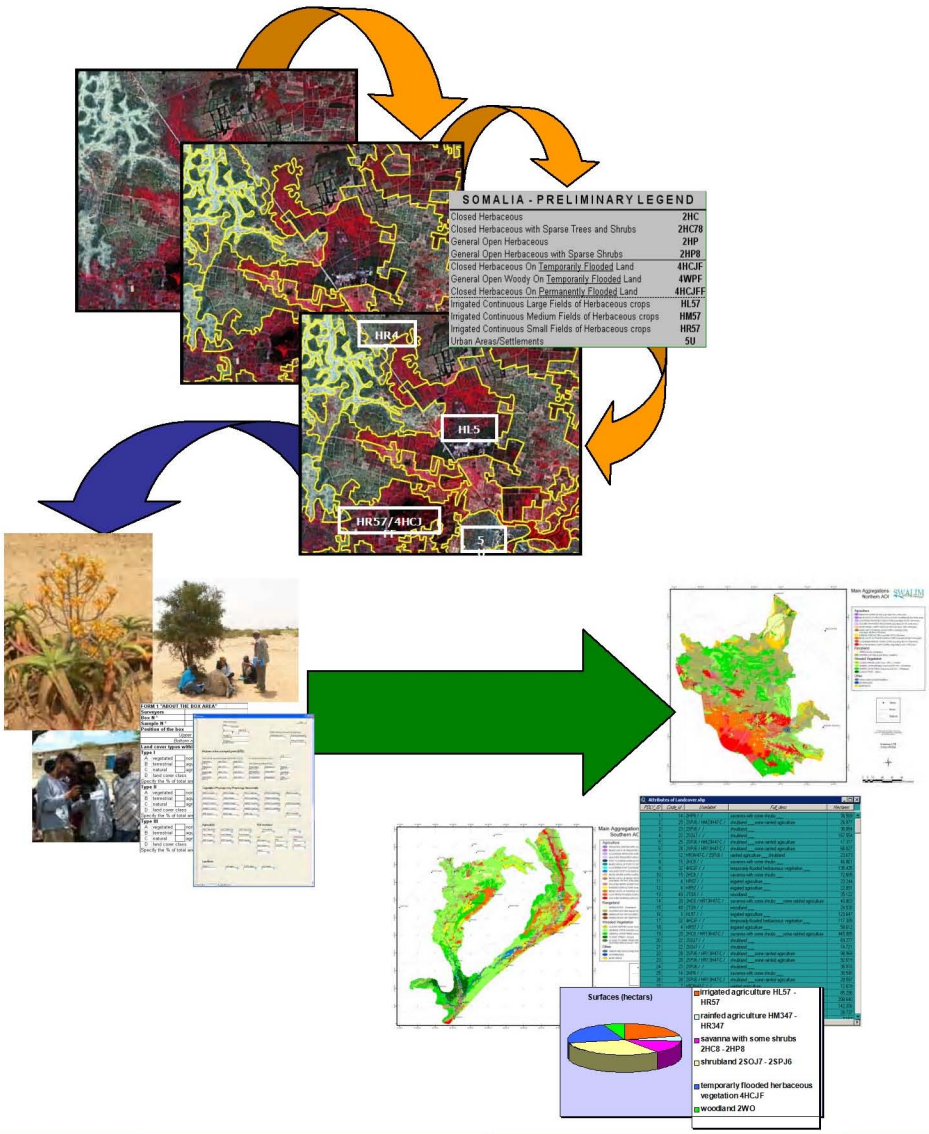
Land Cover of Selected Study Areas in Somaliland and Southern Somalia



Project Report N°L-03

February 2007

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Funded by the European Union and implemented by the Food and Agriculture Organization of the United Nations

This document should be cited as follows:

Monaci, L., Downie, M., Oduori, S. 2007. Land Cover of Selected Study Areas in Somaliland and Southern Somalia. FAO-SWALIM. Project Report No L-03. , Nairobi, Kenya.

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List of acronyms

FAO – Food and Agriculture Organisation of the United Nations
SWALIM - Somalia Water and Land Information Management System
AOI – Area of Interest
LCCS – Land Cover Classification System
LMU - Land Mapping Unit
NASA – National Aeronautics and Space Administration
SRTM – Shuttle Radar Topography Mission
DEM – Digital Elevation Model
UNDP – United Nations Development Project
DIMU – UNDP Data and Information Management Unit
GIS – Geographical Information System
RS – Remote Sensing
UNEP – United Nations Environment Programme
MSS – Multispectral Scanner
VNIR - Very Near Infrared Radiometer
SVNIR - Short Wave Infrared Radiometer
IAO - Istituto Agronomico D'Oltremare (Florence)
IUCN - The World Conservation Union
EOS - Earth Observation System
CCs - Colour Composites
FCCs - False Colour Composites
NDVI – Normalized Differential Vegetation Index
ETM – Enhanced Thematic Mapper
DB – Database
GPS – Global Positioning System
SDRN – Environment and Natural Resources Service (Sustainable Development Department)
PAT – Polygon Attribute Table
FAT - Feature Attribute Table
asl – above sea level

Acknowledgements

The authors wish to acknowledge the considerable support given by the Project Task Force during preparation of this report.

Many thanks to the ecologists Abdulkadir Aden, Mohamed Ibrahim and Ahmed Jama Sugulle, who worked tirelessly collecting field data. The survey team benefited immensely from the support of many people whose collective effort contributed to the success of the field survey; their help is sincerely acknowledged.

Special thanks are due to the FAO staff in the Hargeisa office: Mohamed Jama Gahayr, Amran Ibrahim and Asha the FAO-Hargeisa office secretary who provided effective administrative and logistic backup, obtaining daily mission security clearances, hiring vehicles, payments, purchasing of materials, record-keeping and meeting arrangements.

Sincere acknowledgement also to the Somali drivers, and the Somali Organisations that were contacted for information are also thanked, including the Somali Mine Action Centre, Ministry of Agriculture and Cadastral Survey.

1 INTRODUCTION

This report is one of the outputs of Activity 2.B.8 of the FAO – Somalia Water And Land Information Management Project (SWALIM Phase II).

The main focus is the description of Land Cover mapping undertaken by the SWALIM Photointerpretation unit of two Areas of Interest (AOI) in Somaliland and southern Somalia.

This report includes descriptions of the methodology and the results obtained for:

- the land cover of the northern and southern AOI, with databases verified by field survey

Due to worsening security in the riverine areas of southern Somalia, the anticipated collection of field data necessary for validating the Land Cover map was delayed for the southern AOI. Therefore, the results for the northern AOI are based on field survey of May-June 2006 whereas those of the southern AOI are based on field survey in March 2007.

As indicated in the Implementation Plan of the SWALIM project, activities for the production of land baseline information include an "Assessment of Land Suitability and Agricultural Production Potential for the Riverine Areas in Southern Somalia and for the Dur-Dur/Gebiley AOI in North Western Somalia" (Activity 2B.8).

Land cover is defined as the observed (bio) physical cover on the earth's surface (LCCS classification concepts and user manual – FAO, 2005).

In order to predict behaviour of land in response to specific patterns of utilisation, data on landform, land cover, land use, soil and climate need to be collected and properly integrated into the process of generating Land Mapping Units.

A Land Mapping Unit (LMU) is a mapped area of land, homogeneous according to the above-mentioned environmental factors, and is described in terms of its qualities. The LMU is the spatial unit of analysis for evaluation of land suitability.

A Land Cover map contains data about the distribution of vegetation, agriculture, bare areas and built up surfaces. In addition to its use as a thematic layer during suitability analyses, it is also used in the generation of land use maps.

Transformation from a Land Cover to a Land Use map takes place through a link between Land Cover classes and available socio-economic data (Annex 1).

The project document indicated two areas for assessment of physical land suitability: the Dur-Dur and Gebiley AOI in Somaliland, and riverine areas in southern Somalia. The detailed boundaries of these two AOI were delineated considering existing available Somali territory datasets and also taking into account areas mapped by the unverified 1:100 000 Land Cover map of the Juba and Shabelle riverine areas produced during SWALIM Phase I (Annex 2).

1.1. Delineation of the study area

1.1.1 The Northern AOI

The northern AOI was defined following evaluation of the NASA 90 meters SRTM-DEM. The delineation took into account the following areas:

- sub-catchments extracted from the DEM;
- agricultural areas identified from available satellite imagery.

Following morphological criteria, the following areas were selected:

- the basin including the town of Baki (Dur-Dur is the main togga within this area);
- the basin including the towns of Hargeisa and Arabsiyo (the main toggas of this area are Hog, Kadar and Biji);
- certain sub-catchments on the eastern side of interest due to presence of irrigated cultivation;
- certain sub catchments on the southern-eastern side of interest due to rainfed cultivation and tiger bush areas.

The limits of the northern AOI are:

- the coast in the north;
- the sub-catchment of Togga Maroodijeex, including Hargeisa town, to the east;
- the boundaries with Ethiopia in the south;
- the limit of the Dur-Dur watershed in the north-west.

1.1.2 The Southern AOI

In the southern AOI the following data were evaluated:

- NASA 90 meters SRTM-DEM;
- FAO Africover - Landform;
- UNDP/DIMU Flooded areas data set 1981 and 1987
- FAO SWALIM Phase I - Land Cover;
- available satellite imagery.

Delineation took into account the following areas:

- watershed limits extracted from the NASA SRTM DEM;
- alluvial plains (code L11ap) and floodplains (both L11wa and L11we) extracted from the Africover Landform;
- agricultural areas extracted from the Land Cover prepared during SWALIM Phase I image interpretation.

After the above layers were overlapped, morphological criteria guided selection of the shape of the study area. The Juba and Shabelle rivers form a unique watershed that can be subdivided into many sub-watersheds.

Taking into consideration the new type of information product requested in the project document (Activity 2B.8) and the land cover map prepared during SWALIM Phase I, the following specifications were adopted for defining the area of interest:

- the eastern boundary of the AOI corresponds to the Shabelle main watershed limit;
- the southern boundary corresponds to the coastline;
- the western boundary corresponds to the Juba main watershed limit, not including a tributary entering from Kenya;
- the northern boundary corresponds to the Somalia/Ethiopia border;
- the central, empty, part of the AOI has been excluded following the eastern main watershed limits of the Juba, and the limits of the alluvial plain defined by the FAO-Africover layer.
- If an important agricultural area was found to be outside of watershed limits but in proximity to it, then it was included (Annex 3).

Comparing the AOI delineated during Phase I with the revised one of Phase II, the following were the major modifications:

- addition of some areas on the north-eastern and eastern boundary of the AOI in order to fully include the limits of the Shabelle main watershed;
- exclusion of a tributary coming from Kenya on the western boundary that was only partially included in the Land Cover map produced during SWALIM Phase I;
- addition of a substantial area on the northern boundary in order to fully include the limits of the Juba main watershed;
- addition of the Lower Shabelle area along the coast, which was not interpreted during Phase I due to unavailability of cloud free satellite imagery;
- elimination of areas partially included in Xudur and Tayeglow districts (Bakool region) in the central region.

It is important to highlight that these changes were made only with regard to the extent of the area where the suitability assessment was to be performed.

Land Cover map boundaries as shown in Annex 4 are the result of the addition of new areas interpreted during SWALIM Phase II to the land cover map originally produced during Phase I.

1.1.3 General

The scale of work adopted for production of the land cover map and all thematic layers needed for the assessment of the physical land suitability in agricultural areas in western Somaliland and in some pilot areas in southern Somalia (still to be selected according to field accessibility), was 1:50 000. Land cover, landform, land use and soil maps related to the two AOI were produced at a scale of 1:100 000 (see Annex 3).

2 CONCEPTUAL FRAMEWORK

The main issues that had to be addressed to produce the land cover map for the two AOI were:

- lack of available data on land cover at a scale compatible with the expected results (1:100 000 and 1:50 000 in the selected agricultural areas);
- field survey constraints in terms of accessibility (road condition, seasonality and insecurity);
- the vast area to be investigated (12 939 km^2 for the northern AOI and 103 976 km^2 for the southern AOI) at a semi-detailed working scale;
- available time and human resources;
- the need to set up an adequate survey campaign to inventory the land resources.

The solution adopted was to produce a land cover map through on-screen interpretation of satellite imagery and validated through collection of field data, the latter being a crucial phase in validating information collected during the interpretive activities. Some of the advantages of this methodology were:

- consistent stratification of the land into homogenous areas, providing boundaries that separate different land cover types through identification of useful interpretative keys. In this phase it is more important to assign consistent codes following the same rules throughout the AOI, than to assign well-chosen codes. This will facilitate updating of the adopted legend following field survey/s.
- stratification of the land cover optimises the selection of samples for field survey. When a sample is optimised it can provide more information, thereby maximising results.
- having a standard methodology available for employment in possible new AOI or for periodical monitoring of present ones.
- using the most recent remote sensing and GIS technologies, in particular very high-resolution images and DEM. Information extracted from these technologies is increasingly accurate and reliable, enhancing the above-mentioned advantages.

The production of the Land Cover map can be subdivided into five main phases:

1) Preparatory phase:
    - Preliminary overview of the AOI
    - Remote sensing data acquisition
    - Image processing
    - Setting up of the preliminary legend
2) Base map production:
    - Photointerpretation activity
3) Field data collection:
    - Field work
    - Field data analysis
4) Legend updating and Map revision:

- Legend updating
- Revision of the map

5) Data analysis and spatial modelling:
   - Aggregations
   - Areas subdivision (tabular) analysis

A detailed description of each phase is provided in Chapter 4 - Material and Methods. Production of the land cover maps (1:50 000 and 1:100 000 scales) of the Dur-Dur and Gebiley AOI in Somaliland involved all the above-mentioned phases.

A slightly different, partial sequence of phases was adopted for riverine areas. New areas added on the basis of morphological criteria adopted for the delineation of the AOI were photointerpreted, and then matched to the unverified map produced during Phase I. Two cloud-free images of the lower Shabelle area were acquired, and the interpretation made during Phase I was revised accordingly.

Some of the considerations made during the revision of the legend in the northern AOI following the results of the field data collection were also applied to the south, where a revision of the adopted codes was performed as is explained in detail in Chapter 4.

THE OBJECTIVE OF THE STUDY

The objective of this study was:

- To produce the land cover map for the northern and southern AOI, with their databases

2. STUDY AREAS

2.1 Introduction

The following descriptions are a brief introduction to the climate, vegetation and agriculture of the area, as the main environmental components determining land cover. The two AOIs will be introduced separately.

All reported information is based on the available bibliography (see Chapter 8). Among the available ancillary data were two vegetation distribution maps: the *Carta geobotanica dell'Africa Orientale (Eritrea Ethiopia, Somalia)* produced by R.E.G. Pichi-Sermolli at a scale of 1:5 000 000 (Pichi-Sermolli, 1957), and the *Generalized map of vegetation zones of Somaliland* produced by C. F. Hemming (Hemming, 1966).

Both maps provide good, detailed community descriptions and locations at a small scale. The map produced by Pichi-Sermolli, in particular, constitutes a comprehensive description at the national level and allows a ready comparison between the two AOI (Figure 5).

The primary factor limiting development of vegetation is rainfall. As a consequence of the extreme and uniform climate in both of the AOI, the "zonal" vegetation is monotonous and the number of plant species in vegetation communities is not high. Plant species have developed several features to adapt to the arid and semiarid climate. To a greater or lesser extent, they consist of xerophytes and heliophytes and are tolerant of high calcium carbonate concentrations and poor soil conditions. Most of them occur over a vast variety of soil types. On the other hand, their competitiveness decreases in more developed and complex phyto-cenosis in wetter environments. The vegetation is very resilient, and is able to recover even after serious droughts. Climax formations and species' distributions (particularly herbaceous species) have been altered, mainly by human activities. The above-mentioned characteristics complicate determination of vegetation subdivisions.

Most important "azonal" communities are found in the coastal areas in brackish and gypsum soils, and along rivers.

Two different types of agriculture in terms of water supply and productivity, i.e. rainfed and irrigated cultivation, are present in both AOI. Irrigated areas are mainly located in the southern AOI, along the Juba and Shabelle rivers where there is high potential for the development of large irrigated farming systems, while in the northern AOI only a few scattered irrigated areas, suitable only for small or household farms, occur scattered along seasonal streams (toggas).

2.2 General features of the Northern Area of Interest (NAOI)

2.2.1 Climate

The region lies at the extremity of the sub-Saharan semi-arid zone commonly referred to as the Sahel, which traverses the continent from Senegal to Somalia. The climate of the study area is hot, dry desert in the coastal plain (Lughaya and northern part of Baki districts) and arid in Borama and surroundings. Semi-arid conditions prevail at higher altitudes of the Al Mountains and south of Gebiley. Mean annual rainfall ranges from 200 – 300 mm in the coastal areas of Lughaye, to 500 – 600 mm in the east of Borama and surroundings. The rest of the study area has a mean annual rainfall of 300 – 500 mm (see Figure 3).

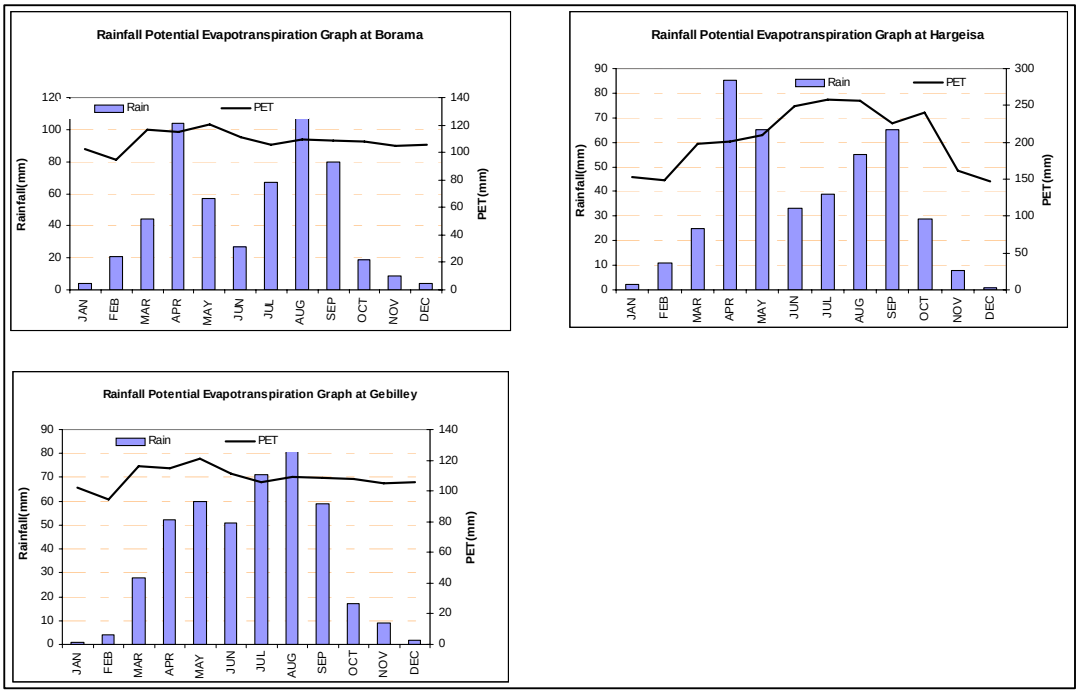
The study area lies entirely between the two subtropical anticyclone belts. The main weather pattern is controlled by the seasonal monsoon winds, and rainfall in the area is consequently bimodal (see Figure 1). The south-west monsoon brings the primary *Gu* rains between March and June. The *Gu* is followed by a hot dry period called *Xagaa* (June/July). The onset of the north-east monsoon marks the beginning of the short *Deyr* rains from August to October followed by the cooler long *Jilaal* dry period between November and February.

Temperatures in the area are influenced by altitude and the strength and temperatures of the seasonal winds. Figure 2 illustrates how temperature decreases with increasing altitude. At the higher altitudes of the Al Mountains and plateau areas, temperatures vary considerably through the seasons, with a mean annual temperature of 20-24C°, while the coastal region has mean annual temperatures of 28-32°C.

Relative humidity of the highlands is mostly around 40%, except during rainy periods when it increases to 80%. High temperatures in the coastal areas combine with a high relative humidity of more than 70% to create an exceedingly hot, humid environment.

The major winds in the study area occur during the *Xagaa* dry season, particularly (June to July) and in *Jilaal* (December to February) every year when the weather is hot. The hot, calm weather occurs between the monsoons (part or whole of April and part or the whole of September). Generally, in the northwest the winds are strongest during the southwest monsoon. Weaker winds generally occur during April-May and October-November. Average wind speeds vary from 8 - 10 m/s, but during a large part of the year, strong winds of up to 17 m/s occur, causing frequent dust-devils all over the coastal plains and plateaus.

The study area is subject to high potential evapotranspiration (PET), with an annual average of < 3 000 mm. Annual rainfall is very far below the potential evapotranspiration and a large water deficit exists during most of the year throughout the region. This low rainfall is not always sufficient for successful crop production (Figure 1).



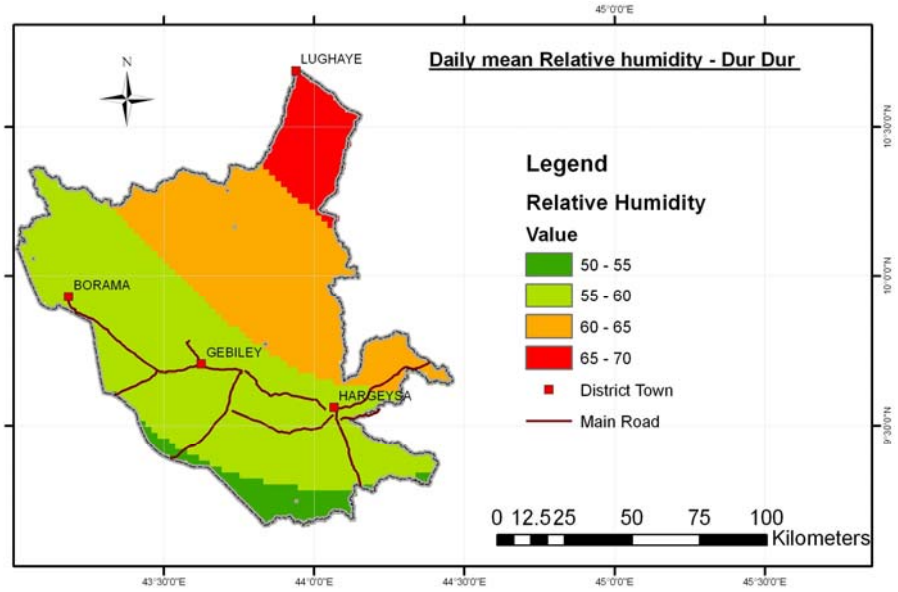


Figure 1: Rainfall and potential evapotranspiration

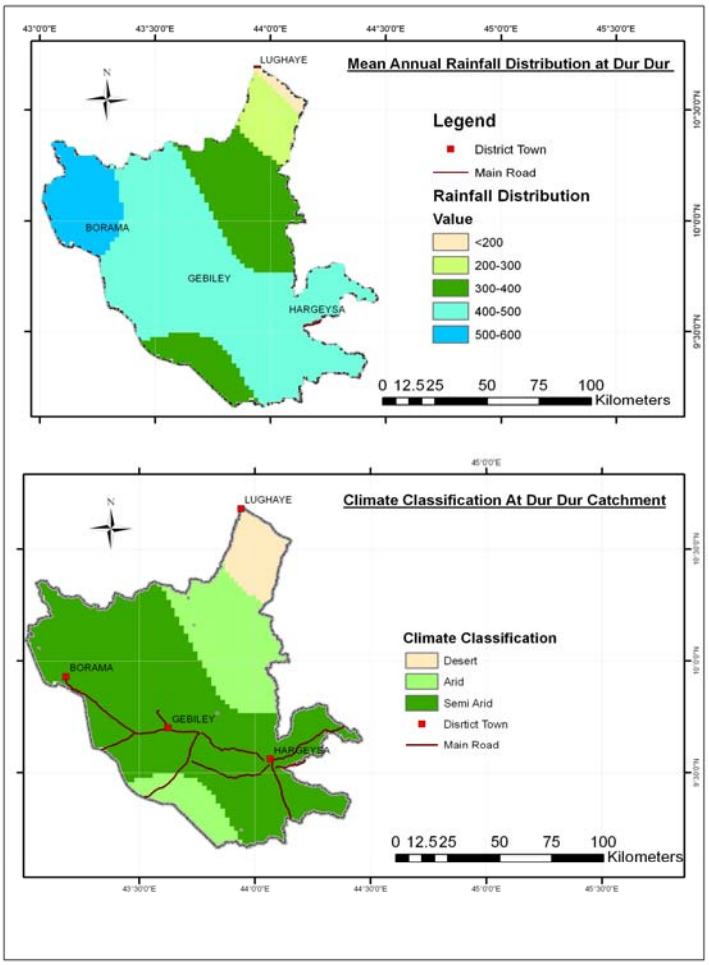


Figure 2: Relative humidity of the study area

Figure 3: Rainfall distribution and climate classification of the study area

2.2.2 Geology/Lithology

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

The basement complex covers an extensive area of the Al Mountains around Borama and Baki districts. In other parts of the region it is covered by Jurassic limestone and Miocene bio-limestone, Pleistocene basalts and Recent alluvial and aeolian deposits. Igneous rocks consist mostly of basalts and rhyolites, while metamorphic rocks include a wide range of schists, ortogneiss, quartzite, migmatites, marble, calcosilicate and paragneiss, intruded by granite, diorite and gabbro.

Pleistocene basalt outcrops and other volcanic rock outcrops occur dispersed along the northern escarpment and coastal plain.

2.2.3 Landform and Soils

From a geomorphological point of view, the study area can be divided into the following landscapes: Plateau (both dissected and normal), Mountainous and Hilland, Piedmonts and the Coastal Plain. There are three main ephemeral river systems (Togga Durdur, Togga Biji and Togga Waheen) that drain from the plateau, traversing the mountain range in the direction of the Red Sea and from the southern side of the same mountain to the southern highlands respectively.

According to the bibliography, the northern AOI is characterised by the following land features:

1. A narrow coastal plain, washed by the waters of the Gulf of Aden which is fairly depressed in relation to the mountain range at its rear;
2. A mountain range, oriented almost E-W, parallel to the coast, with a very rugged topography that rises up from the coastal plain to the country's highest peak (2 407 m, outside of the AOI);
3. Highlands and plateaus, southward of the mountain range, consisting of gently undulating or almost flat terrains dipping toward the south-east, cut by several wadis and with wide alluvial plains.

With regard to the hydrography, in the northern AOI there are a number of ephemeral rivers (locally called *togga, tug* or *wadi* - Faillace, 1986), which contain water only during the rainy season. Drainage follows the general relief from the almost E-W mountain range to the northern Gulf of Aden coast, and also from the same mountain range to the inner south-facing highlands. They give rise to deep gorges in the inner part of the mountain range.

According to the Sogreah soil survey report (Sogreah, 1983), soil distribution patterns closely follow the geomorphology of the region. On the high plateau, soils were mapped as predominantly deep and heavy textured Vertisols. The Mountainous and Hilland areas were mapped as rocky or covered by shallow Entisols and some Aridisols. The soils in the Piedmont areas were classed as Entisols and Aridisols. A big portion of the region is covered by Rocky soils that were mapped as a separate non soil class.

2.2.4 Land cover

On the basis of vegetation types described by Pichi-Sermolli (1957) (Figure 4), the northern AOI is characterised by:

- Grass, perennial and sub-shrubs steppe (*Steppa graminosa, perennierbosa e suffruticosa*)
- Shrub steppe (*Steppa arbustata*)
- Xerophyllous open woodland (arid zones) (*Boscaglia xerofila rada*)
- Xerophyllous open woodland (semi-arid zones) (*Boscaglia xerofila*)
- Montane evergreen thicket and scrub (*Boscaglia e fruticeto sempreverdi montani*)
- Savanna
- Coastal formations (*Formazioni costiere*)

Grass, perennial and sub-shrubs steppe (or sub-desert shrub and grass) **-** Includes all those cenosis consisting of grasses, graminoids and suffrutexes. Perennial plants are rare. Degrees of cover and floristic composition can change according to edaphic conditions. They are common on gypsum soils. A typical species is *Chrysopogon auchieri* var. *quinqueplumis*.

Shrub steppe (subdesert bush and thicket) - Similar to the Sub-desert shrub and grass category, but differs from it due to the presence of a shrub layer and scattered trees. Shrubs can be obconical or hemispherical, sometimes clustered in groups of 2-4 plants together with smaller shrubs and herbs, forming a small thicket. There are wide empty spaces between individual plants and plant groups.

Xerophyllous open woodland (arid zones) **-** An open vegetation formed by woody plants. Shrubs 3-5 meters in height and perennial graminoids are dominant, and scattered trees are typical. Shrubs are scattered, sometimes grouped but never impenetrable. Suffrutexes and perennial grasses have a discontinuous cover that is filled by annual (therophytes) after rainfall. The most common Acacias are *Acacia bussei*, *A. etbaica*, *A. nilotica*, *A. tortilis* and *A. senegal*.

Xerophyllous open woodland (semi-arid zones) – Of greater density and higher species richness of both high shrubs and perennial grass when compared to the previous vegetation formation.

Montane evergreen thicket and scrub (Evergreen shrubs) – this is characterised by dense gathering of suffrutexes (2-3 meters in height) or evergreen shrubs (3-5 meters in height). Normally they are sclerophyllous or aphyllous. Rushes, succulent plants, lianas and deciduous plants are present. Trees are scattered. *Euphorbia candelabrum* is present in some cenosis as an emergent. This vegetation develops on slopes from 1 000 to above 2 000m asl; at lower altitudes suffrutexes dominate, while higher up where there is greater humidity, evergreen shrubs dominate.

Savanna - Composed of annual grasses (usually xerophytes). Cyperaceae and Graminaceae are the most common families, forming a continuous layer 80 cm high. Trees or shrubs are usually present, but the herbaceous layer is dominant. They can be isolated or in small groups or thickets.

Coastal formations - These associations are distinguished by various dominant life forms according to different edaphic conditions, but they are characterised by the direct influence of the sea. They occupy the coral beaches, sandy shores, estuaries, deltas, coastal dunes (stabilised or mobile) and the salty plains. Typical examples are *Suaeda fruticosa*, *Adenium* sp. on rocky areas, and *Salsola foetida* on deep, dry soils.

2.2.5 Land Use

The main land use in the study area is extensive grazing (pastoralism). Other land uses include rainfed agriculture, irrigated orchards along alluvial plains, and wood collection.

Rainfed agriculture is found in what is considered as the sorghum belt of Somaliland, practiced in combination with pastoralism and wood collection. This class of land use is the economic basis of households in the study area.

Cultivation of irrigated orchards is a cash-oriented activity in the area, involving the growing of fruit trees such as citrus, guava, papaya and mango. Supplementary water for irrigating the crops is obtained from wells, dams and other water bodies.

Wood collection for charcoal production is very frequent, occurring in all well-treed areas. Preferred tree species are *Acacia bussei, A. nilotica* and *A. etbaica.* Interventions to help introduce sustainable sources of cooking energy are important and urgent.

Most of the area is used for extensive grazing, or pastoralism. Goats and sheep are grazed mostly on sloping areas, whereas cattle and camels are grazed in flatter areas. Sedentary pastoralism around homesteads is a common practice. Hay harvesting from enclosures supports this land use, as harvested hay can be used in the dry season. However, hay harvesting may be a source of conflict as enclosures are not generally welcomed. Hay production requires further research to establish its levels of sustainability without being a cause of conflict in the study area.

Urban centres offer a good market for farm produce, but due to poor access roads are inaccessible to most farmers. The urban centres are also points of high demand for charcoal.

2.2.6 Population

The study area constitutes the districts of Dila, Gebiley, Faraweyne and Allaybaday and parts of the districts of Hargeisa, Borama, Baki and Lughaya. The size of this study area is effectively a little more than one third of the total area of Awdal and Waqooyi Galbeed Regions. According to Somalia UNDP 2005 (Table 1), the estimated population for Hargeisa by mid-2005 was 560.028, making it the second largest town in Somalia. Borama had a population of 215.616 and Gebiley 79.564. These three are the main towns in the study area.

Table 1: Regions, districts, and their populations (Somalia UNDP 2005, draft version)

		District	**Estimated population**		
Zone	**Region**	**(* Regional capital)**	**2005 (Mid-year)**		
			Total	**Urban**	***Non-urban***
North-west			**1,828,739**	**819,989**	**1,008,750**
	Awdal		**305,455**	**110,942**	**194,513**
		Borama *	215,616	82,921	132,695
		Baki	25,500	8,577	16,923
		Lughaye	36,104	14,010	22,094
		Zeylac	28,235	5,434	22,801
	Woqooyi Galbeed		**700,345**	**490,432**	**209,913**
		Hargeisa *	560,028	422,515	137,513
		Berbera	60,753	42,070	18,683
		Gebiley	79,564	25,847	53,717

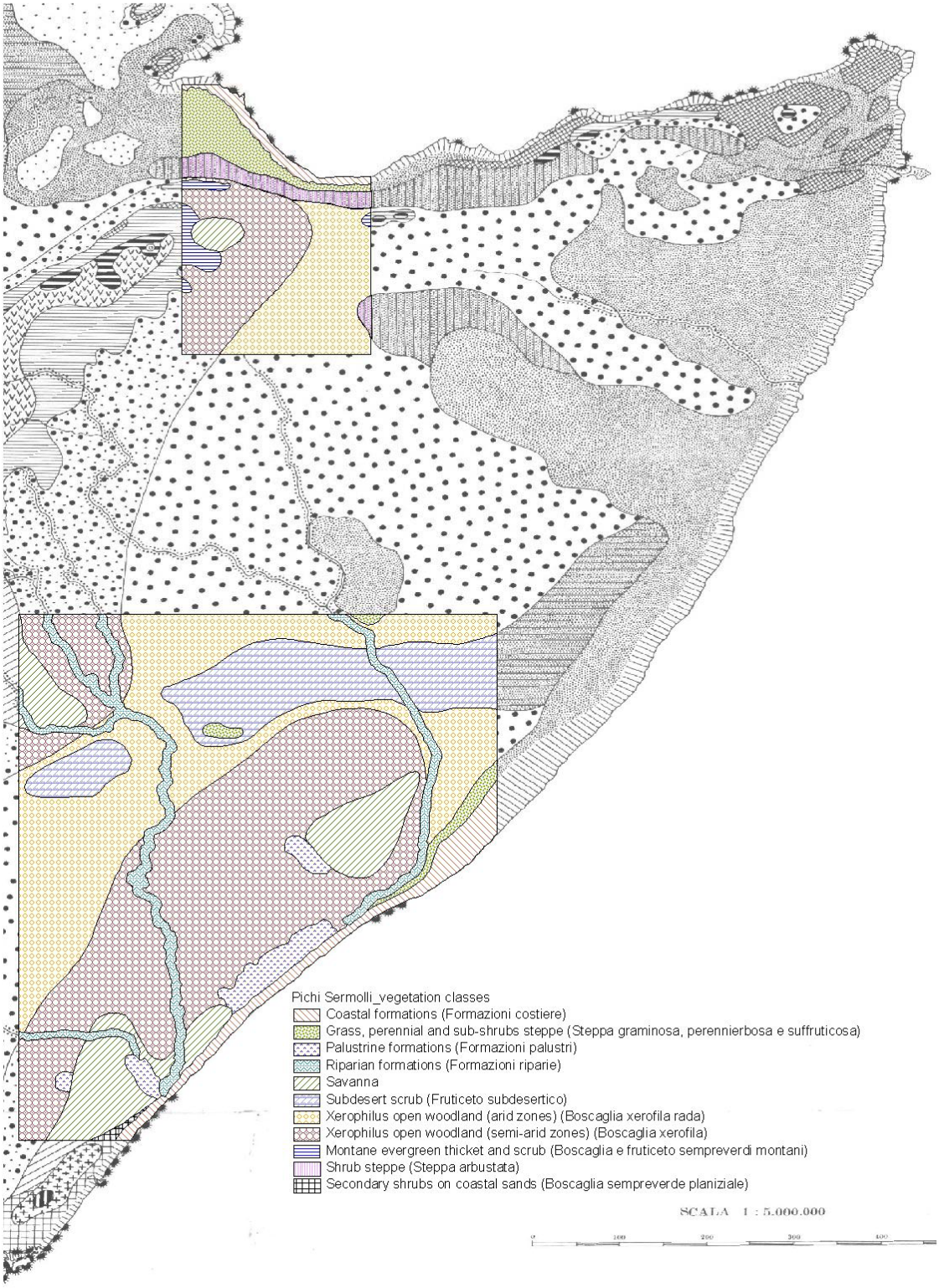


Figure 4: Carta geobotanica dell'Africa Orientale by Rodolfo E.G. Pichi-Sermolli (Map of the vegetation of East Africa)

2.3 Southern Area of Interest (SAOI)

2.3.1 Climate

The climate of the river basin areas of southern Somalia is tropical/arid to dry/sub humid and is influenced by the north-easterly and south-easterly air flows of the Intertropical Convergence Zone (ITCZ). The north-easterly and south-easterly air masses meet in the Intertropical Front (ITF) and consequently raise air upwards, producing rain. The annual movement of the ITCZ from north to south across Africa and back, gives rise to four different seasons in Somalia, comprising two rainy seasons alternating with two marked dry seasons as follows:

- *Gu*: April to June; the main rainy season for the entire country
- *Xagaa*: July to September; littoral showers, but dry and cool in the hinterland
- *Deyr*: October to December; the second rainy season for the entire country
- *Jilaal*: January to March; longer dry season for the entire country

The rainfall in the study area is erratic, showing a bimodal pattern except in the southern riverine areas close to the coast, where some showers may occur even during the *Xagaa* (see Figure 5). Total rainfall varies considerably over the study area, with the *Gu* delivering about 60% of the total mean. Total mean annual rainfall ranges from 200–400 mm in areas bordering Ethiopia in Hiiraan, Gedo and Bakool regions, and 400–500 mm in the central Bay, and northern part of Middle and Lower Shabelle Regions. High rainfall areas receiving more than 600 mm occur in the Middle Juba region around Jilib in the southern riverine areas. Rainfall is usually in the form of intense, short rainstorms, which are often temporally and spatially erratic.

The study area has a high inter-annual rainfall variation and is thus subject to recurrent droughts every 3-4 years, and more severe droughts every 7-9 years.

Air temperatures are generally influenced by altitude and by the strength of the seasonal winds. In *Xagaa* (the first dry season) the days are often cool and cloudy all over the region, with short showers in the areas closest to the coast. In *Jilaal* (the second dry season) the days are hot to very hot, and dry. The hottest period coincides with the months of March and April.

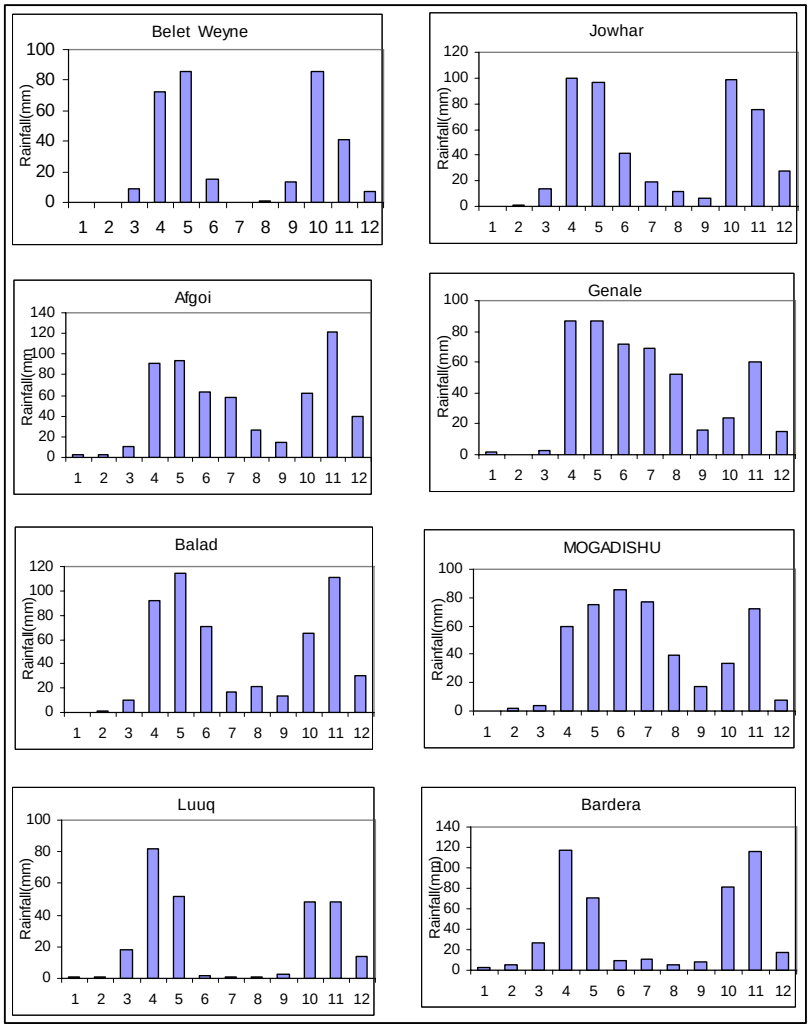


Figure 5: Mean monthly rainfall patterns in the study area (1963-2001)

Temperatures vary in the different seasons, with mean annual temperatures ranging between 23-30°C, a maximum temperature of 41°C in March (Baardheere) and minimum temperature of 24°C in July. In areas near the major rivers the relative humidity is high, ranging between 70-80%, but further inland away from the rivers the air is much drier. Relative humidity is higher in the coastal areas, where it is normally greater than 87%. The high relative humidity is often compounded by higher temperatures.

The major winds are in response to the north and south seasonal movements of the Intertropical Convergence Zone, particularly the Intertropical front. In the study area the winds blow persistently from the northeast during *Jilaal* (December to February) when the weather is hot or very hot, and from the southwest during *Xagaa*, (June to August) when the weather is cool and cloudy.

The weather is hot and calm between the monsoons (part or whole of April and part or whole of September). In the *Jilaal* periods the prevailing winds are strong and blow in heavy dust storms from the Arabian Peninsula. Weak winds generally occur during the inter-monsoonal periods of April-May and October-November. Average wind speed varies from 2–6 m per second.

Evapotranspiration is consistently high throughout the study area, the highest potential evapotranspiration occurring in the northern areas of Gedo, Bakool and Hiraan regions with more than 2 000 mm/yr, and between 2 000 mm/yr and 1 500 mm/yr. over the rest of the area. Annual rainfall (P) is far below the potential evapotranspiration (PET) and there is a large moisture deficit over most of the year.

The area experiences a tropical semi-arid to arid climate (Figure 6), with seasonal rainfall patterns influenced by the monsoon winds. Rains occur between April-June and September-November.

Three broad climatic zones may be recognised, characterised by differences in rainfall patterns:

- The coastal zone - with significant amounts of rain occurring from July to August (*Hagi* rains) that lengthen the *Gu* season.
- The semi-arid zone – with two strongly-defined rainy seasons and an additional light rainy season that may occur during July-August.
- The arid zone – with a lower annual rainfall amount and a dry period in July-August. The monsoon winds are the important factor affecting the climate and the timing of the rainy periods. The south-west monsoon winds prevail during June, July and August. The north-east monsoon winds prevail during December, January and February.

Rainfall tends to be variable and unreliable. Failures of the rains are not uncommon, particularly in arid areas. Rainfall can vary considerably from the average. This is an important factor to consider in assessing the value of seasonal rains in term of agriculture.

2.3.2 Geology

The southern AOI is characterised by outcropping of the metamorphic basement complex, made up of migmatites and granites. Sedimentary rocks such as limestones, sandstones, and gypsiferous limestones and sandstone are present, as is an extensive, wide coastal system of sand dunes. Basaltic flows are present in the northwest part of the AOI. From a tectonic point of view, this AOI is characterised by a fault system parallel to the coast in the alluvial areas, and by a system of NW-SE oriented faults in the metamorphic basement complex.

Some late Tertiary fluvio-lagunal deposits occur in the Lower Juba plain and part of the Southern Shabelle, consisting of clay, sandy clay, sand, silt and gravel.

Recent fluvial deposits are common along the two major rivers, the Juba and the Shabelle, consisting of sand, gravel, clay and sandy clay. Other Recent Alluvial Deposits occur in small valleys in Gedo and Bakool regions and in the Buur area, and consist of gravelly sand or red sandy loam materials. A wide dune system occurs along the coast.

2.3.3 Landform / Soils

According to the bibliography, the southern AOI is characterised by the following land features:

1. the two main river valleys (Jubba and Shabelle) that incise the generally smoothed and undulating morphology of the area;
2. hilly topography in the middle of the AOI, cut by wadis, and gently undulating wide plains toward the coast;

3. coastal dune complex, known as the Merka red dunes, following the coast and extending beyond the Kenyan border, which separate the narrow coastal belt from the Uebi Shebeli alluvial plain (Carbone & Accordi, 2000).

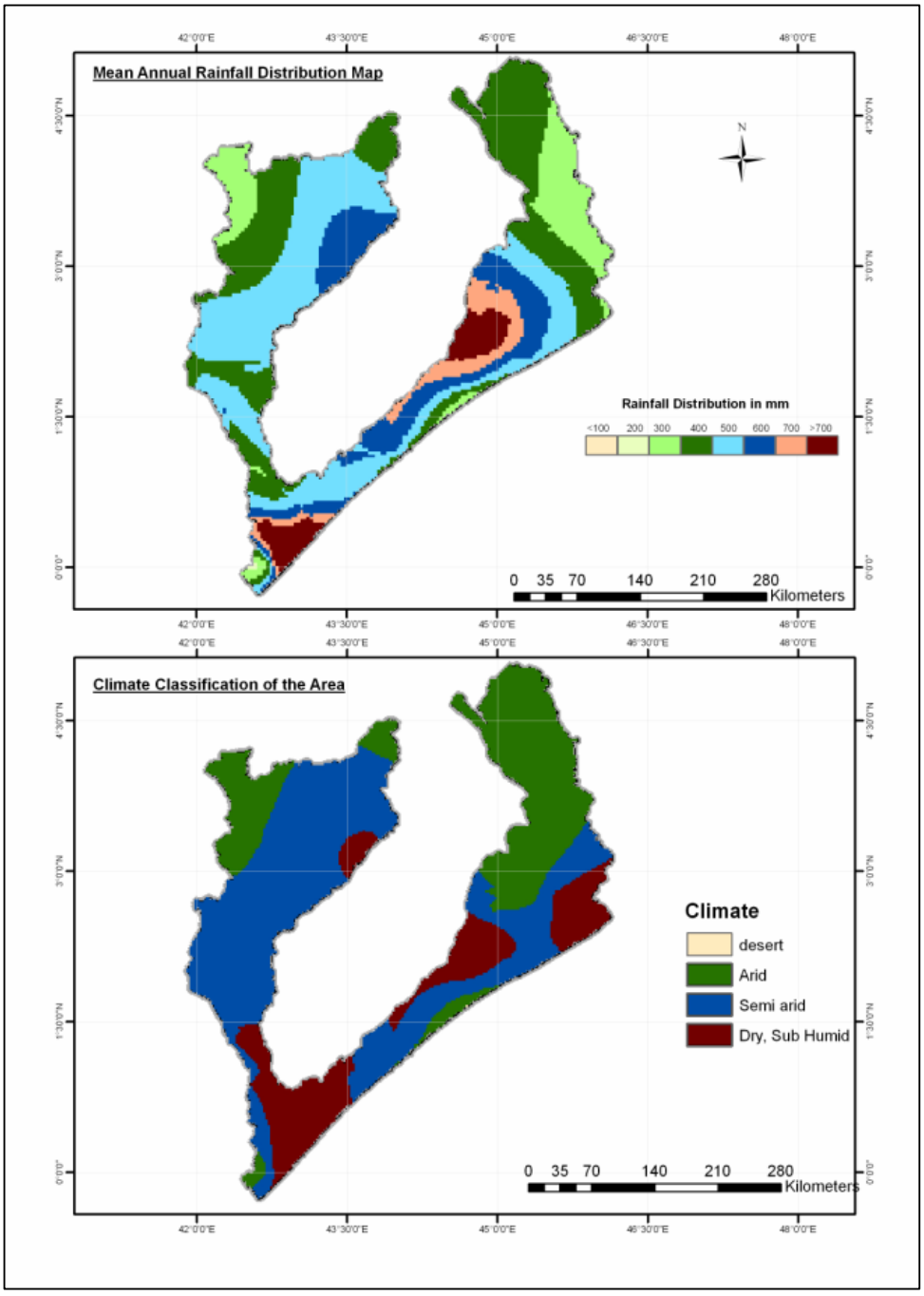


Figure 6: Mean annual rainfall distribution map and climate of study area

The hydrography of the southern AOI is dominated by the presence of the distal portions of the two main perennial rivers of the Horn of Africa flowing from the highlands of

Ethiopia towards the Indian Ocean: the Jubba (700 km within Somalia out of its 2 000 km total length) and the Shabelle (1 560 km within Somalia out of its almost 1 800 km total length). The Jubba flows into the Indian Ocean almost at Kismaayo, while the Shabelle impounds itself a few kilometres before reaching the lower tracts of the Jubba.

Because of the predominance of alluvium, many soils consist of layers of deposited materials which, because of the semi-arid climate, have been little-affected by normal soil-forming processes. Despite their variability, most soils share the characteristics of heavy texture and low permeability, with a tendency to poor drainage.

2.3.4 Land Cover

On the basis of the vegetation types described by Pichi-Sermolli (1957) the southern AOI is characterised by:

- Grass, perennial and sub-shrubs steppe (*Steppa graminosa, perennierbosa e suffruticosa*)
- Subdesert scrub (*Fruticeto subdesertico*)
- Xerophyllous open woodland (arid zones) (*Boscaglia xerofila rada*)
- Xerophyllous open woodland (semi-arid zones) (*Boscaglia xerofila*)
- Savanna
- Coastal formations (*Formazioni costiere*)
- Riparian formations (*Formazioni riparie*)
- Palustrine formations (*Formazioni palustri*)

Grass, perennial and sub-shrubs steppe (or sub-desert shrub and grass) **-** Includes all those cenosis constituted by grass, graminoids and suffrutexes. Perennial plants are rare. Cover values and floristic composition can change according to edaphic conditions. They are common on gypsum soils. A typical species is *Chrysopogon auchieri* var. *quinqueplumis*.

Subdesert scrub - Formed by low trees (less than 3 m high), shrubs, suffrutexes and spaced-out high succulent grasses. Tubers and bulbs occur among the herbs. Annual grasses grow in the rainy season. Perennial graminoids are absent.

Xerophyllous open woodland (arid zones) - An open vegetation type, formed by woody plants. In this formation, shrubs between 3-5 m in height and perennial graminoids are dominant. Scattered trees are typical. Shrubs are scattered or sometimes grouped, but never impenetrable. Suffrutexes and perennial grasses have a discontinuous cover occupied by annuals (therophytes) after rainfall. The most common Acacias are: *A.bussei*, *A.etbaica*, *A.nilotica*, *A.tortilis* and *A.senegal*.

Xerophyllous open woodland (semi-arid zones) - Of greater density and higher species richness of both high shrubs and perennial grass when compared to the previous vegetation formation.

Savanna - Composed of annual grasses (usually xerophytes). Cyperaceae and Graminaceae are the most common families, forming a continuous layer 80 cm. in height Trees or shrubs are usually present, but the herbaceous layer is dominant. They can be isolated or in small, sometimes impenetrable thickets.

Coastal formations - These are vegetated by various dominant life forms, according to edaphic conditions but are affected by the direct influence of the sea. Essentially they occupy the coral beaches, sandy shores, estuaries, deltas, coastal dunes (stabilised or

mobile) and salty plains. Typical examples are *Suaeda fruticosa*, *Adenium* sp. on stony areas and *Salsola foetida* on deep, dry soils.

Riparian formations - These formations develop along temporary or permanent streams and rivers. Due to higher soil moisture content they stand out from surrounding, dryer vegetation, from which they are also distinguished by their floristic composition.

Palustrine formations - These comprise all plant communities within swamps, i.e. areas which are wet for most of the year. Vegetation typically occurs in shallower waters. Central, deeper parts of swamps are characterised by rooted or free-floating aquatic plants. The most common are palustrine graminoid plants in association with Cyperaceae.

2.3.5 Land Use

Land use in the study area consists mainly of grazing and wood collection for fuel and building. Rangelands in the Juba and Shabelle catchments support livestock such as goat, sheep, cattle and camels. Livestock ownership is private, but grazing lands are communal, making it very difficult to regulate range use. Rangelands are utilised by herders using transhumance strategies (Shaie, 1977). Land cover associated with this land use includes forest, bushlands and grasslands (GTZ, 1990).

Farmers in these two river valleys are sedentary, practicing animal husbandry in conjunction with crop production. They tend to keep lactating cattle, a few sheep and goats near their homes, while non-lactating animals are herded further away, in the manner of herding nomadic stock. However, rainfed and irrigation farmers keep relatively small numbers of livestock, mainly cattle and small ruminants.

Animal feed is primarily from natural vegetation and crop residues, while dry season watering of animals is from rivers. Crop residues provide forage for non-browsers such as cattle and sheep. Several *wars* provide water in the wet season and also serve as alternative water sources to rivers. Groundwater is also an important source of water for livestock, other sources including hand-dug wells, swamps, creeks and boreholes.

Other land uses include rainfed agriculture, which includes agriculture that is entirely dependent upon rainfall. Crops under this category of land use include sorghum, millet, maize, groundnuts, cowpeas, mung beans, cassava and other minor crops, and are grown twice a year in the *Gu* and *Deyr* seasons.

Small-scale irrigated fields are also found along the Shabelle and Juba river valleys, growing maize, sesame, fruit trees and vegetables while large-scale plantations include sugar cane, bananas, guava, lemon, mango and papaya.

Flood recession cultivation in *desheks* (natural depressions) on the Juba River floodplain is common, crops including sesame, maize and vegetables. Major crops in the *desheks* are maize, sesame, tobacco, beans, peas and vegetables, watermelon and (rarely) groundnuts. Cropping is either single or mixed.

3 3. MATERIALS AND METHODS

The following is a list of materials used and tasks performed during production of the land cover map.

3.1 Materials

3.1.1 Bibliographic data

A list of documents consulted concerning aspects of vegetation in Somalia and in the two AOI in particular, is provided in Chapter 7.

3.1.2 Ancillary data

- 1:100 000 topographic maps from the 1970s (revised in the early 1990s) produced by the Defence Mapping Agency – USA (Annex 5 and Annex 6).
- 1:200 000 land cover map of Somalia produced by FAO Africover through visual interpretation of digitally enhanced LANDSAT TM images (Bands 4,3,2) acquired mainly between 1995-1998. The land cover classes were developed using the FAO/UNEP international standard LCCS classification system.
- 1:100 000 land cover map of the Juba and Shabelle riverine areas by SWALIM Phase I (unverified), produced through visual interpretation of digitally enhanced LANDSAT TM images (Bands 4,3,2) acquired mainly between 2000-2002. The land cover classes were developed using the FAO/UNEP international standard LCCS classification system.

3.1.3 RS data

- Landsat 7 Enhanced Thematic Mapper 2000-2001-2002 (Annex 6 and Annex 7)
- Landsat 5 Thematic Mapper 1985-1986
- MSS 1972-1973 e 1976
- IKONOS 2001 – 2003
- Aster VNIR and SVNIR 2002 – 2005
- Shuttle Radar Topography Mission Digital Elevation Model (SRTM-DEM)

Details on sensor type, image acquisition data, pixel resolution and wavelengths are provided in Interim Report GIS Li-01.

3.1.4 Software

Digital interpretation was performed using ESRI GIS package and Geovis (Terranuova).

The module Imagework (PCI) was used to support the photointerpretation routine, allowing some enhancement of satellite images.

The FAO software Land Cover Classification System (LCCS) was selected for creating the Land Cover legend.

3.2 Methodology

Methodology adopted for the production of the Land Cover map can be subdivided into five main phases:

3.2.1 Preparatory phase

Preliminary overview of the AOI
SWALIM's photointerpretation and GIS/RS coordinators initially reviewed available data on the vegetation and agriculture of Somalia and the two areas of interest in particular, in order to evaluate the complexity of the landscape and the potential usefulness of the data.

Available data (included geological maps and data on geomorphology) were collected in Italy from Istituto Agronomico D'Oltremare (IAO), the libraries of the faculties of Agriculture and Botany of the University of Florence, and the Geology Departments of the Universities of Florence and Pisa. Additional documents and reports were collected in Nairobi, from the Internet, from the library of IUCN, and in Somaliland by the Land Coordinator.

Remote sensing data acquisition
Several sets of satellite images were acquired during SWALIM Phase I:

- Landsat 7 Enhanced Thematic Mapper 2000-2001-2002
- Landsat 5 Thematic Mapper 1985-1986
- MSS 1972-1973 e 1976
- IKONOS frames (5x5 and 7x7km) 2001 – 2003

Additional remote sensing data were collected during SWALIM Phase II:

- Aster VNIR and SVNIR 2002 – 2005
- Shuttle Radar Topography Mission Digital Elevation Model (SRTM–DEM)

Image processing
Image processing preceded pre-processing. Pre-processing is the basic cleaning, correction and registering of raw primary data. Image processing operations include all operations performed in order to assist visual interpretation and facilitating extraction of information from original images.
The GIS unit digitally processed the images and was also responsible for some specific pre-processing, due to available RS data being in different formats and projections.

Aster datasets were delivered in EOS format and required fine registering before being integrated into the GIS. The SRTM-DEM data was imported into ArcInfo grid, re-projected from decimal degrees (DD) to Universal Transverse Mercator (UTM) and pre-processed for basins and stream delineation. All datasets were available in single bands as shown in Annex 08.

The following processes were performed:

- Colour composite
- Enhancement
- Calculation

Colour composite - Single bands are employed for generating Colour Composites (CCs). A composite is a coloured image where, for each of the three primary (additive) colours (red, green and blue), a spectral band is used. The true colour composite uses the bands 1 red, 2 green and 3 blue, for the primary colours red, green and blue**.**

There are particular combinations of bands (thermal band included) that are significant for the identification of the spectral signature of land cover types and were chosen for generating False Colour Composites (FCCs).

The list of the CCs images produced for each sensor type by the GIS unit is shown in Table 2.

Table 2: CCs images produced by SWALIM GIS unit

Landsat	Aster	Ikonos
Composite 432	Composite 321	Composite 432
Composite 743	Composite 654	Composite 321 (true colours)
Composite 456	"NDVI" index	"NDVI" index
Composite 765		
Panchromatic		
Pan (increasing details) and/or sharpen (enhancing details) added images eventually required among the previous composites.		
"NDVI" index		
"Thermal – Capacity" index		
T = thermal; 2, 3, 4, 5 and 7 are the other Landsat7 ETM bands implied		

Enhancement - Single band images, used in black and white or combined in composites, were enhanced by the following processing:

Adding panchromatic – applied to Landsat (ETM bands only) and IKONOS - the information of a colour composite image is combined with the more detailed panchromatic. Panchromatic sensors have a greater geometric resolution than sensors devoted to a restricted wavelength range. A higher resolution shadow is added to the added colours in order to increase object shape details and to help in evaluating surface roughness (e.g. homogeneous tree cover).

Stretching – (applied to any single band) – this process expands (proportionally reallocates) tonal distribution from lower and higher values present in the original image, to the full available grey scale display (usually subdivided into 255 grey tones). Contrast enhancement is characterised by improved appearance of different bodies with similar tones, emphasising patterns and, to a lesser extent, roughness.

Filtering (sharpen) – (applied to any single band) – a new value is applied to each pixel of an image, based on elementary calculations employing the value of the pixel itself plus surrounding pixels. This process is called convolution. These pixels are selected and their values are weighted through the employment of a "matrix" or "box" centred on the target pixel. These matrices are usually 3x3 or 5x5 pixels in size and can provide different results. In our case they sharpened the edges of objects in images, improving the capability of distinguishing and delineating them. In particular, it enhances edges and boundaries between different land cover types, emphasising pattern and roughness.

Calculation – sets of single bands available for an image frame can be employed as variables of mathematical equations. These equations are derived from conceptual relationships between physical phenomena and the light reflectance/emission response. From mathematical combination of bands it is possible to create indices. The ones used for the interpretation of the Land Cover were the Normalized Differential Vegetation Index (NDVI) and the Thermal Capacity. Images obtained from equations do not represent reflectance of the bodies but some of their properties

NDVI - (Normalized Differential Vegetation Index) is the expression of the intensity of photosynthetic activity. It is strictly correlated with photosynthesis, and through implication can also supply information about vegetative activity and biomass. These two factors can help to identify vegetation types, or can be associated with vegetation types in order to formulate hypotheses on their vegetative condition.

Thermal Capacity Index - this is an expression of the moisture level or mass capacity level, and is correlated with the mass of water present in soils. It can be used in support of the composites to identify depressions with an aquifer close to the surface, and wet areas. Response is strongly affected by season.

Setting up of the preliminary legend

Classification of the Land Cover was performed using the FAO Land Cover Classification System software (LCCS) developed by Antonio Di Gregorio and Louisa J.M. Jansen (see LCCS classification concepts and user manual – FAO, 2005). The advantages of this system are that:

- It allows class description at any convenient categorical level of detail according to available data. It is therefore possible to employ the same classification system for AOI with different map scale representation and working conditions.
- It supplies the advantage of a standardised *apriori* classification system, which is consistent in the choice of legend codes.
- It keeps the flexibility of a *posteriori* classification system (because it is not composed by a predefined classes set, but by a predefined classifier set and syntax to build well-fitting classes).
- It is adaptable to any environment, for any purpose, and is provided with a tool to import external legends. This feature allows accommodation and correlation with any other Land Cover map.
- All the features characterising legend codes are organised as a text string. This structure allows querying, selection or grouping of codes according to desired characteristic at different taxonomic levels.
- It facilitates the extensive use of outputs by a wide variety of end-users through enhanced capabilities in rearranging land cover classes.

Land cover classes are defined through the use of a combination of sets of independent diagnostic criteria - the so-called classifiers - that are hierarchically arranged to assure a high degree of geographical accuracy. Due to the heterogeneity of land cover, the same set of classifiers cannot be used to define all land cover types. The hierarchical structure of the classifiers may differ from one land cover type to another. Therefore, the classification has two main phases:

- an initial Dichotomous Phase, where eight major land cover types are distinguished; and
- a subsequent Modular-Hierarchical Phase where the set of classifiers and their hierarchical arrangement are tailored to the major land cover types.

All Primarily Vegetated land cover classes are derived from a consistent physiognomic-structural conceptual approach that combines the classifiers Life Form, Cover and Height (in (Semi) Natural Vegetation) and Life Form (in Cultivated Areas) with Spatial Distribution. The Primarily Non-Vegetated classes have a similar approach, using classifiers which deal with surface aspects, distribution/density and height/depth.

The preparation of the legend was preceded by the inventory and study of all available data collected during the preparatory phase, such as reports, documents, maps and any information on the distribution of vegetation and types of agriculture in the areas of interest. Information contained in these datasets was translated into classes through the selection of appropriated classifiers during the creation of the legend using LCCS.

The original list of classes was therefore improved through revision and/or creation of new classes on the basis of the Land Cover types identified on the interpreted images. The final version of the legend adopted for the Land Cover map is presented in Annex 9. Figure 7 shows a summary of the classes, grouped by main Land Cover type.

3.2.2 Base map production

Photointerpretation activity

A general definition of interpretation is “the identification of the objects seen in the image and communication of this information to others” (Lillesand & Kiefer, 1979). Homogeneous surfaces are identified and enclosed within boundaries. An area delimitated in this way is treated as an object and is called a “polygon”. Polygons are classified with the assignment of a label. The code(s) composing the label are selected from the adopted legend (Fig 02).

The two basic principles to follow and to strictly monitor during the production of the map, are internal and external consistency. The same interpretation keys identified on the image have to be adopted for different parts of the frame in order to maintain the consistency inside the interpreted frame (internal consistency). All photo-interpreters in the team meet and verify interpretations they have attributed to elements identified in their respective images, in order to avoid the risk of using different labels for labelling the same thing, or vice versa. Consistency is important, as with a consistent classification land is subdivided in stratified homogeneous areas, allowing optimisation of field data collection and easier upgrading and correcting. This facilitates revision of the preliminary map.

SWALIM’s land theme photointerpreters edited the Land Cover geo-feature class, through visual interpretation of available RS images using the ESRI (ArcGis) platform and Geovis software. Polygons represented on the map are in vector format and can be directly managed as a spatial feature dataset and for performing analyses (see Chapter 3.2.5 on Data analysis and spatial modelling).

SOMALIA - LANDCOVER LEGEND		
	A12-NATURAL AND SEMINATURAL TERRESTRIAL VEGETATION	
Herbaceous terrestrial	Closed to Open Herbaceous (>15%)	**2HL**
	Herbaceous (>1%) with Sparse Shrubs (1-15%)	**2HL8**
	Closed to Open Herbaceous (>15%) with Sparse Trees and Shrubs	**2HL78**
	General Open Herbaceous (on ex-irrigated schemes)	**2HP-x**
	Sparse Herbaceous	**2HR**
Shrubs terrestrial	Closed Shrubs	**2SC**
	General Open Shrubs	**2SP**
	General Open Shrubs with Open Herbaceous	**2SP6**
	General Open Shrubs with Herbaceous from Closed to Open (on ex-irrigated schemes)	**2SPJ6-x**
	General Open Shrubs with Trees 1-15%	**2SP7**
	Sparse Shrubs	**2SR**
	Sparse Shrubs with Herbaceous 1-15%	**2SR6**
Woody terr.	Open Woody	**2WO**
Trees terrestrial	Closed Trees with Shrubs from Closed to Open	**2TC8**
	General Open Trees with Herbaceous 1-65%	**2TP6**
	General Open Trees with Shrubs 1-65%	**2TP8**
	STRIPED Very Open Trees With General Open Shrubs And Herbaceous (Tiger Bush)	**2TV86Zs**
	CELLULAR Very Open Trees With General Open Shrubs And Herbaceous (Tiger Bush)	**2TV86Zc**
	Sparse Trees with Shrubs 1-15%	**2TR8**
	A24-NATURAL AND SEMINATURAL AQUATIC VEGETATION	
	Closed Herbaceous On Temporarily Flooded Land	**4HCJF**
	General Open Herbaceous On Temporarily Flooded Land	**4HPJF**
	General Open Woody On Temporarily Flooded Land	**4WPF**
	Closed Trees with Shrubs from Closed to Open On Temporarily Flooded Land	**4TCF8**
	Open Trees with Shrubs from Closed to Open On Temporarily Flooded Land	**4TOF8**
	Closed Herbaceous On Permanently Flooded Land	**4HCJFF**
	A 11-CULTIVATED TERRESTRIAL AREAS AND MANAGED LANDS	
Herbaceous Crop - Rainfed	Rainfed - Continuous Medium Fields of Herb. crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HM47-C**
	Rainfed - Clustered Medium Fields of Herb. crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HM147-C**
	Rainfed - Isolated Medium Fields of Herb. crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HM247-C**
	Rainfed - Medium Fields of Herb. crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HR47-C**
	Rainfed - Clustered Small Fields of Herb. crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HR147-C**
	Rainfed - Isolated Small Fields of Herb. crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HR247-C**
Herbaceous Crop - Irrigated	Irrigated Continuous Large Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HL57**
	Irrigated Continuous Medium Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HM57**
	Irrigated Clustered Medium Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HM157**
	Irrigated Continuous Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR57**
	Irrigated Clustered Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR157**
	Irrigated Isolated Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR257**
Trees Crop - Irrigated	Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**TR3H57**
	Irrigated Clustered Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**TR13H57**
	Irrigated Isolated Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**TR23H57**
	General Open Trees with Shrubs 1-65% OR Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**2TP8//TR3H57**
Herbaceous Crop - Post Flooding	Post Flooding - Continuous Medium Fields of Multiple Herbaceous crops	**HM3HY**
	Post Flooding - Isolated Medium Fields of Multiple Herbaceous crops	**HM23HY**
	Post Flooding - Continuous Small Fields of Multiple Herbaceous crops	**HR3HY**
	Post Flooding - Clustered Small Fields of Multiple Herbaceous crops	**HR13HY**
	Post Flooding - Isolated Small Fields of Multiple Herbaceous crops	**HR23HY**
	Rainfed - Continuous Medium Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize) OR Post Flooding - Continuous Small Fields of Multiple Herbaceous crops	**HR47-C//HR3HY**
	Rainfed - Isolated Small Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize) OR Post Flooding - Isolated Small Fields of Multiple Herbaceous crops	**HR247-C//HR23HY**
	B15-ARTIFICIAL SURFACES AND ASSOCIATED AREAS	
	Airport	**5A**
	Urban Areas/Settlements	**5U**
	B16-BARE AREAS	
	Loose and Shifting Sands	**6L**
	Dunes	**6LD**
	Salt Crust (Sandy area)	**6LZ**
	Bare Soil	**6S**
	Bare Soil with Scattered Vegetation	**6SV**
	B27-ARTIFICIAL WATERBODIES	
	Artificial Waterbodies Standing	**7WP**
	B28-INLAND WATERBODIES	
	Tidal Area	**8WT1**
	River	**8WFP**
	Seasonal Rivers	**8WFN**
	Seasonal Rivers with Scattered Vegetation	**8WFNV**
	Natural Waterbody	**8W**

Figure 7: Summary of the legend by main Land Cover type

Legend codes were assigned following LCSS rules. For a detailed explanation, see LCCS classification concepts and user manual – FAO edition, Rome, 2000.

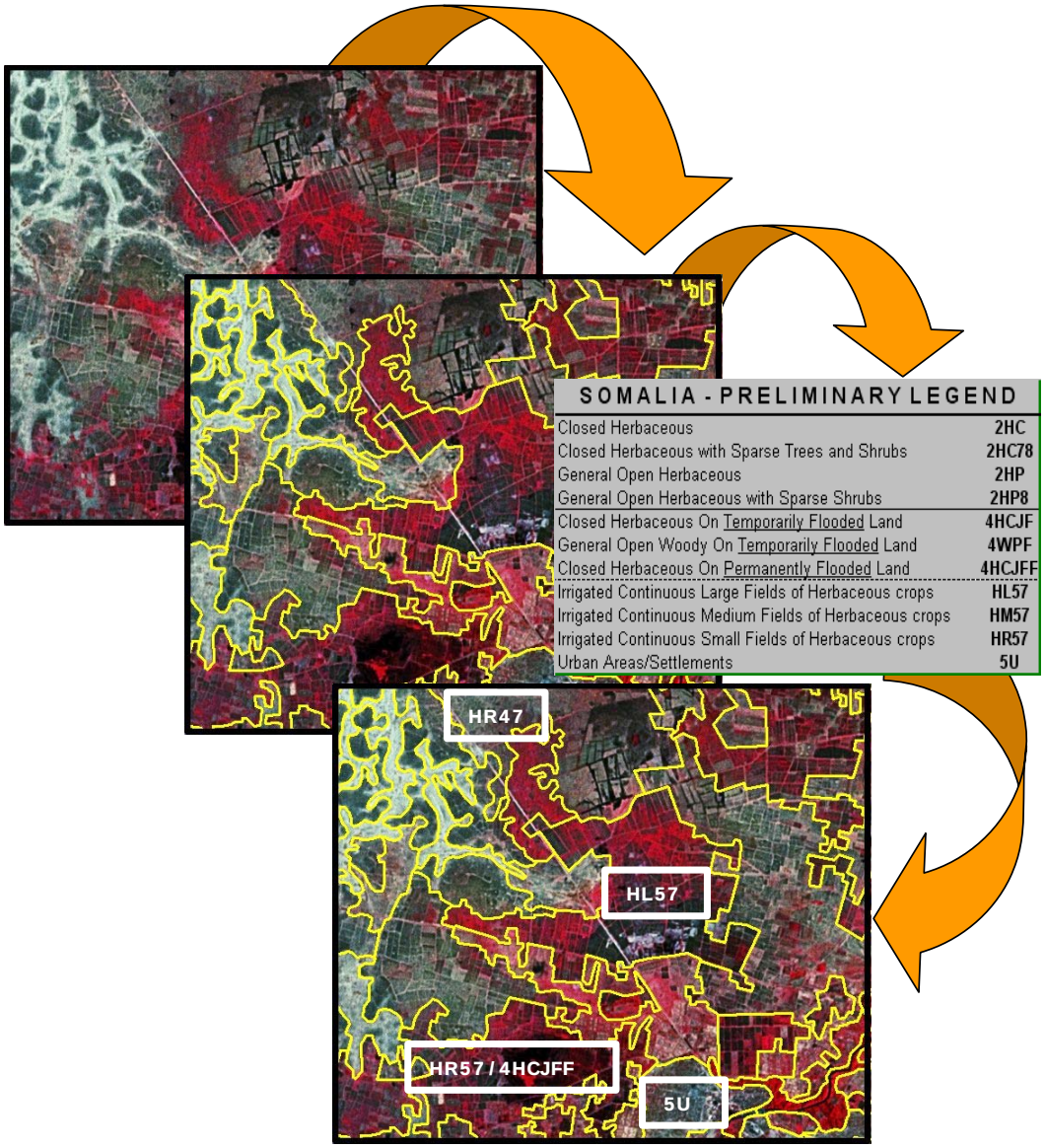


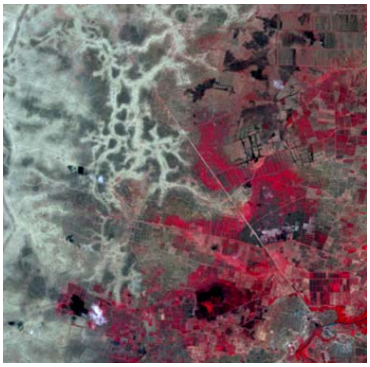
Figure 8: Photointerpretation

Satellite images such as Landsat (ETM sensor: 30 m sized pixels) or Aster (VNIR sensor: 15 m sized pixels) were interpreted on the basis of:

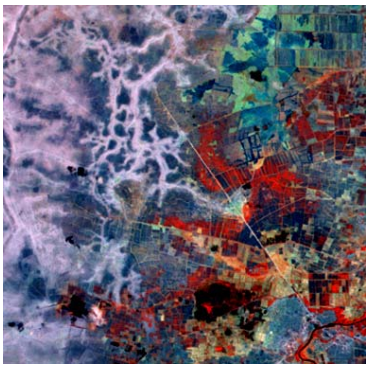
- Tone and colour brightness;
- Spectral signature;
- Texture, which is the frequency of changes and arrangement of tones;
- Contrast, or the difference in tone between a body and the background;
- Pattern, the regular repetition of colours, tones and features such as lines or shadows;
- Size, shape of the objects and their topological relationship/s.

As already explained in the previous paragraph on Image processing, FCCs images were created by selecting and combining bands considered significant for the identification of different land cover types. Combinations used for the interpretation were:

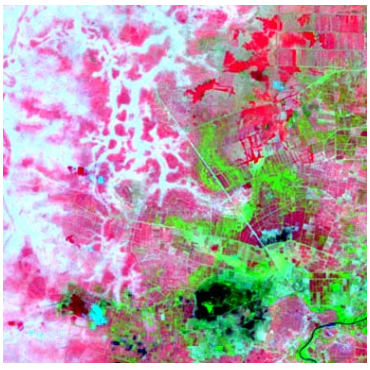
Composite 432 mainly for vegetation, soils, and settlements



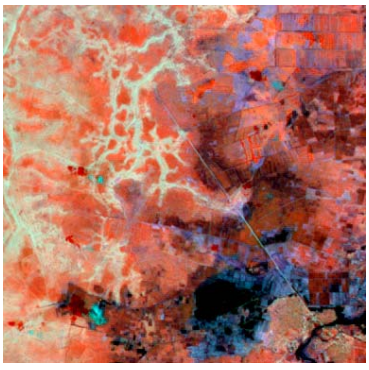
Composite T43 mainly for wet areas, irrigated agriculture, and vegetation



Composite 457 mainly for vegetation and soil conditions



Composite T75 mainly for wet areas, soil and vegetation conditions, and irrigated agriculture



Typical composite Landsat432 and corresponding Aster 321 were the more frequently used.

The following paragraphs explain the conceptual framework used to extract information using images with differing spatial, radiometric and spectral resolutions, or in temporal sequences.

The main evaluations and comparisons performed on available datasets were:

Superimposing Ikonos samples on Landsat or Aster - Using IKONOS images for land cover identification can be considered as an activity that partially replaces some aspects of the field survey. It is possible to accomplish a level of sampling for certain basic parameters, allowed for by the very high resolution of the sensor.

IKONOS images allow direct identification and recognition of small objects such as plants, and structure of vegetation formations. Furthermore, some parameters can be more accurately collected if compared with field samples. An example is vegetation canopy coverage, which is one of the most important parameters used in many processes of analysis. While field samples mostly supply information about vertical structures, IKONOS can supply information about horizontal structures, improving correlations with vegetation and environmental conditions.

The vertical perspective can be compared with results from images such as Landsat and Aster, which have a lower resolution.

Locations of IKONOS imagery were accurately selected for the southern AOI during the preliminary photo-interpretation. Parameters considered were:

- combination/s of trees and shrubs, coverage and medium diameter;
- presence and coverage of eventual emergent;
- total coverage (max 100%);
- herbaceous presence in particular seasonal conditions;
- crop patterns, life forms and water supply;
- geomorphological information and related processes (drainage, erosion, etc.);
- vegetation horizontal patterns (plant distributions: regular, irregular or grouped).

Superimposing different Landsat derived images - This method uses a type of stratification or matrix. The basic principle is that every image can be interpreted in different ways (formulating hypotheses), but that sometimes the only way is to combine two or more different images.

Specific band combinations:

- composites Landsat 432 and 457 and Aster (VNIR) 321, used in combination with NDVI for detecting vegetation;
- composite Landsat 432, T43, 457, Aster (VNIR) 321, Landsat panchromatic, NDVI and Thermal Capacity for detecting agriculture;
- composite T43, Thermal Capacity and NDVI indices for assessing soil moisture. When soils are moist the composite T43 is dark red or violet; the Thermal Capacity is bright while the NDVI is dark, showing that moisture is not held by vegetation.

Temporal series crossing among corresponding Landsat images - Different temporal series of Landsat images from the years 1988, 1990 and 2000 were made available by the FAO Africover project from their archive, which were used to identify agricultural schemes and wet areas. Images acquired at different times and, when available, of different seasons (for the same area) were compared. The main feature noted was the

dynamism in terms of cultivated surfaces over the years, which assisted in understanding actual distributions.

Draping images to SRTM-DEM - This allowed a better understanding of features relating to terrain shapes, such as lithology or shadows, that influence and alter vegetation spectral signatures.

An example is the approach followed to determine the Land Cover in the Lower Juba area. A similar approach was followed for Medium Shabelle.

The basic features to detect and extract were:

- Agriculture (presence or absence of any kind of irrigation system)
- Natural vegetation (wet or terrestrial)

Two Landsat images were available for the area:

1. P165r60 collected on 2nd April, 2000
2. P165r60 collected on 17th September, 2000

The two images are separated by seven months and were collected at the end (image 1) and the beginning (image 2) of the *Jilaal*, the long dry season, respectively.

The parameters used for classification were:

Heat response - The first analysis was based on the heat response. The thermal infrared has a small emission while water is stored within soils. Water in soils can be associated with wet natural vegetation and irrigated agriculture.

Image 2 was collected during the last part of *Deyr*, the short rainy season and clearly shows wet areas, mostly distributed in the central-upper portion of the river. The shape of these areas is consistent with depression formations, and their position is close to water bodies that are apparently in spate. Image 1, collected between the end of *Jilaal* and the beginning of *Gu*, the main rainy season, shows water bodies in flood (with some associated wet areas) in the south-west areas, which matches with stream flows from drainage systems emanating from the Kenyan border areas.

The two images seem to show an irregular rain distribution when comparing the two lower Juba areas, but are able to indicate flood water dynamics.

Image patterns - Image patterns are repeated textures, colours, shapes and objects on the earth's surface. Natural vegetation is characterised by gradual changes in colour and by irregular clustering of shapes, with variable density and distribution.

In this approach, geometric patterns are considered as main indicators of human activities, including agricultural schemes. This kind of pattern is characterised by abrupt colour changes, straight boundaries, corners and geometric shapes.

Pattern typology - Three main geometric patterns may be distinguished in the area:

- Burned areas, not strictly related with agriculture.
- Patches and dots, principally related with household agriculture characterised by different types of water supply: rainfed, post flooding (*desheks*), bank breaking and uncontrolled riverine flooding.

- Big irrigation schemes usually occur in big farming projects. The main channels are straight, long (up to several kilometres) and clearly visible. The pattern is squared and very regular. It is not possible to directly detect amounts of silt and consequently the effective functionality of the channels, but it is possible to make hypotheses on soil moisture content.

In the case of dry soils and big irrigation schemes it may be deduced that channels are present, but silted and not in use. Presence or absence of rain-fed agriculture has to then be verified. Ex-irrigated schemes, when identifiable, are mapped for their importance in defining Land Utilization Types.

A flowchart of considerations made during the interpretation is presented in Figure 03.

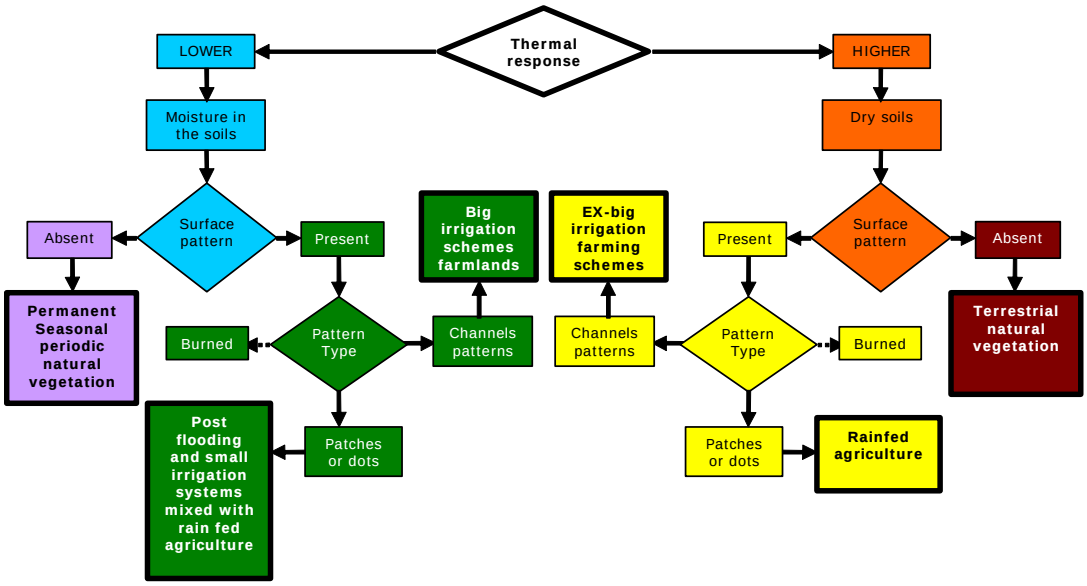


Figure 9: Flowchart

3.2.3 Field data collection

Field work

Planning standards and procedures for a field survey are a critical step in implementing land cover analysis, as the reliability of the entire work is based on the analysis of data collected (ground truthing).

A tailored methodology for field data collection was defined, taking into account the skill levels of selected Somali surveyors, the "language" of the classification system adopted and the field survey methodology developed by FAO Africover.

A simplified version of the legend structure was developed together with forms for data collection. The methodology, structure and content of the forms are explained in detail in Report L-01 – Field Survey Manual.

The field survey was performed only in the north-western AOI and the southern riverine areas. For the northern AOI the field survey was performed in May-June 2006 while for the southern riverine areas it was performed in March 2007. The delay in the southern AOI field survey was due to the problem of insecurity that was attributed to the war in South Somalia.

The field survey boxes, in both the areas, (indicating the areas to be investigated) were selected after evaluation of their representativeness, distribution, total number, accessibility, possibility of creating clusters and available time. Priority was given to:

- homogeneous areas (labelled by a code) that cover large areas;
- the most frequent codes (labelling more polygons);
- very complex areas not directly understood through image analysis;
- locations with better accessibility;
- clustering of field sample sites in order to facilitate planning and route selection;
- areas of major economic and/or environmental importance.

The following tools were provided for the field survey:

- preliminary 1:130 000 maps printed on A0 paper in sets of two sheets, each showing land cover polygons, boxes, and roads on Landsat images;
- a hardcopy list of the boxes with information on coordinates, sizes, preliminary codes and an identifier derived from the field samples boxes geo-dataset;
- an adequate number of field forms to be used in data collection;
- laminated tables designed to assist in estimation of percentage of cover and evaluation of dominant natural vegetation layers;
- measuring tools (compass, tape measure, etc.) and digital cameras;
- hardcopies of the Field Survey Manual;
- manuals for plant identification.

Field data analysis

The data collected in each box during the field survey are composed by:

- a set of forms describing land cover types identified;
- four digital pictures (one from each cardinal point);

- additional information and descriptions on vegetation physiognomy, floristic composition, etc.

In order to make data usable for analysis and revision, the following tasks were performed:

Data entry - an appropriate Microsoft Access template was designed to convert and store data in digital format. Every field form has its corresponding tables linked together in a relational database. Data entry is handled through appropriate masks developed with essential validation rules, to guide operators and reduce mistakes.

Built a point geo-feature class for sites location (x and y coordinates) - GPS positions of sampled sites were converted to a geo-feature class (shapefile) in order to register locations of sites together with images and land cover geo-feature classes, allowing comparative viewing, querying and analysis through GIS.

Validation of sites forms set - descriptions and parameters collected were checked for completeness and consistency. Forms with missing/divergent information, coordinates, codes or photographs were not considered during analysis.

Attribution of an LCCS code to each site – an LCCS code (both single class and mixed unit) was attributed to each site form and photo set on the basis of the evaluation of collected data. Some new LCCS classes were created to better fit part of the site sample. A subsequent selection of codes provided the final legend.

3.2.4 Legend updating and map revision

Parameters and descriptions collected in the field in both the northern and southern AOI were compared with the preliminary map, and results used for revising the legend and interpretation.

Legend classes were consequently confirmed, revised and/or updated with new ones. The updating of natural vegetation classes was based on descriptions of life forms (coverage and heights of tree, shrub and herbaceous layers), evaluation of photographs and eventual additional information recorded.

Agricultural classes were revised after consideration of field form descriptions of crop life form and species and evaluation of photographs, and field sizes and densities were derived from satellite images.

Extensive comparative work was conducted on information collected on the ground in order to identify relationships among different zones of the AOI. Similar areas/codes identified on maps were then evaluated in order to consistently extend analyses to un-surveyed areas of the map.

A list of all classes obtained from the preliminary legend, as well as revised and new classes resulting from field data analysis, was checked in order to avoid overlap of classes (some aggregations of cover thresholds were required), and the final legend was created in LCCS.

Before starting final revision of the interpretation, a conversion table was created to automatically transform, where possible, old codes into new ones. In some cases it was possible to automatically dissolve bordering polygons. The majority of classes were however replaced or confirmed through visual revision of the interpretation.

Codes assigned to similar areas were updated according to results of field data collected in the north.

This homogenisation process was mainly concerned with natural vegetation and rainfed/irrigated agriculture codes. The final bordering polygons generated were automatically dissolved where possible and manually checked in the remaining cases.

The final Land Cover legend adopted for both AOI is shown in Annex 09.

3.2.5 Data analysis and spatial modelling

Spatial analyses are the most important functions of a GIS. Relationships between the database and the geographic components (topological connections) enable GIS to create models and representations of the real world. All spatial modelling was performed in line with the FAO SDRN method and may be subdivided into two main types:

Aggregations

Aggregations involve spatial features and tabular data, and are mappable. They are an abstraction mechanism, used for clustering “objects” at a superior level. Aggregations are used to progressively obtain more complex and meaningful new objects from elementary objects. Starting from a lower taxonomic level, higher levels are created. This process is extremely important as it allows display, understanding and practical usage of geo-datasets. Different aggregations can be designed and performed for different users, according to their technical competences and needs.

The aggregation model is characterised by two components:

- identification of subsets of objects, which may be grouped into a more complex object;
- rules applied during selection of each subset.

As already explained, LCCS is an extremely sophisticated classification system. It can store voluminous information concerning vegetation, agriculture physiognomy, physiology and other associated environmental features.

LCCS was designed considering the linkages between land cover and the actions of people in their environment. Production of aggregation according to the GLCN method leads to a basic subdivision of the land in raw land-use types. These aggregations supply a base map for land-use classes that will be developed in further studies, providing the spatial locations for them.

In order to obtain this result from LCCS codes, a set of rules was applied to obtain several taxonomic ranks as follows:

1) The first level of aggregation (*Aggregated Classes*) was created based on:

    - the most important LCCS class present in the code, where agriculture is always dominant: a code with 2 classes, where the main class is that of natural vegetation and the secondary one is that of isolated rainfed agriculture (coverage = 10-20%) grouped as an (isolated) agricultural area.

    - In the case of agriculture, they share the same irrigation system, coverage rate (spatial distribution or macropattern), crop types, and field size. All these features are closely related with major differences in management and labour/mechanization.

2) The second level of aggregation (*Main Aggregations*) was created by grouping all very similar classes.

   - In the case of vegetation, all classes conceptually belonging to similar natural formation types were grouped. As a general rule, classes sharing the same dominant life form were grouped (for example, “Shrub Open with Trees Sparse” or “Shrub Open with Herbaceous Open”). The main formation types obtained were: “Grassland” (herbaceous can be of any height and cover value, but shrubs and trees are absent), “Savanna and other spaced woody formations” (general sparse shrubs and/or trees; herbaceous can be of any height and cover value), “Shrubland” (general open shrubs) and “Woodland” (general open trees). Dominance between layers, according to LCCS rules, is maintained. For example, the class “Open Trees with Closed to Open Shrubs” is included in the aggregation “General Open Trees – (woodland)”, due to the influence of the larger life form despite similar coverage between the two layers. Regarding coverage of dominant layers in natural vegetation, only the broad LCCS ranges are considered (generally sparse 1-15%, generally open 16-65% and closed >65%).
   - At this level, agricultural aggregations report irrigation system and spatial distribution. The last feature can suggest the weight of agriculture versus other activities, such as pastoralism.

3) The third and highest level of aggregations (*Vocation*) arranged Land Cover in the main agricultural or natural subdivisions affecting land-use:

   - Rainfed Agriculture
   - Irrigated Agriculture
   - Post-Flooding Agriculture
   - Wooded Vegetation (suitable for charcoal, wood exploitation and grazing)
   - Rangeland (suitable for grazing only)
   - Other (including urban areas, settlements, water bodies and bare areas)

   Agricultural aggregations can include activities such as charcoal, wood exploitation and grazing. This is particularly true if agriculture is scattered or isolated.

All these rules are implicitly present in the “Conversion Table” (Figure 04 shows cartographic aggregations generated according to the Conversion Table). The table is a reference that defines a typical link from One (the aggregations) to Many (all the related polygons in the PAT). This table also stores the area rating for each land cover code.

Areas subdivision (tabular) analysis

This is based on spatial feature attributes (tabular data only). In the present exercise the aim was a statistical allocation of surfaces according to meaningful land cover typologies.

Transformations and handling of data required the employment of two functions:

1. *Generation function* – information contained in each land cover code was extracted and merged in a new categorical grouping regarding LCCS structure. In this classification system, the most elementary classes are the so called “single classes” composing the legend. The codes assigned to a land cover type can range from 1 up to a combination of 3 single classes (mixed units) following the system rules. Each class is referred to a particular vegetation or agricultural type or to other kinds of land cover, such as urban, bare areas or water bodies. Each class in

a code has an assigned coverage rate (the sum of the classes composing a code must be 100%). This percentage can be assigned according to the attributes describing the class or the relative importance of the class in the mixed unit. For example, in a mixed unit consisting of two natural vegetation classes, the main class is assumed to cover 60% of the area, while the secondary class covers 40%. Agricultural classes are determined based on the coverage rate classifiers. In the case of rain fed agriculture up to three classes can be required, specifying whether coverage is between 10-20% (isolated), 20-50% (clustered), or more (continuous).

Such fusions are categorical only, since they are not mappable. In fact, single classes were extracted from the codes (labels) and were merged according to any interested feature but those features concerning coverage rate (spatial distribution). For a particular kind of rainfed agriculture, each concerned class has a different weight in surface attribution according to assigned percentage.

2. *Calculation function* – tabular information is used as a variable in mathematical equations. In GIS applications, homogenous spatial features are called “polygons”. Each polygon is described by a linked record in a Feature Attribute Table (FAT), which stores the land cover code (simple classes or mixed units), and areas derived by projecting the geo-dataset in Albers Equal-Area projection (in which all areas are proportional to the same areas on the earth). In this phase, each class code of each record in the FAT is assigned an area. For example, if the polygon area is 142 ha and comprises two natural vegetation classes, the main class comprises 60% = 85 ha and the secondary one 40% = 57 ha. Calculated areas are summarised on the basis of defined categorical groupings. One subset of very similar natural vegetation classes can be summarised together, without taking into account whether such classes are primary or secondary in the original code.

In conclusion, calculated areas are not referred to polygons themselves, but to different land cover typologies that they include. Results are arranged in categorical groupings very similar to the cartographic aggregations. The main differences between the two are:

- Categorical groupings never need distinctions about cover percentage. They are not mappable.
- Cartographic aggregations are basically based on the dominant class of the code. Secondary classes are not considered, despite the fact that they can represent an important part of the polygons.

ACTIVITY OF FOCUS	MAIN_AGR	AGGR_AGR
IRRIGATED	IRRIGATED AGRICULTURE (crop fields >80% of the area)	Irrigated - Continuous Large Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)
		Irrigated - Continuous Medium Fields of Herbaceous crops (single (Rice, Banana) or multiple herbaceous crops)
		Irrigated - Continuous Small Fields of Herbaceous crops (single (Rice, Banana) or multiple herbaceous crops)
		Irrigated - Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)
	MIXED UNITS OF IRRIGATED AGRICULTURE (crop fields 80-50% of the area)	General Open Trees with Shrubs 1-65% OR Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)
		Irrigated - Mixed Continuous Medium Fields of Herbaceous crops (single (Rice, Banana) or multiple herbaceous crops)
	CLUSTERED IRRIGATED AGRICULTURE (crop fields 50-20% of the area)	Irrigated - Clustered Medium Fields of Herbaceous crops (single (Rice, Banana) or multiple herbaceous crops)
		General Open Trees with Shrubs 1-65% OR Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)
		Irrigated - Clustered Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)
	ISOLATED IRRIGATED AGRICULTURE (crop fields 20-10% of the area)	Irrigated - Isolated Small Fields of Herbaceous crops (single (Rice, Banana) or multiple herbaceous crops)
		Irrigated - Isolated Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)
RAINFED	RAINFED AGRICULTURE (crop fields >80% of the area)	Rainfed - Continuous Medium Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
		Rainfed - Continuous Small Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
	MIXED UNITS OF RAINFED AGRICULTURE (crop fields 80-50% of the area)	Rainfed - Mixed Continuous Medium Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
		Rainfed - Mixed Continuous Small Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
	CLUSTERED RAINFED AGRICULTURE (crop fields 50-20% of the area)	Rainfed - Clustered Medium Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
		Rainfed - Clustered Small Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
	ISOLATED RAINFED AGRICULTURE (crop fields 20-10% of the area)	Rainfed - Isolated Medium Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
		Rainfed - Isolated Small Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
POST FLOODING	POST FLOODING AGRICULTURE (crop fields >80% of the area)	Post Flooding - Continuous Small Fields of Multiple Herbaceous crops
	MIXED UNITS OF POST FLOODING AGRICULTURE (crop fields 80-50% of the area)	Post Flooding - Mixed Continuous Medium Fields of Multiple Herbaceous crops
		Post Flooding - Mixed Continuous Small Fields of Multiple Herbaceous crops
	CLUSTERED POST FLOODING AGRICULTURE (crop fields 50-20% of the area)	Post Flooding - Clustered Small Fields of Multiple Herbaceous crops
	ISOLATED POST FLOODING AGRICULTURE (crop fields 20-10% of the area)	Post Flooding - Isolated Medium Fields of Multiple Herbaceous crops
		Post Flooding - Isolated Small Fields of Multiple Herbaceous crops
MIXED WATER SUPPLY	MIXED WATER SUPPLY AGRICULTURE (crop fields >80% of the area)	Rainfed - Continuous Medium Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
	MIXED WATER SUPPLY AGRICULTURE (crop fields >50% of the area)	Rainfed - Continuous Small Fields of Multiple Herbaceous crops (Cereals) OR Post Flooding Continuous Small Fields of Multiple Herbaceous crops
	ISOLATED MIXED WATER SUPPLY AGRICULTURE (crop fields 20-10% of the area)	Rainfed - Isolated Small Fields of Multiple Herbaceous crops (Cereals) OR Post Flooding Isolated Small Fields of Multiple Herbaceous crops
	MIXED UNITS OF MIXED WATER SUPPLY AGRICULTURE (crop fields >50% of the area)	Irrigated - Clustered Small Fields of Herbaceous crops (single (Rice, Banana) or multiple herbaceous crops)
		Rainfed - Continuous Small Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
		Rainfed - Clustered Small Fields of Herbaceous crops (single or multiple) - cereals (Sorghum, Maize)
		Post Flooding - Mixed Continuous Small Fields of Multiple Herbaceous crops
WOODED VEGETATION	CLOSED TREES - (Forest)	Closed Trees (> 65%) with Shrubs from Closed to Open
	CLOSED SHRUBS (crown cover > 65%) - (Thicket)	Closed Shrubs (>65%)
	GENERAL OPEN TREES (crown cover 65-15%) - (Woodland)	General Open Trees (15-65%) with Sparse Herbaceous
		General Open Trees (15-65%) with Close to Open Shrubs
		CELLULAR Very Open Trees (40-65%) with General Open Shrubs and Herbaceous (Tiger Bush)
		STRIPED Very Open Trees (40-65%) with General Open Shrubs and Herbaceous (Tiger Bush)
	GENERAL OPEN SHRUBS (crown cover 65-15%) - (Shrubland)	General Open Shrubs (15-65%)
		General Open Shrubs (15-65%) with Open Herbaceous
		General Open Shrubs (15-65%) with Sparse Trees
		General Open Shrubs (15-65%) with Herbaceous from Closed to Open (on ex-irrigated schemes)
		Open Woody (40-65%)
	CLOSED TO OPEN TREES OR WOODY VEGETATION ON TEMPORARILY FLOODED AREAS (cover > 40% - < 4 months)	Closed Trees (> 65%) on Temporarily Flooded Area
		Open Trees (40-65%) on Temporarily Flooded Area
		General Open Woody vegetation (15-65%) on Temporarily Flooded Area
RANGELAND	HERBACEOUS - (Grassland)	Herbaceous (15-100%)
		General Open Herbaceous (15-65%) (on ex-irrigated schemes)
		Sparse Herbaceous (1-15%)
	HERBACEOUS ON TEMPORARILY FLOODED AREAS (cover > 40% - <4 months)	Closed Herbaceous (> 65%) on Temporarily Flooded Area
		General Open Herbaceous (15-65%) on Temporarily Flooded Area
	HERBACEOUS ON FLOODED AREAS (cover > 40% - >4 months)	Closed Herbaceous (> 65%) on Perennial Flooded Area
	SAVANNA (and other spaced Woody Vegetation)	Herbaceous (1-100%) with Sparse Shrubs
		Herbaceous (15-100%) with Sparse Trees and Shrubs
		Sparse Shrubs (1-15%)
		Sparse Shrubs (1-15%) with Sparse Herbaceous
		Sparse Trees (1-15%) with Sparse Shrubs
OTHER	URBAN AND ASSOCIATED AREAS	Airport
		Urban Areas/Settlements
	BARE AREAS	Loose and Shifting Sands
		Dunes
		Salt Crust (Sandy area)
		Bare Soil
		Bare Soil with Scattered Vegetation
	WATERBODIES	Artificial Perennial Waterbodies
		Natural Waterbody
		Seasonal Rivers (Wadi)
		Seasonal Rivers with Scattered Vegetation (Wadi)
		River
		Tidal Area

Figure 70: Cartographic aggregations

4 RESULTS

4.1 Northern AOI results from survey validation

All available field data was evaluated as a whole and combined with edited land cover and satellite imageries to formulate an appropriate usage of classes that was adopted in the final legend. The indications given for the revision of the base map were also based on partial correlations with geomorphological features that became evident during field data analysis. Integration between the two layers will be completely developed during preparation of the Land Mapping Units. A description of the codes followed is provided in Table 3.

The revision mainly concerned:

- *Natural Herbaceous layer* – This layer is strongly affected by rainfall variability and livestock movements. It is related to deeper soils (sandy and clay). Considering the erratic rainfall and periodic droughts that characterise the country, it was decided to describe the herbaceous presence by adopting a class defined by a wide range of coverage (from scattered to open/closed).

- *Rainfed Herbaceous crops* – The presence of one or more herbaceous intercropped crops is related to the amount of rain in each season, making it difficult to recognize the different typology on the ground. It was therefore decided to adopt new classes without this information.

- *Identification of classes to be used in specific areas*:

1 Sparse Shrub with Herbaceous (2SR6) was confirmed when used on the dissected plateau and mountain slopes, but replaced with Sparse Shrubs Only (2SR) where soil was shallow to discontinuous (very stony or rocky) in the sedimentary/limestone crests (all the hills, mesas, buttes and other outcrops on the plateau).

2 The classes 2HR, 2SP, 2SP7and 2TP8 were adopted on mountain slopes at medium-high altitudes and on the eastern side of the AOI. In these classes the herbaceous layer was indicated as sparse, or omitted.

3 A soil (6S) used to label *toggas* (riverbeds).

4 Bare Soil with Scattered Vegetation (6SV) was used to label stony/rocky slopes and badlands.

5 Seasonally Wet Waterbodies (8WFN and 8WFNV) were confirmed in the coastal area, but were changed to Bare Soil (6S) in riverbeds of river valleys within the mountain range, pediment and dissected plateau.

- *Identification of mixed units to be used in specific areas:*

1 River valleys – several *toggas* are buffered by two particular land cover types: Irrigated Agriculture (tree crop and cash crops) and General Open Trees and Shrubs. It is easy to separate them from surrounding areas such as riverbeds, but not from each other. It was therefore decided to label areas with the mixed unit 2TP8//TR3H57 eventually combined with bare soil (6S).

2 Farming systems/schemes on the plateau – the distribution of cultivated, grazed and charcoal collection areas and consequently the status of the adjacent areas of natural vegetation, is related to the proximity and density of settlements. These variations are however not easily detectable at the adopted scale of work unless they cause abrupt changes and discontinuities in the vegetation physiognomy. As a consequence, the land cover is more homogeneous than it appears from the field survey. It was therefore decided to select some sets of classes to be used in combination with classes of rainfed

agriculture: (2TP6) in the south east area, close to tiger bush; (2HL78) in the more populated westward area; and (2HL8 and 2HL) in the more degraded areas. All these classes are present on the gentle rolling plateau where soil is continuous and fairly deep (sandy-loamy soil). In these classes the range adopted for describing the coverage of the herbaceous layer is extremely wide (from scattered to open) to compensate for its annual variability.

Table 3: Land Cover codes

2SR6	Sparse Shrubs with Herbaceous 1-15%
2SR	Sparse Shrubs
2HR	Sparse Herbaceous
2SP	General Open Shrubs with Open Herbaceous
2SP7	General Open Shrubs with Trees 1-15%
2TP8	General Open Trees with Shrubs 1-65%
6S	Bare Soil
6SV	Bare Soil with Scattered Vegetation
8WFN	Seasonal Rivers
8WFNV	Seasonal Rivers with Scattered Vegetation
2TP8//TR3H57	General Open Trees with Shrubs 1-65% OR Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)
2TP6	General Open Trees with Herbaceous 1-65%
2HL78	Closed to Open Herbaceous (>15%) with Sparse Trees and Shrubs
2HL8	Herbaceous (>1%) with Sparse Shrubs (1-15%)
2HL	Closed to Open Herbaceous (>15%)

4.2 Land Cover cartographic aggregations

Cartographic aggregations of the northern AOI are shown in Map 1, while Map 2 corresponds to the southern AOI.

There are two main considerations guiding the grouping of natural vegetation classes.

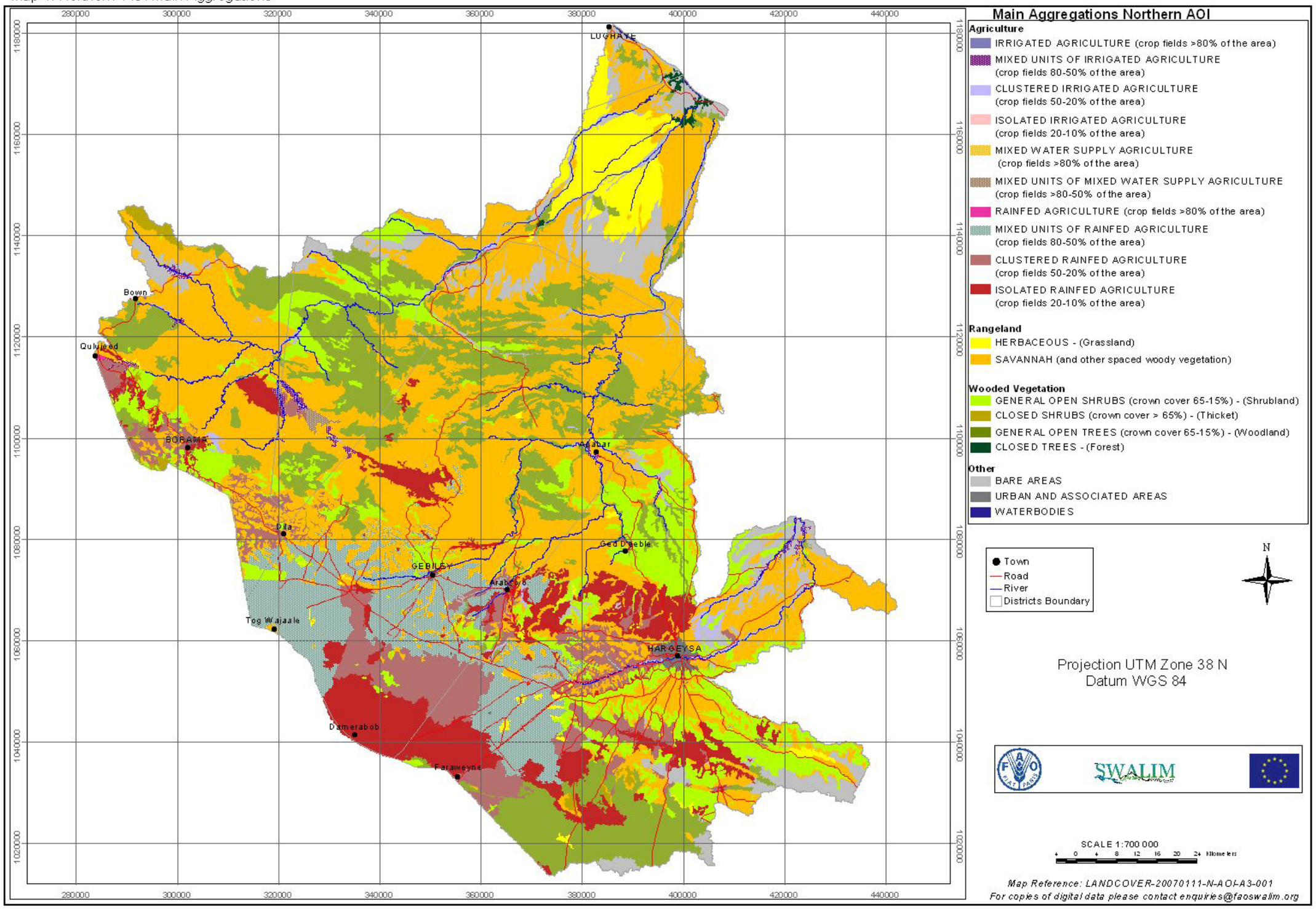
The first involved an attempt to display the ability of vegetation to protect soils. The main related feature is cover (coverage). In order to show different levels of protection, grouping according to LCCS spatial distribution rules was assumed to be sufficient.

The second consideration is that separating savanna from woodland is subjective, since the two terms have several definitions, their floristic composition is similar and detection by photointerpretation is difficult. It was finally decided that savanna aggregation refers to any kind of African savanna (shrub savanna and tree savanna) and any very open wooded vegetation that can be partially matched with “Xerophyllous open woodland” and “Subdesert bush and thicket”.

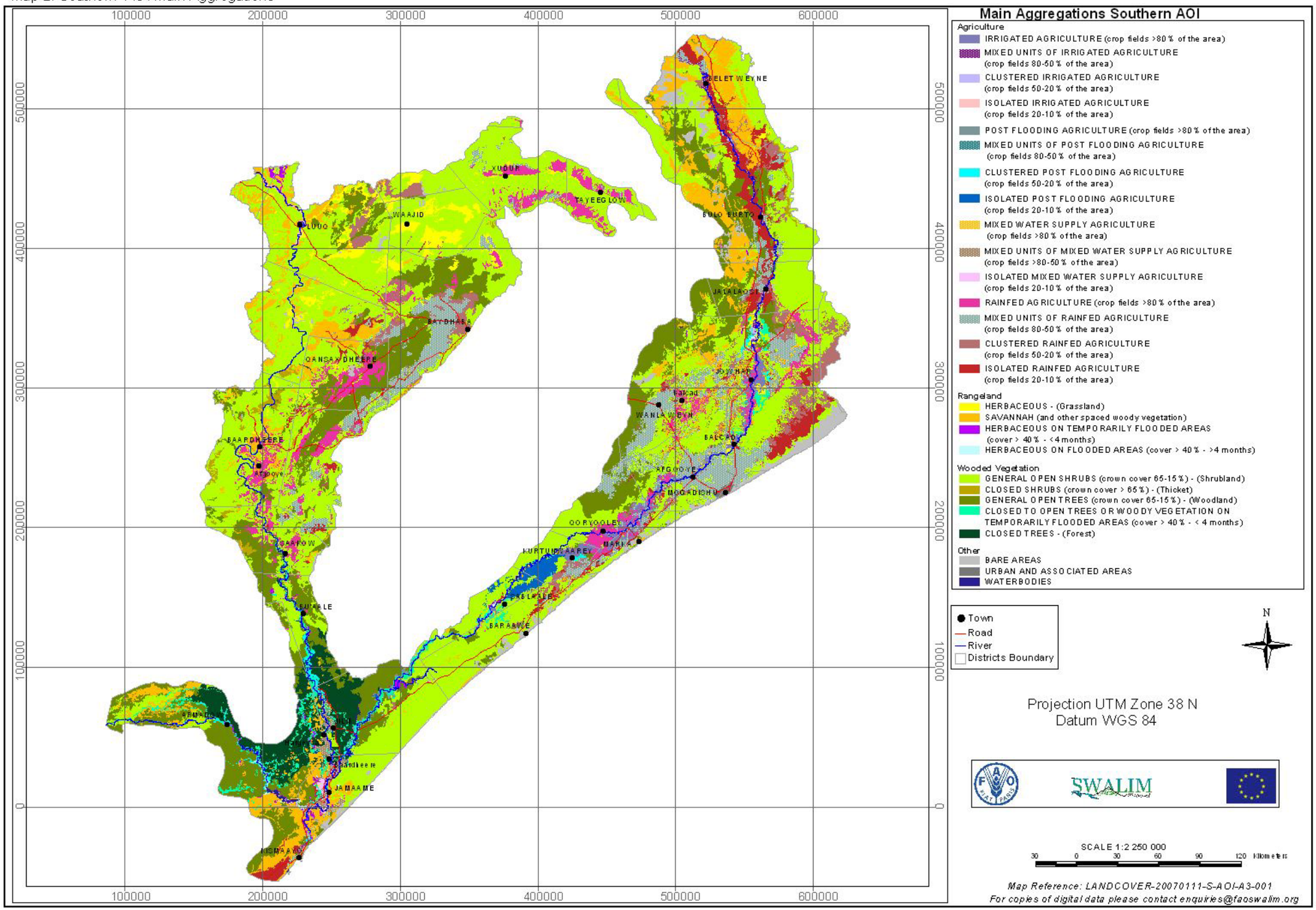
NB - At the taxonomic level of “Main Aggregations” it is assumed that, if agricultural types are defined as clustered or isolated, the influence of activities depending on natural vegetation should also be considered.

Annex 1 gives the vegetation of the AOI as established from the field assessment.

Map 1: Northern AOI Main Aggregations



Map 2: Southern AOI Main Aggregations



4.3 Land Cover surface statistics

4.3.1 Dur-Dur and Gebiley AOI – northern AOI

Results presented for the northern AOI are derived from statistical analysis of aggregated surfaces of the Land Cover map, produced through visual interpretation of satellite images and validated by data collected in the field.

The results described here show the composition and distribution of land cover types of the Dur-Dur and Gebiley AOI (Map 1).

The northern AOI has a total area of 1 293 899 ha, with 83% covered by Natural Vegetation (Chart 1).

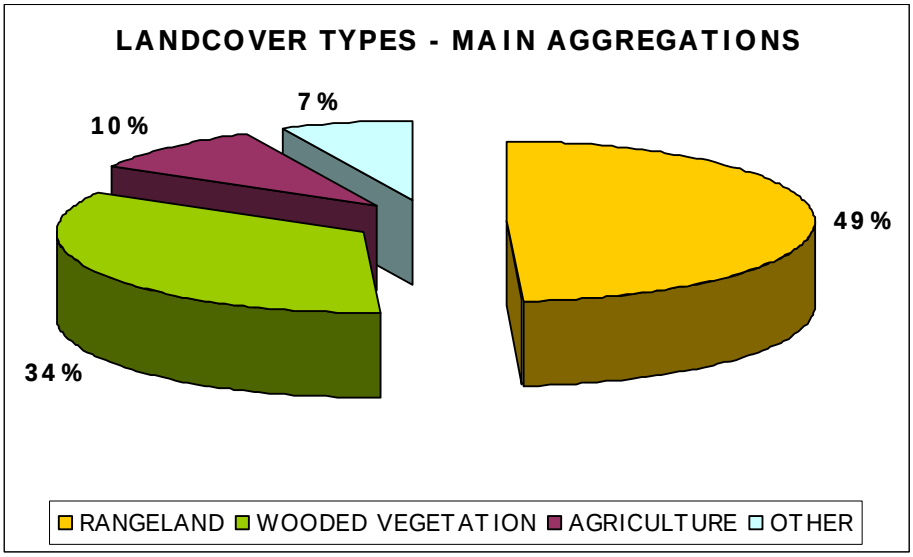


Chart 1: Distribution of main aggregations of Land Cover types

The more representative vegetation type is Rangeland, covering 49% of the mapped area (about 638 ha). The remaining area is distributed between Wooded Vegetation (441 ha) and Agriculture (125 ha).

About 91 ha are occupied by Non Vegetated Areas, indicated as Other in the chart. These include:

- Urban and Associated Areas (Settlement/Towns and Airport)
- Bare Areas (Bare Soils and Sandy areas)
- Natural Waterbodies

RANGELAND

The Rangelands of the AOI are mainly formed of Savanna and only in small part by pure grassland (Chart 2).

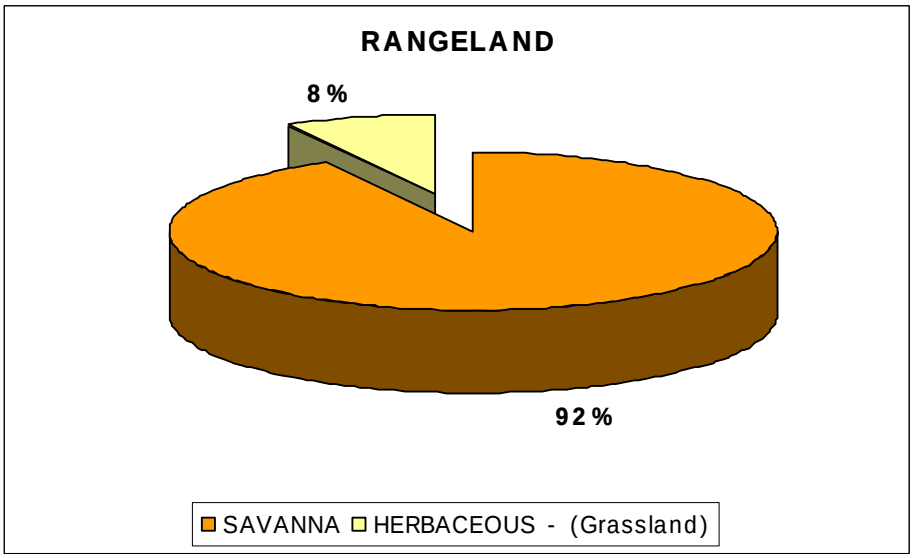


Chart 2: Rangelands distribution

The total area covered by Savanna is 587 000 ha (Table 4). The most representative vegetation type is composed of Sparse Shrubs occasionally in association with Sparse Trees. From a physiognomic point of view it consists mainly of sparse wooded vegetation with a layer of herbaceous vegetation influenced by rainfall and soil types, as well as grazing pressure).

Sparse shrubs with a herbaceous layer are mainly located on the dissected plateau and on mountain slopes, while sparse shrubs only are found where soil is shallow to discontinuous (very stony or rocky) on sedimentary/limestone crests (all the hills, mesas, buttes, and other outcrops on the plateau). Grasslands cover a low percentage of the area and are mainly distributed on sandy and clay soils.

Table 4: Rangeland areas

RANGELAND 637 556	**SAVANNA**	**586 729**	**% cover**
	Sparse Trees (1-15%) with Sparse Shrubs	199 993	31
	Sparse Shrubs (1-15%) with Sparse Herbaceous	133 695	21
	Sparse Shrubs (1-15%)	129 095	20
	Herbaceous (1-100%) with Sparse Shrubs	81 379	13
	Herbaceous (15-100%) with Sparse Trees and Shrubs	42 568	7
	HERBACEOUS (Grassland)	**50 828**	
	Herbaceous (15-100%)	25 521	4
	Sparse Herbaceous (1-15%)	25 307	4

WOODED VEGETATION

Wooded vegetation present in the AOI is composed almost equally of general open formations of shrubland and woodland (Chart 3).

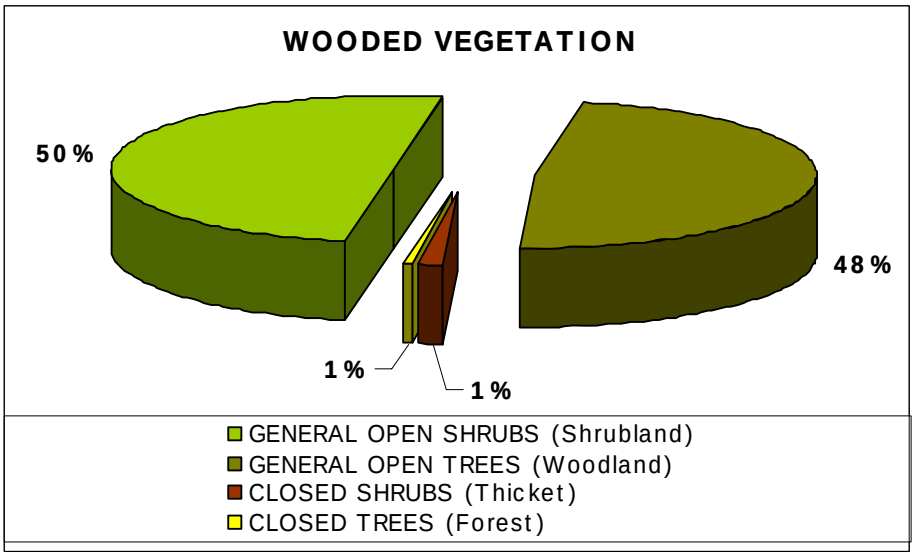


Chart 3: Wooded vegetation types distribution

A main layer of Shrubs, in some areas associated with a layer of sparse trees and/or herbaceous, forms Shrublands with a total surface area of 220 709 ha (Table 5). Woodlands consist of a primary tree layer, with or without shrubs and very open trees with shrubs with a fragmented macropattern (tiger bush). Tiger bush can display an interrupted cover of either striped or cellular fragmentation. Degraded types have a cellular pattern.

Table 5: Wooded vegetation areas

WOODED VEGETATION 440 715	**GENERAL OPEN TREES (crown cover 65-15%) (Woodland)**	**211 942**	**% cover**
	General Open Trees (15-65%) with Sparse Herbaceous	12 193	3
	General Open Trees (15-65%) with Close to Open Shrubs	169 004	38
	CELLULAR Very Open Trees (40-65%) with General Open Shrubs and Herbaceous (Tiger Bush)	15 028	3
	STRIPED Very Open Trees (40-65%) with General Open Shrubs and Herbaceous (Tiger Bush)	15 717	4
	GENERAL OPEN SHRUBS (crown cover 65-15%) (Shrubland)	**220 709**	
	General Open Shrubs (15-65%)	47 467	11
	General Open Shrubs (15-65%) with Open Herbaceous	52 668	12
	General Open Shrubs (15-65%) with Sparse Trees	120 574	27
	CLOSED SHRUBS (crown cover > 65%) (Thicket)	**5 752**	
	Closed Shrubs (>65%)	5 752	1
	CLOSED TREES (Forest)	**2 313**	
	Closed Trees (> 65%) with Shrubs from Closed to Open	2 313	1

With the exception of tiger bush present in the southern parts of the AOI towards the Ethiopian border, these formations are mainly located on mountain slopes at medium-high altitude and on the eastern side of the AOI.

Only 2% of the AOI is covered by dense vegetation; less than 6 000 ha is occupied by closed shrubs vegetation; while forests cover about 2 300 ha.

AGRICULTURE

Cultivated areas represent 10% of the total AOI. Their total surface is equal to about 124 800 ha. The most widespread agricultural practice is rainfed agriculture (>90%) where crop establishment and development is completely dependent on rainfall. Irrigated cultivation occupies less than 10% of the mapped area (Chart 4).

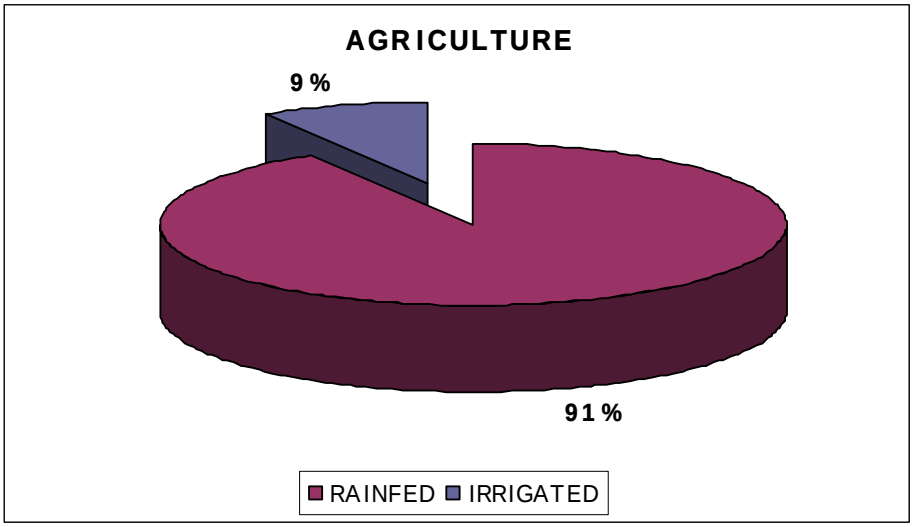


Chart 4: Agriculture distribution

The total area of rainfed agriculture is about 114 000 ha (Table 6). It is characterised by fields of small dimensions (<2ha) growing cereals. Maize and sorghum are the most important crops and are cultivated either as single crops or in combination. Depending on rainfall, the same crop (maize – maize) or two different crops (maize – sorghum) can be cultivated sequentially, i.e. in sequence on the same field within one year.

Rainfed fields of a shrub crop are also present (*Catha edulis* – Qaat) but their size is too small and distribution too scattered to be mapped at the scale of work adopted.

Table 6: Agriculture areas

AGRICULTURE 124 834	**RAINFED**	**113 998**	**% cover**
	Medium Fields (2-5ha)	24 744	19.8
	Small Fields (<2ha)	89 254	71.5
	IRRIGATED	**10 837**	
	Small Fields (<2ha)	10 286	8.2
	Mixed units	551	0.4

Nearly 11 000 ha are cultivated, supplying water to crops through an irrigation system. Irrigated fields are usually distributed along seasonal rivers. Water is pumped to the crops through pipes. Fields are usually cover less than 2 ha, with fruit tree crops (papaya, mango, and lemon) and vegetables (tomatoes, onions and watermelons).

Due to their location along the *toggas* where open or fragmented riparian formations of natural trees are also present, identification of irrigated fields is quite difficult.

This uncertainty, encountered during interpretation work, required the creation of a special class described in the legend as "General Open Trees with Shrubs 1-65% OR Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)". It was felt to be most appropriate to aggregate the areas classified with this code as Mixed units of irrigated agriculture.

4.3.2 Riverine area – southern AOI

Results for the southern AOI are derived from statistical analysis of aggregated surfaces of the Land Cover map produced during Phase I, integrated with additional areas interpreted from satellite images during Phase II. The preliminary results were validated in the month of March 2007 when the field work was conducted. Ultimately, the final results were obtained and presented in this report.

The southern AOI has a total area of 10 399 916 ha, 74% of which is covered by Natural Vegetation (Chart 5).

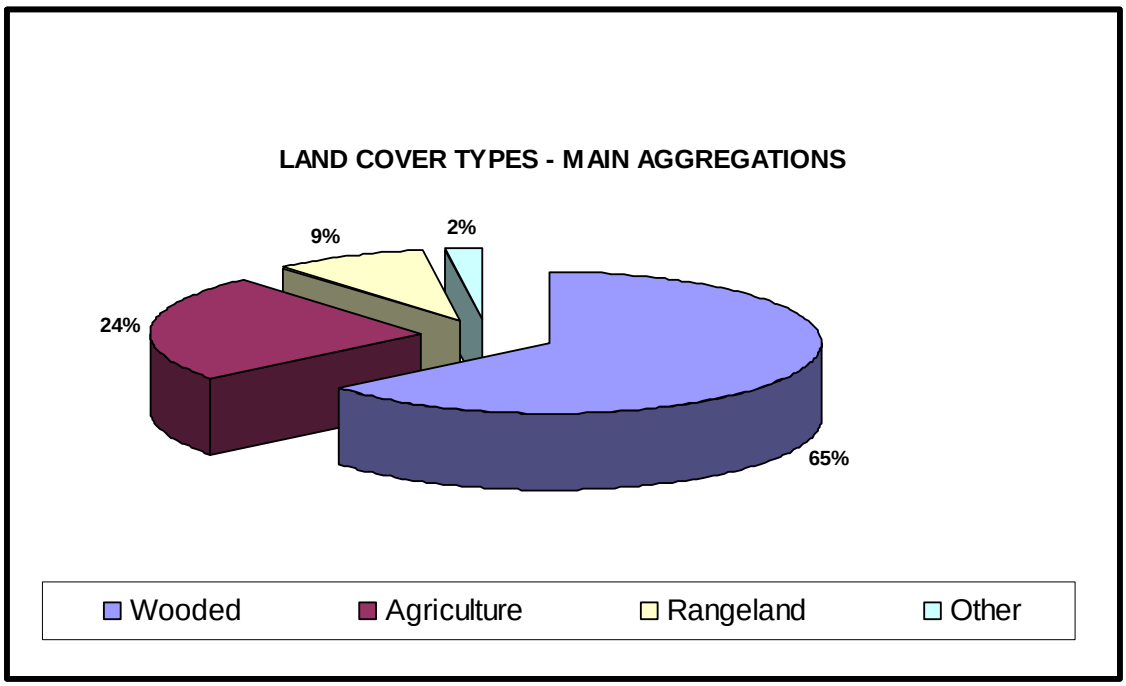


Chart 5: Distribution of main aggregations of Land Cover types

The total area of 7 627 926 ha of natural vegetation are composed of 65% wooded vegetation (6 671 021 ha) and 9% rangelands. Around 2 536 709 ha are occupied by cultivated areas.
The remaining part of the investigated area, around 235 280 ha, is covered by Non Vegetated Areas, indicated as "Other" in the chart. This aggregation includes the following Land Cover types:

- Urban and Associated Areas (Settlement/Towns and Airport)
- Bare Areas (Bare Soils and Dunes/Sandy areas)
- Natural/Artificial Waterbodies.

WOODED VEGETATION

This aggregation includes natural and semi-natural vegetated areas of trees and shrubs on terrestrial or temporarily flooded areas (Chart 6).

Shrubland is the dominant wooded vegetation type with a total surface of **7731282** ha (80%) of the total area covered by the wooded vegetation.

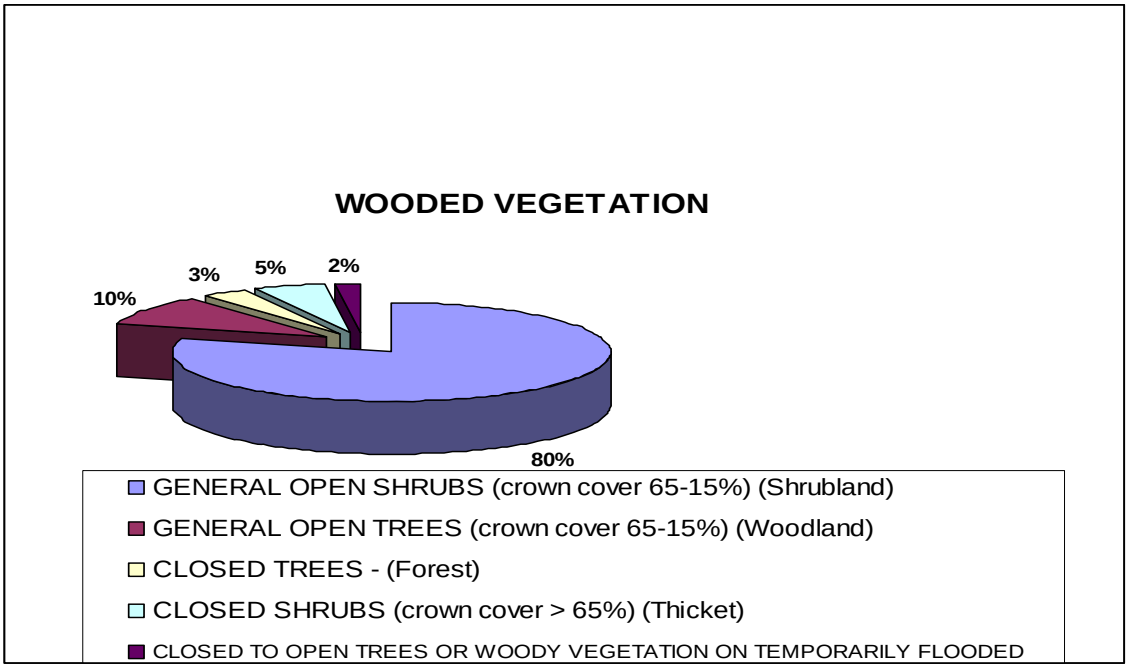


Chart 6: Wooded vegetation types distribution

The dominant layer consists of shrubs or woody vegetation (an intricate mixture of trees and shrubs), with crown coverage ranging from 15-65%, in some cases associated with a second layer of herbaceous vegetation. This type of vegetation is also present on formerly irrigated schemes areas abandoned during the civil war period.

Woodland represents 10% of the natural vegetation of the AOI. Both vegetation forms, trees and shrubs, are present with crown cover from very open to open, but in this case trees are the dominant layer.

Very open trees with shrubs, characterised by a fragmented macropattern (tiger bush) are also included in this group. The total surface covered by woodland was equal to **999 544** ha as indicated in Table 7.

Only 8% of the AOI is covered by dense vegetation: around **323 274** ha are occupied by forests, while closed shrubs vegetation amount to less than **497 657** ha.

In the southern AOI there are transitional areas between pure terrestrial and aquatic systems (Lower Juba and Lower Shabelle regions), consisting of areas that are regularly flooded but where water cover does not remain for a substantial period of time. The vegetation of these temporary flooded areas consists of closed to open trees or woody, and occupies a total surface of about **195257** ha.

Table 7: Areas of Wooded vegetation

WOODED VEGETATION 7 060 016	**GENERAL OPEN SHRUBS (crown cover 65-15%) (Shrubland)**	**7731282**
	General Open Shrubs (15-65%)	253288
	General Open Shrubs (15-65%) with Open Herbaceous	4700582
	General Open Shrubs (15-65%) with Sparse Trees	2729906
	General Open Shrubs (15-65%) with Herbaceous from Closed to Open (on ex-irrigated schemes)	7136
	Open Woody (40-65%)	40370
	GENERAL OPEN TREES (crown cover 65-15%) (Woodland)	**999 544**
	General Open Trees (15-65%) with Close to Open Shrubs	873 867
	CELLULAR Very Open Trees (40-65%) with General Open Shrubs and Herbaceous (Tiger Bush)	11 326
	STRIPED Very Open Trees (40-65%) with General Open Shrubs and Herbaceous (Tiger Bush)	114 351
	CLOSED TREES - (Forest)	**323 274**
	Closed Trees (> 65%) with Shrubs from Closed to Open	323 274
	CLOSED SHRUBS (crown cover > 65%) (Thicket)	**497 657**
	Closed Shrubs (>65%)	497 657
	CLOSED TO OPEN TREES OR WOODY VEGETATION ON TEMPORARILY FLOODED AREAS (cover > 40% - < 4 months)	**195257**
	Closed Trees (> 65%) on Temporarily Flooded Area	149 964
	Open Trees (40-65%) on Temporarily Flooded Area	25 385
	General Open Woody vegetation (15-65%) on Temporarily Flooded Area	19 908

RANGELAND

Rangelands of the AOI consist of 63% Savanna and 37% grassland on terrestrial or flooded areas (Chart 7).

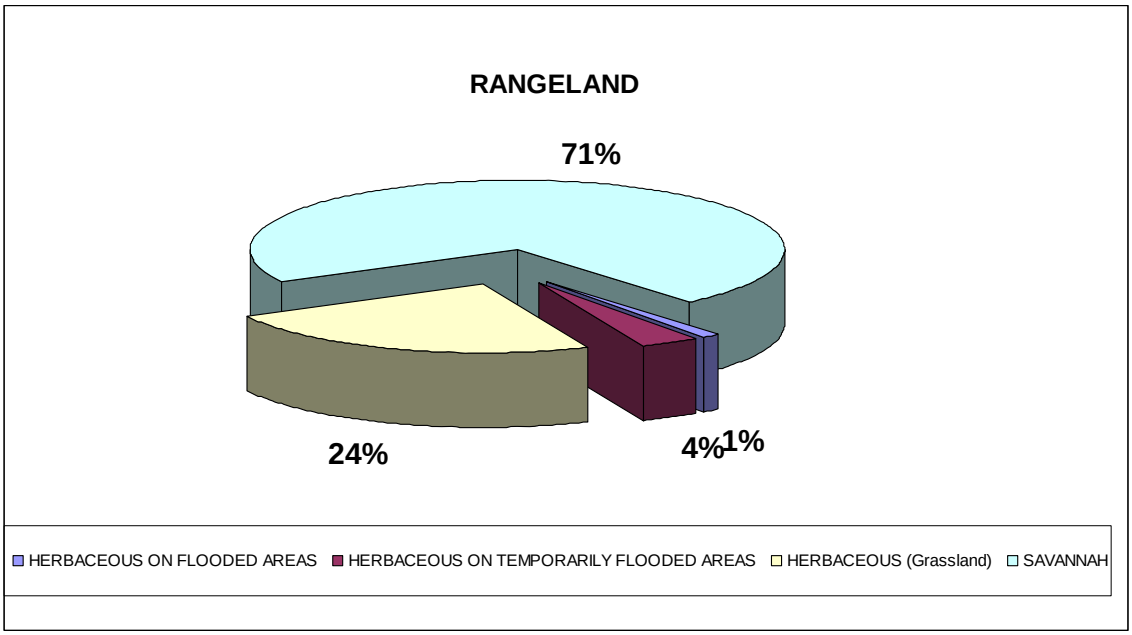


Chart 7: Rangelands distribution

Savannas are characterised by sparse shrubs and/or sparse trees with a dominant herbaceous layer. The total area of this Land Cover type is about 905203 ha (Table 8). Formations of herbaceous vegetation only cover **255462** ha, of which 86% is terrestrial and 14% (90 825 35 ha) is represented by grasslands on flooded areas.

Table 8: Rangeland areas

RANGELAND 1 757 873	**SAVANNA**	**649741**
	Herbaceous (15-100%) with Sparse Trees and Shrubs	190840
	Herbaceous (1-100%) with Sparse Shrubs	353135
	Sparse Shrubs (1-15%)	105766
	HERBACEOUS (Grassland)	**213683**
	Herbaceous (15-100%)	195806
	General Open Herbaceous (15-65%) (on ex-irrigated schemes)	17876
	HERBACEOUS ON FLOODED AREAS (Grassland)	**9161**
	Closed Herbaceous (> 65%) on Perennial Flooded Area	9161
	HERBACEOUS ON TEMPORARILY FLOODED AREAS	**32618**
	Closed Herbaceous (> 65%) on Temporarily Flooded Area	23844
	General Open Herbaceous on Temporarily Flooded Area	8774

AGRICULTURE

Cultivated areas represent 13% of the total AOI mapped in southern Somalia, with a total surface area of about 1 315 032 ha. Similarly to the northern AOI, the most widespread practice is rainfed agriculture, occupying 84% of the total agricultural areas (Chart 8). The remaining surface is cultivated using different water supply systems. Around 6% is represented by irrigated crops and 4% by post-flooding cultivation.

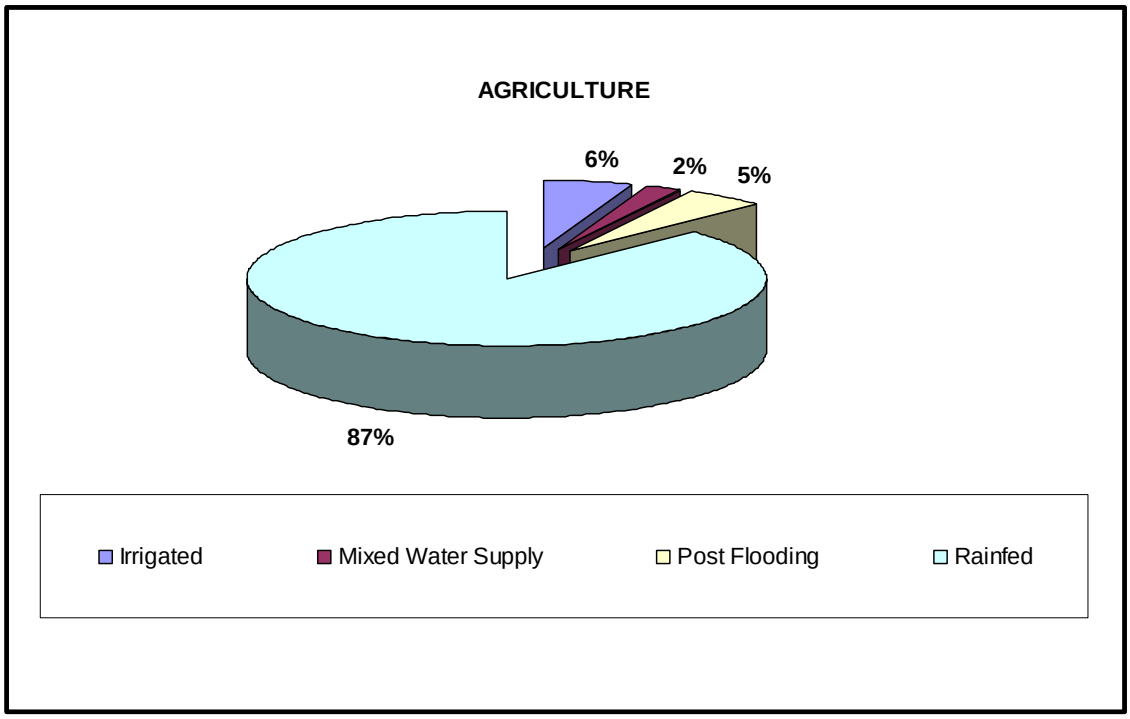


Chart 8: Agriculture distribution

The total area occupied by rainfed agriculture amounts to about 2570484 ha (Table 9). It is mainly represented by fields of small to medium dimensions (up to 5 ha) cultivated with cereals and sesame. Maize and sorghum are the most important crops and are cultivated either as single crops or in combination. This type of agriculture is completely determined by rainfall.

Irrigated systems are characterised by an artificial, regular supply of water to crops, in addition to rain. The total area of irrigated crops is 129 754 ha, mainly distributed along the Juba and Shabelle rivers. Crops are rice and other cereals, bananas, vegetables and trees such as mango and papaya, cultivated as single or multiple crops. Field dimensions are almost equally distributed between small and medium-sized fields. Large fields (>5ha) represent only 5% of total irrigated cultivation and belong mainly to big farms developed before the civil war.

Table 9: Agriculture areas

AGRICULTURE 1 315 032	**RAINFED**	**2241999**
	Medium fields (2-5ha) of herbaceous crops	602 726
	Small fields (< 2ha) of herbaceous crops	510 300
	IRRIGATED	**144078**
	Large fields (> 5ha) of herbaceous crops	6 451
	Medium fields (2-5ha) of herbaceous crops	51 433
	Small fields (< 2ha) of herbaceous or tree crops	71 870
	POST FLOODING	**127212**
	Medium fields (2-5ha) of herbaceous crops	2 082
	Small fields (< 2ha) of herbaceous crops	45 035
	MIXED WATER SUPPLY	**57195**
	Rainfed OR Postflooding Small fields (< 2ha) of herbaceous crops	25 136

Post-flooding cultivation systems are also present in the AOI, with a total area of about 47 000 ha. Inundated areas are cultivated when water recedes, and water infiltrated into the soil is used intentionally as a water reserve for crops. The dimensions of the herbaceous fields cultivated with this system are usually small (less than 2ha).

For several areas of the AOI, satellite images were not available for different seasons, making it difficult in some cases to distinguish between rainfed and post-flood cultivation. This required the creation of a special class described in the legend as “Rainfed Continuous Small Fields of Multiple Herbaceous crops (Cereals) OR Post Flooding Continuous Small Fields of Multiple Herbaceous crops”. During the thematic grouping for surface estimation it was felt to be appropriate to aggregate the areas classified with this code under the vocation Mixed Water Supply.

5 5. CONCLUSIONS AND RECOMMENDATIONS

The northern AOI, Dur-Dur and Gebiley AOI (Somaliland), has a total area of 1 293 899 ha, comprising 83% Natural Vegetation and 10% Agriculture. The remaining 7% includes Non Vegetated Areas. The most common natural vegetation type is Rangeland (49% of natural vegetation surfaces), represented almost totally (92%) by Savanna with a small area covered by pure Grassland (8%).

Wooded vegetation occupies 34% of the natural vegetated areas and consists almost equally of general open formations of Shrubland and Woodland

The majority of agricultural areas are characterised by rainfed cultivation. Less than 10% of the area is cultivated with irrigated crops.

The southern, riverine AOI has a total area of 10 397 600 ha, of which 84% is covered by Natural Vegetation and only 3% by Agriculture. The remaining 13% includes Non Vegetated Areas. The most common natural vegetation type is Wooded Vegetation (67% of natural vegetation surfaces), dominated by open formations of Shrubland (67%) and Woodland (24%).

Rangelands occupy 17% of the natural vegetated areas, and are mostly covered by Savanna (63%). The remaining surfaces are covered by Grasslands.

The majority of agricultural areas are characterised by rainfed cultivation. Only 10% of the area is irrigated.

The land cover geo-dataset presented in this report is an important output containing information about cover types of the mapped areas and their distribution. It is not just a static set of thematic maps, printable in different map scales, but a geo-referenced dataset (in vector format) serving several purposes and with various possible uses.

All attributes are stored following LCCS structure that enhances the performance of the database in facilitating and improving its spatial modelling and statistical analysis capabilities. An example of this has been presented in Chapter 5.

In particular, the classifiers and syntax adopted by LCCS allows handling of the codes according to various environmental features that can match with “characteristics” and “qualities” adopted in FAO’s framework for land evaluation (FAO, 1976). The study and understanding of these classifiers by users is highly recommended in order to maximise LCCS potential.

Spatial modelling and aggregations provide further improved results. The Land Cover can also be used as a base map. Additional information, particularly from field surveys, can be combined through a process of synthesis and linkage, promoting the land cover to new thematic layers involving different disciplines such as geo-botany (vegetation communities and formations), planning (land use) and other environmental studies.

By producing the new thematic layers in this way it is possible to obtain a more stable and consistent model, as:

- topological errors can be controlled more efficiently.
- conceptual consistency can be easily maintained, avoiding incompatibility between layers.
- simplifying the geometry of the various feature classes dataset can facilitate and optimise geo-processing activities like intersection and update, where different

layers are combined, and polygons are increased using the original boundaries of all entered layers.

Further possible uses of the Land Cover might include interventions in sub-catchment and river basin catchment areas (FAO, 1993)..

Both map scales adopted (1:50 000 for agricultural areas of the northern AOI and 1:100 000 for the whole extent of the two AOI) are suitable for inventory use and for performing supporting interventions such as:

- district-level multipurpose land use planning for (re)settlement schemes (Subcatchment areas - scales of inventory and evaluation: 1:50 000 to 1:100 000);
- catchment-level assessment of water resources and their potential use, especially downstream (conservation or reforestation projects in upstream parts, irrigation and drainage projects in lower parts; fishery development); identification and protection of high biodiversity values; national parks and indigenous delineation of reserves (river basin catchments areas - scale of inventory and evaluation: 1:100 000 to 1:250 000).

This geo-dataset constitutes one of the baseline thematic layers for assessment of land suitability, soil erosion and land degradation, through generation of Land Mapping Units. This kind of spatial analysis requires combination of the Land Cover with other thematic layers, in particular landform, climate classifications and soil datasets.

In order to maximise quality and accuracy of the results, the following activities were incorporated in the study:

- field data collection in both the northern and southern AOI for validation of the unverified results;
- the use of IKONOS (or Spot) images in addition to or as a partial substitution of the survey (in the event that security issues disallow it);
- take advantage of IKONOS and extend coverage - some IKONOS frames were acquired during SWALIM Phase I and used to improve interpretation as explained in Chapter 3.2.2. Continuing this activity in the southern AOI and extending it to the northern AOI could be very useful for further validation of the map;
- perform meaningful aggregations, starting from the ones presented in the results, for developing the land use dataset;
- use the Land Cover geo-dataset extensively, exploring its potential for forming the “facets” constituting the administrative units of the landscape in the Land Mapping Units. New and better-fitting aggregations should be developed in a gradual, interactive way, checking the results at each step, leading to more complex aggregations. Particularly, a the more reliable way of linking LCCS codes to well-defined vegetation and land use types, should be explored with the support of survey results. In a second phase, the facets aggregation should be combined with optimized landform aggregations through an intersection operation.

6 THE VEGETATION MAP OF THE NAOI

6.1 Introduction

The vegetation map of the Dur-Dur and Gebiley Area of Interest (AOI) was derived from the Land Cover map and from quadrat sampling during the land cover field surveys. The detailed land cover map was a generalised one, providing broad land cover classes of the AOI. The vegetation in each land cover class was described using results of the field vegetation sampling, due to the limited number of samples available for producing a more detailed vegetation map of the AOI. This may be attributed to the fact that the vegetation assessment was not very detailed, focusing only on the composition of dominant species. The main foci were vegetation cover and frequency. Vegetation was assessed at the same time as the land cover and other thematic surveys. However, the results presented here give a realistic picture of the vegetation of the AOI.

Floristic composition is an important attribute of vegetation studies as it aids in facilitating comprehensive classification of vegetation. Knowledge of vegetation allows an understanding of environmental conditions affecting intensity of degradation and grazing.

Data collection for this study was undertaken between May and June, 2006. The main objective was to produce a generalised vegetation map of the Northern AOI, to provide a plant species inventory and to determine the main vegetation types.

6.2 Materials and Methods

The adopted methodology provided a rapid assessment of the **abundance** and **frequency** of all species sampled. Trees and shrubs were assessed separately from herbaceous vegetation, using different methodologies.

6.2.1 Trees and shrubs

Trees and shrubs were assessed using a tape measure along line transects of 100 m. In this method, each whole number (1 m, 2 m, 3 m and so on up to 100 m) was considered as a node. For each of the 100 nodes, woody crown interceptions with the line transect were noted. At each interception, the plant was identified and the corresponding node noted. The approach involved assigning the closest node to the trunk.

For each species thus selected, the following were required:

1. an identifier in the **species list form**.
2. the species name in the **species list form**.
3. to note an identifier in the box of the corresponding node in the **floristic relieve form**.
4. to measure the length of tape intersecting the crown (under its shadow) and to write the measurement (in cm) in the box of the corresponding node in the **floristic relieve form**.

6.2.2 Herbaceous Vegetation

Every 20 m along the line transect, a 50x50 cm box, or quadrat was used to assess the herbaceous vegetation. The tape unrolled several times to reach 100 meters, allowing the definition of 5 segments of 0.5 m each. A 25 cm ground radius was examined on either side of the tape (i.e. a diameter of 50 cm). The details of this procedure are as follows:

1. Starting from the first quadrat (a box of 50x50 cm, from 0 to 0.5 m) identify all species inside it and list them on the floristic list form. Take care to write the correct segment number on the floristic form corresponding to the line transect segment.

2. For each species, assess the coverage rate expressed in percentage or using the Braun-Blanquet scale, refer to the segment area.
3. For each species measure the height in cm.
4. Pass to the next segment, from 0.5 up to 1 m. Repeat the operation. All the species already found in previous segments are included in the new floristic list form with the same identifier.
5. Go through all the segments until the last (the tenth), repeating the same operations.

All unidentified species were collected and labelled with a piece of masking tape, writing numbers of the **Site ID** and **Species ID** on it. For herbaceous plants it is important to collect sufficient parts of the plant to assist in identification; in the case of woody plants, a small branch was collected. Care was taken to keep leaves and/or buds and/or flowers and/or fruits to aid identification. Collected material was preserved in a plant press.

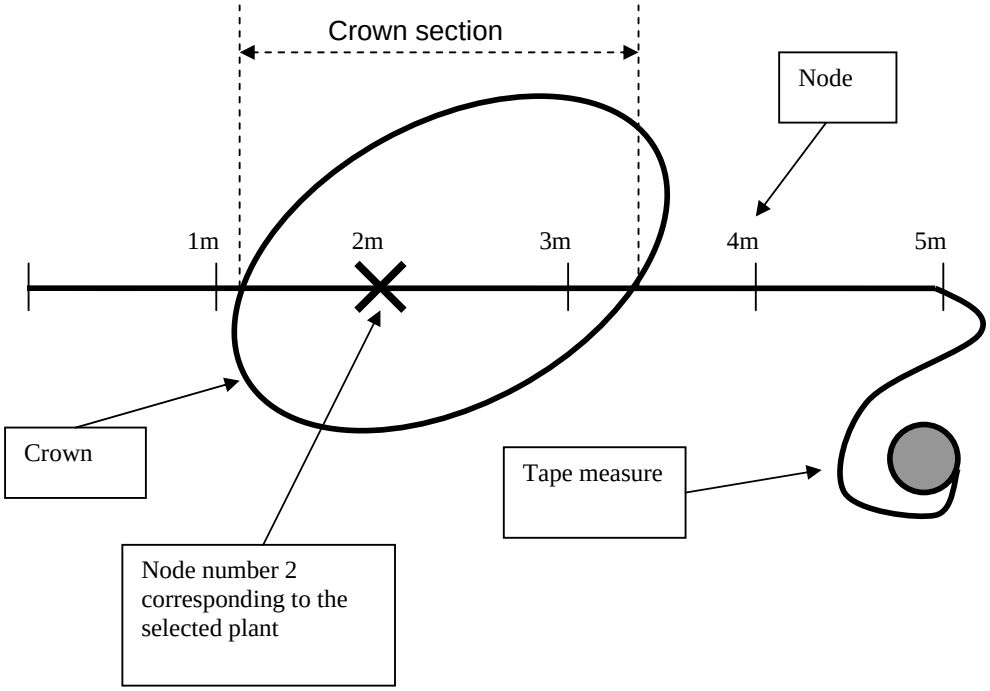


Figure 6. Showing how to use the ruler, select plants and take measurements.

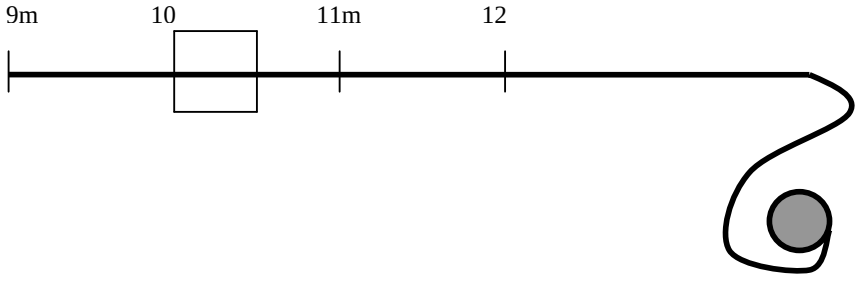


Figure 7. Showing the second 0.5x0.5 m segment, located at 10 m.

Figure 8. The Floristic Relieve Form

FLORISTIC RELIEVE

Node Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Species Identifier	ID	ID 1	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Section Cm	cm	cm 220	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm

FLORISTIC LIST FORM

Species Identifier	**Species Name**	**Tot Crown Section Cm**
1	**Acacia bussei**	

Here is an example of how to fill the floristic relieve and the floristic list form.

Herbaceous FLORISTIC RELIEVE BOX N._____
FLORISTIC LIST FORM SITE N.:_____

Segment N. (from1 to5):_____				
Species Identifier	species Name		Height	Cover

The Braun-Blanquet scale:

R = rare
+ = coverage not measurable
1 = coverage < 5%
2 = coverage 5% – 25%
3 = coverage 25% - 50%
4 = coverage 50% - 75%
5 = coverage > 75%

In the data analysis, the cover and frequency of occurrence for the different species present in each sample were established. The samples were grouped according to the various cover classes and used to characterize and eventually map the vegetation in the AOI. In this classification, the species composition, in order of dominance was established.

6.3 Results

The results of the vegetation assessment included a vegetation map with 25 classes as shown in Figure 70 below. A summary of results are:

1. Closed Shrub – this class covered about **5,525 ha** and included the following:
Woody Species:
Acacia etbaica, A. nilotica, A. senegal, A. bussei, Cassia obovata, Grewia tenax, Hypoestes hildebrandtii, Aloe spp., *Solanum carense.*
Herbaceous Species:
Chrysopogon auchieri, Sporobolus marginatus, Cenchrus ciliaris

2. Closed Shrubs/Isolated Rainfed Crops (267 ha)
Woody Species:
Acacia etbaica, A. nilotica, A. senegal, A. bussei, Cassia obovata, Grewia tenax, Hypoestes hildebrandtii, Aloe spp., *Solanum carense*
Herbaceous Species:
Chrysopogon auchieri, Sporobolus marginatus, Cenchrus ciliaris
Crops:
Sorghum, Maize, Cowpeas, Simsim, Millet

3. Closed Trees (2 198 ha)
Woody Species:
Acacia tortilis, A. nilotica, A. bussei, Prosopsis juliflora, Sueda fruticosa

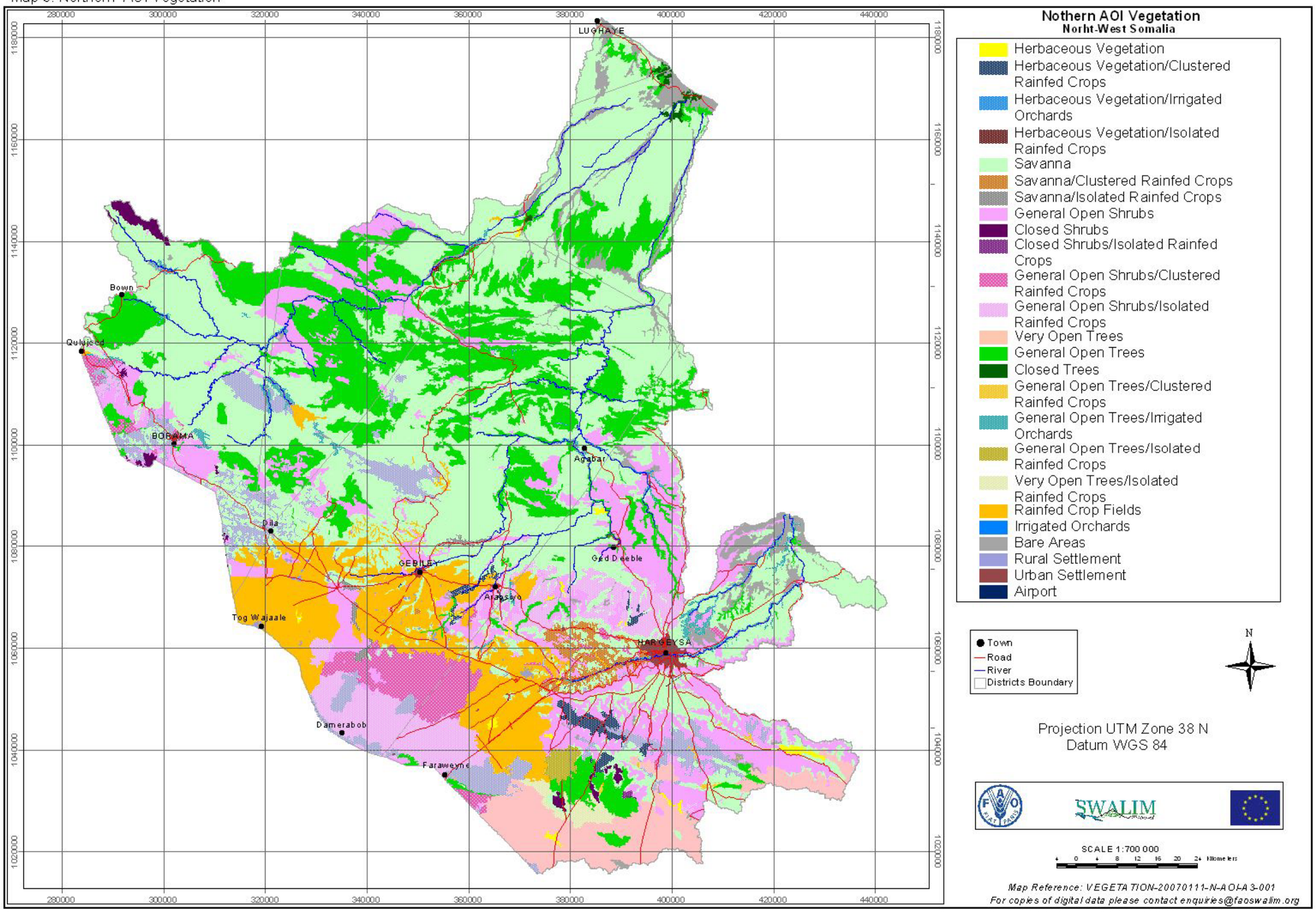
4. General Open Shrubs (157 211 ha)
Woody Species:
Acacia etbaica, A. nilotica, A. senegal, A. bussei, Cassia obovata, Grewia tenax, Hypoestes hildebrandtii, Aloe spp., *Solanum carense*
Herbaceous Species:
Chrysopogon auchieri, Sporobolus marginatus, Cenchrus ciliaris

5. General Open Shrubs/Clustered Rainfed Crops (31 707 ha)
Woody Species:
Acacia etbaica, A. nilotica, A. senegal, A. bussei, Cassia obovata, Grewia tenax, Hypoestes hildebrandtii, Aloe spp., *Solanum carense*
Herbaceous Species:
Chrysopogon auchieri, Sporobolus marginatus, Cenchrus ciliaris
Crops:
Sorghum, Maize, Cowpea, Simsim, Quat

6. General Open Shrubs/Isolated Rainfed Crops (59 577 ha)
Woody Species:
Acacia etbaica, A. nilotica, A. senegal, A. bussei, Cassia obovata, Grewia tenax, Hypoestes hildebrandtii, Aloe spp., *Solanum carense*
Herbaceous Species:
Chrysopogon auchieri, Sporobolus marginatus, Cenchrus ciliaris
Crops:
Sorghum, Maize, Cowpea, Simsim, Quat

7. General Open Trees (211 638 ha)
Woody Species:
Acacia etbaica, A.nilotica, A. mellifera, A. bussei, Balanites glabra, Solanum incanum
Herbaceous Species:
Aloe somaliensis, Chrysopogon auchieri, Dactyloctenium aegyptium, Cynodon dactylon, Sporobolus marginatus

Map 3: Northern AOI Vegetation



8. General Open Trees / Clustered Rainfed Crops (777 ha)
Woody Species:
Acacia etbaica, A.nilotica, A. mellifera, A. bussei, Balanites glabra, Solanum incanum
Herbaceous Species:
Aloe somaliensis, Chrysopogon auchieri, Dactyloctenium aegyptium, Cynodon dactylon, Sporobolus marginatus
Crops:
Sorghum, Maize, Cowpea, Simsim, Millet

9. General Open Trees / Irrigated Orchards (13 345 ha)
Woody Species:
Acacia tortilis, Dobera glabra, Acacia bussei, Grewia tenax
Crops:
Papaya, Citrus, Guava, Watermelon, Tomato, Banana

10.General Open Trees / Isolated Rainfed Crops (3 568 ha)
Woody Species:
Acacia etbaica, A.nilotica, A. mellifera, A. bussei, Balanites glabra, Solanum incanum
Herbaceous Species:
Aloe somaliensis, Chrysopogon auchieri, Dactyloctenium aegyptium, Cynodon dactylon, Sporobolus marginatus
Crops:
Sorghum, Maize, Cowpea, Simsim, Millet

11.Herbaceous Vegetation (3 541 ha)
Dactyloctenium aegyptium, Panicum turgidum, Cleome brachycarpa, Aristida adscensionis

12.Herbaceous Vegetation / Clustered Rainfed Crops (7 338 ha)
Herbaceous Species:
Dactyloctenium aegyptium, Panicum turgidum, Cleome brachycarpa, Heliotropium undilatifolia
Crops:
Sorghum, Maize, Millet, Simsim, Cowpea, Quat

13.Herbaceous Vegetation / Irrigated Orchards (136 ha)
Herbaceous Species:
Dactyloctenium aegyptium, Panicum turgidum, Cleome brachycarpa, Heliotropium undulatifolium
Crops:
Papaya, Citrus, Guava, Watermelon, Tomato, Banana

14.Herbaceous Vegetation / Isolated Rainfed Crops (49 618 ha)
Herbaceous Species:
Dactyloctenium aegyptium, Panicum turgidum, Cleome brachycarpa, Heliotropium undulatifolium
Crops:
Sorghum, Maize, Millet, Simsim, Cowpea, Quat

15.Irrigated Orchards (172 ha)
Crops:
Papaya, Citrus, Watermelon, Tomato, Guava, Cucumber, Mango, Banana

16.Rainfed Crop Fields
Crops:
Sorghum, Maize, Millet, Cowpea, Quat, Simsim

17.Savannah (519 476 ha)
Woody Species:
Acacia nubica, A. tortilis, A. senegal, A. bussei, Aloe spp., *Croton gillettii, Hypoestes hildebrandtii, Acalypha fruticosa, Grewia tenax, Balanites aegyptiaca,*
Herbaceous Species:
Cenchrus ciliaris, Cynodon dactylon, Sporobolus marginatus, Tragus racemosus, Aristida adscensionis.

18.Savannah / Clustered Rainfed Crops (10 915 ha)
Woody Species:
Acacia nubica, A. tortilis, A. senegal, A. bussei, Aloe spp., *Croton gillettii, Hypoestes hildebrandtii, Acalypha fruticosa, Grewia tenax, Balanites aegyptiaca,*
Herbaceous Species:
Cenchrus ciliaris, Cynodon dactylon, Sporobolus marginatus, Tragus racemosus, Aristida adscensionis.
Crops:
Sorghum, Maize, Millet, Cowpea, Quat, Simsim

19.Savannah / Isolated Rainfed Crops (2 500 ha)
Woody Species:
Acacia nubica, A. tortilis, A. senegal, A. bussei, Aloe spp., *Croton gillettii, Hypoestes hildebrandtii, Acalypha fruticosa, Grewia tenax, Balanites aegyptiaca*
Herbaceous Species:
Cenchrus ciliaris, Cynodon dactylon, Sporobolus marginatus, Tragus racemosus, Aristida adscensionis.
Crops:
Sorghum, Maize, Millet, Cowpea, Quat, Simsim

20.Very Open Trees (50 428 ha)
Woody Species:
Acacia etbaica, A. nilotica, A. mellifera, A. bussei, Balanites glabra, Solanum incanum
Herbaceous Species:
Aloe somaliensis, Chrysopogon auchieri, Dactyloctenium aegyptium, Cynodon dactylon, Sporobolus marginatus
Crops:
Sorghum, Maize, Cowpea, Simsim, Millet, Quat

21.Very Open Trees / Isolated Rainfed Crops (5 573 ha)
Woody Species:
Acacia etbaica, A. nilotica, A. mellifera, A. bussei, Balanites glabra, Solanum incanum
Herbaceous Species:
Aloe somaliensis, Chrysopogon auchieri, Dactyloctenium aegyptium, Cynodon dactylon, Sporobolus marginatus
Crops:
Sorghum, Maize, Millet, Cowpea, Simsim, Quat

22.Urban Settlement (4625 ha)

23.Rural Settlement (2 281 ha)

24.Airport (42 ha)

25.Bare Areas (44 259 ha)

6.4 Conclusions and Recommendations

Samples used to characterise vegetation in the AOI were few and limited, resulting in a vegetation map that is very general, and a more detailed assessment of vegetation is desired. Many vegetation attributes, such as biomass and density, were not considered in the assessment. Information on species composition was not exhaustively established, as most unidentified samples were not subjected to identification procedures and remain unknown.

Sampling was only conducted during the dry season. It is recommended that more intensive field work be performed in both dry and wet seasons to produce a more representative picture of the vegetation of the AOI.

Given that negative activities like charcoal burning are on the increase in the AOI and that charcoal burning is selective with regard to tree species, it is important to monitor trends in tree density over time. However, the results of this study form an important basis for further investigations on vegetation of the AOI.

The results indicate that the AOI is predominantly covered by natural vegetation. This explains why the economy of the AOI is basically pastoral, which in turn explains why vegetation studies should be given more attention as they form the basis of livestock management.

It is also desirable that a more comprehensive report on species composition is produced, showing which plant species are most threatened by human activities. This information would be an important input to pastoral land use policy formulation. *Acacia bussei* is the tree most exploited for charcoal for example, and therefore needs protection. Density trends of *A. bussei* are highly desirable and can only be achieved through exhaustive vegetation studies.

7 7. BIBLIOGRAPHY

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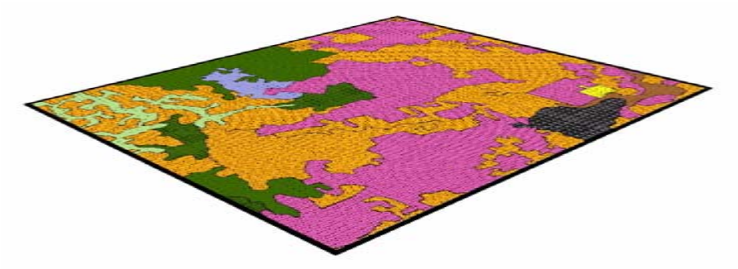
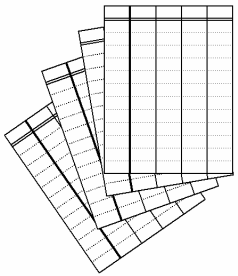
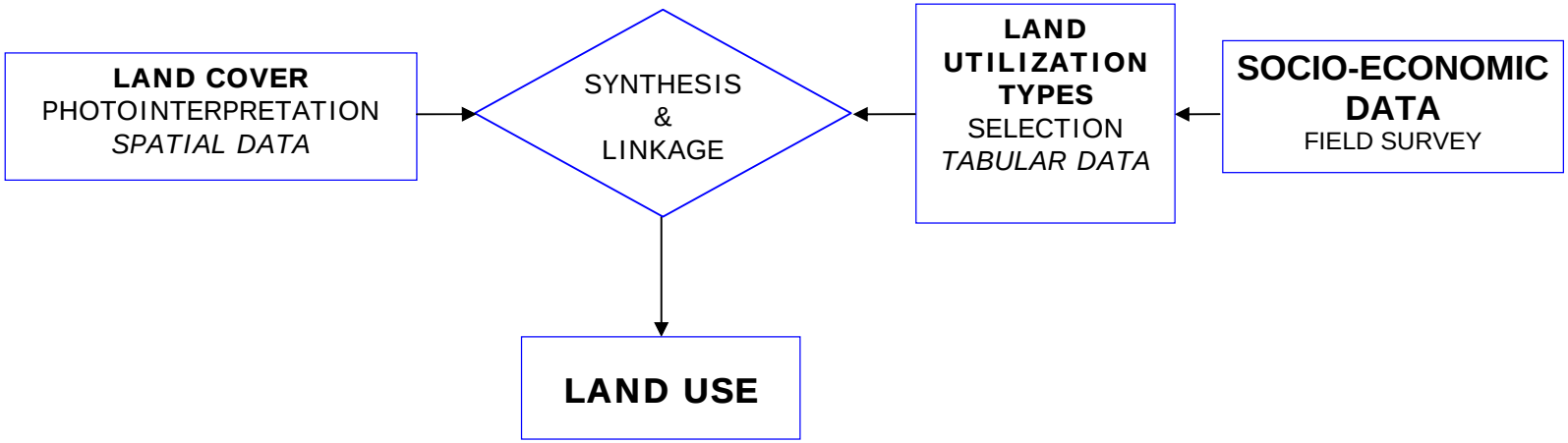
ANNEXES

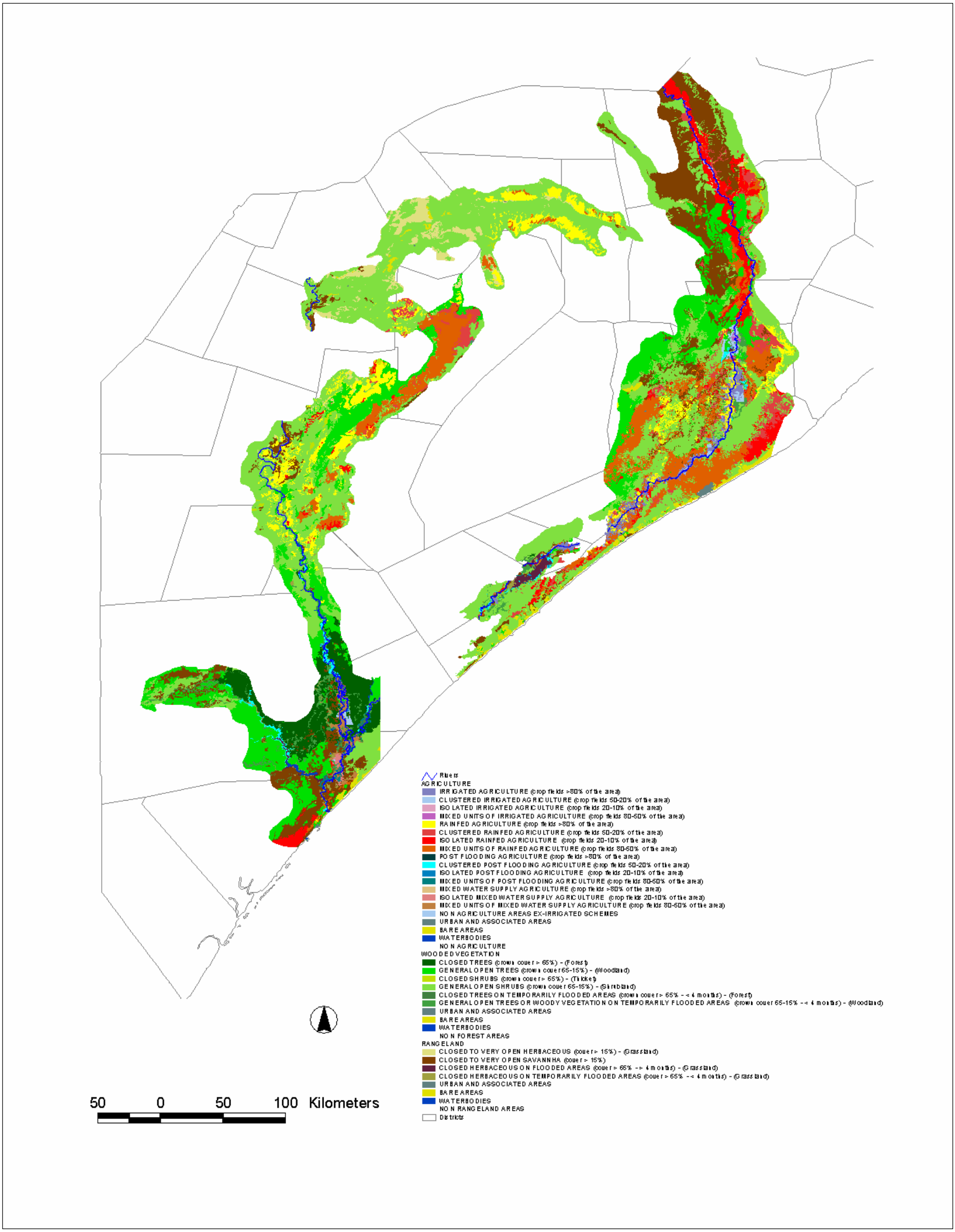
Annex 1 - From Land Cover to Land Use map



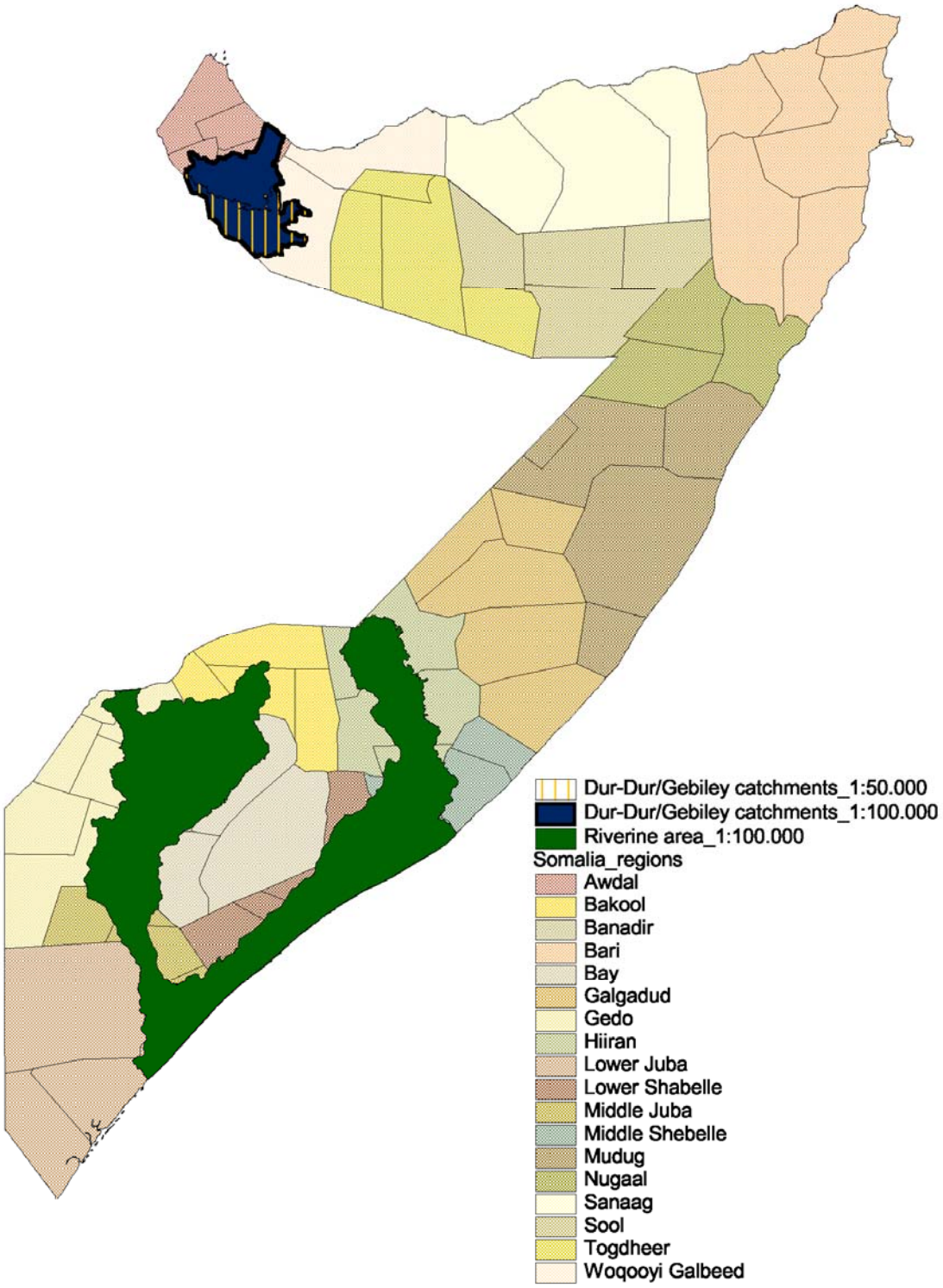




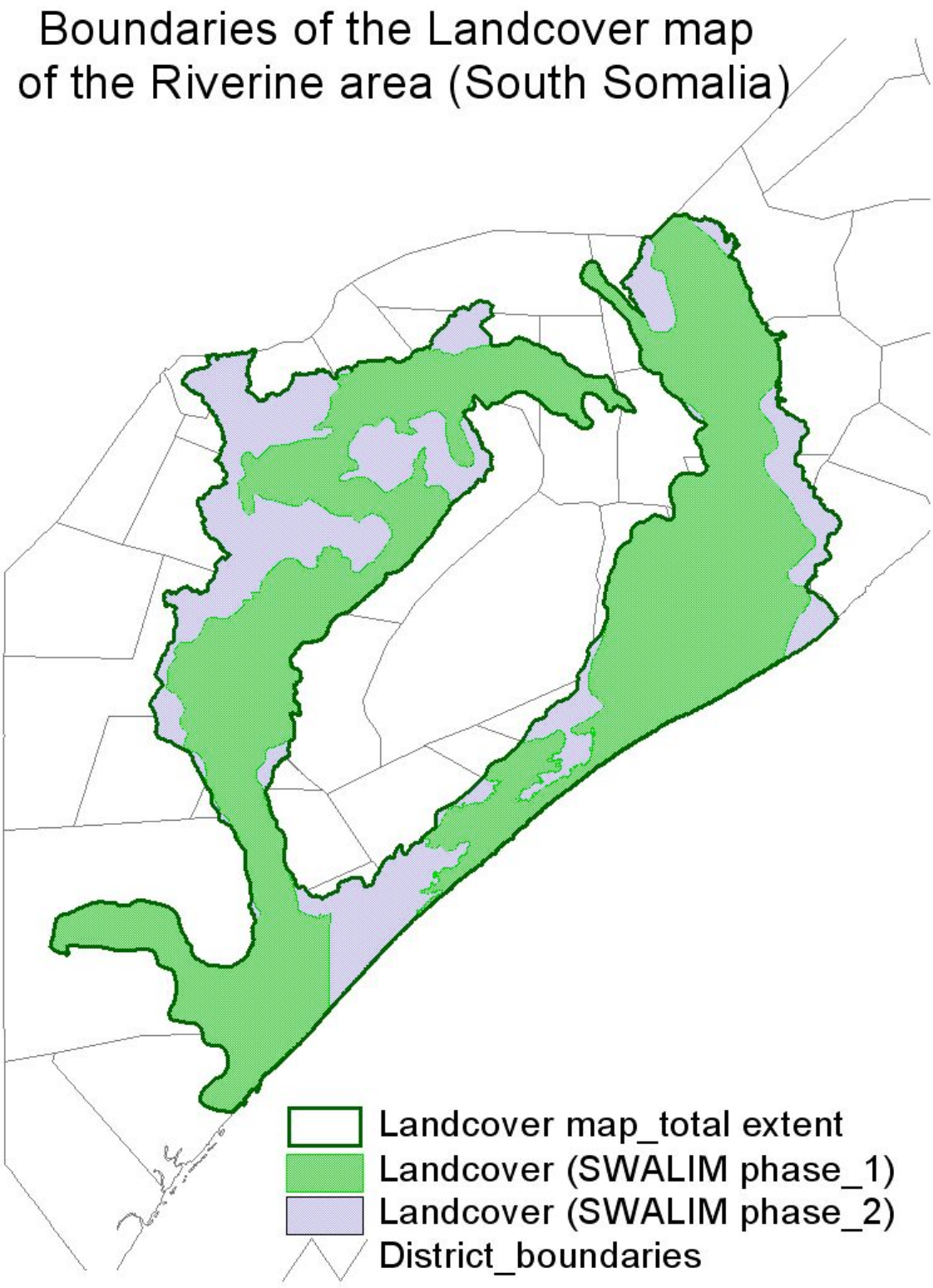
Annex 2 – Unverified Land Cover map of the Juba and Shabelle riverine area at 1:100 000 scale produced during SWALIM Phase I



Annex 3 – Boundaries and mapping scale of the two areas of interest

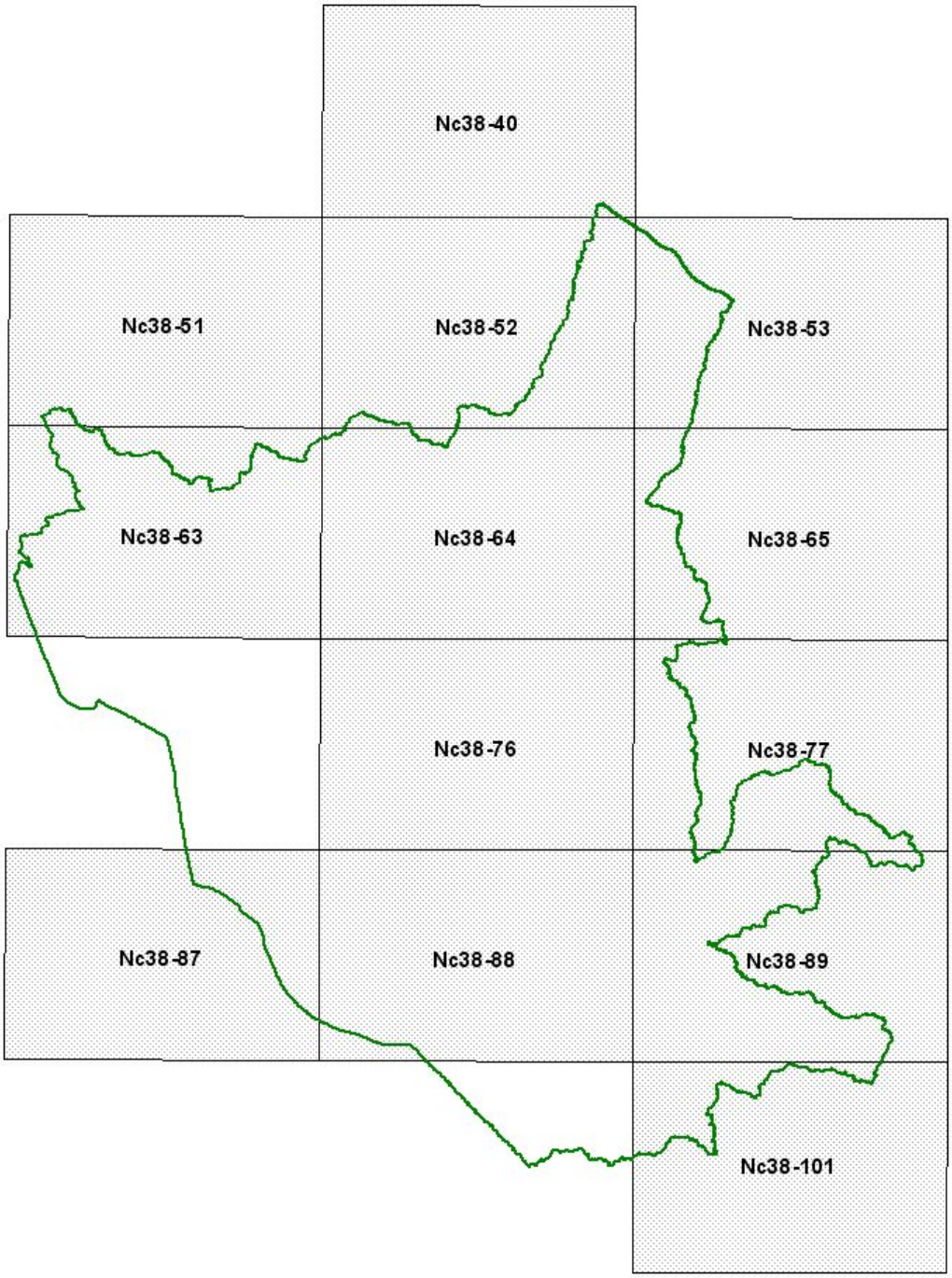


Annex 4 – Boundaries of the LC map of the riverine area



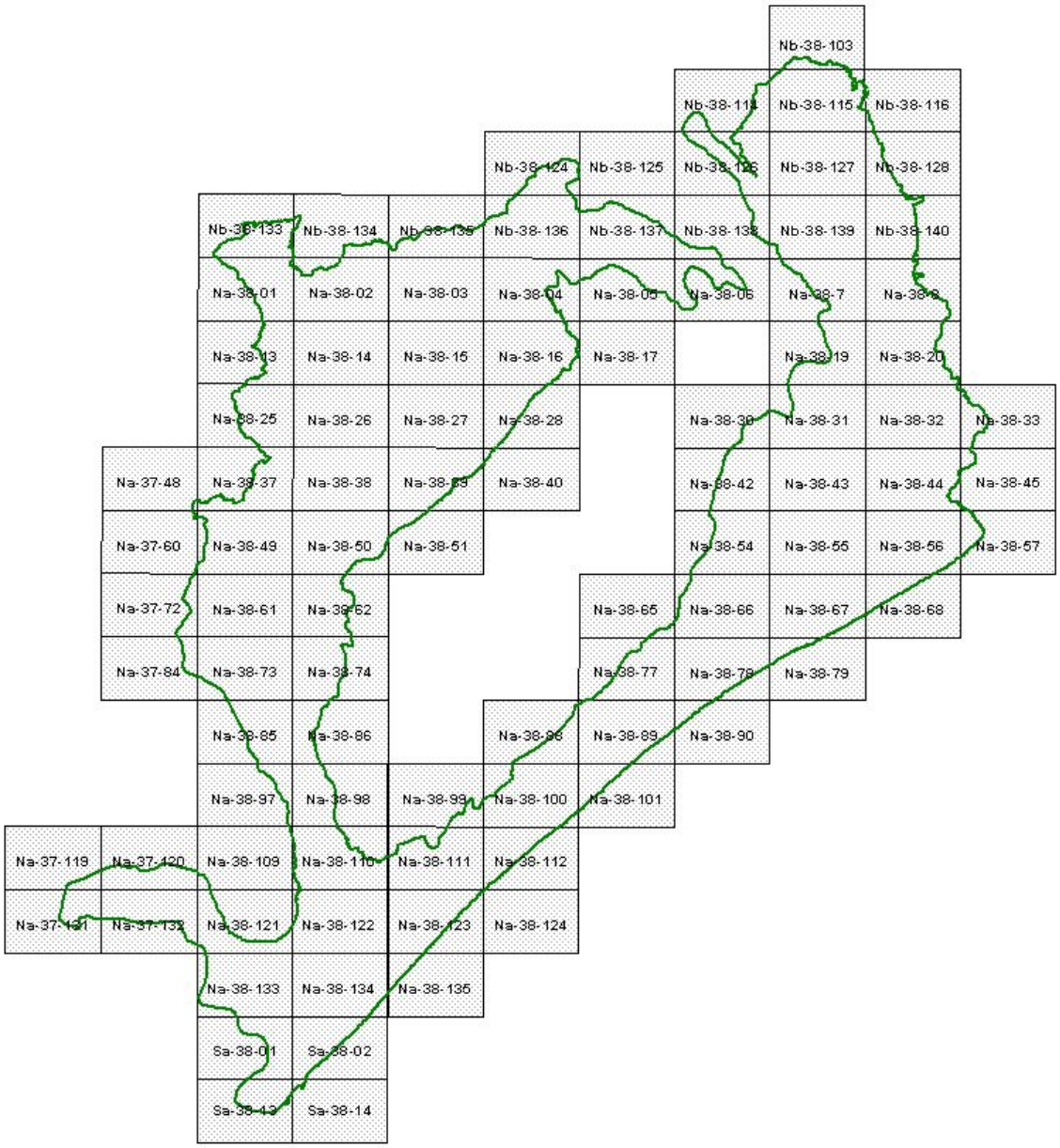
Annex 5

Northern AOI - Topographic map sheets used for the Landcover mapping



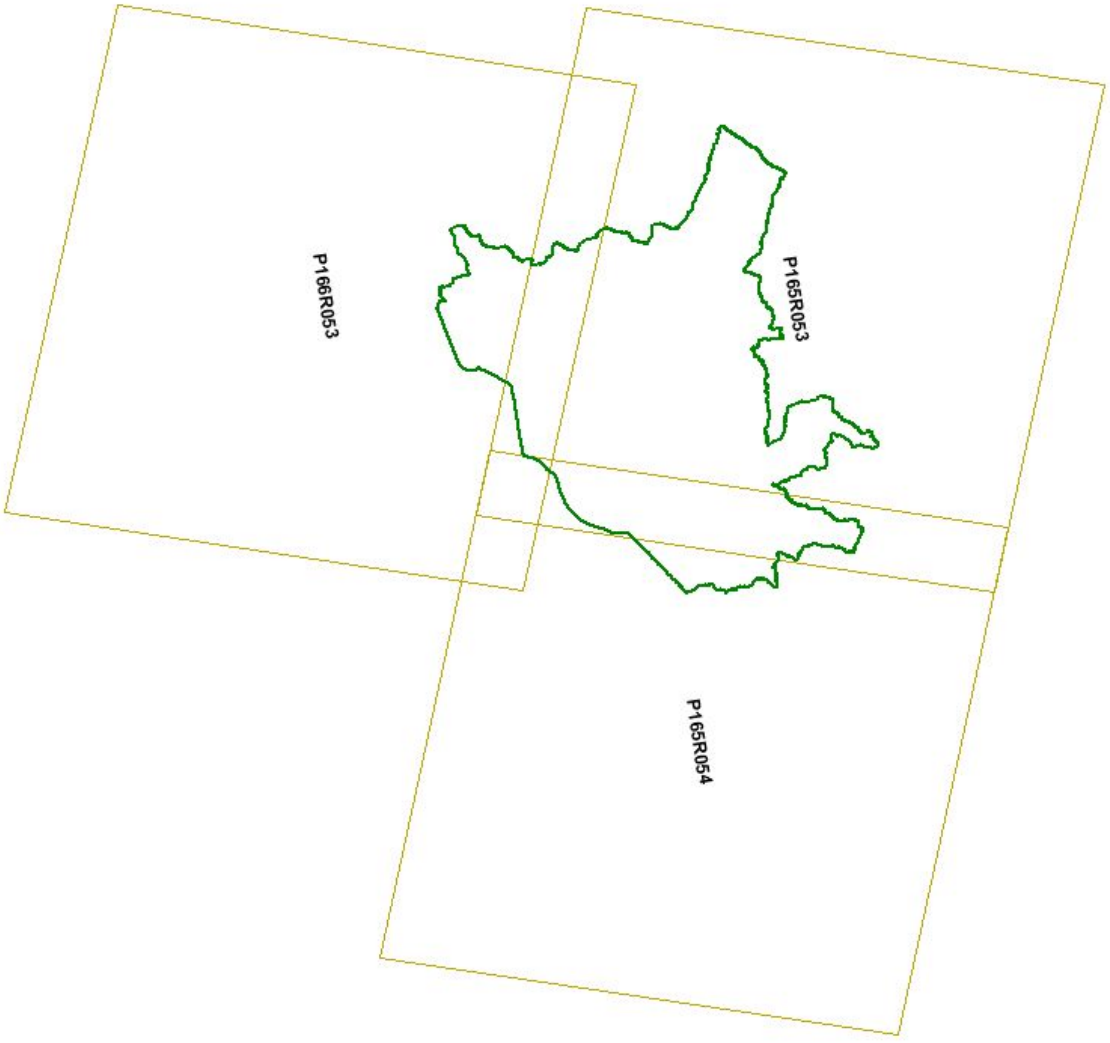
Annex 6

Southern AOI - Topographic map sheets used for the Landcover mapping



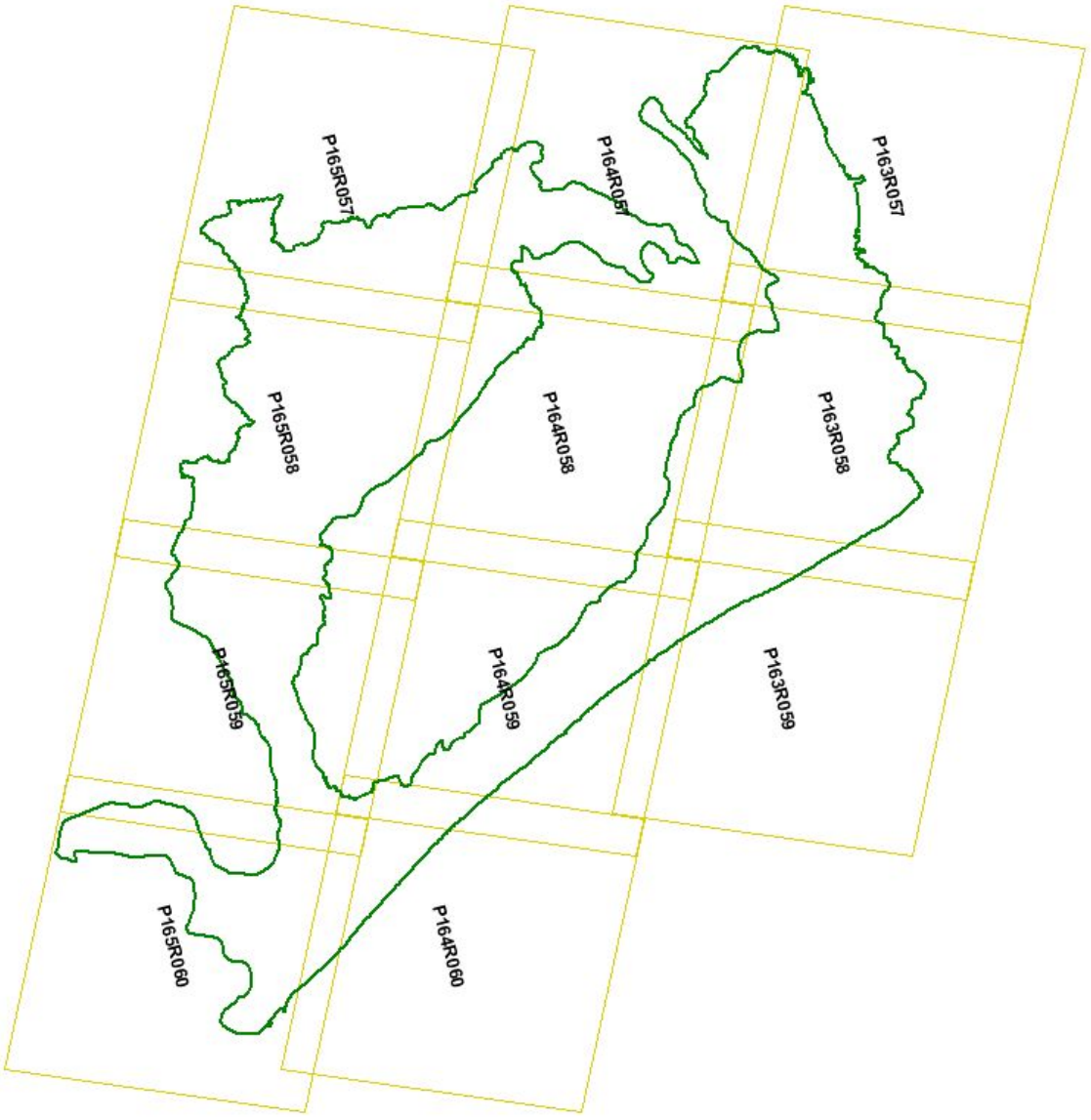
Annex 7

Northern AOI - Path and Row of Landsat 7 ETM interpreted for the Landcover mapping



Annex 8

Southern AOI - Path and Row of Landsat 7 ETM interpreted for the Landcover mapping



Annex 9 – Land Cover Pictures from the NAOI

Picture 1: Wide River Bed with water (Photo by M. Shaie)

Picture 2: Dry riverbed (Photo by M. Shaie)

Picture 3: Sparse Shrubs/Isolated Rainfed Crop Fields (Photo by M. Shaie)

Picture 4: Sparse Shrubs/Herbaceous Open/Clustered Rainfed Crop Fields (Photo by M. Shaie)

Picture 5: Closed Shrubs (Photo by M. Shaie)

Picture 6: Open Shrubs (Photo by M. Shaie)

Picture 7: Sparse Shrubs (Photo by M. Shaie)

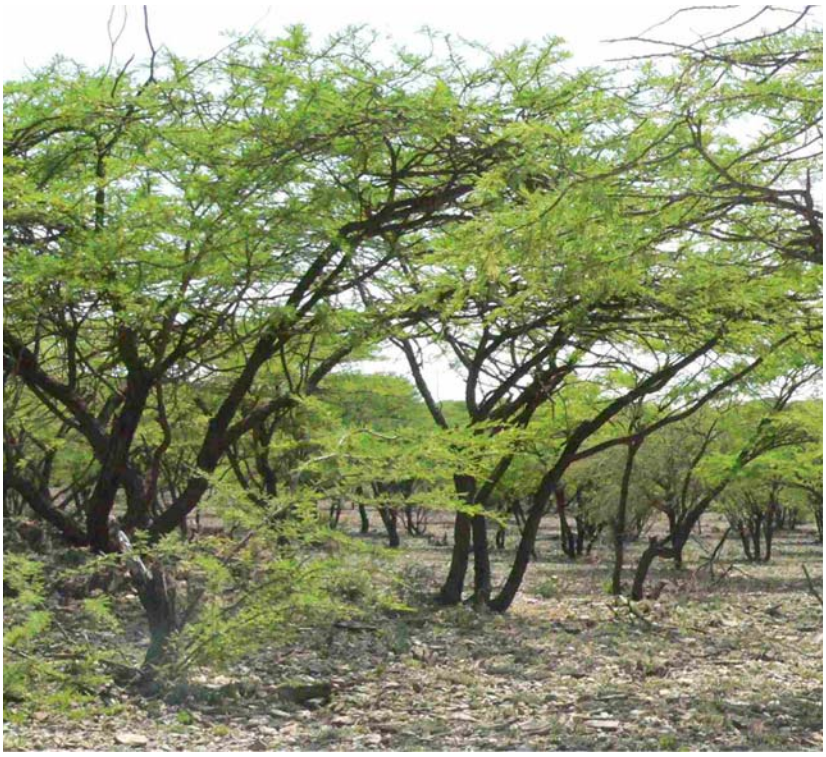
Picture 8: Sparse Shrubs/Open Shrubs/Isolated Rainfed Crops (Photo by M. Shaie)

Picture 9: Open Shrubs/Sparse Shrubs/Isolated Rainfed Crop Fields (Photo by M. Shaie)

Picture 10: Sparse Shrubs/Isolated Rainfed Crop Fields (Photo by M. Shaie)

Picture 11: Sparse Shrubs (Photo by M. Shaie)

Picture 12: Riparian Open or Fragmented Forest with Irrigated Crop Fields (Photo by M. Downie)



Picture 13: *Acacia etbaica* forest (photo by M. Downie)

Picture 14: *Acacia bussei* forest (photo by M. Downie)

Picture 15: Closed Herbaceous (Photo by M. Downie)

Picture 16: Open Herbaceous (coastal plain with the sea in the background) (Photo by M. Shaie)

Picture 17: Irrigated papaya fruit trees near Hargeisa (Photo by S. Oduori)

Picture 18: Urban area (Hargeisa) (Photo by R.Vargas)

Picture 19: Bare Areas (notice the village in the middle of the photograph) (Photo by S. Oduori)

Picture20: Bare area/stony surface (Photo by R.Vargas)

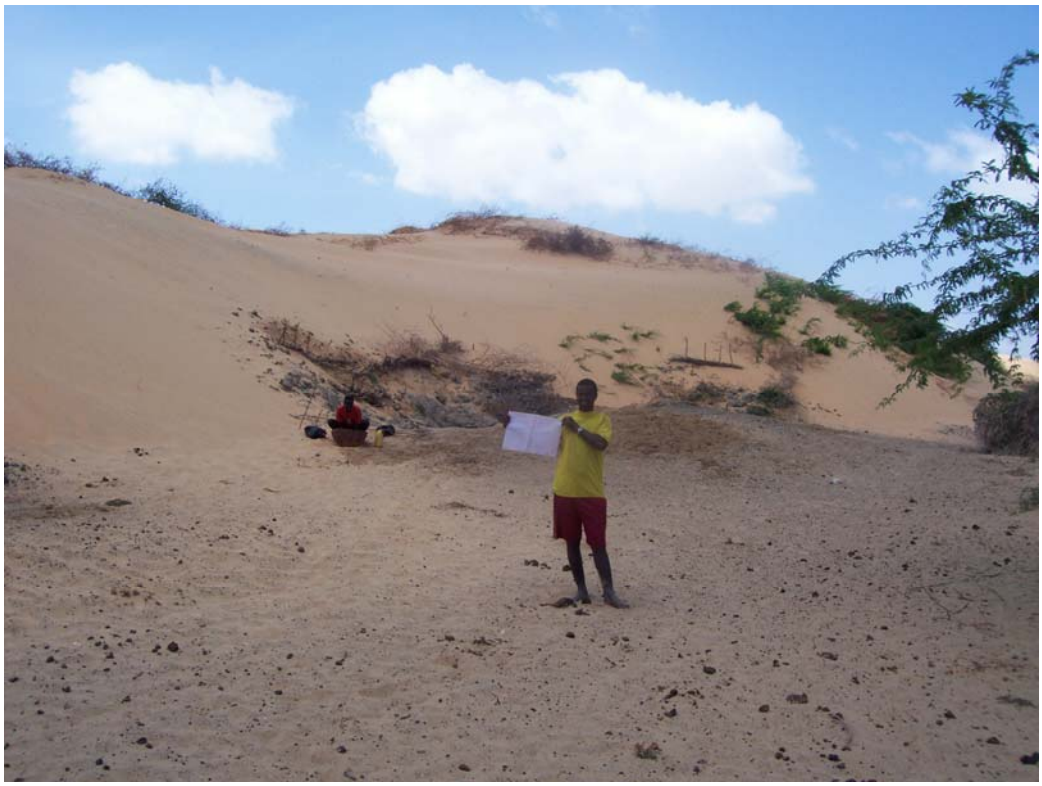
Annex 10 – Land Cover Pictures from the SAOI

Picture 21: Grazing of Standing Crop Residue. *Photo by Musse Shaie Alim – FAO SWALIM*

Plate Picture 22: Rainfed Agriculture. *Photo by Musse Shaie Alim – FAO SWALIM*

Picture 23: Irrigated Fields. Notice the fruit trees and the herbaceous crops. *Photo by Mohamed Farah – FAO SWALIM.*

Picture 24: Rainfed Agriculture Sorghum, Harvested Sesame and Maize Inmtercropped. *Photo by Musse Shaie Alim – FAO SWALIM.*



Picture 25: Sand Dune. *Photo by Mohamed Farah – FAO SWALIM.*

Picture 26: Water Body. *Photo by Mohamed Farah – FAO SWALIM.*

Picture 27: Rural Settlement with Pond for Water (human and Livestock). *Photo by Musse Shaiei – FAO SWALIM.*

Picture 29: Urban Area. *Photo by Ibrahim Dagane Ali – FAO SWALIM*

Picture 30: Open Shrubs. *Photo by Ibrahim Dagane Ali – FAO SWALIM*

Picture 31: Dry River Bed. Photo by Ibrahim Dagane Ali – FAO SWALIM

Picture 32: Closed Shrub. Photo by Ibrahim Dagane Ali – FAO SWALIM

Picture 33: Sparse Shrubs. Photo by Ibrahim Dagane Ali – FAO SWALIM

Annex 10 – Somalia Land Cover legend

SOMALIA - FINAL LEGEND

LCC Own Description	Map Code	LCC Level	LCC Label
A12-NATURAL AND SEMINATURAL TERRESTRIAL VEGETATION			
Herbaceous terrestrial			
Closed to Open Herbaceous (>15%)	**2HL**	A2 = Herbaceous	Continuous Closed to Open Herbaceous Vegetation
		A20 = Closed To Open 15% - 100%	
		B4 = 3 - 0.03 m	
		C1 = Continuous	
Herbaceous (>1%) with Sparse Shrubs (1-15%)	**2HL8**	A2 = Herbaceous	Closed to Open Herbaceous Vegetation with Shrubs
		A10 = Closed >65%	
		B4 = 3 - 0.03 m	
		C1 = Continuous	
		F2 = 2nd layer	
		F6 = Shrubs	
		Z1 = Sparse 15-1%	
		G3 = 5 - 0.3 m	
Closed to Open Herbaceous (>15%) with Sparse Trees and Shrubs	**2HL78**	A2 = Herbaceous	Closed to Open Herbaceous Vegetation with Trees and Shrubs
		A20 = Closed To Open 15% - 100%	
		B4 = 3 - 0.03 m	
		C1 = Continuous	
		F2 = 2nd layer	
		F5 = Trees	
		F10 = Sparse 15-5%	
		G2 = > 30 - 3 m	
		F2 = 3rd layer	
		F6 = Shrubs	
		F10 = Sparse 15-1%	
		G3 = 5 - 0.3 m	
General Open Herbaceous (on ex-irrigated schemes)	**2HP-x**	A2 = Herbaceous	Continuous Open Herbaceous Vegetation
		A11 = Open General 65-15%	
		B4 = 3 - 0.03 m	
		C1 = Continuous	
		Z6 = ex-irrigated schemes	
Sparse Herbaceous	**2HR**	A2 = Herbaceous	Sparse Herbaceous Vegetation
		A14 = Sparse General 15-1%	
		B4 = 3 - 0.03 m	
Shrubs terrestrial			
Closed Shrubs	**2SC**	A4 = Shrubs	Continuous Closed Shrubland (Thicket)
		A10 = Closed >65%	
		B3 = 5 - 0.3 m	
		C1 = Continuous	
General Open Shrubs	**2SP**	A4 = Shrubs	Open Shrubs (Shrubland)
		A11 = Open General 65-15%	
		B3 = 5 - 0.3 m	
General Open Shrubs with Open Herbaceous	**2SP6**	A4 = Shrubs	Shrubland with Open Herbaceous
		A11 = Open General 65-15%	
		B3 = 5 - 0.3 m	
		C1 = Continuous	
		F2 = 2nd layer	
		F4 = Herbaceous	
		F9 = Open General 65-15%	
		G4 = 3 - 0.03 m	
General Open Shrubs with Herbaceous from Closed to Open (on ex-irrigated schemes)	**2SPJ6-x**	A4 = Shrubs	Medium To High Shrubland with Herbaceous
		A11 = Open General 65-15%	
		B14 = 5 - 0.5 m	
		C1 = Continuous	
		F2 = 2nd layer	
		F4 = Herbaceous	
		F7 = Closed to Open	
		G4 = 3 - 0.03 m	
		Z6 = ex-irrigated schemes	
General Open Shrubs with Trees 1-15%	**2SP7**	A4 = Shrubs	Shrubland with Emergents
		A11 = Open General 65-15%	
		B3 = 5 - 0.3 m	
		C1 = Continuous	
		F2 = 2nd layer	

		F5 = Trees	
		Z2 = Sparse 15-1%	
		G2 = > 30 - 3 m	
Sparse Shrubs	**2SR**	A4 = Shrubs	Sparse Shrubs
		A14 = Sparse General 15-1%	
		B3 = 5 - 0.3 m	
Sparse Shrubs with Herbaceous 1-15%	**2SR6**	A4 = Shrubs	Sparse Shrubs and Sparse Herbaceous
		A14 = Sparse General 15-1%	
		B3 = 5 - 0.3 m	
		F2 = 2nd layer	
		F4 = Herbaceous	
		Z3 = Sparse 15-1%	
		G4 = 3 - 0.03 m	
Woody terrestrial			
Open Woody	**2WO**	A1 = Woody	Continuous Open ((70-60) - 40%) Woody Vegetation
		A12 = Open 65-40%	
		B1 = 7 - 2 m	
		C1 = Continuous	
Trees terrestrial			
Closed Trees with Shrubs from Closed to Open	**2TC8**	A3 = Trees	Trees with Shrubs
		A10 = Closed >65%	
		B2 = >30 - 3 m	
		C1 = Continuous	
		F2 = 2nd layer	
		F6 = Shrubs	
		F7 = Closed to Open	
		G3 = 5 - 0.3 m	
General Open Trees with Herbaceous 1-65%	**2TP6**	A3 = Trees	Woodland with Herbaceous Layer
		A11 = Open General 65-15%	
		B2 = >30 - 3 m	
		F2 = 2nd layer	
		F4 = Herbaceous	
		Z4 = Closed to Open 1-65%	
		G4 = 3 - 0.03 m	
General Open Trees with Shrubs 1-65%	**2TP8**	A3 = Trees	Woodland with Shrubs
		A11 = Open General 65-15%	
		B2 = >30 - 3 m	
		F2 = 2nd layer	
		F6 = Shrubs	
		Z5 = Closed to Open 1-65%	
		G3 = 5 - 0.3 m	
STRIPED Very Open Trees With General Open Shrubs And Herbaceous (Tiger Bush)	**2TV86Zs**	A3 = Trees	Fragmented (Striped) Open (40 - (20-10)%) Trees with Open Shrubs and Open Herbaceous
		A13 = Very Open 40-15%	
		B2 = >30 - 3 m	
		C2 = Fragmented	
		C4 = Striped	
		F2 = 2nd layer	
		F6 = Shrubs	
		F9 = Open 65-15%	
		G3 = 5 - 0.3 m	
		F2 = 3rd layer	
		F4 = Herbaceous	
		F9 = Open 65-15%	
		G4 = 3 - 0.03 m	
CELLULAR Very Open Trees With General Open Shrubs And Herbaceous (Tiger Bush)	**2TV86Zc**	A3 = Trees	Fragmented (Cellular) Open (40 - (20-10)%) Trees with Open Shrubs and Open Herbaceous
		A13 = Very Open 40-15%	
		B2 = >30 - 3 m	
		C2 = Fragmented	
		C4 = Cellular	
		F2 = 2nd layer	
		F6 = Shrubs	
		F9 = Open 65-15%	
		G3 = 5 - 0.3 m	
		F2 = 3rd layer	
		F4 = Herbaceous	
		F9 = Open 65-15%	
		G4 = 3 - 0.03 m	
Sparse Trees with Shrubs 1-15%	**2TR8**	A3 = Trees	Sparse Trees With Sparse Shrubs
		A14 = Sparse 1- 15%	

		B2 = >30 - 3 m	
		F2 = 2nd layer	
		F6 = Shrubs	
		Z1 = Sparse 15-1%	
		G3 = 5 - 0.3 m	
A24-NATURAL AND SEMINATURAL AQUATIC VEGETATION			
On Temporarily Flooded Areas (more than 2 but less than 4 months)			
Closed Herbaceous On Temporarily Flooded Land	**4HCJF**	A2 = Herbaceous	Closed Medium To Tall Herbaceous Vegetation On Temporarily Flooded Land
		A12 = Closed >65%	
		B15 = 3 - 0.3 m	
		C2 = < 4 months/y	
General Open Herbaceous On Temporarily Flooded Land	**4HPJF**	A2 = Herbaceous	Open Medium To Tall Herbaceous Vegetation On Temporarily Flooded Land
		A13 = Open General 65-15%	
		B15 = 3 - 0.3 m	
		C2 = < 4 months/y	
General Open Woody On Temporarily Flooded Land	**4WPF**	A1 = Woody	Open Woody Vegetation On Temporarily Flooded Land
		A13 = Open General 65-15%	
		B1 = 7 - 2 m	
		C2 = < 4 months/y	
Closed Trees with Shrubs from Closed to Open On Temporarily Flooded Land	**4TCF8**	A3 = Trees	Trees With Shrubs On Temporarily Flooded Land
		A12 = Closed >65%	
		B2 = >30 - 3 m	
		C2 = < 4 months/y	
		F2 = 2nd layer	
		F6 = Shrubs	
		F7 = Closed to Open	
		G3 = 5 - 0.3 m	
Open Trees with Shrubs from Closed to Open On Temporarily Flooded Land	**4TOF8**	A3 = Trees	Woodland With Shrubs On Temporarily Flooded Land
		A14 = Open 65-40%	
		B2 = >30 - 3 m	
		C2 = < 4 months/y	
		F2 = 2nd layer	
		F6 = Shrubs	
		F7 = Closed to Open	
		G3 = 5 - 0.3 m	
Herbaceous aquatic - On Permanently Flooded Areas			
Closed Herbaceous On Permanently Flooded Land	**4HCJFF**	A2 = Herbaceous	Closed Medium To Tall Herbaceous Vegetation On Permanently Flooded Land
		A12 = Closed >65%	
		B15 = 3 - 0.3 m	
		C1 = flooded > 4 months/y	
A 11-CULTIVATED TERRESTRIAL AREAS AND MANAGED LANDS			
Herbaceous Crop - Rainfed			
Rainfed - Continuous Medium Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HM47-C**	A3 = Herbaceous crop	Permanently Cropped Area With Herbaceous Crop(s) Crop Type: Cereals
		B4 = Medium (2-5 ha)	
		B5 = Continuous	
		D1 = Rainfed	
A3B1B5XXD1D9-B4-S3		D9 = Permanent	
		S3 = Cereals	
Rainfed - Clustered Medium Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HM147-C**	A3 = Herbaceous crop	Scattered Clustered Field(s) Of Permanently Cropped Area With Herbaceous Crop(s) Crop Type: Cereals
		B4 = Medium (2-5 ha)	
		B6 = Scattered - Clustered	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
Rainfed - Isolated Medium Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HM247-C**	A3 = Herbaceous crop	Scattered Isolated Field(s) Of Permanently Cropped Area With Herbaceous Crop(s) Crop Type: Cereals
		B4 = Medium (2-5 ha)	
		B7 = Scattered - Isolated	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
Rainfed - Continuous Small Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HR47-C**	A3 = Herbaceous crop	Permanently Cropped Area With Small Sized Field(s) Of Herbaceous Crop(s) Crop Type: Cereals
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
Rainfed - Clustered Small Fields of Herbaceous crops (single or multiple)	**HR147-C**	A3 = Herbaceous crop	Scattered Clustered Permanently

- Main crop: cereals (Sorghum, Maize)		B2 = Small (less than 2ha)	Cropped Area With Small Sized Field(s) Of Herbaceous Crop(s) Crop Type: Cereals
		B6 = Scattered - Clustered	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
Rainfed - Isolated Small Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize)	**HR247-C**	A3 = Herbaceous crop	Scattered Isolated Permanently Cropped Area With Small Sized Field(s) Of Herbaceous Crop(s)Crop Type: Cereals
		B2 = Small (less than 2ha)	
		B7 = Scattered - Isolated	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
Herbaceous Crop - Irrigated			
Irrigated Continuous Large Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HL57**	A3 = Herbaceous crop	Permanently Cropped Area With Irrigated Herbaceous Crop(s)
		B3 = Large (more than 5 ha)	
		B5 = Continuous	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Continuous Medium Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HM57**	A3 = Herbaceous crop	Permanently Cropped Area With Irrigated Herbaceous Crop(s)
		B4 = Medium (2-5 ha)	
		B5 = Continuous	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Clustered Medium Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HM157**	A3 = Herbaceous crop	Scattered Clustered Field(s) Of Permanently Cropped Area With Irrigated Herbaceous Crop(s)
		B4 = Medium (2-5 ha)	
		B6 = Scattered - Clustered	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Continuous Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR57**	A3 = Herbaceous crop	Permanently Cropped Area With Small Sized Field(s) Of Irrigated Herbaceous Crop(s)
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Clustered Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR157**	A3 = Herbaceous crop	Scattered Clustered Permanently Cropped Area With Small Sized Field(s) Of Irrigated Herbaceous Crop(s)
		B2 = Small (less than 2ha)	
		B6 = Scattered - Clustered	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Isolated Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR257**	A3 = Herbaceous crop	Scattered Isolated Permanently Cropped Area With Small Sized Field(s) Of Irrigated Herbaceous Crop(s)
		B2 = Small (less than 2ha)	
		B7 = Scattered - Isolated	
		D3 = Irrigated	
		D9 = Permanent	
Trees Crop - Irrigated			
Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**TR3H57**	A1 = Trees	Permanently Cropped Area With Small Sized Field(s) Of Irrigated Tree Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period).
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		C2 = Multiple crop	
		C3 = One additional crop	
		C7 = Herbaceous terrestrial	
		C17 = Simultaneously	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Clustered Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**TR13H57**	A1 = Trees	Permanently Cropped Area With Scattered Clustered Small Sized Field(s) Of Irrigated Tree Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B2 = Small (less than 2ha)	
		B6 = Scattered - Clustered	
		C2 = Multiple crop	
		C3 = One additional crop	
		C7 = Herbaceous terrestrial	
		C17 = Simultaneously	
		D3 = Irrigated	
		D9 = Permanent	
Irrigated Isolated Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**TR23H57**	A1 = Trees	Permanently Cropped Area With Scattered Isolated Small Sized Field(s) Of Irrigated Tree Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B2 = Small (less than 2ha)	
		B7 = Scattered - Isolated	
		C2 = Multiple crop	
		C3 = One additional crop	
		C7 = Herbaceous terrestrial	

		C17 = Simultaneously	
		D3 = Irrigated	
		D9 = Permanent	
General Open Trees with Shrubs 1-65% OR Irrigated Continuous Small Fields of Tree crops (fruit trees) and Herbaceous crop (pulses and vegetables) (with distinct patterns on the same field)	**2TP8//TR3H57**	A3 = Trees	Woodland with Shrubs OR Permanently Cropped Area With Small Sized Field(s) Of Irrigated Tree Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period).
		A11 = Open General 65-15%	
		B2 = >30 - 3 m	
		F2 = 2nd layer	
		F6 = Shrubs	
		Z5 = Closed to Open 1-65%	
		G3 = 5 - 0.3 m	
		OR	
		A1 = Trees	
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		C2 = Multiple crop	
		C3 = One additional crop	
		C7 = Herbaceous terrestrial	
		C17 = Simultaneously	
		D3 = Irrigated	
		D9 = Permanent	
Herbaceous Crop - Post Flooding			
Post Flooding - Continuous Medium Fields of Multiple Herbaceous crops	**HM3HY**	A3 = Herbaceous crop	Post Flooding Cultivation Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B4 = Medium (2-5 ha)	
		B5 = Continuous	
		C2 = Multiple Crop	
		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
Post Flooding - Isolated Medium Fields of Multiple Herbaceous crops	**HM23HY**	A3 = Herbaceous crop	Post Flooding Cultivation Of Scattered Isolated Field(s) Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B4 = Medium (2-5 ha)	
		B7 = Scattered - Isolated	
		C2 = Multiple Crop	
		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
Post Flooding - Continuous Small Fields of Multiple Herbaceous crops	**HR3HY**	A3 = Herbaceous crop	Post Flooding Cultivation Of Small Sized Field(s) Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		C2 = Multiple Crop	
		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
Post Flooding - Clustered Small Fields of Multiple Herbaceous crops	**HR13HY**	A3 = Herbaceous crop	Post Flooding Cultivation Of Scattered Clustered Small Sized Field(s) Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B2 = Small (less than 2ha)	
		B6 = Scattered - Clustered	
		C2 = Multiple Crop	
		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
Post Flooding - Isolated Small Fields of Multiple Herbaceous crops	**HR23HY**	A3 = Herbaceous crop	Post Flooding Cultivation Of Scattered Isolated Small Sized Field(s) Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period) .
		B2 = Small (less than 2ha)	
		B7 = Scattered - Isolated	
		C2 = Multiple Crop	
		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
Rainfed - Continuous Medium Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize) OR Post Flooding - Continuous Small Fields of Multiple Herbaceous crops	**HR47-C//HR3HY**	A3 = Herbaceous crop	Permanently Cropped Area With Small Sized Field(s) Of Herbaceous Crop(s) Crop Type: Cereals OR Post Flooding Cultivation Of Small Sized Field(s) Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period)
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
		OR	
		A3 = Herbaceous crop	
		B2 = Small (less than 2ha)	
		B5 = Continuous	
		C2 = Multiple Crop	

		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
Rainfed - Isolated Small Fields of Herbaceous crops (single or multiple) - Main crop: cereals (Sorghum, Maize) OR Post Flooding - Isolated Small Fields of Multiple Herbaceous crops	**HR247-C//HR23HY**	A3 = Herbaceous crop	Scattered Isolated Permanently Cropped Area With Small Sized Field(s) Of Herbaceous Crop(s) Crop Type: Cereals OR Post Flooding Cultivation Of Scattered Isolated Small Sized Field(s) Of Herbaceous Crop(s) (One Additional Crop) (Herbaceous Terrestrial Crop With Simultaneous Period)
		B2 = Small (less than 2ha)	
		B7 = Scattered - Isolated	
		D1 = Rainfed	
		D9 = Permanent	
		S3 = Cereals	
		OR	
		A3 = Herbaceous crop	
		B2 = Small (less than 2ha)	
		B7 = Scattered - Isolated	
		C2 = Multiple Crop	
		C3 = 1 add. Crop	
		C7 = Herbaceous Terrestrial	
		C17 = Simultaneously	
		D2 = Post flooding	
B15-ARTIFICIAL SURFACES AND ASSOCIATED AREAS			
Airport	**5A**	A4 = Non linear	Industrial And/Or Other Area(s)Built-Up Object: Airport
		A12 = Industrial and other	
		A21 = Airport	
Urban Areas/Settlements	**5U**	A4 = Non linear	Urban Area(s)
		A13 = Urban area	
B16-BARE AREAS			
Loose and Shifting Sands	**6L**	A6 = Loose and shifting sands	Loose And Shifting Sands
Dunes	**6LD**	A6 = Loose and shifting sands	Shifting Sands / Dune(s)
		B1 = Dunes	
Salt Crust (Sandy area)	**6LZ**	A6 = Loose and shifting sands	Loose And Shifting Sands With Salt Flats
		B13 = Salt Flats	
Bare Soil	**6S**	A5 = Bare soil a/o other unconsol. mat.	Bare Soil And/Or Other Unconsolid. Material(s)
Bare Soil with Scattered Vegetation	**6SV**	A5 = Bare soil a/o other unconsol. mat.	Bare Soil And/Or Other Unconsolidated Material(s) Scattered Vegetation Present
		U1 = Scattered vegetation (> 4%)	
B27-ARTIFICIAL WATERBODIES			
Artificial Waterbodies Standing	**7WP**	A1 = Artificial Waterbodies	Artificial Perennial Waterbodies (Standing)
		A5 = Standing	
		B1 = Perennial	
B28-INLAND WATERBODIES			
Tidal Area	**8WT1**	A1 = Inland Water	Tidal Area (Surface Aspect: Sand)
		B3 = Tidal Area	
		B6 = Sand	
River	**8WFP**	A1 = Natural Waterbodies	Perennial Natural Waterbodies (Flowing)
		A4 = Flowing	
		B1 = Perennial	
Seasonal Rivers	**8WFN**	A1 = Natural Waterbodies	Non-Perennial Natural Waterbodies (Flowing)
		A4 = Flowing	
		B2 = Non-Perennial	
Seasonal Rivers with Scattered Vegetation	**8WFNV**	A1 = Natural Waterbodies	Non-Perennial Natural Waterbodies (Flowing) Scattered Vegetation Present
		A4 = Flowing	
		B2 = Non-Perennial	
		U1 = Scattered vegetation	
Natural Waterbody	**8W**	A1 = Natural Waterbodies A5 = Standing	Natural Waterbodies (Standing)