is the mean trend of the degradation processes within the LUS unit. %Area, degree, and rate of land degradation in Equation (1) are obtained from the questionnaires as explained in [13] (http://www.wocat.org/QUEST/mape.pdf).

$$\textbf{SLMI} = \textbf{\% Area} * \textbf{(Effectiveness + Effectiveness trend) / 2} \qquad (2)$$

where %Area is the area covered by a specific SLM and effectiveness is defined in terms of how much the SLM practices reduces the degree of land degradation in the LUS unit [13]. Once the indices were calculated, their thresholds for mapping different types of degradation and conservations efforts in Somalia were developed using the guidelines in Table 2.1.

Table 2.1: Thresholds for categorizing land degradation maps from expert assessment

CLASS	DI	CLASS	SLMI
Non degraded	0-10	No SLM	0
Slight	11-26	Very scattered	0.1-5
Moderate	27-50	Moderate	06-10
Strong	>51	Few	11-78

2.2 Remote sensing method for assessing land degradation

2.2.1 Approach used

Remote sensing signals of vegetation cover were used to identify potential areas with land degradation symptoms. They were used mainly because; 1) they are easy to obtain especially for areas with challenges for field surveys, 2) they exist both for historical events and current status of the land, and 3) they have fairly accurate representation of trends of vegetation cover dynamics than many other indicators [6].

In Somaliland, loss of vegetation cover has been variously mentioned as the trigger for other types of land degradation [3, 14, 31]. Identification of areas with significant loss of vegetation cover can therefore be an important first step towards assessment of land degradation in the country.

The most commonly cited approach for using NDVI as indicator of land degradation involves determination of declining or increasing trend of the difference between remotely sensed NDVI and rainfall-predicted NDVI over time (Figure 2.4). The NDVI prediction from rainfall is done in an attempt to remove climatic effects from the remote sensing signals of vegetation cover dynamics over time [5, 6]. This is achieved by fitting a uniform global model for NDVI-rainfall relationship for all locations in a given area of interest (e.g. over entire Somaliland). The difference between the actual and predicted NDVI is then used to identify areas with improvement or loss of vegetation cover (Figure 2.4).

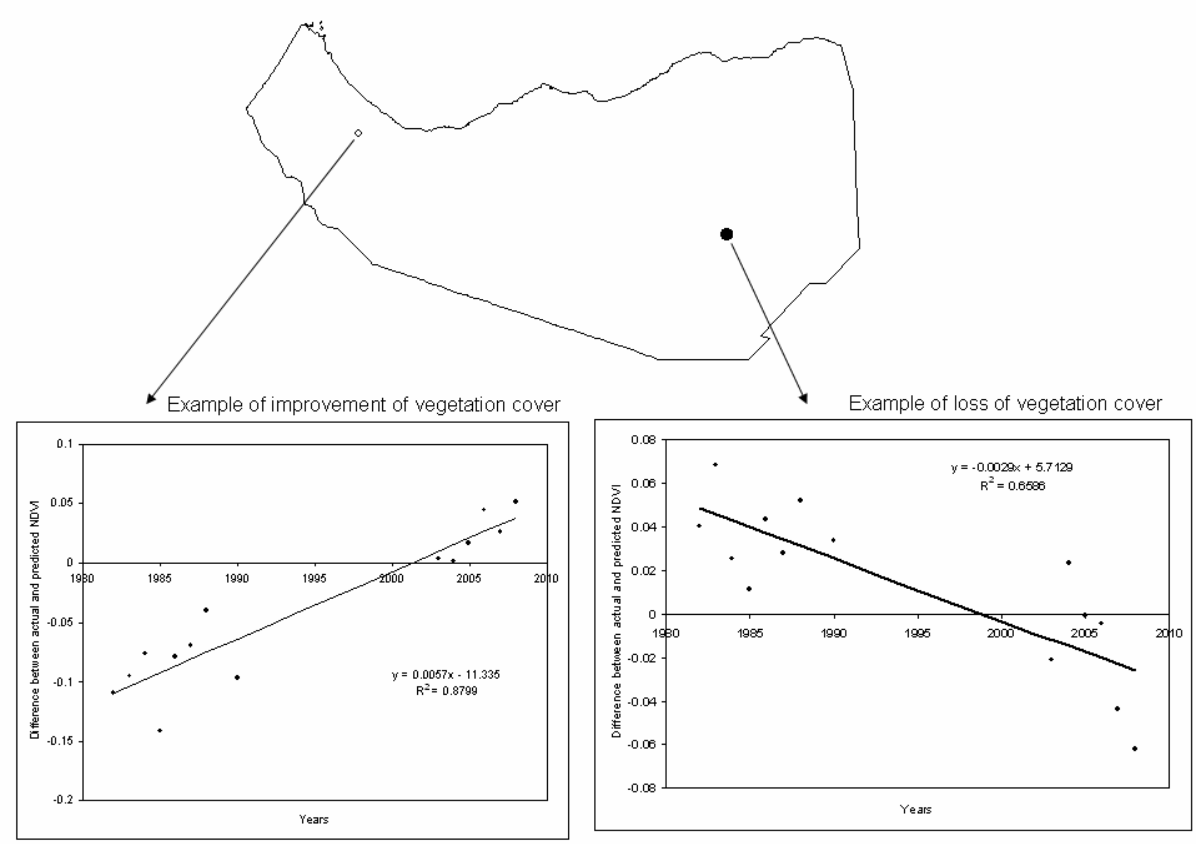


Figure 2.4: Identification of degraded land using remote sensing analysis

Although this approach has been shown to be promising in detecting potential areas with land degradation, it is important to note that it has limitations too. It does not identify changes in vegetation species, which is a type of land degradation, and it can be potentially biased in identifying changes in vegetation cover dynamics if NDVI-rainfall relationship is not statistically well-determined. In the study of land degradation in Somaliland using this approach, a slight modification was made with respect to statistical modelling of NDVI-rainfall relationship. Instead of fitting a uniform global model for all locations in the study area, different models were fitted depending on the dominant vegetation types. Mixed-effects modelling technique was used for this purpose. Mixed-effects modelling is a form of regression analysis which simultaneously determines landscape-level environmental relationships and the same relationship for different homogeneous units within the landscape [21, 23]. When tested in Somalia, it gave a better representation of NDVI-rainfall relationship compared to one-model approach as is traditionally used in the NDVI analysis for land cover dynamics. The performance of mixed-effects was better because it incorporated vegetation types in NDVI-rainfall relationship; which is realistic since different vegetation types have different response characteristics to rainfall that cannot be generalized with one model. Appendix 3 shows how mixed-effects modelling was done for NDVI-rainfall relationship in Somalia. After modelling NDVI-rainfall relationship, a simple linear regression of time and the differences between actual and predicted NDVI was then used to identify land degradation spots as demonstrated in Figure (2.4). Equation (3) shows the model for this regression.

$$\mathbf{e} = slope_{res} * \mathbf{Time} + intercept_{res} \tag{3}$$

where, **e** is a vector of the difference between actual and predicted NDVI, **Time** is a vector of time, and $slope_{res}$ and $intercept_{res}$ are the slope and intercept of the regression line, respectively. Identification of degraded land using Equation (3) was based on the $slope_{res}$: where non-degraded areas were those with significant positive $slope_{res}$ and degraded areas were those with significant negative $slope_{res}$ (Figure 3.4). The significance of $slope_{res}$ was tested at 95% confidence interval.

2.2.2 Data

Data for land degradation assessment using NDVI analysis included time-series NDVI images, monthly rainfall amounts, land cover map, and Digital Elevation Model (DEM). Time series NDVI data consisted of 10-days composite AVHRR 8 km images from January 1982 till December 2008. These images were downloaded from http://earlywarning.usgs.gov/adds/datatheme.php on 15th January 2009. They were already pre-processed and contained maximum 10-day composite NDVI [27].

The rainfall data consisted of monthly rainfall amounts from 46 recording stations in Somalia. The data was obtained from FAO-SWALIM (www.faoswalim.org) and contained monthly rainfall records from January 1982 to December 1990 and from January 2003 to December 2008 [15]. The gap between 1991 and 2003 was occasioned by the socio-political upheavals in the country during this period. No attempt was made to fill these gaps and the corresponding NDVI data for this period was removed from the subsequent analysis in order to maintain consistency in the entire dataset.

The land cover map was obtained from AFRICOVER (www.africover.org, accessed on 12th January 2009). It contained 38 dominant vegetation classes mapped at the scale of 1: 200 000. The DEM was downloaded from http://srtm.usgs.gov on 15th August 2008 and was used to derive parameters for extrapolating monthly rainfall amounts using regression kriging method [9, 19].

2.2.3 Validation of NDVI analysis of land degradation

71 points from two areas were used to verify the outputs from the NDVI assessment of land degradation: 25 points from eastern and 46 points from western parts of Somaliland. These points were collected by FAO-SWALIM land team during land degradation assessment of western Somaliland in 2007 and during a study of pastoral resources of eastern Somaliland in 2007. Table 2.3 gives the guidelines used to assess evidence of loss of vegetation in the field. Also, some of the georeferenced photographs taken land degradation assessment of western Somaliland were compared with corresponding georeferenced photographs taken by AFRICOVER in 1998. The comparison was done to check if changes during the period between 1998 and 2007 were also detected by NDVI analysis.

Table 2.3: Guidelines for assessing loss of vegetation cover in the field

Status of vegetation	Evidence of human-induced vegetation loss
Presence of loss of vegetation	Tree stumps or cut branches Evidence of charcoal production Evidence of livestock overgrazing < 10% vegetation cover Report of declining vegetation cover in the last five to ten years
No loss of vegetation	>10% vegetation cover No evidence of charcoal production No evidence of livestock overgrazing No reports of declining vegetation in the last five to ten years

3. RESULTS AND DISCUSSIONS

3.1 The land use systems map of Somaliland

The validated land use systems map had twenty three units (Map S1). The description of these units is given in appendix 6.

3.2 Experts assessment of land degradation in Somaliland

3.2.1 Identification of causes, status, and responses to land degradation

Expert characterization of land degradation causes, statuses, impacts, and responses for Somaliland is shown in Figure 3.1.

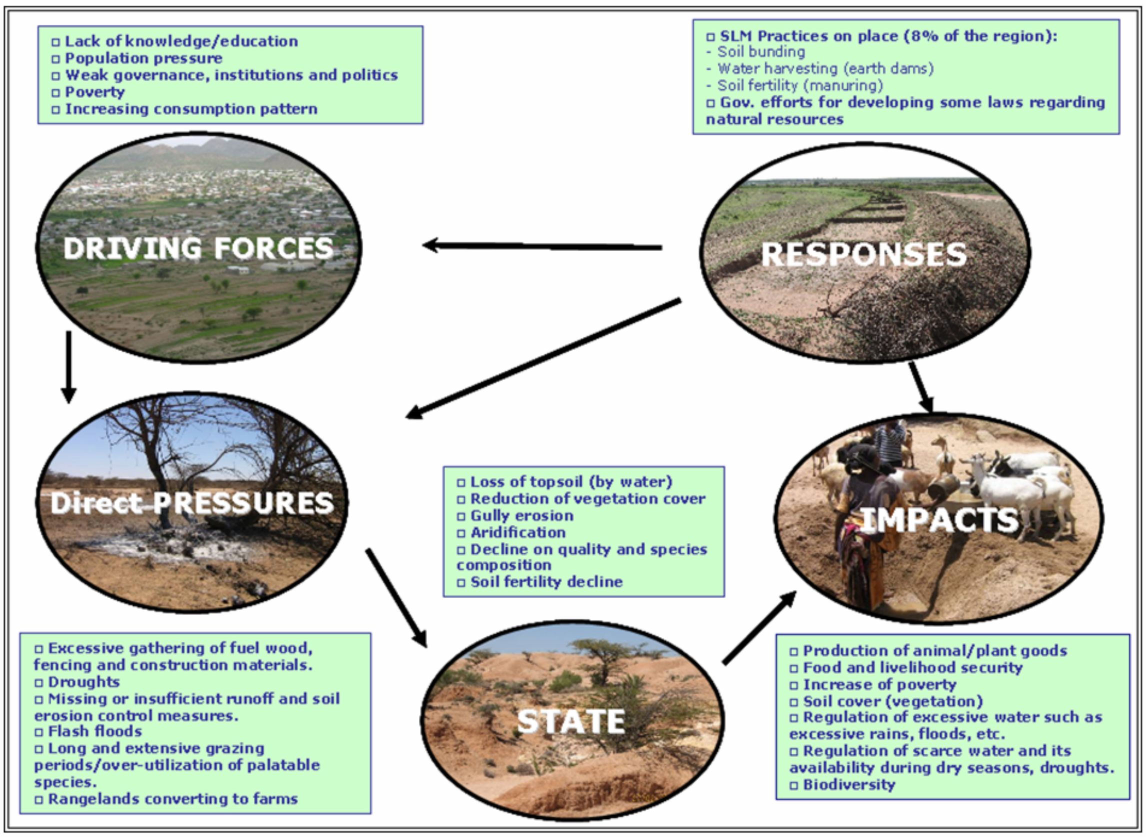
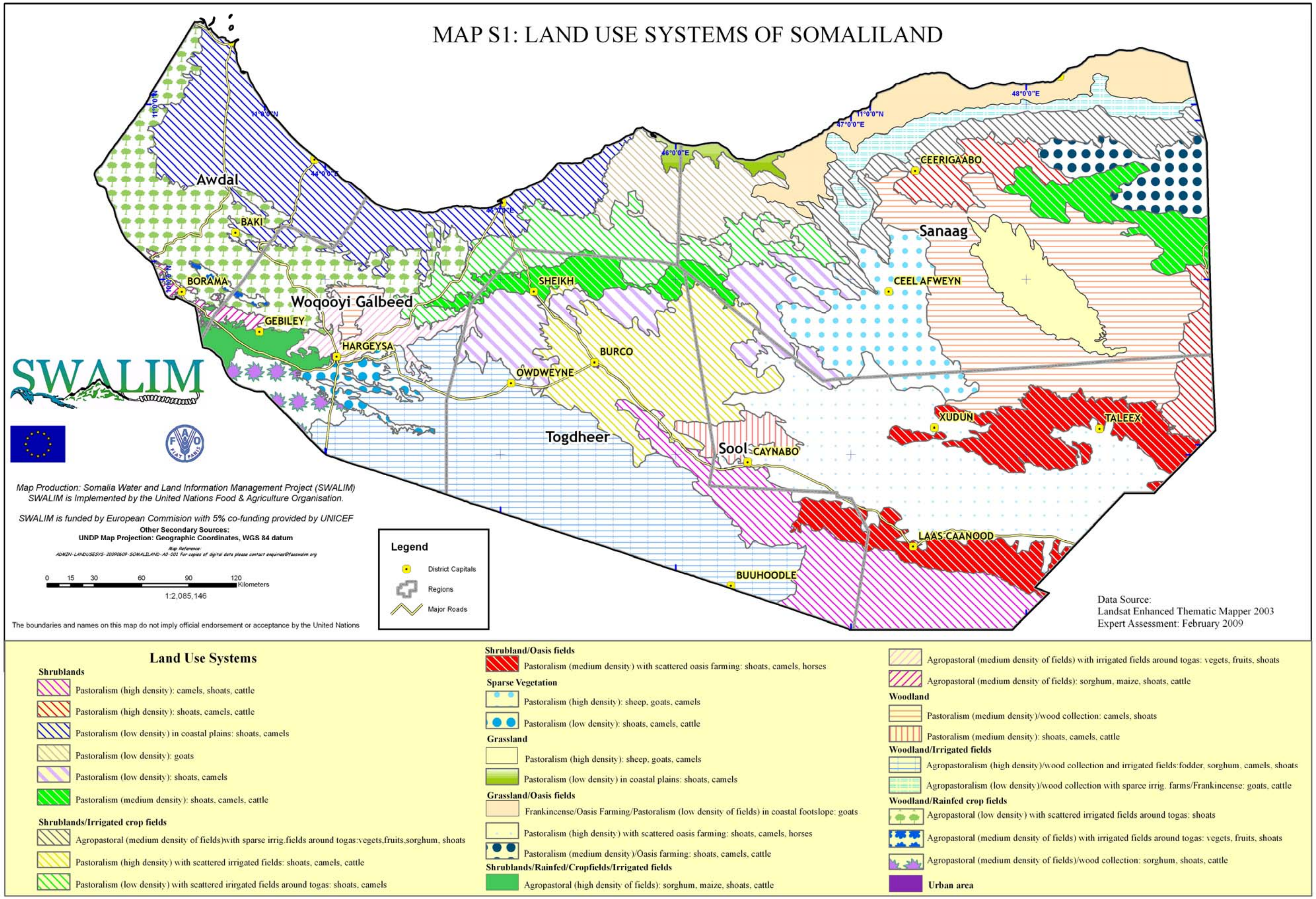


Figure 3.1: DPSIR framework for Somaliland



MAP S1: LAND USE SYSTEMS OF SOMALILAND
Awdal
BAKI
BORAMA
Woqooyi Galbeed
GEBILEY
HARGEYSA
SHEIKH
BURCO
OWDWEYNE
Togdheer
Sool
CAYNABO
BUUHOODLE
LAAS CAANOOD
XUDUN
TALEEX
CEEL AFWEYN
Sanaag
CEERIGAABO
SWALIM
Map Production: Somalia Water and Land Information Management Project (SWALIM)
SWALIM is Implemented by the United Nations Food & Agriculture Organisation.
SWALIM is funded by European Commision with 5% co-funding provided by UNICEF
Other Secondary Sources:
UNDP Map Projection: Geographic Coordinates, WGS 84 datum
Map Reference:
ADMIN-LANDUSESYS-20090609-SOMALILAND-A0-001 For copies of digital data please contact enquiries@faoswalim.org
0 15 30 60 90 120 Kilometers
1:2,085,146
The boundaries and names on this map do not imply official endorsement or acceptance by the United Nations
Legend
District Capitals
Regions
Major Roads
Data Source:
Landsat Enhanced Thematic Mapper 2003
Expert Assessment: February 2009
Land Use Systems
Shrublands
Pastoralism (high density): camels, shoats, cattle
Pastoralism (high density): shoats, camels, cattle
Pastoralism (low density) in coastal plains: shoats, camels
Pastoralism (low density): goats
Pastoralism (low density): shoats, camels
Pastoralism (medium density): shoats, camels, cattle
Shrublands/Irrigated crop fields
Agropastoral (medium density of fields)with sparse irrig.fields around togas:vegets,fruits,sorghum, shoats
Pastoralism (high density) with scattered irrigated fields: shoats, camels, cattle
Pastoralism (low density) with scattered irirgated fields around togas: shoats, camels
Shrubland/Oasis fields
Pastoralism (medium density) with scattered oasis farming: shoats, camels, horses
Sparse Vegetation
Pastoralism (high density): sheep, goats, camels
Pastoralism (low density): shoats, camels, cattle
Grassland
Pastoralism (high density): sheep, goats, camels
Pastoralism (low density) in coastal plains: shoats, camels
Grassland/Oasis fields
Frankincense/Oasis Farming/Pastoralism (low density of fields) in coastal footslope: goats
Pastoralism (high density) with scattered oasis farming: shoats, camels, horses
Pastoralism (medium density)/Oasis farming: shoats, camels, cattle
Shrublands/Rainfed/Cropfields/Irrigated fields
Agropastoral (high density of fields): sorghum, maize, shoats, cattle
Agropastoral (medium density of fields) with irrigated fields around togas: vegets, fruits, shoats
Agropastoral (medium density of fields): sorghum, maize, shoats, cattle
Woodland
Pastoralism (medium density)/wood collection: camels, shoats
Pastoralism (medium density): shoats, camels, cattle
Woodland/Irrigated fields
Agropastoralism (high density)/wood collection and irrigated fields:fodder, sorghum, camels, shoats
Agropastoralism (low density)/wood collection with sparce irrig. farms/Frankincense: goats, cattle
Woodland/Rainfed crop fields
Agropastoral (low density) with scattered irrigated fields around togas: shoats
Agropastoral (medium density of fields) with irrigated fields around togas: vegets, fruits, shoats
Agropastoral (medium density of fields)/wood collection: sorghum, shoats, cattle
Urban area

3.2.1.1 Direct causes of land degradation in Somaliland

There were two main direct cause of land degradation in Somaliland identified by experts: overuse of vegetation and agricultural extensification. Overuse of vegetation was mainly in gathering fuelwood, fencing and construction materials, grazing of livestock, and charcoal production. This is an un-controlled activity which selectively clears trees cover (especially *Acacia busei*). It is further complicated by the diminishing natural resilience of the vegetation occasioned by frequent and prolonged drought in the last few years.

Agricultural extensification (i.e. increase of rainfed/irrigated farms) into the rangelands was also another direct cause of land degradation. The reasons were two-fold: first, the rangelands were marginally suitable for farming purposes and especially if good land management practices are implemented. The current lack of good farming practices was said to be exacerbating land degradation in the regions where agriculture was practiced. Second, farming in rangeland areas affected traditional livestock grazing patterns. As a result, livestock grazing was said to be increasingly being concentrated in certain parts. This was cited as one of the major causes of overgrazing. The original vegetation of the over-grazed field could not regenerate and their places are increasingly being colonized by invasive plant species.

3.2.1.2 Indirect causes of land degradation

The main indirect causes of land degradation in Somaliland were: increase in human and livestock population, poverty, and lack of appropriate policies and strong implementation of the available policies (Figure 3.1). Like in many places in the world, the population in Somaliland has been growing. Although there is no official figure in the public domain, the population growth rate is reported in various literatures to be around 3% annually [2, 29]. This growth definitely puts pressure on the limited land resources.

Poverty is also another indirect cause of land degradation. As the resources base is limited, people demand more goods from the main assets such as pastoralism and farming activities. Since the household income is limited, the land users cannot invest in any input for improving land management and consequently degrading the land.

Lack of appropriate policies and strong low enforcement by the government are also other indirect causes of land degradation in Somaliland. Although the Somaliland government is trying to control land resources utilization, additional effort and support is still needed in this regard.

Other indirect causes of land degradation in Somaliland are lack of knowledge and education, and increasing consumption pattern (Figure 3.1)

3.2.1.3 Status of land degradation

Prevalent land degradation types in Somaliland are: loss of topsoil by water and wind, reduction of vegetation cover, gully erosion, aridification, decline of palatable plant species, and soil fertility decline in agriculture potential areas (Map S2). Although these degradation types occur in combination in many parts of Somaliland, generally loss of topsoil by wind erosion is dominant in the north-western coastal areas, aridification is dominant in the centre, and loss of vegetation in south-western parts of Somaliland. Loss of topsoil by water erosion covers the largest area and can therefore be said to be the most widespread type of land degradation in Somaliland (Table 3.1)

Table 3.1: Extent of prevalent land degradation types in Somaliland from Map S3

Degradation Type	Area (sq. km)	Area affected (%)
Soil erosion by water	76661.09	45.21
Biological degradation	51673.45	30.48
Water degradation	16055.44	9.47
Soil erosion by wind	13520.54	7.97
Chemical soil deterioration	1365.61	0.80
Urban	47.44	0.03
Non-degraded areas	10235.75	6.04
Total	169559.32	100

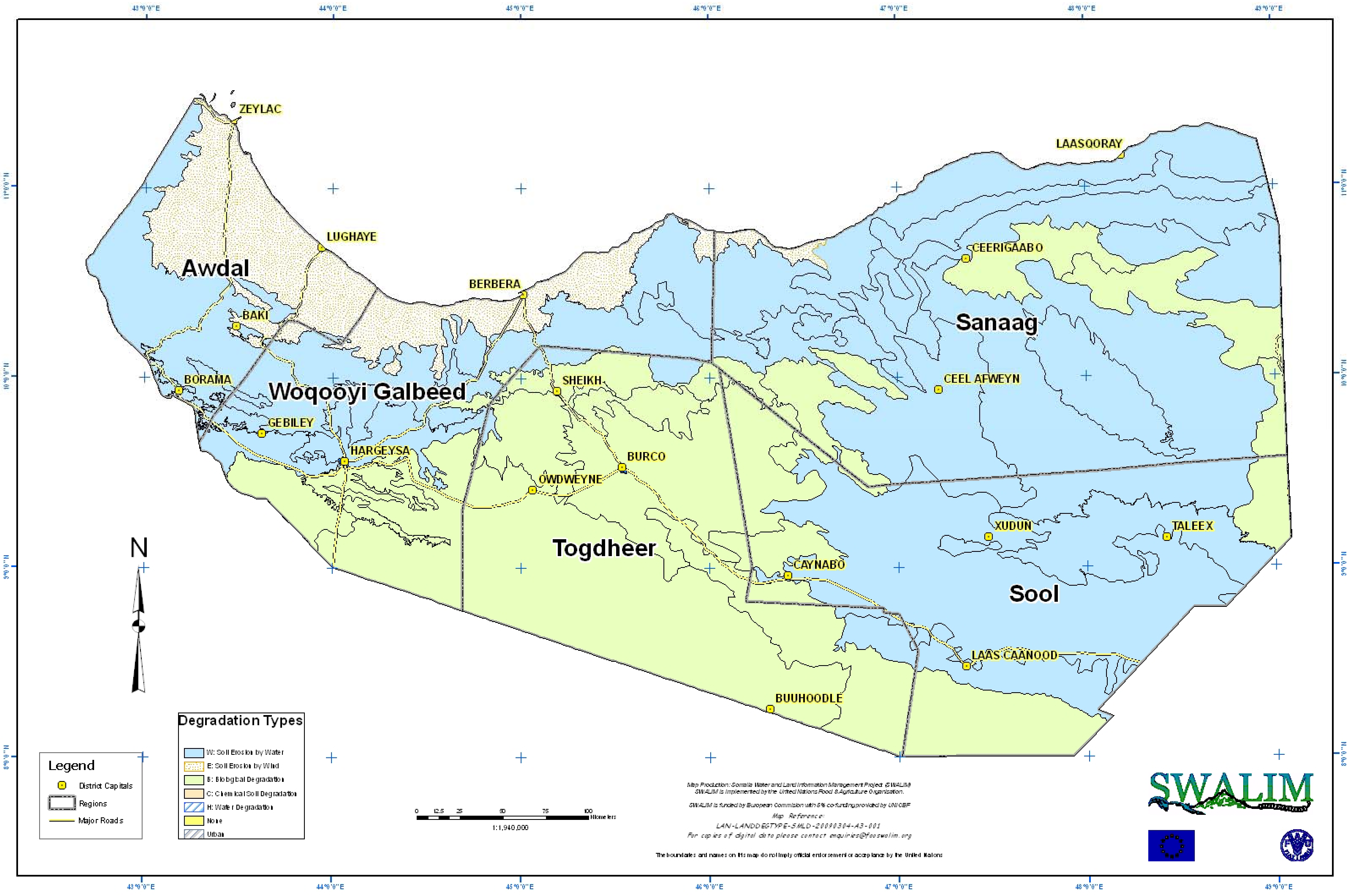
The above different types of land degradation were combined to produce a composite land degradation map by expert assessment (Map S3). Table 3.2 shows areal extent of land degradation in Somaliland. Overall, about 36% of the area is considered degraded by expert assessment. The overall degradation is moderate to strong.

Table 3.2: Extent of land degradation in Somaliland from Map S2

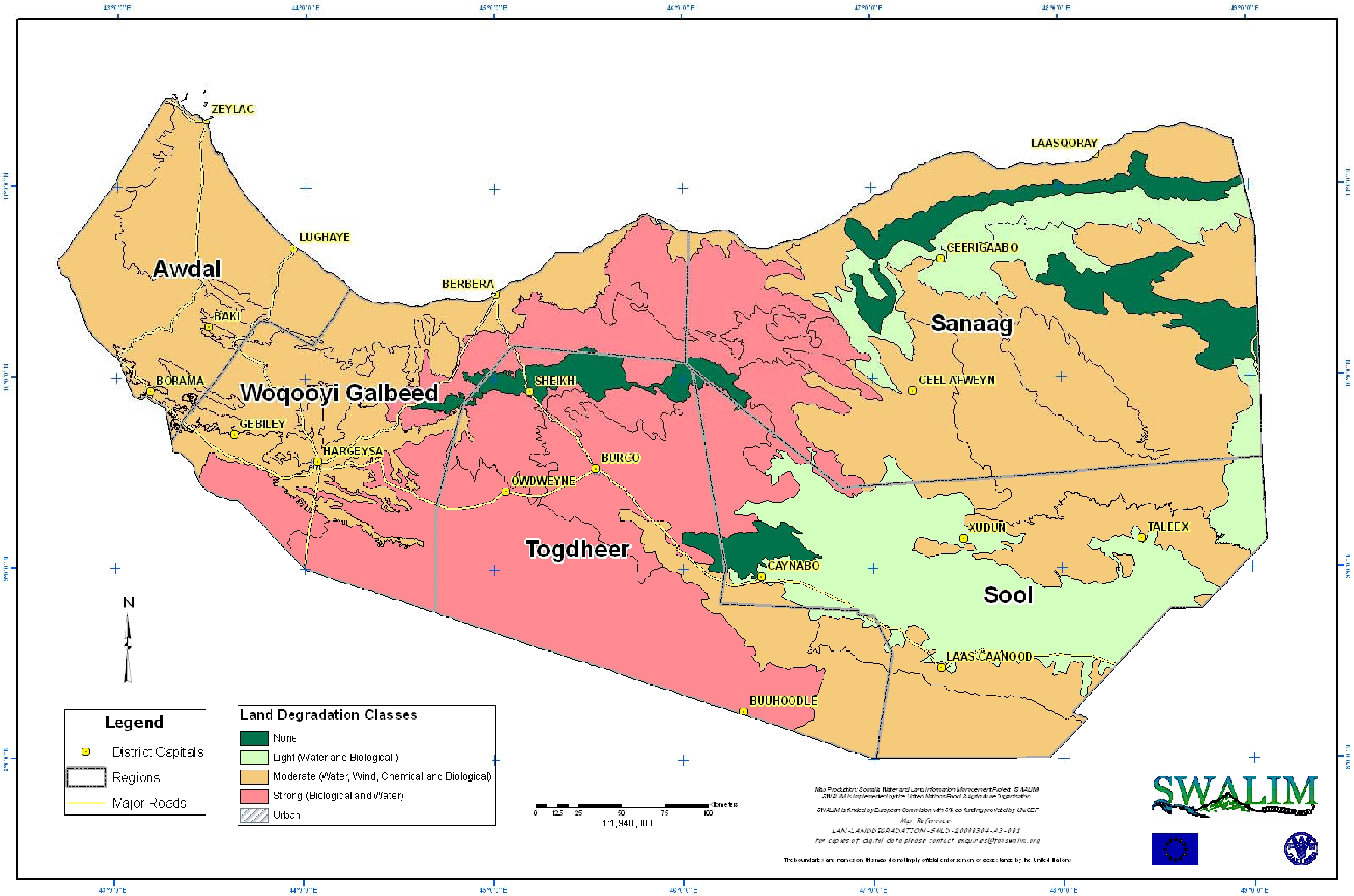
Land Degradation status	Areas affected (sq. km)	Areas affected (%)
None	10235.75	6.04
Slight	26186.15	15.44

Moderate	83819.81	49.43
Strong	49270.17	29.06
Urban	47.44	0.03
Total	169559.32	100

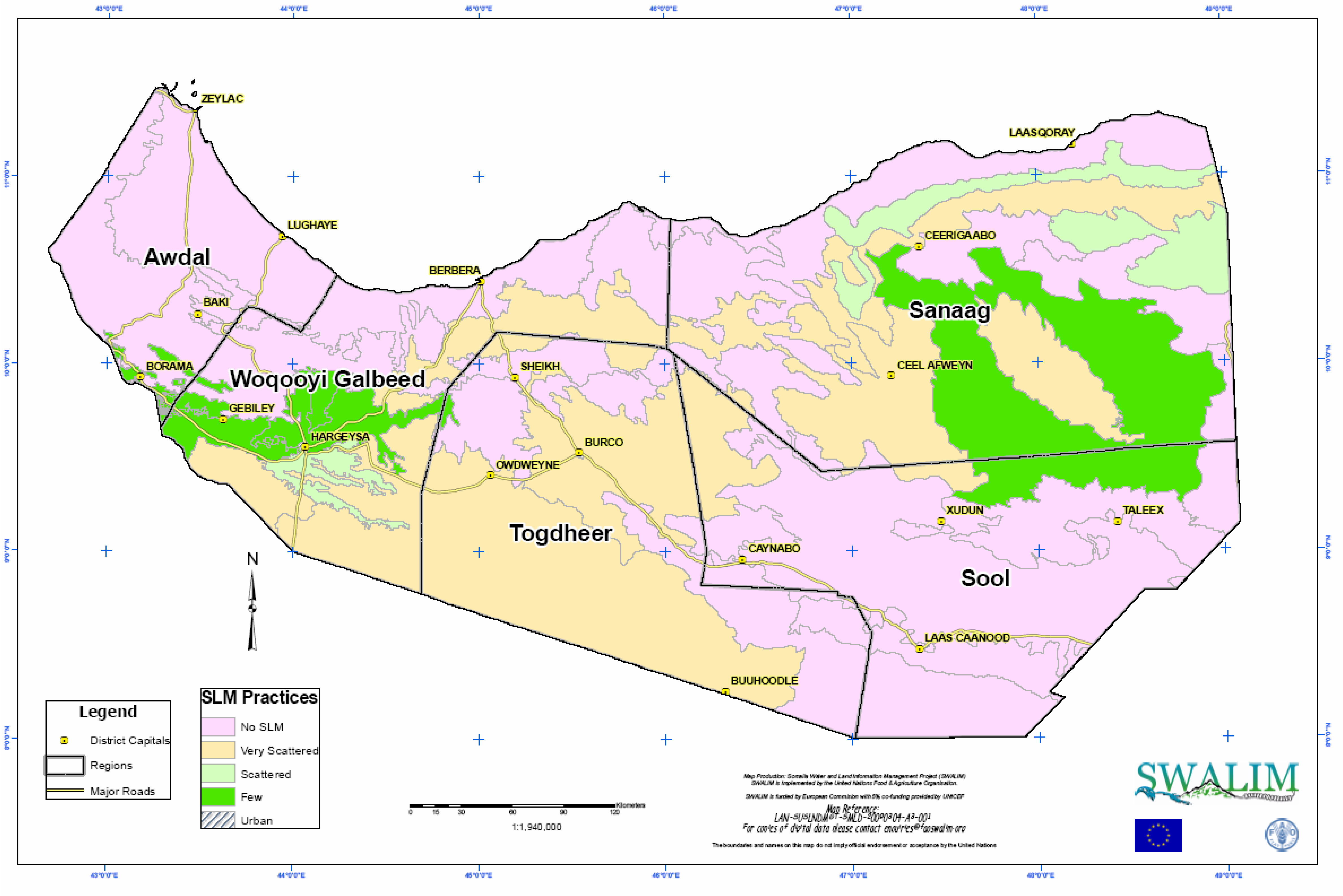
MAP S2: LAND DEGRADATION TYPES- SOMALILAND (EXPERT ASSESMENT)



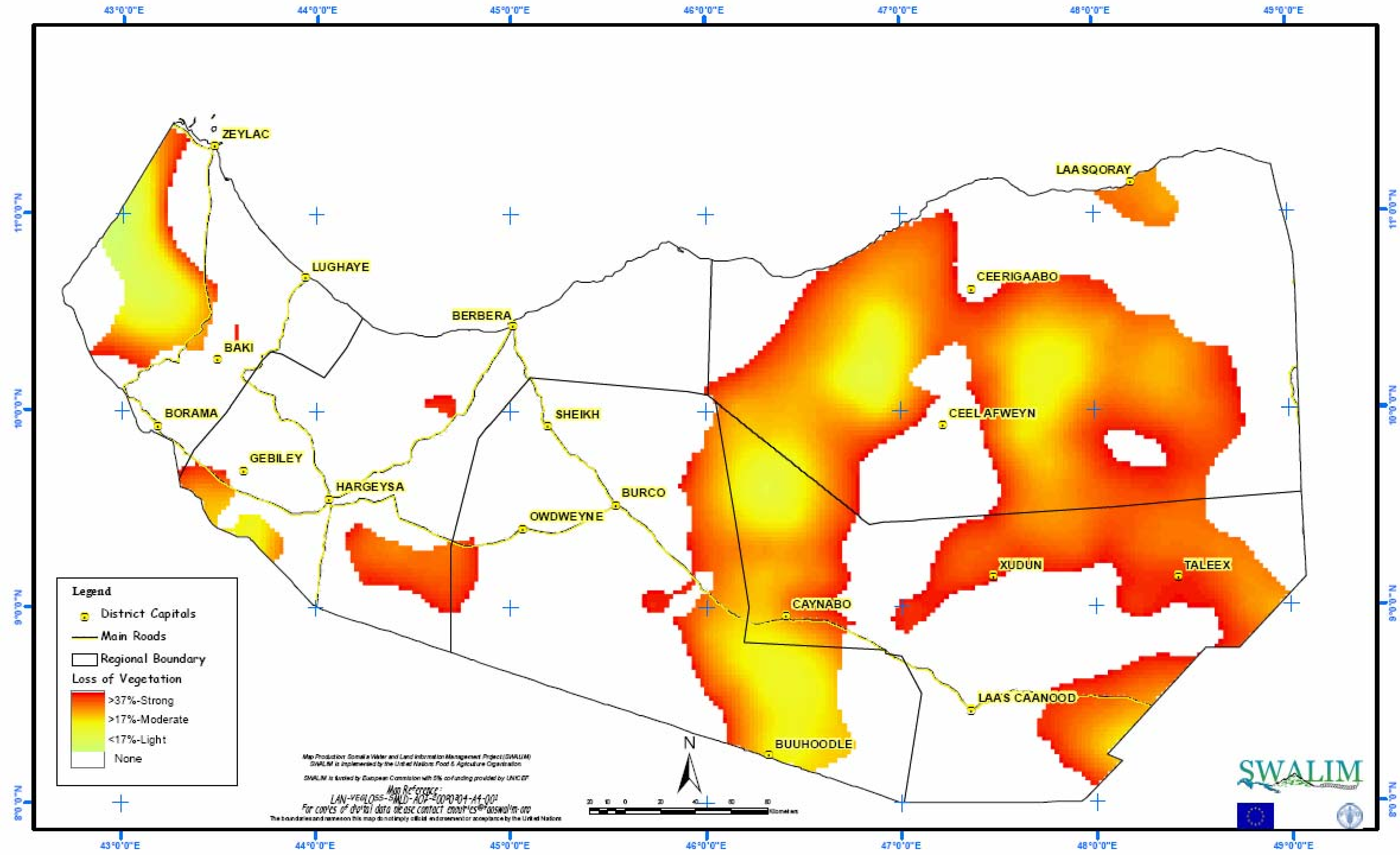
MAP S3: LAND DEGRADATION- SOMALILAND (EXPERT ASSESMENT)



MAP S4: SUSTAINABLE LAND MANAGEMENT PRACTICES (SLM)- SOMALILAND (EXPERT ASSESMENT)



MAP S5: LOSS OF VEGETATION COVER Between 1982-2008 (SOMALILAND)



3.2.1.4 Impacts on ecosystem services and responses to land degradation

There were varied responses from the experts with respect to the impacts of land degradation on the ecosystem services. The most identified impacts were those touching on animal/plant products, food and livelihood security, soil cover, regulation of water, and biodiversity. The most common resource conservation practices in Somaliland are: soil bunds, water harvesting, and gully stabilization (Figure 3.2 and map S4). Most of these responses are located around the main agro-pastoral systems where loss of topsoil, nutrient decline, and water scarcity are the dominant land degradation types. A few applications of manure to increase soil fertility in irrigated agriculture and measures for river embankment can also be found in other places.

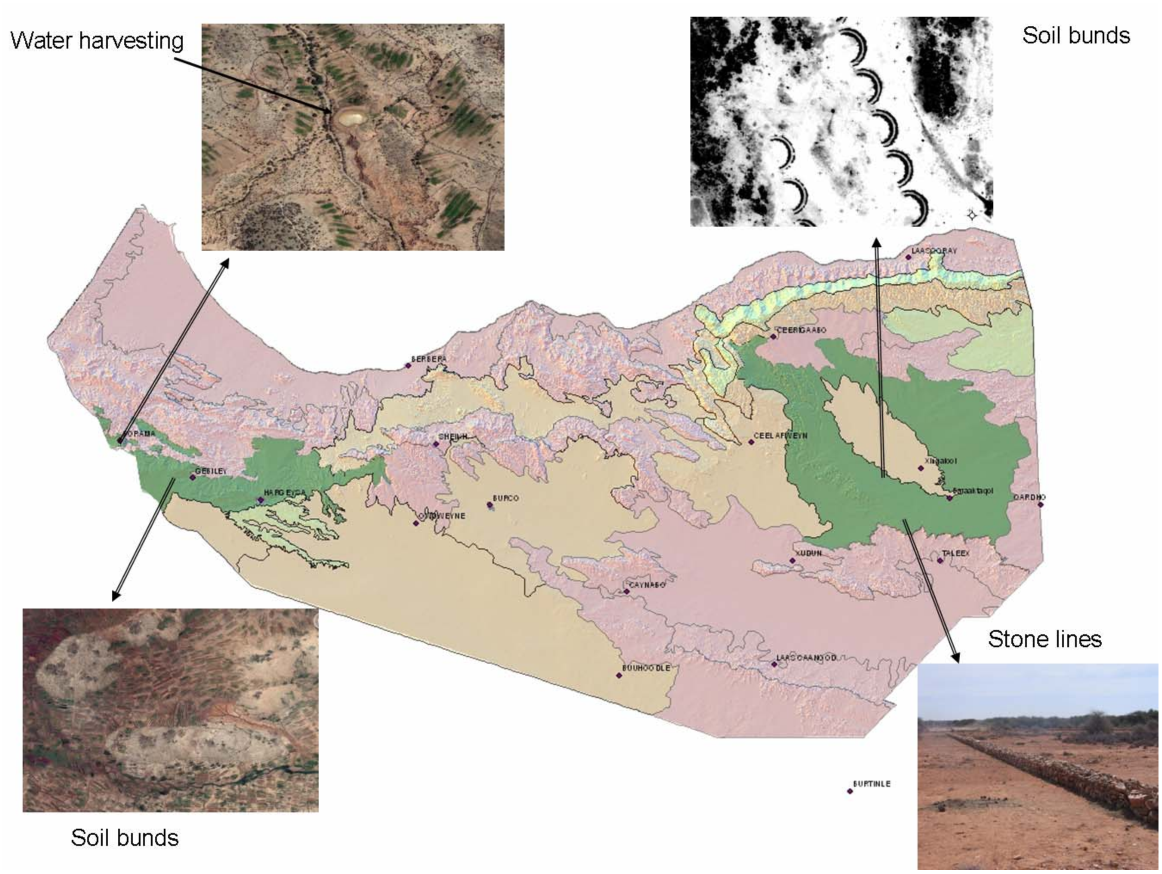


Figure 3.2: Responses to land degradation in Somaliland

Although the above responses are implemented by many organizations in Somaliland, there is a deficiency of consistent documentation or assessment of the implemented practices. Furthermore, their efforts are not yet well coordinated to enhance synergy and effectiveness in retarding land degradation in Somaliland.

3.3 Loss of vegetation cover in Somaliland

3.3.1 Identification of affected areas

Remote sensing analysis identified many places with loss of vegetation cover between 2003 and 2008 (Map S5). The central areas towards the eastern part of Somaliland were depicted to have more loss of vegetation cover compared to the other areas. Some parts of south-western and western Somaliland also had significant loss of vegetation cover. Table 3.4 shows the most affected LUS units. The dominant vegetation types in these units were grass, forbs, sparse shrubs, and short trees. These vegetation types of grass and *Acacia* type of trees, are prime targets for pasture for livestock and charcoal production in Somaliland [3]. It was therefore not surprising that they showed the largest decline in time-series NDVI signals. More so, the pattern is related to the distribution of settlements and terrain features. For example, between Zeylac and Baki, the spatial pattern of strong vegetation loss is linear and related to vegetation formations along the escarpment of the Golis Mountain, besides charcoal production for local use and exports to Djibouti. Another example is the strong vegetation loss pattern around Talex settlement. In this area, the Tiger bush landscape of mainly *Acacia busei* (Somali name Galool) associated with *Andropogon kelleri* (Somali name Duur) is exploited for charcoal production and grazing for livestock. A study by SWALIM on tree cutting monitoring in this area revealed an annual tree density change rate of about 5% (SWALIM Project Report L-15 of 2009).

Overall, NDVI-rainfall analysis identified about 38% of Somaliland with significant loss of vegetation cover between 1982 and 2008. Comparing the map of land degradation and that of loss of vegetation in Somaliland, the areas with loss of topsoil by water are the same areas with strong loss of vegetation cover. This implies that the loss of vegetation cover led to loss of topsoil by water; which supports use of NDVI analysis as proxy indicator of land degradation since it can index other types of degradation as well.

Table 3.4: Loss of vegetation cover by land use systems units in Somaliland

LUS code	Description	Area affected (%)
63	Pastoralism (medium density)/wood collection: camels, shoats	81
55	Pastoralism (medium density) with scattered oasis farming: vegetables, shoats, camels, horses	52
32	Pastoralism (high density): sheep, goats, camels	50
23	Pastoralism (high density) with scattered irrigated fields: shoats, camels, cattle	49
47	Pastoralism (low density)/timber collection with scattered irrigated farms/Frankincense: goats, cattle	49
17	Frankincense/Oasis Farming/Pastoralism (low density) in coastal footslope: goats	45
65	Pastoralism (medium density): shoats, camels, cattle	43
7	Agro-pastoral (medium density of fields)/wood collection: sorghum, shoats, cattle	41
34	Pastoralism (high density): shoats, camels, cattle	40
51	Pastoralism (low density): shoats, camels	40
2	Agro-pastoral (high density of fields): sorghum, maize, shoats, cattle	39
24	Pastoralism (high density) with scattered oasis farming: shoats, camels, horses	38
14	Agro-pastoral (medium density of fields) with sparse irrigated fields around togas: vegetables, fruits, sorghum, shoats	33
31	Pastoralism (high density): camels, shoats, cattle	32
38	Pastoralism (low density) with scattered irrigated fields around togas: shoats, camels	27
27	Pastoralism (high density)/wood collection and scattered irrigated fields: fodder, sorghum, camels, shoats	26
52	Pastoralism (low density): shoats, camels, cattle	25
39	Pastoralism (low density) with scattered irrigated fields around togas: shoats	24
49	Pastoralism (low density): goats	20
36	Pastoralism (low density) in coastal plains: shoats, camels	16
13	Agro-pastoral (medium density of fields): sorghum, maize, shoats, cattle	2

3.3.2 Validation of remote sensing method for land degradation assessment

NDVI-analysis correctly identified 75% of the locations with human-induced loss of vegetation cover. It correctly identified truly affected areas with an accuracy of 76% and non-affected areas with an accuracy of 72%. However, it misclassified seven affected areas as non-affected. Six of these areas were located in eastern Somaliland, where selective tree cutting for charcoal production was said to have been undertaken in 1990s [22]. However, after 2002 most of the areas were re-colonized by grass or new tree species and were therefore not easily identified with loss of vegetation cover using 8 km NDVI images. Similarly, eight of the 11 misclassified areas without signs of loss of vegetation cover were located on the edges between vegetated and sparsely vegetated areas at the footslopes of a rocky escarpment in western Somaliland. Their misclassification was could also have been due to a combination of lack of proper identification of new tree species and coarse spatial resolution of the input NDVI images.

Comparison of georeferenced photographs taken in 1998 and the corresponding ones taken in 2006/7 also showed that NDVI analysis performed well in identifying loss of vegetation. Figure 3.4 shows examples of photographs taken at/near similar spots in 1998 and in 2006/7 in western Somaliland. The upper photographs were taken at the same spot in 1998 and in 2007 while the lower photographs were taken near similar spots in 1998 and 2006. The results from NDVI analysis showed significant decline in vegetation cover for the spot where the upper photographs were taken and no significant decline in vegetation cover for area around where the lower photographs were taken. Looking at the photographs, it shows that the change from natural vegetation to cropland obviously reduced the vegetation cover; which was positively reflected in the decline of NDVI signals. In areas where the vegetation cover remained fairly the same, the NDVI signals remained invariant over time as shown in the lower photograph in Figure 3.4.

The above results show that NDVI analysis has potential in identifying human-induced loss of vegetation. Since vegetation cover protects other land resources from degradation (e.g. soil erosion, loss of soil moisture), its loss may be correlated with some types of land degradation. The approach, however, does not identify other types of land degradation such as invasive plant species, chemical degradation, decline in water quality, etc. More comprehensive assessment is necessary to conclude the use of NDVI as surrogate predictor of land degradation.

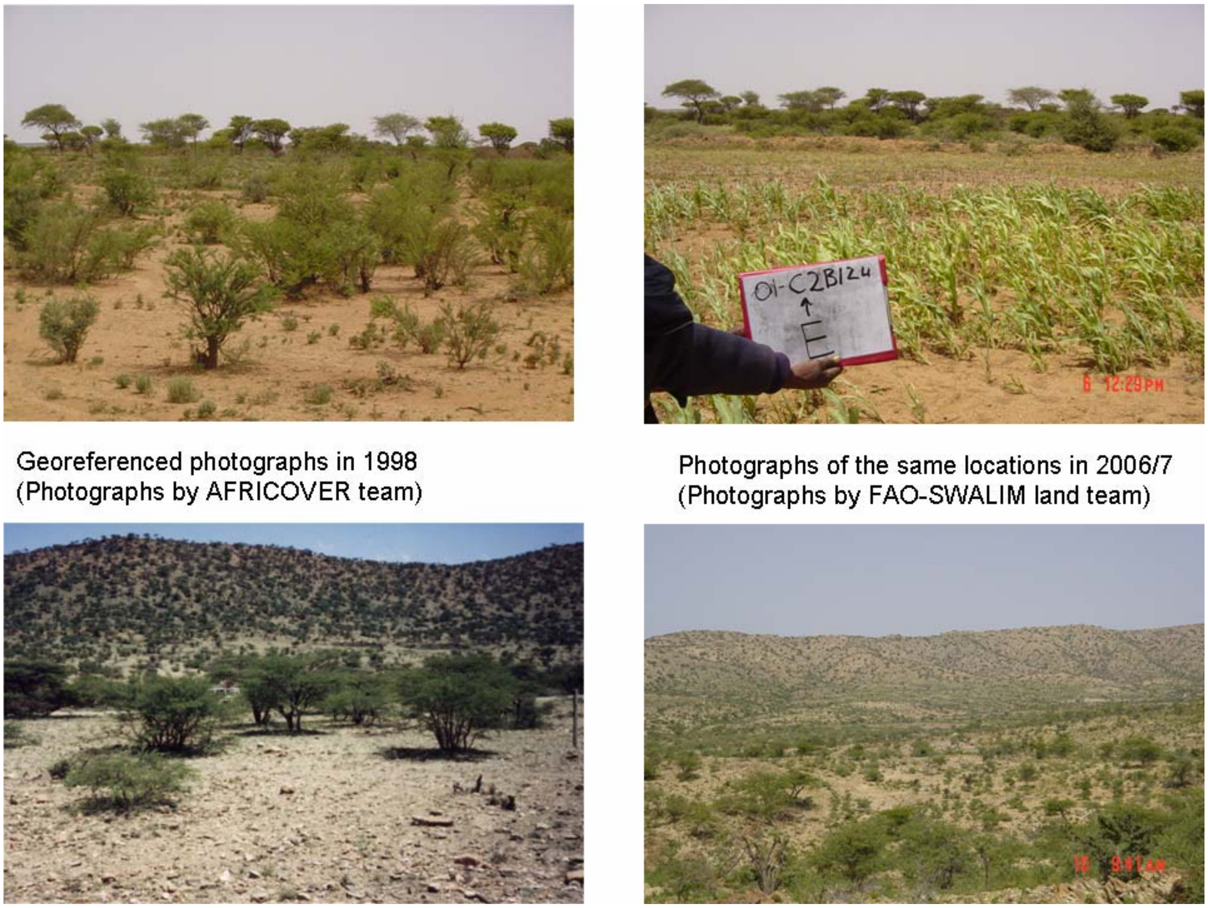


Figure 3.4: Selected photographs for validating NDVI analysis of loss of vegetation cover

3.4 Integrating expert assessment and remote sensing results for land degradation in Somaliland

A comparison was made between land degradation by NDVI analysis and expert assessment (Table 3.6). The two methods agreed for 12 cases out of 19 cases (or 63% of the time). The concurrence between these two sources of evidence of land degradation show that: 1) Somaliland is indeed having notable signs of land degradation, and 2) that expert assessment or NDVI analysis have some degree of accuracy and can be reliably used in assessing land degradation at the national level.

Table 3.6: Comparison of expert assessment and NDVI prediction of land degradation in Somaliland

LUS Unit	Expert Land Degradation	% of the unit covered NDVI loss	NDVI loss of vegetation cover	Presence of SLM
36	Moderate	6	Moderate	None
39	Moderate	4	Moderate	None
2	Moderate	36	Moderate	Few
7	Strong	30	Strong	Very scattered
27	Strong	12	Moderate	Very scattered
52	Moderate	4	Moderate	Scattered
31	Moderate	25	Moderate	None
23	Strong	45	Moderate	Very scattered
65	None	100	Moderate	None
24	Light	22	Strong	None
55	Moderate	45	Strong	None
32	Moderate	90	Moderate	Very scattered
63	Moderate	85	Moderate	Few
38	Strong	30	strong	Very scattered
17	Moderate	30	Moderate	None
47	None	15	Light	Scattered
14	Light	12	Light	Very scattered
51	Strong	90	Strong	None
34	Light	55	Light	None

In general, NDVI analysis and expert assessment concurred that about 37% of Somaliland is degraded and that the degradation is moderate on average. Figure 3.5 reflects this agreement and highlights bright and hotspots for land degradation.

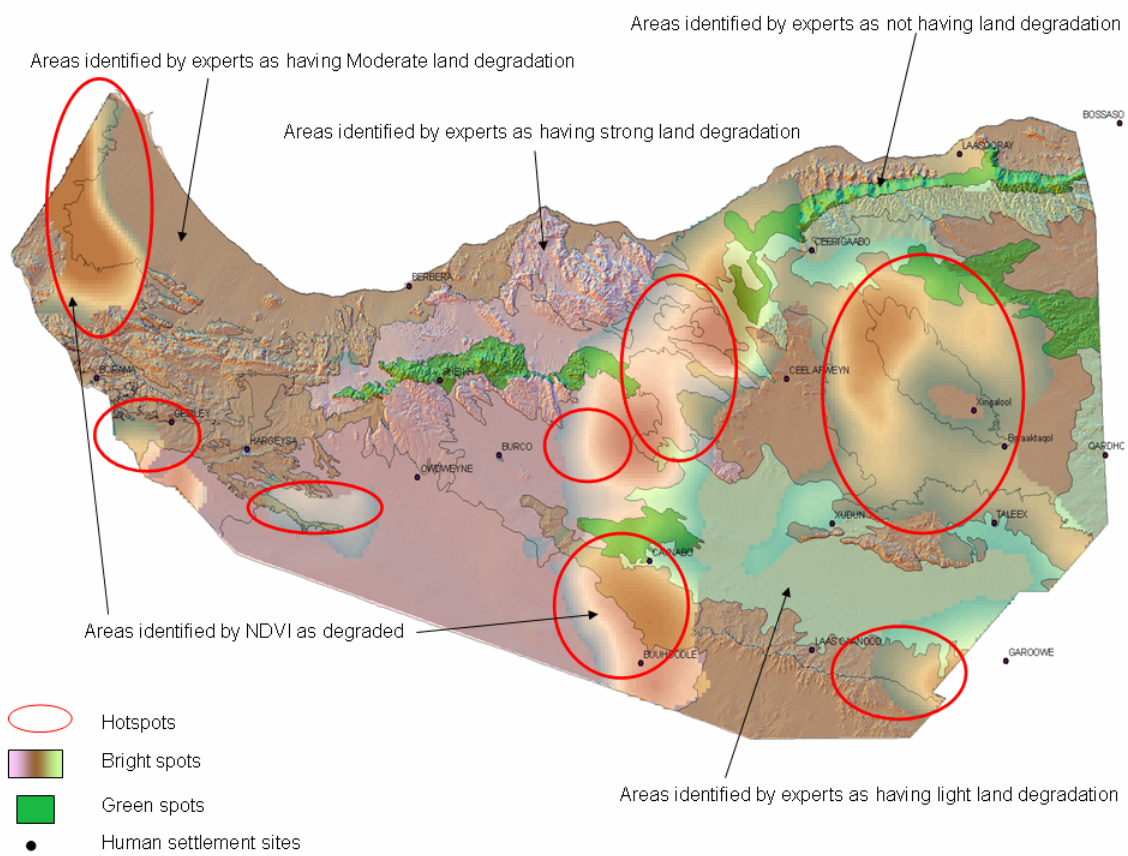


Figure 3.5: Bright and hotspots map for land degradation in Somaliland

4. CONCLUSIONS AND RECOMMENDATIONS

This study has shown that land degradation is moderate to strong in Somaliland. About 37% of Somaliland is degraded and the most common degradation types are loss of topsoil due to wind and water erosion, loss of soil nutrient in agriculture productive areas (mainly western part of Somaliland), loss of vegetation cover (in eastern part, parts of north-western and south-eastern). Soil loss by water erosion and loss of vegetation were the most widespread types of land degradation in Somaliland.

Although the degradation is moderate to strong, its trend is increasing. Therefore sustained and strategic measures are needed to control the degradation. Already there are some resource conservation practices which can be up-scaled to support effective control the degradation. For example, there are soil bunds which were built by the colonial government and are currently being rehabilitated or expanded to new areas by many local and international NGOs. These practices can be up-scaled in consultation with Somaliland government to control loss of topsoil and diminishing soil moisture. The organizations implementing these practices should collaborate with FAO-SWALIM to support strategic locations for implementing the conservation measures.

Loss of vegetation cover was identified in this study as a potential indicator for monitoring land degradation in Somaliland. Through use of remote sensing and field visits, loss of vegetation can effectively identify land degradation fronts. This is because vegetation is important in protecting land resources in Somaliland. Remote sensing applications can also potentially monitor changes in vegetation cover and so be useful in monitoring land degradation in Somaliland because the images can be freely downloaded every 10 days.

PART II: LOCAL ASSESSMENT OF LAND DEGRADATION IN A SELECTED STUDY AREA

5. LAND DEGRADATION ASSESSMENT IN A SELECTED AREA IN SOMALILAND

5.1 Study area

The selected study area is located between the latitudes 9° 10′ 30.8″ and 10° 41′ 36.54″ North and the longitudes 43° 0′ 52.3″ and 44° 27′ 54.22″ East (Figure 5.1) thus covering a total area of 12 915 km^2. It lies between the Ethiopian border and the Red Sea and covers the Districts of Dila, Gebiley, Faraweyne and Allaybaday, and parts of the districts of Hargeysa, Borama, Baki and Lughaya.

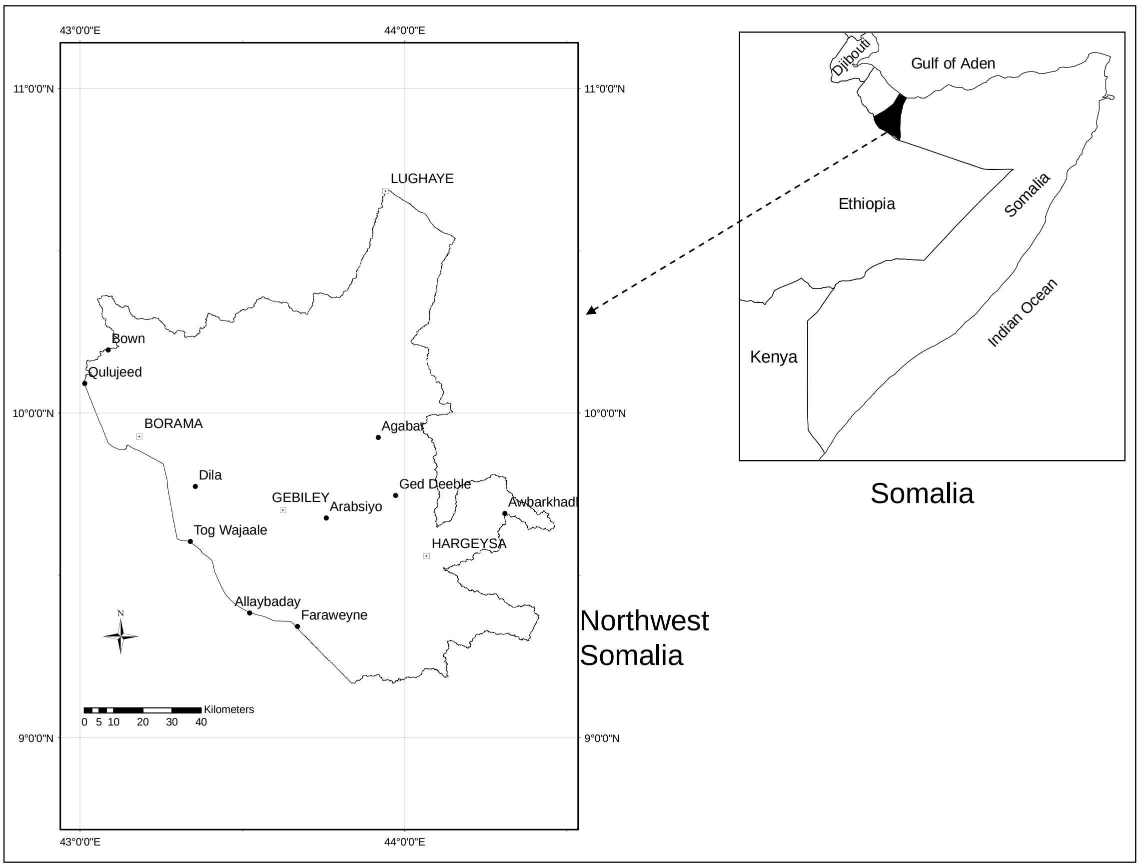


Figure 5.1: Location of the study area

5.1.1 Climate and geography of the study area

The climate of the study area is hot dry desert in the coastal plain (Lughaya and northern part of Baki districts) and arid in Borama and surrounding areas. Semi-arid conditions prevail at the higher altitudes of the Al Mountains (in the central part of the study area) and south of Gebiley. Mean annual rainfall ranges from below 200 mm in the coastal area of Lughaya, to 500 – 600 mm in the east of Borama and surroundings, while the rest of the areas have a mean annual rainfall between 300 – 500 mm.

The study area lies entirely between two subtropical anticyclone belts. The main weather pattern is controlled by the passage of the seasonal monsoon winds. The northeast monsoon brings the primary *Gu* rains from March to June, followed by a hot dry period called *Xagaa* in June and July. Short rains, which are also locally known as *Deyr*, occur between August and October followed by a cool long dry period between November-February. This dry period is locally known as *Jilaal*, but short rains occur in December and January at the coastal area.

Temperatures in the higher altitudes of the Al Mountains and Plateau areas vary considerably with seasons, with a mean annual value of 20 - 24 ^{o}C, while the coastal region has a mean annual temperature of 28 - 32 $^{\circ}$C. Like temperature, relative humidity also varies a lot with the altitude. In the high altitude areas, it is mostly around 40%, except during rainy periods when it may go up to 80%. In the coastal region, a high value of more than 70% prevails and combines with high temperatures to create an exceedingly hot and humid environment.

The study area experiences strong winds between June to July during the *Xagaa* dry season, during the southwest monsoon and in *Jilaal* between December and February. Hot and calm weather is experienced between the monsoons during April and September). Generally in the north-west, winds are strongest during the southwest monsoon. Average wind speed varies between 8 - 10 m/s, but during a large part of the year strong winds of up to 17 m/s may occur, thus causing frequent "dust-devils" over the coastal plains and plateaus.

The study area has a high potential evapotranspiration (PET), with an annual average value of between 2000 mm and 3000 mm. Annual rainfall is far less than the PET and a significant water deficit exists throughout the region for most parts of the year.

5.1.2 Geology / Lithology of the area

The study area is covered by rocks dating from Pre-Cambrian to recent times and comprises of sedimentary, igneous, and metamorphic rocks. The tectonic arrangement of rock outcroppings in the region is complex and is severely affected by many different systems of faults and fractures that are mainly oriented parallel to the coast (i.e. WNW-ESE).

The basement complex covers an extensive area in Al Mountain around Borama and Baki districts. Other parts of the region are covered by Jurassic limestone and Miocene bio-limestone, Pleistocene basalts, and recent alluvial and aeolian deposits. The igneous rocks consist mostly of basalts and rhyolites while metamorphic rocks include a wide range of schists, ortogneiss, quartzite, migmatites, marble, calcosilicate and paragneiss that are intruded by granite, diorite, and gabbro.

5.1.3 Landform and Soils of the area

5.1.3.1 Landforms

From geomorphological point of view, the study area may be divided into three landscapes: (1) Piedmonts and the Coastal Plain, (2) Mountainous and Hilland, and (3) Plateau.

(1) *Piedmonts and the Coastal Plain*. They consist of a small northern section of the study area that is taken up by gently sloping coastal plain (locally known as *Guban*) with the elevation ranging from the sea level up to about 600 m. They are characterised by debris and colluvial material often carried by several streams from the mountains and crossing the plain to the sea. The beds of the streams are very wide and are often exposed to flash floods during the rainy season.

(2) *Mountainous and Hilland*. They are largely in the middle of the study area and include the Al Mountains (Golis Mountains), which are oriented almost E-W parallel to the coast. This type of landscape has a very rugged topography rising to more than 1500 m asl. Both sides of the mountains, especially towards the sea and southern hinterland, are drained by numerous streams of varying sizes.

(3) *Plateau*. They are large, gently undulating, and almost flat highlands and plateaus in the south of the Al Mountains. They have varying altitude between 1500 – 1900 m asl and are cut by several streams (called Togga, Tug or Wadi).

5.1.3.2 Soils

In the high plateau, soils are predominantly deep and heavy textured Vertisols while the mountains and highland areas are largely Leptosoils and Regosols. In the flat valleys zones between the mountains the soils are Fluvisols and Cambisols. In some other places of pediment plains are covered by Calcisols and Solonchaks. The soils in the Piedmont and coastal plain areas are mainly Arenosols, Regosols and Leptosols.

5.1.4. Land cover and land use types in the area

The land cover of the study area consists mostly of natural vegetation that includes open shrubs, open trees, and open to closed trees, sparse shrubs, sparse trees, open or closed herbaceous or mixed trees and shrubs, mixed trees and herbaceous and mixed shrubs and herbaceous. Other land cover mapping units in the study area include urban and associated areas (settlements/towns and airport), bare areas (bare soils and sandy areas), and natural water bodies. The details of these land cover and vegetation characteristics are contained in the FAO-SWALIM Technical Report No. L-03.

The main land use in the study area is extensive grazing (pastoralism). Other land uses include rainfed agriculture, irrigated orchards along alluvial plains, and wood collection. Rainfed agriculture is found in what is considered as the sorghum belt of Somaliland and is practised in combination with pastoralism and wood collection. This class of land use is the economic mainstay of many households in the study area. Cultivation of irrigated orchards is a cash-oriented activity in the area, involving the growing of fruit trees such as citrus, guava, papaya, mango and vegetables. Water for supplemental irrigating of the crops is often obtained from wells, dams, and rivers.

Wood collection for charcoal production is also very frequent and occurs almost in all parts of the study area. However, the *Acacia* tree species are preferred for charcoal production and especially *Acacia bussei*, *A. nilotica* and *A. etbaica.* Charcoal production is for both local household consumption and income generation through sales in the local markets and for export outside the study area.

In terms of pastoralism, the animals kept are mainly camels, goats, sheep, and cattle. Goats and sheep are grazed mostly on sloping areas and coastal plains, whereas cattle and camels are grazed in flatter areas. Sedentary pastoralism around homesteads is also a common practise. Hay harvesting from enclosures supports this land use, as harvested hay can be used in the dry season. During dry seasons, especially in the central and northern parts, trees are lopped and brought to the livestock in the fields or moved to the coastal area.

6. METHODS

6.1 Participatory identification of land degradation problems, user needs, and establishment of a task force

A participatory workshop for identification of land degradation problems was carried out in Hargeysa, Somaliland on the 3rd March, 2007. This workshop brought together different stakeholders from various ministries in the government of Somaliland, local and international NGOs, local land users, and community based organizations (CBO's) (Figure 6.1). During the workshop, land degradation problems, indicators of the degradation, and users' needs were identified in the study area. A LADA taskforce was also set up (see also annex 1).

Figure 6.1: Land degradation workshop in Hargeysa

6.2 Stratification and sampling strategy

After participatory identification of land degradation types and their indicators, a stratification and sampling strategy was developed for detailed assessment of the degradation at the local level. The stratification was done using land use system map. A transect sampling scheme described in [30] was then used for field sampling (Figure 6.2).

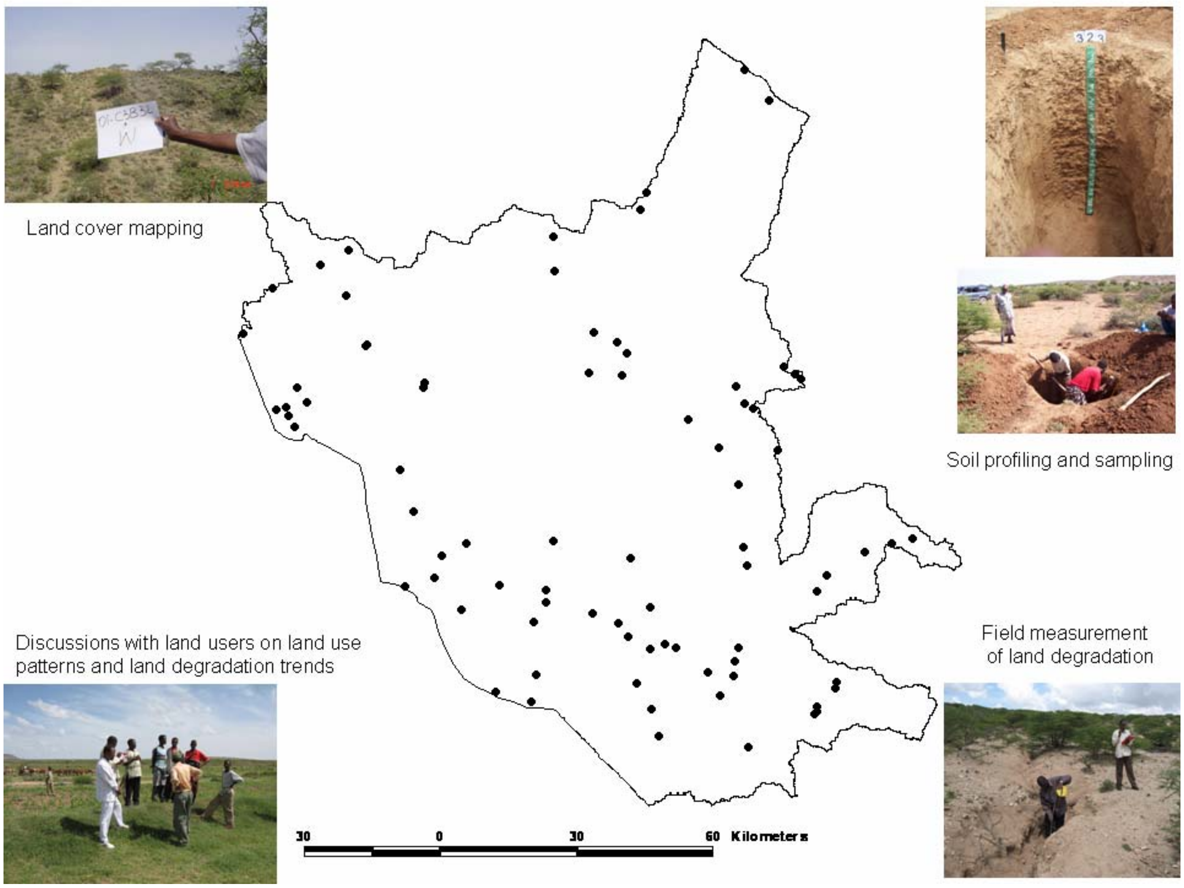


Figure 6.2: Field sampling strategy

6.3 Local assessments

Local assessment of land degradation was done through the use of field measurements, laboratory analysis of samples collected from the field, and high-resolution remote sensing images. Field measurements were done to determine the rates of soil loss (loss of topsoil and gully erosion) using the methods in [26]. The methods are also documented in the field survey manual (FAO-SWALIM Report No.

L01). The presence of degradation features and conservation measures in the field were also recorded. High-resolution images were used to determine loss of vegetation using remote sensing method as described in section 2.2.

6.3.1 Field survey

Field survey for detailed local assessment of land degradation was conducted in 82 locations using transect sampling scheme as described in [30]. During the survey, soil samples and information on the status of land management practises were collected. The soil samples were then analyzed in a laboratory for a number of degradation indicators (Table 6.1).

Table 6.1: Summary statistics of soil profile data

Soil property	Minimum	Maximum	Std. deviation
Sand (%)	6.0	92.0	20.6
Silt (%)	4.0	74.0	11.4
Clay (%)	2.0	80.0	19.8
Bulk density (g/cm^3)	1.2	1.7	0.1
Carbon (%)	0.0	1.8	0.3
Nitrogen (%)	0.0	0.2	0.0
Phosphorous (mg P/kg)	0.5	39.4	5.7
pH (in H2O)	7.7	10.0	0.3
Electrical Conductivity (mS/cm)	0.1	10.6	1.4
Cation Exchange capacity (me/100g)	0.3	45.3	7.9
Calcium (me/100g)	5.0	112.7	12.6
Magnesium (me/100g)	0.3	37.0	3.5
Potassium (me/100g)	0.1	2.0	0.4
Sodium (me/100g)	0.0	11.0	1.4
Exchangeable sodium Percent (%)	0.0	116.7	52.1
Limestone (%)	1.0	37.4	8.5

In addition to the above data on soil properties, 24 georeferenced soil properties and profile data were also obtained from [25]. This data included soil chemical and physical properties for topsoil (between 0 and 20 cm depth) (Table 6.2). They were collected in 1982 during a feasibility study for agricultural development of western Somaliland. Out of 24 sampled locations, only 18 coincided (within a radius of 100 m) with FAO-SWALIM baseline database. They were therefore used for assessing changes in soil properties between 1982 and 2006.

Table 6.2: Summary statistics of soil properties for samples collected in 1982

Soil property	Minimum	Maximum	Std. deviation
Sand (%)	15.00	91.00	24.83
Silt (%)	3.00	32.00	10.02
Clay (%)	6.00	62.00	16.25
Bulk density (g/cm3)	1.40	1.45	0.03
Carbon (%)	0.19	3.10	0.72
Nitrogen (%)	0.16	1.64	0.37
pH (in H_2O)	7.60	8.90	0.28
Phosphorous (mg P/kg)	0.06	36.52	13.81
Calcium (me/100g)	0.56	29.80	9.48
Magnesium (me/100g)	0.32	6.30	2.31
Potassium (me/100g)	0.05	1.87	0.54
Sodium (me/100g)	0.02	0.66	0.21
Limestone (%)	3.40	25.00	6.16

6.3.2 Field validation

Besides soil sampling, field validation was also carried out. The process entailed assessment for evidence of land degradation (e.g. features of soil erosion, compaction, surface sealing, surface stoniness, evidence of loss of vegetation, and conditions of crop health and density in the field) and measurement of soil erosion rates using Stocking and Murnaghan methods [26](Figure 6.3). The methods are also documented in the field survey manual (FAO-SWALIM Report No. L01). There were 28 random points for field-measurements of soil erosion rates using this method.

Figure 6.3: Field validation (see also the methods in FAO-SWALIM Report No. L01)

6.4 Quantitative assessment of different types of land degradation

6.4.1 Measurements and spatial representations

Quantitative assessment was done for four major types of land degradation in the study area: loss of vegetation, loss of topsoil, gully erosion, decline in soil nutrients, and water degradation.

Loss of vegetation was determined using time-series mixed-effects modelling of NDVI-rainfall relationship as explained in Part I of this report. Sixteen-day 250-m MODIS images from January 2003 to December 2008, monthly rainfall amounts for the same duration, and land cover map were used in determining loss of vegetation.

Loss of topsoil was determined from time-series soil loss modelling using the Revised Universal Soil Loss Equation (RUSLE) [19]. The modelling was done annually from

2000 till 2008 at 250-m resolution. The input variables for this exercise were rainfall amounts, MODIS NDVI images, land use map, DEM, and soil texture and were used to derive the RUSLE factors as described in Appendix 1. For the time-series modelling process, only NDVI and rainfall amounts varied annually while the other inputs remained constant. They were held constant partly because they didn't change much annually and partly because they had no time-series data.

Gully erosion was qualitatively determined as the density of gully network in the study area. This was done by semi-automatic extraction of gullies from high-resolution images [32]. 15-m ASTER images were used for this exercise.

Decline in soil nutrients for agricultural production was done by comparing historical data of soil chemical properties with those from a recent study by FAO-SWALIM [30]. Eighteen georeferenced soil profiles by SOGREAH [25], which coincided with the latest soil profiles from FAO-SWALIM were used as the historical data. Consistent soil chemical properties available for comparison were soil organic carbon, carbon-nitrogen (C/N) ratio, calcium-magnesium (Ca/Mg) ratio, and pH. These chemical properties were extrapolated to the entire study using regression kriging method. The extrapolation was done to produce results comparable areal extent as the outputs for other land degradation types in the same study area.

Water degradation was assessed using two approaches: 1 km mean monthly soil moisture images between January 2005 and November 2008. The soil moisture data were radar soil surface moisture signals from Advanced SAR instrument onboard ENVISAT (http://www.ipf.tuwien.ac.at/radar). Soil moisture was regressed with time for each pixel. A normalized deviation of 2008 soil moisture data from the mean between 2005 and 2008 was used to index the decline in soil moisture content using the SAR soil moisture data. In terms of density of water points, the spread of water points in 1982 was compared to that of 2008 to index to determine the changes in water supply.

6.4.2 Classification of degrees of the degradation types

Each land degradation type map was grouped into four classes: Extreme, strong, moderate, and light degradation. Grouping was done using fuzzy analysis clustering and implemented in R software. After categorizing the maps, they were combined to produce composite land degradation map. A classification and regression trees

(CART) was used to group similar categories of degrees of land degradation together and produce composite map of land degradation in the study area.

7. RESULTS AND DISCUSSIONS

7.1 Participatory identification of land degradation problems and user needs

Five land degradation types were identified during the stakeholders' workshop: loss of vegetation, loss of topsoil, gully erosion, decline in soil nutrients, and changes in water supply (quantity) (Figure 7.1).

Figure 7.1: Identification of land degradation types in the study area

The most common land degradation types identified by stakeholders were soil erosion (by wind and water), loss of vegetation, decline in soil nutrients, and invasive unpalatable plant species.

7.2 Assessment of land degradation in the selected area of interest

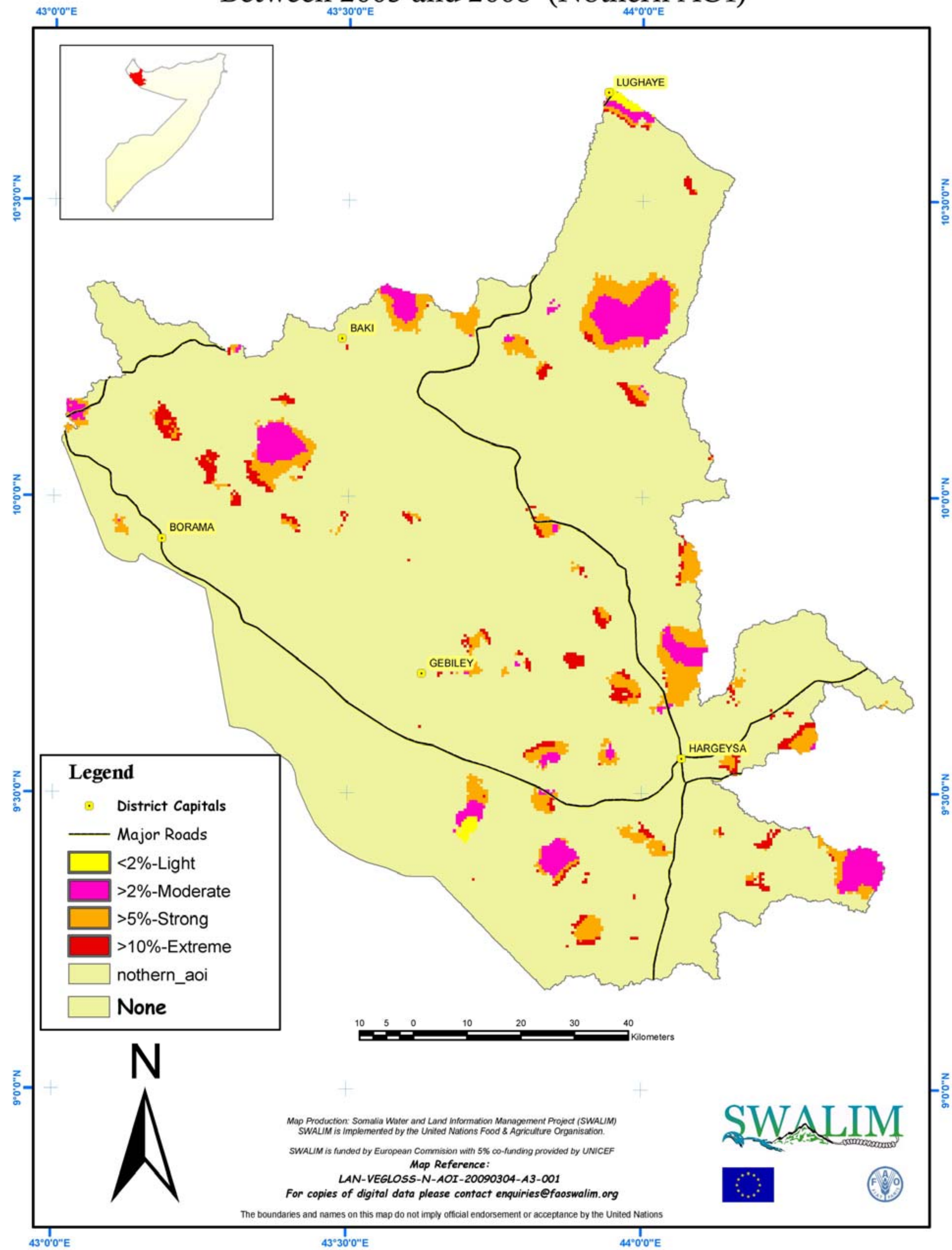
7.2.1 Loss of vegetation

Between 2000 and 2008, the study area lost 8.47% of its vegetation cover (Map S6). Land use systems unit with grazing areas where charcoal production and supplemental irrigation are practiced was the most affected unit (Table 7.1). The economic activity in this unit suggests that the major contribution to loss of vegetation is livestock grazing and agricultural activities.

Table 7.1: Loss of vegetation cover between 2000 and 2008 in the study area from Map S6

LUS-Code	Description of the land use unit	Percent loss
63	Pastoralism (medium density) wood collection	25.4
27	Pastoralism (high density) wood collection and scattered irrigated fields	21.5
36	Pastoralists (low density) in coastal plains	17.7
6	Agropastoralism (low density) with irrigated field around togas	13.7
52	Pastoralism (low density)	7.6
7	Agropastoralism (medium density) with wood collection	7.3
39	Pastoralism (low density) scattered irrigated field around togas	5.3
2	Agropastoralism (high density fields)	3.4
13	Agropoastoralism (medium density of fields)	2.6

MAP S6: POTENTIAL LOSS OF VEGETATION
Between 2003 and 2008 (Nothern AOI)



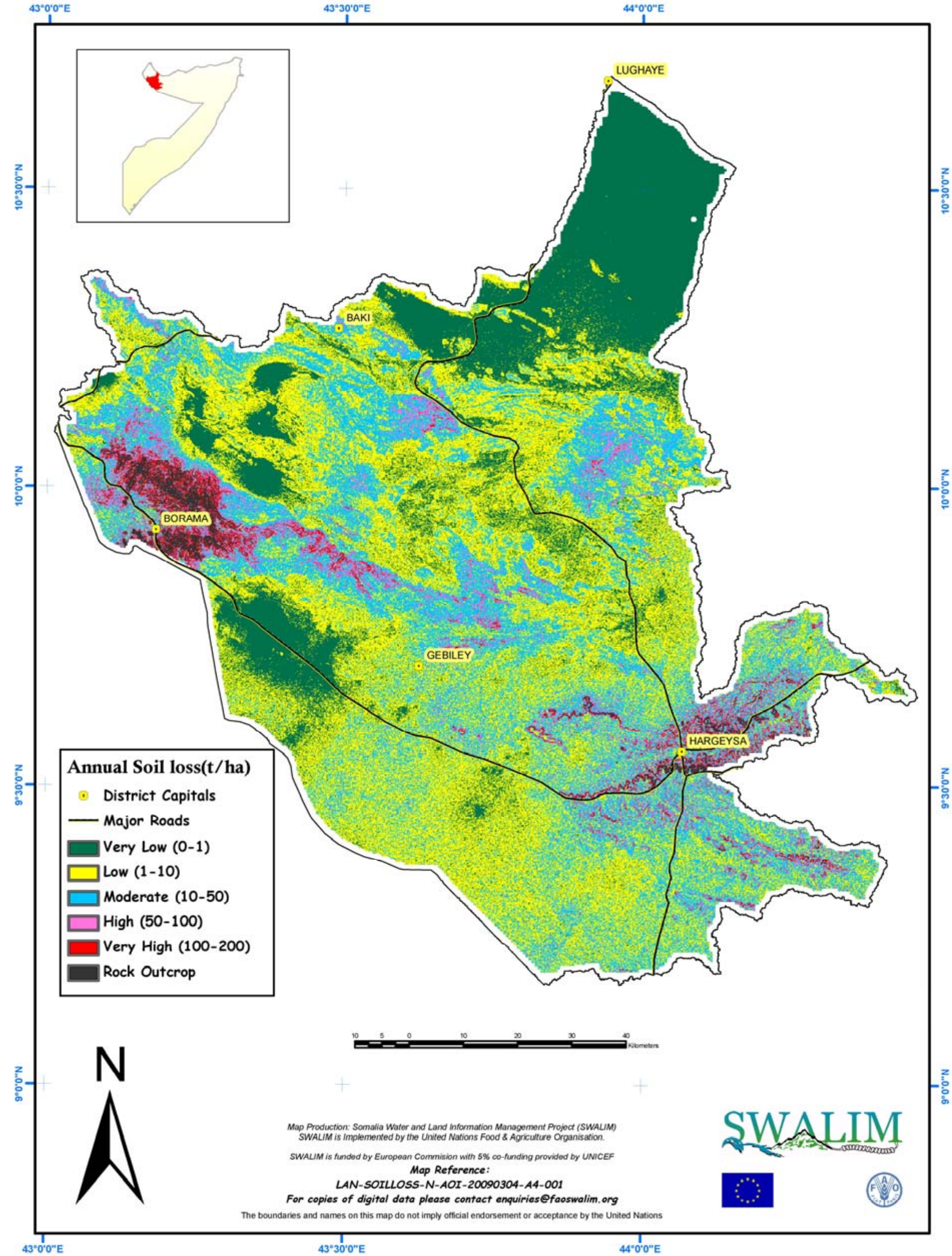
7.2.2 Loss of topsoil

The average rate of loss of topsoil due to sheet erosion in the study area was estimated as 20.47 ton ha^{-1} (with standard deviation of 6.51 ton ha^{-1}) (Map S7). About 24% of the study area had low rate of loss of topsoil due to water erosion (0 – 1.0 ton ha^{-1} yr^{-1}). These areas are largely in the northern parts and a few places in the western parts (Figure 8.3). Areas that had moderate rates of loss of top soil (10 – 50 ton ha^{-1} yr^{-1}) comprised of about 27% of the total study area. They are mainly in the north-western and south-eastern parts (Figure 8.3).

Very high rates of loss soil of topsoil (>200 ton ha^{-1} yr^{-1}) occupy about 2.2% of the study area and are largely in the steep slopes of the south-eastern and north-western parts of the study area. A combination of steep slopes, high rainfall, and close proximity to urban centres in the study area (Hargeysa in the south-eastern side and Borama in the north-western side) are the major causes of loss of topsoil in these areas.

The remaining parts of the study area have low rate of loss of topsoil (about 1-10 tons ha^{-1} yr^{-1}). A comparison of these soil loss estimates with field measurements showed about 80% accuracy (Figure 7.2); thus, indicating that the area has light to moderate loss of topsoil by water erosion.

MAP S7: POTENTIAL LOSS OF TOPSOIL (Nothern AOI)



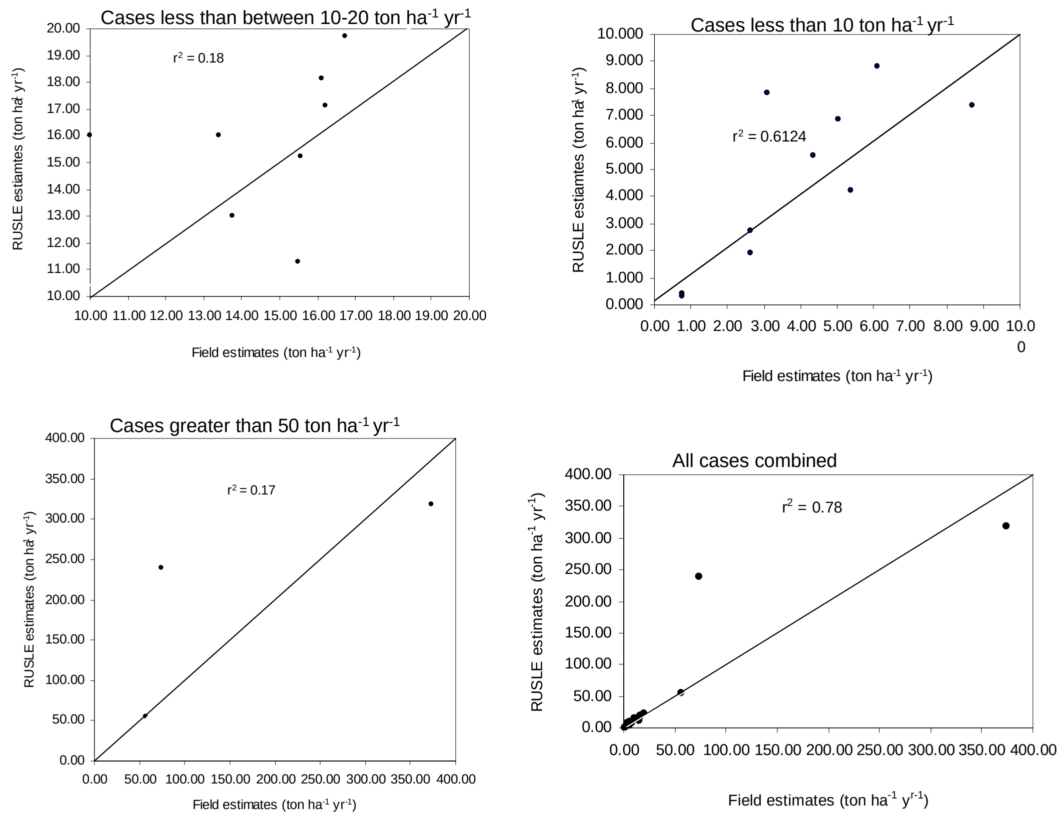


Figure 7.2: Comparison of RUSLE estimates of loss of topsoil and field measurements

Time-series analysis of loss of topsoil between 2003 and 2008 showed that urban areas and areas with combination of livestock grazing and crop cultivation had the highest percent increase in loss of topsoil (Table 7.2).

Table 7.2: Increase in loss of topsoil by land use systems

LUS Code	Description of the land use systems unit	Increase in soil loss (%)
70	Urban area	24.3
52	Pastoralism (low density): shoats, camels, cattle	10.8
6	Agro-pastoral (low density of fields) with irrigated fields around togas: vegetables, fruits, shoats	8.2
27	Pastoralism (high density)/wood collection and scattered irrigated fields: fodder, sorghum, camels, shoats	4.5
39	Pastoralism (low density) with scattered irrigated fields around togas: shoats	4.3
13	Agro-pastoral (medium density of fields): sorghum, maize, shoats, cattle	3.1
2	Agro-pastoral (high density of fields): sorghum, maize, shoats, cattle	2.6

7.2.3 Gully erosion

In addition to loss of topsoil, gully erosion was also assessed. The results show that most hillscarps in the centre of the study area had the densest network of gullies (Map S8). Other areas such as northwest and southeast also had few gullies although they were longer and deeper than those in the hillscarps. Land use units most affected were those in which pastoralism and scattered irrigation were dominant (units number 39 and 52). About 35% of these areas had high density of gullies.

7.2.4 Loss of soil nutrients

Decline in soil nutrients was assessed by comparing historical data of soil nutrient indicators with those from FAO-SWALIM (Table 7.3).

Table 7.3: Comparison of average soil properties over time

Soil property	Average value in 1982	Average value in 2006	Change (%)
Sand (%)	50.58	43.27	-14.45
Silt (%)	18.74	18.30	-2.32
Clay (%)	30.68	38.42	25.22
Bulk density (g/cm3)	1.43	1.49	4.50
Carbon (%)	1.42	0.69	-51.30
Nitrogen (%)	0.77	0.07	-90.64
pH (in H_2O)	8.29	8.26	-0.44
Phosphorous (mg P/kg)	8.98	10.28	14.37
Calcium (me/100g)	12.70	21.10	66.17
Magnesium (me/100g)	3.19	2.49	-22.10
Potassium (me/100g)	0.83	0.86	3.63
Sodium (me/100g)	0.25	1.28	408.32
Limestone (%)	12.25	17.94	46.40

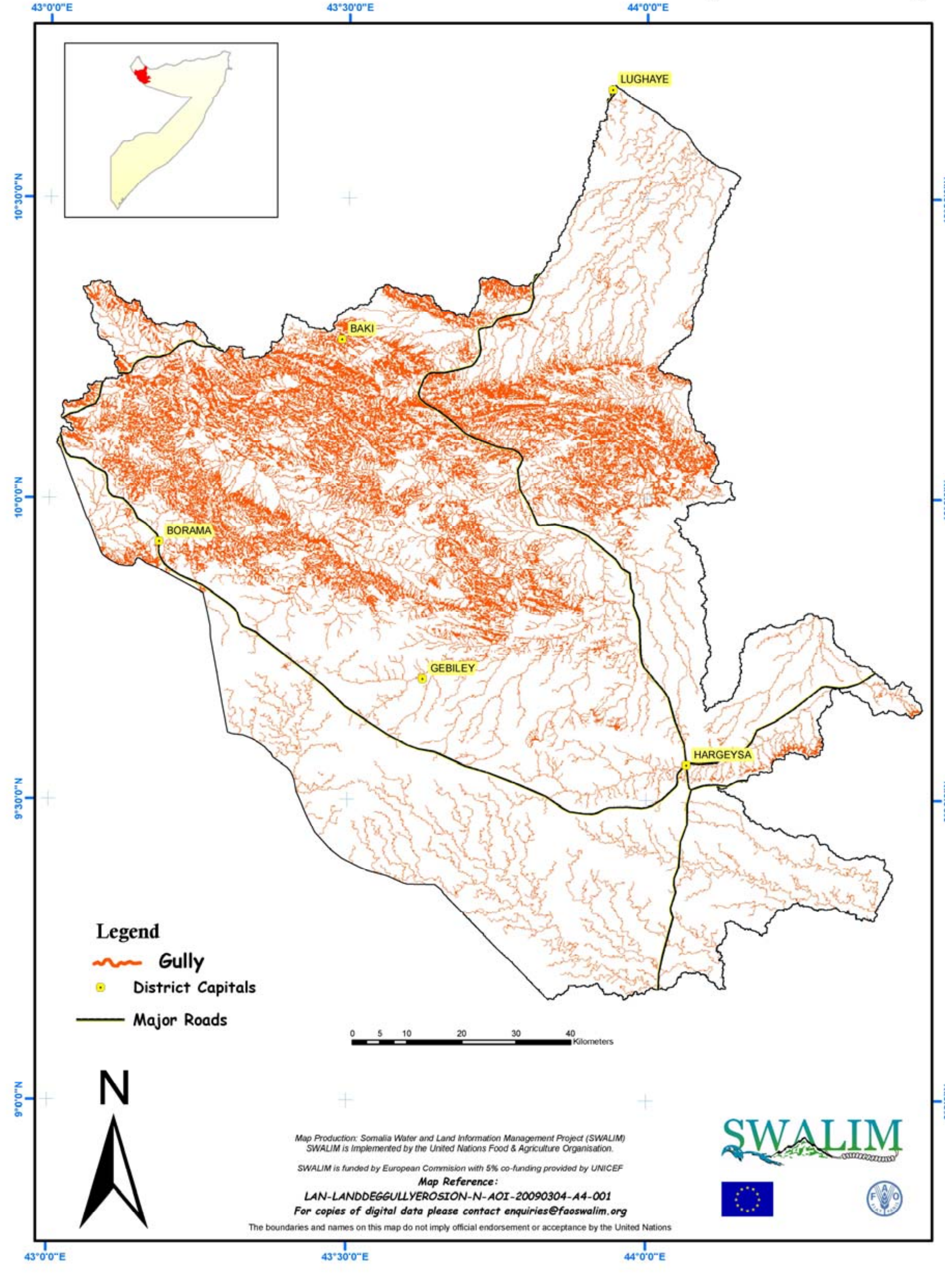
Although the sampling period (season of the year) and analytical procedures for determining the soil properties could have been significantly different between the two datasets, the percent changes in Table 4.3 indicates that there seem to have been a decline in soil nutrient condition between 1982 and 2006. A better comparison of soil chemical properties that takes care of potential differences in sampling time was done using soil organic carbon, carbon-nitrogen (C/N) ratio, calcium-magnesium (Ca/Mg) ratio, and pH (Table 7.4). This analysis showed that, on average, soil organic carbon had declined in as much as 50% between 1982 and 2006 while calcium-magnesium ratio and carbon-nitrogen ratio had increased by over 100% (Table 7.4). The increase in carbon-nitrogen ratio implied poor transformation of organic matter into soil nutrients (mainly Nitrogen) while the increase in calcium-magnesium ratio implied an unbalanced composition of Magnesium. These results are an indication of decline in soil nutrient status, which constitute chemical deterioration for agricultural productivity.

Table 7.4: Average changes in soil chemical properties (nutrient status) for 18 topsoil (0-20 cm) samples in the study area

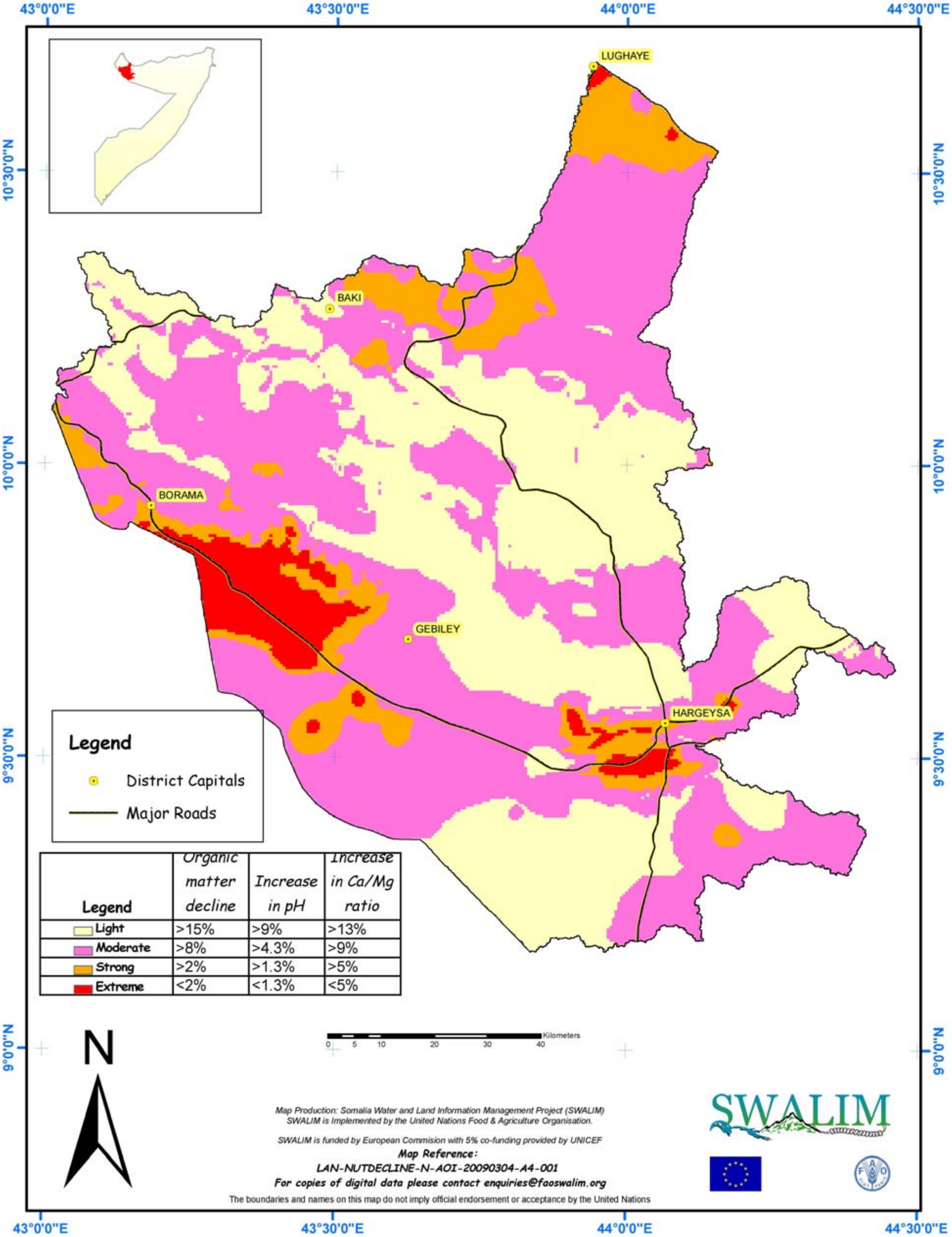
Soil property	Measured values				Mean changes
	In 1982		In 2006		(%)
	Mean	Std. Dev	Mean	Std. Dev	
Organic carbon (%)	1.42	0.72	0.69	0.34	-51.3
Calcium-Magnesium ratio	4.60	2.05	11.48	8.44	149.3
Carbon-Nitrogen ratio	1.79	0.20	10.42	5.11	481.0
pH	8.29	0.28	8.20	0.20	-0.44

The above changes in soil nutrient status were mainly in the western part of the study area and around Hargeysa town (Map S9). The most affected land use systems units were unit 13 (which had 38% of the area with extreme decline and 38% moderate decline in soil nutrients) and units 2, 6, 7 and 52 with over 50% area having moderate decline in soil nutrients. Land use unit 27 and 36 had moderate decline in soil nutrients covering over 63% of their areas.

MAP S8: POTENTIAL GULLY EROSION (Nothern AOI)



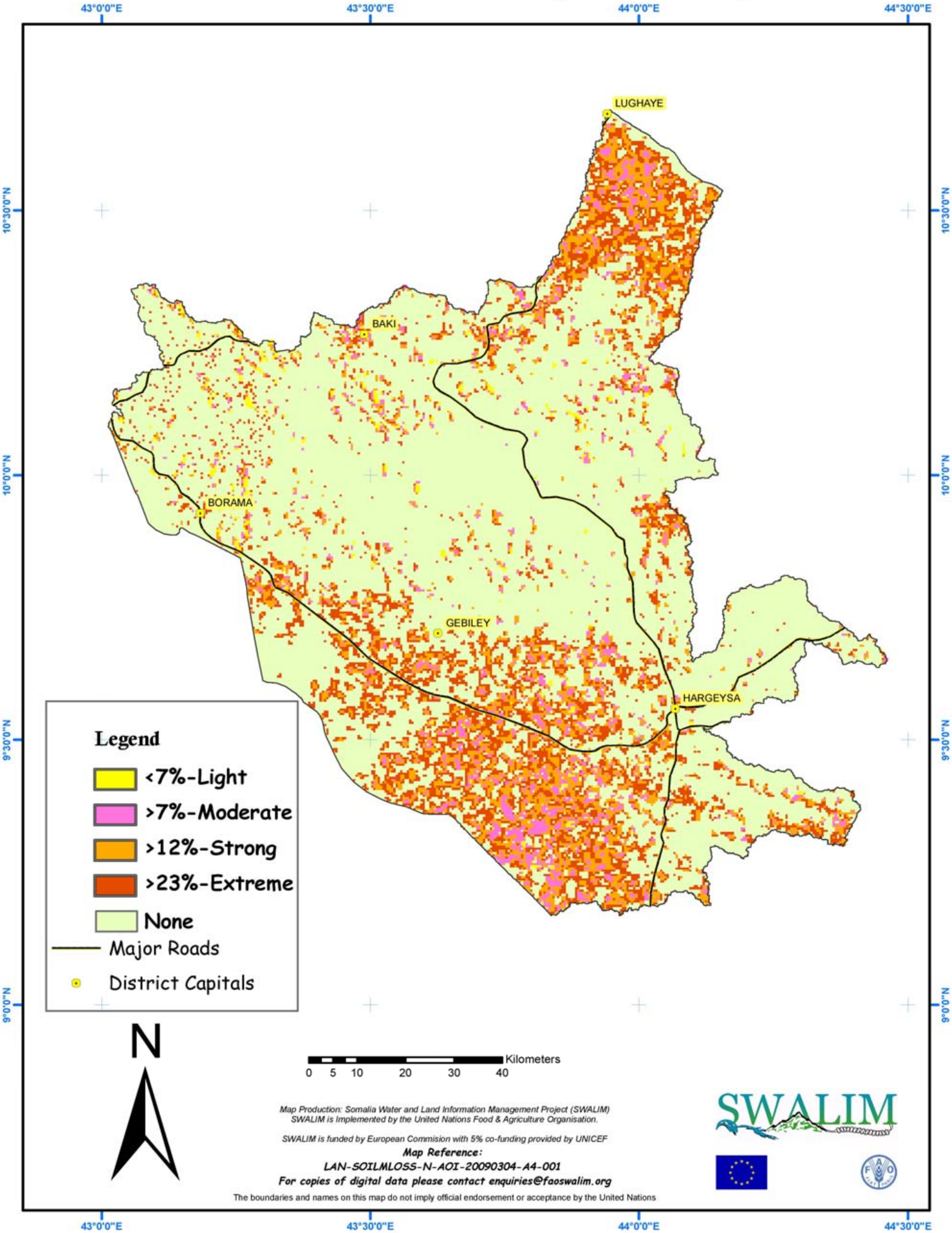
MAP S9: POTENTIAL NUTRIENT DECLINE
Between 1982-2006 (Nothern AOI)



7.2.5 Water degradation

Changes in soil moisture content from SAR images showed that the coastal region and southern part of the study area (south of Hargeysa town) seem to have experienced high decline than other parts. The decline in these areas was between 1 to 19% (Map S10). The most affected land use units were units 7 (where 63% of the area was affected), units 27and 36 (with about 48% of the areas affected), and unit 2 (with 41% of the area affected).

MAP S10: POTENTIAL SOIL MOISTURE DECLINE
Between 2005 and 2008 (Nothern AOI)



7.2.6 Documentation of organizations supporting resource conservation practices activities and potential ways of controlling land degradation in Somaliland

7.2.6.1 IFAD / UNOPS

This project has been working in the districts of Gabiley, Faraweyne and Borama since 2000. It follows an integrated watershed management (IWM) approach and works closely with the local communities. Due to the high cost of implementing IWM projects and funding limitations, the project has selected a number of pilot catchments with the aim future upscaling. Within the pilot catchments, the project works with the community as the operation unit. Initially, the community is screened to determine if planned activities will be successfully implemented. If the results of the screening process are found satisfactory, then Participatory Rural Appraisal (PRA) is done to profile community assets and prioritize interventions. This is followed by community sensitization and education.

The above community engagement activities are facilitated by local NGOs. Once the community is engaged, IFAD technical staffs then proceed to prepare plans and budget and do technical survey and designs where necessary. The project incorporates strong monitoring and evaluation components. Activities include runoff control in the upper and steeper parts of the catchments (which are also generally more stony and impervious). They also do soil bunds using earth moving bulldozers in cropping areas, gully protection in the heavily eroded areas and river embankments, sand storage, and runoff check dams in the lower reaches of the selected catchments.

In one of the pilot catchments in the Dila areas, the community indicated that, the livelihood situation in the areas was so bad before the project that many of them emigrated. The project then selected a number of catchments and embarked on integrated watershed management using labour intensive approach instead of bulldozers. At the top of the selected catchment, water absorption terraces were used to trap and absorb excess runoff. Below these terraces, soil bunds were used to hold and retain runoff within the cropped areas. The treatment on the upper reach of the catchments protected soil bunds from heavy runoff and were able to stabilize quickly with minimum maintenance. Reduction of runoff yields in the upper reaches led to the reduction in soil loss and gully development in the lower reach while the absorbed water contributed to ground water recharge.

Three sites with severe gully erosion were also identified and gully healing activities initiated. In this case, they used stone gabions combined with re-vegetation within the gully. Runoff diversion channels were also constructed to divert water from the gullies. The diverted water was put into small earth dams and could be used by livestock.

In the lower reaches of the catchment, the project constructed riverbed embankment to protect it from being eroded by storm waters. A sand dam and two runoff check dams were also constructed. These dams have improved water supply in the lower reaches of the catchment. Within a few years of the project's operation, it has started to improve the standards of livelihoods of the communities in this area. There is increasing number of small irrigation farms producing vegetable for local consumption along the dry river valleys. A number of conclusions can be draw from the above experiences:

- To succeed with an IWM project, it should have a long term focus. Adequate time is required to create awareness and sensitize the communities. It is also important to note that the integrated projects need time to bring about positive impacts.
- IWM projects are costly and it is necessary to do thorough screening and prioritizing of project activities. Proper technical expertise is required and these may not be available in a single project. Different stakeholders need to partner synergize.
- To minimize the amount of time required to engage the community, initial activities can be carried concurrently, for example, when one agency is undertaking awareness creation and community profiling, the other partner agency may undertaking survey work and technical design.
- Even with modest budget, the IFAD project in this area demonstrated that an integrated approach is possible and could be a good example on how to address land degradation.
-

7.6.4.2 Agriculture Development Organization

The Agricultural Development Organization (ADO) is a non-governmental organization involved in various agricultural development activities in Somaliland. It works in four areas i.e. Adwal, W. Galbeed, Togdheer, Saaxil and Sanaag. It has its head office in Hargeysa and branch offices in Boorama and Burco. A fourth office is being planned for Cerigaabo by the end of 2007. The organization works closely with the Ministry of Agriculture especially in developing technical manuals and in developing communities training courses. It involves the communities through farmers associations at village and district levels. The same approach will be taken upwards and a national farmers union is planned by 2008.

In the areas of land degradation, ADO is involved in implementing different Soil and Water Conservation (SWC) practises including soil bunds, stone terraces, check dams, sand storage dams and tree nurseries. Other related interventions include irrigation canal construction, training of farmers in SWC and irrigation management, soil fertility management and energy saving technologies. These activities are supported by different partner organization. For SWC, ADO is collaborating with WFP and UNHCR. The project has established soil bunds in four regions where it operates and stone terrace in the Adwal area, which has steep slopes. It has established three government and two community tree nurseries and has distributed over 20,000 tree seedlings of different species depending on the needs of the communities. The project has established check dams in the areas where project is constructing irrigation canals. Similar activities will be expanded to cover other areas of Somaliland. The long term aim is to expand project activities to cover the whole of Somaliland and to make the project long term.

7.6.4.3 Barwaaqo Voluntary Organization

The Barwaaqo Voluntary Organization (BVO) works in the regions of Awdal, Saaxil, and W. Galbeed. Its activities include environmental management, food security and agriculture, income generating activities, community capacity building, training and women empowerment. In relation to land degradation related activities, the project is involved in environmental management awareness creation, tree distribution and training in environment and sustainable use of natural resources. Training is undertaken by local experts with field experiences. These are engaged by the organization to undertake the training on its behalf.

BVO has also established Green Watch youth groups which are involved in environmental awareness creation and advocacy. Each Green Watch group consists of 20 youth who have completed high school or university levels of education. Currently, five groups have been formed and more are going to be formed. The Green Watch groups work on voluntary basis and are very active on environmental issues. These groups however require logistic support such as transport and basic farming inputs to help them achieve their goals. To engage more youth, the groups are planning to develop communication materials including a website.

In the area of income generation and agriculture, the group is supporting farmers in bee keeping projects. The group is encouraging farmers to work in groups to cut cost and to support each other. To help the bee keeping farmers with marketing, the group buys the honey from the farmers and then sells it to traders in various towns in Somaliland. The bee keeping project is encouraging farmers to plant more trees so as to provide a good environment for bees for honey production.

7.6.4.4 German Agro-Action (GAA)

German Agro Action (GAA) has operation in Borama and Baki districts in the Awdal region of Somaliland. The area is facing land degradation problems both in the cropped areas and in the rangelands. The projects works through a community based approach and collaborates closely with the ministry of Agriculture and ministry of Pastoral development and Environment. The project has its offices in Borama. The project’s land degradation related activities includes the construction of soil bunds, stone terraces, runoff check dams and earth dams, and establishment of tree nurseries and protection of forest and seasonal grazing areas. Other project activities include construction of irrigation canals and feeder roads and community training and awareness creation.

Most of the land degradation work is concentrated in Borama district (Goroyo Cawl Camuud, Tuur Qaylo and Carro Cad / Qolujeed). Soil bunds are approximately 1.2 meters wide (0.4 meters wide at the top) and 0.6 meters high. The lengths vary between 50 to 100 meters while the spacing depends on the land slope but ranges from 18 to 30 meters. The stone terraces are 0.4 – 0.6 meters wide and 0.6 meters high. Runoff check dams consist of stone gabions. A tree nursery is located at Baki town and supplies tree seedlings to community members at no cost. The seedlings are mainly used to establish live fences on farms.

Some of the problems observed include lack of maintenance of the soil bunds and stone terrace by community members, the destruction of soil bunds by livestock before they are well established and rapid spread of land degradation activities in the areas especially the removal of vegetation cover through tree cutting. Depletion of ground water level has also been observed.

7.6.4.5 Candlelight, PENNA, NOVIB and WFP

These four organizations, Candlelight for health, education and environment, Pastoral and Environmental Network in the Horn of Africa (PENHA), NOVIB and World Food Project (WFP) and are implementing or supporting various land degradation related activities within the Saaxil (Gacan-Libaax mountain area, Sheikh District) and Sanaag (Daallo mountain area, Cerigaabo District) regions of Somaliland. Candlelight is a local NGO while PENNA and NOVIB are international NGOs. WFP is a UN agency. The activities implemented or supported by these organizations involve the local community in different phases of the project: design, implementation, monitoring and evaluation. The Ministry of Pastoral Development and Environment provides local experts to guide the project design and also provide technical backstopping.

Land degradation related activities implemented or supported by these organizations include soil bund and stone terraces establishment, gully healing and runoff check dam. Soil bunds are on average 1 meter wide, 1 meter high and 20 – 25 meters long. Spacing depends on the slope. The stone terraces are 0.5 meters high, 1 meter wide and 25 meters long. Spacing is 30 – 40 meters. Stone filled gabions are used for gully healing and runoff check dams. The main problem observed is the destruction of soil bund by torrential rains.

7.6.5 Example of the documentation of soil and water conservation technologies in Somaliland

Soil Bunds by IFAD

Country: Somaliland

Area: Durdur / Gabiley

Climate: Semi arid / Arid

Rainfall: 300 – 500 mm per year

Land use: Cropland

SWC Measure: Structural/ Vegetative

Photo *A new soil bund in the Dila area of Gabiley district, Somaliland. This bund is constructed using a new design in which the earth used for the construction is removed in form of ponds in front of the bund. These ponds trap soil and water and have higher moisture content hence less drought* *tolerant crops can be planted in them.*

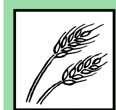
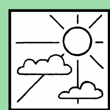
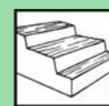
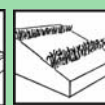
Soil bunds consist of earth dikes constructed in cropped areas experiencing severe moisture deficits. Functionally, they impound surface runoff and increase infiltration and soil moisture. In return, soil bunds lead to improved crop growth and yield. Although they are used mainly in cropped areas, they can also be used in grazing areas. Soil bunds are found both on steep and gentle slopes. By impounding surface runoff, the bunds also help to reduce top soil erosion within the cropped areas and gully erosion downstream.

Soil bunds were introduced in the rainfed agricultural areas of Somaliland, the Durdur – Gabiley areas, in the early 1960s through a soil and water conservation project funded by the US Agency for International Development. Since then, other development projects in the areas have either rehabilitated the initial soil bunds or constructed new ones. Both new and old soil bunds are common across the entire area. The success of soil bunds depend largely of their design, construction and protection from livestock trampling in the early stages. For proper design, good baseline information is needed. Soil bunds are usually between 1 – 3 meters in width and height and the length vary, depending on the length of the plot. Spacing between the bunds depends on the slope, being shorten on steeper slope and wider on gentle slope. After construction, thorn bushes are used to cover the bunds where possible to protect them from trampling. Grass is allowed to grow on the bund to make them stable and manure can be applied to speed up the process. The ends are protected with stones so that they are not washed off by heavy runoff. In some cases, water passages are provided along the length to allow movement of water from the upper plot to the lower one in steeper areas where heavy runoff is possible. Soil bunds have been very effective in increasing soil moisture and crop yield in this area. An assessment made in the area indicated that crop yield doubled after the soil bunds were constructed. However, in some areas, the bunds are not well maintained and the impact has reduced. Even after four decades, farmers still report that areas with bunds have better crop yields. New bunds in the area, especially those constructed within an Integrated Watershed Management project by IFAD, are well designed, constructed and protected and have established a good grass cover. These bunds will require minimum maintenance in the long term. The bunds have help reduce top soil loss and since they impound harvest runoff in the cropped areas, they curtail gully erosion down stream. Up scaling of soil bunds should be planned carefully so that the pasture areas are not compromised. Many organizations, including local NGOs, are involved in soil bunds projects in different areas and it is necessary to coordinate the efforts to ensure good design and construction. Where possible, farmers can be encouraged to use hand implements to reduce the cost of construction.

Classification

Land use problems

Arid climate results in a severe soil moisture stress during the crop growing period and low crop yield. Runoff especially in the early stages of crop growth lead to water erosion and top soil loss.

Land use	Climate	Degradation		SWC measure	
					
annual crops: Sorghum, millet, maize	semi-arid / arid	water degradation: soil moisture problem	water erosion: loss of top soil	structural: soil bunds	vegetative: grass cover on soil bund

Technical function/impact

main:
- retain / trap dispersed runoff
- Increases water infiltration
- conserves top soil

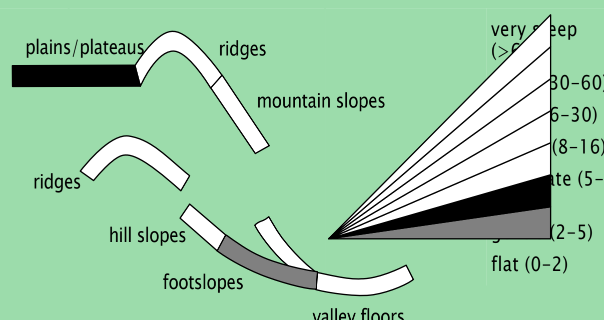
secondary: - Improves cover (grass cover on the bund)

Classification

Natural Environment

Average annual rainfall (mm)	Altitude (m a.s.l.)
>4000	>4000
3000-4000	3500-
2000-3000	3000-
1500-2000	2500-
1000-1500	2000-
750-1000	1500-
500-750	1000-
250-500	100-500
<250	<100

Landform **Slope (%)**



Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- <120

Growing season: 90 - 120 days (May to September)

Soil fertility: low to partly low

Soil texture: fine to medium (clay)

Surface stoniness: spotted rock outcrop

Topsoil organic matter: low (<1.5%)

Soil drainage: medium

Soil erodibility: medium

Human environment

Mixed land per household (ha)	
	>1
▓	1-2
■	2-5
	5-15
	15-50
	50-100
	100-500
	500-1000
	1000-10000
	<10000

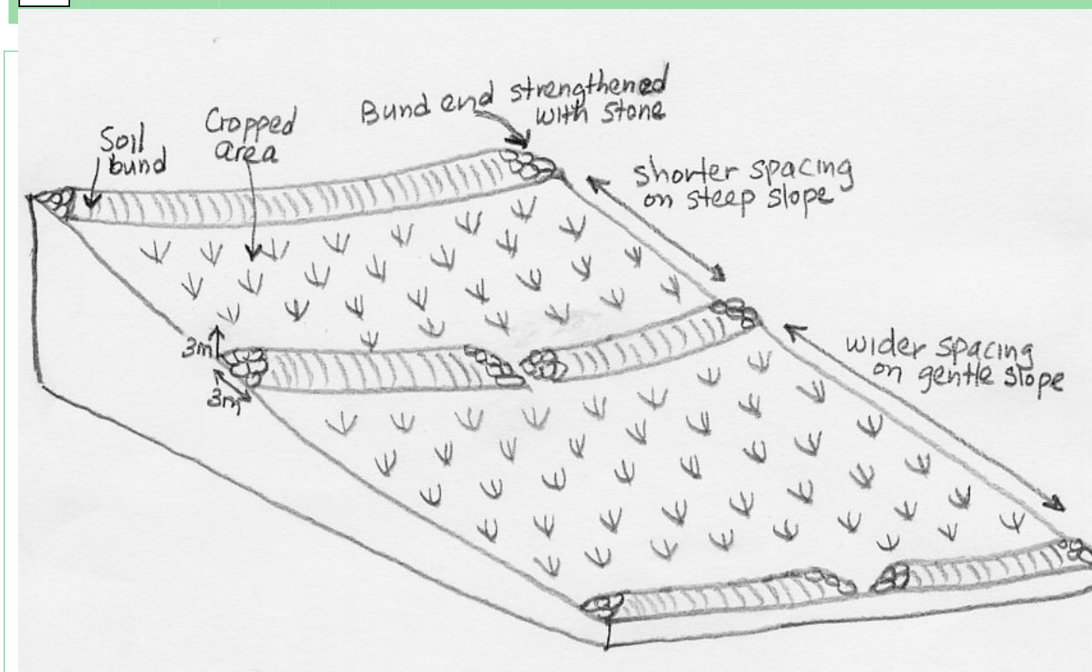
Land use rights: individual (grazing and some cropland)

Land ownership: mixed - communal and individual

Market orientation: mainly subsistence

Level of technical knowledge required: field staff/extension worker: high (design), land user: moderate(maintenance)

Importance of off-farm income: Not well understood but a substantial amount of income comes remittance from the Diaspora



Implementation activities, inputs and costs

Establishment activities

- Area survey and technical design of soil bunds. This is done by qualified technicians provided by collaborating development agencies.
- Construction of soil bunds. This can be mechanized (Bulldozer, tractor or animal traction) or manually by hand
- Strengthening of soil bunds ends using stones and protection using thorn bushes where possible to allow grass to grow. Manure can be added to enhance growth of grass

Duration of establishment: 2-3 years

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Suvey and design		0%
Construction of soil bund		30%
Strengthening of soil bunds		100%
TOTAL		

Inputs	Costs (US$)	% met by

			land user
	Repair of broken areas		100%
	Removal of silt		100%
	TOTAL		100%

Assessment of the Acceptance/adoption

Soil bunds are widely accepted and adopted in the Durdur / Gabiley areas and other rainfed agricultural areas of Somaliland. However, these communities are predominantly pastoral communities and in many cases the bunds are not well maintained. The impact of the bunds is mainly in average and above average seasons.

Benefits/costs according to land user

Benefits compared with costs	short-term:	Long-term:
Establishment*	Negative	Positive
Maintenance/recurrent	Positive	Negative*

Initially, the cost of establishment is high and farmers may have to sell some livestock to pay their 30% share of the construction cost. In the long term, the bunds lead to increased crop production and the grass established on the bund can be used to graze livestock. Maintenance cost is limited initially but may increase in time if the bunds were not well designed and constructed or if they did not establish well.

Impacts of the technology

Production and socio-economic benefits

+	+		Crop yield increase
+			Farm income increase

Production and socio-economic disadvantages

-			Initial cost are high - farmers may have to sell livestock

Socio-cultural benefits

+	+		improved knowledge on SWC
+			community institution strengthening

Socio-cultural disadvantages

-	-		If large areas are cropped, pasture areas may become limited

Ecological benefits

+	+	+	Increase in soil moisture
+	+	+	Soil loss reduction
+	+		Soil cover improvement
+			increase in soil fertility

Ecological disadvantages

-			Can lead to top soil wash if not well designed and constructed

Off-site benefits			Off-site disadvantages
+	+	Reduced in downstream gully erosion	

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Increased soil moisture → Ensure soil bunds are well designed, constructed and maintain so that they remain effective in the long term	High implementation cost → Encourage farmers to use hand in constructing the soil bunds. Also, different organizations can partner to reduce the overall cost
Increased crop yield → Extend soil bunds to all cropped areas. Since areas already experiences severe moisture stress, encourage farmers to farm drought tolerant crops.	Competition for pasture land → Ensure that expansion of cultivated areas is well planned to take care of the pasture needs of the community
Reduced soil loss → Encourage farmers to fertilize soil and use manure to improve soil fertility since the land is cropped each season.	Top soil loss → Ensure that soil bunds are well designed by professional personnel using actual field survey data

Key reference(s): John W. Macarthy; Cynthia Clapp-Wincek; Steven Londer and Abby Thomas: 1985. A soil and water conservation project in two sites in Somalia: Seventeen years later. Aid project impact evaluation report No. 62. US Agency for International Development.

Contact person(s): Sulub A. Aman, Project Officer - ICDP/UNOPS/IFAD/BSF project in Gabiley area, Somaliland. (suluba@unops.org)

8. CONCLUSIONS AND RECOMMENDATIONS

Local assessment of loss of vegetation cover, loss of topsoil, decline in soil nutrients and moisture, and gully erosion were carried out in a selected area in western Somaliland. Loss of vegetation cover was assessed using high-resolution remote sensing images (16-day interval MODIS images) acquired between January 2003 and December 2008. The results show that the area lost 8.5% of its vegetation cover between 2003 and 2008. Remote sensing in this case was given emphasis because of the current socio-political situation which does not allow extensive field activities. The most affected areas were those in which fuelwood collection and livestock grazing are intensively practiced. Decline in soil nutrient was assessed by comparing soil chemical properties sampled in 1982 and 2006. Overall, there was more than 50% decline in key soil properties such as organic matter and phosphorous which are important for crop production. Assessment of loss of topsoil also revealed that area loses about 10 tons of soil per hectare annually due to wind water erosion. This rate of loss of topsoil is likely to increase since the protective vegetative cover is increasingly being lost.

Although the degree of land degradation is moderate to strong degree of degradation in Somaliland with an increasing trend, there are some ongoing resource conservation practices, which have potential of reducing this rate. resource conservation practices such as soil bunds, forestation, runoff water harvesting, gully control, etc are few and far between but seem effective where they have been implemented. They can make a huge impact in controlling land degradation if they are strategically up-scaled to areas with potentially high and severe rate of degradation. It is recommended that the organizations implementing these resource conservation practices collaborate together and with FAO-SWALIM to target degradation hotspots in Somaliland.

The results of local assessment of land degradation were obtained within the limitations of available historical data. The already gathered data during this study can be used as in future as baseline information for exhaustive land degradation assessment in Somaliland at the local level. Figure 8.1 shows a summary of this baseline information for potential future assessment and monitoring land degradation.

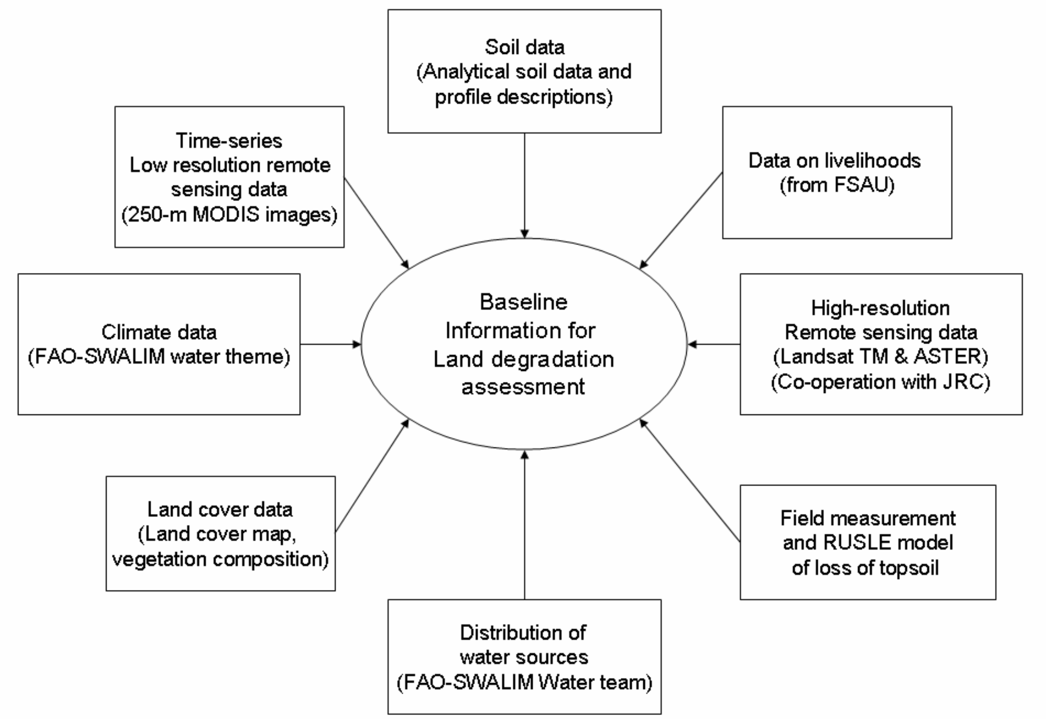


Figure 8.1: Baseline data for assessing land degradation in Somaliland

9. RECOMMENDATIONS FOR LAND DEGRADATION MONITORING FRAMEWORK IN SOMALILAND

The aim of land degradation monitoring will be to identify regions of the country which are experiencing changing trends of land degradation and the trends of specific land degradation types (e.g. loss of topsoil, nutrient decline, loss of vegetation cover, and water degradation) in Somaliland. This study on land degradation generated necessary baseline information which can be the starting point for instituting a land degradation monitoring framework for Somaliland. Various methods of assessment and data analysis were established and it is anticipated they are used periodically can provide opportunity for monitoring the degradation. Figure 9.1 shows how these measurements and analysis can be pieced up together to monitor changes in land degradation status.

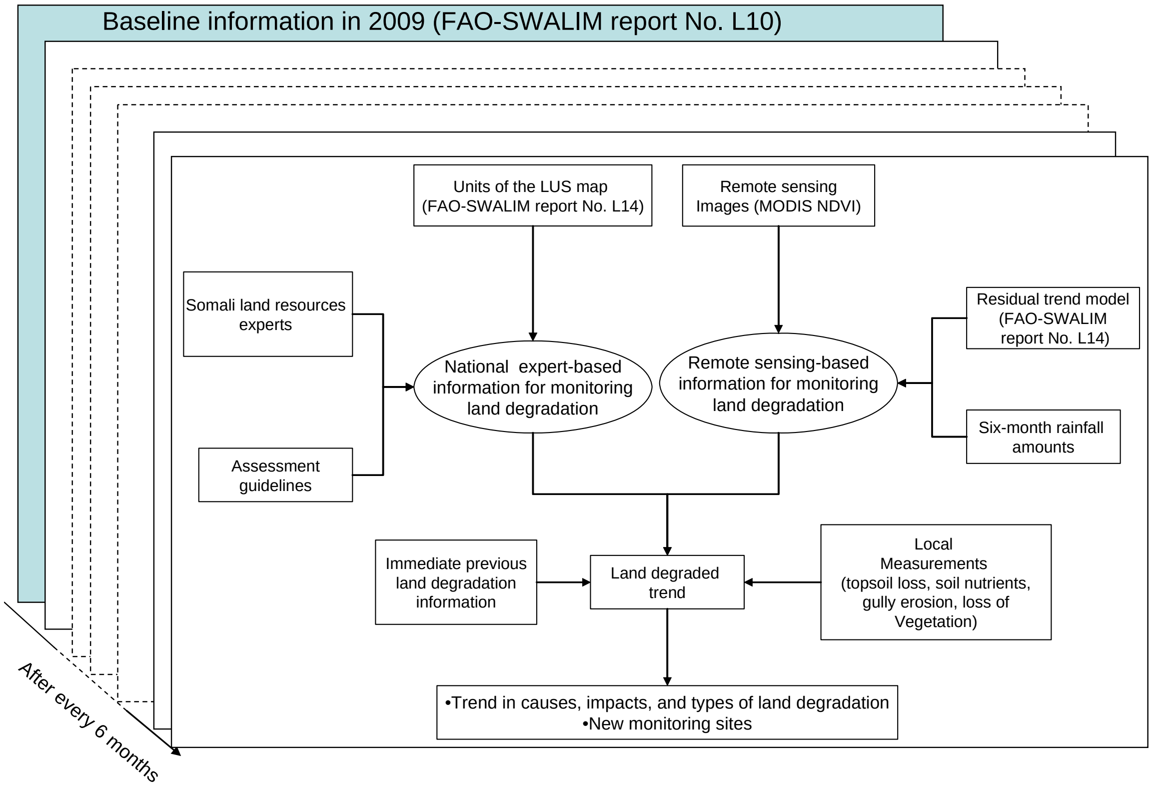


Figure 9.1: Conceptual monitoring framework for land degradation in Somaliland.

9.1.1 Expert-based information for monitoring land degradation

During this study on national assessment of land degradation, 14 Somali land resources experts were trained and used to assess land degradation in Somalia. The training involved the use of LADA-WOCAT guidelines for assessing land degradation and how to integrate previous land resources information for quantifying different aspects of land degradation. It is recommended that these experts be contacted again after every 12 months to provide information on the trends of land degradation in the country.

There are two guiding references which should be used for gathering expert information about land degradation: land use systems (LUS) map produced during this study and the LADA-WOCAT guidelines. Experts will use these references to update national land degradation characteristics. The updates will then be analyzed to determine the trend of the degradation (Figure 9.2). The process should be repeated periodically. It is recommended that it should initially be repeated annually and then later changed to biannually once the dynamics of land degradation shall have been well understood.

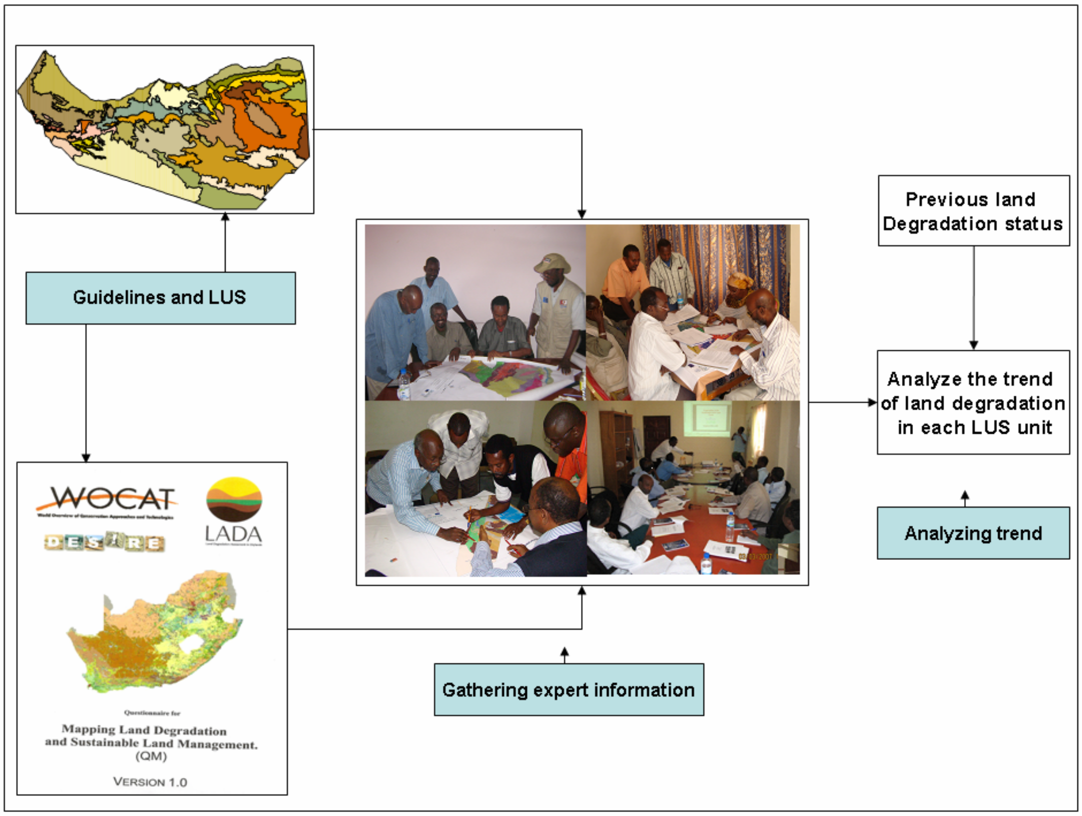


Figure 9.2: Monitoring trend of land degradation using expert opinion

9.1.2 Remote-sensing-based information for monitoring land degradation

Monitoring of land degradation using remote sensing information will principally involve the use of 250-m MODIS NDVI images. These images are downloadable from http://pekko.geog.umd.edu/usda/apps and are freely available for every 16 days. Six-month maximum NDVI from this data can be analyzed alongside rainfall data to determine six-month NDVI-rainfall relationship (Figure 5.3). Mixed-effects models developed by FAO-SWALIM (see section 3.2.2 of this report) can be used to analyze the NDVI-rainfall relationship. This relationship should be determined for every LUS unit to facilitate easy comparison with information from expert assessment. Once established, it will then be used to evaluate the NDVI residual (the difference between NDVI and rainfall predicted NDVI); which has been shown in this study to be a good indicator of land degradation. The trend of land degradation will then be determined from the augmented trend of residuals (which is a composite of the current residual added to the previous residuals trend). The residual trend developed in 2009 from the current study should be used as the starting point for further analysis of NDVI residuals trend.

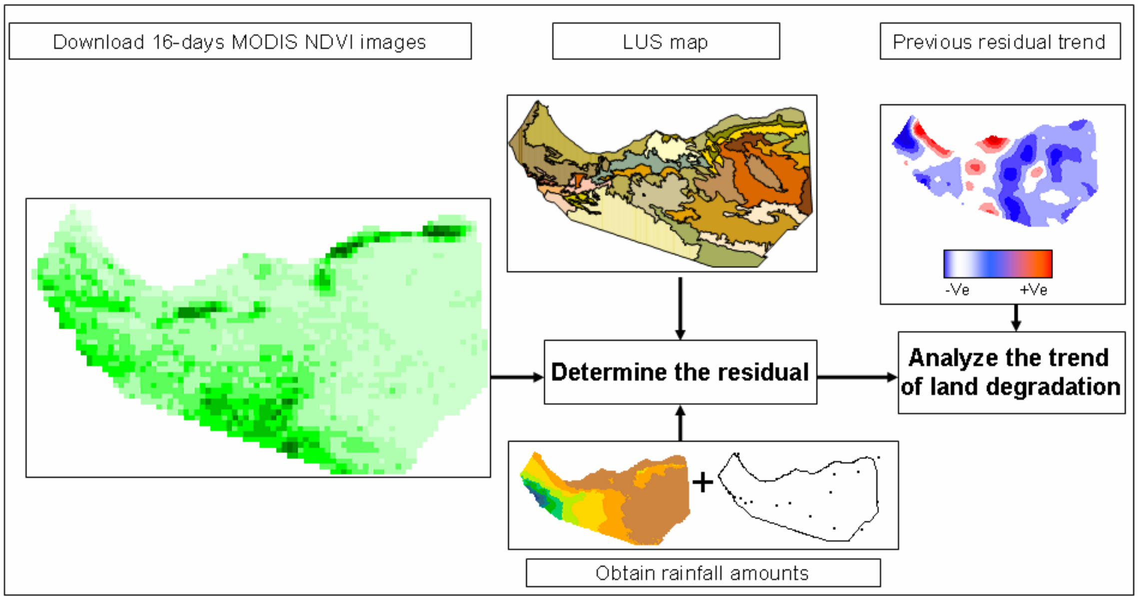


Figure 9.3: Monitoring trend of land degradation using remote sensing

9.1.3 Local measurements for monitoring land degradation

Local measurements for monitoring soil erosion will include:

1. Measuring loss of topsoil
2. Soil sampling for chemical properties
3. Measuring gully erosion
4. Recording loss of vegetation

FAO-SWALIM report No. L01 has described how these measurements can be done in the field. Figure 9.4 also shows how soil sampling for chemical analysis can be done.

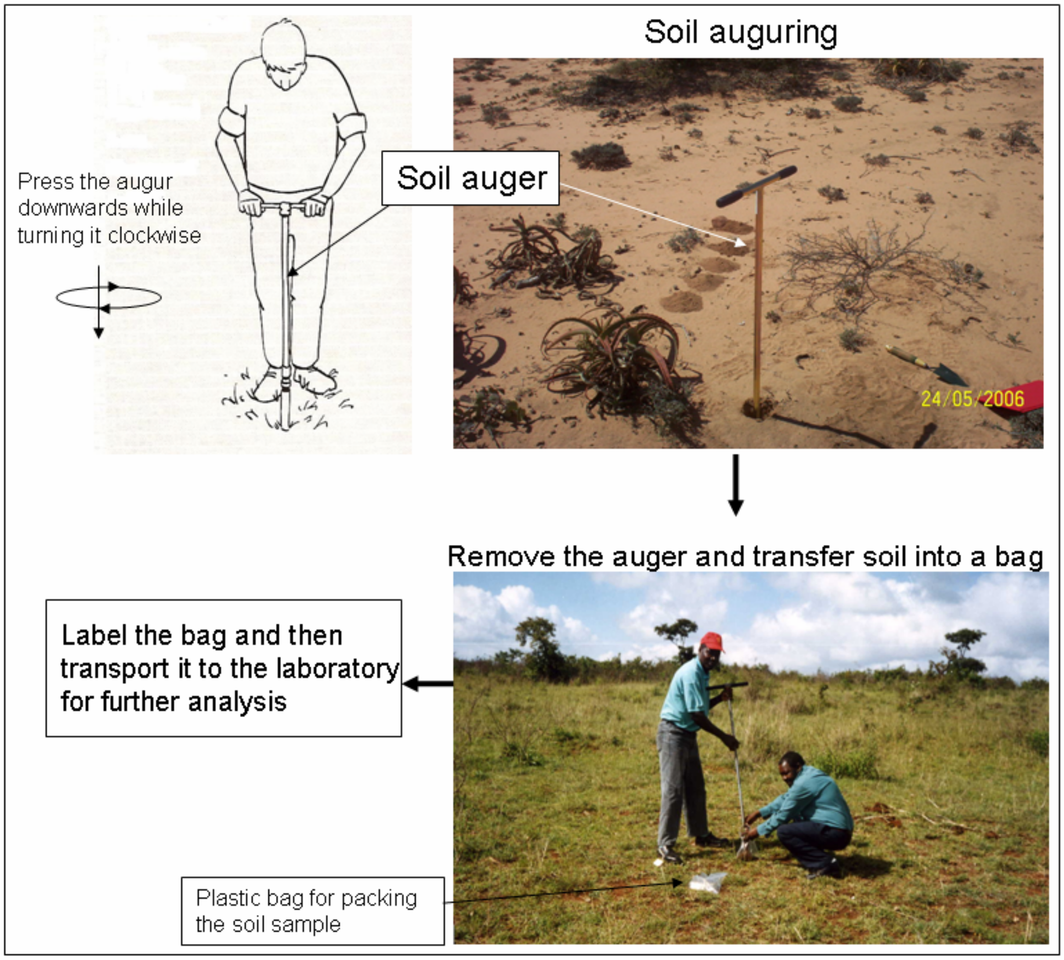


Figure 9.4: Soil sampling for nutrient content analysis.

9.1.4 Practical steps for implementing land degradation monitoring

Implementing a land degradation monitoring framework requires (Figure 9.5):

1. Suitable theoretical/technical guideline
2. Institutional support (policy environment, personnel, communication, etc)
3. Capacity building (training of personnel, equipment and software, financial)

This study has proposed a theoretical framework for monitoring land degradation based on expert knowledge and use of remote sensing. The framework will involve recurrent information gathering from these two sources (from between six months for remote sensing to one year for expert knowledge, see section 5.1 above). The information will then be used to monitor the national trend of land degradation so that appropriate action can be targeted to regions of the country experiencing rapid negative changes.

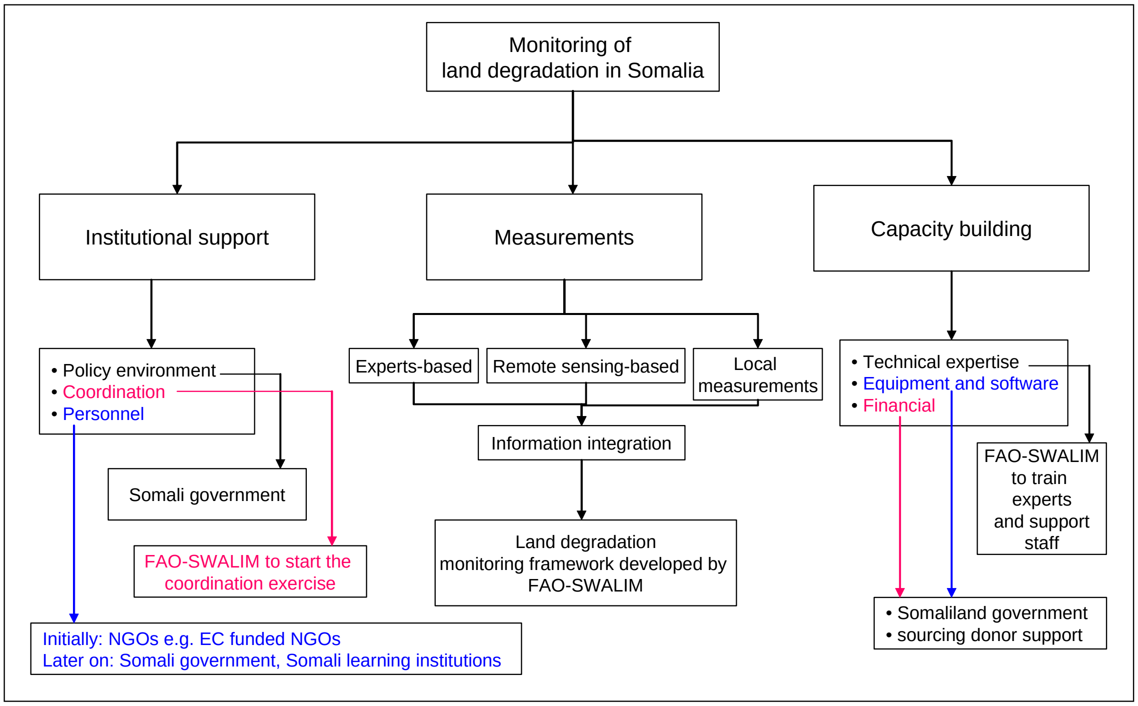


Figure 9.5: Practical steps towards implementing land degradation monitoring

In order to implement the proposed theoretical framework, there should be a strong institutional support. Institutional support in form of policy environment, government or non-governmental departments responsible for implementing the monitoring framework, and communication structures for flow of information (e.g. protocol for issue of directives, etc). The policy environment will involve strengthening the laws and act of parliament to enforce proper utilization of land resources, set up of responsible commissions, taskforces, or government departments to carry out land degradation assessment, monitoring and control, and to report their progress to policy makers.

Although the current situation in Somaliland is still developing with respect to institutional support, there are future promises envisaged especially in northwest and northeast of the country. Meanwhile, non-governmental organizations working in the country may still carry out the implementation of land degradation monitoring and put in place structure which will be inherited by future Somaliland government departments. This can be achieved, for example, through MoUs between NGOs funded by a common donor or consortium of donors. Through the MoU, the NGOs can undertake joint land degradation monitoring activities such as participating in giving expert information in sections of the country where they are actively involved or supporting field validation of remote sensing information about land degradation. Future Somali government departments will then pick from what the NGOs shall have done and continue with strengthening policies in respect to land degradation monitoring in the country.

Whichever the line of support for implementation of land degradation monitoring, a proper way of communicating ideas, networking with regional and global initiatives in the same discipline, and overall flow of information will also be necessary. In a way, this will involve some form of coordination which is an integral component of institutional support for implementing land degradation monitoring. FAO-SWALIM, who initiated the land degradation activities, can begin the coordination of land degradation activities amongst the organizations envisaged to participate in the exercise and later on hand over the exercise to the Somaliland government (Figure 9.5).

The other important factor to be considered in implementation of a national land degradation monitoring framework is the need for capacity building (Figure 5.4). Since the whole process will involve people of diverse disciplines and also personnel without sufficient background and equipment, it will be necessary that capacity building exercise be strongly emphasised. The exercise should be seen from three perspectives:

- technical training on the required steps
- financial support in carrying out the exercise
- equipment and software needed to synthesis information

The technical training of the personnel to be involved in the exercise will include:

- Training on LADA-WOCAT guidelines for expert assessment
- Training on acquiring and analysis of remote sensing images
- Training on reporting of land degradation monitoring outputs

FAO-SWALIM has already produced models for assessing land degradation. These models can be improved and routinely used in monitoring land degradation in the country. The computer programs produced for acquiring and analysing remote sensing images should be developed into training manuals for training future personnel who will be involved in land degradation exercises. With support from the existing Somali government and donor funding, FAO-SWALIM can initiate the initial steps land degradation monitoring steps and hand over the exercise to the future government.

9.1.4 Proposed timeline for implementing the monitoring framework

The above theoretical and practical steps have been integrated into a proposed timeline for initiating the land degradation monitoring framework in Somaliland. Table 5.1 shows the proposed tentative timeline. From the land degradation study in 2009, the process can be developed by first initiating a network with stakeholders, choosing the appropriate personnel, training, and carrying out the first monitoring activities (Table 9.1).

Table 9.1: proposed timeline for implementing land degradation monitoring in Somaliland

Duration	Activity	Institutions
-	Obtaining the baseline information (FAO-SWALIM report No. L14)	FAO-SWALIM, Somaliland government line ministries
6 months	Develop training manuals Develop training program for experts in consultation with Somali government	FAO-SWALIM

2 months	Establishing network with stakeholders (Somali government ministries, NGOs, UN agencies) Organize stakeholders workshop Select working groups and personnel responsible for monitoring and reporting land degradation activities	FAO-SWALIM, EC funded NGOs, UN Agencies, Learning institutions in Somaliland, Somaliland government line ministries, Local NGOs in Somaliland
3 months	Train the personnel on land degradation monitoring	FAO-SWALIM and selected contact persons for implementing the monitoring framework
1 month	Initiate the first land degradation monitoring exercise (monitoring exercise, updating of steps, and reporting) Put in place a plan for future periodic monitoring exercise	FAO-SWALIM and selected contact persons for implementing the monitoring framework, Somaliland government
-	Begin the monitoring activity	FAO-SWALIM and selected contact persons for implementing the monitoring framework, Somaliland government

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FAO-SWALIM Land reports series

L-01 Field Survey Manual *(FAO-SWALIM, 2007)*

L-02 Landform of selected areas in Somaliland and Southern Somalia

(Paron, P. and Vargas, R.R., 2007)

L-03 Land cover of selected areas in Somaliland and Southern Somalia

(Monaci, L., Downie, M. and Oduori, S.M., 2007)

L-04 Land use characterization of a selected study area in Somaliland

(Oduori, S.M., Vargas, R.R. and Alim, M.S., 2007)

L-05 Soil survey of a selected study area in Somaliland

(Vargas, R.R. and Alim, M.S., 2007)

L-06 Land suitability assessment of a selected study area in Somaliland

(Venema, J.H. and Vargas, R.R., 2007)

L-07 Land use characterization of the Juba and Shabelle riverine areas in Southern Somalia *(Oduori, S.M., Vargas, R.R. and Alim, M.S., 2007)*

L-08 Soil survey of the Juba and Shabelle riverine areas in Southern Somalia

(Vargas, R.R. and Alim, M.S., 2007)

L-09 Land suitability assessment of the Juba and Shabelle riverine areas in Southern Somalia *(Venema, J.H. and Vargas, R.R., 2007)*

L-10 Land degradation assessment and recommendation for a monitoring framework in Somaliland

(Vargas, R. R., Omuto, C.T., Alim, M.S., Ismail, A., Njeru, 2009)

L-11 Application of remote sensing techniques for the assessment of pastoral resources in Puntland, Somalia *(Oroda, A. and Oduori, S.M.)*

L-12 Land resources assessment of Somalia *(Venema, J.H., 2007)*

L-13 Land use planning guidelines for Somaliland

(Venema, J.H., Alim, M., Vargas, R.R., Oduori, S and Ismail, A. 2009)

L-14. Land degradation assessment and a monitoring framework in Somalia

(*Omuto, C.T., Vargas, R. R., Alim, M.S., Ismail, A., Osman, A., Iman. H.M. 2009*)

APPENDICES

Appendix 1. Example of filled questionnaire for national assessment of land degradation in Somaliland

DATA ENTRY TABLE

Please fill out one table for each mapping unit! Make copies of this table as required to fill in information for other mapping units..

Name: Abdirisak Bashir **Country:** Somaliland

Group 3

Mapping Unit Id: 19 -> 23

Land Use System (Step 2)		
LUS	a) Area trend	b) Intensity trend
pastoralism (high density) with scattered irrigated farms: shoats camels, cattle	-1	-1

Land degradation (Step 3)								
a) Type *i*	*ii*	*iii*	b) Extent	c) Degree	d) Rate	g) Direct causes	f) Indirect causes	e) Impact on ESS
Bc			40%	2	2	g1, e1, s2	P, h, e, g	P1-2, S4-2, E2-2
Et			40%	2	2	e1, g1	P, h, e, g	P1-2, E8-2, S4-2
Ha	Wt		15%	2	2	g3, e1, n6	P, h, r	P1-2, P2-2, E4-2, S4-2

Appendix 2. List of participants for expert assessment of land degradation

EXPERT NAME	INSTITUTION	EMAIL ADDRESS
Sadia Ahmed Musse	PENHA-INGO	Penhasld@yahoo.co.uk
Ahmed Jama Sugule	Min. Pastoral & Environment, Somaliland	Kori-bustard@hotmail.com
Ismail Mohamed Mohamoud	SECDO (LNGO)	jarafleh@hotmail.com
Mohamed Liban Ismail	Min of Agriculture, Somaliland	
Hassan Hirsi Farah	Consultant	hassanjv@hotamil.co m
Ali Ahmed Olhaye	Former IFAD/UNOPS	aliolhaye12@hotmail.com
Mohamed (Abshir) Migane	SPSDRA-LNGO	spsdra@gmail.com
Abdillahi Mohamed	GAA-INGO	ami.daaus@gmail.com
Abdulkadir M. Gafane	GAA-INGO	gaa.awdal@gmail.com
Mohamoud Egeh	Amoud University, Borama	megeh@hotmail.com
Abdirazak Bashir Liban	Candle light-LNGO	abdirizaklibah127@hotmail.com
Hassan Jama	UNDP, Hargeisa	hassan.jama@undp.org
Mohmaed Ali	Min. Water & Mineral Resources, Somaliland	Karaamo99@hotmail.com
Omer Haji Duale	Consultant	
Facilitators		
Ali Ismail Ibrahim	FAO/SWALIM Liaison Officer Somaliland	alikoos2002@yahoo.com
Hussein Moalim Iman	FAO/SWALIM Liaison Officer Southern Somalia	husseinimaan@yahoo.com

Appendix 3. Analytical methods for assessing land degradation

Appendix 3.1 Modelling NDVI-rainfall relationship

The relationship between NDVI and rainfall can be general written as,

$$\begin{aligned} &\mathbf{y} = f(\mathbf{x}, \phi) + \mathbf{e} \\ &e_i \sim N(0, \sigma^2), \qquad i = 1,2,\ldots n \end{aligned} \tag{1}$$

where **y** is a vector of NDVI, **x** is a vector of rainfall amounts, **e** is a vector of the residuals which represents the difference between actual and predicted NDVI, σ is the standard error of the residuals, *n* is the number of observations, and *f* is a statistical model for the NDVI-rainfall relationship with ϕ fitting parameters. *f* can be linear or non-linear in its fitting parameters and its parameters determined using likelihood function,

$$L(\mathbf{y} \mid \varphi, \sigma^2) = \prod_{i=1}^{n} \left[\frac{1}{\sigma\sqrt{2\pi}} \exp\left(\frac{\left(\mathbf{y}_i - f(\mathbf{x}_i, \phi)\right)^2}{-2\sigma^2} \right) \right] \tag{2}$$

where *L* is the likelihood function.

The estimated parameters from Equation (2) contain terms related to the rate of NDVI response to rainfall (or the slope of the curve) and the minimum NDVI during dry spells (also related to the NDVI intercept of the curve). In dryland ecosystems, it is common to find different vegetation types with different NDVI signals during dry periods and varied rates of response to rainfall. Their NDVI-rainfall relationship cannot be adequately represented by an average curve. Therefore, the only realistic NDVI-rainfall model for them should be a family of curves to take care of their varying responses. A single curve, such as is in the current application, is therefore not adequate in representing the true NDVI-rainfall relationship and consequently is not able to accurately remove climatic effects in NDVI images. Mixed-effects modelling is a reliable method for modelling the family of curves. Its modelling formulation of NDVI-rainfall relationship is written generally as,

$$\begin{aligned} &\mathbf{y}_i = f_i(\mathbf{x}, \boldsymbol{\varphi}) + \mathbf{e}_i \\ &\boldsymbol{\varphi}_i = \mathbf{D} * \boldsymbol{\beta} + \mathbf{B} * \mathbf{b}_i \qquad\qquad i = 1, 2, \ldots, m \qquad\qquad (3) \\ &\mathbf{b}_i \sim N(0, \boldsymbol{\psi}), \quad e_i \sim N(0, \sigma^2) \end{aligned}$$

where **y** is a vector of NDVI, **x** is a vector of rainfall, *m* is the number of groups of individuals (e.g. vegetation types) in the population, β is a vector of population average parameters (also known as fixed-effects), **b** is a vector of random variations of the fitting parameters for the groups of individuals around the population averages (also known as random-effects), **D** and **B** are design matrices for solving Equation (3), and ψ is a variance-covariance matrix for the random-effects. The random-effects, which are associated with grouping of individual units in the population, provide the opportunity for including the influence of vegetation types into modelling NDVI-rainfall relationship.

The solution for Equation (3) comprises of φ parameters vector, parameters of the ψ variance-covariance matrix, and the residual variance σ^2. These parameters can be obtained by solving the likelihood function in Equation (2). However, since the random-effects are non-observed data the likelihood function is best solved using marginal densities as shown in Equation (4).

$$L[\mathrm{y} \mid \varphi, \psi, \sigma^2] = \prod_{j=1}^{n_i} \left[p\left(\mathrm{y}_j \mid \varphi, \sigma^2\right) * p\left(\mathrm{b}_i \mid \psi\right) \right] \tag{4}$$

where n_i is the number of observations in each group of individuals, $p(\mathbf{y}|\varphi, \psi, \sigma^2)$ is the marginal density of **y**, $p(\mathbf{y}|\varphi, \sigma^2)$ is the conditional density of **y** given the random-effects $\mathbf{b}_i$, and $p(\mathbf{b}_i|\psi)$ is the marginal distribution of the random-effects.

After proper accounting for climatic variations in the NDVI signals using Equation (1) or (3), the remaining residual variance contains human-induced variation and modelling errors. Assuming that modelling errors are constant over time, a regression line between the residuals vector **e** and time can be used to identify human-induced variations. This is done as follows,

$$e_j(t_i) = v * t_i + c \tag{5}$$

where $e_j(t)$ is the residual in pixel j at time t_i, v is the slope, and c is the intercept of the regression model between time and the residuals $e(t)$. In Equation (5), if human-induced variations have caused loss of vegetation cover over the time, the slope v would have a negative sign. Conversely, the slope is positive for improvements in vegetation cover over the time. This implies that that the slope c can be used to identify human-induced loss of vegetation cover.

Appendix 3.2 Mixed-effects modelling results of NDVI-rainfall relationship in Somalia and comparison with a global model

$NDVI_{max}$ -rainfall relationship was modelled with an exponential function because of the exponential trend between *$NDVI_{max}$* and *rainfall* for Somalia. Equation (6) gives the mixed-effects modelling formulation for this exponential relationship.

$$y_{ij} = (\beta_1 + b_{1i}) * \exp[(\beta_2 + b_{2i}) * x_j] + e_{ij} \qquad i = 1, 2, \ldots, 38 \text{ and } j = 1, 2, \ldots, 279220 \qquad (6)$$

where y represent *$NDVI_{max}$*, x is the *rainfall*, β represent fixed-effect, b_i are the random-effects for vegetation types, j are pixels in the *NDVI* image, and i represent vegetation class in the land cover map. There were 38 vegetation classes in the land cover map (Table A1).

Equation (6) had two fixed-effect parameters for the exponential function: β_1 for average intercept and β_2 for average slope. The average intercept was related to minimum NDVI during dry periods and the average slope was related to the rate of NDVI response to rainfall in the whole country. The random-effects in Equation (6) represented the difference between the fixed-effects and slope or intercept of *$NDVI_{max}$-rainfall* relationship for each vegetation class. They were either negative or positive with respect to the fixed-effects; being negative if the *$NDVI_{max}$-rainfall* model for a given vegetation class was lower than the average *$NDVI_{max}$-rainfall* relationship or positive if the model for the vegetation class was above the average model for the whole country. The overall variation for the random-effects was described using the ψ variance-covariance matrix given by,

$$\psi = \begin{array}{cc} & \begin{array}{ccc} b_1 & b_2 & \sigma \end{array} \\ \begin{array}{c} b_1 \\ b_2 \\ \sigma \end{array} & \begin{bmatrix} 1 & r_{12}^2 & \sigma_{b1}^2 \\ & 1 & \sigma_{b2}^2 \\ & & \sigma^2 \end{bmatrix} \end{array} \tag{7}$$

where σ_b^2 is the variance of the random-effect, r^2 is the covariance between the random-effects, and σ is the residual standard error (RSE). A general positive-definite structure for this matrix was used in solving Equation (6). The general positive-definite structure was used since the number of vegetation classes (m = 38) was larger than the number of parameters in the variance-covariance matrix (w = 4). General positive-definite structures for variance-covariance matrix are best suited for cases where the number of parameters in the matrix is less than the total number of cases for the random-effects.

Table A1: Summary of land-cover classes and vegetation types in Somalia

Class	Description of land cover and vegetation types*
1	Continuous closed to very open grass and forbs
2	Closed to very open grass and forbs mixed with trees and shrubs
3	Closed to very open grass and forbs mixed with shrubs
4	Park-like patches of sparse (20- 4%) grass and forbs
5	Continuous closed medium to high shrubland (thicket)
6	Medium to high thicket with emergents
7	Continuous closed dwarf shrubland (thicket)
8	(70 - 40%) medium to high shrubland with open medium to tall forbs and emergents
9	Shrubland with grass and forbs
10	Sparse shrubs and sparse grass and forbs
11	(40 - 10%) shrubland mixed with grass and forbs
12	(40 -10%) medium to high shrubland with medium to tall forbs and emergents
13	Broadleaved deciduous forest with shrubs
14	Broadleaved deciduous (70- 40%) woodland with open grass layer and sparse shrubs
15	Broadleaved deciduous (70- 40%) woodland with shrubs
16	Needle-leaf evergreen woodland (mostly juniperus trees)
17	Woodland mixed with shrubs
18	Broadleaved deciduous trees mixed with sparse low trees
19	Broadleaved deciduous (40 - 10%) woodland with grass layer and sparse shrubs
20	Broadleaved deciduous (40 - 10%) woodland with shrubs
21	Broadleaved deciduous closed woody vegetation with medium high emergents
22	Open woody vegetation with grass layer
23	Closed to open grass and forbs on permanently flooded land
24	Closed grass and forbs on temporarily flooded land
25	Open medium to tall forbs on temporarily flooded land
26	Broadleaved evergreen forest on permanently flooded land (brackish water quality)
27	Open woody vegetation with grass and forbs on temporarily flooded land (fresh water quality)
28	Urban area(s)
29	Loose and shifting sands
30	Bare rock(s)
31	Bare soil and/or other unconsolidated material(s)
32	Non-perennial natural flowing water bodies
33	Perennial natural standing water bodies
34	Tidal area (surface aspect: sand)
35	Permanently cropped area with surface irrigated herbaceous crop(s)
36	Small sized field(s) of rainfed herbaceous crop(s)
37	Permanently cropped area with small sized field(s) of surface irrigated herbaceous crop(s)
38	Continuous large to medium sized field(s) of tree crop(s). dominant crops: fruits, nuts, date palm

*Descriptions were done by AFRICOVER (www.africover.org)

The likelihood function for Equation (6) was solved in R computing environment using Gauss-Newton algorithm for the penalized least-squares in Equation (7) [16]. Table A2 shows typical results from the mixed-effects model. The model used seven parameters to model *$NDVI_{max}$-rainfall* relationship: two parameters for the fixed-effects, four parameters for the variance-covariance matrix, and one parameter for the residuals (Table A2). This number of parameters was a compromise between two parameters (in the case of a global model in Equation (8)) and 80 parameters (in the case of a separate model for each vegetation class in the entire study area). Thus, mixed-effects approach portrayed a more parsimonious model than the other regression modelling approaches.

$$\begin{aligned} &\mathbf{y} = f(\mathbf{x}, \boldsymbol{\phi}) + \mathbf{e} \\ &e_i \sim N(0, \sigma^2), \qquad i = 1,2,\ldots n \end{aligned} \tag{8}$$

where **y** is a vector of NDVI, **x** is a vector of rainfall amounts, **e** is a vector of the residuals which represents the difference between actual and predicted NDVI, σ is the standard error of the residuals, *n* is the number of observations, and *f* is a statistical model for the NDVI-rainfall relationship with ϕ fitting parameters.

Table A2: Summary of Mixed-effects modelling of NDVI-rainfall relationship for first half of 1983

Model Parameter	Random effects			Fixed-effects	
		Correlation matrix			
	Std. Deviation	intercept	slope	Estimate	Std. Error
Intercept	0.0183	1		0.076	0.00430
Slope	0.0002	-0.53	1	0.001	0.00003
Residual	0.0053				

The average standard errors for the fixed-effects were about 20% of the standard deviation for the random-effects (Table A2). This implies that a substantial amount of the variability in NDVI images occurred due signals from different vegetation types compared to climatic variations (Table A2). Mixed-effects modelling accounted for this variability through random-effects in the NDVI-rainfall modelling process. Suppose the influence of vegetation types was not considered, RSE would have been higher than 0.0053 and which would have caused low accuracy in accounting for the interaction between vegetation and climate.

Mixed-effects modelling also gave more information for assessing the modelling process and which were potential in eliminating modelling errors such as over-parameterization. For example, in Table A2, the low magnitude of slope random-effects suggests that the $NDVI_{max}$ response to *rainfall* did not vary so much between vegetation types. Experience in statistical modelling would want parameters with low random-variations to be treated as fixed-effects only in order to minimize over-parameterization problems during modelling. Thus, attempts may be made to remove the slope parameter from the list of random-effects. This is done by remodelling Equation (6) as

$$y_{ij} = (\beta_1 + b_{1i}) * \exp[\beta_2 * x_j] + e_{ij} \quad = 1, 2, \ldots, 38 \text{ and } j = 1, 2, \ldots, 2792 \qquad (9)$$

It is important to note how the random-effects b_i has been removed from the slope parameter β_2 in Equation (9). The results for this model were compared to the outputs of Equation (9) using Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). The comparison results showed that AIC for Equation (6) was -6018 and BIC = -5985 while AIC for Equation (9) was -5917 and BIC = -5895. Low AIC and BIC favoured Equation (6) in modelling $NDVI_{max}$-*r*ainfall relationship for Somalia. The two models were also significantly different ($p < 0.0001$ at 5% level of significance), which indicated that the slope random-effect was indeed significantly different between the vegetation types. This analysis not only shows the excellent modelling abilities of mixed-effects but also important revelations such as the fact that $NDVI_{max}$ response to *rainfall* is significantly different between different types of vegetation in Somalia.

While accounting for vegetation effect in NDVI-rainfall relationship, the random-effects also identified unique $NDVI_{max}$ response to rainfall for different vegetation types (Figure A1). For example, in 2006 the vegetation in land cover classes 2 and 14 had negative intercept random-effects; which imply that they had low $NDVI_{max}$ signal during dry periods. Since the year 2006 was not a dry year, low $NDVI_{max}$ signal by these vegetation classes was most likely not due to rainfall deficiency. There was a large difference between the intercept random-effects for land cover class 15 and

14 in spite of almost similar vegetation types in these two classes (Table A1). They two land cover classes were also located adjacent to each in southern Somalia; which eliminated differences in soil types as the possible cause of the difference in their NDVI signals. Perhaps the first signal of human-induced loss of vegetation cover could be suspected at this modelling level using the difference in their random-effects. Class 14 vegetation types were mainly found in small pockets between Borama and Hargeisa and near the southern tip of the country while class 2 were found around Belet Weyne and between Eyl and Galckayo.

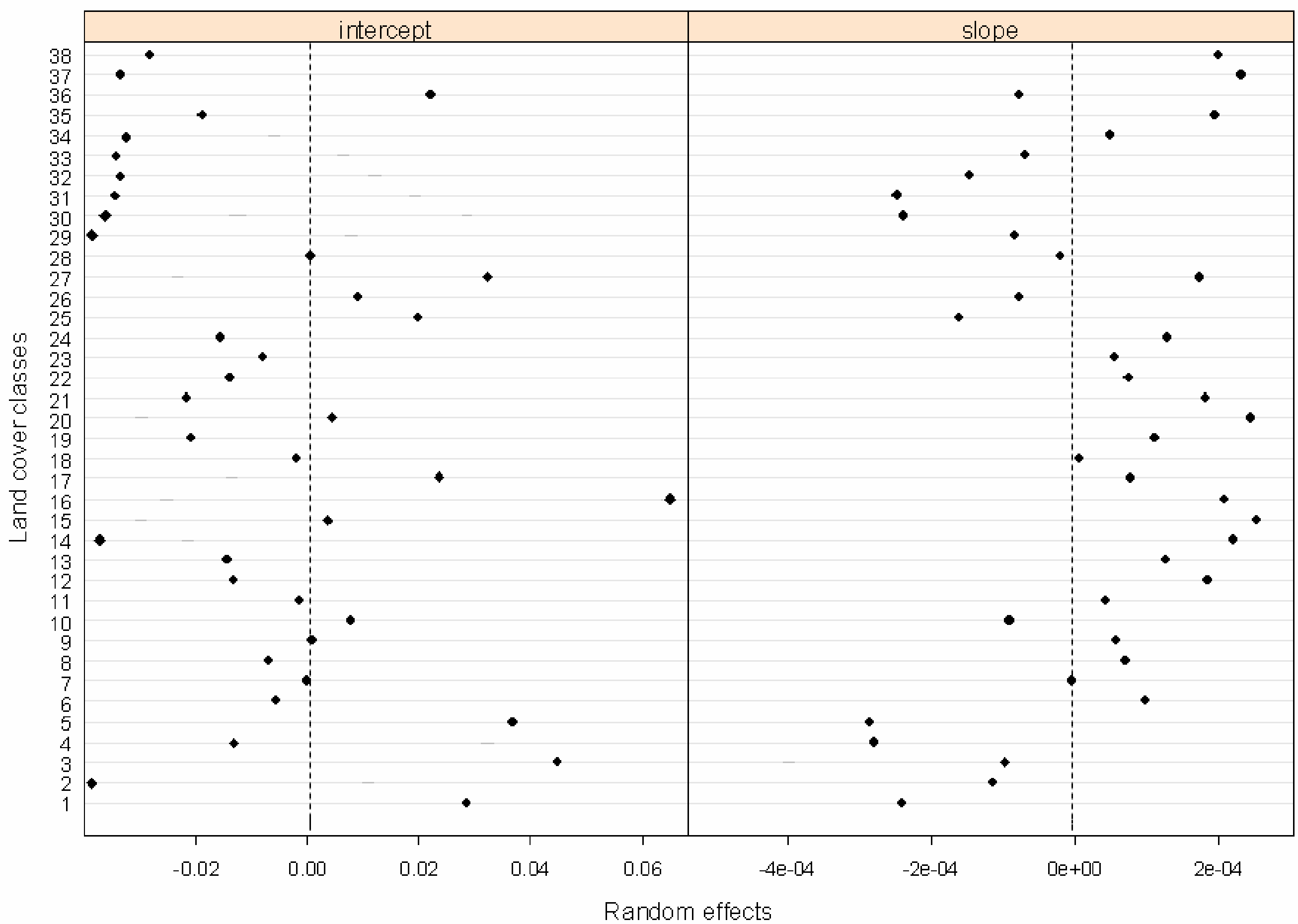


Figure A1: Typical plot of random-effects for different land cover types in Somalia

The above results show that mixed-effects was not only capable of incorporating vegetation types in the modelling NDVI-rainfall relationship but also a robust and informative modelling method compared to other regression models. It can identify varied vegetation response characteristics to rainfall and give an advance insight of the potential areas and vegetation types experiencing human-induced loss of vegetation cover.

Comparison with a global model

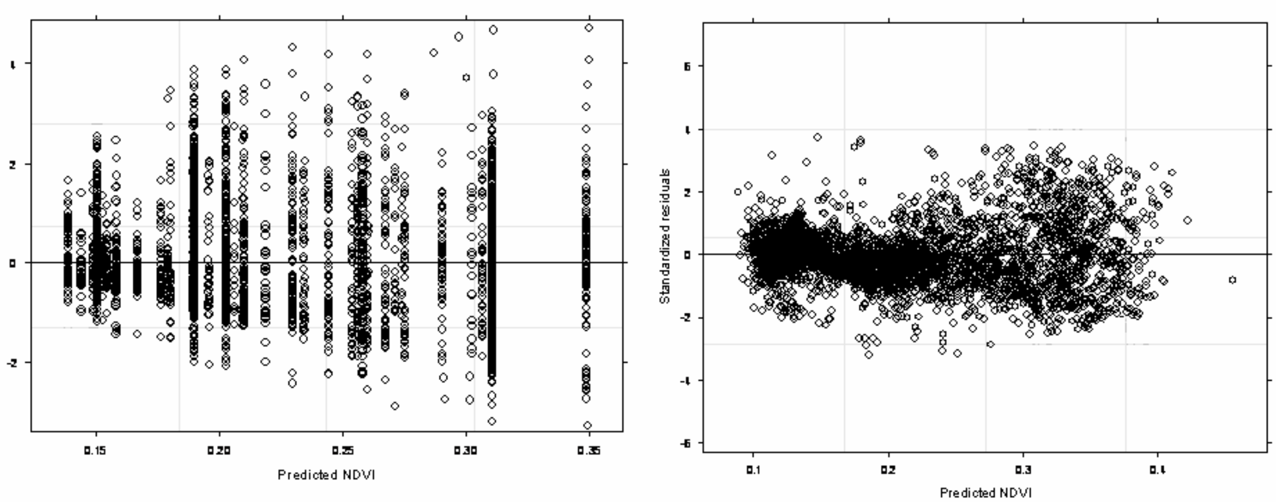
Mixed-effects model produced the best unbiased linear relationship between $NDVI_{max}$ and *rainfall* (Table A3). It had low residual standard error (RSE) and high correlation between predicted and measured values compared to the global model. On average, its residual standard errors were about half the residual standard errors of the global model; which indicated that it accounted for more variability in NDVI images than the global model.

Table A3: Summary of NDVI-rainfall modelling outputs for mixed-effects and global models

	Mixed-effects model		Global model	
Year	RSE*	r^2	RSE	r^2
1982	0.0077	0.63	0.134	0.41
1983	0.0052	0.79	0.102	0.54
1984	0.0044	0.92	0.092	0.53
1985	0.0058	0.81	0.117	0.60
1986	0.0052	0.84	0.117	0.46
1987	0.0059	0.62	0.099	0.42
1988	0.0048	0.94	0.098	0.32
1989	0.0052	0.72	0.101	0.52
1990	0.0073	0.76	0.125	0.55
2003	0.0051	0.88	0.120	0.60
2004	0.0076	0.66	0.129	0.56
2005	0.0062	0.67	0.141	0.29
2006	0.0069	0.67	0.116	0.59
2007	0.0083	0.62	0.141	0.52

*RSE-Residual standard error

Apart from the lower performance of the global model than the mixed-effects model, the global model also violated its modelling assumptions. Its residuals were negatively skewed and increased with predicted $NDVI_{max}$ (Figure A2a). Mixed-effects approach, however, did not violate its modelling assumptions. Its time-series residuals were zero-centred and had constant variances (Figure A2b). Analysis of its prediction also revealed a uniform correlation with actual values throughout the whole range of observed $NDVI_{max}$. This uniform prediction implies that the model reliably predicted NDVI response to rainfall for all vegetation types in the entire study area. The global model poorly predicted high $NDVI_{max}$ and gave the impression that its results were uncertain for wet areas or densely vegetated areas.



(a) Standardized residuals and global model predicted NDVI

(b) Standardized residuals and mixed-effects predicted NDVI

Figure A2: Plots of standardized residuals and predicted NDVI for assessing modelling assumptions

Appendix 3.3 RUSLE factors estimation

Loss of topsoil risk factors includes climate, soil type, land cover, topography, and land use practises to control soil loss. The Revised Universal Soil Loss (RUSLE) model combines these factors to predict the risk of annual soil loss. The model, which is also amenable with GIS is given in Equation (6).

$$E_{RUSLE} = R * K * LSt * C * P \tag{6}$$

where E_{RUSLE} is the RUSLE estimate of the risk of soil loss in tons ha^{-1}yr^{-1}, R is the climate factor and is known as rainfall erosivity (in MJ mm ha^{-1} hr^{-1} yr^{-1}), K is the soil factor known as erodibility (in tons ha hr ha^{-1} MJ^{-1} mm^{-1}), C is the index of land cover factor, and P is the support practise factor.

Erosivity was determined using the model

$$R = 0.029 * \left(3.96 * (\sum_{i=1}^{12} P_i) + 3122 \right) - 26 \tag{7}$$

where P_i is the mean monthly rainfall amounts (in mm) for month i and R is erosivity in MJ mm ha^{-1} hr^{-1} yr^{-1}. The input P_i in Equation (7) was obtained from the spatially interpolated mean monthly rainfall amounts.

The soil factor (K) was determined using the model

$$Erodibility = 0.0035 + 0.00388 * \exp\left[-0.5 * \frac{(\log D_g + 1.519)^2}{0.57517} \right] \tag{8}$$

where D_g is mean soil particle diameter and which is estimated by

$$D_g = \exp\left[\sum_i 0.01 * f_i * \ln\sqrt{d_{i1} d_{i2}}\right] \tag{9}$$

where f_i is the particle fraction in percent, d_1 is the maximum diameter (mm) of the soil fraction, and d_2 is the minimum diameter (mm) of the soil fraction. The inputs for this determining K included f_i from interpolated soil textural fractions, d_1 taken as 2 mm for sand, 0.05 mm for silt, and 0.002 mm for clay, and d_2 taken as 0.05 mm for sand, 0.002 mm for silt, and 0.0005 mm for clay.

The slope-length factor (*LSt*) was determined by

$$L = \frac{\left(A_{in} + pixel^2\right)^{m+1} - A_{in}^{m+1}}{pixel^{m+2} * (|\sin\alpha| + |\cos\alpha|)^m * (22.13)^m} \tag{9}$$

where A_{in} is the drainage contributing area at the inlet of a grid for which L is being estimated, *pixel* is the DEM grid resolution, α is the flow direction within the grid, and m is the exponent that addresses the ratio of rill-to-interrill soil loss. The value of m was taken as 0.4 for slope angle $St > 3^\circ$, 0.3 for $2^\circ < St \le 3^\circ$, 0.2 for $1^\circ < St \le 2^\circ$, and 0.1 for $St \le 1^\circ$. The slope St and L were combined to produce *LSt* factor using

$$LSt = \left(\frac{L}{22.13}\right)^m \left(0.065 + 4.56 * \sin St + 65.41 * \sin^2 St\right) \tag{10}$$

where *St* is in degrees and *m* is obtained as in Equation (9).

The land cover factor (*C*) was determined by

$$C = \exp\left(-\alpha * \frac{NDVI}{\beta - NDVI}\right) \tag{11}$$

where α and β are constants. van Der Kniff *et al*. (1999) suggested values of β as 1 and α as 2.

The land use practise factor (*P*) was developed from a monograph by Wischmeier and Smith (1978) according to land use types.

Appendix 4: Photographs of land degradation problems in Somaliland

Loss of vegetation

..due to charcoal production

..and overgrazing

Soil erosion

..due to urbanization

..and also due to no cover

Nutrient decline

..due to lack of nutrient management

..and poor tillage practises

Appendix 5: Photographs of responses to land degradation in Somaliland

Agroforestry program by BVO

Controlled grazing by the community

Stone gabions by IFAD

Runoff water harvesting

Small scale irrigation in river valleys

Emigration

Appendix 6: Description of land use systems

Land Use Systems for Somalia

Land Use System Code	Land Cover	Climate	Region / District	Landform / Soil	Livelihood	Land Degradation problem	Soil and Water Conservation
2	Rainfed Crop Fields/Irrigated fields/Shrubland	Semiarid with relatively high rainfall	Waqooyi Galbeed	Plateau with deep good soils	Agro-pastoralism (high density of small scale rainfed fields growing sorghum maize); farming is integrated with livestock rearing of shoats and cattle		
6	Woodland/ Rainfed Crop Fields	Semiarid	Waqooyi Galbeed, Hiiraan, Bakool/ Hargeisa district	pediment, shallow to deep of relatively good soils	Agro-pastoralism (low density of rainfed fields with some irrigated fields around togas; vegetables and fruits; shoats		
		Semiarid	Awadal/ Boorama and Baki districts	pediment, shallow to deep of relatively good soils	Agro-pastoralism (medium density of rainfed fields with some irrigated fields around togas: vegetables, fruits, shoats		
7	Woodland/Rainfed Crop Fields	Semiarid with relatively good rainfall	Waqooyi Galbeed region/ Hargeisa and Faraweyne districts	Dissected Plateau	Agro-pastoralism (medium density of rainfed fields for sorghum production)/ wood collection; livestock keeping: shoats & cattle		Some soil and water conservation interventions
13	Shrubland/Rainfed Crop Fields/Irrigated fields	Semiarid with good rainfall	Awdal and Waqooyi Galbeed/ Boorama and Gabiley districts	Dissected plateau, fertile soils	Agro-pastoralism (medium density of rainfed fields growing sorghum & maize ; holding a small number of shoats and cattle		
14	Shrubland	Semiarid	Sanaag to Bari region/ Cergaabo, Laasqoray and Boosaaso districts	southern escarpment of Golis Mountains	Agro-pastoralism (medium density of rainfed sorghum, fields with sparse irrigated fields vegetables and fruit around togas; shoats		
17	Grassland	Arid low rainfall	Sanaag & west Bari regions/ Laasqoray, Cerigaabo, Boosaaso districts	Coastal plain and Sub-coastal footslope	Pastoralism (low density livestock/ goats; Oasis farming low density fields/ frankincense production		No conservation intervention
23	Shrubland	Arid	Togdheer and Sool regions/ Burco, Caynabo and Oodweyne districts	Alluvial Plain, loamy sand or sandy soils	Pastoralism (high density livestock of shoats, camels, cattle) with scattered small irrigated fields		
24	Sparse Vegetation	Arid low rainfall	Sool and Nugaal regions/ Caynabo, Xudun, Laascaanood and Garoowe districts	Nugaal Valley / mostly saline soils	Pastoralism (high density livestock of shoats, camels, horses) with scattered oasis farming:	Expanding semi-settled agro-pastoralism	
27	Woodland	Arid low rainfall	Waqooyi Galbeed and Togdheer regions/ Hargeisa, Oodweyne, Caynabo and Buuhoodle	Hawd Plateau, loamy sand to sandy soils	Pastoralism (high density livestock of camels, shoats)/ rainfed sorghum production, Scattered spate irrigation fields, wood and fodder collection	reduction of tree cover and increasing problems of overgrazing in rangelands	little intervention of soil and water conservation

31	Shrubland	Arid	Togdheer, Sool and Nugaal and Gedo regions/ Caynabo, Buuhoodle, Laascaanood, Garoowe, Buurtiinle, Jeriiban and Ceel-Waaq districts	Eastern part of Hawd plateau shallow, gravel and stony soils	Pastoralism (high density livestock of camels, shoats& cattle	Overgrazing and soil erosion by water	No soil and water conservation intervention

32	Grassland	Arid	Sanaag region/ Badhan district	Plain located south of Golis Mountain; Shallow soils with many sinkholes	Pastoralism (high density livestock sheep, goats, camels)		
	Sparse Vegetation	Arid	Sanaag and Sool region/ Ceelafweyn, and Xudun districts	hills south of Golis Mountain range/ shallow stony and rocky soils	Pastoralism (high density livestock of sheep, goats, camels)		
34	Shrubland	Semi-arid	Sanaag region/ Cerigaabo district	Golis Mountain range	Pastoralism (high density livestock of: shoats, camels, cattle	Reduction of vegetation cover	No conservation intervention

36	Shrubland	Extremely arid	Awdal/ Zeylac Lughaya; Waqooyi Galbeed/ Barbara; Togdheer region- Ceelafweyn	Coastal plains along Red Sea (called Guban)	Pastoralism (low density livestock/ shoats, camels)	Invasion of Prosopsis juliflora	No conservation intervention
38		Arid	Waqooyi Galbeed to Togdheer regions/ Barbara, Sheikh and Ceelafweyn districts	Hilly escarpment of Golis Mountain with stony and rocky soils	Pastoralism (low density livestock of shoats, camels); scattered irrigated fields around togas:		
39	Woodland/Rainfed Crop Fields	Semi-arid	Waqooyi Galbeed/ Awdal regions, from Zeylac to North Hargeisa	Golis Mountain, rocky terrain with intermittent streams and narrow valleys	Pastoralism (low density livestock/ shoats), scattered irrigated farming		No conservation intervention

47	Woodland	Semiarid	Sanaag/ North Cerigaabo and south Laasqoray	Golis Mountain range	Pastoralism (low density livestock goats and cattle), timber collection/ frankincense extraction/ Scattered irrigated fields		No conservation intervention
49	Shrubland	Arid with very low rainfall	Waqooyi Galbeed/ Berbera and Ceelafweyn districts; Bari/ Caluula district	Golis Mountain range/rocky and stony shallow soils	Pastoralism/ low density livestock mainly goats		No conservation intervention
51	Shrubland	Arid	Togdheer, Sanaag and Hiiraan regions/ Oodweyne, Sheikh, Ceelafweyn and Baladweyne districts	Southward piedmont of Golis Mountain, shallow stony and rocky soils	Pastoralism (low density livestock mainly shoats and camels		
52	Sparse Vegetation	Slightly arid	Waqooyi Galbeed/ south-eastern part of Hargeisa district	Ridged terrain with mainly stony soils	Pastoralism (low density livestock composed of shoats, camels & cattle)	Overgrazing and expanding private enclosures	No soil and water conservation intervention
55	Shrubland	Arid with low rainfall	Sool and Nugaal regions/ Laascaanood, Xudun, Taleex, Garoowe and Eyl districts	Escarpment on north and south of Nugaal Valley with saline, stony and rocky soils	Pastoralism (medium density livestock consisted of shoats, camels, horses) with scattered oasis farming	Overgrazing	No soil and water conservation intervention
60	Sparse Vegetation	Arid	Sanaag region/ Badhan; Bari region/ Boosaaso, Iskushuban districts	Dharoor valley/ shallow stony and rocky soils	Pastoralism (medium density livestock of shoats, camels and cattle)/ scattered Oasis farming:	soil erosion by water, reduction of vegetation cover	No conservation intervention

63	Woodland	Slightly semiarid	Sanaag, Galgaduud and Hiiraan regions/ Ceelafweyn, Badhan, Matabaan, Baladweyne,Buu lobarde districts	south of Golis Mountain on Sool plateau with shallow to deep loamy sand soils	Pastoralism (medium density livestock of camels, shoats); wood collection	Reduction of vegetation cover; soil erosion by water	Some soil and water conservation activity implemented
			Waqooyi Galbeed / north of Hargeisa	Golis Mountain/ shallow stony soils	Pastoralism (medium density livestock of camels, shoats)/ wood collection		
65	Shrubland	Arid	Sanaag to Bari regions/ Badhan, Dhahar, Iskushuban, Bandarbeyla	South of Karkaar Mountain	Pastoralism (medium density livestock of shoats, camels, cattle		
			Togdheer, Sool, Sanaag and Bari and Mudug regions/ Sheikh, Burco, Dhahar, Caynabo, Qardho and Iskushuban, Jeriiban and Hobyo districts	South escarpment of Golis Mountain and eastern Karkaar Mountain and sub-coastal zone; Stony and rocky or sandy soils in Mudug	Pastoralism (medium density livestock of shoats, camels & cattle)		
70	Urban Area				High Concentration of buildings and infrastructure in urban settlements; high population density and many economic activities; little or proper water supply; new settlements and IDPs camps	Sewage and proper supply systems; spatial distribution; lack of proper planning	

ANNEXES

Annex 1. Concept note for assessment of land degradation in Somaliland

LAND DEGRADATION ASSESSMENT AND MONITORING FRAMEWORK FOR SOMALIA

Concept Paper

BACKGROUND

Land Degradation implies the reduction of land resource potential by one or a combination of processes such as water or wind erosion, sedimentation, long-term reduction in the amount or diversity of natural vegetation, and salinization and sodication (UNEP, 1992). Land degradation can be defined as the reduction in the capacity of the land to perform ecosystem functions and services (including those of agro-ecosystems and urban systems) that support society and development (LADA, 2005).

Somalia is a country where many different land degradation types are present at various extents and severity levels. There is evidence of rangeland degradation as a result of strife and insecurity, however the scale and extent has not been properly validated (IUCN, 2006). Rangeland degradation affects certain parts of the country, particularly those close to urban areas, and areas such as the Sool plateau. This is exacerbated by prolonged droughts, insecurity and charcoal trade, which cause localized degradation. Some preliminary studies have found certain parts of the country to be seriously degraded (as much as 50%) owing to steep slopes, large numbers of livestock, and proximity to ports for livestock export (World Bank, 1987; Oduori et al., 2006).

Currently, there is a lack of technical information regarding land degradation processes in the country in good detail to guide intervention measures. This study intends to establish a framework for the assessment and monitoring of land degradation in the country at national and local levels.

OBJECTIVES

To design a framework for assessing and monitoring land degradation in Somalia based on pilot studies in different parts of the country (Somaliland, Puntland, Juba and Shabelle riverine areas in the south and central Somalia).

METHODOLOGY

Two steps will be used to understand land degradation process in the country and to provide basis for designing its monitoring framework. The first step will consist of a national assessment using available low-resolution data (as a basis for identifying local spots to guide comprehensive assessment). The principle methodology for this assessment will be a combination of GLADA approach and the use of LADA/WOCAT Questionnaires for the national level (Bai and Dent, 2008; FAO, 2007). The second step will involve semi-detailed local assessment in three pilot areas in the country (Somaliland, Puntland, Juba and Shabelle riverine). A combination of tools and the LADA-WOCAT national/local level approach will be adopted for this step (FAO, 2007).

National land degradation assessment

Available Data:

- Landform map produced by SWALIM (NOAI –Somaliland and SAOI-Juba and Shabelle riverine areas). Data gaps at the national scale will be filled with 1:350 000 data produced by AFRICOVER.
- Land cover map produced by SWALIM (NOAI –Somaliland and SAOI-Juba and Shabelle riverine areas). Data gaps at the national scale will be filled with 1:200 000 data produced by AFRICOVER.
- Soil map from SOTER and SWALIM soil maps (NOAI –Somaliland and SAOI-Juba and Shabelle riverine areas).
- Length of Growing Period (LGP) map produced by SWALIM and the global dataset for Somalia.
- Climate maps produced by SWALIM and available global datasets (to be provided by LADA).
- Agro-ecological zones (AEZ) map for Somalia produced by SWALIM.
- Available Normalized Differential Vegetation Index (NDVI) and NPP images from remote sensing (8 km AVHRR images).
- Global livestock density (to be provided by LADA); data from the Food Security Analysis Unit (FSAU).
- Global map for rural/urban population (to be provided by LADA); this map will possibly be updated using data from UNDP and FSAU.

Activities

- Maps of Agro-ecological Zones (AEZ), present land use and available socio-economic attributes (livelihood zones from FSAU) will be used to define and map Land Use Systems. The F-CAM approach will be used for this exercise (George and Petri, 2006).

- NDVI indicators, rainfall, and soil moisture maps will be used as proxy indicators of human induced land degradation (for producing hot and bright spots). The GLADA approach will be used for this activity (Bai and Dent, 2008).

- Validation of the GLADA output will be done through a participatory assessment using the LADA/WOCAT National level methodology.

Local land degradation assessment

Somaliland

<u>Available Data:</u>

- Land resources baseline data (soils, landform, land use, land cover, climate maps, etc).
- Land suitability and land degradation maps from SWALIM II.
- Remote sensing data (MODIS 250 m and ASTER 15m).

<u>Activities</u>

- Improvement of the GLADA national assessment using successive application of high-resolution remote sensing data (SPOT 1km, MODIS 250 m, ASTER 15m) to assess loss of vegetation.
- Assessment of chemical degradation through comparison of historic soil data (e.g. carbon content and pH) with those produced during SWALIM II.
- Qualitative gully extraction from ASTER satellite images.
- Integration of the loss of vegetation, chemical degradation, and physical degradation (soil loss from LD assessment in SWALIM II). A new hot and bright spots map will be produced.

Garowe

<u>Available Data:</u>

- Global and regional land resources maps
- Land cover maps at 1:50.000 from SWALIM
- Biomass map from SWALIM
- Outputs from GLADA national level assessment approach using high resolution data.

<u>Activities</u>

- Adaptation of the LADA/WOCAT National to Local assessment frameworks. The aim will be to find out the issue of tree cutting for charcoal production and invasive species.
- Application of the LADA VSA approach for the determination of the current soil quality.
- High resolution change-detection of tree cutting using IKONOS images.

- Qualitative gully extraction from ASTER satellite images.

Juba and Shabelle riverine areas

Available Data:

- Land resources baseline data (soils, landform, land use, land cover, climate maps, etc).
- Applied information (land suitability maps)

Activities

- Land degradation assessment using the LADA/WOCAT National level framework.
- Biological degradation (loss of vegetation) using the multiscale NDVI proxy indicators of degradation.
- Chemical degradation: nutrient decline by applying a comparative assessment of historical and current soil analytical data. Salinization will be assessed using the SWALIM soil data sets.
- Physical degradation: soil erosion and sedimentation will be studied by the application of different types of models such as RUSLE3D, USPED and Thornes. This will be combined with soil erosion and sedimentation modeling activity in SWALIM III.
- The verification of results and validation of models will be done as soon as the security situation improves.
- The LADA/WOCAT questionnaire will be administrated for getting expert opinion about land degradation.
- All degradation map will be combined to identify degradation hot and bright spots.

Monitoring framework

After collating all land degradation types and indicators at the local level, a monitoring framework will be designed taking into consideration the following;

- Prevalence and incidences of land degradation types in each pilot study area
- Selection of easy-to-measure indicator(s) and their relevance (temporal and spatial resolution) in assessing the identified land degradation types
- Frequency of assessment of the identified degradation type(s)
- Database update (LADA-WOCAT database in each region)
- Activities of the LADA LD taskforce
- Monitoring of the adoption/rejection of WOCAT technologies/approaches in other areas
- Engaging LD taskforce in the LADA/WOCAT network
- Capacity building (for technical staff) and institutional support to sustain future assessment and monitoring activities for land degradation.

TIMETABLE

National assessment

Activities	September	October	November	December	January	February	March
LUS Stratification							
NDVI LD Indicators							
Validation/LADA-WOCAT questionnaires							
Reporting							

Local assessment

Activities	September	October	November	December	January	February	March
Improvement of the biological degradation (Somaliland) from SWALIM II							
Improvement of chemical degradation (Somaliland) from SWALIM II							
Hot and Bright spots (Somaliland)							
LADA Local assessment in Garowe							
Application of LADA/WOCAT in southern Somalia. Erosion and sedimentation modeling							
Design of the monitoring framework							

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Annex 2. FAO-SWALIM feature article on land degradation assessment in Somaliland

SWALIM

Somalia Water and Land Information Management Programme
Funded by the European Commission and implemented by Food and Agriculture Organization (FAO) of the United Nations
Feature Article #8

From land degradation to land rehabilitation in Somaliland. Is it possible?

The question asked in this feature article is *'Why, with so much effort and research devoted to land degradation problems, are we still so far from real solutions? Are we misunderstanding the processes involved, and where are we missing the mark in applying the correct solutions?'*

Simply put, land degradation is the loss of the original capacity of land to serve human activities and environmental processes. Nowadays, this subject is in the arena because it is linked to climate change and subsequent negative environmental changes.

Different organizations dealing with agriculture and environment such as FAO and UNEP are working to produce tools that can help in the assessment of land degradation processes, especially in dryland areas of the world. Other networks like WOCAT are documenting soil and water conservation practices around the world to highlight successes and share experiences in combating loss of the natural potentials of precious land resources.

SWALIM, as part of its mandate to collect land-related information to facilitate intervention activities in Somalia, carried out pilot fieldwork on land degradation assessment in Somaliland. As part of this exercise, a framework for assessing land degradation at the national level was designed. The experiences of others have shown that land rehabilitation and land reclamation must be both on-site and off-site; as - for example - soil erosion can occur upstream as well as generating negative impacts downstream. This was the motivation to apply a world-standard framework incorporating both aspects.

Combining different modern tools such as GIS, remote sensing, pedometrics and frameworks like LADA/WOCAT and, most importantly, fieldwork and local knowledge, we entered into an exercise of assessing forms and the extent of land degradation in Somaliland. We also gathered information on whether residents are aware of this negative process and if they are doing anything about it.

Spatial modelling results showed that the extent and severity of land degradation is high, which is something that is quite evident in the field. However, remote sensing tools and spatial analysis did not detect that there are efforts underway to combat this negative process. Many other workers and institutions have previously highlighted land degradation in Somaliland as a reality. It is however, not well known what measures are being taking to tackle this negative process.

Many different examples of land degradation and efforts to combat it were shown to us. See the pictures below.

Plate 1 (left) depicts a badland while plate 2 (right) depicts a gulley control measure (check dam implemented by IFAD)

Plate 3 (left) depicts an agriculture field without any conservation measure. Plates 4 (right) shows an improved soil bund the purpose of which is to stop soil erosion and mainly hold moisture in the soil (implemented by IFAD)

As stated earlier, while it's very easy to determine a problem and even outline the causes, the challenge lies in finding a suitable solution. Even more challenging is the implementation of the proposed solution. Efforts to find and implement lasting solutions are further complicated by land degradation being an integrated problem combining biophysical aspects, socioeconomic and cultural issues.

However, all hope is not lost; it is definitely possible to combat land degradation and improve the productivity of land as a main source of livelihood for different communities in Somaliland. Finding this lasting solution calls for the integration of the efforts of all stakeholders. The aim is, to preserve lands that are not yet degraded while rehabilitating those that have been severely degraded, such as badlands.

Article by: Ronald Vargas
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Somalia Water and Land Information Management Programme
Kalson Towers, 3rd Flr, Parklands Nairobi, Kenya Phone : +254(20) 3743454, 3743464, 3743486
Website: http://www.faoswalim.org/
Email: enquiries@faoswalim.org