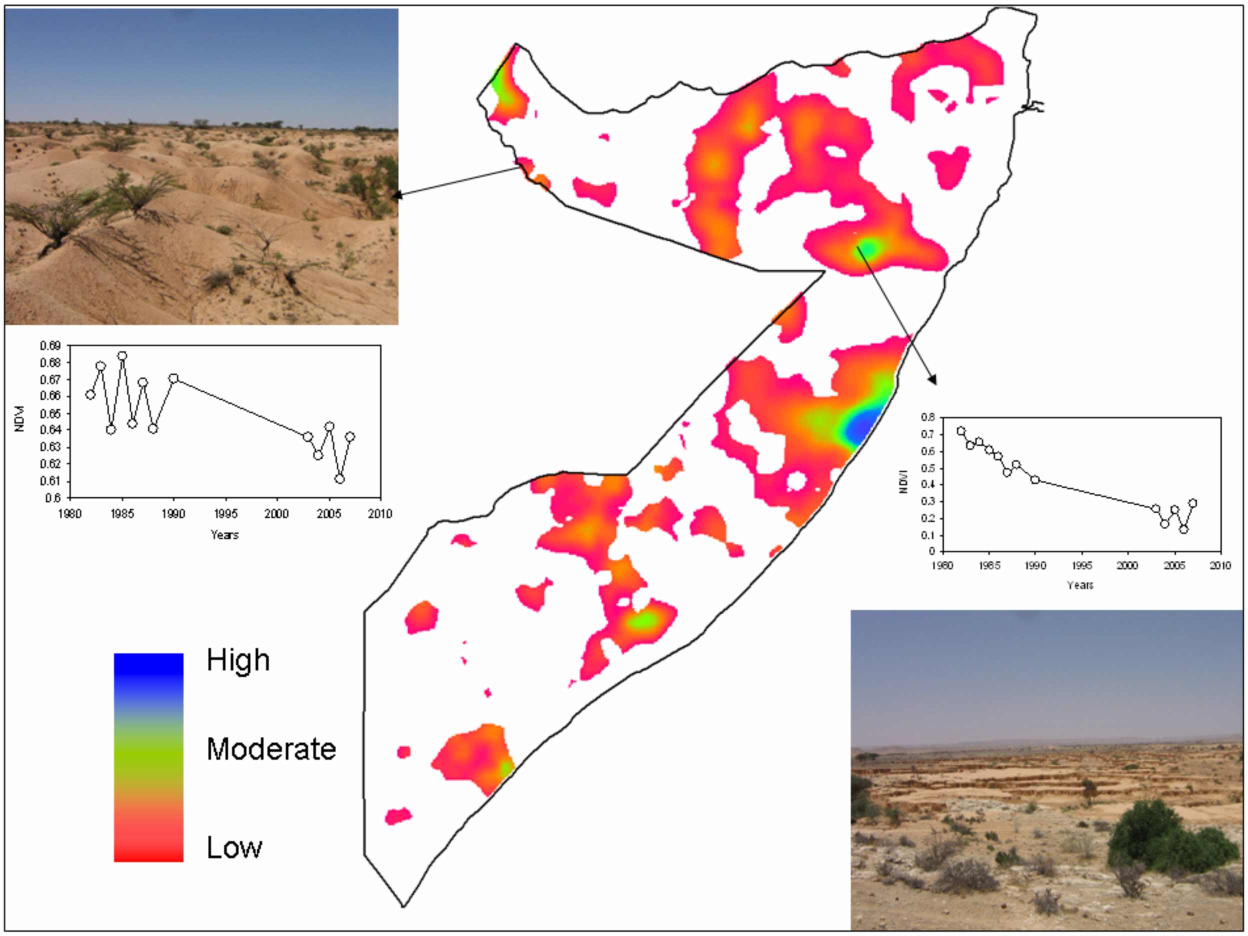
Land Degradation Assessment and a Monitoring Framework in Somalia



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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
ITCZ	- Inter-Tropical Convergence Zone
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

Land degradation assessment was carried out in Somalia 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). A number of claims have been reported in the literature about land degradation trends in Somalia and how it affects livelihoods and implementation of many development programs in the country. However, no conclusive study has been carried out so far to verify these claims. FAO-SWALIM carried out this study on land degradation in Somalia to identify prevalent types of the degradation in the co

untry, extent of the affected areas, and its major causes. The study also identified areas where land conservation efforts have been tried and showed opportunities for upscaling them in the entire country. It is hoped that the results from this study will put land degradation in Somalia in the correct perspective and provide a way forward for its future control and monitoring.

Although “land degradation” is a commonly used term in environmental circles, it is often misconstrued by many people. Especially in Somalia, land degradation has been wrongly conceptualized by many and it is therefore important to have a clear understanding of its concept at the outset before carrying out the assessment. The clarifications given here are not attempting to make a “new” definition of land degradation but rather to highlight the important aspects to be given attention during the assessment and monitoring of land degradation. The first important aspect of land degradation is that it is a process/change but not an event. Land degradation is a gradual negative environmental process which involves one or a combination of processes such as accelerated soil erosion by water or wind, sedimentation, long-term reduction of amount or diversity of natural vegetation, reduction of soil nutrients, increase of aridity, and salinization and sodification, etc [22]. LADA [8] defined it 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. Since it is a process, its assessment and monitoring should be viewed with time-factor in mind. Many studies which: 1) make one-time measurements and 2) compare results of one-time measurement/survey of an area with other areas perceived to be non-degraded often give false alarms about land degradation. This is due to lack of accurate time profile of the land resources dynamics during land degradation assessment. In Somalia, for example, many places may look degraded at a glance but have remained stable for hundreds of years and have been supporting some form of livelihoods in the country. One-time assessment of these areas can potentially lead to a false impression of severe degradation.

Another important aspect of land degradation for consideration during its assessment and monitoring is the human face of the degradation. Land degradation affects human beings and is also accelerated by human activities. It affects human beings through its impacts such as reduction of food production potential, deterioration of environment for human habitation, interference with hydrologic cycle (e.g. through decimation of trees, siltation of surface water reservoirs etc), destruction of road network through gully erosion, etc. It is accelerated by human activities through overexploitation of land resources and land mismanagement. Therefore, the inclusion of human aspect is important for successful and accurate assessment and monitoring of land degradation [14].

In this study, national-level assessment of land degradation was done using time-series remote sensing images from 1982 till 2008 and expert opinion about the history of the degradation in Somalia dating back as far as the experts could remember. The objective of the study was to identify potential causes, types, and impacts of land degradation at the national level and to identify local spots for comprehensive assessment. The outputs from this study was envisaged to support policy decisions for combating land degradation at the national level and to give the general guidelines of the sections of the country experiencing severe degradation so that appropriate planning of the national resources could be instituted. The assessment was stratified according to land use systems units in the country. Land use systems are homogeneous areas of similar human activities (i.e. land use patterns) and biophysical information [14]. In addition to the assessment, the study also established good baseline information for future monitoring of land degradation in Somalia.

2. STUDY AREA

Land degradation assessment was carried out in Somalia. The country is located in northeast Africa in what is commonly referred to as the Greater Horn of Africa. It lies between the latitudes 1° 40' 48" S and 12° 6' N and the longitudes 41° 0' E and 51° 22' 12" E, covering an area of 636,240 Km^2 (Figure 2.1). It shares borders with Djibouti in the northwest, Ethiopia in the west, and Kenya in the southwest. It is also bounded by Gulf of Aden in the north and Indian Ocean in the east.

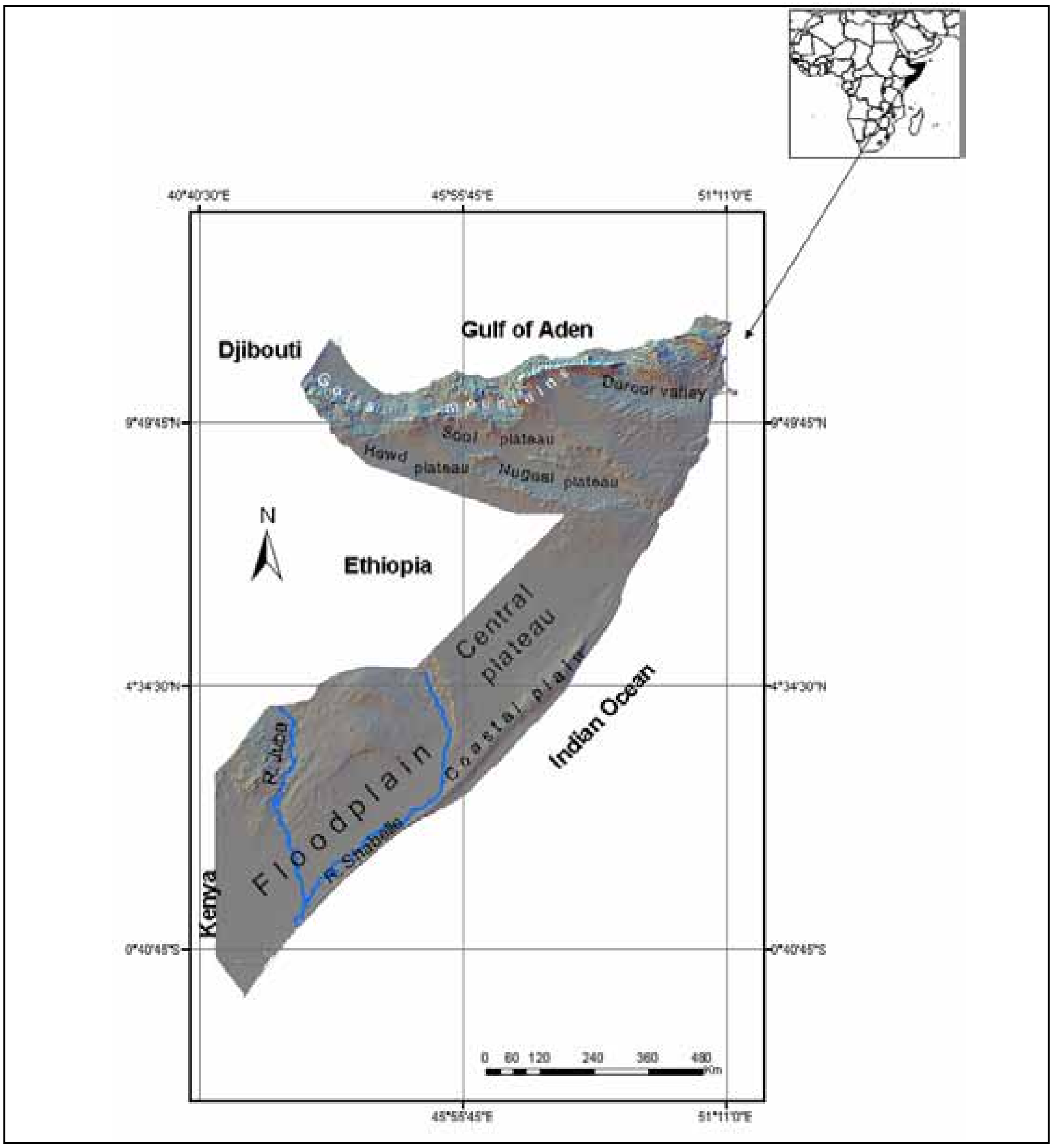


Figure 2.1: The study area

2.1 Climate

The climate of Somalia varies between desert and semi-humid. It is generally influenced by the north and south Inter-tropical Convergence Zone (ITCZ) with alternate movement of northeast monsoon winds blowing from the Arabian coast, southwest monsoon winds blowing from Africa, and south winds from the Indian Ocean. These monsoon winds provide very erratic rainfall which contributes to four seasons; two rainy seasons separated by two dry seasons as follows:

- Gu': April to June, which is the main rainy season for the country.
- Xagaa: July to September, which is cool, dry, and windy in the interior and with some showers in the northwest highlands and south coastal areas along the Indian Ocean.
- Dayr: October to December, which is the second rainy season but with less rainfall amounts than the Gu' season.
- Jiilaal: January to March, which is the longest dry and hot period in the country.

Mean annual precipitation over the country is about 282 mm. It is distributed as follows: about 50 mm along the coast of Gulf of Aden, 150 mm in the interior plateau, 200 to 500 mm in the south, and more than 500 mm in the northwest highlands and south-western parts of the country (Figure 2.2). In addition to low average annual rainfall amounts, the country also experiences frequent mild droughts every 3 to 4 years and severe droughts after every 8 to 10 years. Average annual temperature is about 28 °C in the hinterland, but may be as low as 0 °C in the mountain areas and as high as 47 °C along the coast of the Gulf of Aden. The temperature is hot and dry in the interior and coastal area along the Gulf of Aden but cool along the Indian Ocean coast and inland areas in floodplains between river Juba and Shabelle (Figure 2.2). The hottest months of the year occur during the Xagaa season in the coastal zone of the Gulf of Aden and during the Jiilaal season for the rest of the country. In addition to high temperatures, the country also experiences high relative humidity of between 60 and 80% [12].

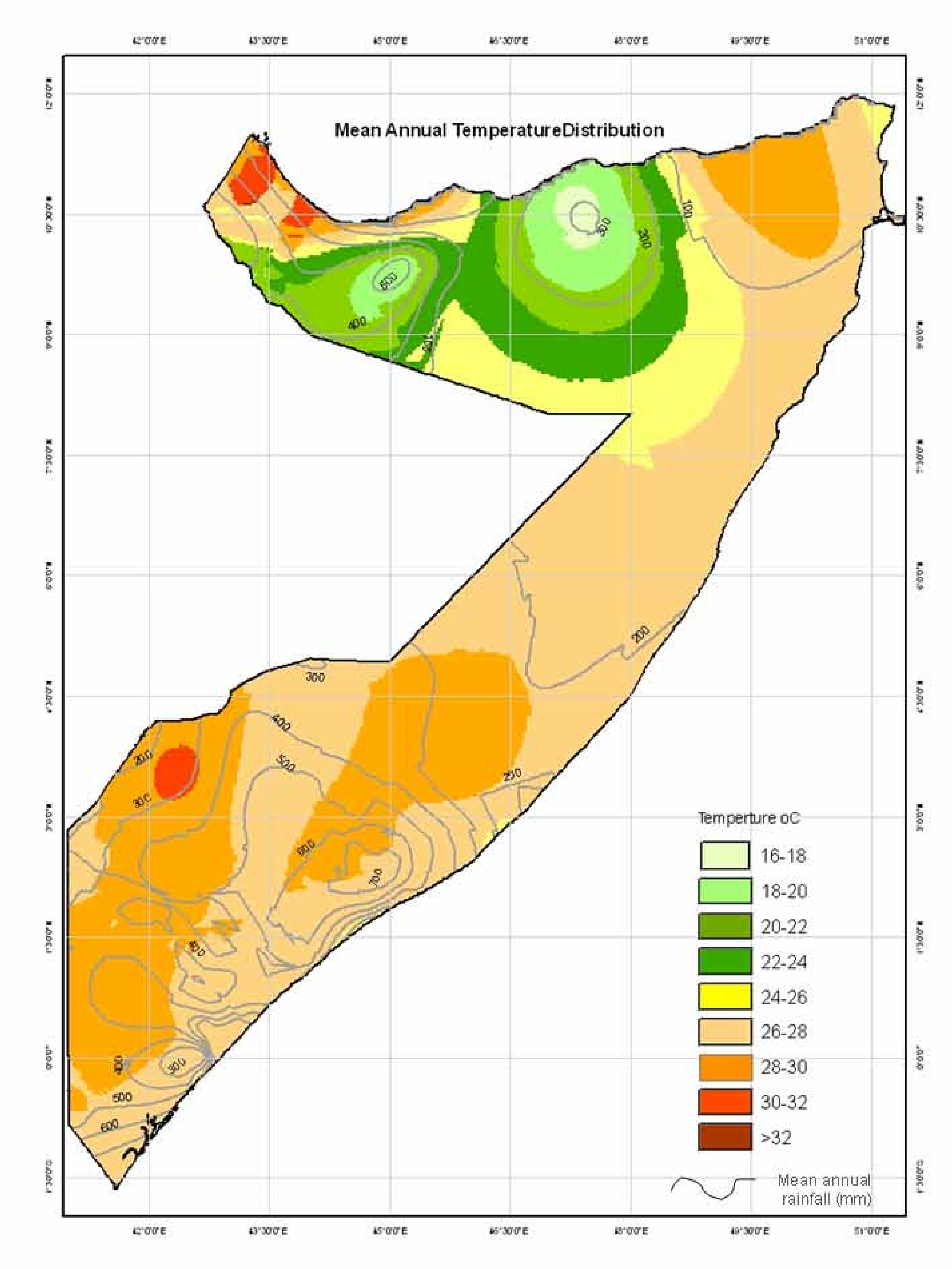


Figure 2.2: Main climatic patterns of Somalia (FAO-SWALIM Report No. W01)

2.2 Soil and Vegetation

The soil of Somalia is generally characterized by well-developed and deeply weathered material with exception of soil in eroded areas, in recent alluvial and sand dune deposits, and in the northern mountain ranges. According to WRB [25] classification, the most common soil types in the northern regions are Leptosols, Regosols, Calcisols, Fluvisols, Solonchaks, Gypsisols, Vertisols and Cambisols. Arenosols are mostly found in the coastal plains. Solonchaks may also be found in some places in the coastal areas while Vertisols and Fluvisols dominate highlands of northwest regions. The area between river Juba and Shabeelle has soils varying from reddish to dark clays, with some alluvial deposits and fine black soil which are classified as Vertisols, Luvisols, Nitosols, Cambisols, Calcisols, Arenosols, and Solonchaks.

The above combination of climate pattern and soil distribution support natural vegetation which range from sparse to dense short grass, shrubs, scattered to dense bush with different kinds of woods, and forests. The areas covered by these vegetation types are shown in Table 2.1 [1].

Table 2.1: Areal coverage of natural vegetation in Somalia

Vegetation Types	**Area Covered (km^2)**
Evergreen forest	344
Riverine forest	45
Plantations/shelterbelts	30
Mangroves	100
Woodland	74116
Wooded bushland	170300
Bushed/Woodland	19400
Bushland	127178
Total area	**391513**

In terms of spatial distribution, the vegetation in Somalia can be described into various regions as follows:

- The coastal plains vegetation consisting mainly of herbaceous plants. The vegetation in this region extents to footslopes of the Golis Mountain. Close to the mountain, the predominant vegetation is sparse bushy Acacia, Balanites aegyptiaca, and Commiphora associations including Boswellia species.

- In the hinterland plateaus, vegetation is dominated by open shrubs and woody plants of Acacia bussei, Acacia etbaica, Boscia spp, Cadaba spp, and Acacia mellifera. Some herbaceous plants mainly Chrysopogon aucheri and Sporobolus spp. can also be found here.
- In the mountain range the vegetation consists of evergreen trees of Junperus procera, Juniperus excelsa forest and open shrubs of Buxus hilderbrandtii, Dodonea viscose and Terminalia brownii etc.
- In the central plains, vegetation varies mainly from extensive grassland along the fixed dune areas to shrubby bushland with scattered trees in the west toward Ethiopian border. They mainly include Andropoon kelleri, Chrysopogon aucheri, Soporobolus ruspolianus, Indigofera ruspolii, Acacia spp., Commiphora spp., Cordeauxia edulis, Delonix elata, Terminalia orbicularis and Dobera glabra etc.
- In the southern parts (in the floodplain), the vegetation type is mainly low deciduous bushland of Acacia spp. which extends to the coastal dunes.
- Parts of Riparian forests are located along the river Juba.
- Mangrove swamp communities are also situated at the tidal estuaries of the potential ephemeral rivers towards the Indian Ocean coast. They include Bushbush, Caanoole and Lag Badanaa.

In general, about 46 to 56% of the country is considered permanent pasture or used as rangeland the vegetation cover, 13% is suitable for cultivation, and less than 4% is forest cover [2, 7]. This pattern, however, is constantly changing due to land degradation.

2.3. Geomorphology and main water sources

In terms of geomorphology, Somalia can be distinguished into (Figure 2.1):

- The coastal plain and sub-coastal plain along the Gulf of Aden. This area is locally known as “Guban”.

- Golis mountain ranges (also known as the Al mountains) running almost parallel to the coastal plain along the Gulf of Aden from the western border with Ethiopia to the east cape of Guardafui or Ras Assayer.
- Dharoor valley separated from the south by Sool plateau to Nugaal valley, which is located south of the Golis Mountain. They are bordered by four large plains, namely Xadeed, Karmaan, Barraado.
- There is also a gently undulated plateau south of Hargeysa and Hawd plateau that extends to south of Nugaal valley and a central plateau in the central regions which has a micro-relief sloping gently towards the coast of Indian Ocean.
- Upper Shabelle valley is characterized with low undulating hills and steep slopes. They are topped by low escarpment.
- Floodplain extending along river Juba and Shabelle.
- Gently undulating plain of stabilized sand dune and mobile sand dune along the coast of Indian Ocean.
- Coastal belt containing gullies, drifts, small cliffs and sand beaches along the coast.
- Gently rolling to rough topography with some flat-topped Mesas in upper Juba of Gedo region.
- Inter-riverine widespread plain, which is gently sloping southwards and wide floodplain in the Juba valley. The floodplain has large depressions ("Deshecks") in the lower Juba zone.

The main permanent water resources are rivers Juba and Shabelle. River Juba flows all year round but river Shabelle sometimes dries-up downstream around Jowhar during the dry seasons. The two rivers supply water for human and livestock consumption and also for crop irrigation. Seasonal rivers (togas) in the mountainous range in the north and in hilly zones in the inter-riverine area of river Juba and Shabelle are also other sources of water. The most prominent togas are Waaheen, Durdur, Saleel, Togdheer, Nugaal, Daroor, Mudug, Waadi Hiiraan, Tog Urugay, Faanweyn, Lag dheera and lag Badanaa. In addition to rivers and togas, there are also springs, pockets of dams and boreholes, which supply water most of the times and occur in different localities. The most important springs include Karin, Dubaar, Galgala, Biyo kulule, Saley biyo kulul in the North and Isha Baydhabo in the south. Surface dams and boreholes are found in many places either as public utilities or private entities [13].

2.4. Population and land use dynamics

Human population in Somalia is generally homogeneous (linguistically and religiously) and consists of the main clan families of Darod, Dir, Issaq, Hawiye, Rahanweyn, and other minority clans. Since the last official census in 1975, there have been no clear and accessible official records of census or human population in the literature. Various estimates exist, though, from around 3.3 million people in 1975 to about 6.8 million in 2003. Recent estimates by UNDP [23] put the population at about 7.5 million with a growing rate of 2.8% per year. The important information from these estimates is that the population has grown considerably since 1975 to date. The population consists largely of nomadic pastoralists, agro-pastoralists, and urban dwellers. There is also a significant proportion of the population in trade (business) and fishing (mainly along the coasts). The population distribution is somehow parallel to the distribution of the natural resources; high population density in the southern regions than in the northern and central regions. About 60% of the total population is in the southern regions while 29% and 11% are in the northern and the central regions respectively [2]. In the recent years, a significant number of the population has been moving to urban centres or more developed areas in search of employment while others have moved elsewhere due to prolonged civil wars.

Due to the persistent civil war, change of governance (from pre-colonial before 1887 to date), and changes in climate, Somalis have changed their land use patterns and policies considerably [24]. Some of these changes have contributed to the present state of land degradation in the country and include: expansion of cultivation agriculture into the rangelands without suitable land management activities, non-regulated charcoal production for local consumption and for export, uncontrolled grazing of livestock, and individual land ownership for urban and agricultural development. In addition, lack of good land management and lack of maintenance of the conservation measures instituted by previous governments (pre-colonial or colonial government) have also catapulted land degradation in some areas [19, 24].

3. METHODOLOGY

From the foregoing description of Somalia and evidences of degradation from the literature, it seems that land degradation history in Somalia dates back to more than the past 50 years. Consequently, adequate and accurate assessment of the trend of the degradation would require good historical datasets and methods which would try to capture the past events. This study used two methods which attempted to capture evidence of land degradation within the past 20 years. The methods used were the LADA-WOCAT method for national assessment and remote sensing image (mainly Normalized Difference Vegetation Index, NDVI) analysis [3, 10] (Figure 3.1). These two methods were used for two reasons: 1) as a basis for identifying local spots to target during detailed local assessment, 2) to give general indications of the causes and impacts of land degradation in the country, and 3) because they were the available versatile methods which could assess land degradation at the prevailing insecurity situation in country. Remote sensing analysis assessed land degradation between January 1982 and December 2008 while expert knowledge went as far as the experts could remember in terms of time. The input requirements, application procedures, and integrated results from these two methods are explained in the proceeding sections of this report.

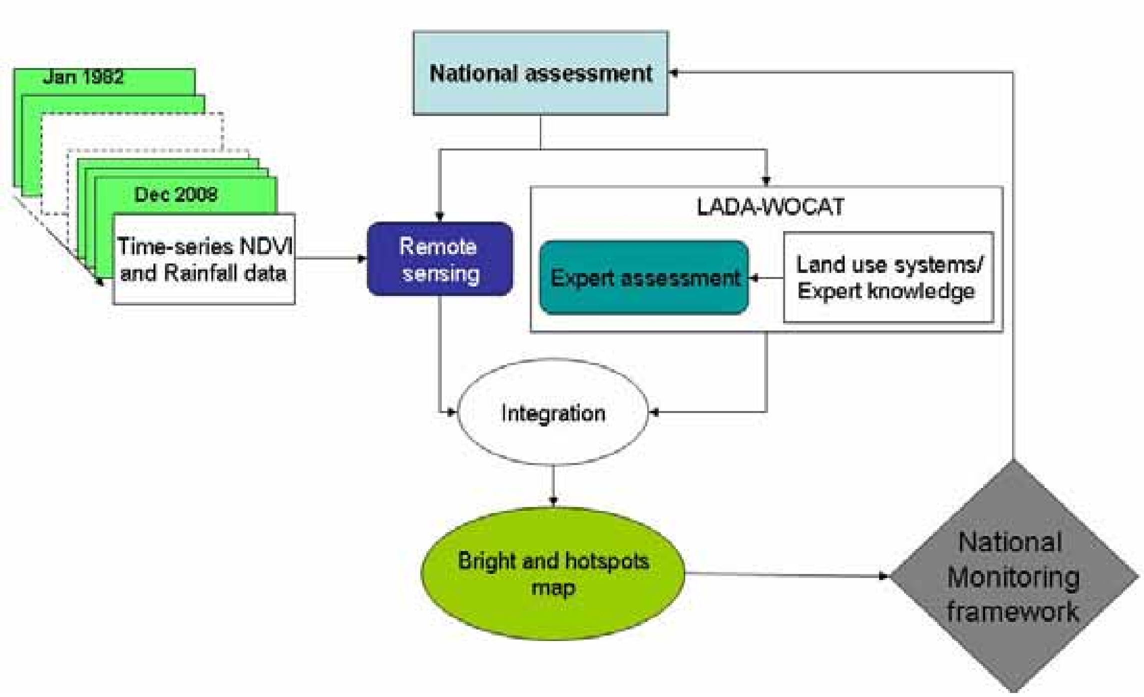


Figure 3.1: National assessment and monitoring of land degradation in Somalia

3.1 LADA-WOCAT method for national assessment of land degradation

Land degradation assessment by LADA-WOCAT method involved: the development of a land use systems (LUS) map, which was the map of reference units for assessment, validation of the map, expert assessment of land degradation using questionnaires, and development of a land degradation map from the expert assessment (Figure 3.2).

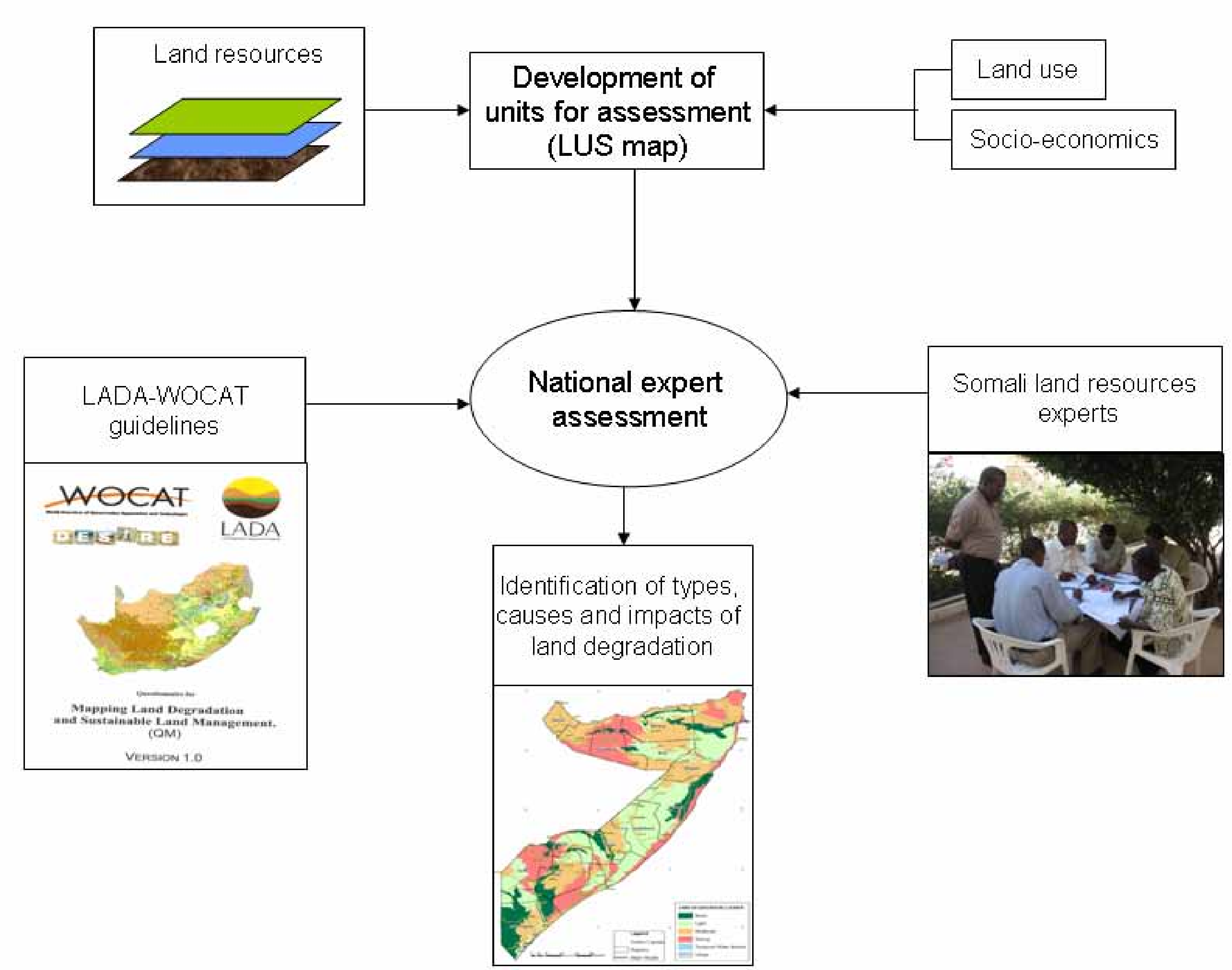


Figure 3.2: Methodology for national assessment of land degradation using expert knowledge

3.1.1 Development of land use systems map

Land use systems (LUS) map is an integral map of homogeneous areas of human activities (land uses) and land resources base. It was proposed by the Land Degradation Assessment in Drylands (LADA) Project to guide regional and national assessment of land degradation. LADA proposed it because it incorporates land use which is the main driver of land degradation. In this study, the methodology given by Nachtergaele and Petri [14] was used to produce the LUS map for Somalia (Figure 3.3). The following were the input data for producing the map: land cover map, land use map, Digital Elevation Model (DEM), livestock distribution map, and livelihoods zones map. These datasets are obtained from FAO-SWALIM (www.faoswalim.org).

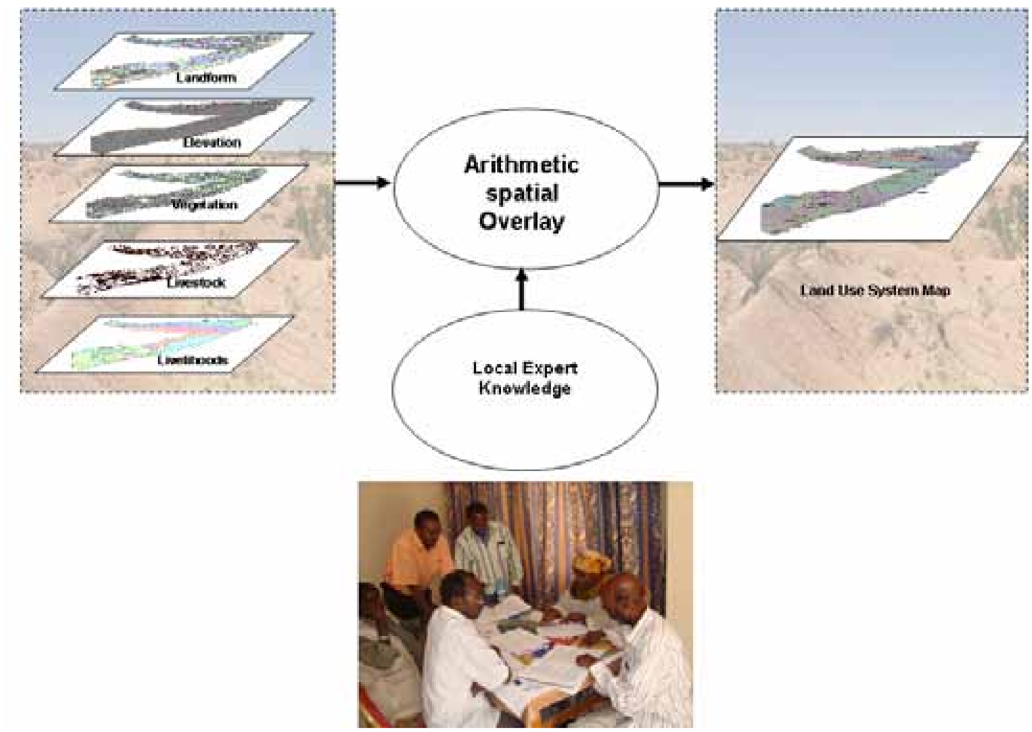


Figure 3.3: Development of land use systems map for Somalia

3.1.2 Validation of LUS map and expert assessment using questionnaire

Validation of the LUS was done at three different times and places due to security situation in Somalia. The first validation was done between 17th and 19th January 2009 in Hargeysa in north-western Somalia. The validation was mainly for north-western parts of Somalia. The second validation was done between 18th and 20th

January 2009 in Garowe in north-eastern Somali. Again, validation of the LUS map during this time was mainly for north-eastern parts of Somalia. The last validation was done between 26th and 28th February 2009 in Nairobi for southern and central Somalia. It was done in Nairobi because the volatile security situation in Southern and Central Somalia could not allow practical implementation of the validation process during that time.

All validations were organized in two steps: step one which involved a brief lecture given to the experts about LUS map and land degradation (definitions, development of LUS map, land degradation assessment, and how to validate LUS map); and step two where the experts were grouped according to their geographic regions of expertise. Each group was given a printed LUS map to validate. The validation then involved checking the LUS map in terms of the boundaries of its units (or polygons) and accuracy of the LUS type, description, and codes for each polygon (Figure 3.4). The experts made their corrections or suggestions on printed LUS map and the corrections later incorporated to produce the final LUS map of Somalia.

A number of Somali experts were involved in the validation process (see Appendix 2 for the list of participants during the validation exercises). They were mainly from government ministries, local and international NGO's, UN organizations and freelance consultants working in Somalia.

Figure 3.4: Somali experts during a land degradation assessment meeting

Expert assessment of land degradation was based on the LUS map. Land degradation types, their driving forces, impacts and on-going responses to combat the degradation were identified for each unit of the LUS map. The experts identified these aspects of land degradation using the LADA-WOCAT questionnaires. Figure 3.5 shows an example of the questionnaire used in this study.

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: ______________________ **Country:** ________________

Mapping Unit Id (LUS + admin. unit): ____________________

Land Use System (Step 2)		
a) LUS area trend	b) LUS intensity trend	c) Remarks (e.g. reasons for trend)

Land degradation (Step 3)									
a) Type			b) Extent	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ecosystem services	h) Remarks
i	*ii*	*iii*							

Conservation (Step 4)											
a) Name	b) Group	c) Measure	d) Purpose	e) % of area	f) Degradation addressed	g) Effectiveness	h) Effect. Trend	i) Impact on ESS	j) Period	k)Ref to QT	l) Remarks

Figure 3.5: Example of LADA-WOCAT questionnaire for assessing land degradation

Description of the entries in the questionnaire and steps for filling them are contained in a manual which can be freely downloaded at http://www.wocat.org/QUEST/mape.pdf. Appendix 1 contains an example of a filled questionnaire during one of the expert meetings in Somalia.

After the assessment, a final plenary discussion was organized where the experts discussed issues regarding pros and cons of the approach, main findings, and the way forward for combating land degradation in Somalia.

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

Once the expert assessment was completed, the information from the questionnaires was first entered into a database to build the baseline information about land degradation in Somalia. They were then statistically analyzed to determine prevalent land degradation types, their causes, and extent of the affected areas. Sustainable land management (SLM) practices and impacts on ecosystem services were also analyzed at this stage. Afterwards, the LUS codes in the database were hyperlinked to the same codes in LUS map in order to translate the questionnaire outputs into maps of land degradation types, their causes, and conservation measures in Somalia.

For representing composite land degradation and SLM map of Somalia, indices for degradation and conservation developed by Lindeque [9] were adopted and adjusted in this study. The indices were degradation index (DI) and sustainable land management practices index (SLMI). They were determined as shown in Equation (1) and (2).

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

where %Area is a weighted average of the areas affected by land degradation types in a given LUS unit (the areas are obtained from column *b* in *step 3* of the LADA-WOCAT questionnaire as shown in Figure 3.5), degree is the average intensity of the degradation processes within the LUS unit (it is the mean of the entries for *degree* in column *c* in *step 3* of Figure 3.5), and rate is the mean trend of the degradation processes within the LUS unit (it is the mean of the entries for *rate* in column *d* of Figure 3.4).

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

where %Area is a weighted average of the areas affected by a given conservation practice in the LUS unit (areas of each land degradation type is obtained from column of *e* in *step 4* of Figure 3.5) and effectiveness is the mean value of the entries for *effectiveness* in column *g* in *step 4* in Figure 3.4. *Effectiveness* is defined in terms of how much the SLM practices reduce the degree of land degradation in the LUS unit [10]. 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 3.1.

Table 3.1: Thresholds for categorizing land degradation maps from expert assessment

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

3.2 Remote sensing method for assessing land degradation

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 for current status of the land; and 3) they have fairly accurate representation of the trends of vegetation cover dynamics than many other indicators [5]. In Somalia, loss of vegetation cover has been variously mentioned as the trigger for other types of land degradation [2, 11, 19, and 24]. 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 approach used for identification of degraded land using NDVI involved: spatial prediction of rainfall amounts, calibration of NDVI images with rainfall data, determination of time-series difference between predicted and remotely-sensed NDVI, and determination of areas with significant decline in vegetation cover (Figure 3.6).

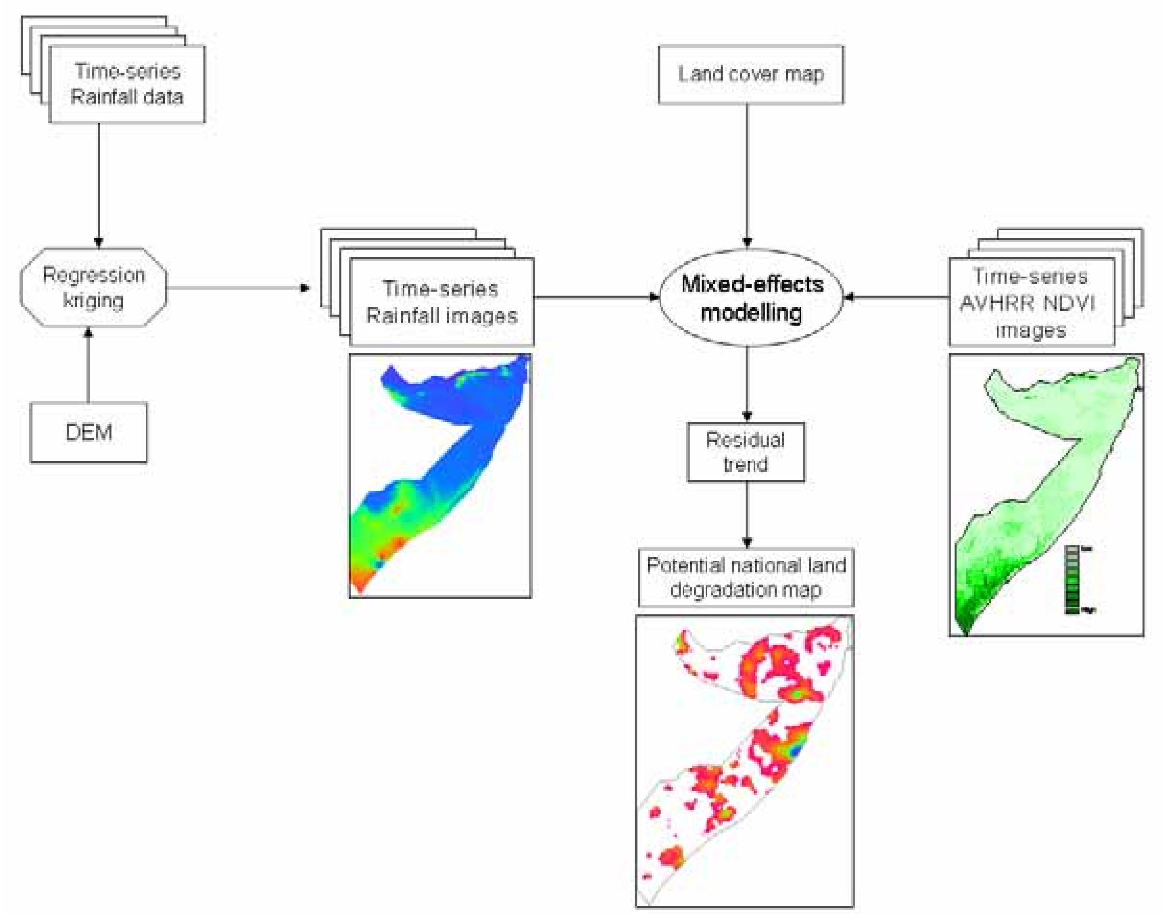


Figure 3.6: Methodology for national assessment of land degradation using remote sensing

3.2.1 Spatial prediction of rainfall amounts

Spatial prediction of monthly rainfall amounts was done to facilitate pixel by pixel analysis of the relationship between NDVI and rainfall amounts. The prediction was done using regression kriging method [15]. Analytical steps in using regression kriging are illustrated in Appendix 3.3. The method utilized the relationship between rainfall distribution in the country, altitude and the distance from the shoreline. Figure 3.7 shows an example of the relationship between annual rainfall amounts and the elevation. Such strong correlation prompted the use of altitude and distance from the shoreline for reliable spatial prediction of six-month aggregated rainfall amounts for each year.

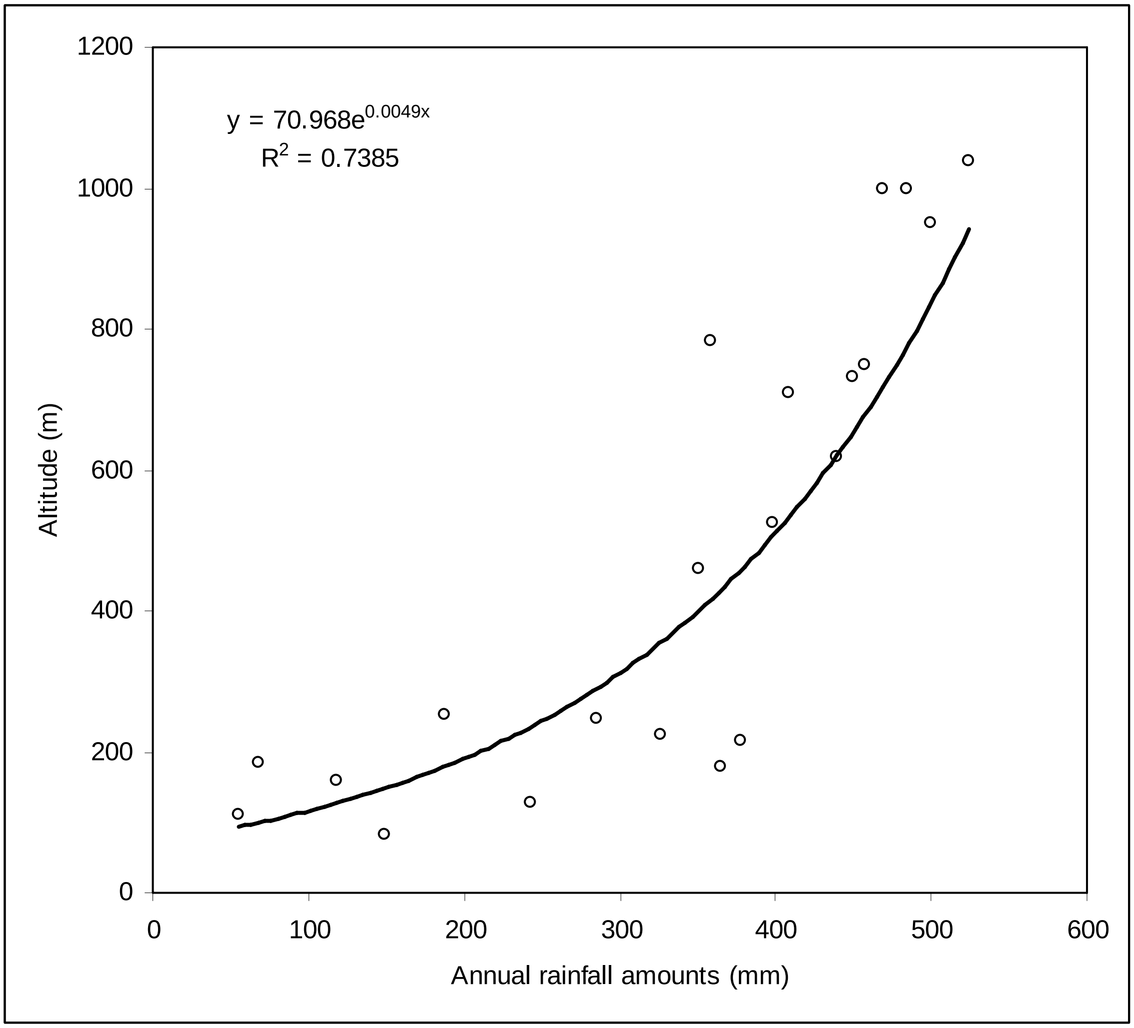


Figure 3.7: Example of the relationship between 1983 rainfall amounts and altitude

The adequacy of spatial interpolation was checked by withholding some rainfall stations and cross-checking with interpolated estimates. Figure 3.8 shows an example of the validation of spatially predicted rainfall amounts and measured rainfall amounts. The close agreement between measured and predicted rainfall amounts gave some confidence in minimal influence of spatially correlated errors in the spatial prediction process [15].

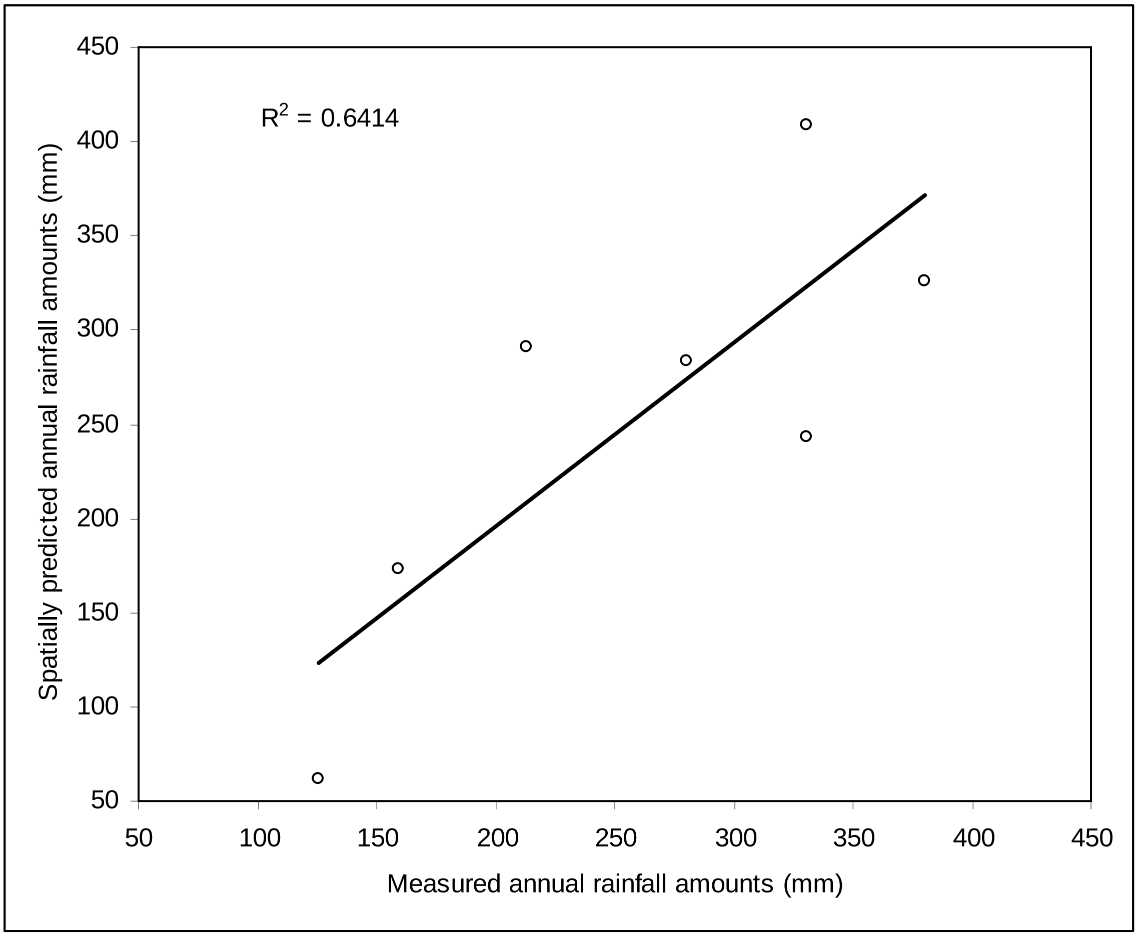


Figure 3.8: Example of validation of spatial prediction of rainfall amounts in 1983

3.2.2 Mixed-effects modelling and trend analysis of the residual from NDVI-rainfall relationship

The most commonly cited approach for using NDVI as an indicator of land degradation involves determination of declining or increasing trend of the difference between remotely sensed NDVI and rainfall-predicted NDVI over time. In this approach, 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 [3, 5]. Fitting of a uniform global model for NDVI-rainfall relationship for all locations in a given area of interest (e.g. over entire Somalia) is often used in this approach. The difference between the actual and predicted NDVI is then graphically analyzed to identify areas with improvement or loss of vegetation cover (Figure 3.9). This approach is commonly referred to in the literature as the residual trend analysis [3, 5].

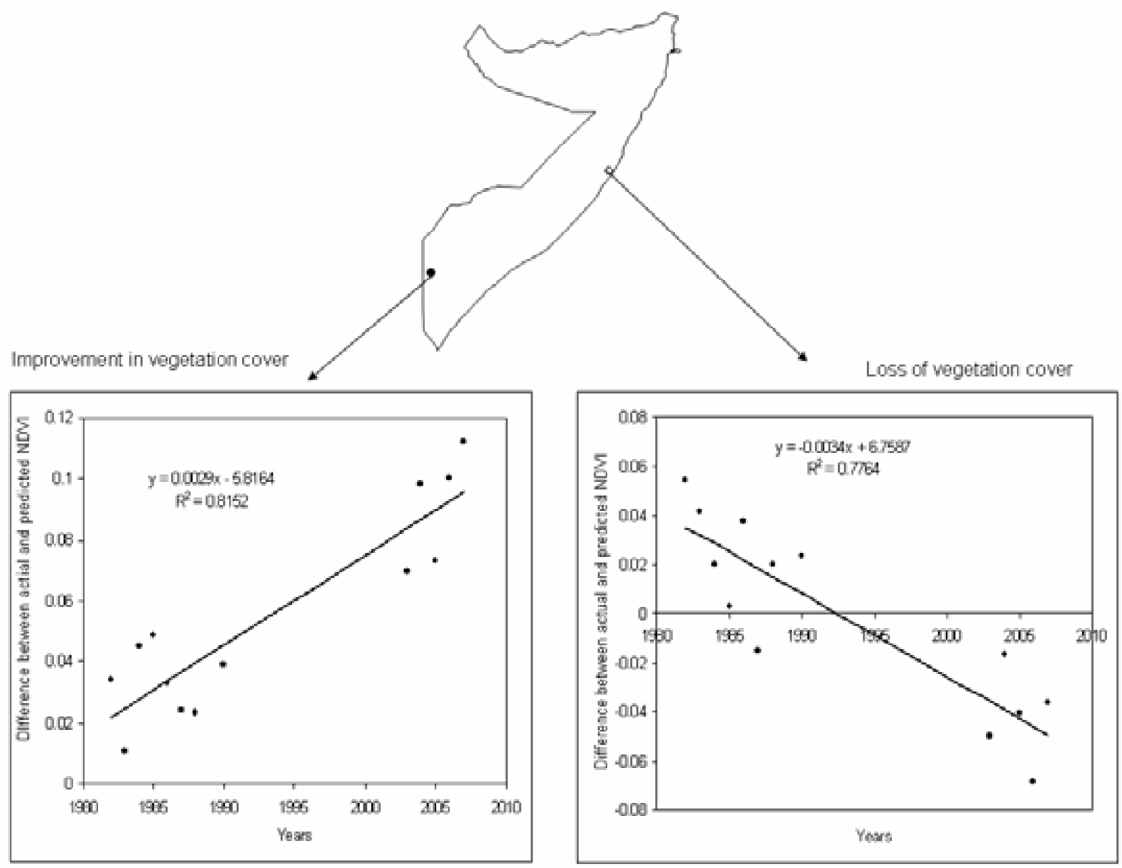
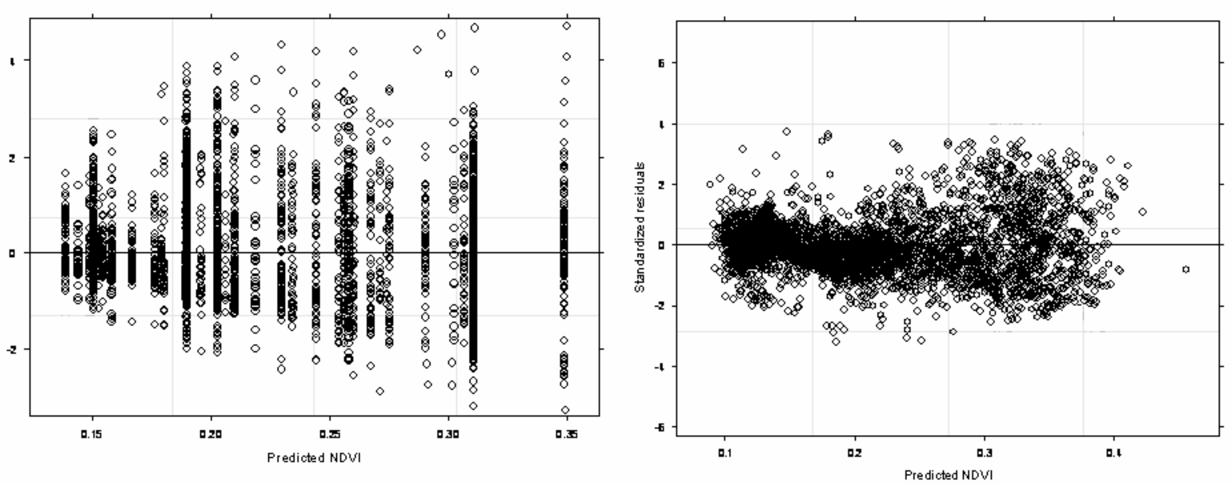


Figure 3.9: Example of identification of degraded land using residual trend analysis in Somalia

Although the approach has been shown to be promising in detecting potential areas with land degradation, it is important to note that it has its limitations too. For example, it does not identify changes in vegetation species, which is also another type of land degradation associated with loss of vegetation. The method can also 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 Somalia 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 [16, 17]. Appendix 3.1 shows how mixed-effects modelling was done for NDVI-rainfall relationship in Somalia. 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. Its prediction gave uniform distribution of standardized residuals which is expected of accurate models [16, 17]. The one-model approach had a wedge-shaped distribution of standardized residuals; thus indicating that it did not accurately predict rainfall distribution (Figure 3.10)



(a) Standardized residuals and predicted NDVI of a one-model approach

(b) Standardized residuals and predicted NDVI of mixed-effects model

Figure 3.10: Comparison of NDVI-rainfall relationship for 1983 using mixed-effects modelling and commonly used one-model approach

The performance of mixed-effects in predicting NDVI from rainfall was better than one-model approach because mixed-effects modelling incorporated vegetation types in the relationship. Incorporation of vegetation types in NDVI-rainfall relationship is realistic since different vegetation types have different response characteristics to rainfall that cannot be generalized with one model.

After modelling NDVI-rainfall relationship, a simple linear regression between time and the differences between actual and predicted NDVI was then used to identify land degradation spots as demonstrated in Figure (3.9). Equation (3) shows the model for this simple linear regression analysis.

$$\mathbf{e} = slope_{res} * \mathbf{Time} + intercept_{res} \quad (3)$$

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 3.9). The significance of $slope_{res}$ was tested at 95% confidence interval.

3.2.3 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 maximum 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 10-days composite maximum NDVI [21]. Figure 3.11 shows examples of these images for Somalia.

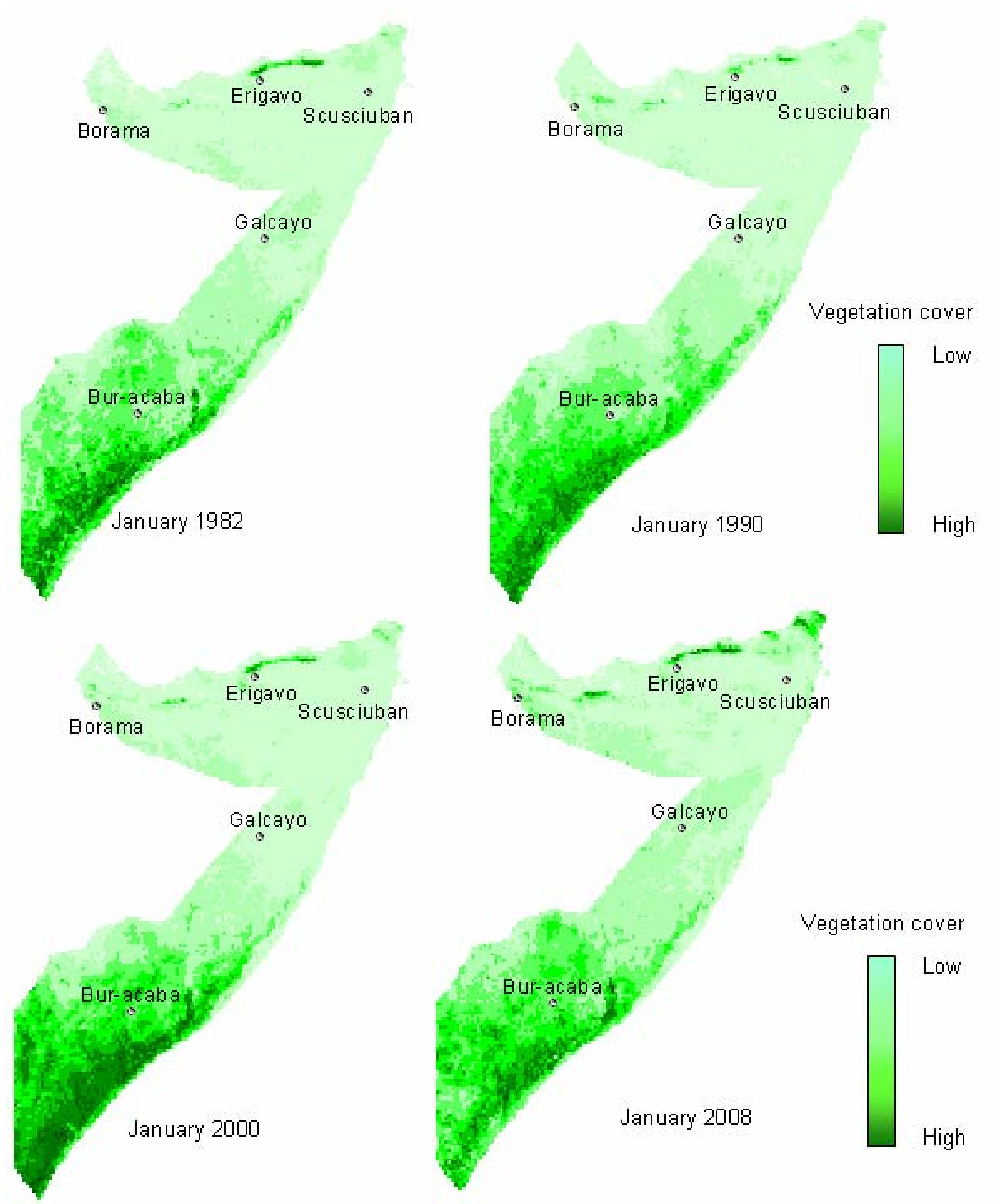


Figure 3.11: Examples of NDVI images for Somalia

A preliminary analysis of the entire NDVI data showed high spatial and temporal variation of vegetation signals in the country (Figure 3.12). This pattern is typical of dryland vegetation types due to the complex interaction between climate, vegetation, and human influence [5].

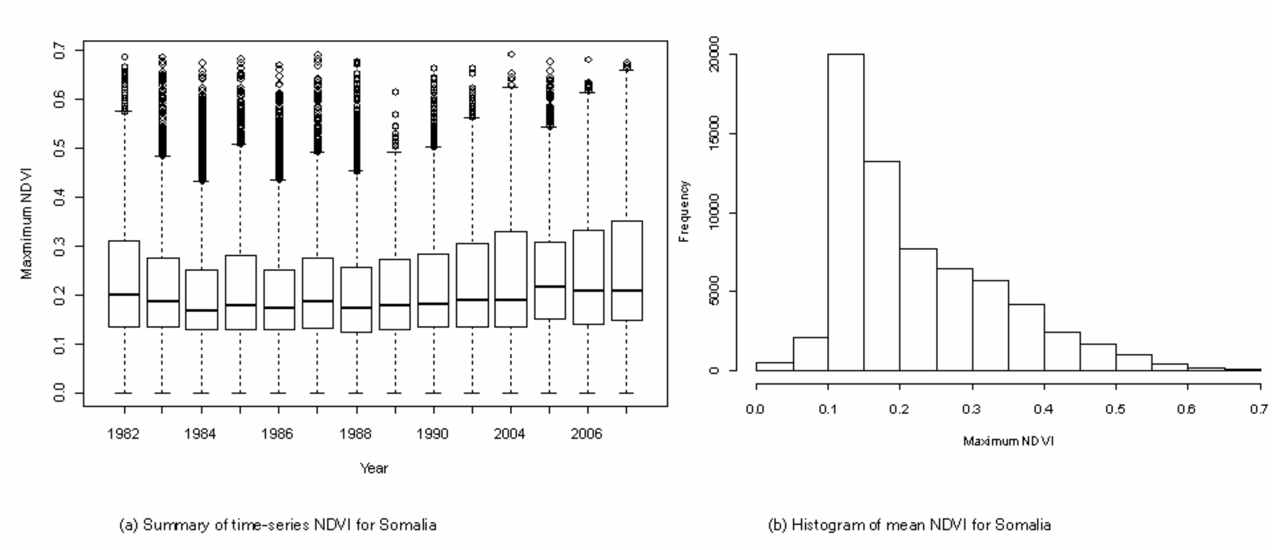


Figure 3.12: Summary of NDVI data for Somalia

The rainfall data consisted of monthly rainfall amounts from 46 recording stations in the country. 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. 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 them and the corresponding NDVI data for this period was removed from the subsequent analysis in order to maintain consistency in the entire dataset. A summary of these rainfall data showed similar distribution as NDVI (Figure 3.13). The variation in the rainfall data was almost similar to NDVI variation, which justifies the hypothesis of a harmonized relationship between NDVI and rainfall in dryland environments [5].

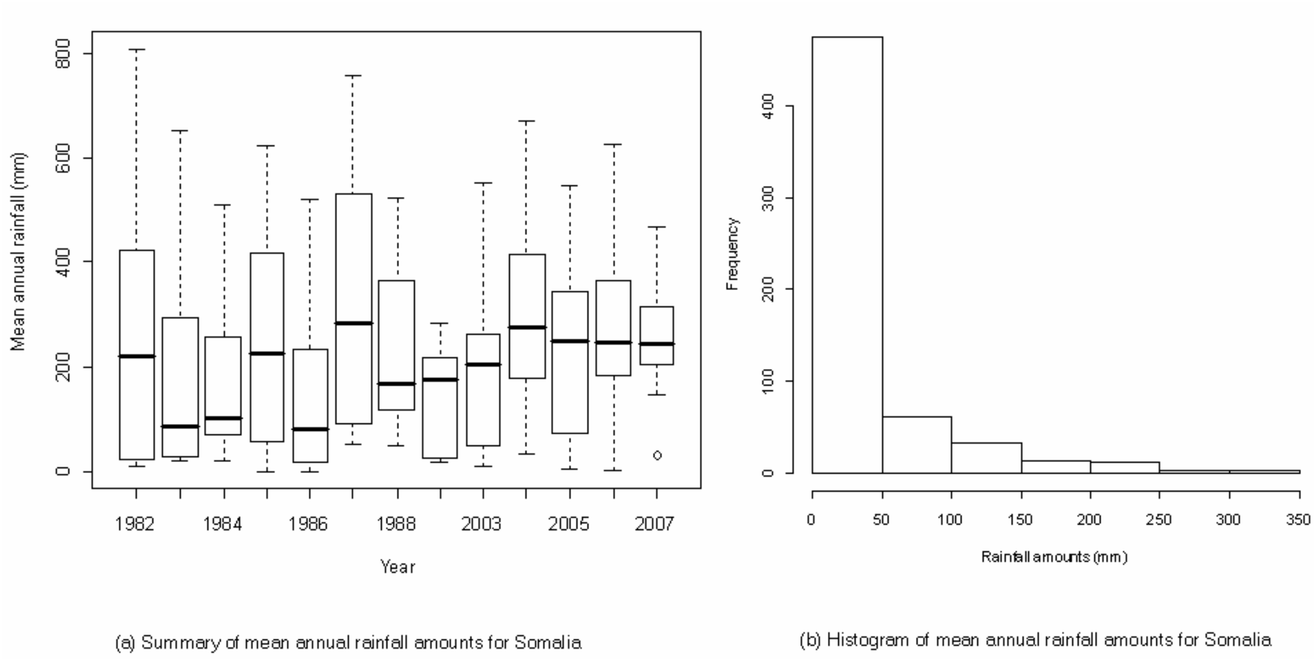


Figure 3.13: Summary of mean annual rainfall for Somalia

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 (www.africover.org). 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 [15].

3.2.4 Validation of NDVI analysis of land degradation

82 points from three areas were used to verify the outputs from the NDVI assessment of land degradation: 25 points from eastern, 46 points from western, and 11 points from southern parts of Somalia. These points were collected by FAO-SWALIM land team during land degradation assessment of western Somalia in 2007, during a study of pastoral resources of eastern Somalia in 2007, and during land cover mapping and soil survey of southern Somalia in 2006. Table 3.2 gives the guidelines used to assess evidence of loss of vegetation from these studies. In addition to the evidences from the field surveys, georeferenced photographs taken during these surveys were compared with corresponding georeferenced photographs taken by AFRICOVER in 1998. This comparison was done to check if changes during the period between 1998 and 2007 were also detected by NDVI analysis.

Table 3.2: 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

4. RESULTS AND DISCUSSIONS

4.1 The land use systems map of Somalia

The validated land use systems map had 70 units (see Map N1). Descriptions of the units in this map are given in Appendix 5. The largest land use system unit occupied about 6.6% of the country. It consisted of high-density pastoralism in which scattered oasis farming are practiced in shrublands. The smallest unit occupied 0.0007% of the country and consisted of irrigated farming in temporal water bodies.

A preliminary analysis of the LUS map showed that pastoralism and wood collection were the dominant land use types; thus giving a strong signal that the major drivers of land degradation in the country were overgrazing and loss of vegetation.

4.2 Experts assessment of land degradation in Somalia

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

The results of expert assessment of land degradation are attached in Appendix 4. They show that reduction of plant cover was the most cited direct cause of land degradation followed by excessive numbers of livestock. Other causes were excessive gathering of fuelwood, droughts, and lack of land degradation control measures. Figure 4.1 shows the general distribution of these driving forces in the country. Livestock overgrazing and excessive gathering of fuelwood seem to affect central and northern Somalia while reduction of vegetation cover affects north-eastern and southern parts of the country (Figure 4.1).

In terms of indirect causes of land degradation, lack of good governance and policy, poverty, and population pressure were the most cited. Lack of governance (law enforcement) and policy could be understandable since the country has had persistence civil war and no central government since early 1990s.

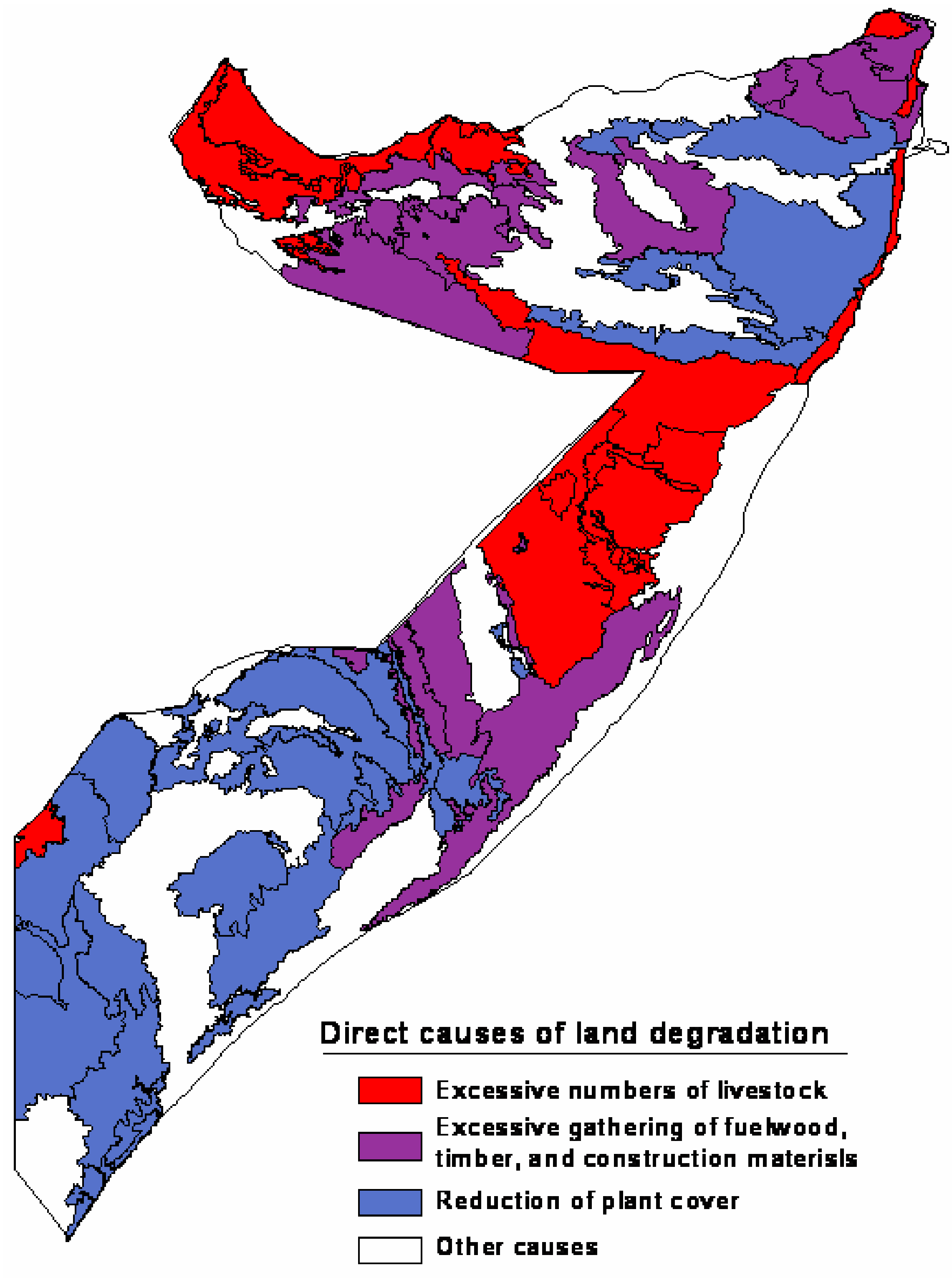


Figure 4.1: Summary of the major direct causes of land degradation in Somalia

A summary of the causes, status, impacts and responses to land degradation in Somalia using the DIPSIR model is shown in Figure 4.2.

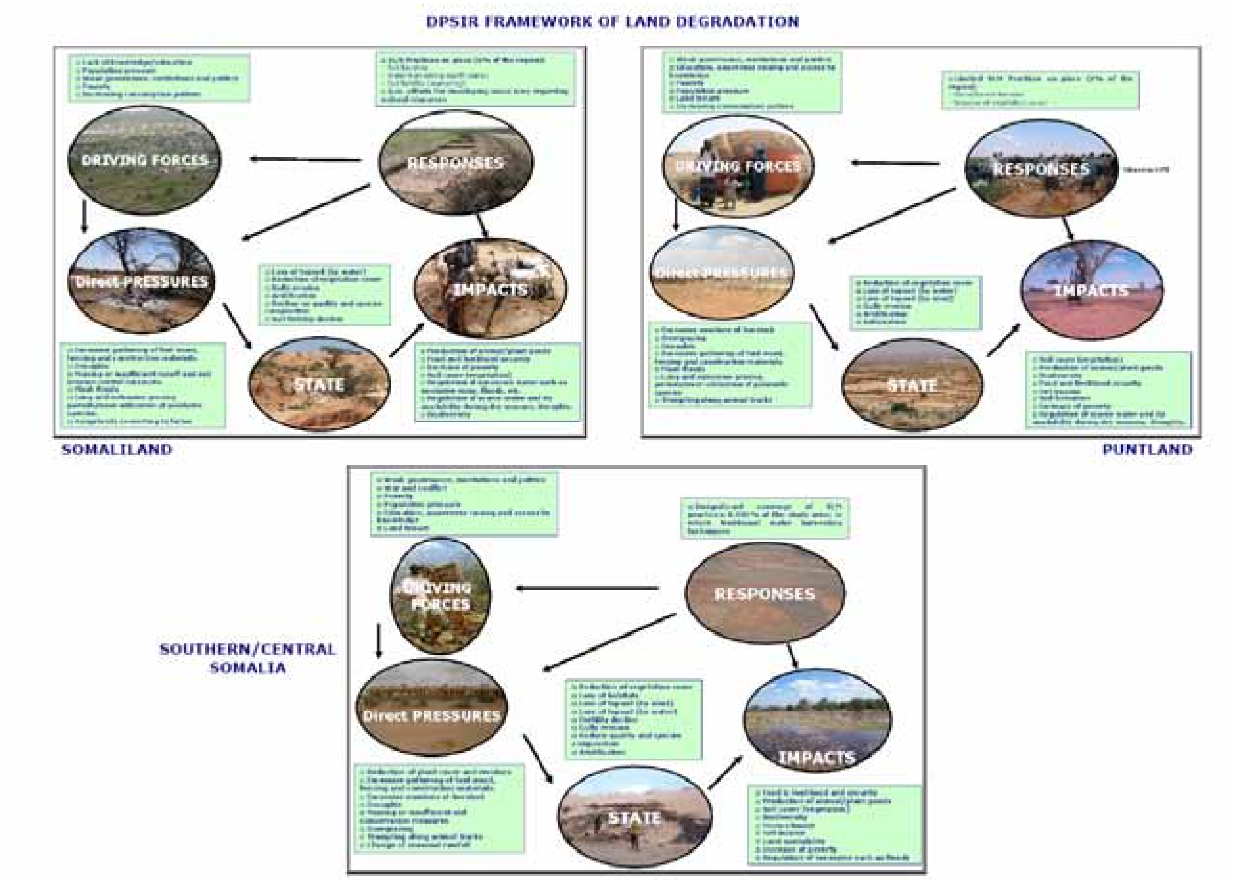
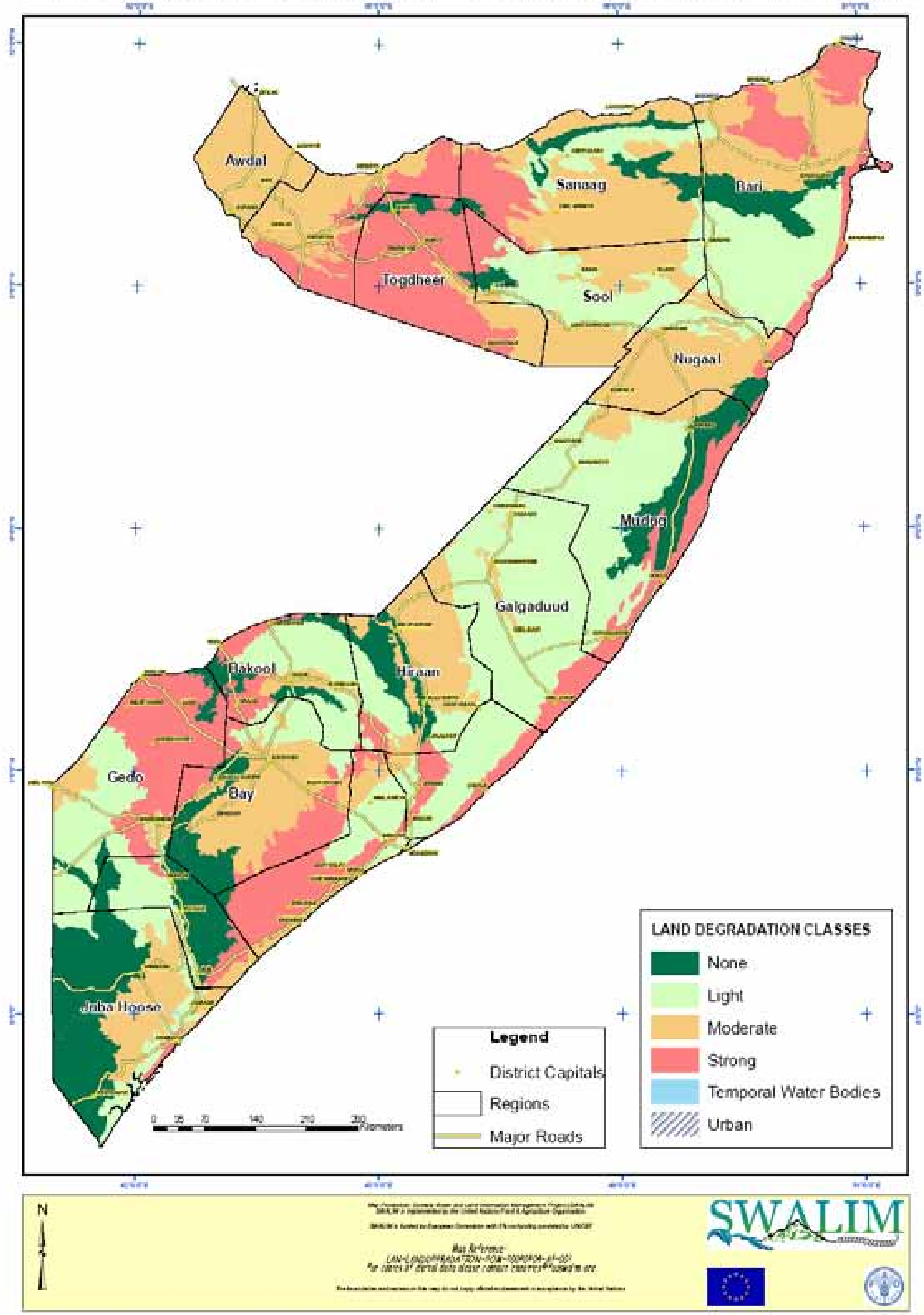


Figure 4.2: DIPSIR model for Somalia

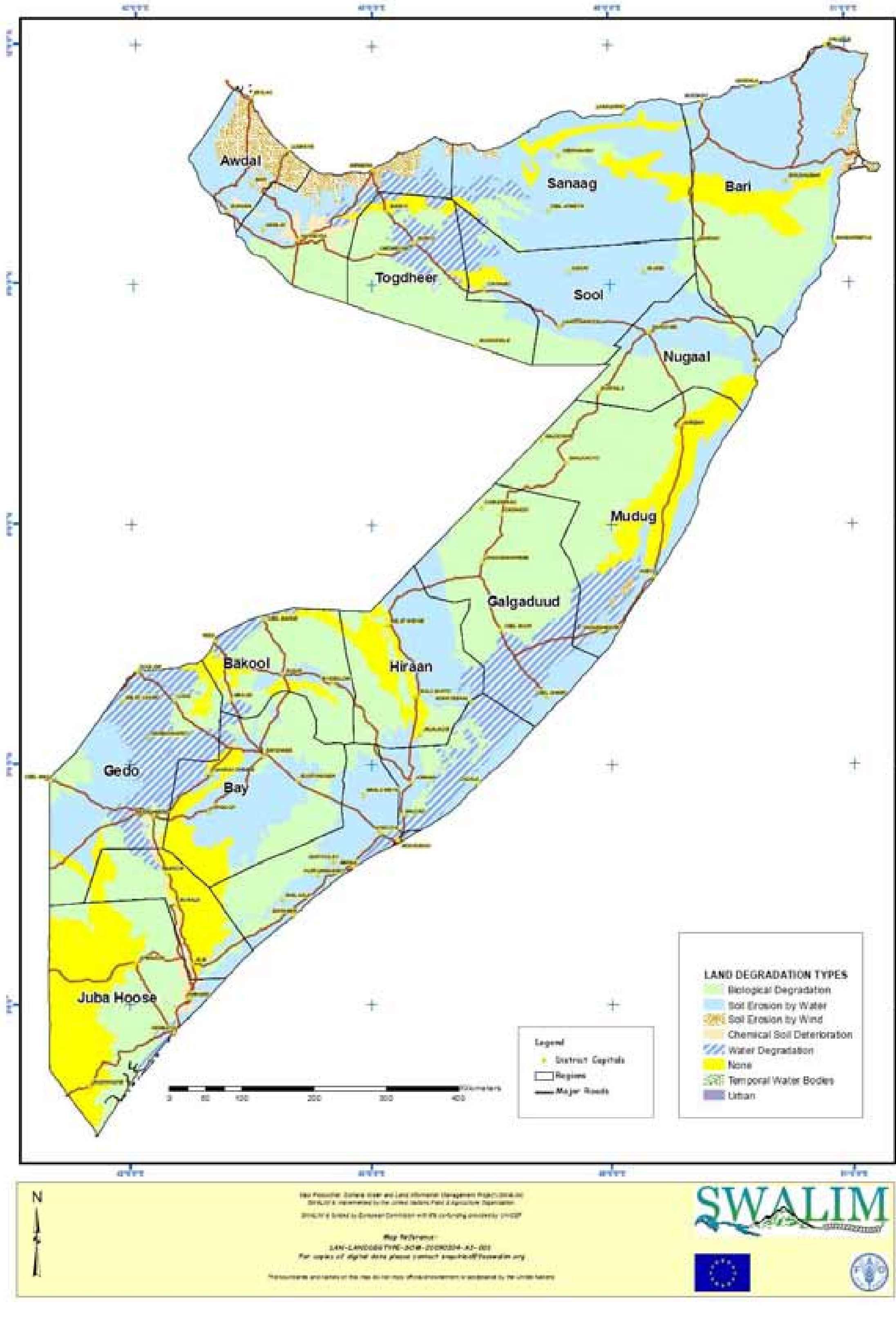
4.2.1.3 Status of land degradation

According to expert assessment, the prevalent land degradation types in Somalia were: loss of topsoil by water and wind (generally soil erosion), reduction of vegetation cover (biological degradation), gully erosion, aridification (water degradation), decline of palatable plant species, and soil fertility decline in agriculture potential areas (Map N3).

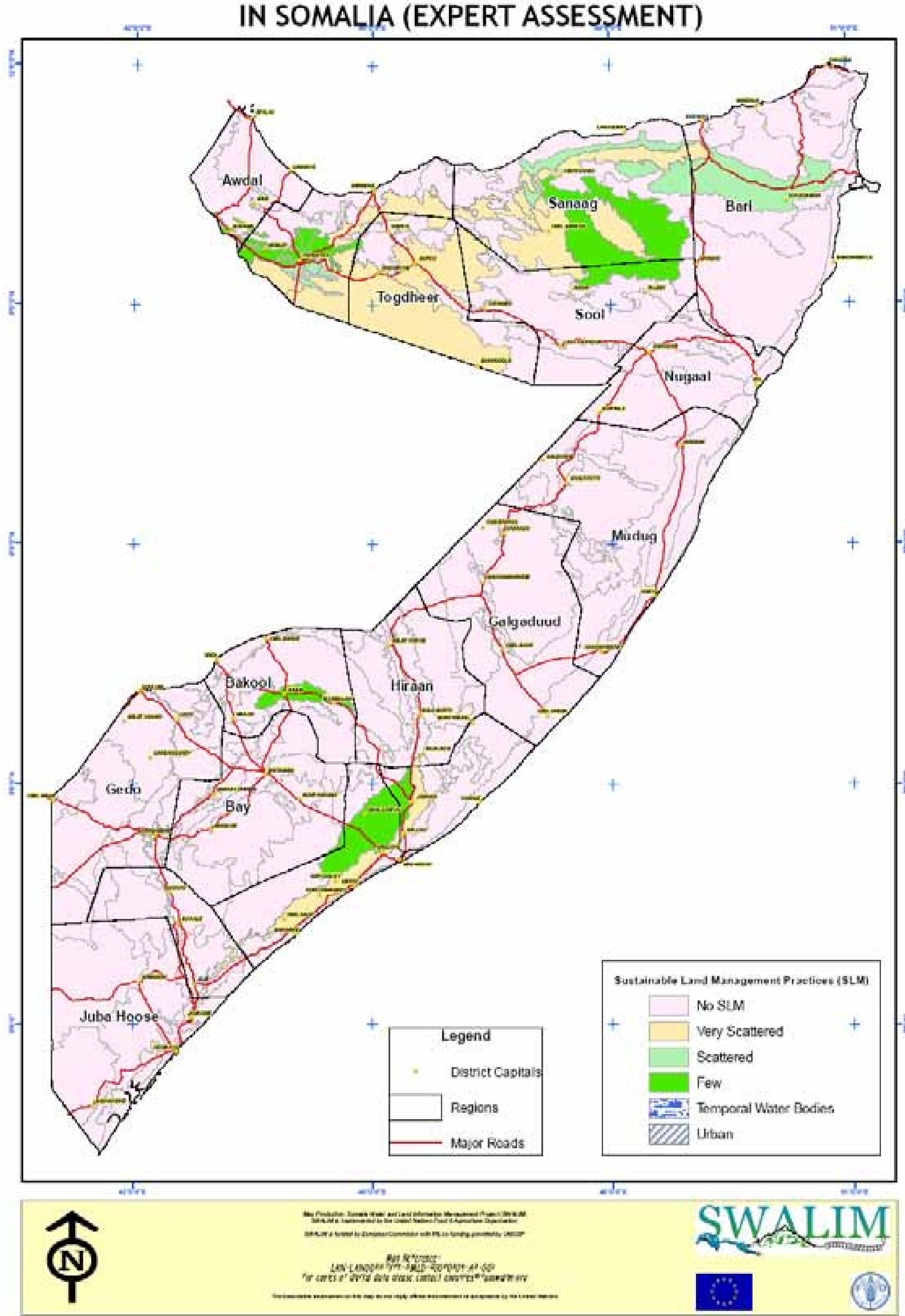
MAP N2: LAND DEGRADATION- SOMALIA (EXPERT ASSESMENT)



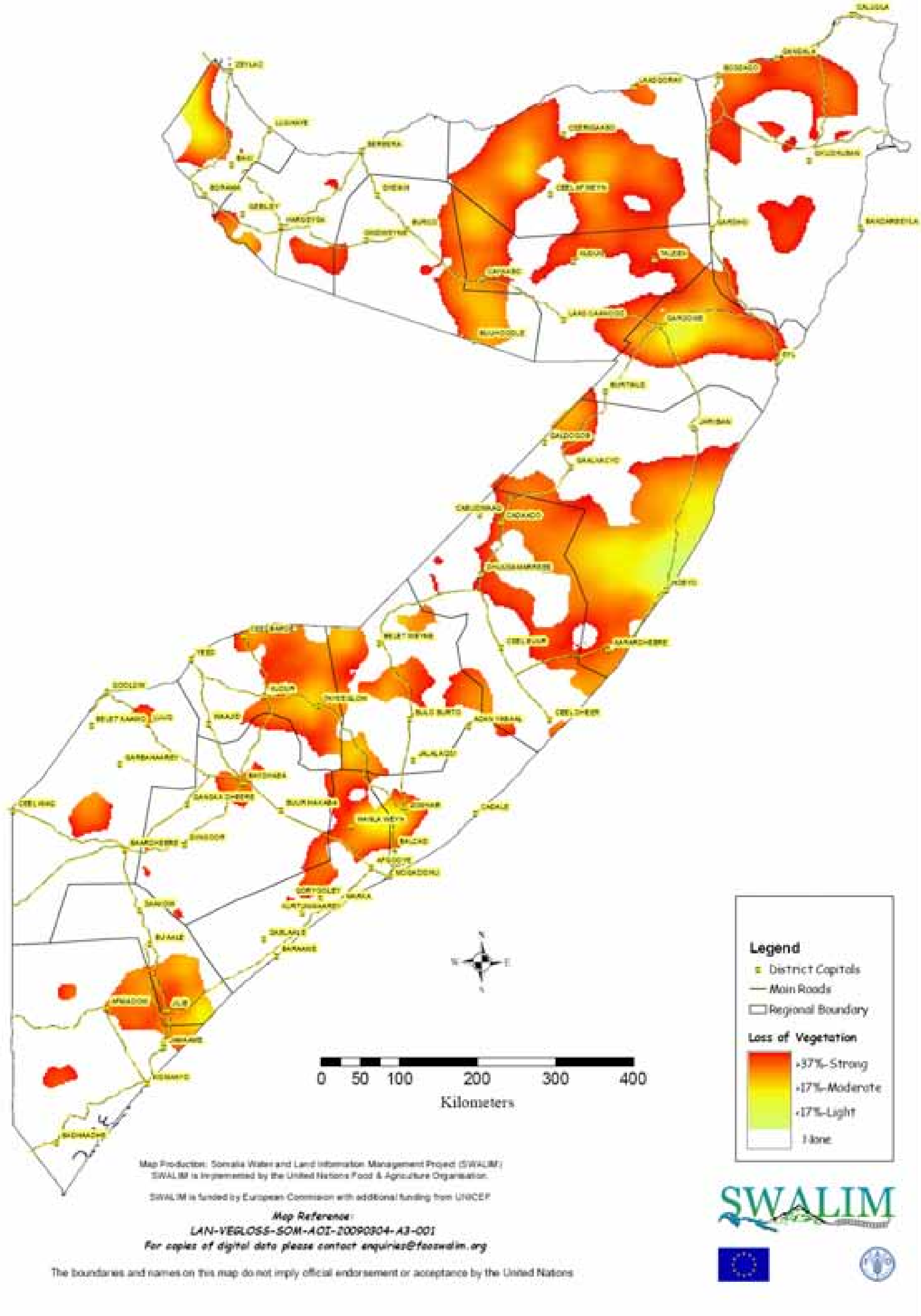
MAP N3: LAND DEGRADATION TYPES- SOMALIA (EXPERT ASSESMENT)



MAP N4: SUSTAINABLE LAND MANAGEMENT PRACTICES (SLM) IN SOMALIA (EXPERT ASSESSMENT)



MAP N5: LOSS OF VEGETATION COVER Between 1982-2008 (SOMALIA)



Although these degradation types occurred in combination in many parts of Somalia, generally loss of topsoil by wind erosion was dominant in the north, aridification was dominant in the south, and loss of vegetation in central and southern Somalia (Map N3). Loss of topsoil by water erosion covered the largest area and could therefore be said to have been the most widespread type of land degradation in Somalia (Table 4.1).

Table 4.1: Extent of prevalent land degradation types in Somalia from Map N3

Degradation Type	Area coverage (Km^2)	Area coverage (%)
Soil erosion by water	217054.73	34.11
Biological degradation	241043.73	37.89
Water degradation	68865.73	10.82
Soil erosion by wind	15766.48	2.48
Chemical soil deterioration	5429.99	0.85
Urban	175.10	0.03
Temporal water bodies	186.33	0.03
None	87717.91	13.79
Total	636240	100

The above different types of land degradation were combined to produce a composite land degradation map by expert assessment (Map N2). Table 4.2 shows areal extent of the composite land degradation in Somalia. Overall, about 27.5% of the area was considered degraded by expert assessment.

Table 4.2: Extent of land degradation in Somalia from Map N2

Land Degradation status	Area coverage (Km^2)	Area coverage (%)
None	85086.39	13.43
Light	212761.78	33.58
Moderate	195070.83	30.79
Strong	140328.06	22.15
Total	633608.50	99.95

4.2.1.4 Impacts on ecosystem services

There were varied responses from the experts with respect to the impacts of land degradation on the ecosystem services. The most identified impacts were negative impacts on productive services (negative effect on food production), negative impacts on soil services (soil services such as soil cover and soil biodiversity), and negative impacts on socio-cultural services (socio-cultural services such as provision of food and livelihood security and poverty). Figure 4.3 is a typical example of the negative impact on water bodies where upland loss of topsoil caused sediment plume into the Gulf of Aden. This example was identified by the experts and confirmed using high resolution remote sensing image.

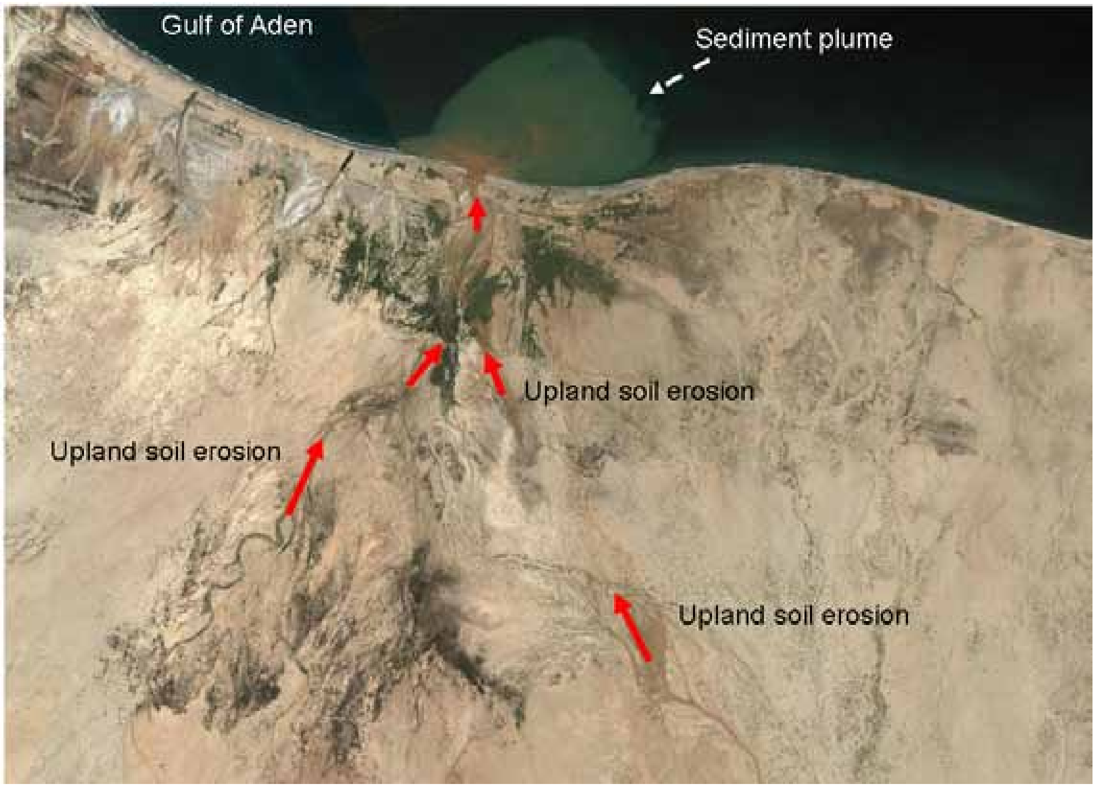


Figure 4.3: Example of impact of land degradation in Somalia

4.2.1.5 Responses to land degradation

The expert assessment identified some Sustainable Land Management (SLM) practices in Somaliland and Puntland and only hand-made soil bunds in Southern Somalia. Table 4.3, Figure 4.4, and map N4 give a summary of some of these responses and their distribution in the country. Generally, the conservation efforts are low and scattered; which cannot properly counter the widespread degradation in the country. However, some of the practices which show great potential in retarding the degradation (such as soil bunds) could be replicated or up-scaled to improve their impact in the entire country. One example of a step towards achieving this would include consistent and proper documentation of their impacts.

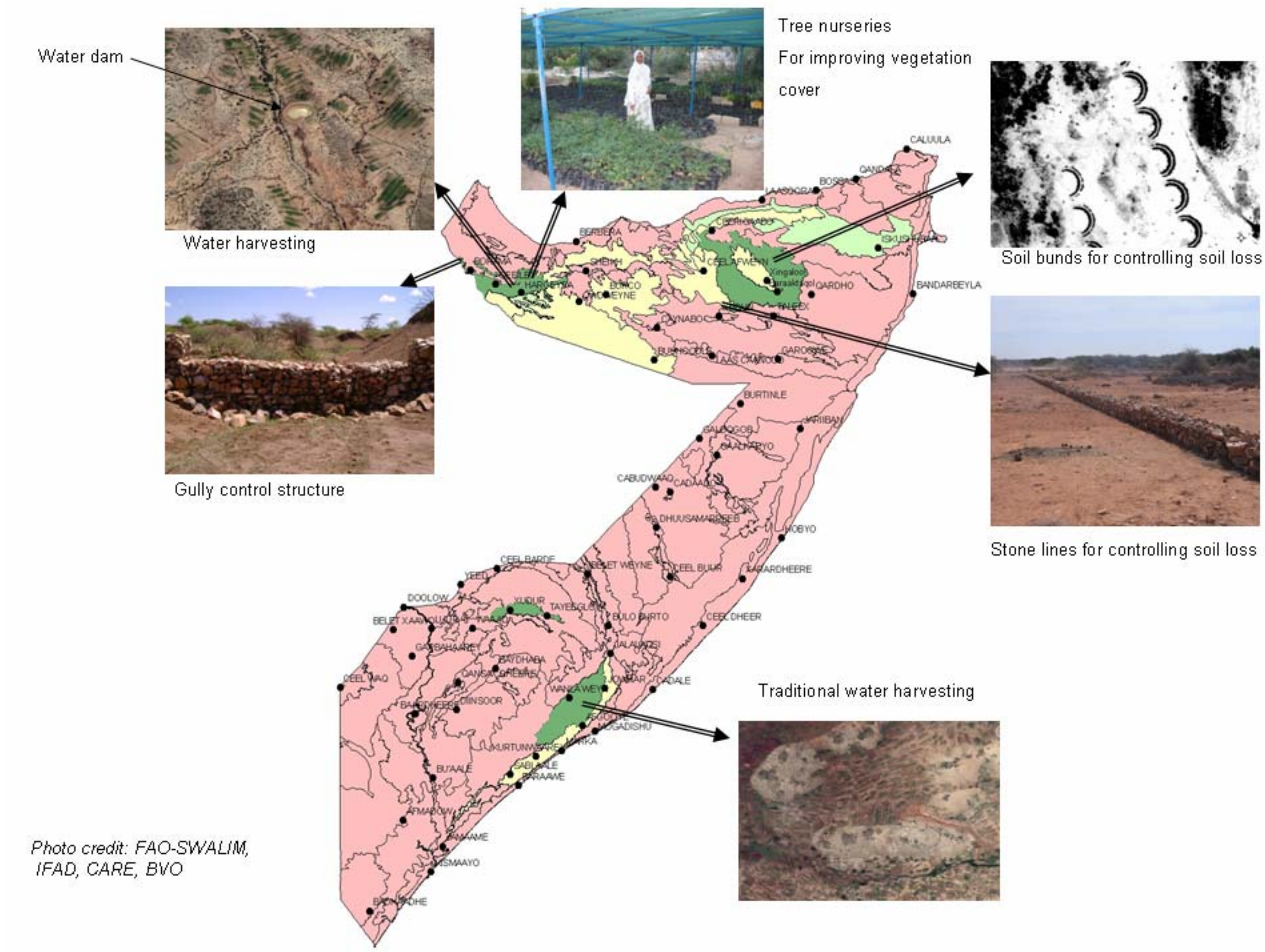


Figure 4.4: SLM responses to land degradation in Somalia

Table 4.3: Distribution of SLM practices in Somalia from Map N4

Presence of SLM practices	**Area in Km^2**	**Area (%)**
No SLM	523751.88	82.66
Very scattered	60411.07	9.53
Scattered	17959.55	2.83
Few	31124.57	4.91
Urban	175.10	0.03
Temporal water bodies	186.33	0.03
Total	633608.50	100.00

4.3 Loss of vegetation cover in Somalia

4.3.1 Identification of affected areas

Remote sensing analysis identified many places with loss of vegetation cover between 1982 and 2008 (Map N5). The central areas and north-eastern parts seem to have had the highest loss of vegetation cover compared to the other areas. Some parts of southern and north-western Somalia also had significant loss of vegetation cover. The most affected LUS classes were: unit 33 (which occupied 9.5% of the total affected areas), LUS unit 63 (8.7%), LUS unit 65 (6.5 %), and LUS unit 28 (6.2%) (Table 4.4). The dominant vegetation types in these units were grass, forbs, sparse shrubs, and short trees. Overall, NDVI-rainfall analysis identified about 34% of Somalia with significant loss of vegetation cover between 1982 and 2008.

Table 4.4: Loss of vegetation cover by land use systems units in Somalia

LUS code	Description of the LUS unit	Area affected (%)
33	Pastoralism (high density)with scattered oasis farming: shoats, camels	9.5
63	Pastoralism (medium density)/wood collection: camels, shoats	8.7
65	Pastoralism (medium density): shoats, camels, cattle	6.5
28	Pastoralism (high density)/wood collection with honey production: sorghum, camels, shoats	6.2
55	Pastoralism (medium density) with scattered oasis farming: shoats, camels, horses	5.8
24	Pastoralism (high density) with scattered oasis farming: shoats, camels, horses	4.5
5	Agro-pastoral (medium density of fields) in stabilized sand dune: cowpea, cassava, shoats, cattle, camels	4.5
22	Pastoralism (high density) in coastal plain/dunes: sheep, cattle, goats	3.7
34	Pastoralism (high density): shoats, camels, cattle	3.3
44	Pastoralism (low density)/Frankincense: goats	3.3
31	Pastoralism (high density): camels, shoats, cattle	3.1
40	Pastoralism (low density) with scattered oasis farming in a gypsiferous surface: shoats, camels, cattle	2.9
11	Agro-pastoral (medium density of fields): sorghum, cowpea, sesame, cattle, shoats	2.9
27	Pastoralism (high density)/wood collection and scattered irrigated fields: fodder, sorghum, camels, shoats	2.6
32	Pastoralism (high density): sheep, goats, camels	2.3
23	Pastoralism (high density) with scattered irrigated fields: shoats, camels, cattle	2.2

4.3.2 Validation of remote sensing method for land degradation assessment

NDVI-analysis correctly identified 63% of previously visited locations in the field as having had human-induced loss of vegetation cover. It correctly identified truly affected areas with an accuracy of 61% and non-affected areas with an accuracy of 82%. It, however, misclassified 19 degraded areas as non-degraded. Ten of these areas were located in north-eastern part Somalia, six in Southern Somalia, and the rest in north-western Somalia. The misclassification in north-eastern Somalia could have been due to selective tree cutting for charcoal production which left the tall grass intact. At 8km pixel resolution, this selective cutting of trees could not be detectable; hence causing the misclassification. In the south and in western, the misclassification was largely due to a combination of lack of proper identification of new vegetation species and coarse spatial resolution of the input NDVI images. Some vegetation species had been replaced by new ones and therefore still showed consistent NDVI response to rainfall. Field visits however identified such areas as degraded; hence resulting into misclassification.

Comparison of the georeferenced photographs taken in 1998 and the corresponding ones taken in 2007 confirmed some areas positively identified by NDVI analysis in terms of changes in vegetation cover (Figure 4.5). In figure 4.5a the photographs were taken southeast of Gabiley. They showed a notable change of vegetation cover between 1998 and 2008. This change was positively identified by NDVI as having had significant loss of vegetation (Map N4). In figure 4.5b, the photographs were taken in eastern Baki. In this case, there was no evidence of loss of vegetation between 1998 and 2007 which corresponded with NDVI analysis (Map N4). The results from these photographs show that NDVI analysis, in general, had the potential to identify human-induced loss of vegetation cover. The approach, however, did not identify other types of land degradation such as invasive plant species, chemical degradation, decline in water quality, etc. More comprehensive local assessment would be necessary to improve the outputs from the NDVI as analysis.

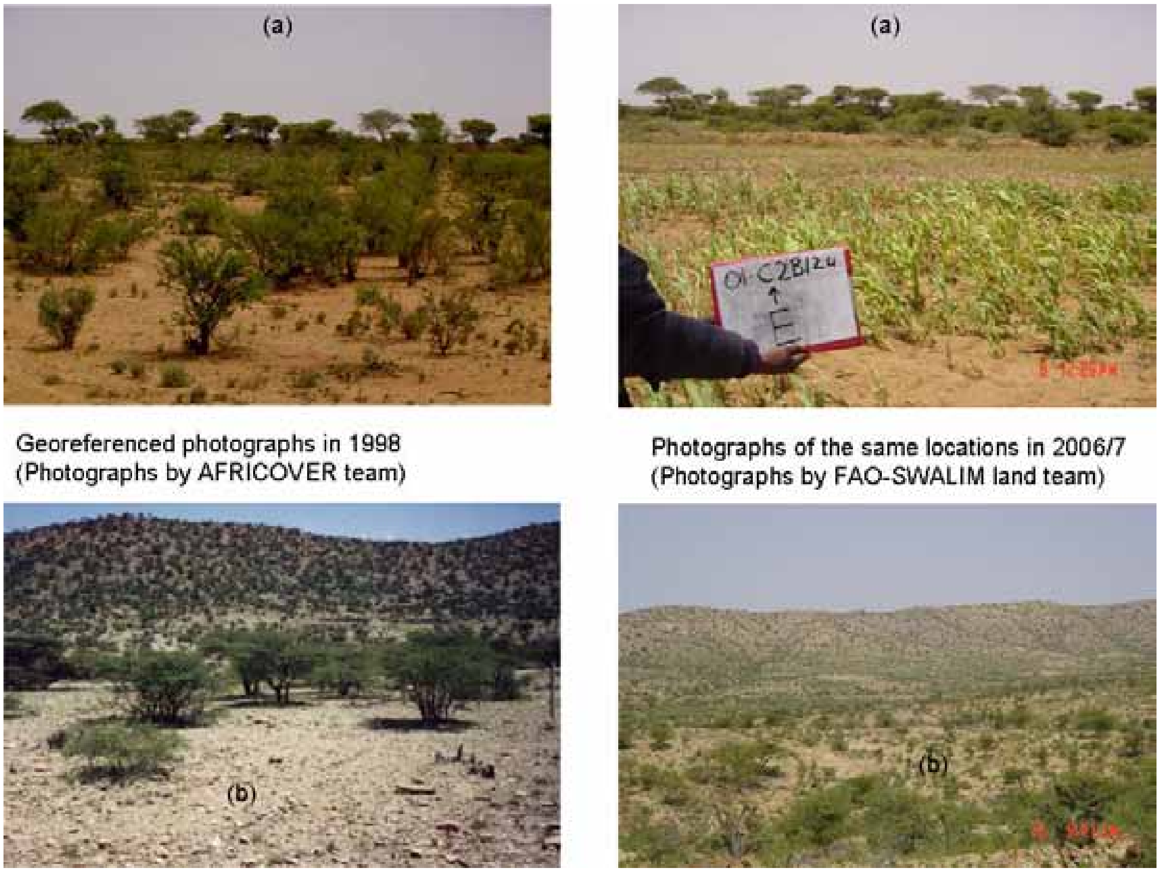


Figure 4.5: Selected photographs for validating NDVI analysis of loss of vegetation cover

4.4 Integrating results from expert assessment and remote sensing analysis of land degradation in Somalia

A comparison was made between land degradation by NDVI analysis and expert assessment. The two methods agreed for 21 cases out of 33 randomly selected test samples (i.e. 64% of the time). The concurrence between these two sources of evidence of land degradation show that: 1) Somalia could be truly having notable signs of land degradation, and 2) that expert assessment or NDVI analysis had some degree of accuracy and could reliably be used in assessing land degradation at the national level.

NDVI analysis and expert assessment also generally agreed that about 30% of Somalia was degraded between 1982 and 2008 and that the degradation was moderate on average. Figure 4.6 reflects this agreement and highlights bright and hotspots for land degradation.

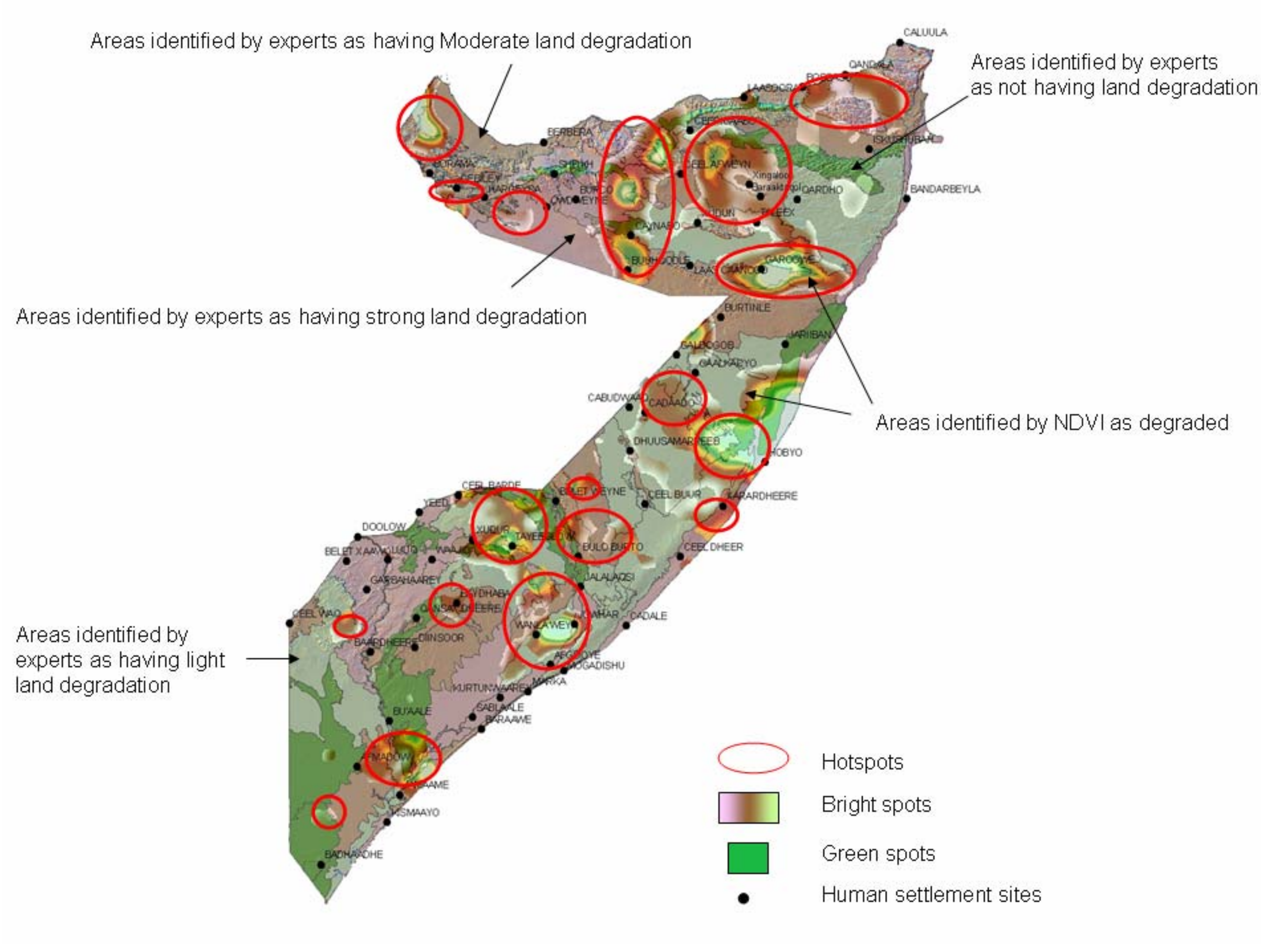


Figure 4.6: Bright and hotspots map for land degradation in Somalia

From the hot and bright spots map, the following sites in Figure 4.7 were proposed for validation of the findings obtained during the study. The geographic coordinates and district locations of the sites are given in Appendix 6.

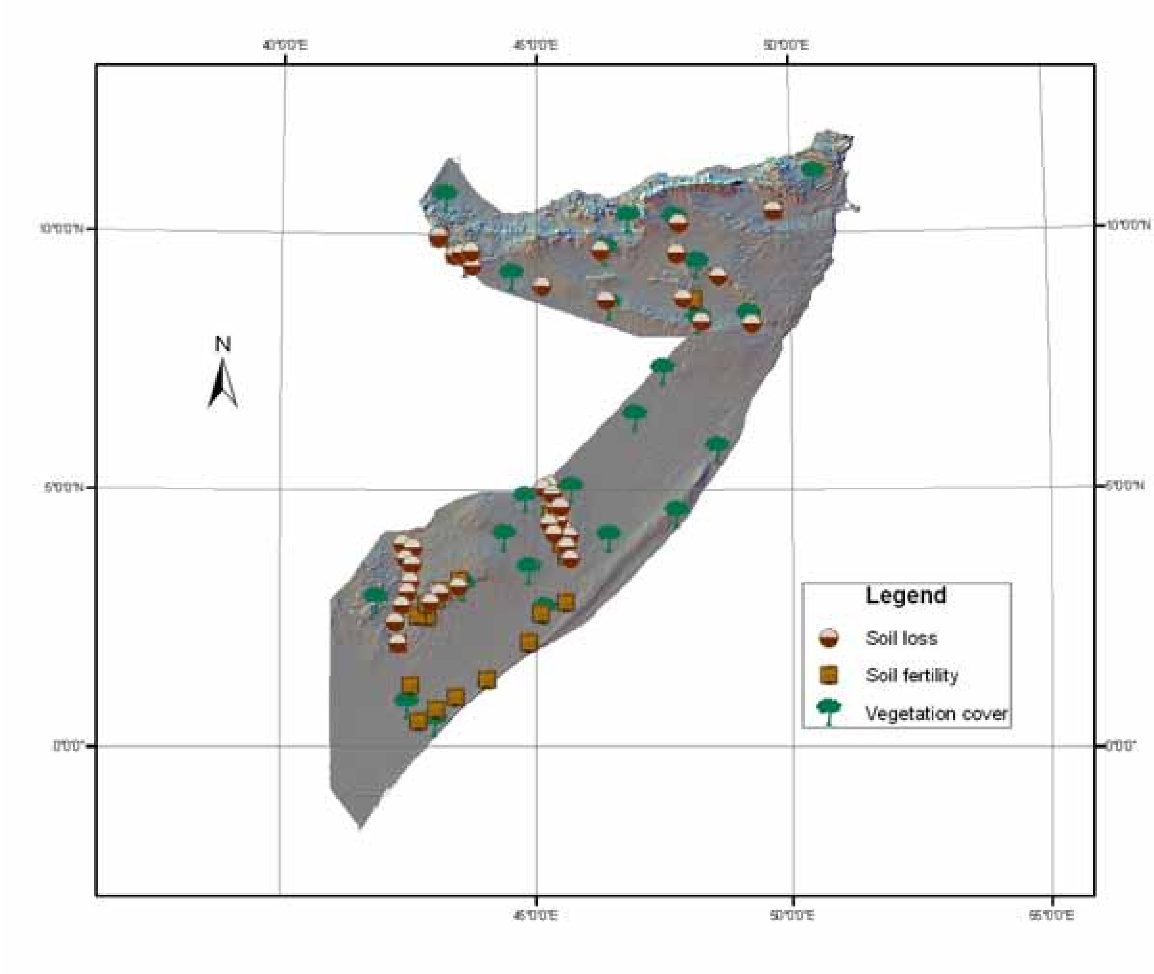


Figure 4.7: Sites for validating land degradation in Somalia

5. RECOMMENDATIONS FOR LAND DEGRADATION MONITORING FRAMEWORK IN SOMALIA

5.1 Theoretical framework for national monitoring of land degradation

The aim of national monitoring of land degradation is to identify regions of the country which are experiencing changing trends of land degradation so that they can be targeted for detailed analysis and subsequent appropriate control measures. In Somalia, the FAO-SWALIM study on land degradation generated necessary baseline information which can be the starting point for instituting a national land degradation monitoring framework. Various methods of assessment and data analysis were established and it is anticipated that if the process is periodically repeated can provide opportunity for monitoring the degradation in the country. Figure 5.1 shows how these measurements and analysis can be pieced up together to monitor changes in land degradation status.

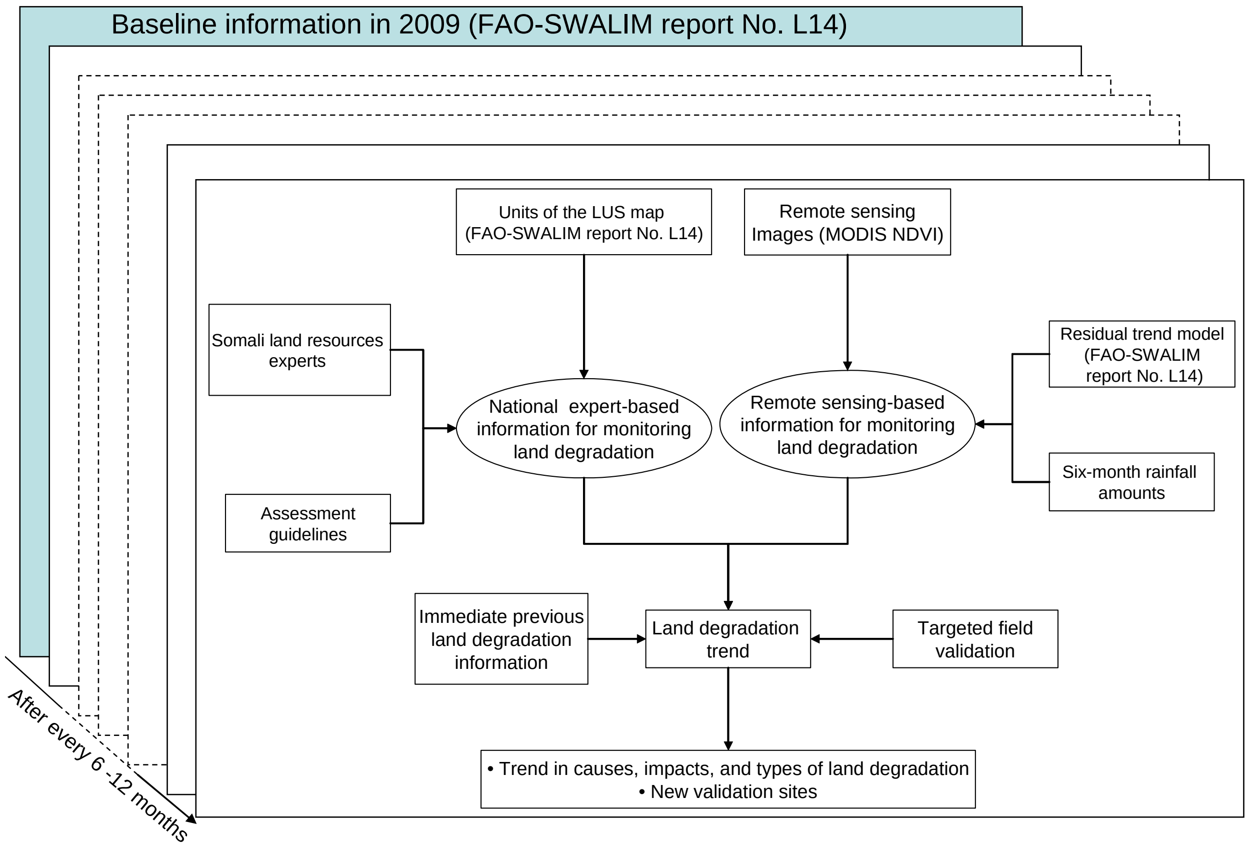


Figure 5.1: Theoretical monitoring framework for land degradation.

5.1.1 Expert-based information for monitoring land degradation

During this study on national assessment of land degradation, 28 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. Two approaches for gathering the information is recommended: 1) bringing all the experts together in a central place and letting them assess land degradation for the whole country or 2) dividing the country into three regions (northwest, northeast, and south and central Somalia) and consequently grouping the experts according to these three regions. Each group is then separately engaged to give information about land degradation trends in their region. The choice of the approach to use will depend on the security situation in Somalia and other factors which may help successful periodic monitoring of land degradation.

There are two guiding references which should be used for gathering 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 5.2). 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.

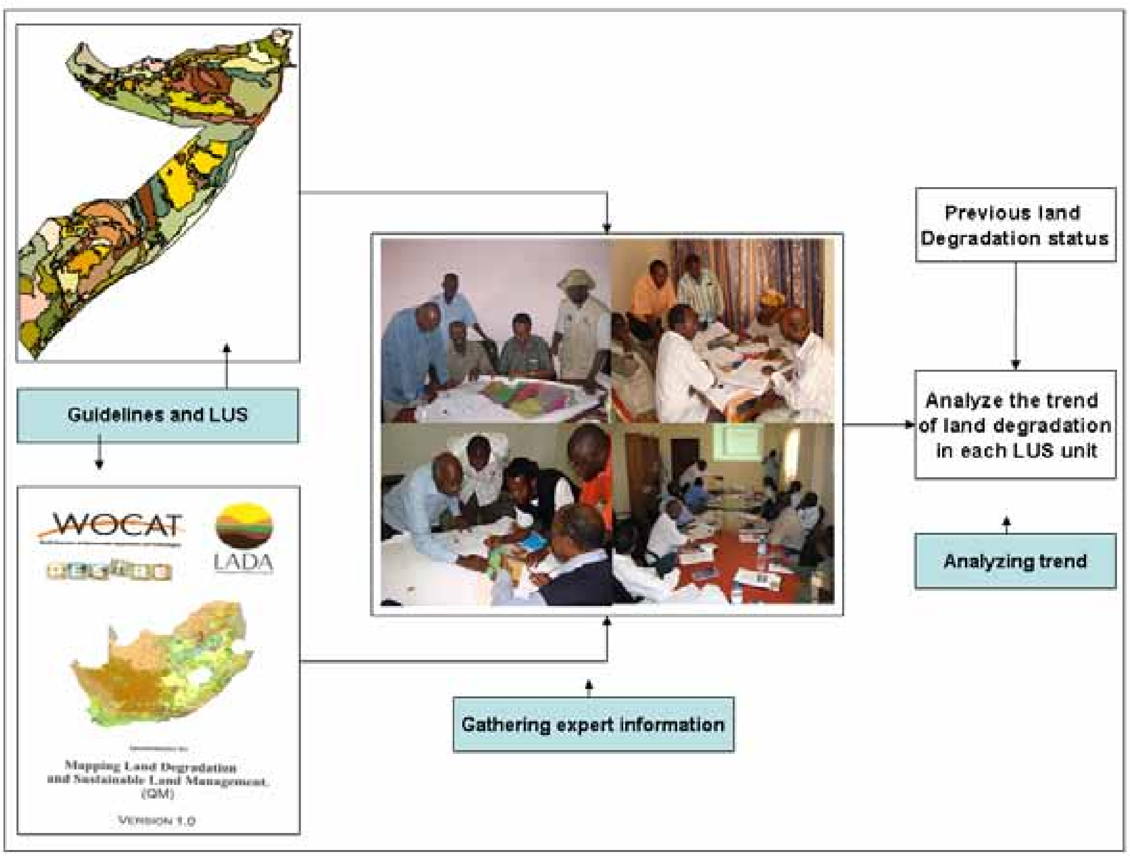


Figure 5.2: Monitoring trend of land degradation using expert opinion

5.1.2 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.

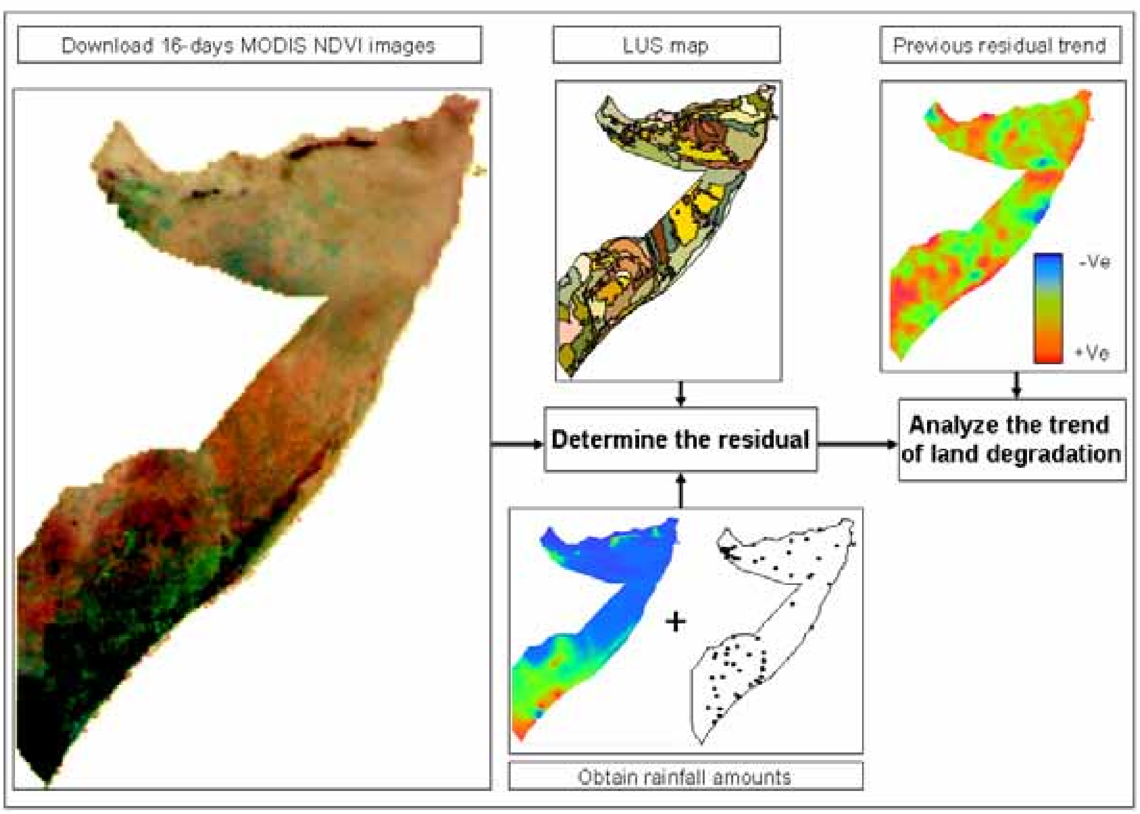


Figure 5.3: Monitoring trend of land degradation using remote sensing

5.2 Practical steps for implementing land degradation monitoring in Somalia

Implementing a land degradation monitoring framework requires (Figure 5.4):

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.

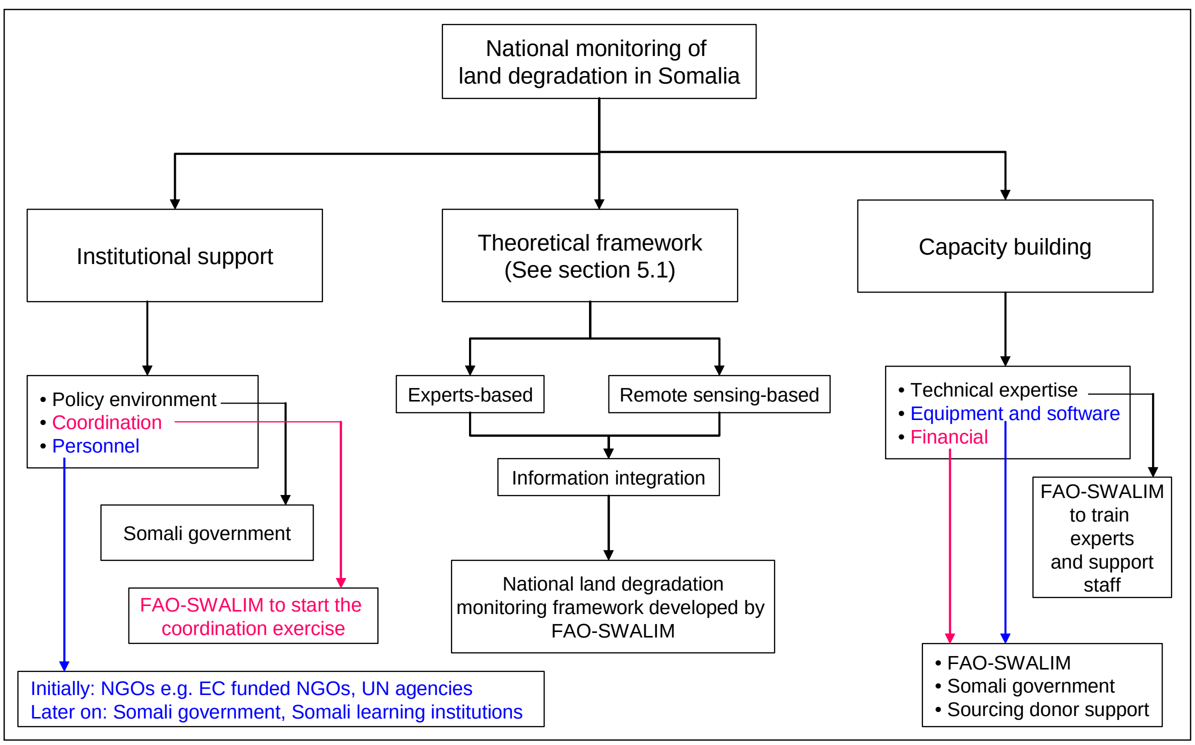


Figure 5.4: Practical steps towards implementing land degradation monitoring in Somalia

5.2.1 Institutional support

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 Somali situation is still volatile 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 Somalia 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 Somali government (Figure 5.4).

5.2.2 Capacity building

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.

5.2.3 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 Somalia. 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 5.1).

Table 5.1: proposed timeline for implementing land degradation monitoring in Somalia

Duration	Activity	Institutions
-	Obtaining the baseline information (FAO-SWALIM report No. L14)	FAO-SWALIM, Somali 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 Somalia, Somali government line ministries, Local NGOs in Somalia
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, Somali government
-	Begin the monitoring activity	FAO-SWALIM and selected contact persons for implementing the monitoring framework, Somali government

6. CONCLUSIONS AND RECOMMENDATIONS

Remote sensing analysis (of NDVI) and expert knowledge were used to assess land degradation at the national level. Remote sensing data were those obtained between January 1982 and December 2008 while expert knowledge went back in time as far as the experts could remember. In general, the two methods effectively assessed land degradation trend in Somalia in the last 26 years.

The above two methods of assessment identify about 30% of Somalia as degraded. The main degradation types identified were loss of vegetation cover, loss of topsoil, gully erosion, and loss of soil nutrient in agriculture productive areas. In the north-western region (Awdal, Waqooyi, Galbeed), the major land degradation types found during the study were reduction of vegetation cover, soil erosion (water and wind), invasive plant species, and decline in nutrient. These degradation types occur due to aridity, over-grazing, tree cutting for charcoal production and construction materials, increase of settlements and water points, continuous mono-cropping, lack of nutrient management, increase of enclosures, and encroachment of crop cultivation into marginal rangelands. In north-eastern parts (Sanaag, Togdeer, Bari, and Nugaal), the major land degradation types are loss of vegetation cover and loss of topsoil. They occur mainly due to tree-cutting for charcoal production, increase of settlements and water points, and increase of enclosures. In the central Somalia (Mudug, Galguduud, Hiran, Shabeelaha, Dhexe), the main land degradation types are loss of vegetation, invasive plant species, loss of topsoil, and salinization. The main causes of these types of degradation include tree-cutting, over-grazing, encroachment of agricultural activity into marginal areas, increase of enclosures, and excessive irrigation, and irrigation mismanagement. In the south, the major land degradation is loss of vegetation cover and soil erosion.

Although the degradation in the country is generally moderate to strong, its trend is increasing. A sustained and strategic control measures are therefore needed in the country. Already there are some sustainable land management practices which can be up-scaled to support the degradation control. For example, the soil bunds initiated by the colonial government and currently being rehabilitated or expanded to new areas by many local and international NGOs. They can be up-scaled in consultation with Somalia 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.

Apart from establishing baseline information on land degradation for future monitoring, the study also identified local spots with increasing trend of land degradation. Detailed follow-up local assessment is recommended to quantify the identified different prevalent types of degradation in the country.

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(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)

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(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 Somalia

Q 1 Mapping

QUESTIONNAIRE

Group 3 ✓

Contributing specialists (Step 1)

If several specialists are involved, write the full data of the main resource person and his/her institution below and add the name of the other person(s) with their institution(s).

Last name / surname: Libah

First name(s): Abdirizak Bashir — female / male ✓

Current institution and address:

Name of institution: Candlelight Health & Environment (CHLE) - Local NGO

Address of institution: ……

City: Hargeisa

Postal Code: ……

State or District: N.W

Country: Somaliland

Tel: 00 252 2 4427818 Fax: …… E-mail: abdirizaklibah127@hotmail.com

Permanent address: ……

City: ……

Postal Code: ……

State or District: ……

Country: ……

Other resource persons involved: / Institution:

1- Hassan Tanya Deria — UNDP/RSL

2 Mohmed Ali Aden — ministry of Water & Minerals

3 Omer H. Duale — Soil scientist / agronomist, Somaliland Ecological Society

Please confirm that institutions, projects, etc. referred to, have no objections to the use and dissemination of this information by WOCAT – LADA - DESIRE.

Date: 18/01/09

Signature: [signature]

Thank you in advance!

Please enter the information in the online database, see www.wocat.net/databs.asp or send the completed questionnaire plus any additional materials back to the respective project / programme coordinators: WOCAT: wocat@giub.unibe.ch; LADA: freddy.nachtergaele@fao.org; DESIRE WB1 coordinator: godert.vanlynden@wur.nl

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			b) Extent	c) Degree	d) Rate	g) Direct causes	f) Indirect causes	e) Impact on ESS
i	*ii*	*iii*						
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

Conservation (Step 4)														
a) Name	b) Group	c) Measure			d) Purpose	e) % of area	f)Degradation addressed			g)Effectiveness	h)Effect. Trend	i) Impact on ESS	j)Period	k)Ref to QT
Reducing run-off + Gully control	RH + W_H	S3	S6		M	3%	W_t	W_g	B_c	\	\	P_1+1, P_2+1, E_1+1 S_4+1	1940s - to date	

Expert recommendation (Step 5)	
Expert recommendation	Remarks and additional information
M	- Increase of biomass through agro-forestry - Improve range management through grazing control & Water Conservation

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: Abdirizak Bashir **Country:** Somaliland

Mapping Unit Id: 31 → (38)

Group 3

Land Use System (Step 2)		
LUS	a) Area trend	b) Intensity trend
Pastoralism (low density) with scattered irrigated fields around togas: shoats, camels	1	0

Land degradation (Step 3)								
a) Type			b) Extent	c) Degree	d) Rate	g) Direct causes	f) Indirect causes	e) Impact on ESS
i	*ii*	*iii*						
Wg			50%	2	2	s_2, f_3, e_1	h, e, g	P_{1-2}, S_{4-2}
Wr			25%	2	2	e_1, P_3	h, e, g	P_{1-2}, S_{4-2}
Ha			15%	2	2	$e_1, m_2,$	P, h, r	$P_{1-2}, P_{2-2}, S_{4-2}$

Conservation (Step 4)

a) Name	b) Group	c) Measure	d) Purpose	e) % of area	f)Degradation addressed	g)Effectiveness	h)Effect. Trend	i) Impact on ESS	j)Period	k)Ref to QT
Reducing run-off	OT*	S9*	M	1%	Wg	1	1	$P_{1}+1$, $P_{2}+1$	1950s	- to date

*Dams = Surface, Subsurface and Sand dams

Expert recommendation (Step 5)

Expert recommendation	Remarks and additional information
M	- Increase of Vegetation cover - Water conservation through dams, - Gully erosion control - Terraces - Gabions / Groyne

Appendix 2 List of participants for expert assessment of land degradation

EXPERT NAME	INSTITUTION	EMAIL ADDRESS
Puntland		
Osman Mohamed Ali	ASAL	asalorg@yahoo.com
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Mohamed Jama Hersi	Ministry of Livestock, Agriculture and Environment, Puntland	
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Mohamed Hassan Barre	CARE	_
Jama Muse Jama	CARE	_
Said Ahmed Mohamed	CARE	_
Mohamed Malable	UNDP	_
Southern Somalia		
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Abdulbari Abdulkadir Sheikh	FSAU	abdulbari51@yahoo.com
Ahmed Mohamed Jazira	FSAU	jazira5@hotmail.com
Alas Abukar Hassan	FSAU	alasabukar@yahoo.com
Nur Moalim (Madobe)	FSAU	ahmedmadobe3@yahoo.com
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Mohamed Mohamud Mohamed	DG Ministry of Agricluture TFG	min.agro@hotmail.com
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Mohamed Isse M.	Consultant	koontro12@yahoo.com
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Lewis Njeru	FAO-SWALIM Information Coordinator	lnjeru@faoswalim.org

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,

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

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,

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

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).

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

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,

$$e_j(t_i) = v * t_i + c \quad (5)$$

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.

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

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,

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

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.

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

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

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

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.

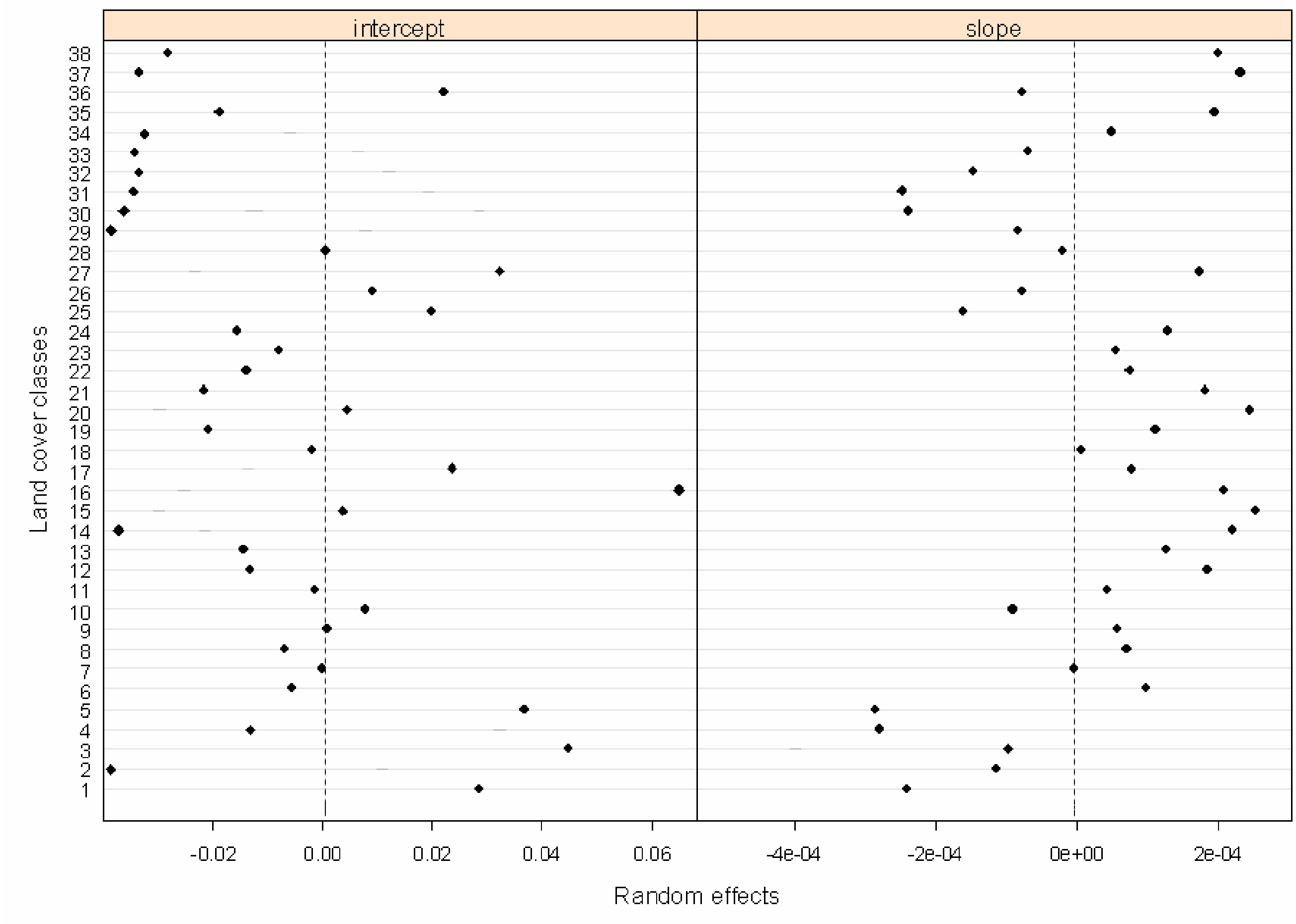

Figure A1: Typical plot of random-effects for different land cover types in Somalia

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

Appendix 4 Results of expert assessment of land degradation in Somalia

LUS	LDTpe1	LD Type	Extent	Degree	Rate	Direct causes	Indirect causes	Impact on ESS
1	W	Wt, Wg, Et, Cn	30	2	1	s5, c1, g2, c6, p3, n2	e, h	P1-2, E5-1, S4-2, S6-1
1	H	Ha, Hg	15	2	1	n2, n6	p, w	P2-1, S5-1
1	B	Bs	10	1	1	c7	w	P1-1, P3-1
2	W	Wt, Wg	20	2	2	s2, s4, c, c6, f3	p, e, h, g	P1-2, E1-2, E2-2, S4-2, S6-2
2	P	Pk	30	2	2	s2, s4, w1	p, e, h, g	E1-2, E5-2, S4-2
2	B	Bc	5	2	2	f3, c1, c6	p, e, h, g	P1-2, E4-2, E3-2, S4-2
3	B	Bc	15	1	1	s1, c4	h, e, l	s4
3	C	Cn	10	1	1	c3	o (monocropping)	o (low yield)
4	H	Ha, Hp	5	1	1	n2, n6	p, w	P1-1, S5-1
5	H	Ha	15	2	1	s1	p, w, g	P3-2, S4-1
5	C	Cn	10	2	1	c4	p, w, g	P3-2
5	B	Bc	15	2	1	e1	p, w, g, t	P3-2, E4-1, S4-1, S3-1
6	W	Wr, Wt	20	2	2	n5, n3, n2, s1, s2	p, h, e, g	p1-2, E1-2, E4-2, S4-2
6	C	Cn, Cs	5	2	2	c2, c5, s2, s1	p, h, e, g	E5-2, E6-2, S4-2
6	B	Bc	20	2	2	f3, s1, s2	p, h, e	P1-2, S4-2
7	B	Bc	35	2	2	s2, c, f2, f3, n2, w1	p, h, e, g	p1-2, E2-2, S4-2, S4-1
7	W	Wt, Wg	10	2	2	s2, c1, c6, f3, w1, n2	p, h, e	p1-2, E2-2, S4-2
7	B	Bs	35	2	2	c8, g3	g, e	E8-1, S4-2
8	B	Bc, Bh	30	2	2	c1, f4, e1, g1, g3	p, t, h, c, g	P1-1, E3-1, E4-1, E8-1, S4-1
9	B	Bs	25	2	1	c7, c8	e, g, h	P3-2, P1-1, E8-3
9	E	Et, Wt, Cn	30	1	1	s2, c1, g2, n5, n6	p, e, h, g	P1-2, P3-1, E5-2
10	W	Wt	20	2	1	s5, c1, g2, c6, p3, n2	e, h	P1-2, E5-1, S4-2, S6-1
10	W	Wg	20	3	2	s2, c1, g2, c6	e, h	P1-2, E5-1, S4-1, S6-1
10	B	Bs	5	1	1	c7	w	P1-1, P3-1
11	W	Wt	15	1	1	s2, c1, g2, c6, p3, n2	e, h	P1-2, E5-1, S4-2, S6-1
11	B	Bs	10	1	1	c7	w	P1-1, P3-1
12	W	Wt, Et, Cn	25	1	1	s5, c1, g1, g3, g4	p, c, t, g	P-1-1, P3-2, S4-1
13	W	Wt, Wg	25	2	2	s2, c1, c6, f3	p, h	P1-2, E2-2, S4-1
13	B	Bc, Cn	10	2	2	s2, c1	p, h, e	E3-2, E4-2, S4-2
13	B	Bs	2	2	2			E8-1, S4-2
14	W	Wt, Wg, Wr	20	2	1	g3	g, e, h	E8-2, S4-2
14	E	Et	3	2	1	g4	g, e, h	E4-2, S4-2
14	B	Bc	10	3	1	g5	h, e, g	E4-2, E8-1, S4-2
15	N	NA						
16	N	NA						
17	W	Wt, Wr	20	2	1	n5, n9	p, e, g	S4-1, P1-1
17	E	Et, Ha	35	2	1	n6	p, e, g	S4-1, P1-1, S8-1
18	C	Cs, Pw	10	2	0	n5	h	P1-1, E5-1, E6-1, E8-1, S4-1
18	W	Wr	5	2	1	s2, n5	t, g	P1-1, E1-1, S4-1
19	W	Wr, Wo	40	3	3	s4, c5, c9, , n5	w, g	P1-2, P3-2, S4-3, S6-2
19	C	Cn, Cs	20	2	1	s5, c5, c8, o5, n5	h, r, e	P1-2, P3-2, E6-2, S4-2
19	P	Pw, Pc	20	2	1	n5, s4, o5, c5	h, r, e	E5-2, S4-1
19	B	Bs	25	3	3	e8, g1, c9	g, e, w	P1-2, P3-3, E8-3
20	B	Bc, Bh, Bq	50	3	3	f1 (harvesting for commercial purpose)	p, t, h, e, g	E8-2, E10-1
21	N	NA						
22	W	Wc	25	3	3	s2, s3,	w, g	E4-2, S4-1
22	E	Et	20	2	2	s2, s3,	w, g	E4-1

LUS	LDTpe1	LD Type	Extent	Degree	Rate	Direct causes	Indirect causes	Impact on ESS
22	B	Bc	15	1	1	s2, s3, g4	w, g	E4-1
23	B	Bc	40	2	2	g, e1, s2	p, h, e, g	P1-2, S4-2, E2-2
23	E	Et, Ha	40	2	2	e1, g1	p, h, e, g	P1-2, E8-2, S4-2
43	H	Ha	100	2	0	c1, e1, g1, g3, o4	p, t, h, e, g, w	P1-1, E8-1, E10-1, S4-1
44	W	Wt, Et	60	1	1	n7, n6, e1, g1, g2, g3, u1	p, t, h, e, g	P1-1, E3-1, E4-1, E5-1, E6-1, E7-1, E8-1, S4-1, S5-1, S6-1
44	B	Bc	55	1	1	e1, g1, g2, g3, g4, u1	p, t, h, e, g	P1-1, E3-1, E4-1, E5-1, E6-1, E7-1, E8-1, S4-1, S5-1, S6-1
45	W	Wt, Et	80	1	1	n7, g1, g2, g4, u1, n5, n6	p, t, h, e, g	PI-2, E3-1, E4-2, E6-2, E8-1
45	B	Bc	60	1	1	e1, g1, g2, g3, g4, u1, n7, n6	p, t, h, e, g	P1-1, E3-1, E4-1, E5-1, E8-1, S4-1, S5-1, S6-1
46	B	Bc	10	1	1	c1, e1, i2, n6	w, g	E4-1, S4-1, S8-1
46	E	Et	15	1	1	c1, e1, i2, n7	w, g	E4-1, S4-1, S8-2
46	C	Cs	10	1	1		o (natural salinity)	P2-1
47	W	Wt, Bc, Wm	10	1	1	f3, s1	h, e, c, g	P1-1, E8-2
47	B	Bh, Bq, Bs	10	1	1	f3, s1, n7	h, e, c, g	P1-1, E4-2, E8-2
48	H	Ha	100	2	2	s2, c1, f2, w1, n6	p, h, g	P1-1, P2-1, E2-1, E10-1, S4-1
48	B	Bc, Bh	30	2	2	c1, e1, g3, u1, n6, n4	p, t, h, w, g	P1-2, E3-1, E4-1, E8-1, S4-1
48	E	Et	30	2	2	c1, g3, n6	p, t, h, g	P1-1, E4, S4-1
49	W	Wt, Et, Ha	40	2	1	g1, g2, g4, n7, n6	p, t, h, e, g1	P1-2, E4-1, E3-1, S4-2, S6-2
49	B	Bc	35	3	1	g1, g2, g3, g4, n6, n7	p, t, h, e, g	P1-2, E3-1, E4-2, E8-1, S4-2, S6-2
50	W	Wt	70	1	1	g1, g4, n7, n6	p, t, e, g	P1-1, E1-1, E7-1, E8-1, S1-1, S4-1
50	E	Et, Ha	60	1	1	g1, g2, g4	p, t, g	P1-1, E1-1, E7-1, E8-1, S1-1, S4-1
50	B	Bc	90	1	1	g1, g2, g4, n5, n6, n7	p, t, g	P1-1, E4-1, E6-1, E8-1, S4-1, S6-1
51	B	Bc, Bh	20	2	2	e1, g4, n4	p, h, e, g	P1-1, E2-1, E8
51	W	Wt, Wg	35	2	2	e1, g4, n4	p, h, e, g	P1-1, E2-1, E8-1, S4-1
51	E	Et, Ed	30	2	2	e1, g4, n4	p, h, e, g	P1-1, E2-1, E8, S4-1
52	B	Bc	25	2	2	e, s2, f3, c1, g1	p, h, e, g	p1-1, E2-2, S4-2, E4-2
52	W	Wt, Wg	9	2	2	n2, n5, u, s2	p, h, e, g	P1-1, E2-1, S4-1
52	B	Bs	25	1	1	g1, f3	p, g, e	P1-1, S4-2
53	B	Bc	10	2	2	c1, O	g	E4-2, E5
54	W	Wg	10	2	2	c1, e1, g3, w1, n3, n5, n7	p, t, p, g	P1-1, P2-1, E4-1, S4-1
54	B	Bc, Bh	5	2	1	c1, e1, g1, g3	p, t, p, g, e	P1-1, E3-1, E4-1, E8-1, E10-1, S4-1
55	W	Wg, Wg	16	2	1	n5, n6, g4	p, e, g	P1-1, E5-1, S4-1
55	W	Wt, Cs, Wm	15	2	1	c1, g4, n5, n6, c3	p, e, o, g	P1-1, E5-1, S4-1, E6-1
55	B	Bc, Bq, Pc	20	2	1	n5, n6	p, e, o, g	P3-1, S4-1, E5-1
56	B	Bc	10	2	1	c1, e1, g3, n6	p, t, h, g	P1-1, E1-1, S4
56	H	Ha	100	2	0	c1, n6, n7	h, g	P1-1, P2-1, E2-1, E10-1, S4-1
57	H	Ha	100	2	1	g3, n6, n7	p, t, h, g	P1-1, P2-1, E2-1, E10-1, S4-1
58	E	Ed	15	1	1	n4, g1,g2, g3	p, t, h, e, g	P1-1, E3-1, E4-1, E7-1, E8-1, S4-1, S5-1, S6-1
58	B	Bc	75	1	1	g1, g2, g3, g4, n4, n6	p, t, h, e, g	P1-1, E3-1, E4-1, E7-1, E8-1, S4-1, S6-1
58	C	Cs	70	1	1	s1, s2	p, c, t, h, e, g	P1-1, E5-1, E6-1, S4-1
59	B	Bc, Bh	1	1	1	c1, s1, f3, e1, g1, n6	h, e, t	P1-1, S4-1
59	W	Wt	1	1	1	c1, g1, n6	h, e, t	P1-1, S4-1
60	W	Wg	12	2	3	n3, n6, n5, g3, c1	c, e, h, g	P1-2, P2-2, E4-2
60	W	Wt, Et	20	2	3	c1, g3	h, e, g	S4-2, S6-2, E8-3, E4-2
60	B	Bc	18	2	2	g3, g4	h, g, e	P1-2, P2-2, S4-2, S6-2, E4-2
61	B	Bc, Bh, Bq	10	2	1	c1, e1, g1, g3	p, t, h, w, g	P1-1, E3-1, E4-1, E8-1, E10-1, S4-1
62	B	Bc, Bh, Bq	30	2	2	c1, e1, g1, g3	p, t, h, e, w, g	P1-1, E3-1, E4-1, E8-1, E10-1, S4-1
63	W	Wt, Wq	10	2	2	e1, g1, n6, c1	p, w, g, e	P1-2, E3-1, E5-1, E8-2, S4-2
63	B	Bc, Bq	20	2	2	e1, g1, n6, c1	p, w, g, e	E8-2, E3-1, E4-1
63	B	Bs, Bh, Et	17	1	1	c1, e1, g1	o, e, g	P1-1, S4-1, E3-1
64	B	Bc, Bh, Et	10	2	1	c1, f4, e1, g1, g3	p, t, h, e, g	P1-1, E3-1, E4-1, E8-1, E10-1, S4-1

LUS	LDTpe1	LD Type	Extent	Degree	Rate	Direct causes	Indirect causes	Impact on ESS
65	B	Bc, Bq	10	1	1	g3, g4	h, e, g	E8-1
65	W	Wt, Wg	10	1	1	c6	c, h, e, g	E4-1
65	B	Bh, Pc	10	1	1	c6	c, h, e, g	E4-1, E8-1
66	W	Wt, Wg, Et	15	1	1	s2, c1, c8, e1, g1, p3, n2, n7	w, e, g, p	P1-1, E3-1, E5-1, E8-1, S4-1
66	W	Wo, Ed	10	1	2	s2, c1, e1, g1, n8	g, e, w	S8-2, P3-1
66	B	Bc, Bh	30	3	3	s2, c1, e1, g1, n6	p, g, w, e	P1-2, E4-1, E5-1, E8-2
67	W	Wr, Wo, Wg	30	2	1	s4, c5, g2, n5	p, h, e	P1-1, P3-2
67	C	Cn, Cs	20	1	1	c5, s5, c8	p, h, r, e	P1-2, P3-2, E6-1, S6-1
67	B	Bs	40	2	2	c8, g1	e, g, h	P1-2, P3-2, E8-3
68	E	Et	5	1	1	s2	p, g	E3-2
68	C	Cn	10	1	1	c3	r	E5-1
68	B	Bc	10	1	1	c1	p, g	B2-1

Appendix 5: Description of land use systems map for Somalia

Land Use Systems for Somalia

Land Use System Code	Land Cover	Climate	Region / District	Landform / Soil	Livelihood	Land Degradation problem	Soil and Water Conservation
1	Woodland/ Rainfed Crop Fields/Irrigated Fields	Semiarid with good rainfall	Bay region/ Baydhabo, Qansaxdheere and Diinsoor districts	Plain with fertile clay soil	Agro-pastoralism (high density of rainfed fields grown with mainly sorghum); medium density of livestock cattle & goats	Water erosion (gulley) in scattered areas	No soil and water conservation interventions
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		
3	Shrubland/Rainfed Crop Fields	Semiarid with good rainfall	Middle Shabelle region/ Jowhar and Balcad districts	Amid stabilized sand dunes and floodplain, Loamy sand, loam and clay soils	Agro-pastoralism (low density of rainfed fields of sorghum & cowpea); Livestock, cattle and goats	Increasing farming, reduction of vegetation cover	
4	Woodland	Semiarid	Bay, Bakool Gedo regions/ Baydhabo, Qansaxdheere, Baardheere, Waajid, Luuq	Pediment and planations surface, marginal loamy sand and sandy clay soils	Agro-pastoralism (low density of rainfed fields, sorghum,) and low density livestock, shoats, camels & cattle	vegetation slightly declining, frequent droughts	No soil and water conservation interventions
5	Rainfed Crop Fields	Arid to semiarid	Mudug, Galgaduud, Middle Shabelle, Banaadir and Lower Shabelle	Sub-coastal stabilized sand dune plain with sandy soils	Agro-pastoralism (medium density of rainfed fields: cowpea, cassava) and livestock keeping (shoats, cattle, camels)	Aridification, soil fertility decline, reduction of vegetation cover for fuel wood and fencing	No soil and water conservation interventions
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
8	Shrubland/ woodland/ Rainfed Crop Fields	Semiarid	Hiiraan, Middle Shabelle and Lower Shabelle and Middle Juba regions/ east Jalalaqsi and east Jowhar, and Southwest Baraawe and north east Jilib districts	Alluvial plain, fertile loamy clay, dark clay soils	Agro-pastoralism (medium density of rainfed fields maize, cowpea, millet); medium density livestock, cattle, goats	Increasing reduction of tree cover due to tree cutting	No control intervention of woodland destruction

9	Woodland/ Rainfed Crop Fields	Slightly arid	East Gedo region/ Baardheere district	Alluvial plain, loamy and clay soils	Agro-pastoralism (medium density of rainfed fields producing sorghum integrated with livestock, cattle, camels & goats)	Declining soil fertility; soil loss by water and wind; shrinking farming and bush encroachment with invasive species mainly Prosopsis juliflora	No soil and water conservation interventions
10	Shrubland/ Rainfed Crop Fields	Semiarid with relatively good rainfall	Bay region/ Buurhakaba district	Alluvial plain, with good fertile clay soil	Agro-pastoralism (medium density of rainfed fields grown with sorghum); medium density livestock, cattle, shoats & camels	Soil erosion by water (sheet, rill and gully), bush encroachment in abandoned fields, slight decline in soil fertility, migration of farmers	No soil and water conservation interventions
11	Woodland/ Rainfed Crop Fields	Semiarid with relatively good rainfall	Middle Shabelle, Lower Shabelle and Bay region	Alluvial plain , Clay loam and clay soil	Agro-pastoralism (medium density of rainfed fields grown with sorghum, cowpea, sesame,); livestock mainly cattle and shoats	Bush encroachment in abandoned fields, migration of farmers due to insecurity	soil bunding for water harvesting and control runoff and soil erosion
12	Rainfed Crop Fields	Semiarid	Bakool region/Waajid, Xudur and Tiyeglow districts	Pediment, sandy clay to clay soils	Agro-pastoralism (medium density of rainfed fields, growing sorghum, maize); Livestock rearing, shoats, camels and honey production	Soil fertility decline, removal of woodland cover, increasing bare land	Soil bunding for harvesting
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		
15	Woodland/Rainfed Crop Fields	Semiarid with relatively good rainfall	Gedo, Middle Juba, Bay and Lower Shabelle	Alluvial plain, loamy and clay soils	Agro-pastoralism (medium density rainfed farming maize, sorghum integrated with livestock mainly cattle and shoats		
16	Woodland	Semiarid with relatively good rainfall	Middle Juba region/ Bu'aale and Jilib districts	Alluvial plain, clay loam to clay soil	Pastoralism (Dry season grazing for cattle, shoats; wood collection	Tsetse fly infested; high incidence of malaria; less population density; increasing tracks	No soil and water conservation interventions
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

18	Irrigated Fields/Shrublands	Semiarid with good rainfall	Middle Juba and Lower Juba region/ Bu'aale, Jilib and Jamaame	Floodplain, clay loam to clay soil	Agro-pastoralism: Irrigated farming (cereals, fruits, vegetables) and livestock mainly cattle	Tsetse fly infested; high incidence of malaria; less population density	
19	Irrigated Fields/Shrublands	Semiarid with good rainfall	Hiiraan, Middle Shabelle, Lower Shabelle, Middle Juba regions/ Jalalaqsi, Jowhar, Balcad, Afgooye, Awdheegle, Marka, Jannaale, Qoryooley, Kurtunwaarey, Sablaale, Baraawe and Jilib	Floodplain, with fertile clay loam and clay soils	Agro-pastoralism Irrigated farming along Shabelle floodplains (cereals, fruits, vegetables) integrated with livestock mainly cattle	Exodus of labour force	
20	Mangroves	Variable climate condition	Lower Juba	Remnant patches along southern coast of Somalia	Wood collection for firewood and construction material	High loss of tree cover	No soil and water conservation interventions
22	Sparse Vegetation	Arid with variable rainfall amount	Nugaal and Mudug regions/ Eyl, Jeriiban and Hobyo districts	Coastal plain of fixed dune with sandy soils	Pastoralism (high density livestock of sheep, cattle, goats)	overgrazing, soil erosion by wind	No recent soil and water conservation interventions
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	
25	Shrubland/Rainfed Crop Fields	Semiarid with good rainfall	Bay region/ Baydhabo district	Dissected plain, with variable types of soils, stony red loamy clay, dark clay or stony soils	Agro-pastoralism (high density livestock, camels, shoats)/ wood collection with sparse rainfed/irrigated fields	Increasing reduction of tree cover due to tree cutting for fuelwood	
26	Shrubland	Semiarid with relatively good rainfall	Middle Juba and Lower Juba regions/ Saakow	Alluvial plain, clay loam or clay soils	Agro-pastoralism (high density livestock, cattle, camels, shoats)/ with sparse flood recession farming	Overgrazing	No soil and water conservation initiatives
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
28	Woodland	Arid	Bay, Bakool and Hiiraan regions/ Ceelbarde, Xudur, Tiyeglow, Waajid, Baydhabo and Buurhakaba	Plateau, variable soils, shallow to deep clay soils or gravel, stony or rocky soils	Pastoralism (high density livestock, camels, shoats)/ wood collection with honey production; small rainfed sorghum production; wood collection	Vegetation slightly decreasing, overgrazing problems	No soil and water conservation interventions

29	Shrubland	Semiarid with good rainfall	Bay region/ Diinsoor, Qansaxdheere and Buurhakaba districts	inselbergs and Dissected alluvial plain	Pastoralism (high density livestock, camels, shoats, cattle)/wood collection with scattered rainfed fields: sorghum,	Reduction of tree cover due to cutting; Soil erosion by water (sheet, rill and gully)	No soil and water conservation interventions
30	Woodland	Semiarid with relatively good rainfall	Middle Juba and Lower Juba regions/ Xagar, Afmadow, Jilib, Kismaayo and Badhaadhe districts	Alluvial plain, loam, clay loam or clay soils	Pastoralism (high density livestock, cattle, shoats, camels)/wood collection with scattered rainfed fields	Deforestation, overgrazing; decline of biodiversity	No soil and water conservation interventions
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)		

42	Shrubland	Arid	Hiiraan region/Baladweyne and Buulo-Barde districts	Undulating terrain, shallow gravel or stony and rocky soils	Pastoralism (low density of livestock/ shoats & camel) with scattered rainfed fields: sorghum, cowpea	Reduction of vegetation cover, increase of bare soil, soil erosion by water, drought and aridification	No soil and water conservation interventions
43	Shrubland	Slightly arid	Lower Juba region/ Kismaayo district	Coastal plain/stabilized sand dune alternating patches of barren mobile dunes, sandy soils	Pastoralism (low density livestock of shoats, camels, cattle)/ scattered flood recession fields (in depressions) with maize, pulses, sesame,	Low soil fertility; tree cutting for charcoal; rapid decline of land cover	No soil and water conservation interventions
44	Shrubland	Arid, good rainfall due to high altitude	Bari/ Boosaaso, Qandala, Puntland	Golis Mountain/ rocky and stony soils	Pastoralism (low density livestock/ goats), frankincense production	reduction of vegetation cover, soil erosion by water	No conservation intervention

44	Shrubland	Arid, good rainfall due to high altitude	Bari/ Boosaaso, Qandala, Puntland	Golis Mountain/ rocky and stony soils	Pastoralism (low density livestock/ goats), frankincense production	reduction of vegetation cover, soil erosion by water	No conservation intervention
45	Woodland	Arid with very low rainfall	Bari/ Caluula and Qandala, Puntland	Golis Mountain range/rocky and stony shallow soils	Pastoralism (low density livestock/ shoats)Frankincense /Oasis farming		No conservation intervention
46	Grassland	Arid	Galgaduud region/ Ceelbuur district	Undulating rocky soils	Pastoralism (low density Livestock/ shoats, camels)/ Quarries in a rocky surface	Reduction of vegetation cover, increase of bare soil, soil erosion by	No soil and water conservation interventions

						water and salinization	
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

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

48	Shrubland	Arid with low rainfall	Gedo region/ Balad-Xaawo, Garbaharrey, Doolow and Luuq districts	Hill complex and dissected pediment, shallow stony and rocky soils	Pastoralism (low density livestock, shoats, camels & cattle)/wood collection with scattered rainfed and irrigated fields	Reduction of vegetation cover, overgrazing, soil erosion by wind and water, expanding Invasive Prosopsis juliflora, recurrent drought	No soil and water conservation interventions
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
50	Shrubland	Arid with low rainfall	Nugaal, Bari regions/ Eyl, Bandarbayla and Iskushuban districts	Coastal plain, stony grave and rocky soils	Pastoralism (low density livestock mainly shoats; fishing	flash flood and wind action; drought; over-utilization of palatable species	No soil and water conservation interventions

50	Shrubland	Arid with low rainfall	Nugaal, Bari regions/ Eyl, Bandarbayla and Iskushuban districts	Coastal plain, stony grave and rocky soils	Pastoralism (low density livestock mainly shoats; fishing	flash flood and wind action; drought; over-utilization of palatable species	No soil and water conservation interventions

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
53	Woodland	Semiarid with good rainfall	Hiiraan, and Middle Shabelle regions/ Jalalaqsi, Aadan-Yabaal and Cadale districts	Stabilized sand dune, sandy soils	Pastoralism (low density livestock, shoats, cattle & camels)	Reduction of vegetation cover, overgrazing, increase of bare soil, soil erosion by wind and water	No soil and water conservation interventions
54	Woodland	Arid with low rainfall	Gedo region/ Eastern Ceel-Waaq district	Hill complex and dissected pediment, shallow to deep loam or clay loam soil	Pastoralism (medium density livestock, shoats, camels, cattle) with scattered rainfed/irrigated fields: sorghum, vegetables,	Increasing reduction of vegetation cover, overgrazing, water erosion (gulley) in some areas, recurrent drought, sedentarization	Water erosion (gulley) in scattered areas

						and increasing water points	
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
56	Woodland	Semiarid	Bay, Bakool and Gedo regions/ Xudur, Waajid, Bardaale and Luuq districts	Pediment and depressions, variable soils, shallow stony and clay soils in depressions	Pastoralism (medium density livestock, camels, shoats) with sparse rainfed fields	Reduction of tree cover, overgrazing, drought, and aridification	No soil and water conservation interventions
57	Woodland/Rainfed Crop Fields	Semiarid	Gedo, Middle Juba, Bay and Bakool Regions/ Saakow, Baardheere, Qansaxdheere, Buurdhuubo and Waajid districts	Hill complex and dissected pediment	Pastoralism (medium density livestock, shoats, & camels) with sparse rainfed fields: sorghum	Reduction of vegetation cover, overgrazing, soil erosion by wind and water, recurrent drought, land use conflict	No soil and water conservation interventions
58	Shrubland	Arid with very low rainfall	Bari region/ Caluula district, Puntland	Coastal area /soils mostly gravel, stony and/or rocky	Pastoralism (medium density livestock/ goats), oasis farming of dates	reduction of vegetation cover, increase of bare soil and soil erosion by wind	No conservation intervention
59	Woodland	Arid	Hiiraan, Bakool and Gedo regions/ Baladweyne, Jalalaqsi, Ceelbarde, Waajid and Luuq districts	Plain, shallow gravel, stony and rocky soils	Pastoralism (medium density Livestock, camels, shoats, cattle)/ gum and resins extraction	reduction of vegetation cover, overgrazing	No soil and water conservation interventions
	Shrubland	Arid	Bakool	Plain, loam to clay soil	Agropastoralism (medium density livestock/goats and camel)/sorghum production	Reduction of vegetation cover, soil nutrient depletion	No soil and water conservation interventions
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
61	Shrubland	Slightly arid	Lower Juba region/ south Kismaayo district	Coastal plain/ stabilized sand dune, sandy soils	Pastoralism (medium density livestock of shoats, cattle, camels)/wood collection with scattered rainfed fields: maize and sesame,	Reduction of vegetation cover, soil erosion by wind	No soil and water conservation interventions

Appendix 6: Proposed sites for validating land degradation in Somalia

Site	Region Name	District Name	Degradation type	X	Y
1	Awdal	Borama	Chemical degradation	293310.8093	1098829.983
2	Woqooyi Galbeed	Gebiley	Chemical degradation	351394.6391	1071434.262
3	Woqooyi Galbeed	Gebiley	Chemical degradation	327008.8914	1068357.403
4	Woqooyi Galbeed	Gebiley	Chemical degradation	325150.1649	1063467.803
5	Woqooyi Galbeed	Gebiley	Chemical degradation	339593.3711	1061630.186
6	Awdal	Borama	Soil loss	293310.8093	1098829.983
7	Woqooyi Galbeed	Gebiley	Soil loss	351394.6391	1071434.262
8	Woqooyi Galbeed	Gebiley	Soil loss	325150.1649	1063467.803
9	Woqooyi Galbeed	Gebiley	Soil loss	339593.3711	1061630.186
10	Bay	Baydhaba	Soil loss	336658.7327	358153.2181
11	Bay	Diinsoor	Soil loss	268428.2925	278640.5791
12	Bay	Baydhaba	Soil loss	300125.8986	335051.573
13	Bay	Diinsoor	Soil loss	245863.8949	280252.3218
14	Bay	Qansax Dheere	Soil loss	265742.0547	305502.9572
15	Bay	Qansax Dheere	Soil loss	285082.9669	315173.4133
16	Shabelle Dhexe	Jowhar	Soil loss	566338.4304	308787.5513
17	Hiraan	Bulo Burto	Soil loss	568568.8989	409530.3806
18	Hiraan	Bulo Burto	Soil loss	556673.0667	438526.4717
19	Hiraan	Belet Weyne	Soil loss	533624.8917	499864.3567
20	Shabelle Hoose	Wanla Weyn	Soil loss	512063.6958	284252.3973
21	Shabelle Hoose	Baraawe	Soil loss	396079.3314	142245.8998
22	Shabelle Hoose	Afgooye	Soil loss	486785.0523	223286.257
23	Shabelle Hoose	Baraawe	Soil loss	326934.8065	104327.9346
24	Juba Dhexe	Jilib	Soil loss	285671.1384	77562.31201
25	Juba Dhexe	Jilib	Soil loss	247009.6836	52655.41325
26	Juba Dhexe	Bu'aale	Soil loss	228794.1904	129234.8333
27	Gedo	Baardheere	Soil loss	202772.0574	221427.5332
28	Sool	Laas Caanood	Soil loss	841863.5575	966230.6288
29	Bari	Iskushuban	Soil loss	1015399.542	1158299.582
30	Togdheer	Burco	Vegetation loss	629582.5795	932728.8366
31	Sanaag	Ceerigaabo	Vegetation loss	875557.5033	1067621.096
32	Sanaag	Ceerigaabo	Vegetation loss	820071.2712	1097302.896
33	Sool	Laas Caanood	Vegetation loss	845281.1828	950568.6604
34	Woqooyi Galbeed	Hargeysa	Vegetation loss	347512.8938	1042092.017
35	Woqooyi Galbeed	Hargeysa	Vegetation loss	448129.1131	1015134.04
36	Awdal	Borama	Vegetation loss	285723.7656	1141500.259
37	Sool	Taleex	Vegetation loss	865181.6575	1009821.447
38	Sanaag	Ceerigaabo	Vegetation loss	756020.1293	1160600.808
39	Sool	Caynabo	Vegetation loss	668008.6472	1004363.37