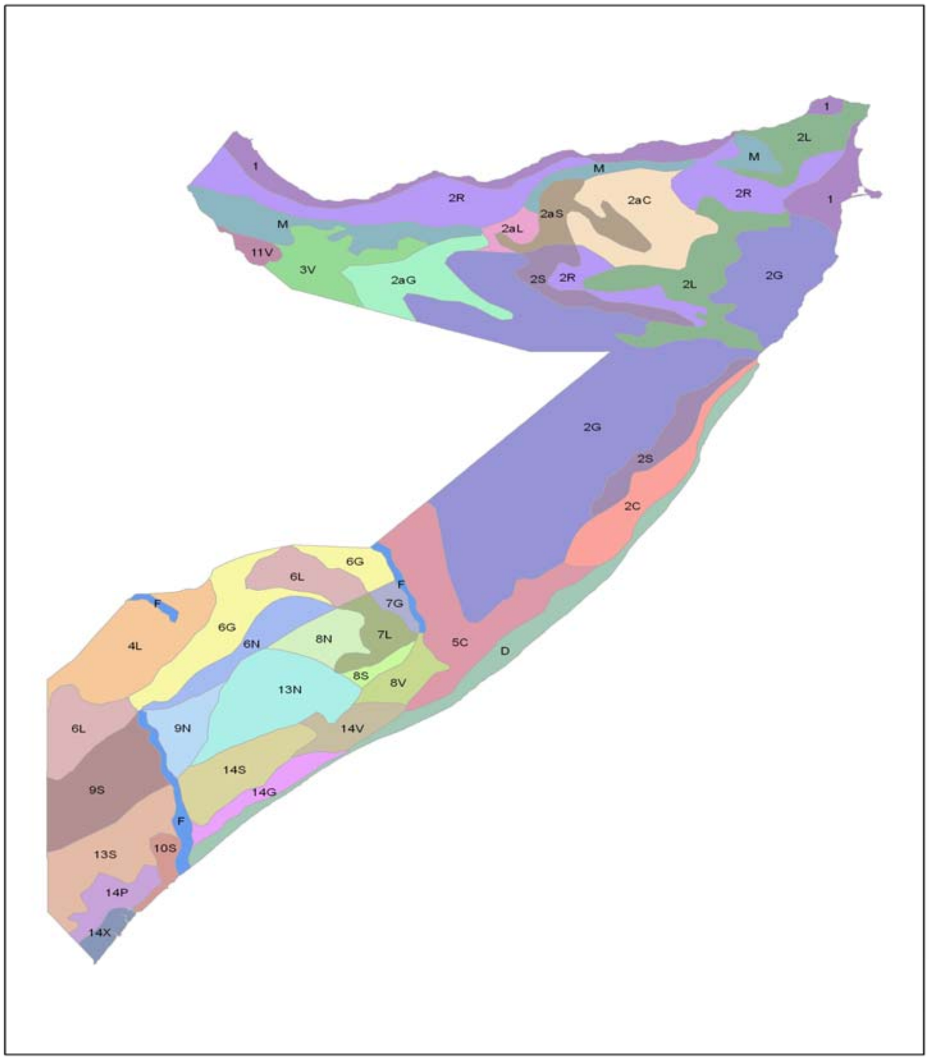
SWALIM

Land Resources Assessment of Somalia



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List of acronyms

AEZ	Agro-Ecological Zone
ALES	Automated Land Evaluation System
AOI	Area of Interest (study area)
FAO	Food and Agriculture Organization
FSAU	Food Security Analysis Unit
GIS	Geographical Information System
GP	Growing Period
ISRIC	International Soil Resources Information Centre
LADA	Land Degradation Assessment
LCCS	Land Cover Classification System
LGP	Length of Growing Period
LUT	Land Use Type
masl	meters above sea level
NAOI	Northern Area of Interest (SWALIM study area)
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
P	Precipitation
PAOI	Puntland Area of Interest (SWALIM study area)
PET	Potential Evapotranspiration
RBU	Resource Base Unit
SAOI	Southern Area of Interest (SWALIM study area)
SOMALES	Somalia Automated Land Evaluation System
SOTER	Soil and Terrain database
SWALIM	Somalia Water and Land Information Management
UNDP	United Nations Development Programme
VCI	Vegetation Condition Index
WOCAT	World Overview of Conservation Approaches and Technologies
WRB	World Reference Base for soil resources

Acknowledgments

This report is based on work by the SWALIM "Land Team", which was headed by Ronald Vargas for 18 months. Technical information and analysis was derived from SWALIM Land Reports, authored by Ronald Vargas, Paolo Paron, Laura Monaci, Michele Downie, Simon Oduori, Prof. Musse Alim, Christian Omuto Ambrose Oroda and Lewis Njeru.

Antony Ndubi, also part of the Land Team, greatly assisted with the preparation of the maps.

Land resources assessment is one of many activities of SWALIM, all executed and brought together under the excellent guidance of Dr Zoltan Balint, SWALIM Chief Technical Advisor.

1 INTRODUCTION

1.1 The need for structured information on water and land resources

During the conception of SWALIM it was recognized that to ensure that water and land resources are developed and managed sustainably, a strategic overview of these resources was required, based on structured, up-to-date, and location specific information. Existing information had been largely lost during years of conflict in Somalia (FAO-SWALIM, 2003).

Similarly, it was acknowledged that stakeholders supporting the rehabilitation and development of rural production systems are faced with a lack of structured information on water and land resources (Project Document, SWALIM phase II).

Soil mapping, land capability assessments, studies on farming systems, irrigation and water management, and soil conservation and water harvesting were undertaken during the 1980s under various projects by World Bank, IFAD (*Ed: in full – not on acronym list*) and USAID (*Ed: ditto*) in the North-west, Bay, and other regions of the country (FAO-SWALIM, 2003). SWALIM managed to recover a large part of this information and added it to its information database. However, a lot of the recovered information is incomplete, incompatible and/or out of date.

During phase II of the project, SWALIM initiated a systematic survey and inventory of water and land resources in Somalia. With respect to land resources, efforts were concentrated largely on three "study areas", chosen in consultation with local authorities. These areas are located in western Somaliland, Puntland and southern Somalia respectively (Map 1).

1.2 Purpose of report

The purpose of the present report is two-fold:

1. to summarize and consolidate the main findings of the various land resource surveys and studies carried out in the three study areas;
2. to give a generalized assessment of the land resources of the whole country, based on existing data (notably on climatic and soils) as well as on recent SWALIM data.

1.3 Structure and content of report

Chapter two gives an overview of the land resources for the whole country. The main focus is on the agricultural[1] potential of the country and is expressed through the delineation and description of agro-ecological zones. This chapter includes information not presented in any other SWALIM reports.

Chapters three and four provide a physical land suitability assessment of the two main SWALIM study areas in western Somaliland and southern Somalia, respectively. They contain information extracted from detailed SWALIM reports on the same subject.

Chapter five is a summary of research done in the study area in Puntland, dealing with the applicability of remote sensing techniques for the assessment of pastoral resources.

Chapter six describes some of the results of a land degradation assessment in the SWALIM study area in western Somaliland.

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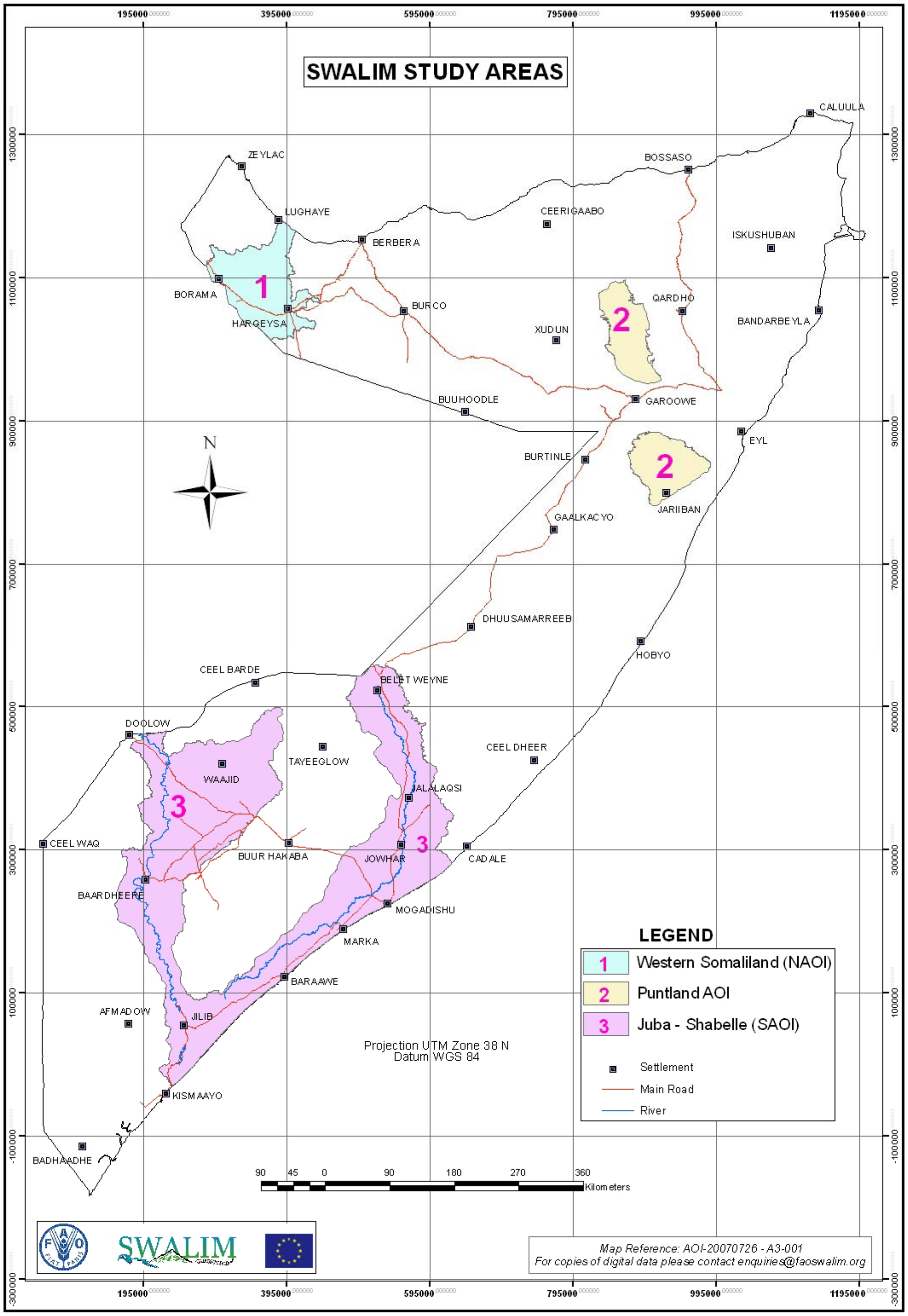
[1] The term "Agriculture" as used in this report encompasses crop production, livestock production, and agro-forestry

Chapter seven lists all major data, maps and publications concerning the land resources of Somalia, both from SWALIM and from other sources.

Chapter eight summarizes the conclusions and recommendations.

Map 1: SWALIM study areas



2 AGRO-ECOLOGICAL ZONES OF SOMALIA

Agro-ecological zones (AEZ) are land resource mapping units, defined in terms of climate, landform and soils, and/or land cover, having a specific range of potentials and constraints (FAO, 1996). The purpose of Agro-ecological zoning is to give an inventory and overview of the physical agricultural potential of an area.

Agro-ecological zones for Somalia have been defined and mapped through a combination of information on soils, landform and climate. Information on soils and landform was mainly derived from the Soil and Terrain (SOTER) Database for northeastern Africa (FAO, 1998), updated with recent information from the SWALIM study areas. Available data on rainfall and potential evapotranspiration (FAOCLIM, 2001) has been used to define Length of Growing Period Zones (LGP Zones), as described in the following sections.

2.1 Length of Growing Period for Somalia

2.1.1 Methodology

The **Length of Growing Period** (LGP) is the period (in days) that moisture supply exceeds half potential evapotranspiration[2] (P > 0.5PET). The LGP is calculated over a whole year and may consist of one or more "**normal**" or "**intermediate**" **Growing Periods** (GP), whereby a normal GP is a period in which P exceeds full PET (P>PET) and an intermediate GP a period in which P exceeds half PET, but is less than PET (0.5PET<P<PET).

Monthly[3] rainfall (P) and potential evapotranspiration (PET) data for 49 stations throughout Somalia were derived from the FAO Climatic Database (FAOCLIM, 2001). Data used span the period 1961-1990. More recent data are also available, but they are inconsistent and fragmented and not suitable for a nationwide LGP analysis.

For each station, monthly P/PET and P/0.5PET was calculated and the number and lengths of normal and intermediate growing periods established.

A classification of all stations was made, based on the number and length of intermediate[4] growing periods and the length of the dry-weather interval in case of a bi-modal rainfall pattern. For stations with a total GP of less than 30 days, a further differentiation was made on the basis of mean annual rainfall and altitude. Such a differentiation was needed because the LGP characterization does not sufficiently highlight existing rainfall patterns and agricultural potential in some arid areas. In this manner, 15 LGP zones were defined and mapped for the whole of Somalia.

2.1.2 Rainfall variability

Although potential evapotranspiration is fairly constant from year to year, rainfall varies considerably, both in terms of total annual rainfall and seasonal rainfall. Table 1 shows the rainfall variability within the main growing season (Gu) for each LGP zone. Table 2 gives the variation in annual rainfall. The estimates of rainfall variability for each zone is based on data from a few rainfall stations, as indicated in Tables 1 and 2. Table 2 also classifies annual rainfall variability for each of the zones in qualitative terms of "low", "medium" and "high".

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[2] It also includes the time required to evapotranspire up to 100 mm of stored soil moisture. This soil moisture storage has not been included in the present assessment, as all growing periods in Somalia are of an "intermediate" nature in which full water requirements are rarely met and little moisture is stored in the soil.

[3] Dekadal data, if available, would be more appropriate for a more accurate calculation of LGP.

[4] Most, if not all, Growing Periods in Somalia are of an intermediate nature

Table 1: Rainfall variability during the main growing season (Gu, April-July)

Zone	Coeff. of var.* (%)	Stations
1	200-400	Alula, **Berbera (200-400%)**, Bosaso, Capo-Guardafui, Scusciuban
2	100-300	Eil, El-bur, **Galcayo (100-300%)**, Las-anod, Obbia, Qardo,
2a		Burco
3	70-100	Erigavo, **Hargeisa (70-90%)**, Shiekh
4		El Mugne, Lug-ganane
5		Bulo-Burti
6		Dinsor
7		Jameco-Mubarak
8		Barro-uen, Belet-uen, Bur-Acaba, Burdhuxul, Giohar, Huddur, Mahaddei-uen
9		Bardera
10		Brava, Giumbo, Jonte, **Khismaio (70-90%)**, Margherita, Modun
11	50-100	Gebiley
12		Borama
13		Afmadu, **Iscia-Baidoa (50-70%)**, Villabruzzi
14		**Afgoi (70-90%)**, **Allessandra (50-90%)**, Balad, Jilib, JSP-Marere, Lafoole, **Mogadishu (75-100%)**, Mogambo, Sablaale,
15		Genale
Note: Stations on which rainfall variability classification was based shown in **bold** ***** coefficient of variation		

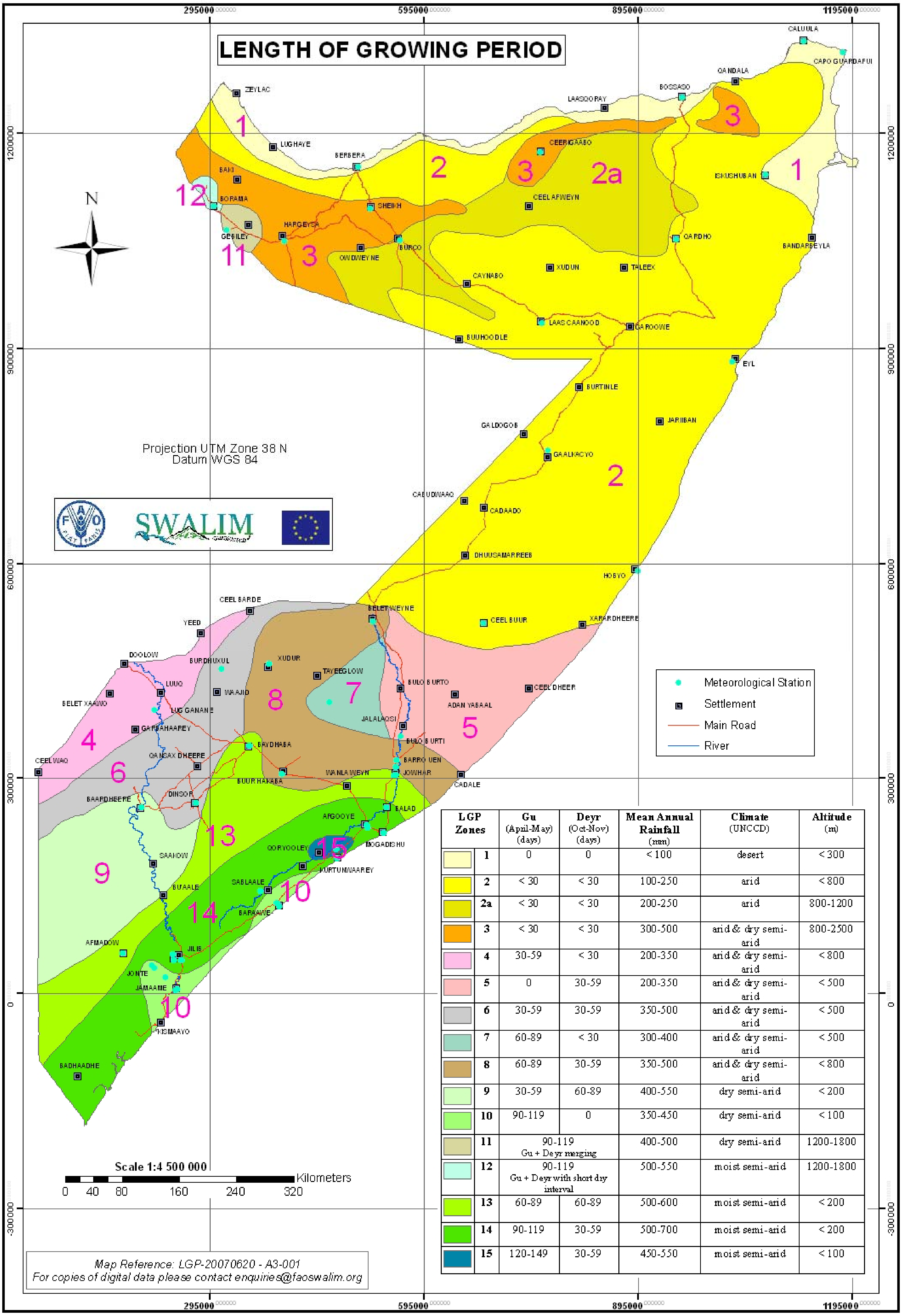
Table 2: Coefficient of variation of annual rainfall (%)

Zone	Coeff of variation		Stations
	%	class	
1	80-160	High	Alula, Berbera, Bosaso, Capo-Guardafui, Scusciaban
2	50-70	High	Eil, El-bur, **Galcayo (65%)**, Las-anod, Obbia, Qardo,
2a	40-50	Medium	**Burco (45%)**
3	30-40	Low	Erigavo, **Hargeisa (25%), Shiekh** (**40%)**
4	40-50	Medium	El Mugne, Lug-ganane,
5	40-70	Medium	Bulo-Burti
6	40-50	Medium	Dinsor
7	40-50	Medium	Jameco-Mubarak
8	40-50	Medium	Barro-uen, **Belet-uen (50%)**, Bur-Acaba, Burdhuxul, Giohar, Huddur, Mahaddei-uen
9	30-50	Medium	**Bardera (40%)**
10	30-50	Medium	Brava, Giumbo, Jonte, **Khismaio (50%)**, Margherita, Modun
11	20	Low	**Gebiley (20%)**
12	20	Low	**Borama (20%)**
13	20-40	Low	Afmadu, Iscia-Baidoa, Villabruzzi
14	20-50	Low	Afgoi, Allessandra**,** Balad, **Jilib (20%)**, JSP-Marere, Lafoole, **Mogadishu (45%)**, Mogambo, Sablaale,
15	40	Low	Genale
Note: Stations on which rainfall variability classification was based shown in **bold**			

2.1.3 LGP map and legend

Based on the definition of the 15 LGP zones, an LGP map was prepared (Map 2). Mapping units (polygons) were identified, using the classification of the 49 stations as a reference and with topographic features as guiding lines. This is a somewhat arbitrary and subjective process and should be repeated and refined when more accurate data become available. An extended legend for the LGP map is given in Table 3.

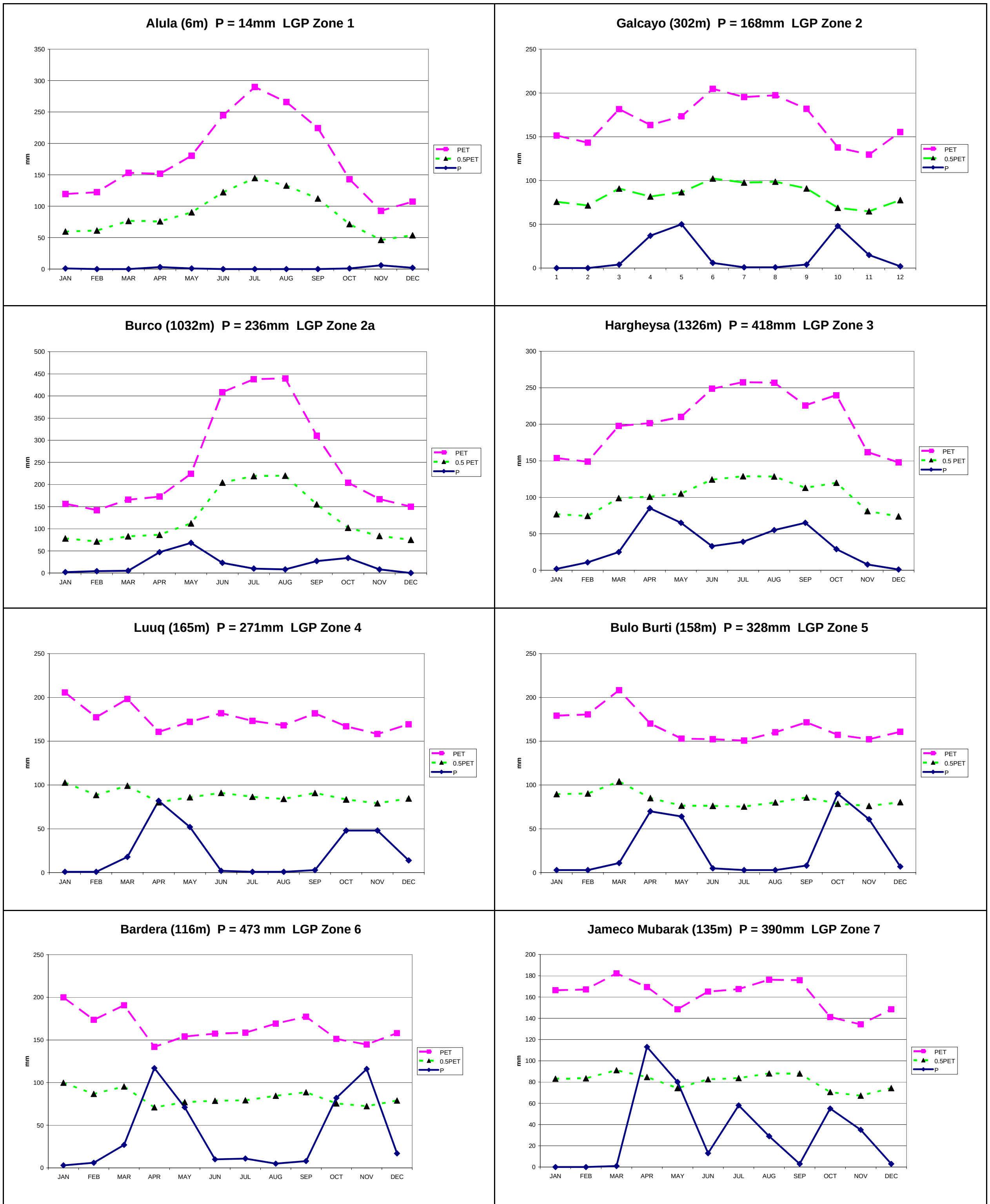
Map 2: Length of Growing Period Zones, Somalia



LGP Zones		Gu (April-May) (days)	Deyr (Oct-Nov) (days)	Mean Annual Rainfall (mm)	Climate (UNCCD)	Altitude (m)
	1	0	0	< 100	desert	< 300
	2	< 30	< 30	100-250	arid	< 800
	2a	< 30	< 30	200-250	arid	800-1200
	3	< 30	< 30	300-500	arid & dry semi-arid	800-2500
	4	30-59	< 30	200-350	arid & dry semi-arid	< 800
	5	0	30-59	200-350	arid & dry semi-arid	< 500
	6	30-59	30-59	350-500	arid & dry semi-arid	< 500
	7	60-89	< 30	300-400	arid & dry semi-arid	< 500
	8	60-89	30-59	350-500	arid & dry semi-arid	< 800
	9	30-59	60-89	400-550	dry semi-arid	< 200
	10	90-119	0	350-450	dry semi-arid	< 100
	11	90-119 Gu + Deyr merging		400-500	dry semi-arid	1200-1800
	12	90-119 Gu + Deyr with short dry interval		500-550	moist semi-arid	1200-1800
	13	60-89	60-89	500-600	moist semi-arid	< 200
	14	90-119	30-59	500-700	moist semi-arid	< 200
	15	120-149	30-59	450-550	moist semi-arid	< 100

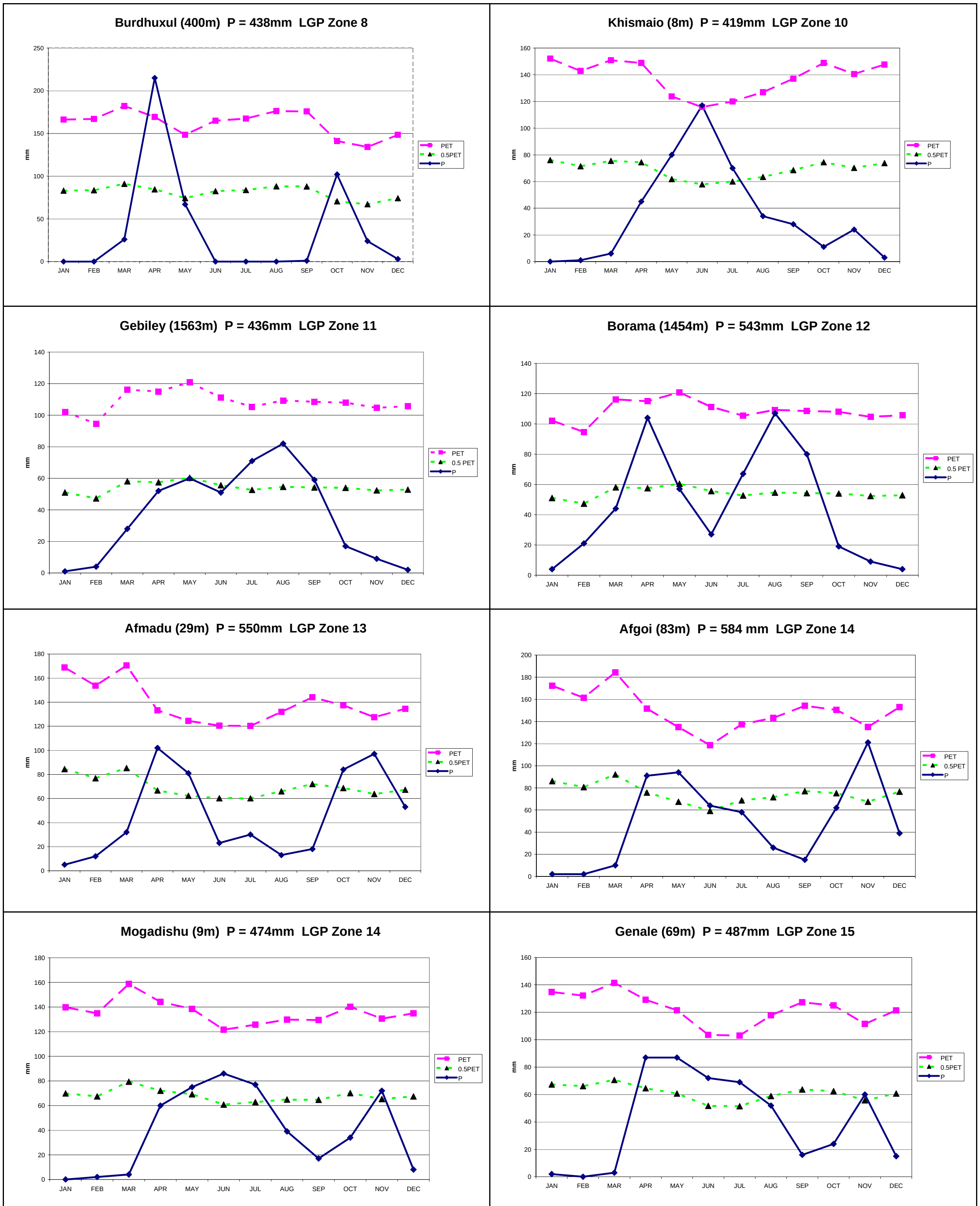
Table 3: Extended legend LGP map Somalia (*Ed: this shld be page 7*)

LGP Zone	**LGP (days)**		**Description**						
	total GP	**longest GP**	**no. of GP**	**Gu (April-May) (days)**	**Deyr (Oct-Nov) (days)**	**Annual rainfall**		**Altitude (m)**	**Climate**
						mm	variability		
1	0	0		0	0	< 100	High	< 300	desert
2	< 30	< 30		< 30	< 30	100-250	High	< 800	arid
2a				< 30	< 30	200-250	Medium	800-1200	
3			1	< 30	< 30	300-500	Low	800-2500	arid & dry semi-arid
4	30-59	30-59	1	30-59		200-350	Medium	< 800	
5			1		30-59	200-350	Medium	< 500	
6	60-89	30-59	2	30-59	30-59	350-500	Medium	< 500	
7		60-89	1	60-89		300-400	Medium	< 500	
8	90-119	60-89	2	60-89	30-59	350-500	Medium	< 800	
9			2	30-59	60-89	400-550	Medium	< 200	dry semi-arid
10		90-119	1	90-119		350-450	Medium	< 100	
11			1	total 90-119 days (Gu + Deyr merging)		400-500	Low	1200-1800	
12			1 or 2	total 90-119 days (Gu + Deyr with short dry interval)		500-550	Low	1200-1800	moist semi-arid
13	120-149	60-89	2	60-89	60-89	500-600	Low	< 200	
14		90-119	2	90-119	30-59	500-700	Low	< 200	
15	150-179	120-149	2	120-149	30-59	450-550	Low	< 100	



Note: vertical scale varies from graph to graph

Figure 1: Mean monthly P and PET for stations representative of LGP Zones (Ed: adjust page nos.)



Note: vertical scale varies from graph to graph

Figure 1 (cont): Mean monthly P and PET for stations representative of LGP zones

2.2 Soils of Somalia

Soil data in Somalia are scarce. The only areas surveyed in any detail are parts of the alluvial plains of the Juba and Shabelle rivers (mostly irrigation feasibility studies) and the western part of Somaliland (SWALIM).

Soil survey in Somalia was done basically in the period 1961-1988. There were no national soil surveying and mapping initiatives. The most important reconnaissance soil surveys at regional level were done in the Juba and Shabelle region (FAO-Lockwood, 1968; Hunting, 1977), and in Somaliland (Sogreah, 1981). Many more studies, usually covering small area, are detailed in *FAO-SWALIM Technical Report L-08.*

The only available soil inventory at national level was carried out by the International Soil Reference and Information Centre (ISRIC) in the period 1987-1988, as part a 1:1 million scale soil map for North East Africa. The inventory is based on information that existed at that time, particularly the soil map of southern Somalia prepared by *Lockwood Survey Ltd* (FAO, 1968) and the *Geological Map of Ethiopia and Somalia* (Merla et al, 1973) as well as on the interpretation of satellite images. The map and associated data were made available in digital format by FAO in 1998 (Land and Water Digital Media Series 2).

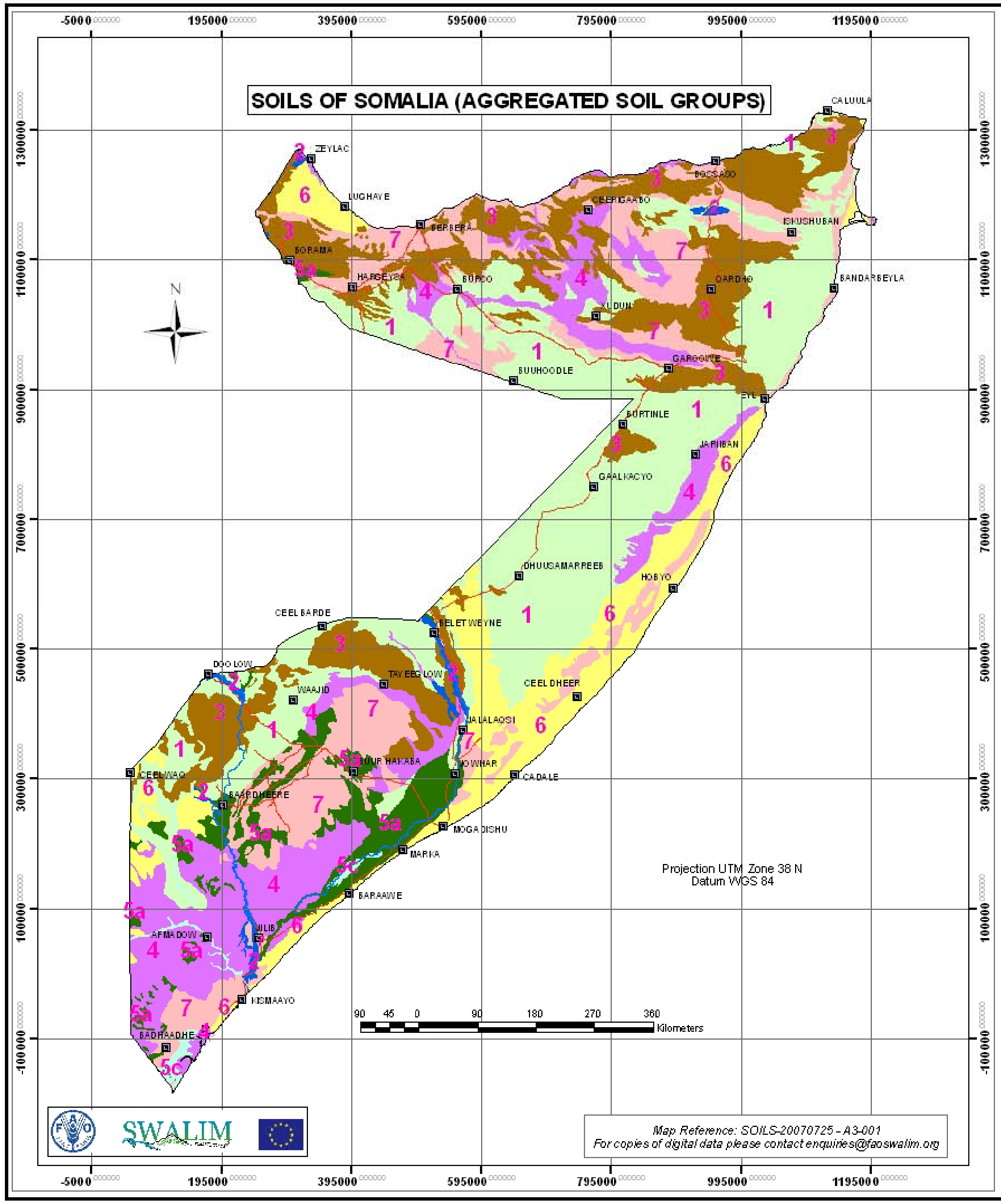
For the purpose of land evaluation and the delineation of AEZ, this map (*Ed*: Map 3?) has been simplified by SWALIM. The various Soil Groups have been aggregated into seven classes, based on the main (physical) limitations to crop production as experienced in Somalia. The Soil Groups have also been re-classified to conform to the World Reference Base for Soil Resource 2006 (IUSS, 2006)5 (Ed: '5' as footnote). The aggregated Soil Groups are listed in Table 4 and shown in Map 3.

The northern part of the country (northern Somaliland and Puntland) is characterized by an association of shallow and/or stony soils and somewhat deeper calcareous soils. A small area with deep, clayey soils is found south of Gebiley in south-western Somaliland. The central part of the country is dominated by sandy soils along the coast and moderately deep loamy soils with a high content of calcium carbonate and/or gypsum further inland. Prominent in southern Somalia are low-lying alluvial plains, associated with the Juba and Shabelle rivers. These plains have mainly clayey soils, some of which have poor drainage and/or high content of salts. Some of the riverine areas are also liable to flooding. The inter-riverine areas have both shallow soils (particularly towards the border with Ethiopia) and deep loamy and clayey soils.

Table 4: Soils of Somalia (aggregated soil groups)

Class	Soil Group (WRB, 2006)			Main limitations for crop production
	Group	prefix	suffix	
1	Calcisols	Haplic Luvic Petric Vertic		low moisture availability low nutrient availability
	Gypsisols	Haplic Petric Calcic		
2	Fluvisols	Haplic Calcic		flooding
3	Leptosols	Lithic Hyperskeletic		stoniness limited rooting depth low moisture availability
	Regosols	Haplic Epileptic	Skeletic	
	Calcisols	Epileptic		
4	Solonchak	Haplic Vertic Stagnic	Sodic	high excess salts low nutrient availability poor drainage
	Solonetz	Gleyic Haplic Salic Vertic		
5a	Vertisols	Haplic Grumic Calcic Mazic		poor workability imperfect drainage
	Cambisols	Vertic		
5b	Vertisols	Salic Sodic		moderate excess salts low nutrient availability poor workability
5c	Vertisols	Stagnic Gleyic		poor drainage
	Stagnosols	Calcic		
	Luvisols	Stagnic		
	Gleysols	Haplic		
6	Arenosols	Rubic Haplic Ferralic		low moisture availability low nutrient retention capacity wind erosion
7	Luvisols	Haplic Stagnic Calcic		
	Phaeozems	Haplic		
	Ferralsols	Haplic	Rhodic	
	Nitisols	Haplic		
	Planosols	Umbric		
	Cambisols	Haplic	Calcaric	
	Regosols	Haplic	Calcaric	

Map 3: Aggregated Soil Groups, Somalia



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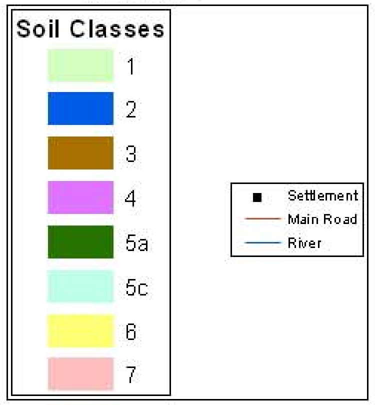


Class	Soil Group (WRB, 2006)			Main limitations for crop production
	Group	prefix	suffix	
1	Calcisols	Haplic Luvic Petric Vertic		low moisture availability low nutrient availability
	Gypsisols	Haplic Petric Calcic		
2	Fluvisols	Haplic Calcic		flooding
3	Leptosols	Lithic Hyperskeletic		stoniness limited rooting depth low moisture availability
	Regosols	Haplic Epileptic	Skeletic	
	Calcisols	Epileptic		
4	Solonchak	Haplic Vertic Stagnic	Sodic	high excess salts low nutrient availability poor drainage
	Solonetz	Gleyic Haplic Salic Vertic		
5a	Vertisols	Haplic Grumic Calcic Mazic		poor workability imperfect drainage
	Cambisols	Vertic		
5b	Vertisols	Salic Sodic		moderate excess salts low nutrient availability poor workability
5c	Vertisols	Stagnic Gleyic		poor drainage
	Stagnosols	Calcic		
	Luvisols	Stagnic		
	Gleysols	Haplic		
6	Arenosols	Rubic Haplic Ferralic		low moisture availability low nutrient retention capacity wind erosion
7	Luvisols	Haplic Stagnic Calcic		
	Phaeozems	Haplic		
	Ferralsols	Haplic	Rhodic	
	Nitisols	Haplic		
	Planosols	Umbric		
	Cambisols	Haplic	Calcaric	
	Regosols	Haplic	Calcaric	

This map is based on data from The Soil and Terrain Database for northeastern Africa (FAO, 1998)

2.3 Agro-ecological Zones

Agro-ecological zones (AEZ) are land resource mapping units, defined in terms of climate, landform and soils, and/or land cover, having a specific range of potentials and constraints (FAO, 1996). Agro-ecological zones provide a foundation for physical land suitability assessment for various types of land use.

Agro-ecological zones for Somalia have been defined and mapped through a combination of LGP Zones (Map 2) and Aggregated Soil Groups (Map 3). The resulting AEZ map (Map 4) shows 29 zones defined by a combination of LGP and soil, and an additional three "inter-zonal" mapping units defined by landform (i.e. dunes, floodplains and mountains).

For each of the zones, the physical land suitability for four major Land Use Types has been indicated. The major LUTs considered are Rainfed Agriculture (crops), Irrigated Agriculture (crops), Pastoralism (extensive grazing) and Forestry (tree plantation). The suitability classification for the whole is based largely on the results of land suitability studies carried out by SWALIM in two study areas, details of which are given in chapters three and four respectively.

Four Suitability Classes are distinguished:

S1 = highly suitable

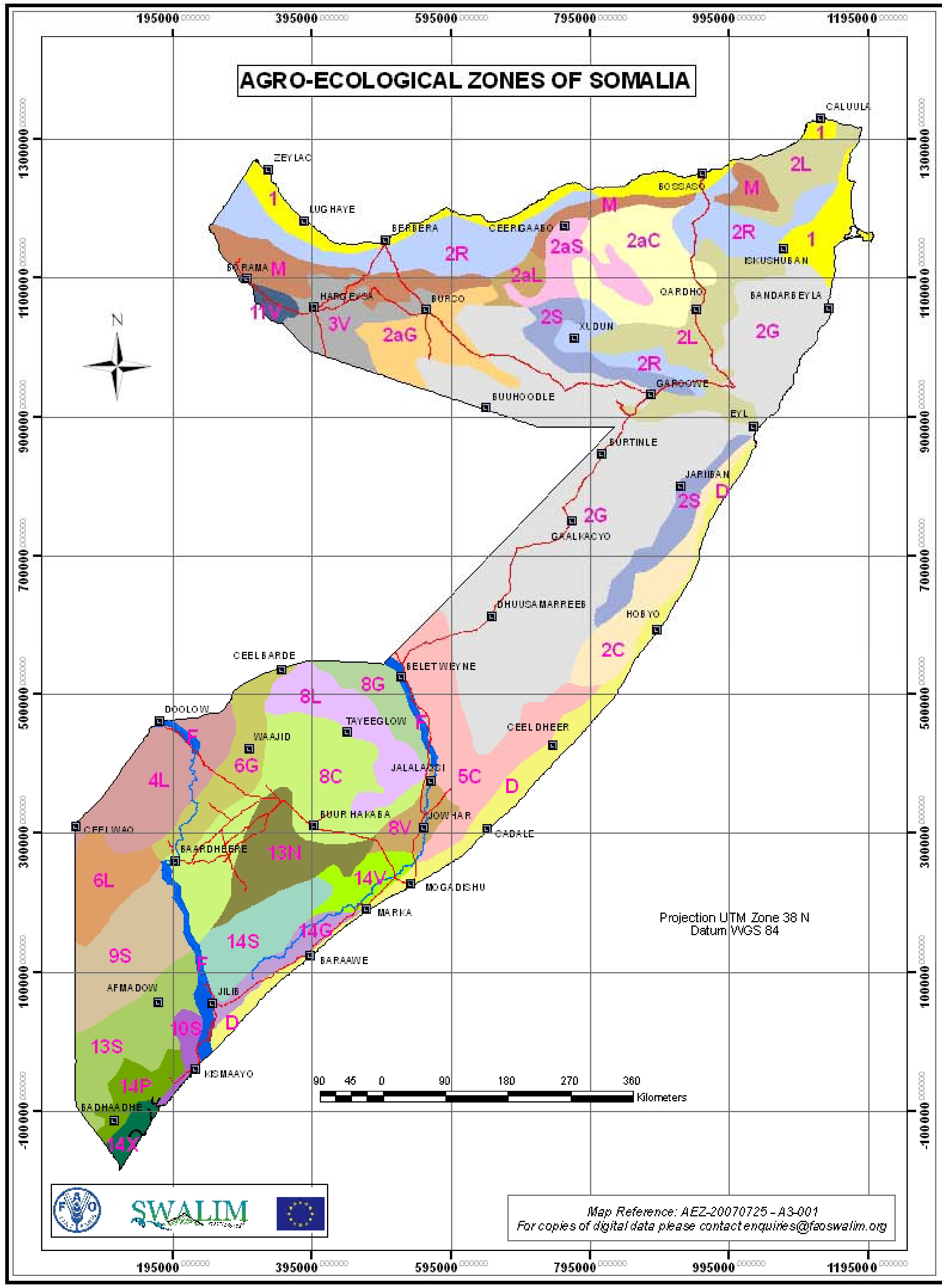
S2 = moderately suitable

S3 = marginally suitable

N = not suitable

Suitability as expressed on the AEZ map refers to physical suitability only, and does not consider social and economic factors. Both the Agro-ecological zoning and the corresponding land suitability assessment should be considered tentative, as it is based on incomplete and/or inferred data. Expert consultations and field verification are needed to further refine the results.

Map 4: Agro-ecological Zones, Somalia



LEGEND

Agro-Ecological Zones

1, 2aC, 2aG, 2aL, 2aS, 2C, 2G, 2L, 2R, 2S, 3V, 4L, 5C, 6G, 6L, 8C, 8G, 8L, 8V, 9S, 10S, 11V, 13N, 13S, 14G, 14P, 14S, 14V, 14X, D, F, M

Settlement
Main Road
River

AEZ	LGP (days)		Soils		Land suitability				Climate
	Gu	Deyr	description	classification	R Rainfed Agric	I Irrigated Agric	P Extensive Grazing	F Forestry plantation	
1	0	0		various	N	N	S3/N	N	desert
2G	<30	<30	calcareous and stony	Calcisols, Gypsisols	N	N	S3	S3	arid
2L	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2S	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2C	<30	<30	1 sandy 2 calcareous	Arenosols Cambisols	N	N	S3	S3	
2R	<30	<30	1 calcareous 2 shallow	Regosols, Fluvisols Leptosols	N	N	S3	S3, N	
2aG	<30	<30	high lime, gypsum content	Calcisols, Gypsisols	N	N	S3	S3	arid + altitude >500m
2aL	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2aS	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2aC	<30	<30	calcareous	Cambisols	N	N	S3	S3	
3V	<30	<30	1 calcareous, clayey 2 calcareous, loamy	Vertisols Regosols	S3	N	S3	S2, S3	arid
4L	<60	<30	shallow and/or stony	Leptosols, Regosols	N	N	S3/N	S3, N	
5C	<30	<60	1 calcareous, loamy 2 sandy	Cambisols Arenosols	S3, N	N	S2	S2, S3	
6G	<60	<60	high gypsum content	Gypsisols	S3	N	S2/3	S2	arid - dry semi-arid
6L	<60	<60	1 shallow 2 stony, calcareous 3 sandy, calcareous	Leptosols Gypsisols, Calcisols Arenosols	N	N	S2/3	S2, S3	
8G	<90	<60	high in gypsum, often stony	Gypsisols	S3	N	S2/3	S2	
8L	<90	<60	shallow	Leptosols	N	N	S3	S3, N	
8C	<90	<60	1 shallow, calcareous 2 high salt content 3 deep and clayey	Calcisols Solonetz Vertisols	S3	N	S2	S3	
8V	<90	<60	deep and clayey	Vertisols	S2	S2, S3	S2	S1	
9S	<60	<90	1 high salt content 2 calcareous, loamy	Solonetz Calcisols	S3	N	S2	S2	dry semi-arid
10S	<120	<30	1 high salt content 2 red loams, clays	Solonetz Luvisols	S2, S3	S3	S2	S2	
11V	60	90	1 deep and clayey 2 calcareous, loamy	Vertisols Calcisols, Regosols	S2	N	S2, S1	S2	
13S	<90	<90	1. high salt content 2 deep and clayey	Solonetz Vertisols	S3, S2	N	S2	S2, S1	moist semi-arid
13N	<90	<90	1 deep, red, clayey 2 slowly permeable 3 deep and clayey	Nitisols Planosols Vertisols	S2, S3	N	S2	S2, S1	
14S	<120	<60	high salt content	Solonetz, Solonchaks	S2, S3	N	S2	S2	
14V	<120	<60	deep and clayey	Vertisols	S2	S2, S3	S2	S1	
14X	<120	<60	1 imperfect drained 2 high salt content	Luvisols Solonetz	S2, S3	N	S2	S1, S2	
14G	<120	<60	1 poor drainage 2 high salt content	Gleysols, Stagnosols Solonchaks	S2, S3	S2, S3	S2	S2	
14P	<120	<60	slowly permeable	Planosols	S2	N	S2	S2	
D	Dunes		sandy	Arenosols	N	N	S3/N	S3	various
F	Floodplains		periodically flooded	Fluvisols	S3	S2	S2	S2	
M	Mountains		shallow	Leptosols	N	N	S3	N, S3	

AEZ = Agro-ecological Zones
LGP = Length of Growing Period (number of days that precipitations exceeds half potential evapotranspiration)
Land Suitability: S1=Highly suitable; S2=Moderately suitable; S3=Marginally suitable; N=Not suitable

Table 5: Legend Agro-ecological Zones Map

AEZ	LGP (days)		Soils		Land suitability				Climate
					R Rainfed Agric	**I** Irrigated Agric	**P** Extensive Grazing	**F** Forestry plantation	
	Gu	**Deyr**	**description**	**classification**					
1	0	0		various	N	N	S3/N	N	desert
2G	<30	<30	calcareous and stony	Calcisols, Gypsisols	N	N	S3	S3	arid
2L	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2S	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2C	<30	<30	1 sandy 2 calcareous	Arenosols Cambisols	N	N	S3	S3	
2R	<30	<30	1 calcareous 2 shallow	Regosols, Fluvisols Leptosols	N	N	S3	S3, N	
2aG	<30	<30	high lime, gypsum content	Calcisols, Gypsisols	N	N	S3	S3	arid + altitude >500m
2aL	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2aS	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2aC	<30	<30	calcareous	Cambisols	N	N	S3	S3	
3V	<30	<30	1 calcareous, clayey 2 calcareous, loamy	Vertisols Regosols	S3	N	S3	S2, S3	arid
4L	<60	<30	shallow and/or stony	Leptosols, Regosols	N	N	S3/N	S3, N	
5C	<30	<60	1 calcareous, loamy 2 sandy	Cambisols Arenosols	S3, N	N	S2	S2, S3	
6G	<60	<60	high gypsum content	Gypsisols	S3	N	S2/3	S2	arid - dry semi-arid
6L	<60	<60	1 shallow 2 stony, calcareous 3 sandy, calcareous	Leptosols Gypsisols, Calcisols Fluvisols	N	N	S2/3	S2, S3	
8G	<90	<60	high in gypsum, often stony	Gypsisols	S3	N	S2/3	S2	
8L	<90	<60	shallow	Leptosols	N	N	S3	S3, N	
8C	<90	<60	1 shallow, calcareous 2 high salt content 3 deep and clayey	Calcisols Solonetz Vertisols	S3	N	S2	S3	
8V	<90	<60	deep and clayey	Vertisols	S2	S2, S3	S2	S1	
9S	<60	<90	1 high salt content 2 calcareous, loamy	Solonetz Calcisols	S3	N	S2	S2	dry semi-arid
10S	<120	<30	1 high salt content 2 red loams, clays	Solonetz Luvisols	S2, S3	S3	S2	S2	
11V	60	90	1 deep and clayey 2 calcareous, loamy	Vertisols Calcisols, Regosols	S2	N	S2, S1	S2	
13S	<90	<90	1. high salt content 2 deep and clayey	Solonetz Vertisols	S3, S2	N	S2	S2, S1	moist semi-arid
13N	<90	<90	1 deep, red, clayey 2 slowly permeable 3 deep and clayey	Nitisols Planosols Vertisols	S2, S3	N	S2	S2, S1	
14S	<120	<60	high salt content	Solonetz, Solonchaks	S2, S3	N	S2	S2	
14V	<120	<60	deep and clayey	Vertisols	S2	S2, S3	S2	S1	
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14P	<120	<60	slowly permeable	Planosols	S2	N	S2	S2	
D	**Dunes**		sandy	Arenosols	N	N	S3/N	S3	various
F	**Floodplains**		periodically flooded	Fluvisols	S3	S2	S2	S2	
M	**Mountains**		shallow	Leptosols	N	N	S3	N, S3	

AEZ = Agro-ecological Zones
LGP = Length of Growing Period (number of days that precipitations exceeds half potential evapotranspiration)
Land Suitability: S1=Highly suitable; S2=Moderately suitable; S3=Marginally suitable; N=Not suitable

3 LAND SUITABILITY ASSESSMENT OF A SELECTED STUDY AREA IN SOMALILAND

Various land resources surveys were carried out by SWALIM in a study area in western Somaliland[5]. The results of these surveys are documented in *FAO-SWALIM Technical Reports no's L-02* (Landform), *L-03* (Land cover), *L-04* (Land use) and *L-05* (Soils) respectively. The following sections give a summary of the land suitability for this particular study area. Detailed information is given in *Report no. L-06* (Venema and Vargas, 2007a).

3.1 Location

The study area is located in western Somaliland between 10° 41' 36" - 9°10' 30" N and 43° 00' 52" - 44° 27' 54" E (see Figure 2), covering a total area of 12 939 km^2. It lies between the Ethiopian border and the Red Sea and covers the districts of Dila, Gebiley, Faraweyne and Allaybaday, and parts of the districts of Hargeisa, Borama, Baki and Lughaya[6].

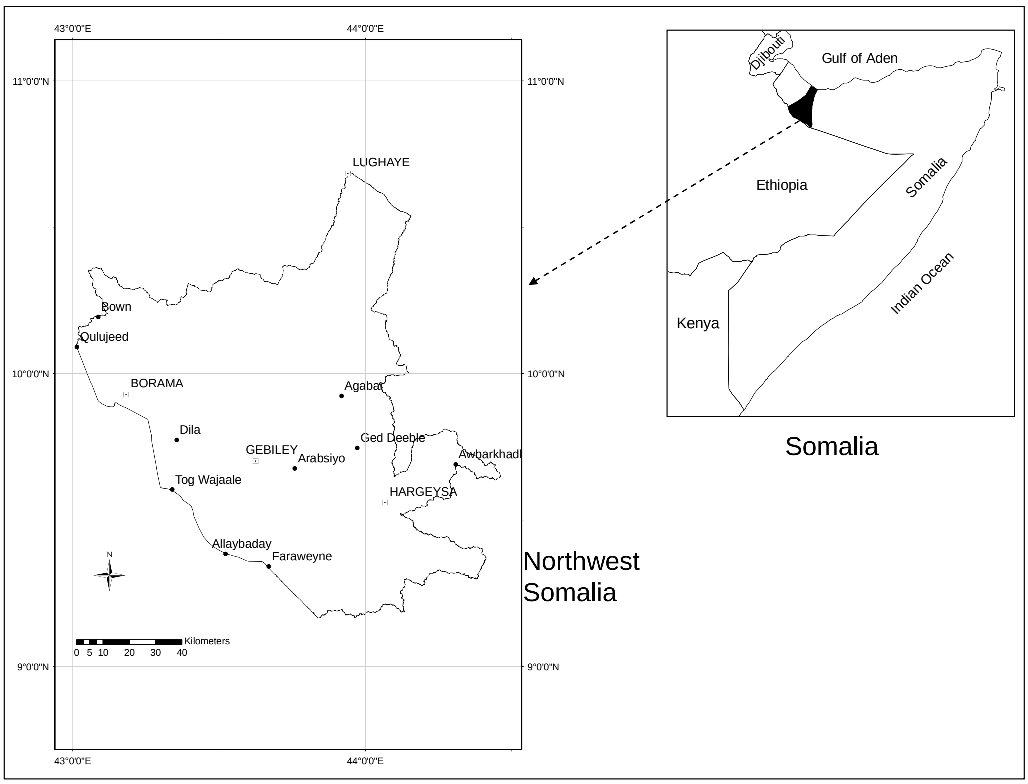


Figure 2: Study area (NAOI)

3.2 Land Evaluation Methodology

For the purpose of physical land suitability evaluation SWALIM developed a tool called Somalia Automated Land Evaluation System (SOMALES). SOMALES is the application of the FAO Framework for Land Evaluation with the use of computer software called the Automated Land Evaluation System (ALES). The FAO methodology for land evaluation was first published in *"A Framework for Land*

[5] Also referred to as Northern Area of Interest (NAOI)

[6] The Districts of Dila, Faraweyne and Allaybaday were recently formed

Evaluation" (FAO, 1976). This document was followed up by a set of documents comprising guidelines for major kinds of land use, such as rainfed agriculture (FAO, 1983), forestry (FAO, 1984), irrigated agriculture (FAO, 1985) and extensive grazing (FAO, 1991). Recently, a revised Framework for Land Evaluation was proposed (FAO, 2007). ALES has been developed by the Department of Soil, Crop & Atmospheric Sciences of Cornell University, USA (Rossiter & Van Wambeke, 1991, 1997). ALES allows land evaluators to build expert systems to evaluate land, according to the FAO method of land evaluation. The *FAO-SWALIM Technical report no. L-06* (Venema and Vargas, 2007a) provides details of SOMALES and how it was applied for the study area .

3.2.1 Resource base units (RBU)

Natural resource surveys form the basis of the land component of the land evaluation system and include inventories of agro-climate, landform, soils, landcover and present land use. SWALIM used multi-spatial and multi-temporal satellite images for mapping the land resources (landform, land cover/vegetation, soils and land use) in the study area. A combination of visual image interpretation techniques, remote sensing, and GIS tools and field survey were used to produce the different baseline data layers at 1:100 000 scale.

The basic units of evaluation are resource base units (RBU), which are defined as land areas, generally smaller than a region but considerably larger than a farm, with a definable combination of climate, relief, altitude, edaphic conditions and natural vegetation (George, *et al* 2006). The RBUs are generated by combining different spatial baseline data layers, including length of growing period (LGP), landscape, vegetation, soil groups and altitude (Figure 3).

Forty-five RBUs have been defined for the study area (see Map 5) and described in terms of more than 20 distinct land characteristics (Annex 3).

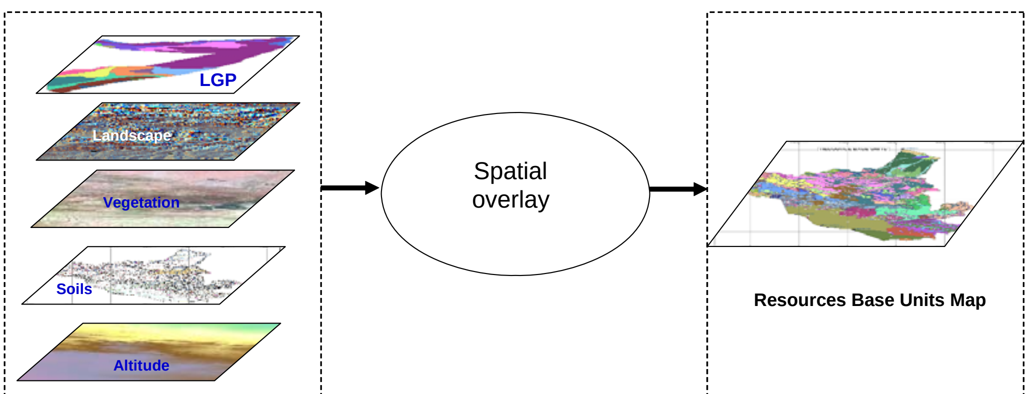
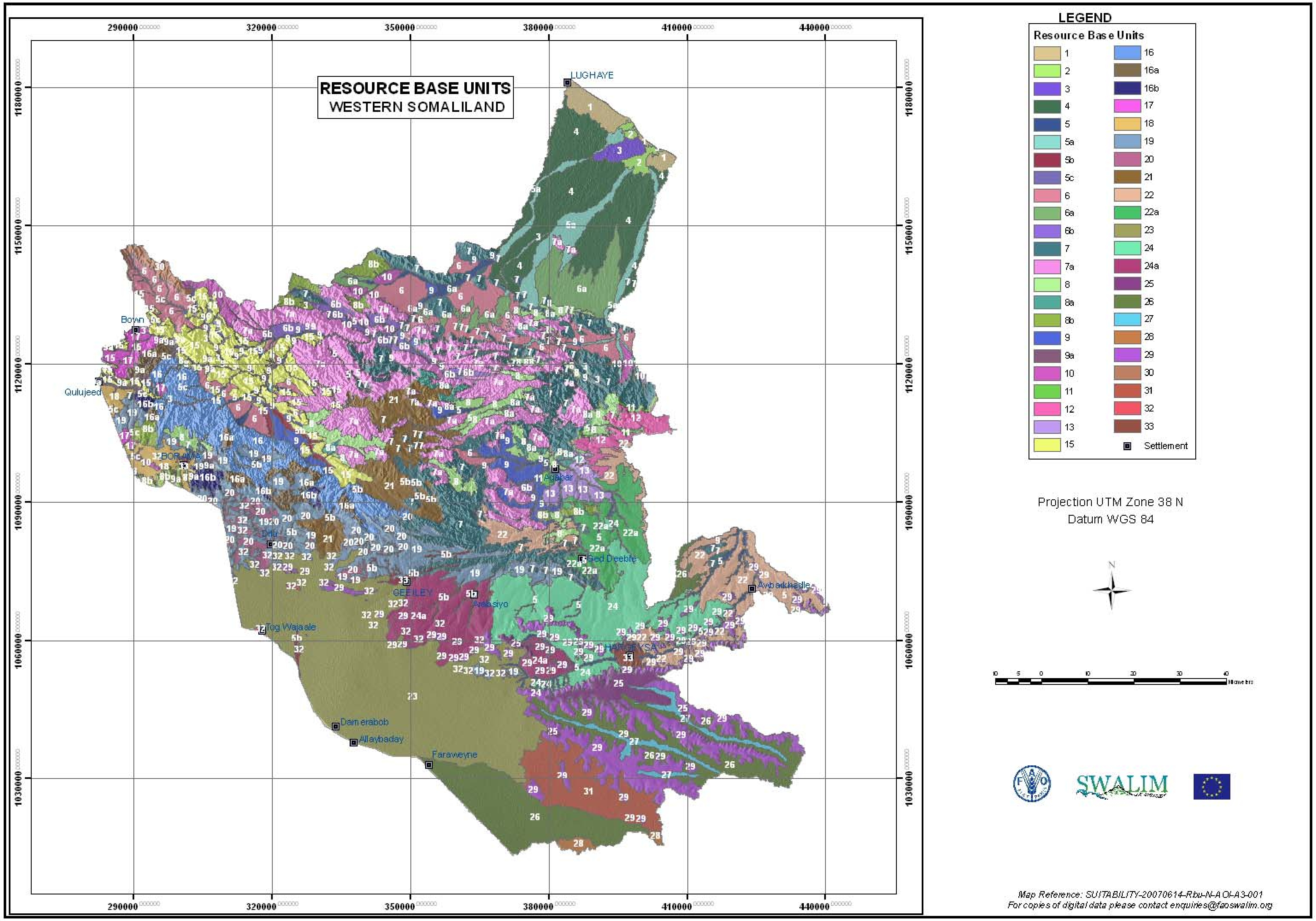


Figure 3: Identification of the RBU's

Map 5: Resource Base Units (NAOI)



3.2.2 Land use types (LUT)

Land suitability is determined for specific land use, which can be defined at two levels of detail. A major kind of land use is a major subdivision of rural land use such as rainfed agriculture, irrigated agriculture, forestry, etc. A land utilization type (LUT) is a classification of land use defined in more detail, according to a set of technical specifications in a given socio-economic setting. Major classifications of land use and LUTs which were included in the land suitability assessment of the study area (FAO-SWALIM Technical Report L-06) are given in Table 6.

Table 6: Land Use Types (NAOI)

Major Kind of Land Use		**Land Use Type (LUT)**	
R	Rainfed Agriculture (crops)	Rs1	Rainfed sorghum; short GP (90-100 days); medium input
		Rs2	Rainfed "Traditional sorghum"; total GP 180 days (including "dormant" period of 50 days; low input
		Rc	Rainfed cowpeas; short GP (80 days); low-medium input
		Rm1	Rainfed maize; short GP (80-90 days); medium input
P	Pastoralism (extensive grazing)	Pc	Extensive grazing of cattle; low input
		Pd	Extensive grazing of camels; low input
		Pg	Extensive grazing of goats; low input
		Ps	Extensive grazing of sheep; low input
F	Forestry (tree plantation)	Fai	*Azadirachta indica* (neem)
		Fan	*Acacia nilotica* (maraa)
		Fat	*Acacia tortilis* (qurac)
		Fba	*Balanites aegyptiaca* (quud)
		Fce	*Casuariana equisetifolia* (shawri)
		Fcl	*Conocarpus lancifolius* (damas, ghalab)
		Fdg	*Dobera glabra* (garas)
		Ffa	*Faidherbia albida* (garabi)
		Fti	*Tamarindus inidica* (raqai)

3.2.3 Land suitability classification

SOMALES has four suitability classes:

S1 = highly suitable

S2 = moderately suitable

S3 = marginally suitable

N = not suitable

A number of suitability subclasses are distinguished, reflecting kinds of limitation, e.g. subclass S3m means "Marginally suitable due to low moisture availability".

3.3 Land Suitability for Rainfed Agriculture

Four LUTs were analyzed, characterized by the production of individual crop varieties. They are: cowpea (Rc: short Growing Period), maize (Rm1: short GP), sorghum (Rs1: short GP) and sorghum (Rs2: long GP). Because of the arid and semi-arid conditions in the area, more attention has been paid to crops with a short GP. However, in Somaliland a variety of sorghum is grown with a long GP of 180 days, called *Elmi Jama*. This variety is drought resistant and can survive long dry periods. It is favoured by farmers because of its taste and forage value (long stalks) and has also been included in the evaluation. The land suitability for sorghum with a short growing period (LUT Rs1) is shown on Map 6.

There is not much difference between the suitability of the four crop varieties studied. This can be explained by the fact that large parts of the study area have severe and over-riding limitations for rainfed agriculture, notably very shallow and stony soils in the mountains and piedmont area and lack of soil moisture (desert and arid conditions) in the coastal zone. Remarkable also is the fact that there is not much difference between the overall suitability for sorghum with a short growing period (Rs1) and a long growing period (Rs2). However, an improved early maturing variety is likely to give a better yield then the traditional late maturing variety. Also, any early maturing crop variety gives the farmer the opportunity to plant a second sequential or relay crop on the same land within a year.

The study area has no land that is suitable (class S1) for the four rainfed crops which have been analysed. This is largely due to the fact that even in areas with relatively high mean annual rainfall (south-western plateau), long-term average crop yields will remain below their potential because of rainfall variability (both seasonal and annual), erosion hazard and low soil fertility. Although both erosion hazard and low soil fertility could be overcome by improved management and increased inputs, this would mean increased costs which are unlikely to be off-set by increased production.

About 14 % of the study area (185000 ha) is moderately suitable (class S2) for all four crop varieties analysed. Most of the moderately suitable land is found on the plateau, around Gebiley (RBU 23). In this area, relatively high rainfall (around 500mm) and moderate LGP (90 - 120 days) combine with deep soils (Vertisols) and gentle slopes to create favourable conditions for the cultivation of drought-resistant crops. Moderate limitations are posed by the variability in rainfall and LGP and by erosion hazard, preventing the realization of sustained high yields.

One-third of the study area is marginally suitable (class S3) for three of the four crop varieties analysed (cowpea, and the two sorghum varieties). For maize (LUT Rm1), which has somewhat higher moisture requirements, only 15% has been classified as marginally suitable. The main limitation is low moisture availability because of arid climatic conditions and/or shallow soils (RBUs 19, 21, 22, 22a, 24, 24a, 26 and 27). Many of the main alluvial plains and floodplains have also been classified as marginally suitable because of flooding hazard (RBUs 5, 5b, 5c, 9, 9a).

More than 50% of the study area is unsuitable (class N) for the rainfed production of cowpea and sorghum, and more than 70% is unsuitable for maize. Most of the study area poses severe limitations for these types of land uses because of arid or desert climatic conditions and/or shallow and stony soils with poor rooting conditions and very low water holding capacity.

3.4 Land Suitability for Irrigated Agriculture (orchards)

No systematic land evaluation has been carried out for irrigated agriculture. There is no water available for irrigation in most of the study area. Even the construction of storage dams or the application of water harvesting techniques would not solve the problem of general water deficit in the area. As explained in Section 2.2, potential evapotranspiration (PET) greatly exceeds precipitation (P) throughout the year. Also, there are no rivers bringing water from outside the study and no known significant underground water reservoirs.

However, small surface and underground water supplies exist locally along the major seasonal rivers (toggas), draining the mountains and the plateau. Small-scale irrigation is possible in these floodplains where water supplies occur close to pockets of deep soil. In fact, most of these areas are already used for irrigated gardens (orchards). Such scattered areas of irrigable land are usually not larger than half a hectare or less and used for the production of fruits (citrus, mango, papaya, guava) and vegetables.

The scale of the present study (1:100,000) does not make it possible to map out all the small pockets of land suitable for irrigation. However, a rough estimate can be made of irrigable land, based on the estimation that roughly 30% of the braided river plains of the plateau, mountains and piedmont have suitable land (see RBU description, Annex 3). Suitable land in this case means gently sloping, slightly elevated land with deep soils along the main sandy and/or stony river beds.

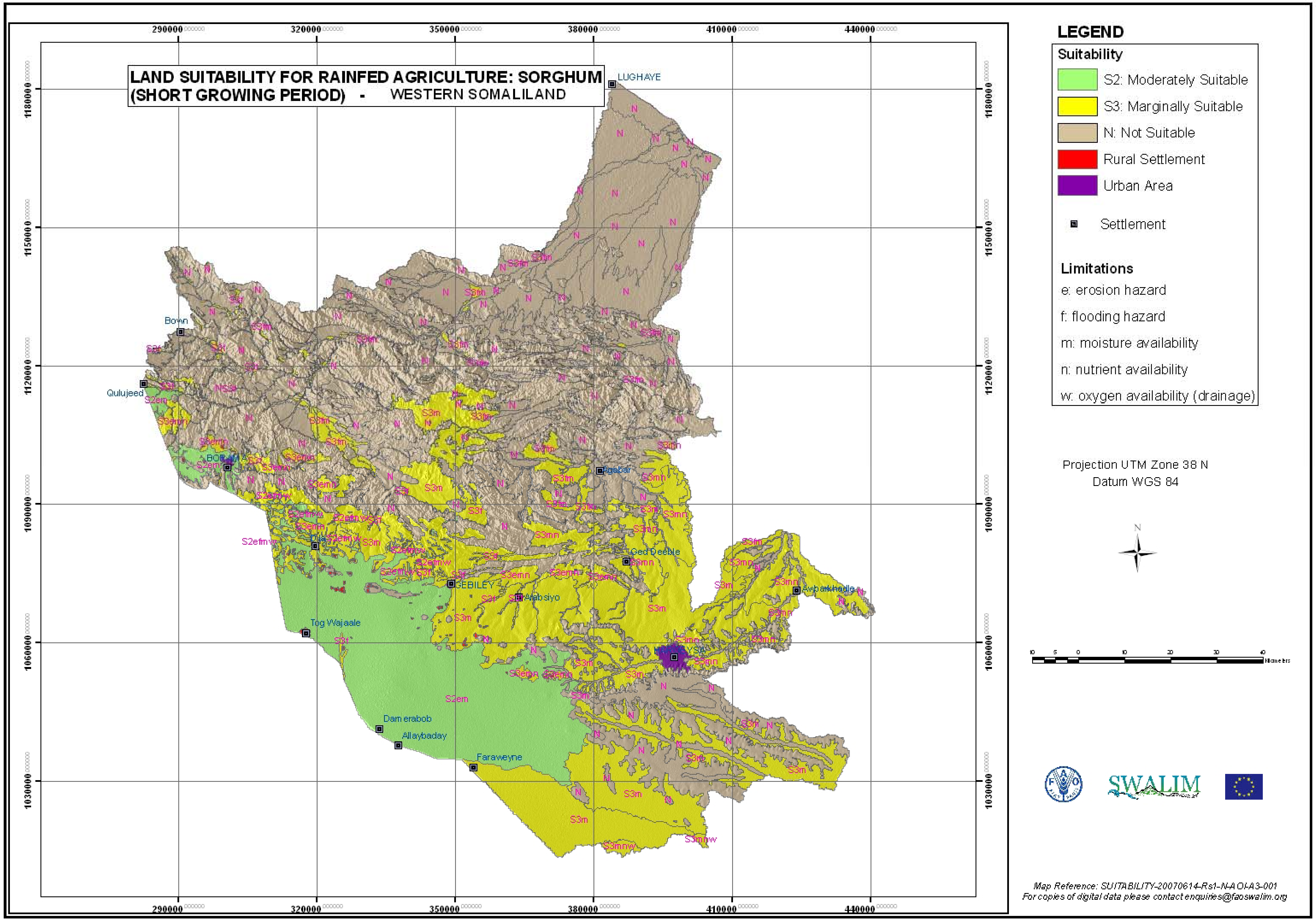
Table 7: Estimated total area of irrigable land in study area (NAOI)

RBU	Relief	LGP Zone	Total area RBU (ha)	Irrigable land (estimate) (ha)
5	Braided river plain in mountains and on plateau	3	26482	7940
5b	Braided river plain on plateau	11	7756	2330
5c	Braided river plain on plateau	12	4042	1210
			Total	10480

Table 7 shows an estimate of irrigable land within RBUs 5, 5b and 5c[7]. The figures presented refer to the total area of irrigable land near a water source and is estimated to cover an area of 10,480 ha, or 0.8% of the total study area. This figure should be seen only as an upper limit. It is not known whether there would be enough water to irrigate all the 10,480 ha. Also, because of land fragmentation irrigation may be impractical or not cost-effective on some of the "suitable" land. More detailed study of RBUs 5, 5b and 5c is needed to reveal the true extent of irrigable land.

[7] These RBUs are included in the legend of Map 2, but are difficult to identify on the hard-copy map included in this report because of its small scale.

Map 6: Land suitability for Rainfed Agriculture: sorghum (short GP) (NAOI)



3.5 Land Suitability for Extensive Grazing (pastoralism)

Four types of grazing (Land Use Types) have been considered: cattle (Pc), camels (Pd), goats (Pg) and sheep (Ps).

Evaluating land for its suitability for pastoralism is somewhat complicated because pastoralists move there livestock over large areas and do not confine themselves to one RBU. Even on land, which in itself provides very little grazing (e.g. coastal desert zone), livestock may be found roaming or passing through and finding some nourishment or water at least for some part of the year. Therefore, a final evaluation should take into account all the land available for individual pastoralists or group of pastoralists and consider the dynamics of extensive grazing. The present study, however, confines itself to the evaluation of individual RBUs.

There is not much difference between the suitability for the four types of grazing. This is due to the fact that most of the study area has an arid or semi-arid climate and low biomass production and low forage availability, affecting the suitability for all grazing and browsing animals.

The study area has a small area of land (13,000 ha, or 1% of the study area) that is suitable (class S1) for the four types of grazing analysed. This land is found in RBUs 9a and 18, that represent depressions and plains of the plateau area near Borama in the extreme west of the study area.

Nearly one-third of the study area (around 410,000 ha) is moderately suitable (class S2) for all four types of grazing. Most of the moderately suitable land is found on the plateau in the south-west of the study area (RBUs 19, 23, 26 and 31). In this area, relatively high rainfall (400 - 500mm) combines with deep soils (Vertisols) and gentle slopes to create favourable conditions for plant growth and movement of livestock. Moderate limitations are posed by the variability in rainfall and length of growing period (LGP). Elsewhere, some of the valleys and alluvial plains have also been classified as moderately suitable (RBUs 5, 5b, 5c, 9 and 27).

One-third of the study area is marginally suitable (class S3) for cattle, camels and sheep. For goats (LUT Pg), which are somewhat more tolerant to adverse conditions, the situation is better with almost 45% marginally suitable. The main limitations are (1) low biomass production because of low rainfall and/or poor soils, and (2) locally poor accessibility for cattle, camels and sheep because of steep and stony terrain.

Around 30% of the study area is unsuitable (class N) for the production of cattle, camels and sheep, and 22% is unsuitable for the production of goats. Unsuitable areas include the northern desert zone (RBUs 1, 2, 3 & 4), mountainous areas (RBUs 15, 16, 16a, 16b) and severely degraded areas (RBUs 22, 22a). The situation for goats is slightly more favourable, as they can also access the steep mountain slopes.

3.6 Land Suitability for Forestry

Nine forestry species were evaluated, five of which are indigenous in the area, namely “Qurac” (*Acacia tortilis*), “Quud” (*Balanites aegyptiaca*), “Damas” or “Ghalab” (*Conocarpus lancifolius*) , “Garas” (*Dobera glabra*) and “Garabi” (*Faidherbia albida* , previously known as *Acacia albida*). Four others are exotic, namely “Maraa” (*Acacia nilotica*), “neem” (*Azadirachta indica*), “Shawri” (*Casuarina equisitifolia*) and “Raqai” (*Tamarindus indica*).

A species that is indigenous to the area and/or that is found growing there is not necessarily highly suitable as a forestry species. Some trees may be survivors or remnants of a past period when conditions were more favourable, or the trees may grow, but only slowly and not to their full potential. In the present study, forestry species are evaluated based on the extent to which all their requirements are met by the resource base and to what degree they can reach their full genetic potential.

A more meaningful evaluation of forestry species could be made if one could ascertain the precise purpose of a planned tree plantation . For example, if the main purpose was soil and water conservation, the actual speed of growth and biomass production would be less important than in the case of a plantation intended for fuel wood or timber production.

There is no ‘highly suitable’ land available, with the exception of a small area (RBU 9a, 3048 ha) that was found to be ‘highly suitable’ (class S1) for only one species (*Acacia nilotica*). The main reason for this is the relatively low rainfall and high potential evapotranspiration in the area together with the lack of shallow groundwater tables.

The area of ‘moderately suitable’ land (class S2) varies from nearly 15,000 ha (1.1% of study area) to more than 220,000 ha (17.2%), depending on the species.

More than 36% of the study area is ‘unsuitable’ (class N) for all species and another 6% is ‘unsuitable’ for all species except one - only *Conocarpus lancifolius* was classified as marginally suitable in the coastal desert zone. Main limitations are low rainfall in the desert zone and low rainfall in combination with very shallow soils.

3.7 Summary of Suitability for the Major Types of Land Use

Because the present land evaluation exercise does not include a cost/benefit analysis for the various LUTs it is difficult to compare the suitability of the major land uses, i.e. rainfed agriculture (R), irrigated agriculture (I), extensive grazing (P), and forestry (F). However, some qualitative assessments can be made.

<u>Rainfed Agriculture</u>: Not surprisingly, only the plateau area with relatively high rainfall, is ‘moderately suitable’ for rainfed crops. This area has two short growing periods (Gu and Deyr respectively), separated by a short dry period (Xagaa). Farmers can follow two strategies: either to grow a crop with a very short growing period in the Gu and/or Deyr period, or to plant a drought resistant crop with a long growth cycle which can make use of both Gu and Deyr. Presently farmers in the area follow the latter strategy and grow a sorghum variety (*Elmi Jama*) with a growing period of 180 days. However, an improved early maturing variety is likely to give a better yield than the traditional late maturing variety. Also, any early maturing crop gives the farmer the opportunity to plant a second sequential or relay crop on the same land within a year.

<u>Irrigated Agriculture</u>: The area of irrigable land in the study area is estimated to be slightly over 10,000 ha. This figure refers to the total area of irrigable land near a water source and comprises a great number the small patches of irrigable land in the narrow valleys of the mountain and plateau area. Although more detailed study is needed, it is likely that most suitable land is already used for irrigation and that future development of irrigated agriculture should focus on improved management of orchards, rather than expansion.

<u>Pastoralism</u>: The assessment did not find much difference between the suitability for cattle, camels or sheep respectively because of overriding limitations such as low biomass production (particularly in the arid and desert zone in the north of the study area), and steep slopes with shallow/stony soils (particularly in the central and

southern mountains). The suitability for goats is slightly better, as they can access steep slopes.

Forestry: For nearly every environment a tree species can be found that will survive, particularly if it is well tended during the first year after planting. Exceptions are areas with very shallow soils and/or extremely low rainfall. However, tree planting may be costly, as the plantations have to be protected for long periods and may only provide benefits after a number of years. Tree planting by outside agencies should only be considered if it is welcomed and protected by local communities. Probably less problematic would be for individuals to engage in tree planting near their homesteads and on their own land .

In most cases, farmers gain their income or sustenance from several activities, including various types of agriculture and trade, or from wages and donations. Like other communities, they too have their traditions, beliefs, prejudices and risk assessments. Any recommendations based on land suitability assessments should take this into account, as farmers may be reluctant sometimes to put all their efforts in what outsiders may consider the most obvious and profitable land use.

4 LAND SUITABILITY ASSESSMENT OF THE JUBA AND SHABELLE RIVERINE AREAS IN SOUTHERN SOMALIA

Various land resources surveys were carried out by SWALIM in the catchment areas of the Juba and Shabelle rivers in Southern Somalia. The results of these surveys are documented in *FAO-SWALIM Technical Reports nos L-02* (Landform), *L-03* (Land cover), *L-07* (Land use), and *L-08* (Soils) respectively. The following sections give a summary of the land suitability for this particular study area[8]. Detailed information is given in *Report no. L-09* (Venema and Vargas, 2007b).

4.1 Location and Delineation

The study area lies between 41°53' and 46°09' east of the Prime Meridian; and between 0°16' south of the Equator and 5°04' north of the Equator. It extends for almost 88,000 square kilometres (8,793,596 hectares) covering the whole Juba river watershed, in its Somali tract, and the greater part of the Shabelle river watershed in Somalia (see Figure 4). The area has an estimated rural population of approximately two million, which is more than 40% of the total rural population of Somalia. The major urban centres of the area are Mogadishu, Kismayo and Marka. All three are situated near the coast.

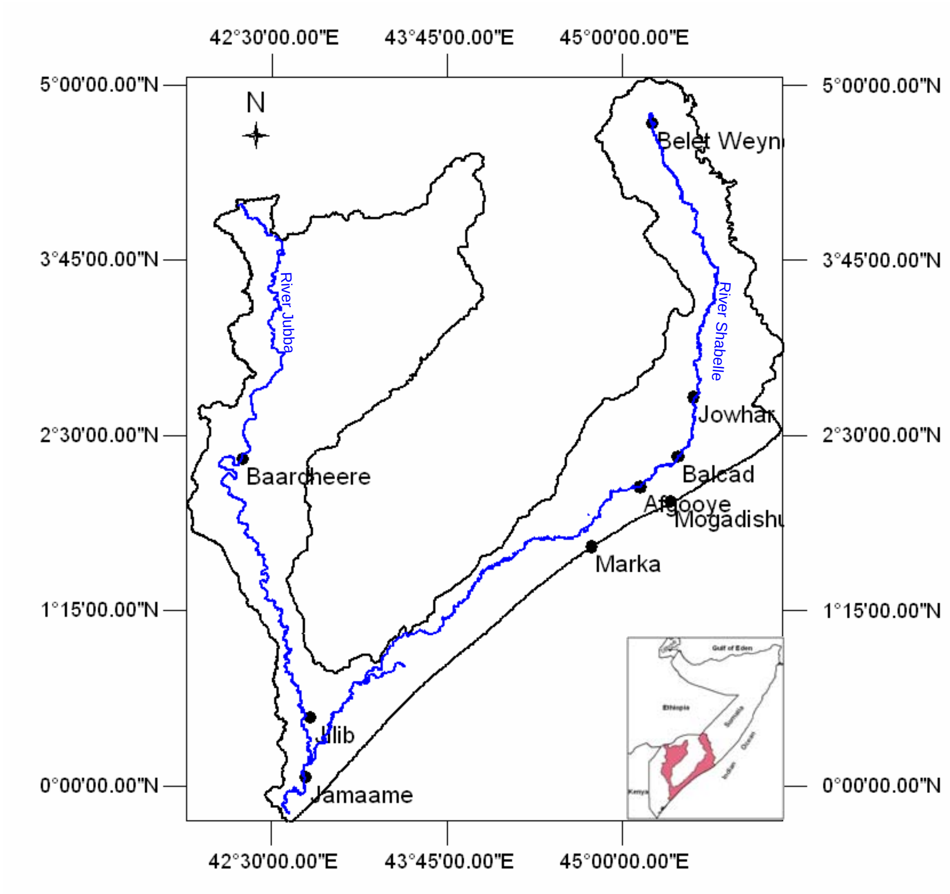


Figure 4: Study area (SAOI)

[8] Also referred to by SWALIM as Southern Area of Interest (SAOI)

4.2 Land Evaluation Methodology

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4.2.1 Resource base units (RBU)

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The basic units of evaluation are Resource Base Units (RBU), which are defined as land areas, generally smaller than a region but considerably larger than a farm, with a definable combination of climate, relief, altitude, edaphic conditions and natural vegetation (George *et al,* 2006). The RBUs are generated by combining different spatial baseline data layers, including Length of Growing Period (LGP), landscape, vegetation, soil groups and altitude (Figure 5).

Fifty-four RBUs were defined for the study area (see Map 7) and described in terms of more than 20 distinct land characteristics (Annex 4).

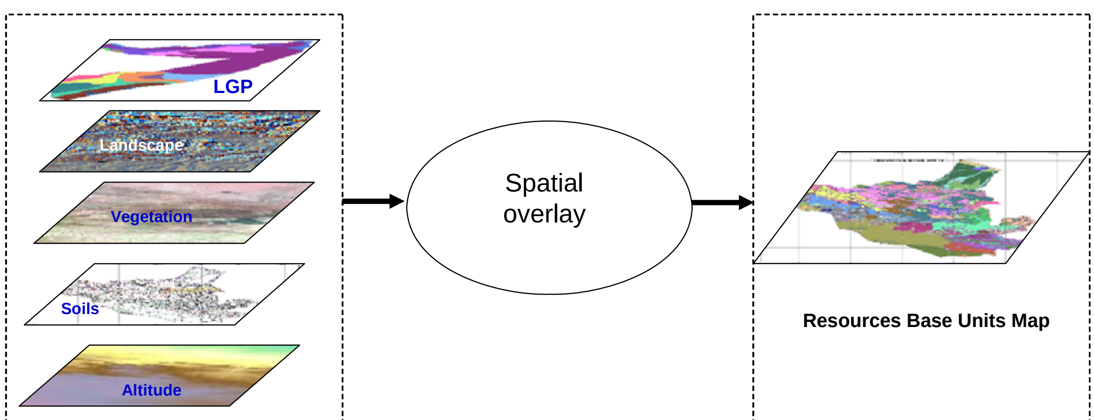
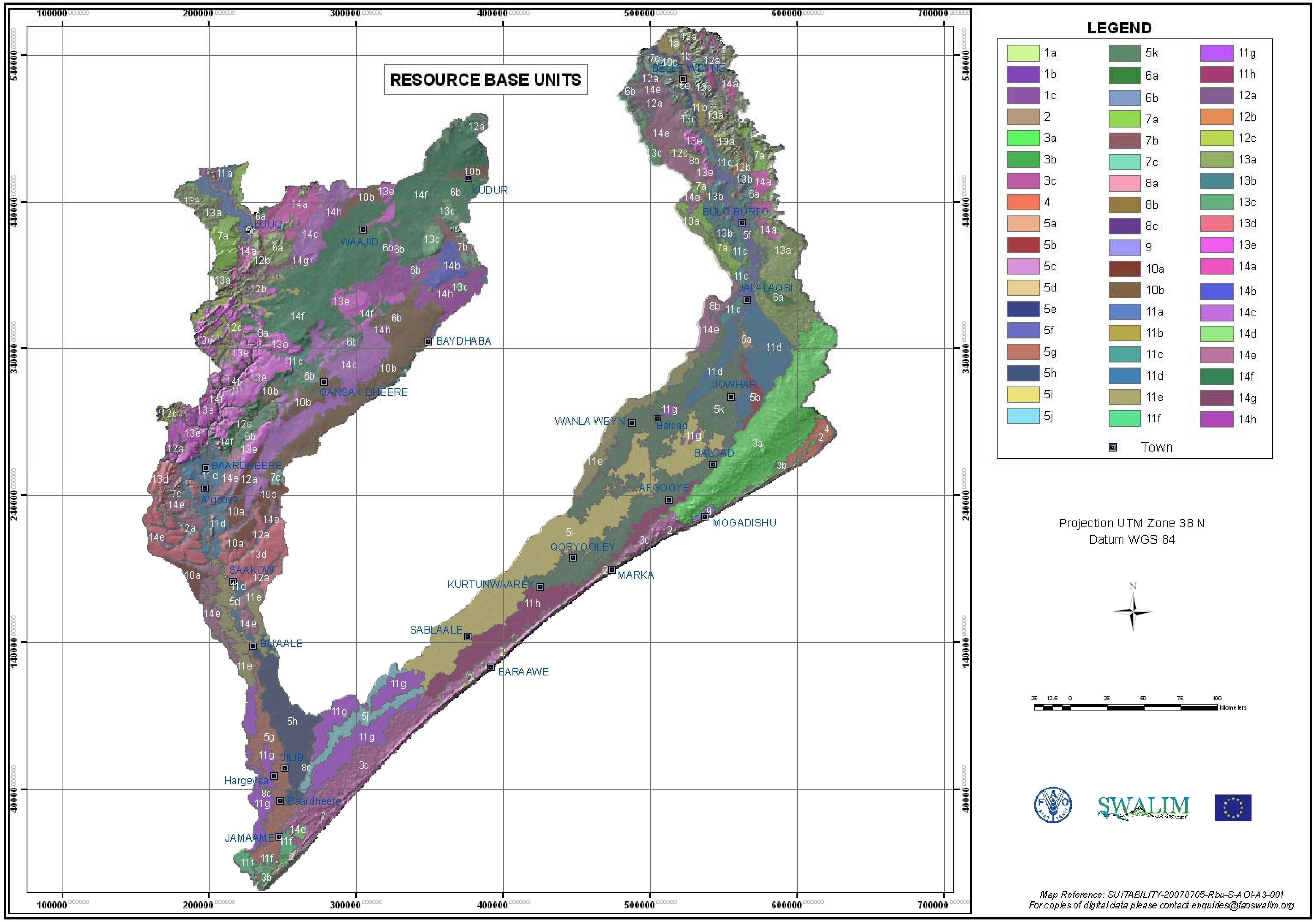


Figure 5: Identification of the RBU's

Map 7: Resource Base Units (SAOI)



4.2.2 Land use types (LUT)

Land suitability is determined for specific land use that can be defined at two levels of detail. A major kind of land use is a major subdivision of rural land use such as rainfed agriculture, irrigated agriculture, forestry etc. A land utilization type (LUT) is a kind of land use defined in more detail, according to a set of technical specifications in a given socio-economic setting. Major kinds of land use and LUTs which were included in the land suitability assessment of the study area (FAO-SWALIM Technical Report L-09) are given in Table 8.

Table 8: Land Use Types (SAOI)

Major Kind of Land Use		Land Use Type (LUT)	
R	Rainfed Agriculture (crops)	Rc	Rainfed cowpea; short GP (80 days); low-medium input
		Rk	Rainfed cotton; GP 160-180 days; medium input
		Rm1	Rainfed maize; short GP (80-90 days); medium input
		Rs1	Rainfed sorghum; short GP (90-100 days); medium input
I	Irrigated Agriculture (crops)	Ir	Flood irrigation of paddy rice; medium input
		Ic	Gravity irrigation of citrus and other fruits, medium input
		Is	Gravity irrigation of sugarcane, medium to high input
P	Pastoralism (extensive grazing)	Pc	Extensive grazing of cattle; low input
		Pd	Extensive grazing of camels; low input
		Pg	Extensive grazing of goats; low input
		Ps	Extensive grazing of sheep; low input
F	Forestry (tree plantation)	Fai	*Azadirachta indica* (neem)
		Fan	*Acacia nilotica* (maraa)
		Fat	*Acacia tortilis* (qurac)
		Fce	*Casuariana equisetifolia* (shawri)
		Fcl	*Conocarpus lancifolius* (damas, ghalab)
		Fdg	*Dobera glabra* (garas)
		Fti	*Tamarindus inidica* (raqai)

4.2.3 Land suitability classification

SOMALES has four suitability classes:

S1 = highly suitable

S2 = moderately suitable

S3 = marginally suitable

N = not suitable

A number of suitability subclasses are distinguished, reflecting kinds of limitation, e.g. subclass S3z means “Marginally suitable due to high salinity”.

4.3 Land Suitability for Rainfed Agriculture

The land suitability for rainfed sorghum (short growing period) is shown in Map 8. The suitability for the other three crops analysed shows a similar pattern. The study area has no land which is highly suitable (class S1) for the four rainfed crops which have been analysed. This is largely due to the fact that even in areas with relatively high mean annual rainfall (lower Shabelle and coastal zone), long-term average crop yields will remain below their biological potential, mainly because of rainfall variability (both seasonal and annual), flooding hazard, low soil fertility (alkaline soils) and/or high soil sodicity. Although some of these limitations can be overcome by improved management and increased inputs, this would mean increased costs that were unlikely to be off-set by increased production.

Roughly 10 to 25 of the study area is moderately suitable (class S2) for one or all of the four crops analysed. Most of the moderately suitable land is made up of the floodplains of the middle Shabelle south of Jowhar (RBUs 5i, 5j, 5k). Another area moderately suitable for rainfed cropping is made up of the upland plateaus in the Juba catchment around Baydhaba, Qansax Dheere and Xudur (RBU 10b). One of the main limitations for cowpea and maize in the alluvial plains of both the Juba and Shabelle is the alkalinity (high pH) of the soil. Locally high sodicity and salinity also limit crop production. Where such conditions exist, tolerant crops such as cotton, and to a lesser extent sorghum, are expected to do better. It is for this reason that some of the alluvial plains of the lower Juba and Shabelle (RBUs 11g and 11h) are classified as moderately suitable for cotton, and marginally suitable or unsuitable for cowpea, maize and sorghum.

Around 35% of the study area is unsuitable (class N) for all four LUTs, and almost 55% is unsuitable for maize (Rm1), which is the most demanding crop. Severe limitations to rainfed cropping exist in the coastal dunes and plains (RBUs 2, 3, 4) because of the low moisture-holding capacity of the soil. Short and unreliable growing periods, often in combination with shallow stony soils, pose a severe limitation in the hills and pediments in the northern parts of both the Juba and Shabelle catchments (RBUs 13a,b,c,e and 14c,g,h). High salinity makes some of the alluvial plains unsuitable for cowpea and maize (RBU 11g).

4.4 Land Suitability for Irrigated Agriculture

Somalia has a long history of irrigated agriculture on the alluvial plains of the Juba and Shabelle rivers. In 1980 about 50,000 ha were under controlled irrigation and 110,000 ha under flood irrigation (Alim, 1987). Large commercial schemes of irrigated sugarcane, rice, banana, citrus and other fruits used to operate in the Shabelle below Jowhar and in the Juba near Jilib. Since the early 1990s much of the irrigation infrastructure has deteriorated. Opportunities exist to revive old schemes or to grow the same crops in smaller schemes. Three LUTs were defined and selected for the suitability assessment:

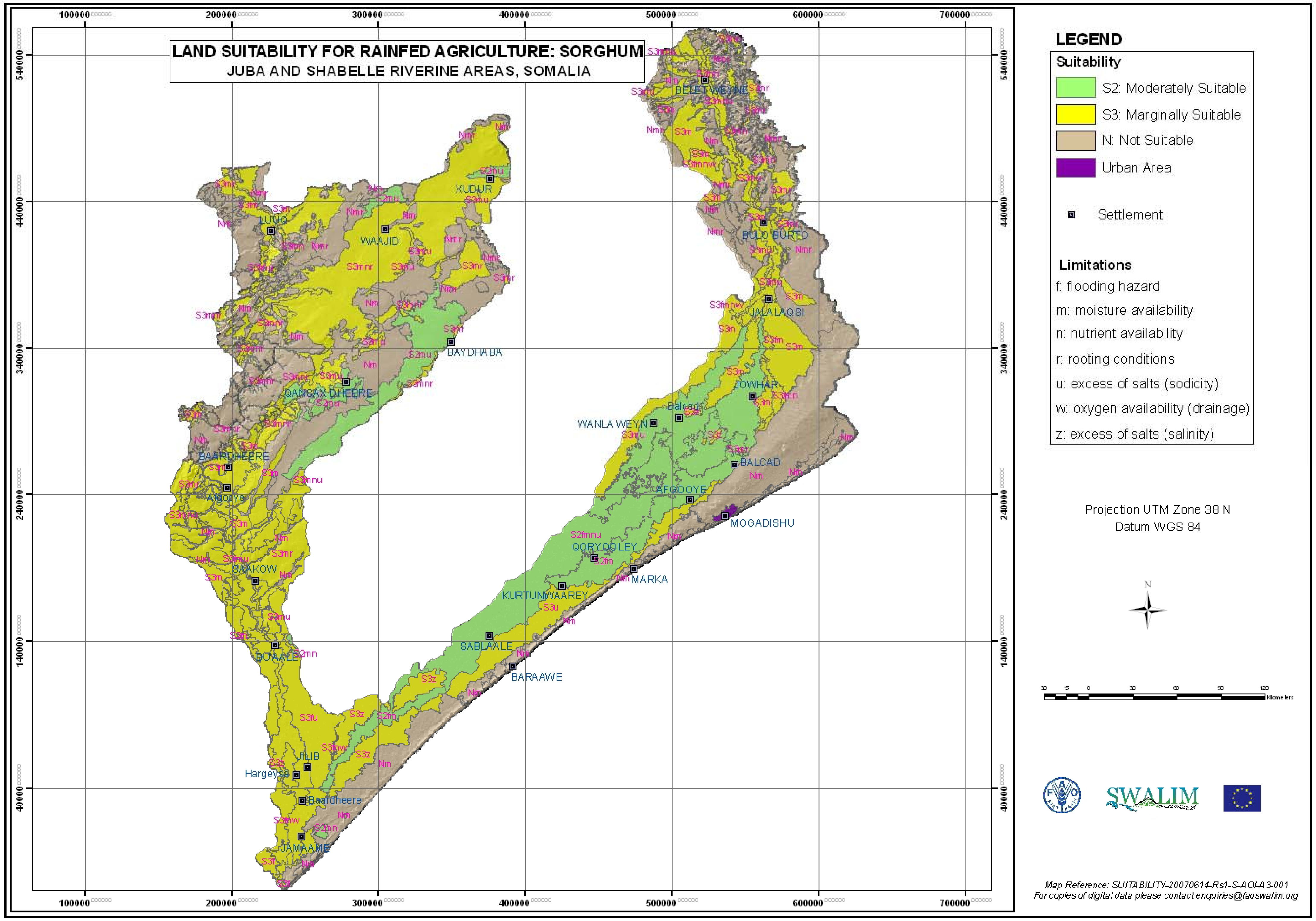
- **Ir**: **Rice.** Flood irrigation of paddy rice, small-scale, low-medium input (NPK fertilizer, irrigation management and infrastructure);
- **Ic**: **Citrus.** (and other fruits[9]). Controlled irrigation, medium-high input (seedlings, fertilizer, pesticides, irrigation management and infrastructure);
- **Is**: **Sugarcane**. Controlled irrigation, medium-high input (fertilizer, pesticides, irrigation management and infrastructure)

The land suitability evaluation that was carried out mainly concentrates on the suitability of the land (notable soils and topography) and less on the availability and quality of water for irrigation, and the assumption has been made that water is available in low-lying areas on the banks of the Juba and Shabelle.[10]

[9] Within the context of the present study it can be assumed that the (physical) land suitability for citrus is the same as that for crops like banana, papaya and mango.

[10] The Water Resources of the Juba and Shabelle riverine areas and of Somalia in general are the subject of additional specialized SWALIM studies.

Map 8: Land suitability for Rainfed Agriculture: sorghum (short GP) (SAOI)



Map 9: Land suitability for Irrigated Agriculture: Sugarcane (SAOI)

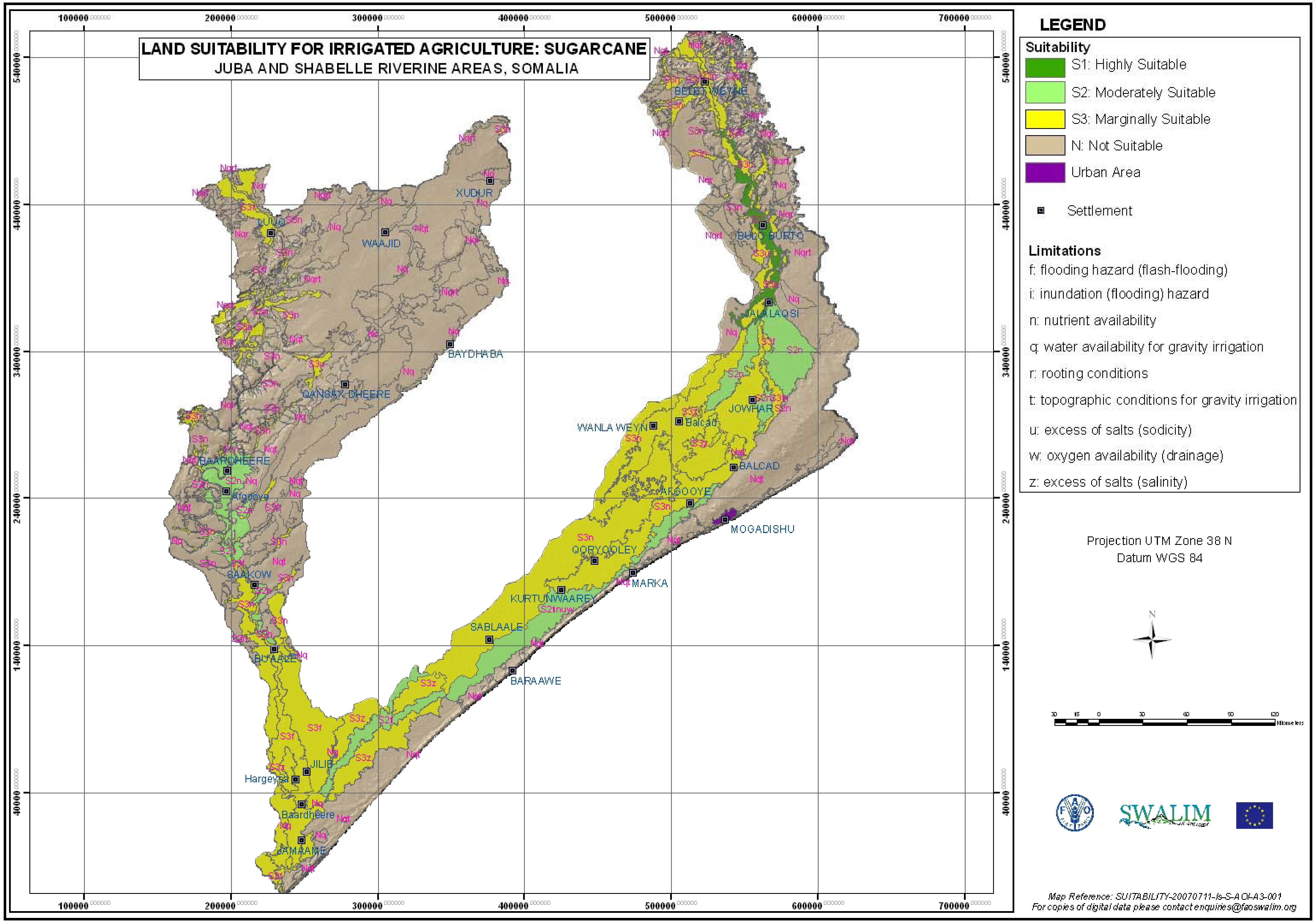


Table 10 gives a summary of the land suitability of the study area for the three LUTs. Map 9 shows the physical land suitability of the study area for sugarcane.

As can be seen in Table 10, there is very little land which has been classified as highly suitable (class S1) for any of the three LUTs. The only exception is a relatively small area (86000 ha) of narrow floodplains in the upper Shabelle (RBU 5f), which is highly suitable for sugarcane (see Map 9).

Moderately suitable land (class S2) is equally limited, with less than 180,000 ha for citrus (2% of total), 92,000 ha for paddy rice (1%) and 667,000 ha for sugarcane (nearly 8%). The main reason why most of the floodplains and alluvial plains of the Shabelle and Juba have been classified as only marginally suitable (class S3) for irrigation is because the soils are very alkaline (pH >8.5), high in sodium (exchangeable sodium of > 40%) and/or are saline (electric conductivity of > 12 dS/m)[11].

In the case of high-input commercial schemes, some soil improvement can be achieved and tolerant crop varieties can be introduced. Under such circumstances the land suitability would be rated differently. To demonstrate the land suitability for irrigated agriculture in the case of ameliorated soils, an “alternative” suitability evaluation has been carried out excluding crop requirements and land qualities related to soil chemical properties, i.e. nutrient availability, sodicity and salinity. The results of this evaluation, carried out for the floodplains and alluvial plains of Juba and Shabelle only, are shown in Table 11. Under conditions of improved soil fertility, the area of land classified as highly suitable (S1) and moderately suitable (S2) increases considerably. In the case of citrus, the area classified as S1 or S2 increases from less than 180,000 ha to more than two million hectares.

From soil data it appears that soil fertility problems relating to irrigated agriculture exist in the floodplains and alluvial plains of the Juba and Shabelle rivers. However, considerable variability in soil properties exist which, because of its generalized scale, cannot be captured in the present study. Also, as mentioned earlier, certain soil properties can be ameliorated if necessary. For these reasons, the suitability assessment for irrigated agriculture given in the present study should be considered as very general and not conclusive.

Table 9: Land suitability for Irrigated Agriculture (SAOI)

	Ic (citrus)		**Is (sugarcane)**		**Ir (rice)**	
	area (ha)	**%**	**area (ha)**	**%**	**area (ha)**	**%**
S1	0	0	85813	1.0	0	0
S2	177689	2.0	667016	7.6	91876	1.0
S3	3239716	36.9	2664576	30.3	2948051	33.5
N	5374900	61.1	5374900	61.1	5752378	65.4
total	8792305	100	8792305	100	8792305	100

[11] Soil data for the floodplains and alluvial plains were mainly derived from Feasibility Studies carried out in 1970s and 1980s, supplemented by recent data from SWALIM (see FAO-SWALIM Technical Report No L-08). Not all reports confirm limitations due to high alkalinity, high sodicity and/or high salinity.

Table 10: Land suitability for irrigated agriculture: with and without soil fertility improvement (SAOI)

RBU	ha	% of total study area	Land Use Type					
			Ic (citrus)		Is (sugarcane)		Ir (paddy rice)	
			Present, low soil fertility	Improved high soil fertility	Present, low soil fertility	Improved, high soil fertility	Present, low soil fertility	Improved, high soil fertility
5a	6257	0.07	S3f	S3f	S3f	S3f	S3f	S3f
5b	25225	0.29	S3fn	S3f	S3fn	S3f	S3fn	S3f
5c	23511	0.27	S3fn	S3f	S3f	S3f	S3fntu	S3ft
5d	24776	0.28	S3fn	S3f	S3f	S3f	S3fntu	S3ft
5e	20714	0.24	S3fn	S3f	S3f	S3f	S3fnu	S3f
5f	85813	0.98	S2n	S1	S1	S1	S3w	S3w
5g	160870	1.83	S3f	S3f	S3f	S3f	S3fuwz	S3fw
5h	185594	2.11	S3f	S3f	S3f	S3f	S3fuz	S3f
5i	585599	6.66	S3n	S2fi	S3n	S2fi	S3n	S2fw
5j	91876	1.04	S2fin	S2fi	S2fi	S2fi	S2fnw	S2fw
5k	588025	6.69	S3n	S2fir	S3n	S2fir	S3n	S2frw
11a	57314	0.65	S3f	S3f	S3f	S3f	S3fz	S3f
11b	52500	0.60	S3n	S2fi	S3n	S2fi	S3nw	S3w
11c	101882	1.16	S3nu	S2irw	S3u	S2irw	Nu	S2r
11d	369219	4.20	S3n	S1	S2n	S1	S3n	S2tw
11e	203932	2.32	S3n	S1	S3n	S1	S3nu	S2rtw
11f	41402	0.47	S3f	S3f	S3f	S3f	S3fwz	S3fw
11g	308284	3.51	S3z	S2fi	S3z	S2fi	S3z	S2fw
11h	205921	2.34	S3u	S2fiw	S2finuw	S2fiw	S3nu	S2f
12a	115429	1.31	S3n	S2r	S3n	S2r	Nw	Nw
12b	50487	0.57	S3n	S2r	S3n	S2r	Nw	Nw
12c	112775	1.28	S3n	S1	S3n	S1	Nw	Nw

Suitability Classes:	Limitations:	
S1 Highly Suitable S2 Moderately Suitable S3 Marginally Suitable N Not Suitable	f flooding hazard (flash flooding) i inundation (flooding) hazard n nutrient availability q water availability for irrigation r rooting conditions	t topographic conditions for irr. u excess of salts (sodicity) w oxygen availability (drainage) z excess of salts (salinity)

4.5 Land Suitability for Extensive Grazing (pastoralism)

Table 11 below gives the physical land suitability of the study area for extensive grazing (pastoralism). Four types of grazing (Land Use Types) have been considered: cattle (Pc), camels (Pd), goats (Pg) and sheep (Ps). The suitability for camels, goats and sheep is also presented in Map 10.

Evaluating land for its suitability for pastoralism is somewhat complicated because pastoralists move there livestock over large areas and do not confine themselves to one RBU. Even on land which itself provides very little grazing, livestock may be found roaming or passing through and obtaining some nourishment or water at least for some part of the year. Therefore a final evaluation should take into account all the land available for individual pastoralists or group of pastoralists and consider the dynamics of extensive grazing. The present study, however, is confined to the evaluation of individual RBUs.

While results are very similar for camels, goats, and sheep respectively, they are somewhat different for cattle.

No land was identified as highly suitable (class S1) for any of the LUTs. The reason for that varies from place to place. In the low lying alluvial plains it may be the presence of tsetse fly, the lack of abundant grazing because of cropping activities, or limited potential biomass because of high soil sodicity or salinity. Most of the northern areas receive limited rainfall and can therefore only provide limited and seasonal grazing.

Equally, very little land was identified as completely unsuitable (class N) for grazing. Most environments support some type of vegetation which seasonally provide at least a minimum of grazing. Less than 2% of the study area was classified as unsuitable, and includes the coastal plains which are devoid of vegetation.

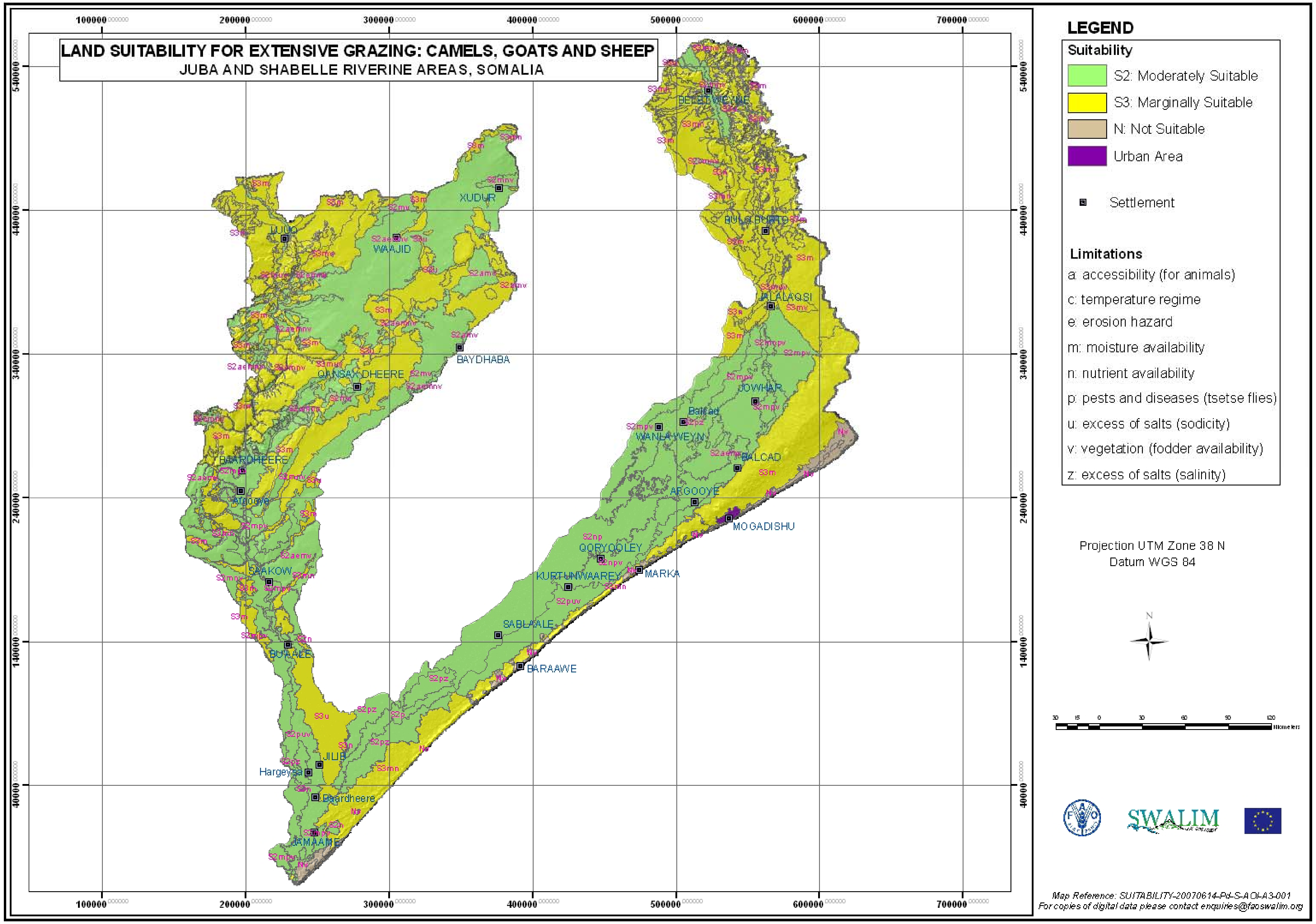
Slightly over 50% of the area is moderately suitable for camels, goats and sheep (class S2), with most of the remainder of the area being marginally suitable (class S2). The main limitation in marginally suitable land is low rainfall (short growing period), particularly in the northern part of the Shabelle catchment and the northwestern part of the Juba catchment.

For cattle, more land is marginally suitable (60% classified as S3) than moderately suitable (38% classified as S2). As compared to camels, goats and sheep, bovines are more sensitive to rough terrain and do not easily access steep slopes and/or stony and rocky areas. The areas most suitable for cattle (class S2) are the extensive alluvial plains of the Shabelle and lower Juba, as well as the gently sloping upland plains of the northeastern Juba catchment (see Map 10).

Table 11: Land suitability for extensive grazing (SAOI)

	Pc (cattle)		**Rd, Pg, Ps (camels, goats, sheep)**	
	area (ha)	%	area (ha)	%
S1	0	0	0	0
S2	3356660	38.2	4508399	51.3
S3	5297116	60.2	4145377	47.1
N	138529	1.6	138529	1.6
total	8792305	100	8792305	100

Map 10: Land suitability for Extensive grazing: Camels, Goats and Sheep (SAOI)



4.6 Land Suitability for Forestry

Table 12 shows the physical land suitability of the study area for seven forestry species. Three of the seven species evaluated are indigenous to the area, namely "Qurac" (*Acacia tortilis*), "Damas" or "Ghalab" (*Conocarpus lancifolius*) and "Garas" (*Dobera glabra*). Four others are exotic, namely "Maraa" (*Acacia nilotica*), "neem" (*Azadirachta indica*), "Shawri" (*Casuarina equisitifolia*) and "Raqai" (*Tamarindus indica*). The suitability for *Conocarpus lancifolius* and *Acacia tortillis* is also depicted in Map 11.

The fact that a species is indigenous to the area and/or that it is found growing there does not necessarily mean that it is highly suitable as a forestry species. Some trees may be survivors or remnants of a past period when conditions were more favourable, or the trees may grow, but only slowly and/or not to their full potential. In the present study, forestry species are evaluated on the basis of which all their requirements are met by the resource base and as to what degree they can reach their full genetic potential. A more meaningful evaluation for forestry species could be made if the precise purpose of a planned tree plantation were known. For example, if the main purpose was soil and water conservation the actual speed of growth and biomass production would be less important than in the case of a plantation intended for fuel wood or timber production.

More than 20% of the study area was found to be highly suitable (class S1) for five of the seven species. The major floodplains and alluvial plains of the Shabelle river have no major limitation for the productive growth of *Acacia nilotica, A. tortilis, Conocarpus lancifolius, Dobera glabra and Tamarindus indica*.

More than 55% of the study area is highly to moderately suitable (classes S1 and S2) for four of the species, namely *Acacia tortilis, Conocarpus lancifolius, Dobera glabra* and *Tamarindus indica*.

Unsuitable (class N) to marginally suitable (class S3) land for forestry occurs in the hilly areas in the north of the study area, where relatively low rainfall and shallow soils form the main constraints.

Of the species analysed, *Acacia tortilis* and *Conocarpus lancifolius* seem the most adapted to the prevailing conditions in the study area (Map 11), followed by *Dobera glabra* and *Tamarindus indica*. Two other species, which have similar requirements and which can be expected to do equally well are *Prosopis cineraria* and *Ziziphus mauritiana* ("gob").

The selection of a tree species for any plantation depends on its adaptability to the prevailing environmental conditions as well as its potential use and acceptance by the land users involved. Some trees may even become over-productive and invasive and/or be resented by people who do not directly benefit from them. Cultural and seemingly irrational beliefs should also be considered when promoting tree plantation.

Table 13 gives an indication of recommended species for the study area. This table is by no means exhaustive, as there are many other suitable species and numerous other functions of trees and uses of forestry products.

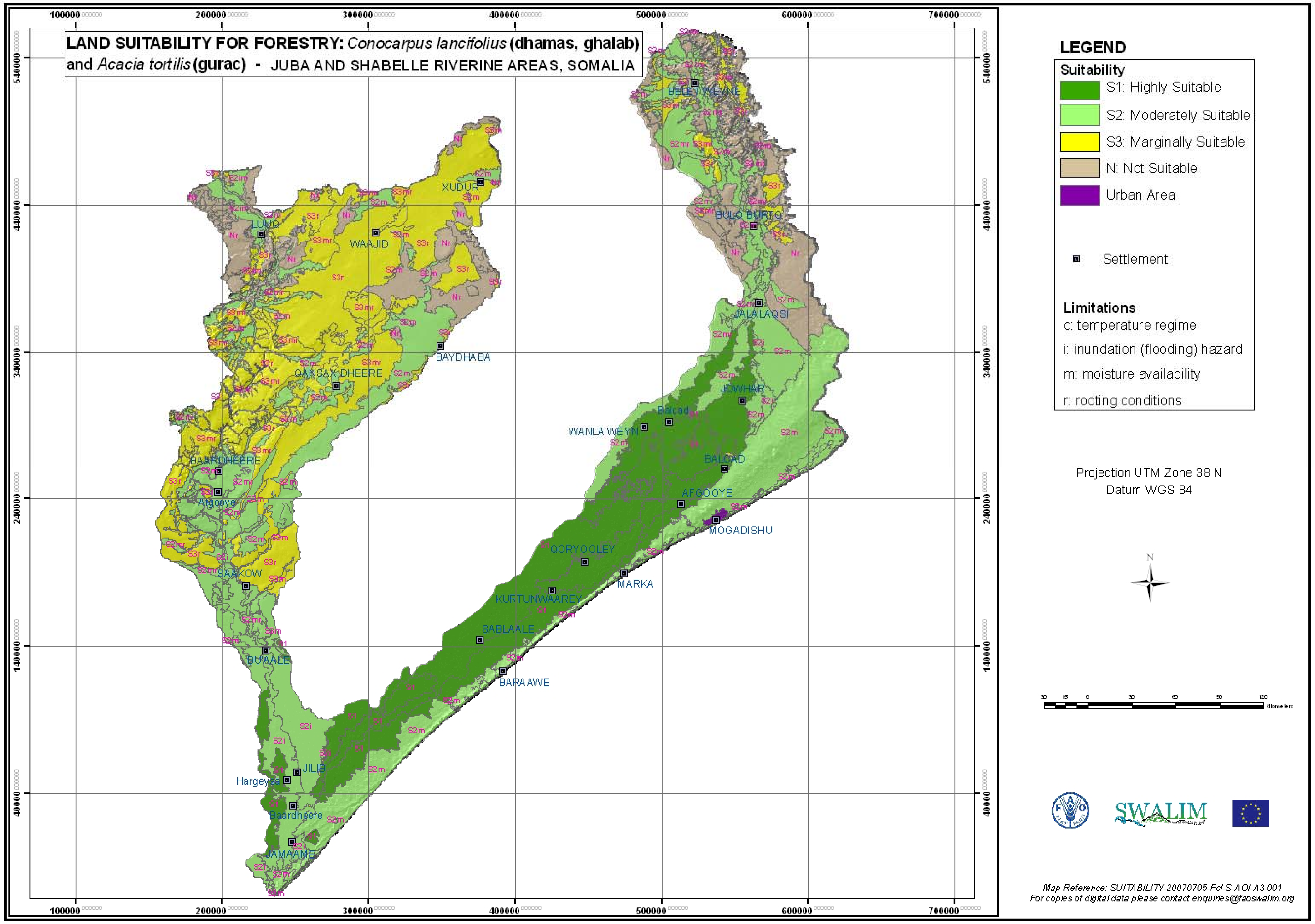
Table 12: Land suitability for forestry (SAOI)

	Fai *Azadirachta indica*		**Fan** *Acacia nilotica*		**Fat, Fcl** *Acacia tortillis Conocarpus lancifolius*		**Fce** *Casuarina equisetifolia*		**Fdg, Fti** *Dobera glabra Tamarindus indica*	
	area (ha)	**%**	**area (ha)**	**%**	**area (ha)**	**%**	**area (ha)**	**%**	**area (ha)**	**%**
S1	0	0	1789895	20.4	1789895	20.4	0	0	1789895	20.4
S2	2254733	25.6	464838	5.3	3423694	38.9	3198620	36.4	3052174	34.7
S3	3911194	44.5	3911194	44.5	2403201	27.3	2967307	33.7	2659292	30.2
N	2626378	29.9	2626378	29.9	1175515	13.4	2626378	29.9	1290944	14.7
total	8792305	100	8792305	100	8792305	100	8792305	100	8792305	100

Table 13: Summary of tree species suitable for various environments and uses (SAOI)

Species	**Fodder**		**Timber, poles**		**Fuel**		**Soil Cons**	
	Lowland Plains	Upland	Lowland Plains	Upland	Lowland Plains	Upland	Dunes	Upland
Acacia nilotica tugaar, maraa	yes		yes		yes			
Acacia tortilis qurac	yes	yes			yes	yes		yes
Conocarpus lancifolius dhamas, ghalab	yes	yes	yes	yes	yes	yes		yes
Dobera glabra garas	yes	yes	yes	yes	yes	yes		
Prosopis cineraria	yes	yes	yes	yes	yes	yes	yes	
Tamarindus indica raqai	yes	yes	yes	yes	yes	yes		yes
Ziziphus mauritiana gob	yes	yes	yes	yes	yes	yes		yes

Map 11: Land suitability for Forestry: *Conocarpus lancifolius, Acacia tortilis* (SAOI)



5 APPLICATION OF REMOTE SENSING TECHNIQUES FOR THE ASSESSMENT OF PASTORAL RESOURCES IN PUNTLAND, SOMALIA

Livestock or pastoral production is an important economic activity in Somalia. In most pastoral systems such as in Somalia, livestock production at farm level contributes as much as 70% to economic production or income (RCMRD *et al*, 2006). Pastoral activities in the Somali context involve the rearing of camels, goats, sheep, and cattle.

In March 2007 SWALIM carried out a pastoral resources study, with the aim of testing and evaluating the applicability of remote sensing tools and products in the assessment of pastoral resources. The study was carried out in Puntland, Northern Somalia, in two separate areas near Garowe in the Sanag, Sool, Nugal and Mudug regions (see Map 1). The areas are Garowe-north and Garowe-south respectively and are jointly referred to as the SWALIM Puntland Area of Interest (PAOI). Details of the study and results are given in *FAO-SWALIM Technical Report L-11* (Oroda *et al*, 2007).

The following sections give the objectives of the study and a summary of the main conclusions and recommendations. This chapter also contains some of the data collected during the survey, which give an indication of past and present pastoral resources in the area, such as land cover change and present herbaceous biomass.

5.1 Objectives and Summary Conclusions of the Puntland Pastoral Study

The main objective of the study was to test the application of remote sensing techniques and products for assessing resources in pastoral areas, in particular with respect to rangeland and environmental degradation. There were four specific objectives which, together with a summary of the main conclusions and recommendations, are given below.

Objective 1: *to assess changes and trends in land cover in the study area, using satellite image interpretation and field surveys*

<u>Conclusion</u>: Different methods of land cover change assessment show greatly varying results. *Automatic digital land cover classification* revealed a change in land cover in the study area of more than 50% over a period of 13 years (1988-2001). The accuracy of interpretation was high. On the other hand, *visual image interpretation* could only identify changes of less than 1%. The visual image interpretation also had a low accuracy of interpretation. According to the interview results, land cover had changed considerably during the period under review and only in a negative sense in most cases. Some of the changes detectable by automatic classification may be too small to be of any significance and as such automatic classification does not necessarily replace visual interpretation completely.

<u>Recommendations</u>: Although expert knowledge in remote sensing and the use of automatic image classification can yield good results in mapping land cover changes, field surveys still remain important. Familiarisation with the areas being interpreted and the use of indigenous knowledge can greatly improve the quality of remotely sensed land cover data. Integration of multiple datasets into remote sensing is highly recommended.

Objective 2: *to assess applicability of the average phenological behaviour of the major vegetation physiognomic groups as an input for the analysis of drought conditions in 2006*

Conclusion: Remote sensing has great potential in studying the phenological behaviour and physiognomic variability of vegetation in the arid and semi-arid environments. Periods of drought (in terms of years) were easily detectable based on NDVI and VCI values. Residents of the area confirmed the results obtained from remote sensing products. Consequently, remote sensing can be used effectively in assessing environmental conditions in areas where field data collection is not possible or is limited. However, the accuracy of assessment can be influenced by the spatial resolution of the sensors used. For example, the NOAA NDVI missed out on some drought events reported in the field, in contrast to SPOT (*Ed: in full – not in acronym list*) Vegetation NDVI data which more accurately pointed out the years of drought.

Recommendations: Remote sensing techniques are fairly accurate and are recommended for use where field data collection may be limited. However, regular calibration of information obtained through remote sensing through information from the field is recommended. The correct selection of remote sensing products is important. For example, whereas the NOAA NDVI data may be relevant in large and expansive areas with homogeneous land cover, it may not be very useful in detailed and heterogeneous land cover assessment because of its course spatial resolution.

Objective 3: *to assess human and animal impacts on the pastoral resources using remote sensing techniques with the focus on settlements, water points and vegetation removal*

Conclusion: Denudation or vegetation removal is easily identifiable by remote sensing. Settlements and areas around water-points did experience high degradation through vegetation removal between 1973 and 2006. Land degradation in the form of denudation can be assessed through NDVI and temperature values derived from Landsat satellite imagery. Information from the field confirmed results from satellite image interpretation. By assessing the extent of vegetation removal, it is also possible to map areas with increased risk of soil erosion.

Recommendations: Remote sensing gives a rapid assessment of the changes in land cover and may also locate possible areas of physical soil degradation by pointing out areas of denudation. However, additional field observations and the use of local knowledge are vital in order to make a correct interpretation, as some features may not be related to human activities but caused by natural phenomena such as droughts.

Objective 4: to *outline potentialities and limitations of remote sensing techniques and products in assessing non-palatable invasive species*

Conclusion: Remote sensing has limited use for the purpose of mapping invasive and non-palatable plant species. In the study area, the invasive and non-palatable vegetation species do not dominate any land cover type and are therefore difficult to detect directly by remote sensing. However, invasive and non-palatable plant species are commonly found in degraded areas and, as a result, some could be detected indirectly by associating them with degraded lands.

Recommendations: The use of remote sensing techniques for the mapping of invasive and non-palatable species in the arid environment of Somalia needs further investigation.

5.2 Observed Changes in Land Cover (1988 and 2001)

Maps 12 and 13 show the land cover in the study area for the years 1988 and 2001 respectively, as observed through automatic digital classification.

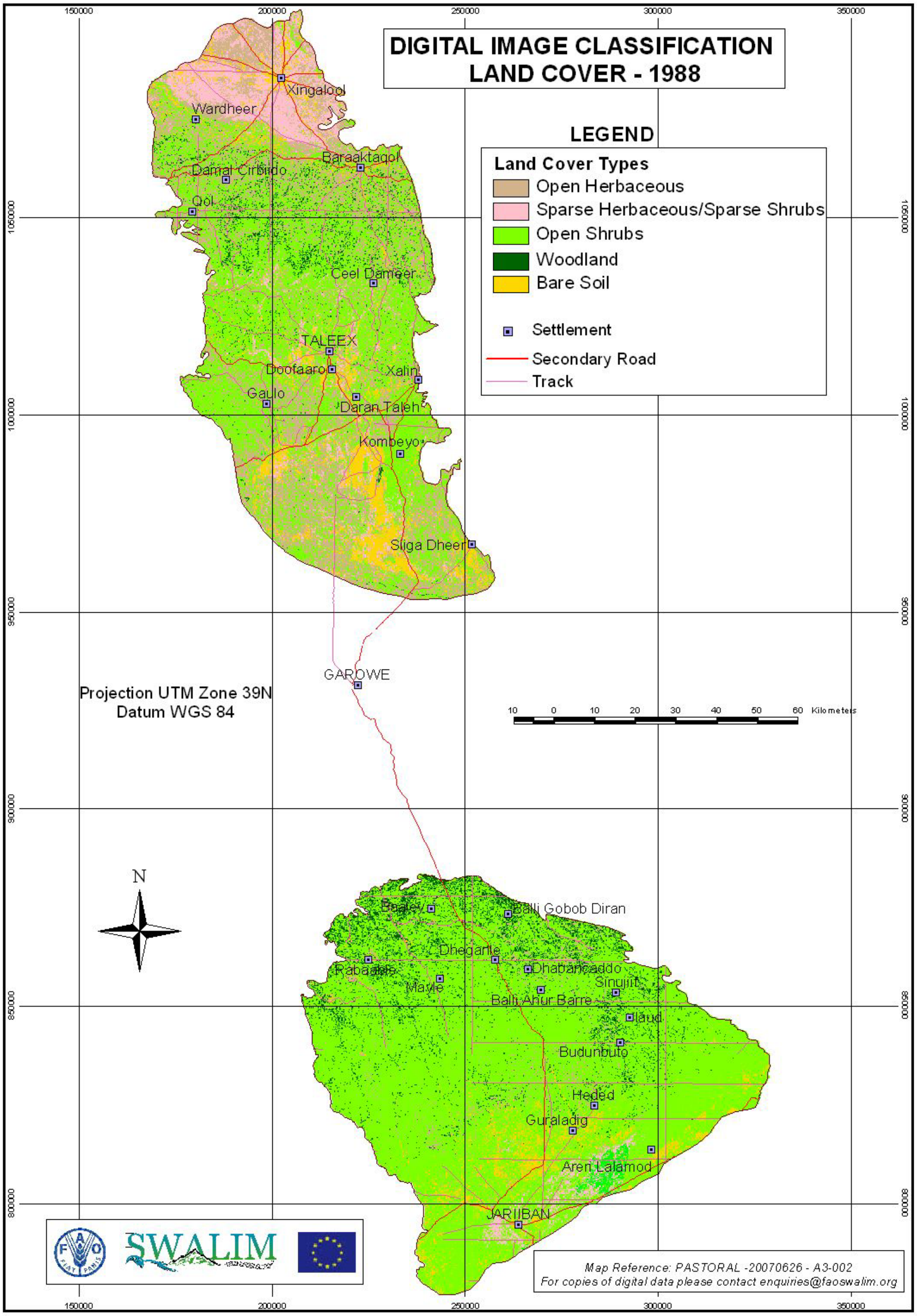
The changes over the 13-year period are considerable, as indicated in Table 14. The changes can be considered very negative as far as forestry is concerned, as areas with open tree vegetation decreased by nearly 90% and were turned into areas with shrub or herbaceous vegetation or even with bare soil. Since the area with bare soil increased by nearly 170%,(*Ed: check %)* the changes are also negative with respect to grazing resources. To ascertain exactly how grazing resources were affected, a further analysis would be needed of the increase or decrease of the various palatable species and biomass.

The changes occurred mainly in the northern part of the study area (northern Garowe) and much less in the southern part (southern Garowe). One reason for this maybe that the northern part experienced more drought conditions than the southern part during the period 1973 – 2001 (see Section 5.3). This implies that one has to be careful to extrapolate findings from one area to another, even if they are close to each other. It also means that negative vegetation changes are not necessarily due to human activity only (tree cutting, overgrazing, cultivation), but could also be caused or accelerated by climatic conditions.

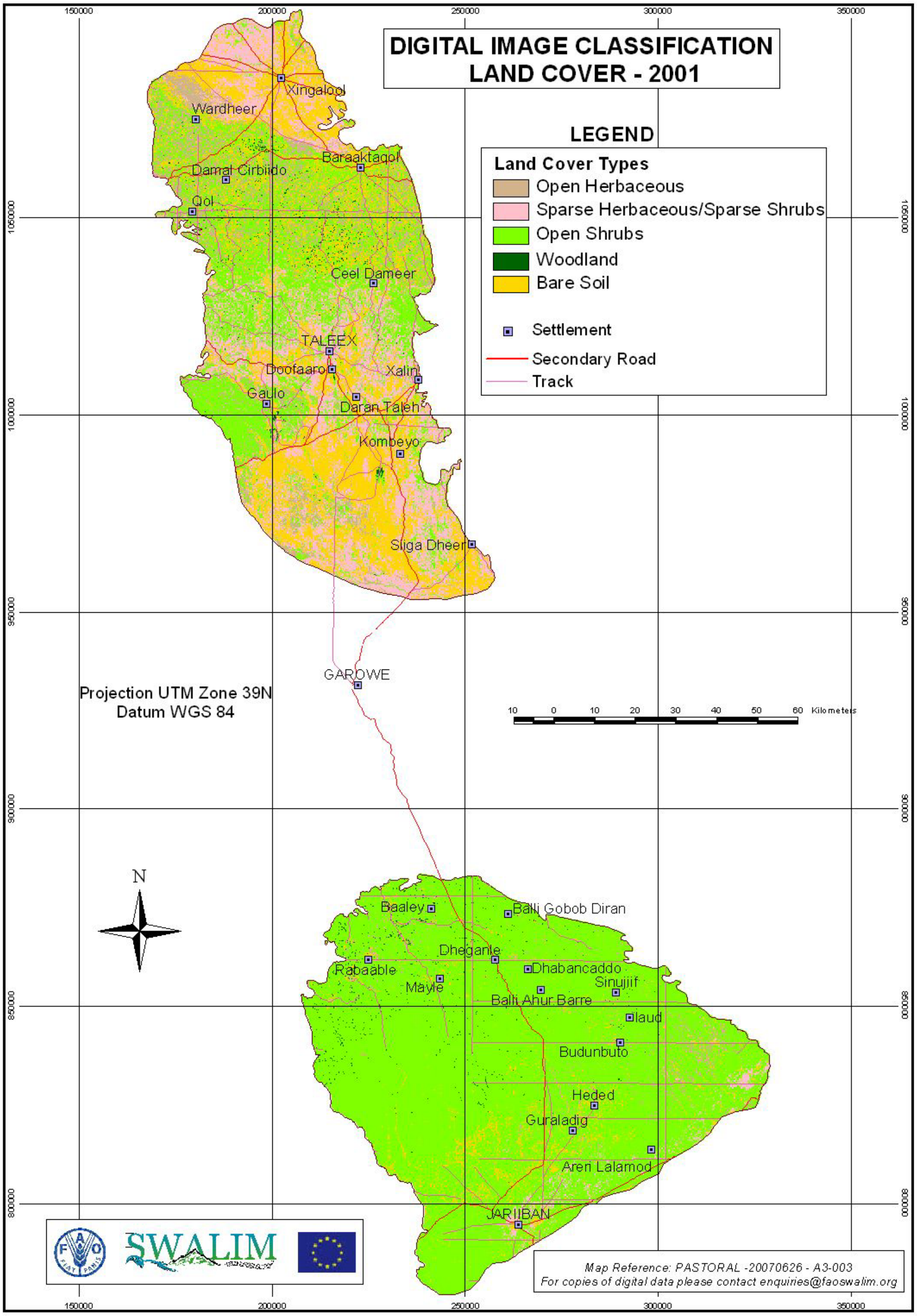
Table 14: Land cover change between 1988 and 2001

Land Cover class	**Area in 1988 (ha)**	**Area in 2001 (ha)**	**Land Cover Change**	
			(ha)	**(%)**
Woodland (Open Trees)	70 686	8 288	-62 4	-88.3
Open Shrubs	910 400	853 915	-56 5	-6.2
Open Herbaceous	239 007	96 545	-142 5	-59.6
Sparse Herbaceous Sparse Shrubs	82 972	185 561	+102 6	+123.6
Bare Soils	93 971	252 580	+158 6	+168.8

Map 12: Land cover Puntland AOI - 1988



Map 13: Land cover Puntland AOI - 2001



5.3 Drought Assessment

Mean annual rainfall in the study area is between 100 and 200 mm. Variability in annual rainfall is high, around 65% in Gaalkacyo, 200 km south of Garowe (see Section 2.1.2). Years with below-average rainfall are therefore a recurrent phenomenon in central and northern Somalia and could be considered “normal”.

Droughts could be defined as prolonged periods with below-average rainfall over large areas, when normal coping mechanisms practised by pastoralists fail and considerable loss of livestock is experienced.

Figure 6 shows the years of drought as remembered by residents of the northern part of PAOI (Garowe-north). It is evident that dry-weather years often come in clusters of consecutive years, e.g. 1989-1992 and 2000-2004. It is these prolonged periods of low rainfall that seriously affect pastoralists.

Periods of drought can be detected by remote sensing through NDVI and VCI values. However, the accuracy of assessment can be influenced by the spatial resolution of the sensors used. For example, NOAA NDVI missed out on some of the drought events reported in the field, in contrast to SPOT Vegetation NDVI data which more accurately pointed out the years of drought.

Figure 7 gives annual SPOT NDVI values for three sample points in Garowe-north for the years 1999 to 2006. Comparing SPOT NDVI values with the residents’ local observations gives a good correlation, at least for the period 1999 to 2006. In both cases below-average vegetation growth was observed and experienced for the period 2001 to 2004. However, the correlation is not perfect: SPOT NDVI values were above average for the year 2002, whereas all residents interviewed reported a drought. Care should be taken therefore to determine drought conditions from remote sensing data only. One would require the use of more than one remote sensing method and verification of results in the field in order to come to definite conclusions regarding present and past drought conditions.

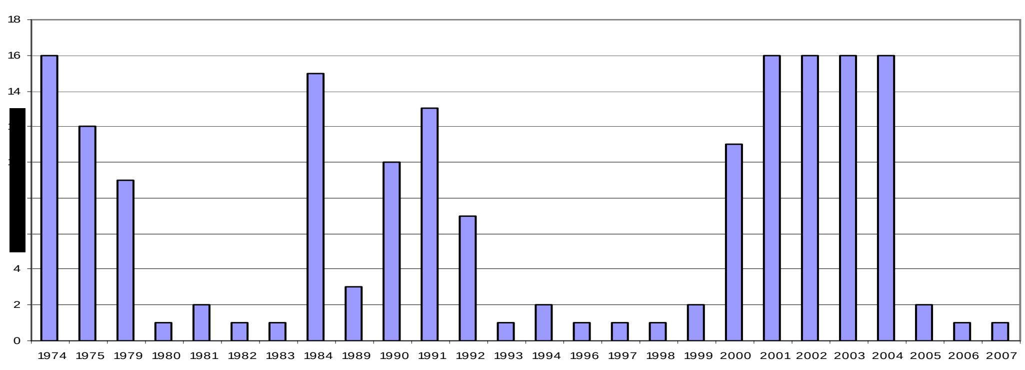


Figure 6: Years of drought as reported by residents (Garowe-north)

Figure 7: SPOT NDVI of sample points in Garowe-north

5.4 Biomass Assessment (dry season)

A biomass assessment was carried out in the northern part of the study area (northern Garowe) during early April 2007. The methodology of the assessment is explained in *FAO-SWALIM Technical Project Report no. L-11*. The results are shown in Table 15 as well as in Map 14. April is the start of the first rainy season (Gu).in the area. At the time of sampling it had not yet rained in the area, and the biomass assessment therefore represents a late dry season situation.

The total herbaceous biomass is estimated at 43,515 tonnes, or 670 kg/ha.

Table 15: Herbaceous biomass (northern Garowe)

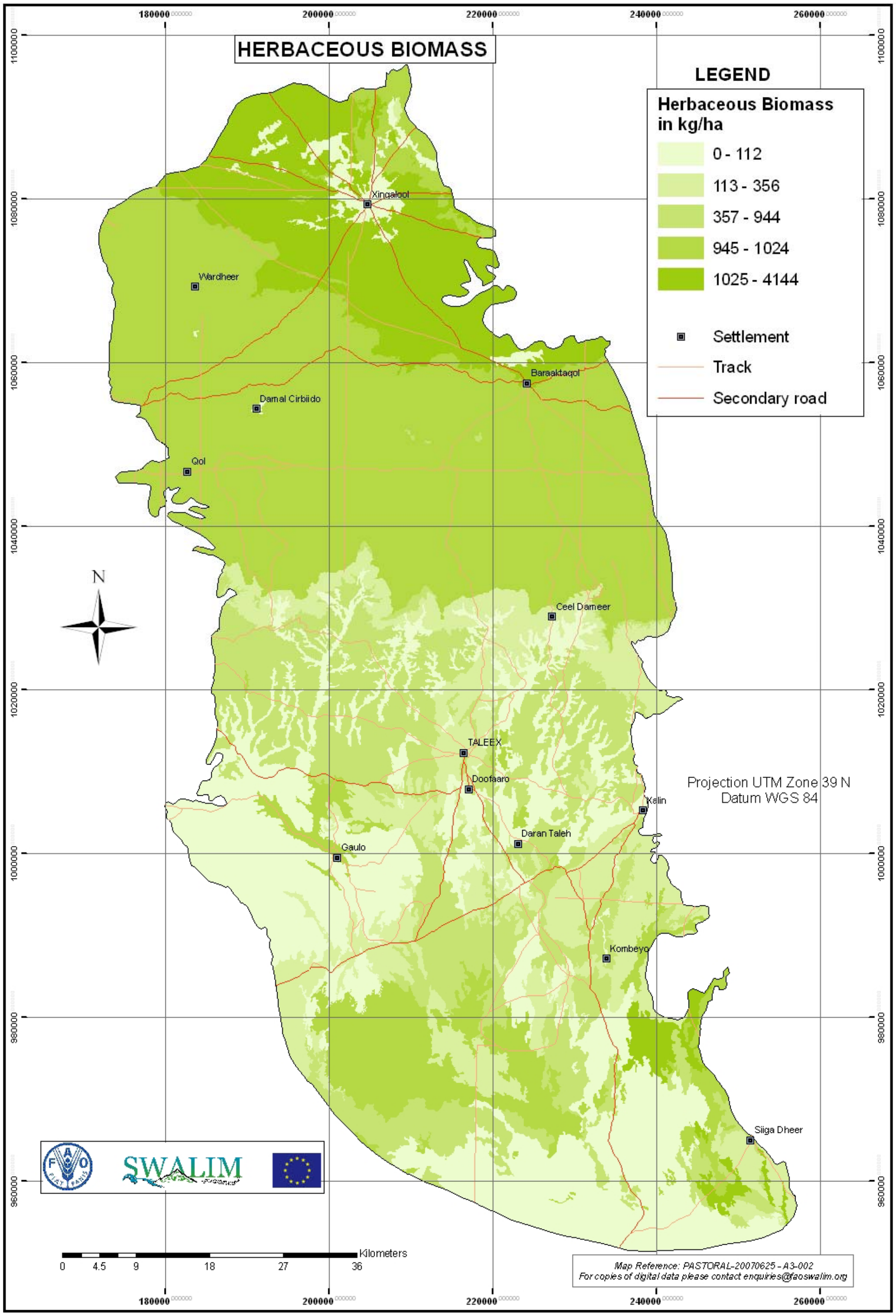
Land Cover Code	Land Cover Class	Area (ha)	Herbaceous Biomass	
			(kg/ha)	total (tonnes)
2SP6	Open Shrubs with Open Herbaceous	5992	1024	6136
2SP6/6S	Open Shrubs with Open Herbaceous mixed with Bare Soil	3512	1016	3568
2SR	Sparse Shrubs	11188	944	10561
2SR6	Sparse Shrubs with Herbaceous	8063	356	2870
2SP	Open Shrubs	4585	112	513
2SP7	Open Shrubs with Sparse Trees	2962	0	0
2SP7/6S	Open Shrubs with Sparse Trees mixed with Bare Soil	18538	0	0
2HR	Sparse Herbaceous	4422	1796	7941
2HL	Closed to Open Herbaceous	2827	4144	11926
6S	Bare Soil	2377	0	0
6SV	Bare Soil with Scattered Vegetation	223	0	0
2TP8	Open Trees with Open Shrubs	183	0	0
2HR/6S	Sparse Herbaceous mixed with Bare Soil	67	0	0
5U	Built Up Areas	12	0	0
	total	64951		43515

The main herbaceous species identified in the area are the grasses *Sporobolus ruspolianus, Sporobolus marginatus, Sporobolus spicatus, Andropogon kelleri,* and *Chrysopogon aucheri* and the herb *Arthrocarpum somalensis.*

Most of the herbaceous species are associated with alkaline, calcareous or gypseous soils and are tolerant of saline conditions. They have low to medium palatability.

The herbaceous biomass assessment carried out by SWALIM should be considered as a first attempt to evaluate pastoral resources in the study area. It is incomplete, as it only includes a dry-season measurement, and only of herbaceous vegetation. To get a true picture of the dynamics of the grazing resources, biomass assessments should be carried out for all three or four seasons, preferably over a number of years. Available biomass from palatable woody vegetation should also be estimated. Palatability and digestibility of grazing resources also should be taken into account.

Map 14: Dry-season herbaceous biomass northern Garowe



6 LAND DEGRADATION ASSESSMENT OF A SELECTED STUDY AREA IN SOMALILAND

A land degradation assessment of a selected study area in Somaliland was made by the SWALIM Land Team during the first half of 2007. Details of this study are given in *FAO-SWALIM Technical Project report no 10* (Vargas, Omuto & Njeru, 2007). The study is based largely on FAO-SWALIM resource inventories, carried out in the same area (FAO-SWALIM Technical Project Reports No's L-02, L0-3, L-04, L-05). The location of the study area is shown in Map 1 and Figure 2 and described in Section 3.1. The long-term goal of the study is to make a degradation assessment for the whole of Somalia. The LADA-WOCAT framework (www.lada.virtualcentre.org) was tested in the study area, for subsequent application at various subnational levels and eventually at the national level. The specific objectives of the present detailed assessment were:

1. to identify relevant land degradation types and indicators in a selected area of interest in north-western Somalia, using available datasets:
2. to be able to successfully apply the LADA-WOCAT methodological approach in assessing land degradation in the above area of interest;
3. to propose a framework for future assessment of land degradation in the entire area of Somalia using the LADA-WOCAT approach.

The following sections give a summary of some of the results and conclusions of the study, with the main focus on biological and physical degradation assessment.

6.1 Participatory Identification of Land Degradation Problems and User Needs

The type of land degradation in Somaliland and associated indicators identified at a stakeholders' workshop are given in Table 16.

Table 16: Type of land degradation in Somaliland and associated indicators

Land degradation type	Indicators
Soil erosion (by wind and water)	Dust storms, conspicuous dust coats on plant leaves and roof tops, presence of gullies, washed away soils, exposure of subsoil
Sedimentation	Colour of river water, soil deposits in river profiles
Soil compaction	Hard pan, shallow penetration of plant roots
Salt intrusion in ground water	Water quality
Stoniness	Presence of stones
Badlands	Lack of tree cover and presence of gullies
Loss of vegetation	Comparison of tree cover over time, new bare lands, charcoal trade
Decline in soil fertility	Soil chemical properties
Alien and unpalatable plant species	Coverage of invasive species
Rapid drying up of rivers	River flow measurements

6.2 Assessment of Land Degradation

6.2.1 Chemical degradation

Chemical degradation refers to the loss of plant nutrients from the soil and is assessed in two stages. In the first stage the present chemical soil fertility of the study area is mapped; in the second stage the in- and outflow of nutrients is estimated from present land use, soil characteristics and other parameters.

Chemical soil fertility

Chemical soil fertility in the study area is low, with the following mean values for the topsoil:

total carbon:	0.79 %
mineralizable nitrogen:	0.08 %
extractable phosphorous:	8.4 mg/kg soil
exchangeable potassium:	0.9 me/100g soil
cation (*Ed: correct sp?*) exchange capacity	20 me/100g soil

Subsoil values are about 60% of the topsoil values.

Four soil nutrient deficiency levels have been defined and mapped, as shown in Figure 8. Soils that are the most fertile have been assigned the class “light nutrient deficiency”, while the soils that are the most infertile have been assigned the class “extreme nutrient deficiency”. Figure 8 shows that the south-western part of the study area is slightly nutrient deficient while the north and north-eastern parts are extremely nutrient deficient.

Chemical degradation processes

Chemical degradation processes are complicated and dynamic and not easily determined. There is a constant in- and outflow of nutrients from the soil. Degradation takes place if the outflow is larger than the inflow over a long period.

One of the major factors influencing nutrient flow is present land use. For example, present cultivation practices in Somaliland are characterized by the continuous removal of nutrients through harvesting and low replenishment through fertilization. Consequently cultivated soils are impoverished over time.

Another factor to consider is the present fertility level and soil type. For example, the sandy soils in the north of the study are of very low fertility and therefore have not much to lose. This is in contrast to the clayey soils on the plateau in the south-west that are moderately fertile and can be easily degraded through poor land use practices.

Land use, soil type, and other factors are combined with present soil fertility levels to estimate and map the chemical degradation (Figure 9).

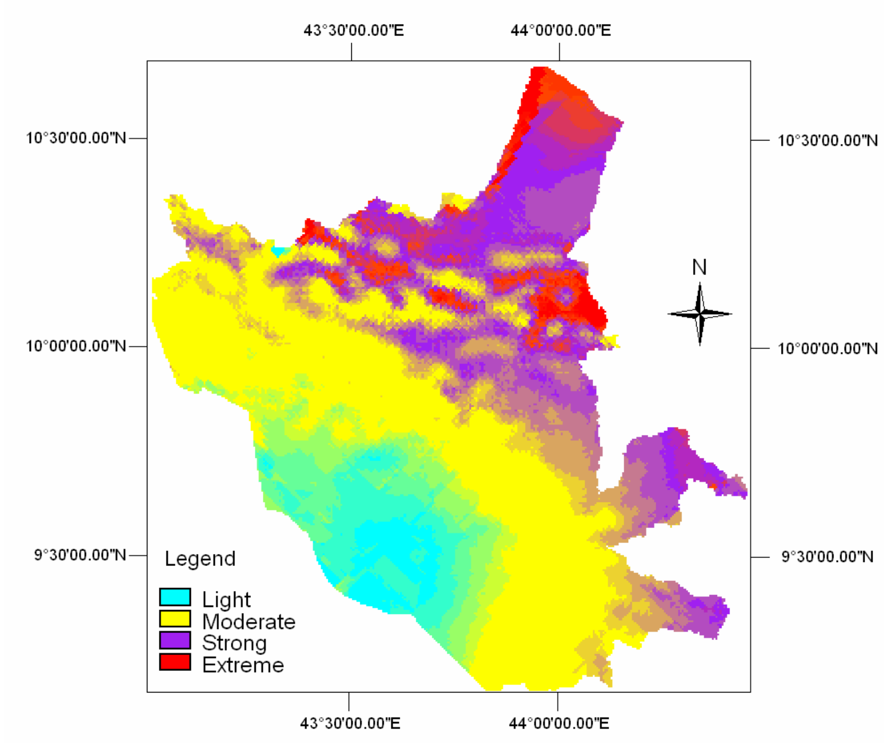


Figure 8: Nutrient deficiency

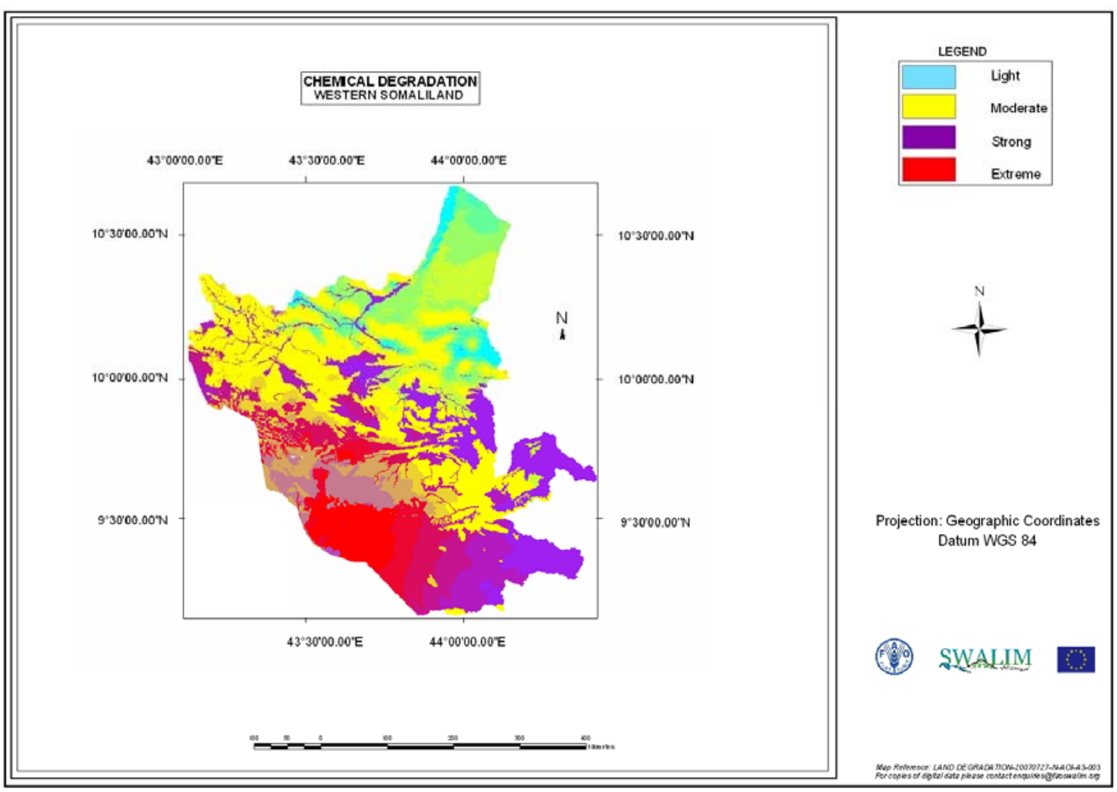


Figure 9: Chemical degradation

6.2.2 Biological degradation

Biological degradation mainly refers to loss in vegetative cover, loss of biodiversity and the increase in undesirable species (invaders).

The change in vegetative cover is measured by comparing past and present NDVI. A comparison of the 17-year long-term NDVI and the NDVI for 2003 is given in Figure 10. There are notable changes in the west and north-west, while the vegetative cover in coastal areas remained fairly unchanged.

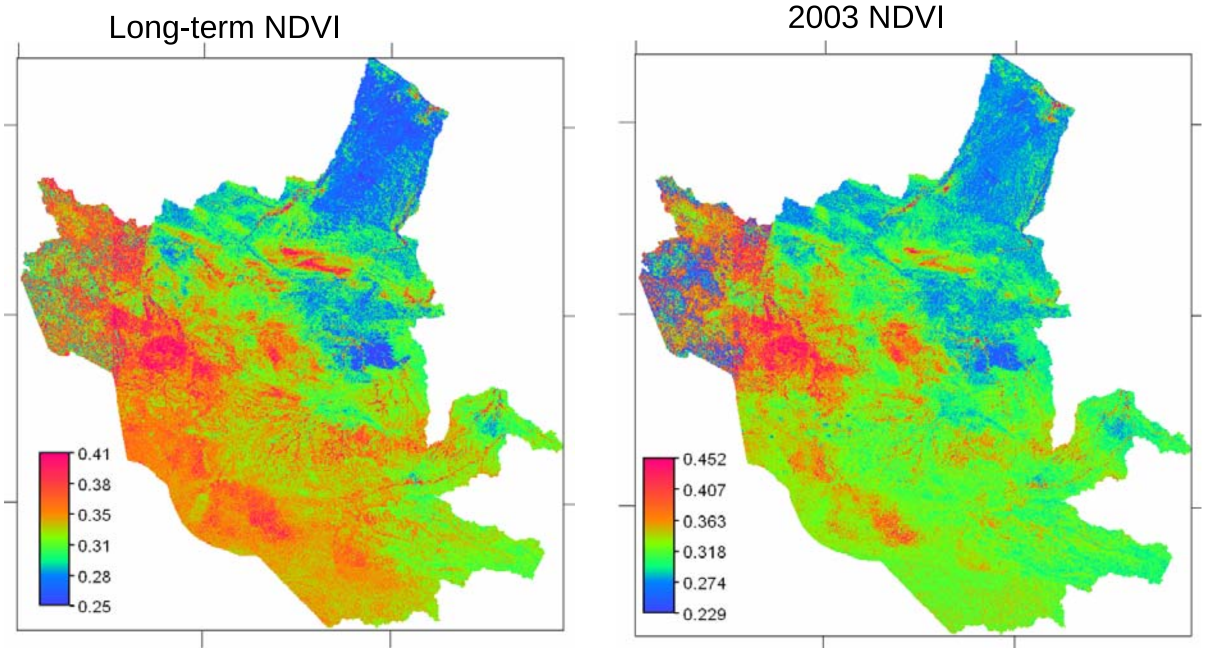


Figure 10: Long term NDVI (span of 17 years) and NDVI for 2003

The biological degradation map (Map 11) is based on a comparison of NDVI of 2003 with the long-term mean. Much of the south, south-west and west of the study areas show strong to extreme loss of vegetative cover, which can be attributed to the expansion of the area under cultivation. Fuel wood collection also contributes to vegetation loss in these areas. In the south-eastern and central parts, the moderate and extreme loss of vegetation is largely due to charcoal production. These areas have or had fairly good coverage of *Acacia bussei*, a tree preferred for charcoal production. The loss of vegetative cover in the northern and central parts can be attributed to grazing and the lopping of trees for animal feed.

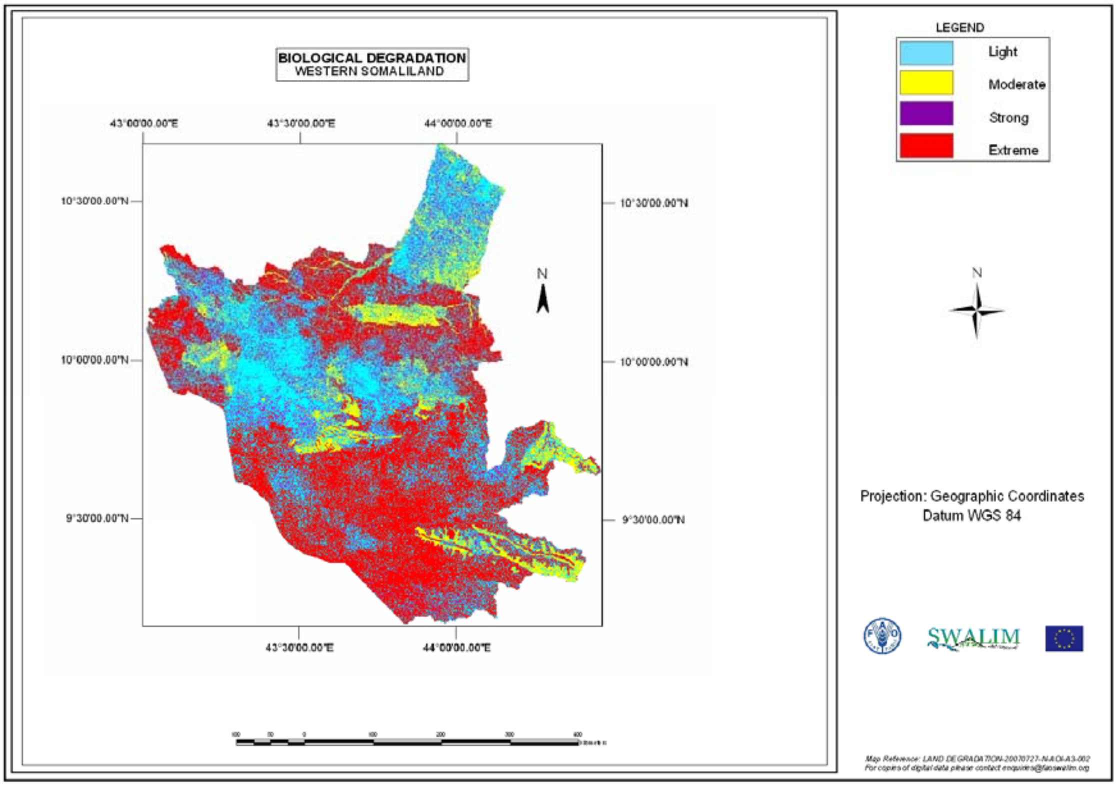


Figure 11: Biological degradation in the study area

6.2.3 Physical degradation

Physical degradation mainly refers to soil loss through erosion, but also includes phenomena such as the deposition of undesirable sediments, deteriorating soil structure and increased stoniness.

Potential annual soil loss through accelerated soil erosion by water was calculated by using the Revised Universal Soil Loss Equation (RUSLE). The result is shown in Figure 12.

Potential annual soil loss ranges from very low (0 – 1.0 ton ha^{-1} yr^{-1}) on the almost flat plains in the north and west of the study area to very high (> 200 ton ha^{-1} yr^{-1}) locally on the steep slopes of the south-east and north-west. Most of the study area (41%) has a low potential annual soil loss of 1-10 tons ha^{-1} yr^{-1}

The average potential annual soil loss for the whole study area is estimated at slightly over 20 ton ha^{-1}.

In addition to topography (slope), soil cover is an important factor that influences potential soil loss. Overstocking, poor cropping practices, and cutting of trees for firewood, charcoal or fodder, lead to decreased soil cover and increased soil loss. The presence of urban centres, such as Hargeisa in the south-east and Borama in the north-west, also contribute to the loss of vegetative cover as a result of fuel-wood collection and urban sprawl.

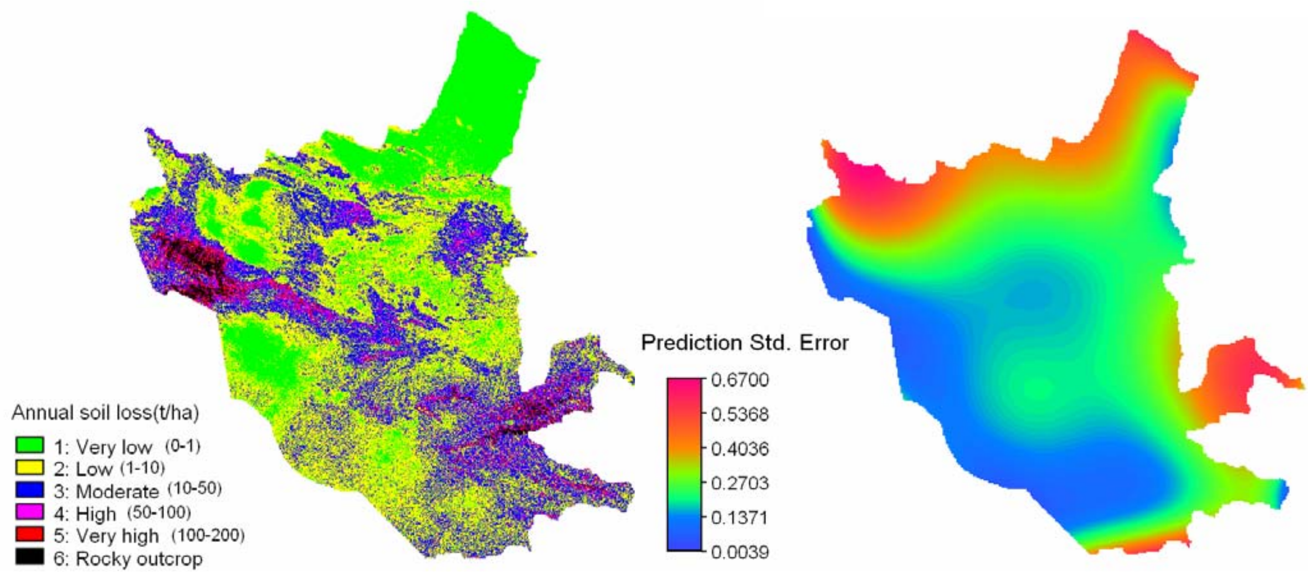


Figure 12: RUSLE prediction of the potential annual soil loss

The RUSLE soil loss prediction (Figure 12), in combination with evidence of stoniness and structural deterioration, gives the soil physical degradation map (Figure 13). Table 18 shows the characteristics of the physical degradation classes in Figure 13.

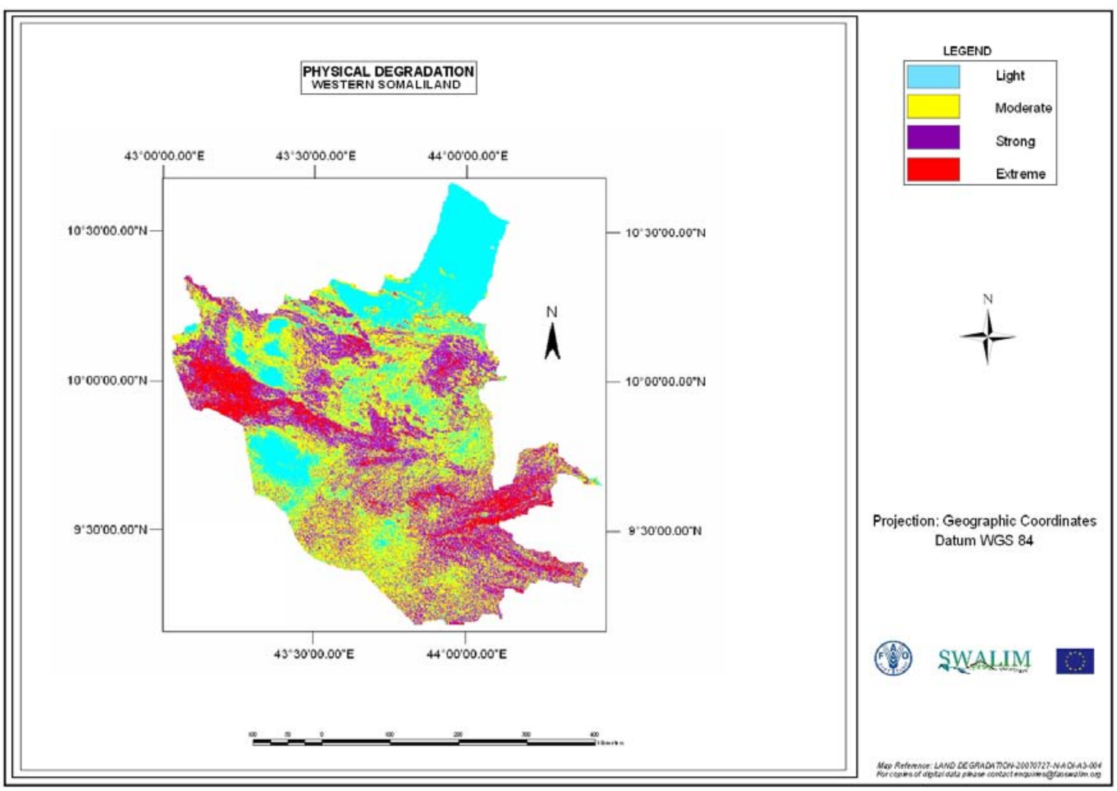


Figure 13: Soil physical degradation in the study area

Table 17: Characteristics of physical degradation classes

Degradation class	Annual soil loss (ton ha^{-1})	Stoniness	Structural deterioration
Light	0 - 10	No stones	Surface sealing
Moderate	10 - 50	No stones	Subsoil compaction
Strong	50 - 100	Stony	Compaction of the profile
Extreme	> 100	Stony	Compaction of the profile

7 INVENTORY OF DATA, MAPS AND REPORTS ON LAND RESOURCES OF SOMALIA

7.1 SWALIM Products

Table 18 gives an overview of the maps, map layers, databases, photographs and reports related to land resources produced by SWALIM for the three study areas and for the whole of Somalia. Most of these data can be downloaded from www.faoswalim.org or requested from enquiries@faoswalim.org. Some maps are also available as hard-copy, or come with the relevant technical land reports. A more detailed list of the FAO-SWALIM Technical Land Reports is given in Annex 1.

7.2 Other Products

Rangeland Surveys (1979-1985) and "Land System Units"[12]

Between 1979 and 1985, rangeland surveys were carried out for the whole country by a London-based company called Resource Management and Research[13]:

The surveys were carried out in three stages, as follows:

Central Rangelands Survey (Watson et al, 1979)
Northern Rangelands Survey (Watson, 1982)
Southern Rangelands Survey (Watson and Nimmo, 1985)

The surveys are based on the interpretation of 1:250 000 scale satellite imagery and extensive fieldwork. Ecological zones and land use systems were mapped and described. In addition to detailed information on livestock-related themes such as vegetation, range conditions, water sources and animal densities, the reports also provide details on climate, landform, soils, erosion and population. Maps at scale 1:1 mln (*Ed: million?*) with ecological zones and land system units for the whole country are included in the PhD thesis of J. Nimmo (1991)[14]. Nimmo in her thesis proposes a "Database system for the evaluation of land resources for planning and development in Somalia", with an exhaustive description of all the 496 Land System Units identified. This proposal, however, was never realized.

The Rangeland Surveys are an untapped source of information on land cover, vegetation and other land resources and could prove useful for determining environmental changes and trends.

Soil data (1968-1990)

The most important reconnaissance soil surveys at regional level were done in the Juba and Shabelle region (FAO-Lockwood, 1968; Hunting, 1977), and in Somaliland (Sogreah, 1981). Soil data are also available from the Master Plan for Juba Valley Development (Agrar und Hydrotechnik, 1990). Many more studies, usually covering small areas are detailed in *FAO-SWALIM Technical Report L-08*. The only available soil inventory at national level was carried out by the International Soil Reference and Information Centre (ISRIC) in the period 1987-1988, as part a 1:1 million scale soil map for North East Africa. The map and associated data was made available in digital format by FAO in 1998 (Land and Water Digital Media Series 2).

[12] Not to be confused with the "Land Use Systems" which are part of recent LADA methodology

[13] The reports of these surveys consist of numerous volumes and parts, a copy of which was acquired by SWALIM in 2007.

[14] Nimmo's thesis consist of 2 volumes, each with two parts and has also been acquired by SWALIM

Table 18: Inventory of SWALIM land maps, map layers, databases and photographs

Coverage (see also Map 1)	**Maps**	**Map Layers (shape files)**	**Databases**	**Photo-graphs**	**Reports**
Somalia (national coverage)	Length of Growing Period Agro-ecological Zones	Length of Growing Period Agro-ecological Zones	Rainfall Pot Evapo-transpiration		L-01 Field Survey Manual L-12 Potentialities and limitations in the use of remote sensing tools in detecting and monitoring environmental changes in the Horn of Africa. Proceedings of Workshop L-13 Land resources assessment of Somalia
Study area Somaliland (NAOI)	Landform Soils Land use Land cover Vegetation Resource Base Units Land use systems Land suitability (various) Land degradation (various)	Landform Soils Land use Land cover Vegetation Resource Base Units Land use systems Land suitability (various) Land degradation (various) Soil Profiles Field sample sites	Soils Land use Land cover Vegetation	Soils Land cover Land use	L-02 Landform of selected areas in Somaliland and Southern Somalia* L-03 Land cover of selected areas in Somaliland and Southern Somalia* L-04 Land use characterization of a selected study area in Somaliland L-05 Soil survey of a selected study area in Somaliland L-06 Land suitability assessment of a selected study area in Somaliland L-10 Land degradation assessment of a selected study area in Somaliland
Juba and Shabelle riverine areas Southern Somalia (SAOI)	Landform Soils Land use Land cover Resource Base Units Land suitability (various)	Landform Soils Land use Land cover Resource Base Units Land suitability (various) Vegetation Soil Profiles Field sample sites	Soils Land use Land cover Vegetation	Soils Land cover Land use	L-02 Landform of selected areas in Somaliland and Southern Somalia* L-03 Land cover of selected areas in Somaliland and Southern Somalia* L-07 Land use characterization of the Juba and Shabelle riverine areas in S. Somalia L-08 Soil survey of the Juba and Shabelle riverine areas in Southern Somalia L-09 Land suitability assessment of the Juba and Shabelle riverine areas in S.Somalia
Puntland study area (north + south Garowe)	Vegetation Land cover Biomass (north Garowe only)	Vegetation Land cover Field sample sites	Land cover Vegetation NDVI Questionnaires	Land cover Land use	L-11 Application of remote sensing techniques for the assessment of pastoral resources in Puntland, Somalia
					** Please note that reports L-02 and L-03 cover two study areas (NAOI and SAOI)*

Geological Map (1994)

A geological map for Somalia was compiled in the period 1987-1991 by Italian and Somali scientists (Abbate et al, 1994). It succeeds the Geological Map of Ethiopia and Somalia at scale 1:2 mln (*Ed: ?)* (Merla *et al*, 1973).

Africover (1997-2002

The Africover project mapped landcover of countries in Eastern and North-eastern Africa, including Somalia, using the FAO/UNEP international standard Land Cover Classification System (LCCS). Africover provides additional information on agriculture, grasslands, and geomorphology. Land cover for Somalia was interpreted from LANDSAT imagery, acquired mainly in the years 1995-1998. The dataset was published in 2002 at a scale of 1:200 000, and available from www.africover.org. Some of the Africover data are included in the Dynamic Atlas (see Section 7.3).

LADA (2005, ongoing)

The LADA programme (www.lada.virtualcentre.org) provides various global datasets, including climate, LGP, livestock densities, irrigation and rural/urban population. In most cases SWALIM has more detailed or more recent information on these subjects for Somalia.

Livelihood Zones (2004)

The Somalia Food Security Analysis Unit (FSAU) has mapped 32 Livelihood Zones in Somalia, mainly based on production systems (FSAU, 2004).

7.3 Dynamic Atlas

Dynamic Atlas is SKE computer software that provides easy access to and manipulation of maps, associated tabular data, and related documents, pictures, websites, etc. SWALIM makes use of this software and regularly enters and updates relevant information. Land-related information available from Dynamic Atlas (Somalia, March 2007) is given in Table 19.

Table 19: Dynamic maps related to land resources (Somalia, March 2007)

Coverage	Maps	Map Layers	Source
Somalia	Length of Growing Period	Length of Growing Period	FAO-SWALIM, 2007
	Landcover	Agriculture Bare areas Woody vegetation Rangeland	FAO Africover Project
	Landform	Landform	
	Soils	Soil Groups Soil Texture	FAO, 1998
	Geology	Geology Geological age	FAO ????
Western Somaliland (SWALIM study area)	Landform	Landscape Relief	FAO-SWALIM, 2007
	Soils	scale 1:100 000 scale 1:50 000 (southern)	
	Land use	Land use	
	Land cover	Agricultural fields Forest and rangeland Vegetation	
Juba and Shabelle riverine areas Southern Somalia (SWALIM study area)	Landform	Landscape Relief	FAO-SWALIM, 2007
	Land cover	Agricultural fields Forests and rangeland	
	Land use	Land use	
Juba Valley	Juba Valley	Lithology Landuse Land capability	Agrar und Hydrotechnik, 1990

8 CONCLUSIONS AND RECOMMENDATIONS

Land Resources Assessment (general)

1. Valuable information from past land resource surveys has been unearthed by SWALIM. It is recommended that SWALIM continues in its effort to integrate valuable data in current systems and formats. The recently acquired maps and reports from the country-wide Rangeland Surveys (Watson et al, 1979-1985) contain data that could be used for improving SWALIM products and for the study of changes in land and land use. *(surveys)*
2. SWALIM has established a considerable database on land resources, which need continuous management and dissemination. (*management, capacity building*).

Land degradation assessment

3. A methodology for land degradation assessment, based on LADA-WOCAT guidelines, was proposed and tested in western Somaliland. It is recommended that this methodology is further refined and applied to other selected areas and eventually to the whole country. A land degradation monitoring system, including formal feedback systems, should be designed and applied for selected areas. (*methodology development; capacity building, application*).

Land suitability assessment

4. A system for physical land suitability assessment (SOMALES) has been designed and tested in two study areas. This system now has to be introduced to technical staff in Somalia and the results disseminated to potential users. (*capacity building; application*).
5. An attempt should be made to introduce socio-economic parameters into the land evaluation system, so that various land use options can be compared on the basis of a cost/benefit analysis. (*methodology development*).
6. One of the main land characteristics which influence land suitability in Somalia are rainfall variability and the occurrence of droughts. To monitor droughts reliably, several remote sensing methods should be used simultaneously and results should be verified in the field if possible. SWALIM is in a good position to propose a drought monitoring system for the whole country. (*methodology development; application*).
7. Although past and current drought conditions can be recorded and monitored, drought forecasting is still unreliable and calls for more attention. Recurrent patterns and trends may be detected through a thorough analysis of long-term rainfall data. (*research; methodology development*)

Rainfed agriculture (crop production)

8. With respect to rainfed agriculture, it was observed that farmers largely grow local crop varieties from local seed. In addition to these local crops there could be potential for improved, early maturing varieties of sorghum, maize and cowpea which suit the largely bi-modal rainfall pattern in the study area. (*research; agricultural extension*)

Irrigated agriculture (crop production)

9. From existing soil reports and from SWALIM soil analysis it appears that the soils of the Juba and Shabelle alluvial plains and floodplain are mostly alkaline, and locally have high sodicity and salinity. More detailed study is needed to establish

the effect of these soil properties on both rainfed and irrigated crop production and how negative effects could be countered by either soil improvements or by selecting tolerant crops and crop varieties. (*research; agricultural extension*).

Pastoralism (extensive grazing)

10. Agro-pastoral land use is developing dramatically at the expense of pure pastoral land use systems. Agro-pastoral systems have other requirements than pastoral systems, particularly with respect to water and grazing requirements. A study on the various types of pastoral and agro-pastoral land use is needed, identifying main issues related to rangeland management and recommending solutions. (*research; surveys*).

11. Land cover changes in grazing areas, such as the Puntland (Garowe) SWALIM study area, are considerable, with a decrease in woody vegetation cover and an increase in herbaceous cover and bare soil. The herbaceous biomass assessment carried out by SWALIM in PAOI in April 2007 should be considered as a first attempt by the project to evaluate pastoral resources. It is incomplete, as it only includes a dry-season measurement, and only of herbaceous vegetation. To get a true picture of the dynamics of the grazing resources, biomass assessments should be carried out for all three or four seasons, preferably for a number of years. Available biomass from palatable woody vegetation should also be estimated. Palatability and digestibility of grazing resources should also be taken into account. (*research; monitoring*)

Forestry (tree plantation; agro-forestry)

12. A recurrent theme in the land resources inventory is the loss of woody vegetation through increased cultivation, and the cutting or lopping of live trees for firewood, charcoal production and animal feed. The land suitability assessment identified several trees for agro-pastoral use that can be grown successfully in Somalia. The next step is to identify management systems of multi-purpose trees which fit into current present farming systems and land tenure systems and are acceptable to farmers. (*research; land use planning and extension*).

Land Use Planning

13. Land use in Somalia has changed dramatically during the last two decades, as a result of factors such as population growth, droughts, changes in traditional land tenure and civil war. The decrease of nomadic systems and the increase of agro-pastoral systems throughout the country, and the partial collapse of irrigated agriculture in the Juba and Shabelle valleys, have had a dramatic impact on the present land use. This creates, in turn, an important starting point for future land use and land use planning. The next logical step for SWALIM is to develop a land use planning methodology, based on the results of the land suitability assessment in Somaliland and Southern Somalia by adapting the FAO methodology to Somali conditions. (*methodology development; capacity building*).

9 Bibliography

Abbate, E. et al., 1994. Geological Map of Somalia, scale 1:1.5 mln. Somali National University & CNR, Italy

Agrar und Hydrotechnik, 1990. Master Plan for Juba Valley Development. Main Report. Essen, Germany.

Alim, Musse Shaiye, 1987. Soil classification and land suitability studies in the Lower Shabelle Region, Somalia. Dept. of Soil Science. University of Uppsala, Sweden.

Bonnemayer, J., 2006. Land use and land resources evaluation. Methodology. FAO-SWALIM Internal Report. March 2006. Nairobi.

FAO-Lockwood, 1967. Agricultural and Water Surveys Somalia. Final Report. Vol I: General. Project FAO/SF:36/SOM

FAO-Lockwood, 1968. Agricultural and Water Surveys Somalia. Final Report. Vol III: Landforms and Soils. Project FAO/SF:36/SOM

FAO, 1976. A framework for land evaluation. Soils bulletin No 32. Rome.

FAO, 1983. Guidelines: land evaluation for rainfed agriculture. Soils Bulletin No 52. Rome.

FAO, 1984. Land evaluation for forestry. Forestry Paper 48. Rome

FAO, 1985. Guidelines: land evaluation for irrigated agriculture. Soils Bulletin No 55. Rome.

FAO, 1989. Arid Zone Forestry. FAO Conservation Guide No. 20. Forestry Dept. Rome

FAO, 1991. Guidelines: land evaluation for extensive grazing. Soils Bulletin No 58. Rome.

FAO, 1993. Guidelines for land-use planning. FAO Development Series 1. Rome.

FAO, 1998. The Soil and Terrain Database for Northeastern Africa. FAO Land and Water Digital Media Series no. 2. Rome.

FAO, 1996. Agro-ecological Zoning – Guidelines. Soils Bulletin 73. FAO, Rome.

FAO, 2001. FAOCLIM. Climatic Database (1961-1990). Sustainable Development Department. FAO, Rome.

FAO. 2003. Data Sets, Indicators and Methods to Assess Land Degradation in Drylands. Rome, Italy.

FAO, 2007. Land Evaluation. Towards a revised framework. Land and Water Discussion Paper 6. FAO, Rome.

FAO-SWALIM, 2003. Broad vision and medium term implementation strategy for water and land information. Working paper. SWALIM phase I. OSRO/SOM/303/EC

FAO-SWALIM. 2007. Somalia Dynamic Atlas. SWALIM, April 2007. Nairobi, Kenya.

FSAU, 2004. Somalia: Livelihood Zones. Nairobi

Horn Relief, 2006. Environmental study of degradation in the Sool plateau and Gebi valley: Sanaag region of northern Somalia.

Hunting Technical Services Ltd., 1977. Inter-riverine agricultural development study. Settlement Development Agency. Somalia

IUSS Working Group WRB. 2006 World Reference Base for Soil Resources 2006. Second ed. World Soil Resources Reports. Vol. 103. FAO, Rome.

Merla, G. et al., 1973. Geological map of Ethiopia and Somalia, scale 1:2 mln. CNR, Firenze, Italy

Monaci, L., Downie, M., and Oduori, S.M., 2007. Land Cover of Selected Study Areas in Somaliland and Southern Somalia. Technical Project Report L-03. FAO-SWALIM. Nairobi.

Nimmo, J.M., 1991. Development of a database system for the evaluation of land resources planning and development in Somalia. D.Phil. thesis (2 Volumes), University of York.

Oduori, S.M., Vargas, R.R. and Alim, M.S., 2007. Land use characterization of the Juba and Shabelle riverine areas in Southern Somalia. Technical Project Report No. L-07. FAO-SWALIM, Nairobi.

Oroda, A.S., Oduori, S.M. and Vargas, R.R., 2007. Application of remote sensing techniques for the assessment of pastoral resources in Puntland, Somalia. FAO-SWALIM Technical Project Report L-11. Nairobi.

Paron, P. and Vargas, R.R. 2007. Landform of selected study areas in Somaliland and Southern Somalia. Integrated landform mapping approach at semi-detailed scale using remote sensing and GIS techniques. Technical Project Report L-02. FAO-SWALIM. Nairobi.

RCMRD, ICPAC, FEWSNET, LINKS/GLCRSP and FAO (Somalia Office), 2006: Technical Report on the Review Study on the current and longer term trend of food security situation in the Greater Horn of Africa (GHA) with special focus on agro-pastoralists.

Rossiter, D.G. and Van Wambeke, A.R. 1991. Automated Land Evaluation System (ALES) Version 3 User's Manual. SCAS Teaching Series 2, Cornell University, Ithaca, N.Y.

Rossiter, D.G. and Van Wambeke, A.R. 1997. ALES Version 4.65 User's Manual. Cornell University. Ithaca, N.Y.

Sir MacDonald & Partners Ltd. 1978. Genale-Bulo Marerta Project. Annex I. Soils. Somali Democratic Republic. Min of Agriculture. Cambridge, UK.

Sir William Halcrow & Partners. 1982. Northern Rangeland Development Project. Report on soils in the project area. Somali Democratic Republic. National Range Agency. London.

SOGREAH Consulting Engineers. 1982. Climatology. Technical Report N 2. North-west Region Agricultural Development Project. Feasibility Study and Technical Assistance. Somali Democratic Republic. Ministry of Agriculture. Grenoble-France. Somalia.

SOGREAH Consulting Engineers. 1982. Soil Survey. North-west Region Agricultural Development Project. Feasibility Study and Technical Assistance. Somali Democratic Republic. Ministry of Agriculture. Grenoble-France. Somalia.

TAMS. 1986. Background and Watershed Management, Final Report. Volume I. Pilot Watershed Management for Soil and Water Conservation and Small Garden

Development. North-west Region Agricultural Development Project. New York, USA-Hargeisa, Somali Democratic Republic.

van Velthuizen, H. and Verelst, L. 1995. Crop Production System Zones of the IGADD Sub-region. Agrometeorology Working Paper Series N. 10. IGADD-FAO. Rome.

Vargas, R.R., Alim, M.S. and Omuto, C.T., 2007. Soil Survey of the Juba and Shabelle riverine areas in Southern Somalia. Technical Project Report L-08. FAO-SWALIM. Nairobi.

Vargas, R.R., Omuto, C. and Njeru,L., 2007. Land degradation assessment of a selected study area in Somaliland.

Venema, J.H. and Vargas, R. R. 2007a. Land suitability assessment of a selected study area in Somaliland. Technical Project Report L-06. FAO-SWALIM. Nairobi.

Venema, J.H. and Vargas, R. R. 2007b. Land suitability assessment of the Juba and Shabelle riverine areas in Southern Somalia. Technical Project Report L-09. FAO-SWALIM. Nairobi.

Watson, R.M., Tippett, C.I., Beckett, J.J. and Scholes, V. 1979. Central Rangeland Survey. Somali Democratic Republic. Resource Management & Research, London

Watson, R.M., 1982. Northern Rangelands Survey. Somali Democratic Republic. Resource Management & Research, London

Watson, R.M. and Nimmo, J,M. 1985. Southern Rangelands Survey. Somali Democratic Rupublic. Resource Management & Research, London.

Annex 1: List of SWALIM Land Reports, Maps, Databases and Photographs

List of FAO-SWALIM Technical Land Reports

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

L-02 Landform of selected areas in Somaliland and Southern Somalia *(Paron, P. and Vargas, R.R., 2007)*

L-03 Land cover of selected areas in Somaliland and Southern Somalia *(Monaci, L., Downie, M. and Oduori, S.M., 2007)*

L-04 Land use characterization of a selected study area in Somaliland *(Oduori, S.M., Vargas, R.R. and Alim, M.S., 2007)*

L-05 Soil survey of a selected study area in Somaliland *(Vargas, R.R. and Alim, M.S., 2007)*

L-06 Land suitability assessment of a selected study area in Somaliland *(Venema, J.H. and Vargas, R.R., 2007)*

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

L-08 Soil survey of the Juba and Shabelle riverine areas in Southern Somalia *(Vargas, R.R. and Alim, M.S., 2007)*

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

L-10 Land degradation assessment of a selected study area in Somaliland *(Vargas, R.R., Omuto, C. and Njeru,L. 2007)*

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

L-12 Potentialities and limitations in the use of remote sensing tools in detecting and monitoring environmental changes in the Horn of Africa. Proceedings of Workshop held in Nairobi 12-13 June 2007. *(Vargas, R.R., Pellikka, P. and Paron, P.)*

L-13 Land resources assessment of Somalia *(Venema, J.H., 2007)*

Annex 2: Correlation Soil Groups WRB 1998 with Soil Groups WRB 2006

Class	**Soil Group (WRB 1998)**		**Soil Group (WRB 2006)**		
	Group	**Prefix**	**prefix**	**Group**	**suffix**
1	Calcisols	Haplic Luvic Petric	Haplic Luvic Petric, Endopetric or Epileptic Endosalic Hypercalcic Vertic (Hypocalcic)	Calcisols	Siltic or Clayic (Chromic) Arenic or Siltic
	Gypsisols	Haplic Petric	Haplic Petric Calcic	Gypsisols	Clayic Siltic or Clayic
2	Fluvisols	Calcaric Eutric	Calcic Haplic Salic	Fluvisols	Calcaric (Arenic) Eutric Calcaric, Clayic
3	Leptosols	Eutric Lithic	Haplic Lithic Hyperskeletic (Lithic)	Leptosols	Eutric (Skeletic) Calcaric (Aridic)
4	Solonchak	Haplic Sodic	Haplic Haplic	Solonchak	Clayic or Arenic Sodic, Clayic
	Solonetz	Gleyic Haplic	Gleyic Haplic	Solonetz	Clayic Clayic
5a	Vertisols	Calcic Eutric	Calcic (Grumic or Mazic) Haplic Stagnic Endoleptic	Vertisols	Calcaric Eutric or Calcaric Calcaric
	Cambisols	Vertic	Vertic	Cambisols	
5c	Luvisols	Stagnic	Stagnic	Luvisols	
	Gleysols	Eutric	Haplic	Gleysols	Eutric
6	Arenosols	Calcaric Cambic Haplic Ferralic	Haplic Brunic Haplic Ferralic	Arenosols	Calcaric Calcaric (Protic) Aridic
7	Luvisols	Chromic Haplic	Haplic Haplic	Luvisols	Chromic Clayic
	Phaeozems	Haplic	Haplic	Phaeozems	Clayic
	Ferralsols	Haplic Rhodic	Haplic Haplic	Ferralsols	Rhodic
	Nitosols	Haplic	Haplic	Nitosols	Nitosols
	Planosols	Eutric Umbric	Haplic Umbric	Planosols	Eutric
	Cambisols	Calcaric Chromic Eutric	Haplic Haplic Haplic Fluvic	Cambisols	Calcaric, Clayic Chromic Eutric
	Regosols	Calcaric Eutric	Haplic Haplic Epileptic	Regosols	Calcaric (Skeletic) Eutric (Skeletic) Aridic, Calcaric

Annex 3: Resource Base Units, NAOI

RBU	Relief	Soil Group	Slope %	LGP Zone	Land cover	Pa	Alt m Ta °C	Dr	pH top	Ca CO3 top	Cfr top	Salin. top	CEC top	OC top	Soil depth	Ca top	Mg top	ESP top	Tex top	Name
1	Sandy coast	Haplic Arenosol	0-4	1	Bare Savanna	DE	7-34 28-30 °C	4	VA	V	VF	NS	L	VL	DD	L	L	NS	SL	Desert; sandy coast
2	Delta	Haplic Fluvisol	0-4	1	Closed trees	DE	3-29 28-30 °C	3	AL	V	N	SS	M	LO	DD	M	H	MS	Si	Desert; delta
3	Delta	Calcic Endosalic Fluvisol	0-4	1	Bare	DE	6-63 28-30 °C	4	AL	V	N	SA	M	LO	DD	M	M	MS	Si	Desert; salty delta
4	Alluvial plain	Haplic Regosol	0-4 4-10	1	Savanna	DE	17-359 28-30 °C	3	AL	S	F	NS	L	LO	DD	M	M	MS	SL	Desert; pre-coastal piedmont (fluvial)
5	Braided river plain	Haplic Fluvisol	0-4	3	Bare Open trees Orchard	LO	306-1469 20-28	4	AL	M	F	NS	L	LO	MD	M	M	MS	L	Dry semiarid & arid; sandy seasonal river
5a	Braided river plain	Haplic Fluvisol (Skeletic)		1, 2	Bare Open trees	LO	6-845 24-30 °C													Desert; sandy seasonal river
5b	Braided river plain	Haplic Fluvisol	0-4	11	Bare Open trees Orchard	LO	996-1633 20-24 °C	4	AL	M	F	NS	L	LO	MD	M	M	MS	L	Dry-moist semiarid; sandy seasonal river (70%) & alluvial plains (30%)
5c	Braided river plain	Haplic Fluvisol Fluvic Cambisol	0-4	12	Bare Open trees Orchard	MO	1049-1596 20-23 °C	4	AL	M	F	NS	L	LO	MD	M	M	MS	L	Dry-moist semiarid; sandy seasonal river (70%) & alluvial plains (30%)
6	Pediment; Dissected pediment	Haplic Regosol & Leptosols	0-4	3	Savanna Herbaceous	LO	308-1481 21-28 °C	4	AL	S	C	NS	L	VL	MD	M	L	NS	SL	Dry semiarid & arid; alluvial and stony piedmont; savanna
6a	Pediment; Dissected pediment	Haplic Regosol & Leptosols	0-4	3	Grassland Open trees	LO	118-829 24-29 °C	4	AL	S	C	NS	L	VL	MD	M	L	NS	SL	Arid; alluvial and stony piedmont; open trees
6b	Pediment; Dissected pediment	Haplic Regosol & Leptosols	0-4	3	Grassland Open shrubs	LO	496-998 24-27 °C	4	AL	S	C	NS	L	VL	MD	M	L	NS	SL	Arid; alluvial and stony piedmont; open shrubs
7	Hill; Hill complex; Ridge; Inselberg	Hyperskeletic Leptosol Lithic Leptosol	25-100	3	Savanna	LO	235-1340 21-28 °C	5	AL	M	D	NS			VS				S	Dry semiarid & arid; stony mountain; savanna
7a	Hill; Hill complex; Ridge; Inselberg	Hyperskeletic Leptosol Lithic Leptosol	25-100	3	Grassland Open trees	LO	179-1614 20-29 °C	5	AL	M	D	NS			VS				S	Dry semiarid & arid; stony mountain; open trees

Annex 3a: Resource Base Units, NAOI (cont ......)

RBU	Relief	Soil Group	Slope %	LGP Zone	Land cover	Pa	Alt m Ta °C	D	pH top	CaCO3 top	Cfr top	Salin. top	CEC top	OC top	Soil depth	Ca top	Mg top	ESP top	Tex top	Name
8	Depression; denudational surface	Haplic Leptosol; mainly skeletic	0-25	3	Savanna	LO	322-1686 19-28 °C	4	AL	M	A	NS							S	Dry semiarid & arid; stony; mountain; savanna
8a	Depression; denudational surface	Haplic Leptosol; mainly skeletic	0-25	3	Grassland Open trees	LO	385-1249 22-28 °C	4	AL	M	A	NS							S	Arid; stony; mountain; savanna
8b	Depression; denudational surface	Haplic Leptosol; mainly skeletic	0-25	3	Grassland Open shrubs	LO	538-1821 18-26 °C	4	AL	M	A	NS							S	Dry semiarid & arid; stony; mountain; open trees
9	Flood plain; Alluvial plain; Dissected pediment; Pediment	Haplic & Calcic Fluvisol; Fluvic Cambisol; Luvic Calcisol	0-4	3	Herbaceous Orchards	MO	421-1334 22-28 °C	4	AL	M	N	NS	H	LO	DD	M	M	MS	L	Arid; alluvial plains; orchards
9a	Depression	Fluvic Cambisol; Haplic Luvisol	0-4	12	Herbaceous Orchards	MO	1052-1699 19-23 °C	4	AL	M	N	NS	H	LO	DD	M	M	MS	L	Dry-moist semiarid; alluvial plains; orchards
10	Talus slope	Hyperskeletic Leptosol	0-10	3	Grassland Open trees	LO	355-721 26-28 °C	6	AL		D	NS			VS				S	Arid; eroded rocky slopes
11	Escarpment	Lithic Leptosol	10-25	3	Savanna	LO	917-1157 22-24 °C	6	AL		D	NS			VS				S	Arid; basaltic plateau; savanna
12	Denudational surface	Hyperskeletic Leptosol	0-4	3	Savanna Grassland Open trees	LO	1026-1300 22-24 °C	6	AL	H	C	NS	H	LO	MD	H	M	NS	SCL	Arid; basaltic plateau; open trees
13	Denudational surface	Hyperskeletic Leptosol	0-10	3	Savanna Bare	LO	1278-1715 19-22 °C	4	AL		D	NS			VS				S	Dry semiarid & arid; basaltic slopes; savanna

Note: numbering of RBUs not continuous due to late modifications in map legend

Annex 3b: Resource Base Units, NAOI (cont ......)

RBU	Relief	Soil Group	Slope %	LGP Zone	Land cover	Pa	Alt m Ta °C	D	pH top	CaCO3 top	Cfr top	Salin. top	CEC top	OC top	Soil depth	Ca top	Mg top	ESP top	Tex top	Name
15	Hill complex; Dissected ridge	Haplic Regosol & Leptosol Lithic Leptosol	10-100	3	Savanna	LO MO	733-1735 19-25	6	AL	V	D	NS			VS				S	Dry semiarid & arid; very eroded limestone hilland; savanna
16	Mountain; Dissected ridge	Lithic Leptosol Hyperskeletic Lithic Leptosol	25-100	12	Savanna	MO	1130-1616 20-23 °C	5	AL		D	NS			VS				S	Dry-moist semiarid; very eroded schist mountain; savanna
16a	Mountain; Dissected ridge	Lithic Leptosol Hyperskeletic Lithic Leptosol	25-100	11	Grassland Open trees	MO	1314-1788 18-22 °C	5	AL		D	NS			VS				S	Dry-moist semiarid; very eroded schist mountain; open trees
16b	Mountain; Dissected ridge	Lithic Leptosol Hyperskeletic Lithic Leptosol	25-100	12	Grassland Open shrubs	MO	1352-1674 19-21 °C	5	AL		D	NS			VS				S	Dry-moist semiarid; very eroded schist mountain; open shrubs
17	Planation surface; Denudational surface	Haplic Regosol (Skeletic)	0-10	12	Grassland Open trees	MO	1228-1738 19-22 °C	4	AL		D	NS			VS				S	Dry-moist semiarid; Piedmont; open trees
18	Plain	Calcic Grumic Vertisol	0-4	12	Shrubs Herbaceous Crops	MO	1360-1590 20-21 °C	4	AL	H	VF	NS	H	ME	VD	M	M	MS	C	Dry-moist semiarid; plain; Vertisols.
19	Dissected plateau; Hill complex	Haplic Leptosol	4-25	11	Savanna Shrubs Rainfed crops	MO	1202-1765 19-22 °C	4	VA	S	C	NS	L	LO	DD	M	M	MS	SL	Dry-moist semiarid; dissected plateau; shallow soils
20	Flat floor valley	Haplic Vertisol. Vertic Calcisol	0-4	11	Herbaceous Isolated fields	MO	1402-1695 19-21 °C	2	AL	H	N	NS	M	ME	DD	M	M	MS	C	Dry-moist semiarid; valleys; Vertisols
21	Dissected pediment	Haplic Regosol Fluvic Cambisol	0-10	3	Grassland Open trees Herbaceous Fields	MO	1130-1613 20-23 °C	4	AL	M	C	NS	L	VL	DD	M	M	NS	SL	Dry semiarid & arid; dissected plateau; shallow soils
22	Badland; Denudational surface	Haplic Regosol Haplic Calcisol	0-10	3	Bare Savanna	LO	967-1366 21-24 °C	4	AL	V	C	NS	L	VL	SS	H	M	MS	SCL	Arid; very eroded; calcaric piedmont; bare
22a	Badland; Denudational surface	Haplic Regosol Haplic Calcisol	0-10	3	Open shrubs & trees	LO	974-1239 22-24 °C	4	AL	V	C	NS	L	VL	SS	H	M	MS	SCL	Arid; very eroded; calcaric piedmont; open shrubs.
23	Plateau	Vertisol	0-4	11	Rainfed crops Shrubs	MO	1343-1716 19-21 °C	3	AL	H	N	NS	H	ME	DD	M	M	MS	C	Dry-moist semiarid; plateau; Vertisols; rainfed crops & shrubs.

Annex 3c: Resource Base Units, NAOI (cont ......)

RBU	Relief	Soil Group	Slope %	LGP Zone	Land cover	Pa	Alt m Ta °C	Dr	pH top	CaCO3 top	Cfr top	Salin. top	CEC top	OC top	Soil depth	Ca top	Mg top	ESP top	Tex top	Name
24	Denudation al surface; Pediment	Calcisols	0-4	3	Savanna Crops Shrubs	LO MO	1044-1517 20-23 °C	3	AL	M	VF	NS	M	ME	MD	M	M	MS	SCL	Dry semiarid & arid; dissected plateau; Calcisols & Leptosols
24a	Denudation al surface; Pediment	Calcisols	0-4	11	Savanna Crops Shrubs	LO MO	1321-1605 20-22 °C	3	AL	M	VF	NS	M	ME	MD	M	M	MS	SCL	Dry-moist semiarid; dissected plateau; Calcisols & Leptosols
25	Plateau; Mesa	Haplic Regosol (skeletic)	0-4	3	Savanna	LO	1244-1576 20-22 °C	4	AL		D	NS			VS				S	Dry semiarid & arid; residual plateau; shallow stony soils; savanna
26	Valley; Pediment	Calcic Vertisol	0-4	3	Very open trees Herbace ous Crops	LO	1067-1443 21-23 °C	4	AL	H	N	NS	M	LO	VD	M	M	MS	C	Arid; pediment; Vertisols; Tiger Bush & some fields
27	Straight river plain	Haplic Vertisol	0-4	3	Grasslan d Isolated crops	LO	1147-1418 21-23 °C	3	AL	H	N	NS	M	LO	VD	L	M	MS	C	Arid; alluvial plain; Vertisols; grassland
28	Playa	Haplic Solonchak	0-4	3	Bare Very open trees	LO	1224-1305 22-23 °C	1	VA	M	N	VS	L	LO	DD	M	M	SO	C	Arid; salted playas
29	Denudation al slopes and hills	Hyperskeletic Leptosol	0-4	3	Grasslan d Open shrubs & trees Savanna	LO	1024-1643 19-23 °C	4	AL		D	NS			VS				S	Dry semiarid & arid; residual plateau slopes; stony shallow soils; sparse vegetation
30	Hill complex; Dissected ridge	Lithic Leptosol	10-100	12	Closed shrubs	MO	1271-1616 20-22 °C	4	AL	V	C	NS			SS				S	Dry-moist semi-arid; steep limestone hilland; closed shrubs
31	Plateau	Vertisol	0-4	3	Open trees Isolated crops	LO	1234-1425 21-22 °C	3	AL	H	VF	NS	M	LO	MD	H	M	MS	C	Arid; plateau; Vertisols; open trees
32	Plateau						1385-1705 19-21 °C													Rural settlements
33	Plateau						1237-1486 21-22 °C													Urban area

RBU	Resource Base Unit	LGP	Length of Growing Period	Pa	Mean annual rainfall	Ta	Mean annual temperature
Cfr	Coarse fragments	Salin.	Salinity	CEC	Cation Exchange Capacity	OC	Organic Carbon;
Ca	Exchangeable Calcium	Mg	Exchangeable Magnesium	ESP	Exchangeable Sodium Percentage	Tex	Texture
Alt	Altitude						

For meaning of class symbols see Annex 5

Annex 4: Resource Base Units, SAOI

RBU	Landscape	Altitude	Ac1	Ca1	Cf1	Cf2	Dr	EC1	ES1	Ex	LCs	LGP	Mg	OC	Pv	Rs	Soils	Sd	Ss	Ta	Text	Ca/Mg	SOIL GROUP (WRB 2006)
		m	top	top	top	sub		top	top	top			top	top									
1a	Piedmont	180-200	AL	V	F	D	4	-	-	L	7-14	2	L	VL	H	3	1	VS	2	VH	L	VH	Haplic Calcisol (Chromic)
1b	Piedmont	180-200	VA	L	F	F	4	MS	ES	L	9	8, 9	M	HI	M	3	1	VD	2	VH	L	L	Haplic Calcisol (Chromic)
1c	Piedmont	180-200	AL	V	F	D	4	-	-	L	6-9	4, 5	L	VL	M	3	1	VS	2	VH	L	VH	Epileptic Calcisol (Chromic)
2	Mobile dune	<150	AL	L	F	F	4	NS	NS	L	14	10	L	VL	M	4b	6	VD	1a-5	VH	S	M	Haplic Arenosol (Calcaric)
3a	Coastal dune	<150	AL	V	F	F	3	NS	NS	H	9, 5	10	H	LO	M	3	6	VD	1a-6	VH	C	H	Ferralic Arenosol (Aridic)
3b	Coastal dune	<150	AL	L	F	F	5	NS	NS	L	14	10	L	VL	M	3	6	VD	1a-6	VH	S	M	Ferralic Arenosol (Aridic)
3c	Coastal dune	<150	AL	L	F	F	5	NS	NS	L	9	10	L	VL	M	3	6	VD	1a-6	VH	S	M	Ferralic Arenosol (Aridic)
4	Coastal plain	<30	AL	L	F	F	4	NS	NS	L	14	10	L	VL	M	3	6	VD	1a-5	VH	S	M	Protic Arenosol (Aridic)
5a	Flood plain	120	AL	V	F	F	3	NS	NS	M	10	8, 9	H	LO	M	2b	5c	VD	1a	VH	C	H	Salic Fluvisol (Calcaric, Clayic)
5b	Flood plain	100-110	VA	M	F	F	3	NS	NS	L	5, 9	8, 9	M	LO	M	2b	2-5a	DD	1a	VH	L	M	Haplic Regosol (Calcaric, Hyposalic)
5c	Flood plain	<155	VA	H	F	F	3	NS	VS	H	5, 6, 13	5	H	LO	M	2b	2-5a	MD	1a-2	VH	C	M	Haplic Fluvisol (Calcaric, Clayic)
5d	Flood plain	40-100	VA	H	F	F	3	NS	VS	H	5, 13, 10	9	H	LO	M	2b	2-5a	MD	1a-2	VH	C	M	Haplic Fluvisol (Calcaric, Clayic)
5e	Flood plain	170-200	VA	H	F	F	3	NS	VS	H	5, 6	8	H	LO	M	2b	2-5a	MD	1a-1c	VH	C	M	Haplic Fluvisol (Calcaric, Clayic)
5f	Flood plain	120-170	AL	M	F	F	4	NS	NS	M	9-5	5	M	LO	M	2b	1, 2	DD	1a-1c	VH	L	M	Calcic Fluvisol (Aridic, Clayic)/Vertic Hypocalcic Calcisol (Aridic, Clayic)
5g	Flood plain	0-50	AL	H	F	F	4	SA	VS	H	5-10	14	H	HI	L	2b	2-5c	DD	1a-1b	VH	C	M	Haplic Fluvisol (Calcaric, Clayic)/Stagnic Fluvisol (Clayic)
5h	Flood plain	15-35	AL	M	F	F	3	SA	ES	H	11	14	V	LO	L	2b	5c	DD	1a-1b	VH	C	L	Stagnic Vertisol (Calcaric)/Salic Solonetz (Clayic)
5i	Flood plain	100-110	AL	M	F	F	3	NS	SO	L	9-5	14	M	ME	L	2b	5b-5c	VD	1a-1b	VH	C	M	Calcic Vertisol (Calcaric)
5j	Flood plain	0-40	AL	L	F	F	4	NS	MS	H	10-9-5	14	M	LO	L	2b	5a-5c	VD	1a-1b	VH	C	L	Gleyic Vertisol (Calcaric, Hyposalic)/Fluvic Vertic Cambisol (Calcaric, Clayic)
5k	Flood plain	55-120	VA	M	M	M	3	NS	NS	L	5	14	M	LO	L	2b	5a-5b-2	DD	1a-1b	VH	L	M	Calcic Mazic Vertisol (Chromic)/Vertic Cambisol (Calcaric, Chromic)
6a	Depression	140-195	VA	H	F	F	3	NS	NS	H	5-7	4, 5	H	HI	M	2a	5a	DD	1a-1c	VH	C	M	Grumic Vertisol (Calcaric, Hyposalic)
6b	Depression	230-530	VA	H	F	F	3	NS	ES	H	6, 5, 9	6	H	LO	M	2a	5a, 2	MD	1a-1c	HH	C	M	Calcic Fluvisol (Arenic)
7a	Erosion surface	170-340	VA	M	F	D	3	NS	NS	L	9, 7	4, 5	M	HI	M	4a	3	VS	1a-3	VH	L	M	Calcic Petric Gypsisol (Siltic)
7b	Erosion surface	400-630	VA	M	F	D	3	NS	NS	L	8, 9	6	M	HI	M	4a	3	VS	1a, 1b	HH	L	M	Epileptic Calcisol (Arenic)
7c	Erosion surface	80-310	VA	M	M	F	3	NS	ES	L	9, 14	8, 9	M	HI	M	4a	3, 1	VD	1a-4	VH	C	M	Calcic Fluvisol (Arenic)/Lithic Leptosol (Aridic)
8a	Lake basin	115-335	VA	M	M	M	2	NS	NS	L	14, 7	6	M	VL	M	2a	2	DD	1a, 1b	VH	L	M	Grumic Vertisol (Calcaric)
8b	Lake basin	40-170	VA	M	M	M	1	NS	NS	L	9, 13	8, 9	M	VL	M	2a	2	DD	1a-1c	VH	L	M	Grumic Vertisol (Calcaric, Hyposalic)
8c	Lake basin	<25	VA	M	M	M	1	NS	NS	L	5, 13	14	M	VL	M	2a	2, 5a	DD	1a-1c	VH	L	M	Protic Arenosol (Aridic)
9	Settlement	<80	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	Technosols
10a	Plain	110-185	AL	H	F	A	4	NS	NS	M	5, 10	9	H	LO	M	3	5a	DD	1a-1c	VH	C	M	Endoleptic Grumic Vertisol (Chromic)
10b	Plain	280-550	VA	H	F	F	3	NS	VS	H	5, 9	6	V	LO	M	3	5a	DD	1a-1b	HH	C	L	Calcic Endoleptic Vertisol (Calcaric, Chromic)
11a	Alluvial plain	160-180	AL	M	F	F	3	SA	MS	M	9, 6	4	M	LO	M	2b	2, 5a	VD	1a-1b	VH	C	M	Calcic Petric Gypsisol (Clayic)/Haplic Vertisol (Hyposalic, Calcaric))
11b	Alluvial plain	180-500	AL	H	F	F	4	NS	NS	L	5, 9, 7	8	M	HI	M	2b	5a, 2	VD	1a-1c	HH	C	H	Calcic Fluvisol (SIltic)/Calcic Mazic Vertisol (Calcaric)
11c	Alluvial plain	130-270	VA	M	M	M	2	NS	ES	H	5, 9, 7	5	H	ME	M	2b	7, 5a	DD	1a, 1b	VH	C	M	Calcic Fluvisol (Arenic)/Lithic Leptosol (Aridic)
11d	Alluvial plain	45-150	VA	H	F	F	3	SS	SO	H	5, 10, 7	8, 9	H	HI	M	2b	1, 5a, 2	DD	1a-1c	VH	C	M	Calcic Endoleptic Vertisol (Humic, Chromic)
11e	Alluvial plain	45-150	AL	H	F	F	3	NS	NS	H	10, 9, 5	8, 9	M	HI	M	2b	1, 5a, 2	VD	1a-1c	VH	C	H	Haplic Solonchak (Sodic, Arenic)
11f	Alluvial plain	<20	AL	H	F	F	4	SA	NS	H	7, 5	10	H	HI	M	2b	2	MD	1a	VH	L	M	Haplic Cambisol (Calcaric)
11g	Alluvial plain	15-90	AL	H	F	F	3	VS	SO	H	10, 9, 7	14	V	LO	L	2b	5b, 5c	DD	1a	VH	C	L	Salic Fluvisol (Calcaric, Clayic)
11h	Alluvial plain	40-90	VA	M	F	F	2	NS	VS	H	5, 9	14	M	LO	M	2b	5a, 2	DD	1a	VH	C	M	Calcic Grumic Vertisol (Calcaric, Pellic)/Haplic Fluvisol (Calcaric)
12a	Lateral valley	70-320	VA	M	F	M	2	NS	NS	L	9, 6, 5	8, 9	M	VL	M	2b	3, 2	MD	1a-1c	VH	L	M	Calcic Fluvisol (Arenic)/Lithic Leptosol (Aridic)
12b	Lateral valley	130-330	VA	M	F	M	2	NS	NS	L	9, 7, 5	4, 5	M	VL	M	2b	7, 2	MD	1a-3	VH	L	M	Calcic Fluvisol (Arenic)/Lithic Leptosol (Aridic)
12c	Lateral valley	100-380	VA	L	F	F	5	NS	MS	M	9, 7	6	L	VL	M	2b	7, 2	DD	1a-1c	VH	L	M	Calcic Fluvisol (Arenic)/Lithic Leptosol (Aridic)
13a	Hilland	140-550	AL	-	D	D	5	-	-	-	9, 7	4, 5	-	-	M	1	3	VS	2-5	HH	S	-	Hyperskeletic Leptosol (Aridic)
13b	Hilland	150-300	AL	-	D	D	5	-	-	-	10	4, 5	-	-	M	1	3	VS	2-5	VH	S	-	Hyperskeletic Leptosol (Aridic)
13c	Hilland	250-720	AL	-	D	D	5	-	-	-	9-7	8, 9	-	-	M	1	3	VS	2-5	HH	S	-	Endopetric Calcisol (Arenic, Aridic)
13d	Hilland	150-315	AL	-	D	D	5	-	-	-	9, 5	8, 9	-	-	M	1	3, 7	VS	2-4	VH	S	-	Hyperskeletic Leptosol (Aridic)
13e	Hilland	130-450	AL	H	M	A	4	NS	NS	M	9, 7, 5	6	M	LO	M	1	3	SS	2-5	HH	C/L	H	Epileptic Calcisol (Siltic, Chromic)
14a	Pediment	115-320	VA	-	D	D	4	-	-	-	9, 7, 5	4, 5	-	-	M	3	3, 1	VS	2-4	VH	S	-	Calcic Petric Gypsisol (Siltic)
14b	Pediment	450-620	AL	-	D	D	5	-	-	-	10, 5	8, 9	-	-	M	3	3, 1	VS	1a-1c	HH	S	-	Grumic Vertisol (Calcaric, Hyposalic)
14c	Pediment	220-500	AL	M	A	D	4	-	-	L	8, 5	6	M	LO	M	3	3	SS	1a-1c	HH	L	M	Epileptic Regosol (Aridic, Calcaric)/Lithic Leptosol (Calcaric)
14d	Pediment	5-75	AL	M	F	F	3	NS	MS	L	10, 7	14	M	LO	M	3	7	VD	1a, 1b	VH	L	M	Haplic Solonchak (Sodic, Arenic)
14e	Pediment	60-330	VA	M	F	M	3	NS	NS	H	10, 5, 7	8, 9	M	ME	M	3	3, 7	SS	1a-3	VH	I	M	Haplic Regosol (Skeletic, Calcaric)/Calcic Endoleptic Vertisol (Chromic)
14f	Pediment	150-650	VA	M	A	D	4	-	-	L	9, 7, 5	6	M	LO	M	3	3, 1	VS	1a-3	HH	L	M	Calcic Fluvisol (Arenic)/Lithic Leptosol (Aridic)
14g	Pediment	170-290	AL	L	F	D	2	NS	NS	L	6	6	M	HI	M	3	3, 1	SS	1a-3	VH	L	L	Epileptic Calcisol (Arenic)
14h	Pediment	220-500	VA	M	M	D	4	-	-	L	8, 9	6	M	ME	M	3	3	VS	1a-3	HH	L	M	Epileptic Calcisol (Siltic, Chromic)

RBU = Resource Base Unit
Dr = Drainage
Ta = Mean annual temperature

LC = Land Cover
Pv = Rainfall variability
Text = Texture
Rs = Relief

Ac = Acidity (pH)
EC = Electric Conductivity
LGP = Length of Growing Period
Ca/Mg = Calcium/Magnesium ratio

Ca = Exchangeable Calcium
ESP = Exchangeable Sodium Perc.
Mg = Exchangeable Magnesium
Sd = Soil depth

Cf = Coarse fragments
Ex = Cation Exchange Cap (CEC)
OC = Organic Carbon
Ss = Slope

For meaning of class symbols see Annex 5

Annex 5: Soil Characteristics used for Land Evaluation

Soil Characteristics

Soil Depth		**Coarse fragments (topsoil & subsoil)**		**Drainage**	
class	values (cm)	class	values volume %	class	description
VS very shallow	< 25	F few	< 5	0	very poor
SS shallow	25-50	M many	5-40	1	poor
MD moderately deep	50-100	A abundant	40-80	2	imperfect
DD deep	100-150	D dominant	> 80	3	moderately well
VD very deep	>150			4	well
				5	somewhat excessive
				6	excessive

Soil Characteristics

Sodicity (subsoil)		**Salinity (subsoil)**		**pH(H2O) (topsoil)**		**CEC (topsoil)**	
class	value (ESP) %	class	value (EC) (dS/m)	class	values	class	values me/100g
NS	< 6	NS	< 2	NE neutral	6.6-7.5	L low	< 16
MS	6-15	SS	2-3	AL alkaline	7.5-8.5	M medium	16-24
SO	15-25	MS	3-5	VA v. alkaline	> 8.5	H high	> 24
VS	25-40	SA	5-8				
ES	>40	VS	8-12				
		ES	> 12				

Soil Characteristics

Ca++ (topsoil)		**Mg++ (topsoil)**		**Ca/Mg (topsoil)**	
class	values me/100g	class	values me/100g	class	value (ratio)
L low	< 10	L low	< 1	VL very low	< 1.2
M medium	10-25	M medium	1-5	L low	1.2-2.3
H high	25-50	H high	5-10	M medium	2.3-10
V very high	> 50	V very high	> 10	H high	10-25
				VH very high	> 25

Soil Characteristics

Organic Carbon (topsoil)		**Calcium Carbonate (topsoil)**		**Surface salts**	
class	values (%)	class	values (%)	class	value %
VL very low	< 0.4	N non-calcareous	< 0.1	0 none	< 0.1
LO low	0.4-0.8	S slightly calcareous	0.1-10	1 low	0.1-15
ME medium	0.8-1.2	M moderately calcareous	10-20	2 moderate	15-40
HI high	> 1.2	H highly calcareous	20-30	3 high	40-80
		V very highly calcareous	> 30	4 dominant	> 80

Soil Characteristics

Texture

S sandy	S Sand	Si silty	Si Silt
	LS Loamy Sand		SiL Silty Loam
L loamy	L Loam		SiCL Silty Clay Loam
	SL Sandy Loam		SiC Silty Clay
	SCL Sandy Clay Loam	C clayey	SC Sandy Clay
			C Clay