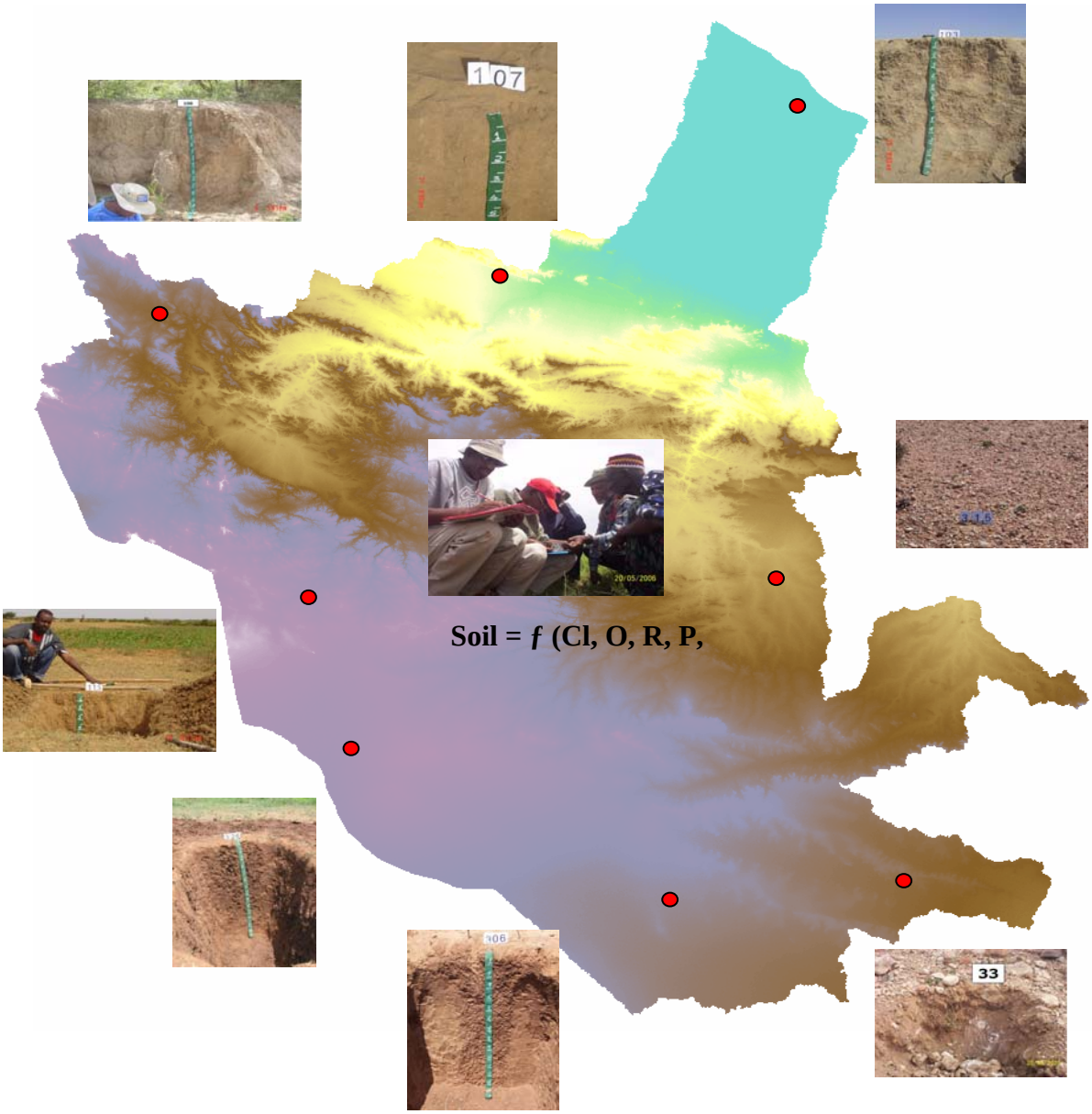
Soil Survey of a Selected Study Area in Somaliland



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

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List of Acronyms

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List of acronyms

AOI	Area of Interest
CMSV	Continuous Model of Spatial Variation
DEM	Digital Elevation Model
DSM	Digital Soil Mapping
DMSV	Discrete Model of Spatial Variation
FAO	Food and Agriculture Organization
GP	Geopedological Approach
GIS	Geographical Information System
ILWIS	Integrated Land and Water Information System
LCCS	Land Cover Classification System
NSM	Newhall Simulation Model
SIHLMA	Somalia Integrated Hierarchical Landform Mapping Approach
SoLIM	Soil Land Inference Model
SRTM	Shuttle Radar Topography Mission
SWALIM	Somalia Water and Land Information Management

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1 INTRODUCTION

Soil information is a key element for natural resources management, and specifically land use planning. In developing countries like Somalia where there is no national spatial data infrastructure, soil data and information is very scarce. Conventional soil surveys were and are the most frequently used method of acquiring soil data at different scales, for various purposes. This is a highly cost- and time-consuming activity, which limits its use over broad scales.

As mentioned by McKenzie *et al* [1], technological advances during the last few decades have created tremendous potential for improving the manner in which soil maps are produced. Remote sensing and photogrammetric techniques provide spatially explicit digital data representations of the Earth's surface. However, in the case of soils, it is less effective due to limitations such as showing information only of the soil cover, and not the depths where soil development takes place. Although these tools can improve soil inventory techniques, soil surveys are the only way of acquiring and understanding the types and properties of soil/s present in a specific area.

Soil surveys in Somalia were primarily undertaken between 1961-1988. There have been no national soil surveying and mapping initiatives at the institutional level. The most important regional soil reconnaissance surveys were conducted in the Jubba and Shabeelle region by FAO-Lockwood in 1967, and another in the northwest area of the country conducted by Sogreah in 1981. Some reconnaissance studies are shown in Table 1.

Table 1: Soil studies

SURVEYOR	LOCATION	AREA (km^2)	SCALE
ICA (1961)	Lower Jubba Valley	4.500	1:650.000
Selchozpromexport (1965)	Lower and Middle Jubba Valley	16.000	1:200.000
FAO/Lockwood (1967)	Project Area	208.500	1:60.000
Technital	Jubba Valley	50.000	1:200.000
HTS (1977)	Project Area	200.000	1:500.000
SOGREAH (1983) [2]*	North-west Somalia	33.500	1:100.000
Sir William Halcrow & Partners[3]	Northern Somalia		1:200.000

***The only soil survey covering SWALIM's study area.

The SOGREAH study was part of the north–west region agricultural development programme. This programme was initiated due to the fact that, after the two major river valleys of the south, the North-West region is the next most populated part of the country with Hargeisa having the highest population. Natural resources inventory and evaluation was carried out between 1979-1983, including a soil survey as one of the main activities, which was later used for various agricultural development initiatives.

Since the start of the war in 1991, no soil surveys have been undertaken and available soil data produced by SOGREAH has been lost, including maps showing spatial variability of soils.

In view of the foregoing, and considering future planning activities in the country, there is a need to generate baseline data that provides an accurate reflection of the current status of natural resources.

SWALIM is mandated to produce natural resource baselines for specific areas of interest, including the north-west. To this end, a soil survey was conducted using a combination of modern and conventional approaches (to overcome the various constraints within the

study area) to map spatial variability of soils as a primary input to land suitability and land degradation assessment components of SWALIM's activities.

The objective of this study was a soil survey which would include soil mapping activities at a multi-scale level, oriented towards a variety of users.

2 STUDY AREA

2.1 Location and delineation

The study area of the Northwest Somalia is located between the latitudes 9^{o} 10' 30.8" and 10^{o} 41' 36.54" North and the longitudes 43° 0' 52.3" and 44° 27' 54.22" East (Figure 1) thus covering a total area of 12 915 km^{2}. It is bounded in the north by the Gulf of Aden and Lughaya District, in the east by Berbera District and the eastern parts of Hargeisa District, in the south by the Ethiopian border, and in the west by the Eastern part of Borama District.

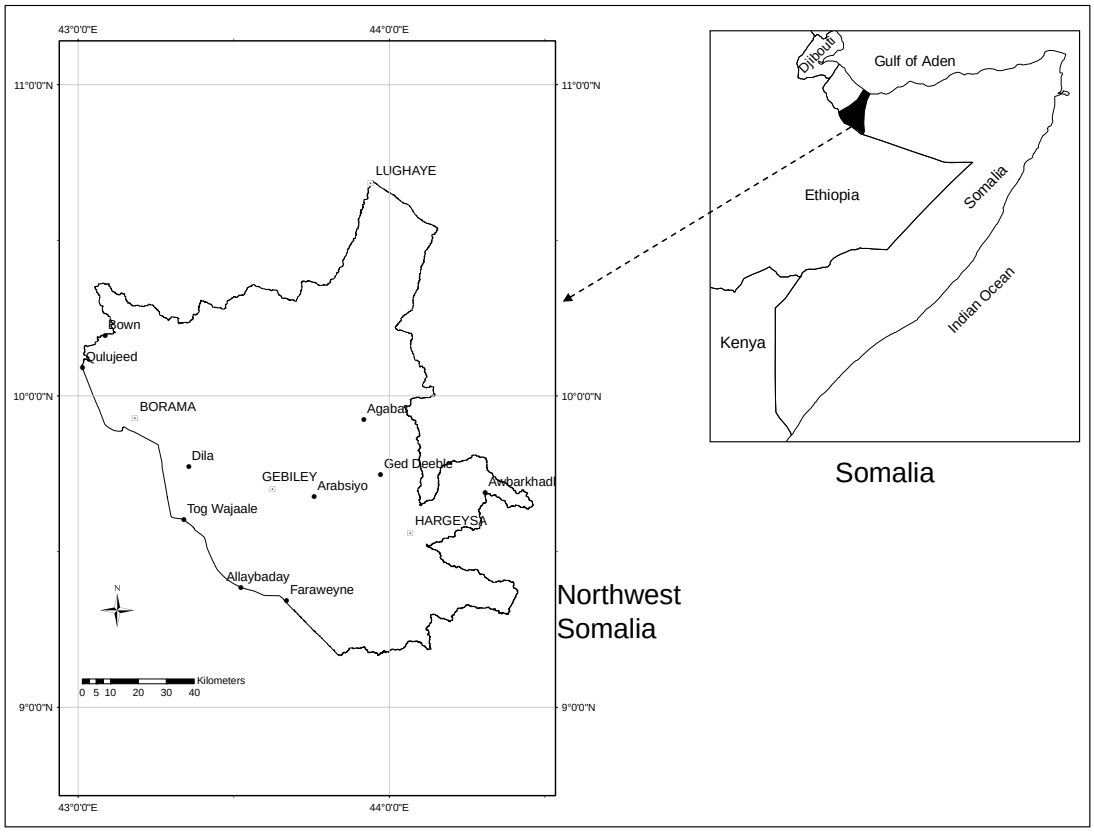


Figure 1: Study area

2.2 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 surrounding area. Semi-arid conditions prevail at the higher altitudes of the Al Mountains and south of Gebilley. Mean annual rainfall ranges from below 200 mm in the coastal area of Lughaye, to 500 - 600mm in the east of Borama and surroundings, while the rest of the study area has a mean annual rainfall of 300 - 500mm (see Figure 4).

The study area lies entirely between the two subtropical anticyclone belts. The main weather pattern is controlled by the passage of the seasonal monsoon winds. Rainfall in the area is thus bimodal (see Figure 2). The northeast monsoon brings the primary *Gu* rains from March to June, followed by a hot dry period called *Xagaa* in June and July. Short rains locally known as *Deyr* also occur between August and October followed by cool long dry *Jilaal* period between November-February.

Temperatures in the area are influenced by altitude and the strength and temperatures of the seasonal winds. Figure 3 shows how temperatures decrease with increasing altitude. In the higher altitudes of the Al Mountains and Plateau areas temperatures vary considerably with the seasons, with a mean annual temperature of 20-24°C, 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 may go up 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 between June to July during the *Xagaa* dry season, during the southwest monsoon and in *Jilaal* between December and February. Hot, calm weather occurs between the monsoons during April and September). Generally, in the north-west winds are strongest during the southwest monsoon. Average wind speed varies between 8 - 10 m/s, but during a large part of the year strong winds of up to 17 m/s occur, causing frequent “dust-devils” over the coastal plains and plateaus.

The study area is subject to high potential evapotranspiration (PET), with an annual average of between 2000 and 3000mm. Annual rainfall is far less than the PET and a significant water deficit exists throughout the region for most of the year. Rainfall is not always sufficient for successful crop production (Figure 2).

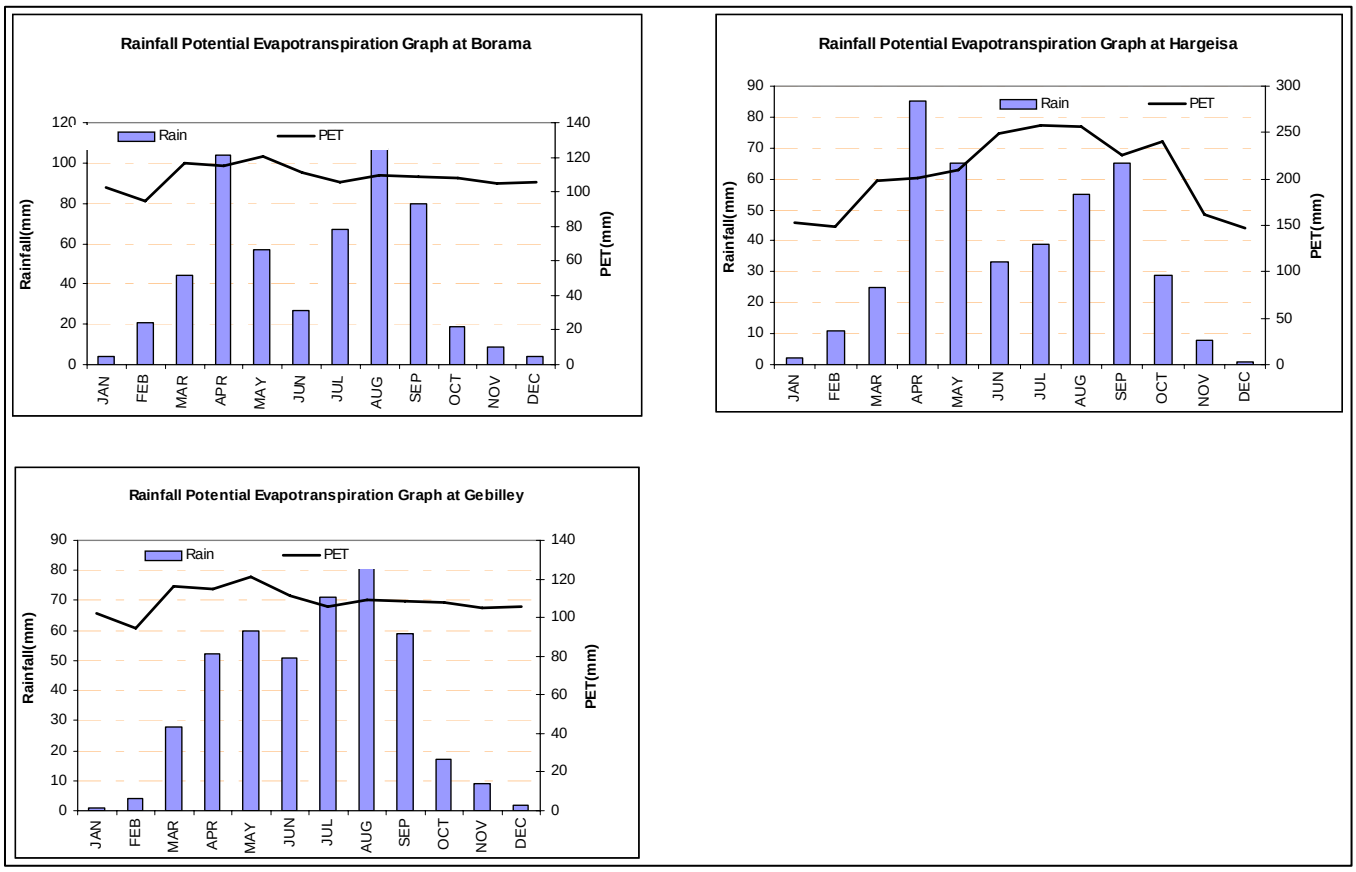


Figure 2: Rainfall and potential evapotranspiration

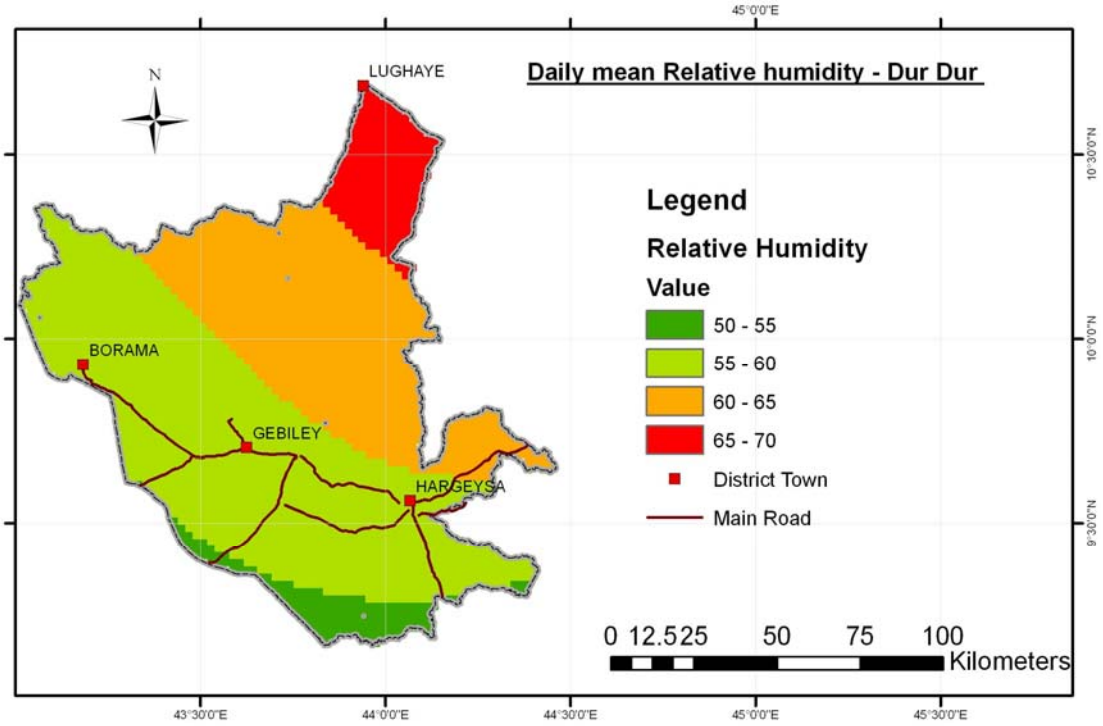


Figure 3: Relative humidity of the study area

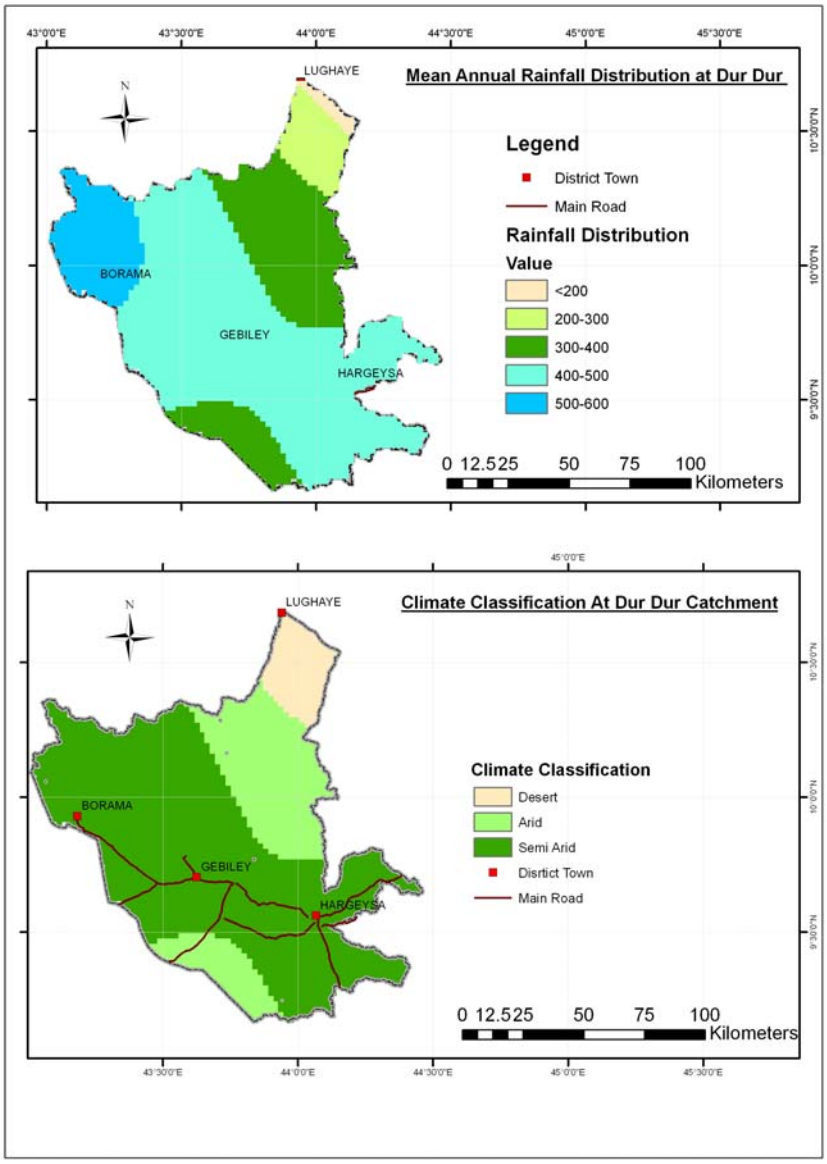


Figure 4: Rainfall distribution and climate classification of the study area

2.3 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 in Al Mountain 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. The igneous rocks consist mostly of basalts and rhyolites, and 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.

2.4 Landform and Soils

From a geomorphological point of view, the study area may be divided into three landscapes: (1) Piedmonts and the Coastal Plain, (2) Mountainous and Hilland, and (3) Plateau (both dissected and normal). The middle mountain range and the southern plateau are locally known as *Oogo*. There are three main ephemeral river systems that drain from the plateau and traverse the mountain range in the direction of the Red Sea, and from the southern side of the same mountain to the southern highlands respectively. They are called *Togga Durdur*, *Togga Biji* and *Togga Waheen*.

(1) *Piedmonts and the Coastal Plain*. A small northern section of the study area is taken up by gently sloping coastal plain (locally called *Guban*) with elevation ranging from sea level to 600m, from the Red Sea southwards up to the foot of the mountains (see Map 1). It is characterised by debris and colluvia carried by several togas crossing the plain to the sea. The beds of the togas are very wide, and subject to flash floods during the rainy season.

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

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

According to the Sogreah soil survey report [2], patterns of soil distribution 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 area 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.

2.5 Land cover

The land cover of the study area consists mostly of natural vegetation. Land cover classes include Open Shrubs, Open Trees and Open to Closed Herbaceous. Closed Trees are not common. Other cover types include Urban and Associated Areas (Settlement/Towns and Airport), Bare Areas (Bare Soils and Sandy areas) and Natural Waterbodies.

The main woody species in the study area include *Acacia nubica, A. tortilis, A. bussei, A. senegal, Aloe* spp*., Croton gilletti, Hypoestes hildebrandtii, Acalypha fruticosa, Grewia tenax,*and *Balanites aegyptiaca.* Common herbaceous species are *Cenchrus ciliaris, Cynodon dactylon, Sporobolus marginatus, Tragus racemosus* and *Aristida adscensionis*. More details on land cover and vegetation of the area can be found in FAO-SWALIM Technical Report No. L-03.

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

2.7 Population

The study area consists of the districts of Dila, Gebiley, Faraweyne and Allaybaday, and parts of the districts of Hargeisa, Borama, Baki and Lughaya. The size of the study area is slightly more than one third of the total area of Awdal and Waqooyi Galbeed Regions.

According to Somalia UNDP 2005 (Table 1), the estimated urban and non-urban population for Hargeisa by mid-2005 was 560 028, making it the second most populated town in Somalia. Borama had a population of 215 616 and Gebiley 79 564 inhabitants. These three centres are the main towns in the study area.

Table 2: 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

3 MATERIALS AND METHODS

3.1 Materials

The basic materials used in this work are given in Table2:

Table 2: Materials

TYPE	MATERIAL
Literature	Project reports Classification key WRB 2006 Thematic maps
Hardware	Soil survey tools Soil laboratory equipment
Software	ArcGIS 9.0 ILWIS 3.3 ArcViews 3.2 SDBmPlus 2.01 NSM Microsoft Excel 2000

3.2 Methods

3.2.1 Bibliographic research and data collection

A complete bibliographic research of principal sources such as reports, internet, grey literature, scientific articles, etc. was performed regarding all soil survey activities carried out in the study area. The SOGREAH study [2] was the primary source of data on soils in the study area. However, attempts to collect data on soil profiles, soil descriptions and soil maps, revealed their unavailability. The soil survey report contains general information about soils, but no map. Some soil profile descriptions were available, but were without coordinates.

3.2.2 The soil mapping model

According to Heuvelink [4], soil spatial variability can be described by two types of models: a discrete model of spatial variation (DMSV), and a continuous model of spatial variation (CMSV). Traditionally, conventional soil surveys follow the discrete model of spatial variation, which produces a polygon type or entity map.

Conventional soil surveys, including mapping activities, should follow standards for scale and sampling intensity, According to Avery and Dent [5, 6] if the objective is to produce a map at scales of 1:50 000 and 1:100 000, the following rules should apply:

At 1:50 000 scale

Medium semi-detailed soil survey, general purpose
Inspection density according to Avery and Dent: 1 per 0.2 km^2 (20 ha) to 1 km^2 (100 ha)
Area of study: 12.936 km^2
Considering the optimum and the area characteristics:

1 sample - 0.2 km^2
X - 12 936 km^2
X = 64684 samples

Considering the minimum and the area characteristics:

1 sample - 1 km^2

X - 12 936 km^2
X = 12936 samples

At 1:100 000 scale

Low semi-detailed soil survey, resource inventory
Inspection density according to Avery and Dent: 1 km^2 (100 ha) to 4 km^2 (400 ha)
Area of study: 12.936 km^2
Considering the optimum and the area characteristics:

1 sample - 1 km^2
X - 12 936 km^2
X = 12 936 samples

Considering the minimum and the area characteristics:

1 sample - 4 km^2
X - 12 936 km^2
X = 3 234 samples

As we can see, a high level of soil sampling is required in order to follow a conventional survey based on determination of relationships between soils and landscapes.

Constraints in this area of interest included poor accessibility (few roads), the mountainous landscape, security restrictions due to the current socio-political situation and the presence of unmapped landmines, hence it was not technically or practically feasible to perform a conventional soil survey. Instead, alternatives had to be considered in order to perform the primary objective of soil mapping. Project constraints demanded the use of rapid automated techniques, combined with relatively time-intensive techniques such as Soil Inference Systems, limited field observation and sampling.

As mentioned by Scull [7], today there are many new methods that aim to improve soil mapping activities in areas with low spatial data infrastructure. These methods are known as DSM (digital soil mapping techniques) [8]. One tool is Predictive Soil Mapping, which infers soil classes based on low soil samples using an inference system relying on expert knowledge.

For the purpose of this study, we adopted the SoLIM (Soil-Land Inference Model) concept [9], which is a predictive soil mapping approach based on a soil-landscape model concept. This contends that soils are predictable when local environmental conditions and soil relationships to these environmental conditions are known. This approach includes use of dedicated software, SoLIM 4.0 [10], which was not used due to the extent of the study area and the lack of certain important data components.

Theoretical background of the model

The State Factor (soil-forming factors) forms the theoretical basis of Predictive Soil Mapping, as well as the traditional soil survey. This is based on the equation of soil forming factors by Jenny [11], who formalised the ideas of Dokuchaev regarding soil formation:

$$\mathbf{S} = F(Cl, O, R, P, T, \ldots..)$$

Where:

S = the formed soil
Cl= Climate
O = Organisms (fauna, flora, human activity)
R = Relief (geomorphology context)
P = Parent material or lithology
T = Time

This equation and theory states that soil profiles found in a given landscape are a function of climate, organisms, relief, parent material and time. This implies that if the spatial distribution of soil forming factors is known, the soil character may be inferred.

We consider two important issues here:

- Wherever soil is present, its presence is due to the combination of soil forming factors. However, specific environmental conditions determine specific soil forming processes because soil forming factors are permanent or constant in the environment.

- The predictive model should try to identify specific soil forming factors and processes acting in the landscape and leading to specific soil formation.

The Inference Model

The model comprises a combination of Expert Systems [12] and Decision Tree Analysis [13].

An expert system consists of: data (information on spatial environmental variables, e.g. climate, landform, etc.), a knowledge base (rules and facts relating to soil variation supplied by an expert, in this case the soil surveyor), and an inference engine (which combines data and the knowledge base to infer logically valid conclusions) [14].

The overall aim of the Decision Tree Analysis is to design a set of predictive rules (e.g. if geology type = A, then soil type = B) developed from training data, which can then be applied to a geographic database to predict the value of a response variable [15].

Our conceptual base consists of the theoretical background of the SoLIM (Soil-Land Inference Model) for the model itself, and the Jenny equation as the general rule for determining the distribution of soil classes.

The following equation corresponds to a contextualized version of the Jenny equation which will guide some of the inference model.

$$\text{SOIL A}\,(b) = f\,(\text{CL}(b)+\text{R}(b)+\text{P}(b)+\text{O}(b)+\text{T}(b))$$

This equation infers that the SOIL A situated in the environment *(b)* is there due to the combination of the principal soil forming factors under the specific environment B which generates specific soil forming processes A-B.

In this regard, the climate factor refers to specific climatic variables acting in that environment *(b)*.

The relief under which all the process are carried out corresponds specifically to the environment *(b).*

The parent material represents the initial material on *(b*), which after some processes have acted upon it will become soil.

The organisms present in environment *(b)* determine many activities acting on its attributes.

Finally, time or age is a very difficult, non-local factor. However, the initial equation relates to soil maturity, a factor that can be assessed in the field through horizon differentiation. In this study the time factor was not considered due to the primary objective being to infer which kind of soils were present in the study area. The geological

time can indirectly represent the soil time forming factor because it shows age of the different rocks.

Components

Data: the different data layers necessary to model the soil-landscape relationship. This corresponds to all the soil forming factors and specific spatial components collected in the field having a direct influence on soil spatial variability.

Expert Knowledge: this component values the knowledge of a soil scientist of the study area which, based on spatial data layers and fieldwork stage characterised the specific environment where each class of soil was developed. Based on those models and this expert knowledge, decision trees were constructed where predictive rules regarding soil formation were specified.

Inference engine: our inference engine was based on the use of ILWIS 3.1 and ArcGis 9.0. softare packages, together with the decision trees. As established by many authors [7], most of the Predictive Soil Mapping work was carried out in small areas in great detail and in far fewer larger areas on a smaller scale.

3.2.3 Landscape stratification (Geopedological approach)

The core of the overall approach was identification and understanding of the soil-landscape model concept. Landscape stratification was performed by adapting the Geopedological (GP) approach [16] to Somalian conditions. The GP approach is an hierarchical system which stratifies terrain from a geomorphological perspective, but with the objective of determining soil formations. This approach utilises six different categorical levels; however, only Landscape, Relief, Lithology and Landform levels were used. The present exercise started from an integrated and modified GP approach. The primary difference lay in the fact that, instead of aiming at producing a soil map using aerial photography (as in a conventional soil survey), the aim was a landform map, using satellite imagery. Spatial and spectral information extracted from an aerial photograph or a satellite image are quite different, even though they can be complementary. In addition, visual image interpretation was integrated with Digital Terrain Analysis, giving rise to integrated landform maps at 1:100 000 and 1:50 000 scales which were verified in the field.

The present approach has been called the Somalia Integrated Hierarchical Landform Mapping Approach – SIHLMA. For a detailed explanation of the procedure and the results, please refer to the Landform Mapping of Somalia Report [17] which is part of the land resources inventory of the SWALIM project carried out in the study area.

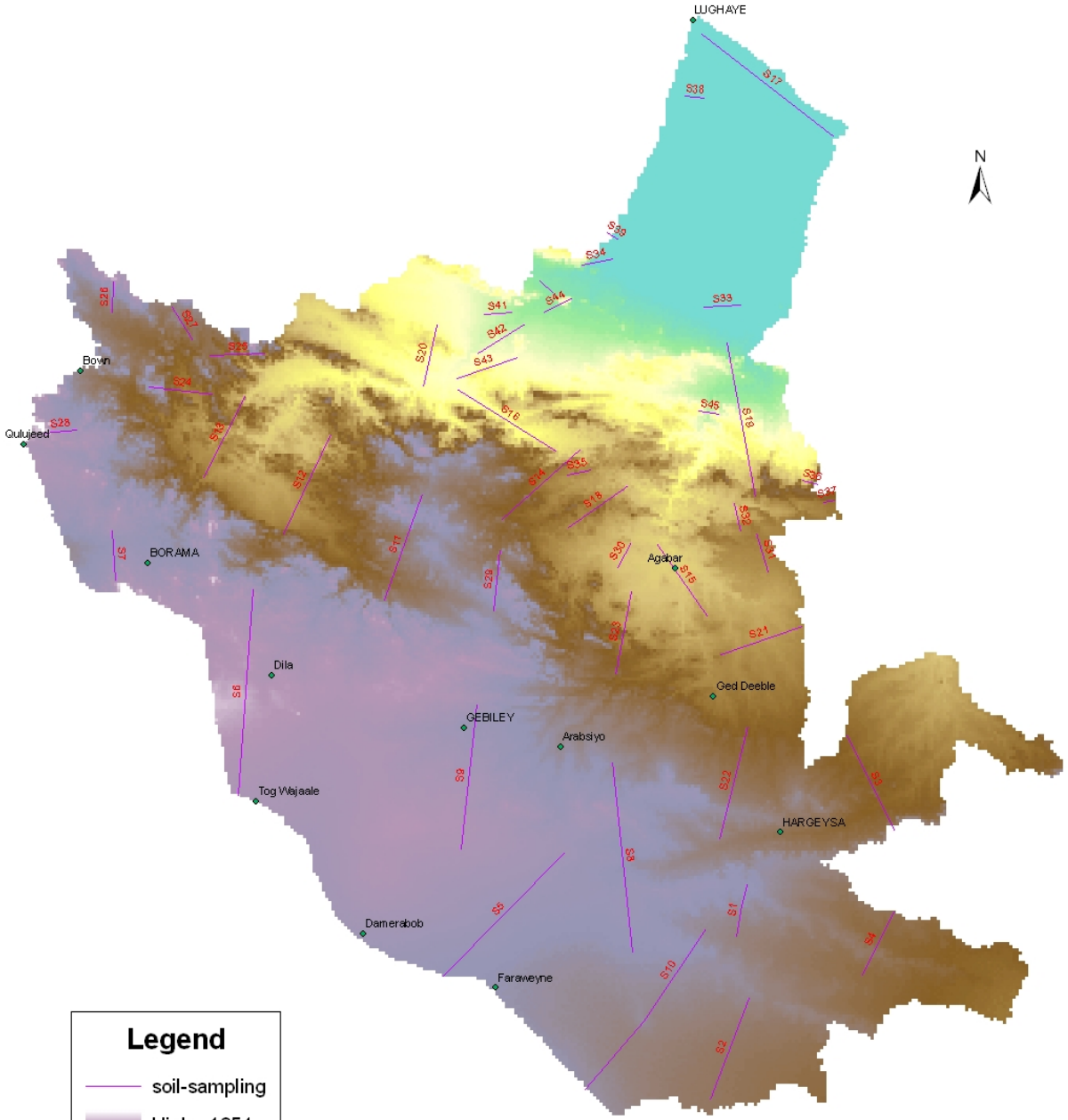
3.2.4 Soil sampling design

Considering the aforementioned constraints and the proposed model of the soil mapping activity, a soil sampling scheme was designed that would consider representative sites that would reveal the spectrum of soil spatial variability.

Using the produced landscape map, variability of different landscapes and relief types were analysed as well as their relation to soil formation, thereby assessing spatial variability and composition of the terrain component.

Referring to the representative landscapes and relief types, the accessibility map, security measures and presence of landmines, a Transect Sampling Scheme (Map 1) was designed that focused field soil data collection on representative sites. Transect locations represent sites where the soil-landscape model concept corresponded with areas of high soil variability.

MAP 1: Soil Transects Location



3.2.5 Soil field-survey

A field-based natural resources inventory was carried out by SWALIM between April and July 2006 in fulfilment of its main objective of land suitability assessment of the Dur-Dur and Gebiley catchments, which included a specific soil survey aimed at collecting soil data.

To support and guide important field activities, the SWALIM land team produced a Field Survey Manual [18].

Conventional soil profile descriptions were carried out along the different relief types found in each planned soil transect. Not all planned soil transects were visited, either due to impeded accessibility or presence of landmines.

At each site, a standard soil pit was dug. A soil collection form was designed to collect site information, soil attributes and pedogenetic indicators (see Annex 1). Physical and chemical soil properties were described for each soil profile and soil samples were taken for laboratory analysis in Nairobi, Kenya. A preliminary soil classification was performed using the WRB 98 soil classification system [19]. Augering was performed in areas where there was the need to definine boundaries between different soil classes.

Sites with rocky or stony soils were not described in detail, but a preliminary classification was still made.

3.2.6 Soil data input

Due to logistics between Hargeisa (Somalia) and Nairobi (Kenya) where the SWALIM office is located, completed soil forms were sent to Nairobi on a weekly basis.

All soil forms were entered into the soil profile database software SDBmPlus 2.1 [20], which is a specialised program for storing soil profile data. Once all soil profiles were entered, use was made of the program's capabilities to display the different soil profiles, the results of which may be seen in Appendix 3.

The software also allowed exportation of all data into a point based soil geographic database . This database was stored as a Microsoft Access file. It should be remembered that an area-class map where this kind of database is very useful, was not produced.

3.2.7 Soil Laboratory analysis

A sample of 500g of soil was collected from each horizon for soil analysis. All soil samples collected in the field were sent to Nairobi on a weekly basis repeat of above. Soil samples were analysed in the KARI (Kenya Agriculture Research Institute) Soil Laboratory following a standard soil analysis. Parameters analysed and methods used were:

<u>Soil texture</u>

Particle-size analysis was done using the Bouyoucos hydrometer method, where A 50g soil sample was placed in a plastic shaking bottle with 50mls calgon dispersion agent. A blank (without soil) sample was also prepared. These were shaken overnight, transferred into sedimentation cylinders and topped up to the 1000 ml mark. The mixture was well stirred using a metal plunger to bring the particles into suspension. A soil hydrometer was used to take readings after 40 seconds and two hours, respectively. The second reading gave the clay content and was calculated as follows:

% Clay = (R2-Rb)/50*100

The first Reading gives the Silt + Clay

which is

% (Silt + Clay) = R1/50*100

%Silt is therefore this reading minus %Clay

% Sand is 100 – % (Silt+Clay)

After determining percentages of sand, silt and clay, a textural classification chart (see below) was used to classify the soil.

Dry Soil Bulk density
Only the first horizon for all the profiles was analysed. Bulk density is best estimated by a core-sampling method. However, undisturbed soil samples were unobtainable so dry bulk density was estimated as follows: Dry the soil in the oven and let it cool. Pour sample into a plastic cylinder. Let the cylinder drop from a height of 5-30 cm for 50 taps. Read the volume and weigh to determine the weight of the soil. The weight of the soil divided by the volume gives the bulk density.

Extractable Phosphorus
The Olsen method was used for this purpose. Dried soil samples were extracted in a1:5 ratio (w/v) with 0.5M sodium bicarbonate solution at pH 8.5. Phosphorus in the extract was determined spectrophotometrically.

Soil pH and EC
Soil pH and EC were determined in a 1:2:5 (w/v) soil- water suspension, using a pH meter and conductivity meter respectively.

Total organic carbon
The calorimetric method was used to determine this important property. All organic carbon in the soil sample was oxidized by acidified dichromate at 150°C for 30 minutes to ensure complete oxidation. Barium chloride was added to the cool digests. After thorough mixing, digests were allowed to stand overnight. Total C was determined spectrophotometrically.

Total Nitrogen
The Kjeldahl method was used for this purpose. Soil samples were digested with concentrated sulphuric acid containing potassium sulphate, selenium and copper sulphate hydrated at approximately 350°C. Total N was determined calorimetrically on a flow analyser.

Cation Exchange Capacity and Exchangeable Ca, Mg, K, Na
Soil samples were leached with 1N ammonium acetate buffered at pH 7. Leachate was analysed for exchangeable Ca, Mg, K and Na. Sample were further leached with 1N KCl, and leachate used for determination of the CEC. Elements such as Na and K were determined with a flame photometer and Ca and Mg with AAS (atomic absorption spectrophotometer). CEC was determined calorimetrically on a flow analszer.

Once soil laboratory results were available, they were integrated into the general database in the SDBmPlus 2.1 software which was used to construct the final soil profile database.

The samples were also sent to ICRAF where they were scanned for spectral reflectance. The results of this analysis can later be used for land degradation assessment.

3.2.8 Soil classification

All soil profiles were preliminarily classified in the field using the WRB 1998 [19]. Once soil laboratory results were available, soil profiles were classified using the new WRB soil

classification system v.2006 [21]. Soils were classified at two levels: at reference group, and prefix and suffix levels. Once this was done, some key soil profiles were sent for revision in terms of classification to ISRIC (Dr. Otto Spaargaren).

3.2.9 Determination and acquisition of necessary environmental variables

The SWALIM land team have generated different thematic layers, mainly as landscape, relief, land cover and land use maps. All are considered important soil forming factors which later were used in the soil modelling process. Some other layers like Soil Moisture Regime and Slope maps were generated using different approaches. All the maps used the same geodesic system, that can be found in Table 4.

Table 4: Geodesic System

GEODESIC SYSTEM	PARAMETERS
Projection	Universal Transversal Mercator (UTM)
Datum	WGS 1984
Ellipsoid	WGS 1984
Zone	38

The different environmental variables that were generated can be found in Table 5:

Table 5: Environmental variables

VARIABLE	DATA TYPE	LEVEL OF DETAIL IN THE SOILS PREDICTION
Landscape	Discrete	General at Reference group (WRB)
Soil Moisture Regime	Continuous	General at Reference group (WRB)
Lithology	Discrete	General at Reference group (WRB)
Land use	Discrete	At prefix level (WRB)
Land cover	Discrete	At prefix level (WRB)
Relief	Discrete	At suffix level (WRB)
Slope	Continuous	At suffix level (WRB)

Landscape and relief maps

Maps mentioned in para 2.3.3 were generated using the GP approach. Project Report L-02 should be consulted for a detailed explanation on procedures and results. Maps 2 and 3 show landscape and relief types in the study area, and Table 6 contains a detailed legend.

Land cover map

This map was generated by the SWALIM team using the LCCS classification system for legend production, and satellite image interpretation combined with fieldwork verification. For a detailed explanation of the land cover refer to Project Report L-03 and Map 4

Land use map

This map was generated by the SWALIM team using the land cover map as the cartographic basis, and a land use field survey using semi-structured interviews. For a detailed explanation of the land cover refer to Project Report L-04 and Map 5.

Table 6: Landscape and relief type legend

Landscape		Relief		Landform	
Code	*Description*	*Code*	*Description*	*Code*	*Description*
HiD	Dissected Hilland	A02	Town, Industrial district	F02	Rill
Hil	Hilland			F03	Gully
		C03	Sandy Coast	F05	River levee
MoB	Block Mountain			F06	Floodplain
MoF	Fault Mountain	E05	Playa	F07	Alluvial Terrace
MoR	Residual Mountain			F09	Depression
Mou	Mountain	F04	Braided river plain	F14	Upper pediment
MoV	Volcanic Mountain	F05	Meandering river plain	F15	Middle pediment
		F08	Badland (complex gully)	F16	Lower pediment
Pie	Piedmont	F09	Gully/Rill erosion surface		
		F10	Sheet erosion surface	X01	Summit of the slope
PlA	Alluvial Plain	F12	Alluvial plain	X02	Shoulder of the slope
PlC	Coastal Plain	F13	Depression	X03	Backslope
PlD	Dissected Plain	F14	Pediment	X04	Footslope
Pln	Plain	F15	Dissected pediment	X05	Toe-slope
		F16	Delta	X06	Upper Slope
Pta	Plateau	F17	Flat floor valley	X07	Lower slope
PtD	Dissected Plateau	F18	River plain	X08	Slope complex
		F25	River incision	X09	Crest
Vay	Valley				
		G08	Talus slope		
		S08	Escarpment		
		S15	Depression (structural)		
		S16	Dissected ridge		
		S24	Inselberg		
		S25	Cuesta		
		S26	Mesa		
		S27	Hog back		
		S29	Hill		
		S30	Hill complex		
		S31	Ridge		
		S32	Planation surface		
		S33	Denudational slope		
		S34	Slope		
		S35	Denudational surface		

Slope map

The slope map was produced using the corrected SRTM Digital Elevation Model. The surface spatial analyst extension of Arc GIS 9.0 was used to derive slope classes according to variability in the area. The slope classes used can be found in Table 7. Map 6 shows slope distribution in the study area.

Table 7: Slope classes

SLOPE CLASS	RANGE %
1	0-3
2	3-8
3	8-15
4	15-25
5	25-40
6	40-65
7	65-100

Soil moisture regime map

Soil moisture and temperature regimes in the area were calculated using climatic data that was entered into the NSM (Newhall Simulation Model) software package [22]. Once the soil moisture regime for each climatic station was obtained, the values were interpolated using ILWIS 3.3. software and incorporating the DEM as a correlation factor. This was not performed for the soil temperature regime due to low variability. The

different soil moisture regimes and temperature regimes can be found in Table 8 and the soil moisture regime for the area can be seen in Map 7.

Table 8: Soil moisture and temperature regimes

STATION	MOISTURE REGIME	TEMPERATURE REGIME	DRY-D/M-MOIST	TENTATIVE SUB-DIVISION
Hargeisa	Aridic	Isohyperthermic	290-70-0	Typic Aridic
Gebiley	Aridic	Isohyperthermic	258-102-0	Typic Aridic
Borama	Aridic	Isohyperthermic	250-110-0	Weak Aridic
Berbera	Aridic	Isohyperthermic	360-0-0	Extreme Aridic
Burao	Aridic	Isohyperthermic	345-15-0	Typic Aridic
Shiekh	Aridic	Isothermic	213-147-0	Weak Aridic

Soil Temperature Regimes

Isothermic
The mean annual soil temperature is 15°C or higher but lower than 22°C.

Isohyperthermic
The mean annual soil temperature is 22°C or higher, and the difference between mean summer and mean winter soil temperature is less than 5°C at a depth of 50 cm.

Soil Moisture Regimes

Aridic
The soil moisture control section is, in normal years:

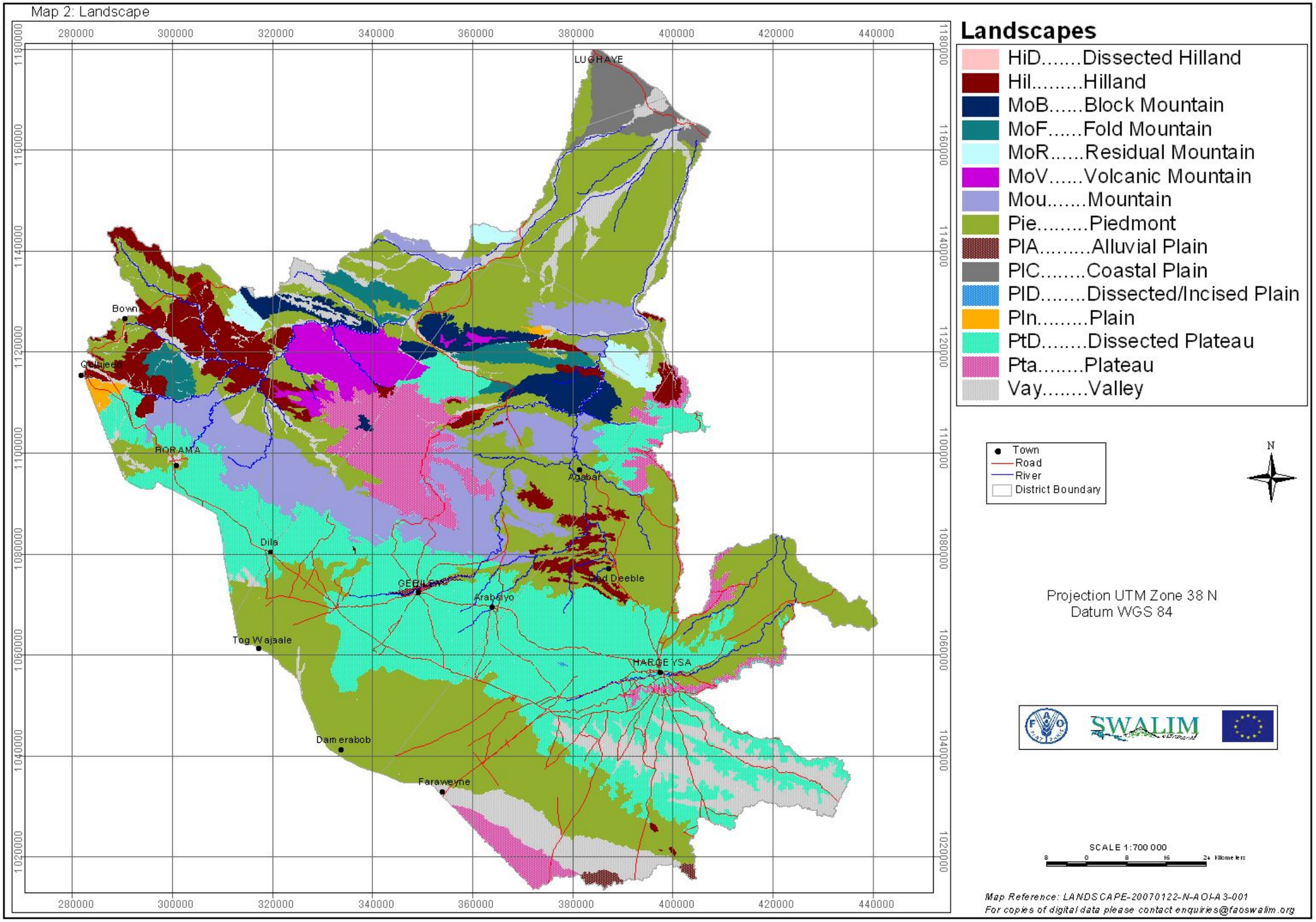
- Dry in all parts for more than half of the cumulative days per year when the soil temperature at a depth of 50 cm from the soil surface is above 5°C; and
- Moist in some or all parts for less than 90 consecutive days when the soil temperature at a depth of 50 cm is above 8°C.

Extreme Aridic
The soil moisture control section is always completely dry. Cultivation is not possible without irrigation.

Typic Aridic
The soil moisture control section is moist in some or all parts at same time in the year for 45 consecutive days or less when the soil temperature at 50 cm depth is more than 8°C. Cultivation is not possible without irrigation.

Weak Aridic
The soil moisture control section is moist in some or all parts at same time in the year for 45 consecutive days or more when the soil temperature at 50 cm depth is more than 8°C. Cultivation is possible without irrigation for a short period.

Map 2: Landscape



Landscapes

- HiD.....Dissected Hilland
- Hil.....Hilland
- MoB.....Block Mountain
- MoF.....Fold Mountain
- MoR.....Residual Mountain
- MoV.....Volcanic Mountain
- Mou.....Mountain
- Pie.....Piedmont
- PlA.....Alluvial Plain
- PlC.....Coastal Plain
- PlD.....Dissected/Incised Plain
- Pln.....Plain
- PtD.....Dissected Plateau
- Pta.....Plateau
- Vay.....Valley

Town
Road
River
District Boundary

N

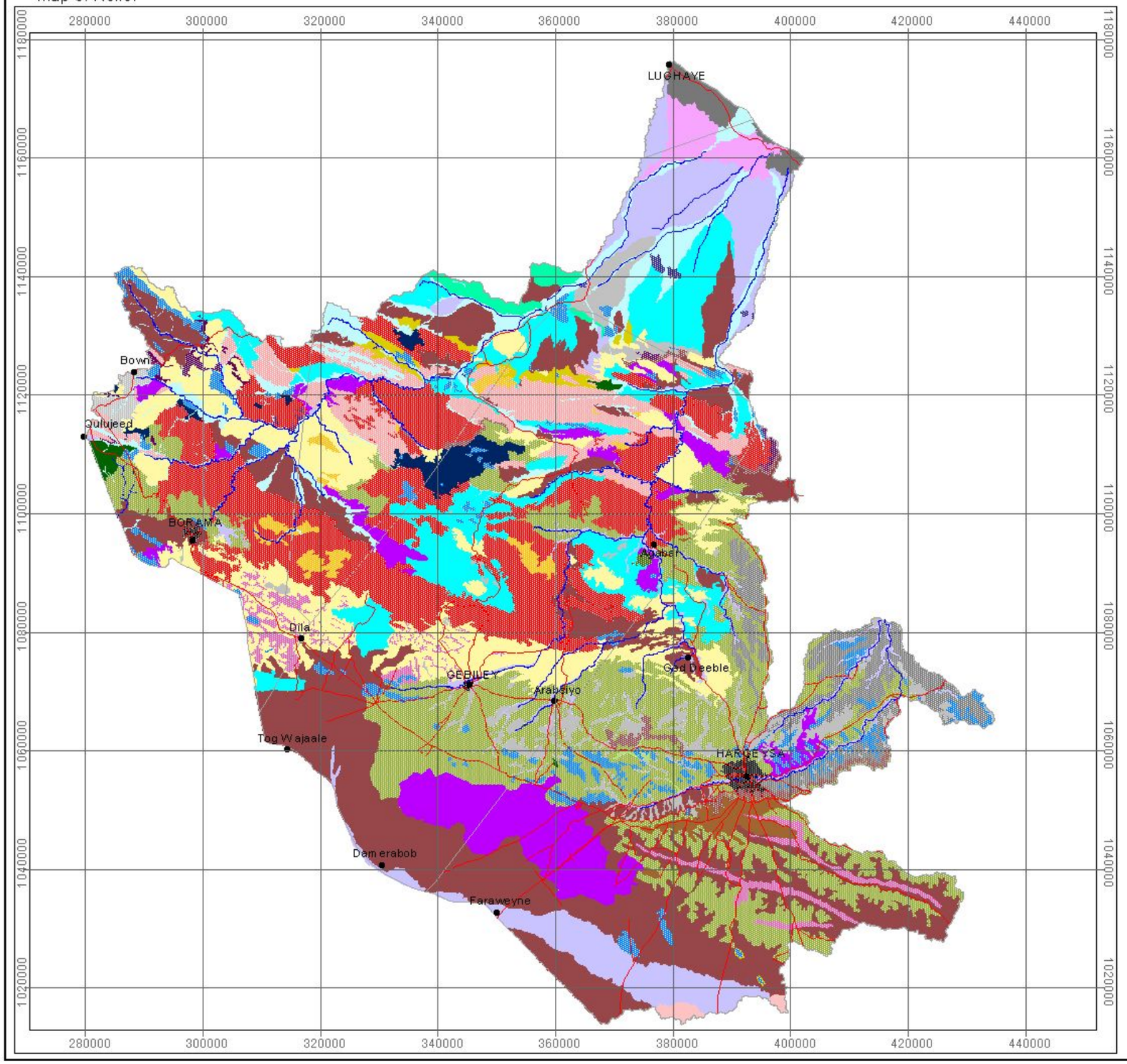
Projection UTM Zone 38 N
Datum WGS 84

SWALIM

SCALE 1:700 000
8 0 8 16 24 Kilometers

Map Reference: LANDSCAPE-20070122-N-AOI-A3-001
For copies of digital data please contact enquiries@faoswalim.org

Map 3: Relief



Relief

- A02.....Industrial District
- C03.....Sandy Coast
- E05.....Playa
- F04.....Braided River Plain
- F05.....Meandering River Plain
- F08.....Badland (Complex Gulley)
- F09.....Gulley/Rill Erosion Surface
- F10.....Sheet Erosion Surface
- F12.....Alluvial Plain
- F13.....Depression
- F14.....Pediment
- F15.....Dissected Pediment
- F16.....Delta
- F17.....Flat Floor Valley
- F18.....River Plain
- F25.....River Incision
- G08.....Talus Slope
- S08.....Escarpment
- S15.....Depression
- S16.....Dissected Ridge
- S24.....Inselberg
- S25.....Cuesta
- S26.....Mesa
- S27.....Hogback
- S29.....Hill
- S30.....Hill Complex
- S31.....Ridge
- S32.....Planation Surface
- S33.....Denudational Slope
- S34.....Slope
- S35.....Denudational Surface

- Town
- Road
- River
- District Boundary

N

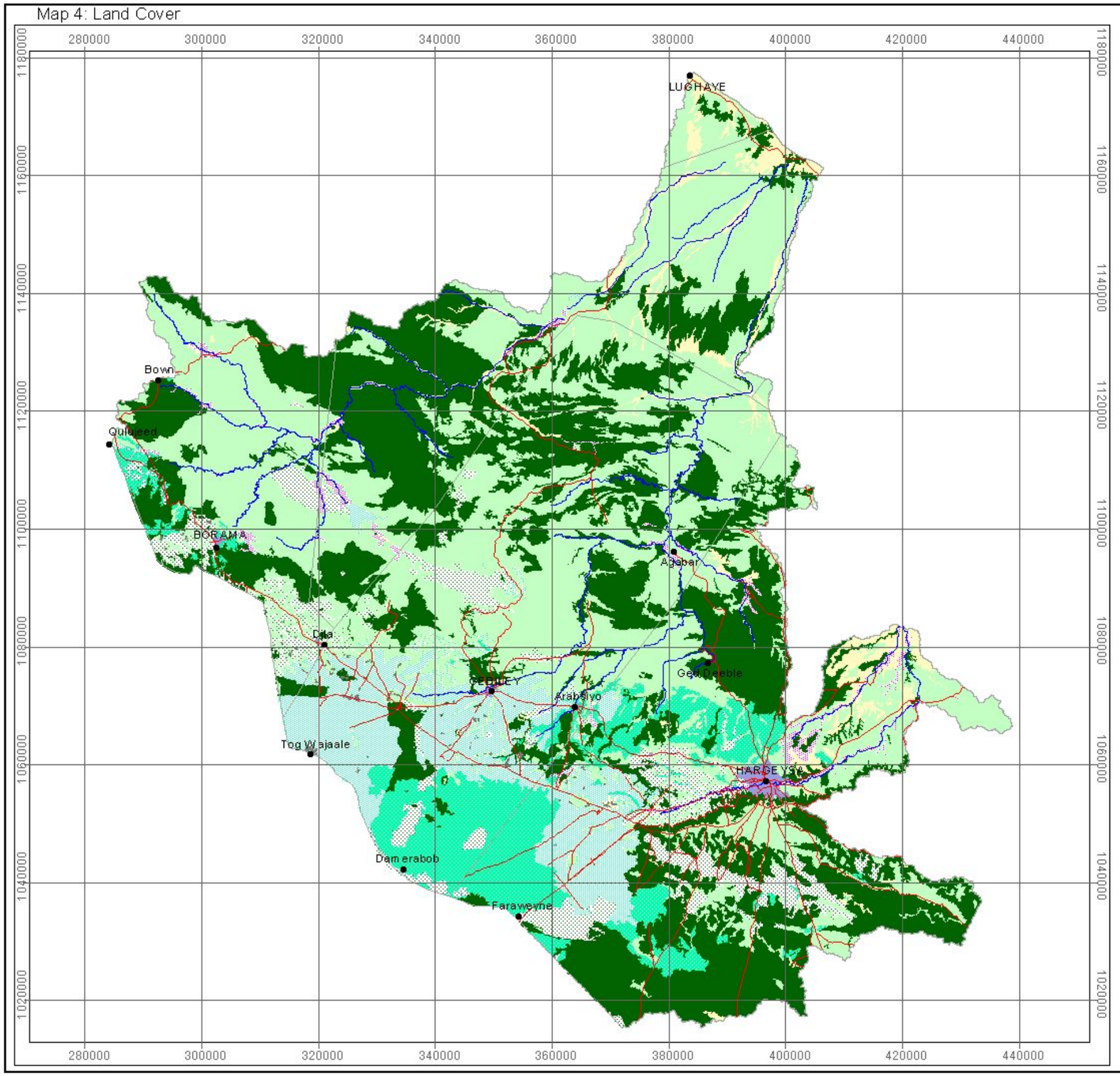
Projection UTM Zone 38 N
Datum WGS 84

SWALIM

SCALE 1:700 000
8 0 8 16 24 Kilometers

Map Reference: RELIEF-20070122-N-AOI-A3-001
For copies of digital data please contact enquiries@faoswalim.org

Map 4: Land Cover



Land Cover

- Herbaceous Vegetation
- Herbaceous Vegetation /Rainfed Crops
- Irrigated Orchards
- Rainfed Crops
- Wooded Vegetation /Rainfed Crops
- Wooded Vegetation
- Bare Areas
- Rural Settlements
- Urban Settlement

- Town
- Road
- River
- District Boundary

N

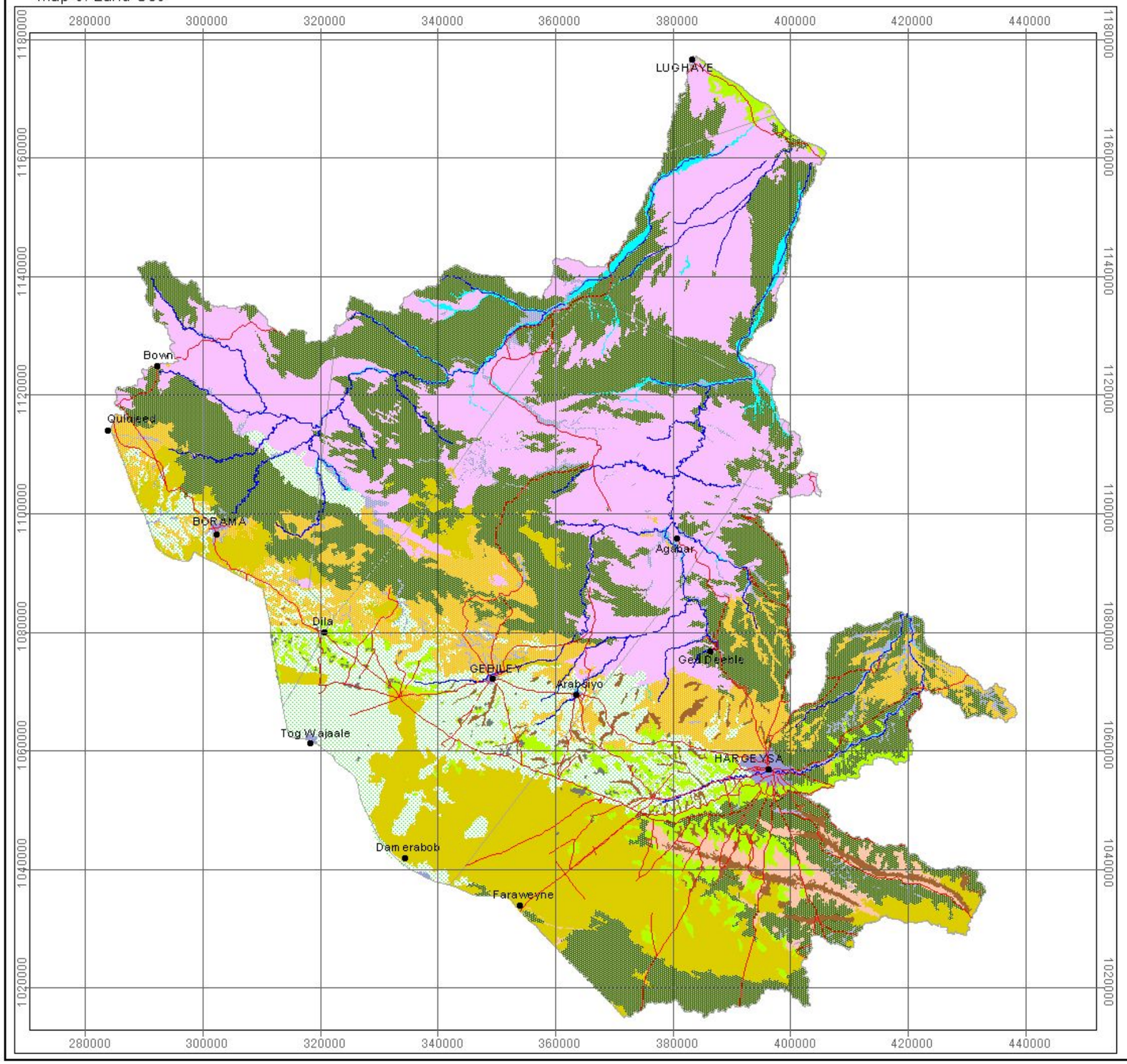
Projection UTM Zone 38 N
Datum WGS 84

SWALIM

SCALE 1:700 000
8 0 8 16 24 Kilometers

Map Reference: LANDCOVER-20070122-N-AOLA3-002
For copies of digital data please contact enquiries@faoswalim.org

Map 5: Land Use



Land Use

- Hay Production /Rainfed Agriculture
- Rainfed Agriculture /Sedent. Pastoralism
- River Water Harvesting
- Semi Sedentary Pastoralism
- Transhumance/Hay /Wood Collection/Rainfed
- Transhumance /Irrigated Orchards
- Transhumance /Rainfed Agriculture
- Transhumance/Rainfed Agriculture/Wood
- Transhumance/Sedentary Pastoralism/Wood
- Transhumance/Semi Sedentary Pastoralism
- Airport
- Rural Settlement
- Urban Area

- Town
- Road
- River
- District Boundary

N

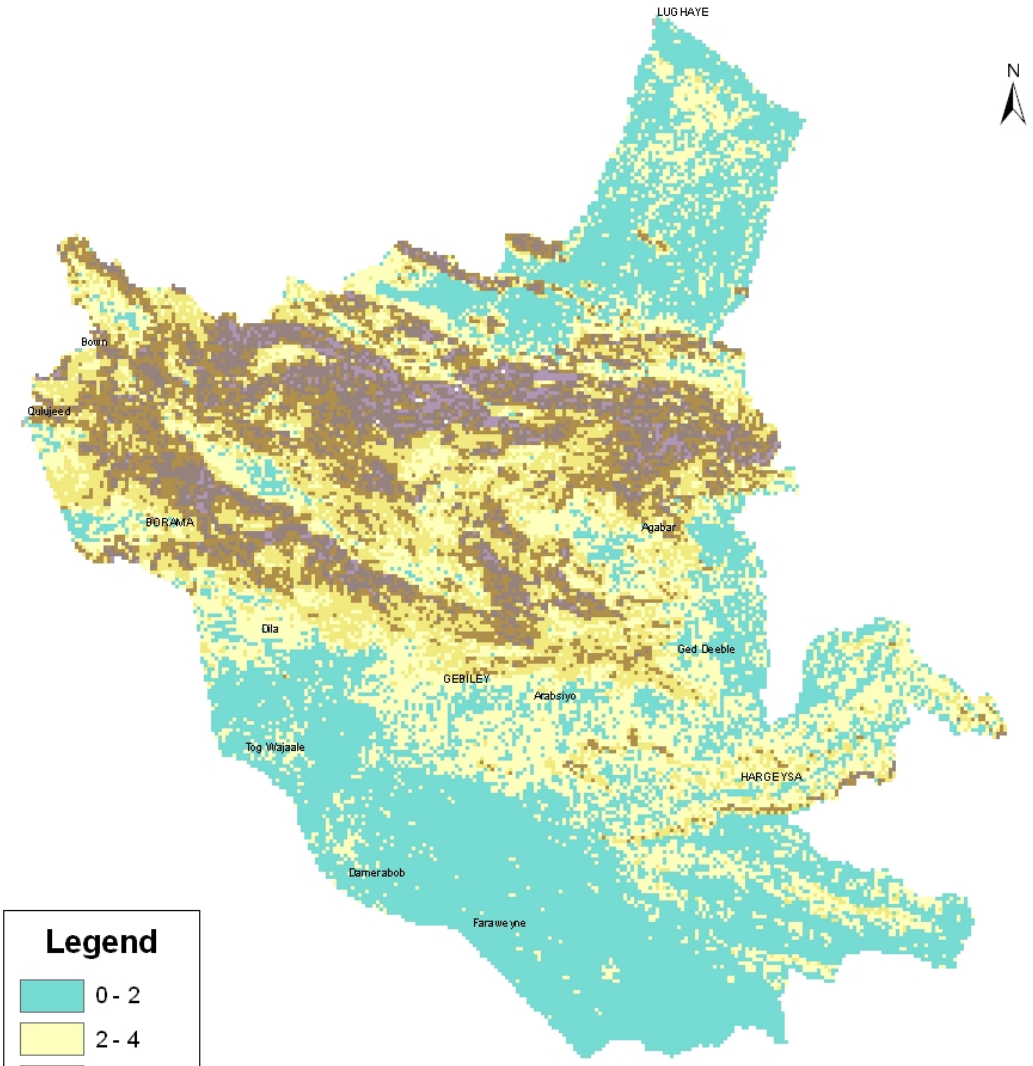
Projection UTM Zone 38 N
Datum WGS 84

SWALIM

SCALE 1:700 000
8 0 8 16 24 Kilometers

Map Reference: LANDUSE-20070122-N-A0-A3-002
For copies of digital data please contact enquiries@faoswalim.org

MAP 6: Slopes



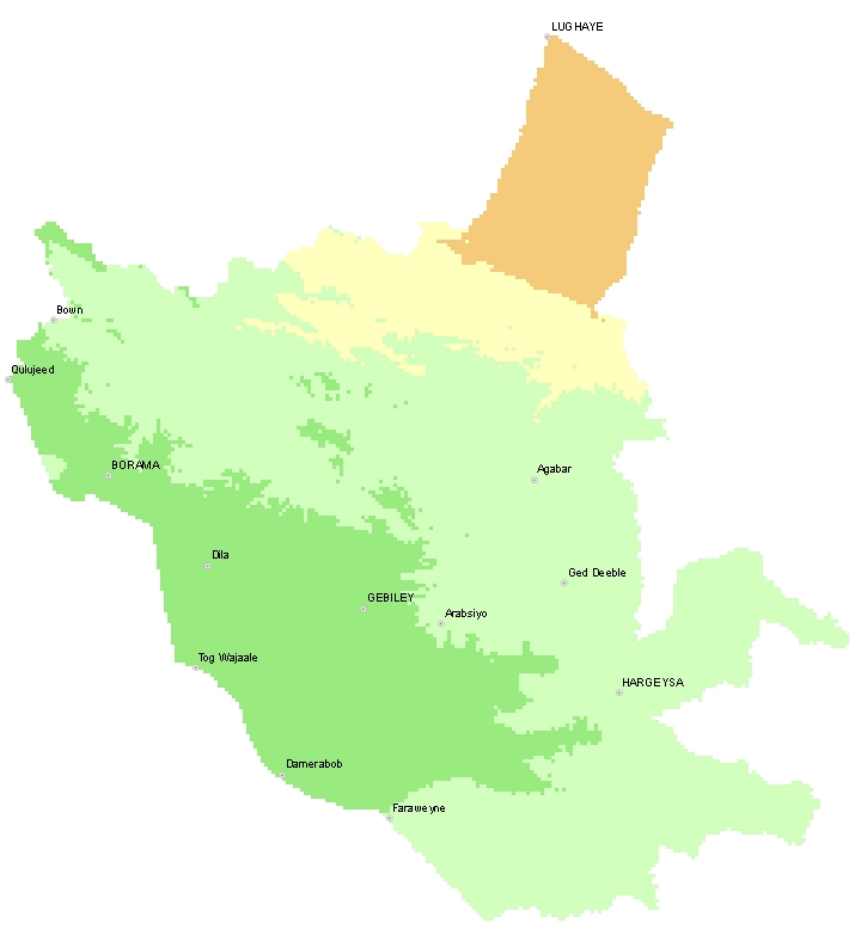
Legend

- 0 - 2
- 2 - 4
- 4 - 8
- 8 - 16
- 16 - 30
- 30 - 50
- 50 - 100
- towns_fs

SWALIM

The boundaries and names on these maps do not imply official endorsement or acceptance by the United Nations

MAP 7: Soil Moisture Regime



Legend

- Extreme Aridic
- Aridic
- Typic Aridic
- Weak Aridic

SWALIM

The boundaries and names on these maps do not imply official endorsement or acceptance by the United Nations

3.2.10 Development of a key to separate soil classes based on environmental variables

Taking into consideration the geographic context of the study area, there is a theoretical soil genesis that has determined the soil classes that can occur there. Overall soil patterns can be understood using the soil-landscape model. However, it was important to develop a key that is able to establish or predict soil type occurrences using the different soil environmental attributes generated previously.

The development of this key is the core behind this model, as it characterises the environment where each individual soil class might be formed.

An example of the key can be found below in Figure 5.

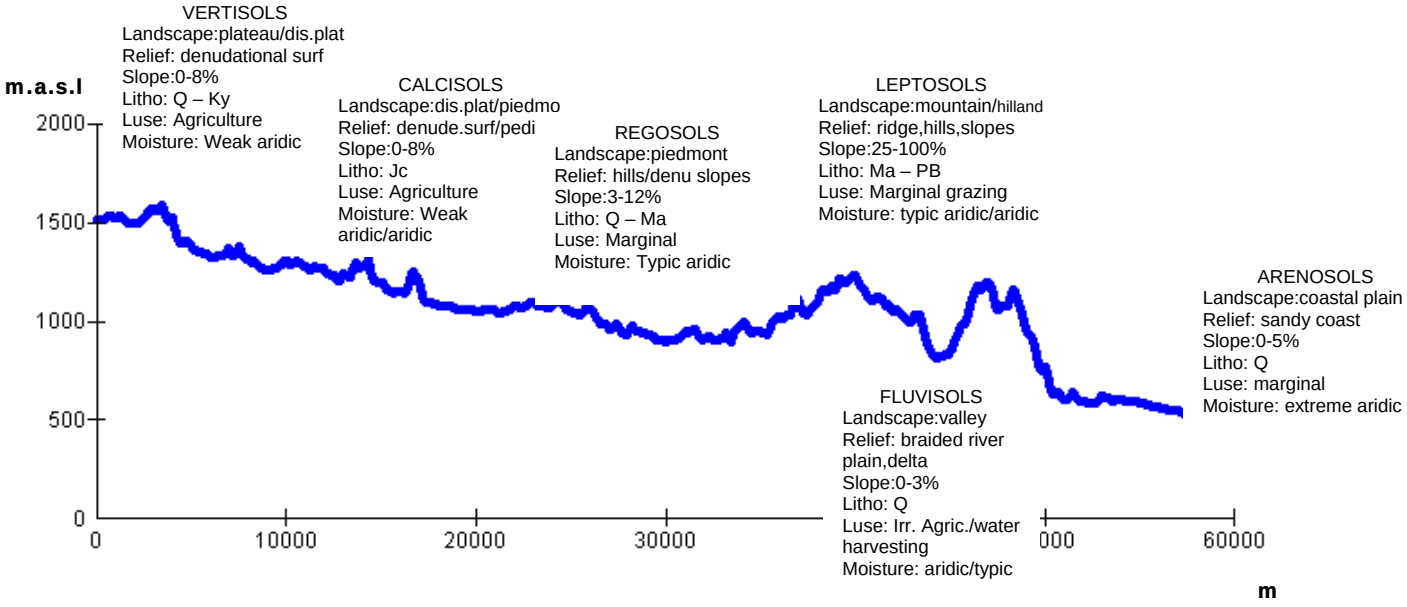


Figure 5: Soil-environmental characterisation

This key was later used to create different decision trees to infer or predict the occurrence of each soil class in a specific geographic position where the environmental characteristics are met.

3.2.11 Characterisation of soil classes (decision tree)

The aim of the decision trees was to design a set of predictive rules, using available data layers to guide the process of prediction or inference of the different soil classes in the study area according to its geographic patterns. These predictive rules were obtained using the key developed previously, where the environmental conditions where each soil class should be found were established. The general decision tree can be observed in Figure 6. and can be read it conditionally from column one and generating the last column where the soil class is expected under those specific environmental variables.

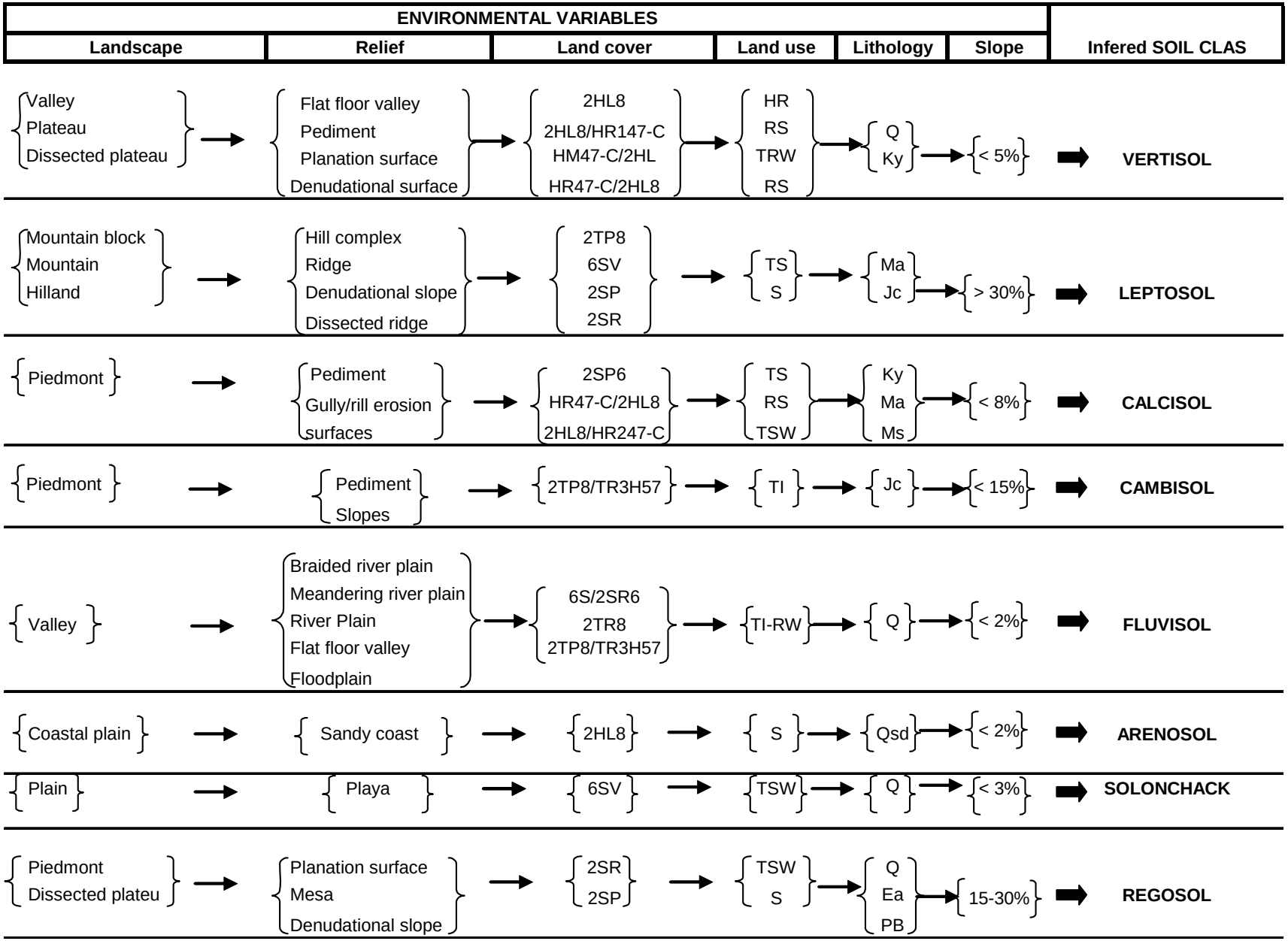


Figure 6: Decision tree

3.2.12 Running the soil prediction model

The prediction model was run using ILWIS 3.3 software. All decision trees created in the previous step were written using Map Calculation formulas into a spatial analysis process.

The model was run twice, according to the two different map scales (1:100.000 and 1:50.000) produced.

An example of the written formulas in the Map Calculation format can be found next:

At 1:100.000

Soil2=iff((lands="Pta")and(relief="S32")and(lc="2SP7/HM147-C") and(luse="TRW")and(Litho=”Ky”), "calcic vertisol", soil1)

At 1:50.000

Soil2=iff((lands="Vay")and(relief="F14")and(lc="2HL/HR147-C") and(luse="HR")and(Litho=”Q”),and (Slope=”1”)and(Moisture=”3”),”b”, soil1)

b=Calcic Grumic Vertisol (Hyposodic, Chromic)

After running all formulas for both map scales, a raster map was produced and exported into a standard format compatible with the Geodataset developed by SWALIM for storing the different data layers. This map was subjected to verification and validation through quality assessment and improvement.

3.2.13 Verification and validation of the soil maps

When producing thematic maps, it is important to indicate accuracy levels for the benefit of users. Verification and validation procedures were applied to the two soil maps produced (at 1:100.00 and 1:50.000), using two different approaches that share the same principle.

Firstly, a *verification process* based mainly on the expert knowledge [10] of a soil scientist familiar with the study area, was conducted. This process involved two steps: a) a reviewed of overall soil patterns of the inferred soil map to determine any mismatches according to the scientist’s own soil-landscape model (which was the main mapping concept). b) After reviewing the overall pattern, a soil scientist evaluated specific knowledge on soil classes, especially in transitional areas where he has field knowledge. This step was done generating random points distributed throughout the study area, through the use of Random Point Generator, an ArcView extension developed by Jenness [23]. The soil scientist then applied his expert knowledge to each random point and compared the inferred soil class with his knowledge of that specific point according to environmental variables forming that specific soil class. An error matrix was produced showing mismatches.

Secondly, a validation process based on field soil profiles collected during the field survey was performed. This involved a similar process of comparison, differing in comparison of observed soil classes in the field and those that were inferred. Similarly, an error matrix was produced showing mismatches between soil classes. A general accuracy for the map was produced using data produced by the error matrix.

Once the verification and validation process was performed, we corrected the main anomalies or mismatches of the prediction system, mainly related to the decision tree, so, we have adjusted the decision tree for some specific cases.

4 RESULTS

4.1 Soil profiles

Eighty-two soil profiles were described in the course of this soil survey. Fifty out of the 82 profiles were completely described, including both site and profile descriptions, and soil samples being sent for chemical and physical analyses. The remaining 32 profiles consisted only of site descriptions due to their rocky and stony characteristics that did not allow digging of profiles and subsequent description. Soil classification was however possible.

All profiles and site descriptions were classified using WRB 2006 and stored in a soils database. Complete soil descriptions can be found in Appendix 3. Map 8 shows the distribution of the 82 profiles in the study area.

4.2 Soil map at 1:100 000 scale

A 1:100 000 soil map (Map 9) of the whole study area was produced using the Reference Soil Groups level and Prefix qualifier level of the WRB 2006 classification system. Soils encountered were mainly Vertisols, Leptosols, Regosols, Calcisols, Fluvisols, Arenosols, Cambisols and Solonchaks. Soils extent and distribution as shown in Map 9 is as follows (Table 9):

Table 9: Area of soil reference classes and key properties

Class (Reference Group)	Km²	%	Key properties
Vertisols			Soils influenced by water; alternating wet-dry conditions, rich in swelling clays.
Calcic Grumic Vertisol	1252	22.9	
Calcic Mazic Vertisol	97		
Calcic Vertisol	1440		
Haplic Vertisol	170		
Fluvisols			Soils influenced by water; floodplains, valleys, marshes
Calcic Endosalic Fluvisol	117	15.1	
Calcic Fluvisol	47		
Haplic Fluvisol	771		
Haplic Fluvisol (Skeletic)	1020		
Calcisols			Soils with accumulation of calcium carbonate.
Endosalic Calcisol	49	9.1	
Haplic Calcisol	558		
Hypercalcic Calcisol	46		
Luvic Calcisol	120		
Petric Calcisol	27		
Vertic Calcisol	368		
Vertic Petric Calcisol	11		
Cambisols			Moderately developed soils.
Fluvic Cambisol	432	3.3	
Arenosols			Sandy soils located in coastal plains.
Haplic Arenosol	89	0.7	
Leptosols			Shallow or extremely gravelly soils.
Haplic Leptosol	216	38.6	
Haplic Leptosol (Skeletic)	304		
Haplic Leptosol (Skeletic)/Haplic Regosol	200		
Hyperskeletic Leptosol	1093		
Hyperskeletic Lithic Leptosol	1392		
Lithic Leptosol	1097		
Hyperskeletic Lithic Leptosol/Haplic Regosol	230		
Hyperskeletic Lithic Leptosol/Haplic Regosol (Skeletic)	462		
Solonchaks			Soils with salt enrichment upon evaporation.
Haplic Solonchak	25	0.2	
Regosols			Soils with no significant profile development.
Haplic Regosol	967	7.5	
Haplic Regosol (Skeletic)	287	2.2	
Haplic Regosol/Haplic Calcisol			
Technosols	49	0.4	Urban soils in the main towns: Hargeisa, Gebiley and Borama.
Total	**12934**	**100**	

The dominant soils in the study area are Leptosols and Regosols. Difficulties were encountered in separating them due to limited field data in this inaccessible area, as well as them sharing some common characteristics.

The second-most dominant soils are the Vertisols, found mainly in agropastoral areas of the area of interest. The Fluvisols are also present, in a considerable extension located mainly in the fluvial system of the area of interest. A considerable amount of Calcisols and Cambisols are also found, which are characteristic soils of the **environment** area?. Arenosols are respresented in a very small area in the coastal region of the area of interest and Solonchaks which are found in the *playas* in the southern part of the area of interest. The Technosols, corresponding to the main urban areas, were not studied in detail, so were kept at the reference group level in WRB 2006.

4.2.1 Technical description of the soil classes

Vertisols (Profiles 101, 109, 122, 125, 303, 305, 307, 309, 306, 308, 323, 329, 117, 121, 301, 120, 123, 302, 325, 316, 328, 102, 304, 321, 326)

Vertisols occur in the Plateau and dissected plateau between Hargeisa, Gebiley and Borama, south of the Al Mountains. The plateau is mostly flat apart from areas of uneven relief, slopes towards streams and rolling surfaces. From a climatic point of view this area is considered as semi-arid due to its higher annual rainfall of 500 mm in comparison to the rest of the study area; this situation positively influences soil formation processes. These soils are located in the unique agro-pastoral system of the study area commonly called the “sorghum belt”. Many water-harvesting techniques hva ebeen and are applied in this area, which in some cases were poorly designed and are causing gully and rill soil erosion.

Vertisols are churning, deep heavy clay soils with a high proportion of swelling clays. These soils form deep, wide cracks from the surface downward to more than 50 cm below the surface when they dry out, which happens in most years. These cracks are not always well represented on the surface due to them filling with sand.

Vertisols are fine-textured soils dominated by expanding montmorillonite clay minerals. The minerals normally expand and contract on wetting and drying, respectively. In the dry condition the soils develop a shallow grumic or granular mulch structure and form wide cracks on the surface. The cracks extend vertically separating blocky and prismatic structures. Some of the mulch falls or is washed into the cracks during rains so that this causes a mix up effect in the whole profile in the alternating wetting and drying when expansion pressure happens in the lower horizon. The effect of the pressure develops slip-faces (slickensides) and wedge shaped structure in the lower horizons and often to gilgai micro-relief at the surface. The soil becomes plastic and sticky when wet and the cracks close. The soils become very hard when dry.

The Vertisols in the study area generally contain more than 35% clay increasing with depth, and they fall exclusively into the clay classes (see Table 10). Parent materials are mostly sediments that contain a high proportion of swelling clays, or products of rock weathering that have the characteristics of swelling clays. The soil structure of these vertisols is largely influenced by prevailing soil moisture content, which is demonstrated in dry conditions where the soils are often very hard except for the top 10 - 20 cm where there is natural, friable self-mulching layer.

PROFILE	LAB_CODE	HORIZON	DEPTH	SAND %	SILT %	CLAY %	TEXTURE	Bulk_density (g/cm)	C_%	N_%	P_ppm	PH(H2O)	EC mS/cm	CECm_meq/100g	Ca++	Mg++	K+	Na+	PSB_%	CaCO3_%
101	1645	A1	0-35	28.0	14.0	58.0	**C**	1.26	0.60	0.03	8.90	8.20	0.22	14.80	24.6	1.6	1.4	2	100.0	28.00
101	1646	A2	35-65	24.0	16.0	60.0	**C**		0.50	0.03	35.50	8.40	0.20	11.80	18.8	0.3	1.1	1	100.0	30.00
101	1647	Bt	65-130	24.0	14.0	62.0	**C**		0.30	0.03	11.50	8.70	0.25	0.30	17.3	0.3	0.8	2	100.0	31.00
102	1648	A1	0-20	38.0	16.0	46.0	**C**	1.46	0.70	0.05	2.60	8.30	0.23	16.20	22.5	2.2	1.9	2	100.0	30.00
102	1649	A2	20-30	24.0	20.0	56.0	**C**		0.50	0.04	8.50	8.10	0.98	17.80	25.8	2.6	1.2	2	100.0	31.00
102	1650	B1	30-50	24.0	20.0	56.0	**C**		0.70	0.03	14.10	8.20	1.30	17.60	24.1	4.4	1.2	3	100.0	30.00
102	1651	B2	50-65	20.0	22.0	58.0	**C**		0.40	0.03	12.80	8.20	1.50	17.60	15	3.1	0.7	3	100.0	24.00
102	1652	C	65-130	22.0	20.0	58.0	**C**		0.40	0.03	10.80	8.20	2.20	16.60	19.4	4.4	0.52	3	100.0	28.00
109	1858	A1	0-10	52.0	4.0	44.0	**SC**	1.51	1.08	0.09	11.00	8.15	0.14	39.22	36.22	3.68	0.91	3.97	100.0	25.65
109	1859	A2	10-45	24.0	20.0	56.0	**C**		0.44	0.03	11.80	8.04	0.24	18.16	86.29	4.57	0.57	1.60	100.0	34.15
109	1860	Bk	45-100	18.0	22.0	60.0	**C**		0.62	0.06	10.90	8.13	2.07	26.22	20.31	7.95	0.60	1.03	100.0	28.15
117	1875	Ap	0-15	32.0	20.0	48.0	**C**	1.44	1.20	0.13	10.00	8.13	0.58	16.88	25.25	3.10	1.57	1.50	100.0	20.65
117	1876	AB	15-40	28.0	16.0	56.0	**C**		0.98	0.11	6.30	8.06	0.58	21.11	38.99	4.72	1.15	1.13	100.0	26.65
117	1877	Bt1	40-75	26.0	14.0	60.0	**C**		0.91	0.09	12.50	8.20	2.98	21.98	20.19	6.41	1.00	1.40	100.0	30.65
117	1878	Bt2	75-96	20.0	26.0	64.0	**C**		0.66	0.05	9.20	8.29	0.30	22.56	22.56	9.23	0.53	2.43	100.0	31.65
117	1879	C	96-135	20.0	14.0	66.0	**C**		0.44	0.04	7.90	8.51	1.80	22.12	17.08	8.22	0.78	4.70	100.0	35.65
120	1889	A1	0-10	30.0	22.0	48.0	**C**	1.42	1.56	0.18	30.40	8.16	0.33	9.86	13.43	2.40	1.08	1.05	100.0	23.50
120	1890	A2	10-40	30.0	18.0	52.0	**C**		1.06	0.11	9.30	8.22	0.40	21.24	24.80	4.72	1.38	1.65	100.0	25.00
120	1891	Bt1	40-75	28.0	14.0	58.0	**C**		0.87	0.08	14.70	8.45	2.65	18.80	19.08	5.99	1.06	3.00	100.0	26.00
120	1892	Bt2	>75	72.0	16.0	12.0	**LS**		0.87	0.04	9.90	8.37	0.20	11.00	20.68	2.07	0.48	0.50	100.0	22.00
121	1893	A1	0-20	30.0	24.0	46.0	**C**	1.54	1.56	0.19	22.60	8.21	0.31	11.00	14.50	2.92	1.72	1.50	100.0	27.00
121	1894	A2	20-45	28.0	14.0	58.0	**C**		0.59	0.06	12.60	8.46	0.32	26.60	25.64	4.52	1.06	1.75	100.0	20.00
121	1895	Bt	45-80	28.0	14.0	58.0	**C**		0.88	0.09	22.30	8.18	1.23	19.80	22.86	4.52	1.46	1.45	100.0	25.00
121	1896	Ck	80-140	20.0	14.0	66.0	**C**		0.51	0.05	13.90	8.47	1.37	19.06	11.29	3.18	0.26	1.85	100	30.00
301	1901	A1	0-30	30.0	22.0	48.0	**C**	1.38	0.77	0.10	10.90	8.25	1.04	19.80	16.88	4.54	0.10	1.65	100.0	20.50
301	1902	A2	30-70	28.0	22.0	50.0	**C**		0.54	0.10	11.90	8.32	0.45	29.18	8.08	3.57	0.80	1.25	100.0	17.50
301	1903	Btk	70-160	32.0	22.0	46.0	**C**		0.53	0.04	7.50	8.28	0.21	24.20	26.80	1.12	1.06	1.10	100.0	18.00
301	1904	C	160-170	12.0	28.0	60.0	**C**		0.41	0.06	8.70	8.80	0.39	14.53	21.26	7.70	0.86	3.75	100.0	23.50
123	2086	A1	0-25	26.0	38.0	36.0	**CL**	1.48	0.74	0.08	8.60	8.04	0.21	13.68	26.88	2.15	0.30	0.45	100.0	16.35
123	2087	A2	25-45	24.0	10.0	66.0	**C**		0.81	0.09	6.80	8.07	0.53	31.28	37.20	8.21	0.56	1.10	100.0	23.35
123	2088	Bt	45-70	22.0	8.0	70.0	**C**		0.63	0.08	4.70	8.28	1.30	21.08	17.06	5.89	0.28	1.50	100.0	30.85
123	2089	C	70->80	14.0	12.0	74.0	**C**		0.46	0.06	16.10	8.42	1.95	19.28	12.44	7.82	0.38	2.55	100.0	31.85
302	2104	Ap	0-15	48.0	10.0	42.0	**SC**	1.39	1.31	0.15	19.30	8.01	0.70	19.08	31.85	1.93	1.24	1.50	100.0	14.85
302	2105	A2	15-45	40.0	10.0	50.0	**C**		0.90	0.13	10.30	7.86	1.20	18.88	25.89	3.36	0.92	0.80	100.0	19.85
302	2106	Btk	45-65	42.0	4.0	54.0	**C**		0.67	0.11	4.60	8.07	0.65	22.08	37.50	5.54	0.58	0.95	100.0	17.85
302	2107	Ck	65->130	36.0	8.0	56.0	**C**		0.35	0.04	12.70	8.38	0.65	16.08	23.43	4.35	0.32	1.95	100.0	25.85
303	2108	Ap	0-20	42.0	4.0	54.0	**C**	1.39	0.96	0.09	10.30	8.14	0.27	18.12	28.40	3.68	1.36	1.45	100.0	23.35
303	2109	A2	20-39	28.0	10.0	62.0	**C**		0.69	0.07	10.90	8.29	0.35	24.28	31.54	2.52	1.24	1.60	100.0	28.85
303	2110	Bt1	39-65	26.0	10.0	64.0	**C**		0.54	0.06	11.80	8.57	0.45	19.28	17.86	7.17	0.80	2.45	100.0	29.35
303	2111	Bt2	65-115	26.0	8.0	66.0	**C**		0.51	0.05	8.00	8.70	0.80	15.48	16.03	8.08	0.40	3.30	100.0	30.85
303	2112	Ck	>115	18.0	10.0	72.0	**C**		0.30	0.04	7.70	8.34	2.80	20.48	8.83	3.24	0.14	2.10	100	32.85
304	2113	A1	0-15	32.0	8.0	60.0	**C**	1.33	0.92	0.13	8.90	8.20	0.50	21.08	38.11	4.05	1.40	1.70	100.0	24.85

304	2114	A2	15-40	26.0	12.0	62.0	**C**		0.77	0.11	8.30	8.09	1.65	21.68	26.98	6.54	0.90	1.95	100.0	28.35
304	2115	Bt	40-100	26.0	8.0	66.0	**C**		0.55	0.06	5.90	8.42	2.15	25.08	22.41	9.93	0.32	1.95	100.0	30.85
304	2116	C	100-130	20.0	8.0	72.0	**C**		0.40	0.05	4.60	8.46	2.70	27.28	18.53	7.87	0.22	2.15	100.0	33.35
305	2117	A1	0-10	32.0	12.0	56.0	**C**	1.45	0.95	0.11	4.50	8.19	0.35	25.07	37.22	3.27	1.30	1.30	100.0	24.85
305	2118	A2	10-35	26.0	14.0	60.0	**C**		0.92	0.10	2.10	8.20	0.35	25.48	30.23	4.43	0.98	1.15	100.0	25.85
305	2119	B1	35-85	28.0	10.0	62.0	**C**		0.61	0.07	3.50	8.70	0.40	22.28	27.17	9.49	0.44	2.20	100.0	27.85
305	2120	B2	85-140	24.0	10.0	66.0	**C**		0.44	0.05	8.20	8.78	0.90	14.08	13.63	10.93	0.16	1.45	100.0	31.85
306	2121	A	0-23	42.0	6.0	52.0	**C**	1.35	0.56	0.08	8.30	8.19	0.40	21.08	33.60	2.99	1.68	1.80	100.0	16.35
306	2122	AB	23-40	46.0	4.0	50.0	**C**		0.66	0.08	11.90	8.01	1.15	22.48	25.92	8.49	0.80	0.80	100.0	17.50
306	2123	Btk	40-85	46.0	6.0	48.0	**C**		0.50	0.06	5.20	8.15	1.00	23.88	21.95	1.24	0.56	0.70	100.0	19.00
306	2124	Ck	>85	38.0	10.0	52.0	**C**		0.40	0.04	5.10	8.32	0.75	23.48	16.97	5.58	0.68	1.95	100.0	21.00
307	2125	A1	0-15	26.0	10.0	64.0	**C**	1.35	0.72	0.09	7.00	8.23	0.29	25.08	37.82	5.11	1.68	2.20	100.0	25.00
307	2126	A2	15-30	30.0	10.0	60.0	**C**		0.68	0.08	9.10	8.49	0.40	26.48	34.01	6.18	1.76	2.65	100.0	27.50
307	2127	B2k	30-110	20.0	12.0	68.0	**C**		0.40	0.06	4.70	8.63	1.55	20.08	18.12	5.45	0.48	3.00	100.0	30.50
307	2128	Ck	110-160	64.0	4.0	32.0	**SCL**		0.22	0.04	2.90	8.34	1.60	7.28	12.34	2.12	0.20	0.70	100.0	18.00
308	2129	A1	0-10	42.0	10.0	48.0	**C**	1.53	1.00	0.10	9.70	8.20	0.45	14.08	22.90	2.28	1.02	1.20	100.0	19.50
308	2130	A2	10-25	34.0	12.0	54.0	**C**		0.79	0.09	5.70	8.11	0.90	24.08	25.23	3.55	0.90	1.20	100.0	23.50
308	2131	Bk	25-85	34.0	8.0	58.0	**C**		0.41	0.05	1.50	8.56	1.80	21.08	22.98	9.54	0.52	2.60	100.0	25.50
308	2132	Ck	85-130	26.0	12.0	62.0	**C**		0.33	0.04	2.80	8.51	2.40	20.08	23.71	8.38	0.40	2.70	100.0	30.00
309	2133	A1	0-15	34.0	16.0	50.0	**C**	1.55	0.71	0.06	8.30	8.33	0.24	19.64	26.74	2.51	1.20	1.40	100.0	26.50
309	2134	A2	15-20	30.0	14.0	56.0	**C**		0.58	0.07	8.30	8.16	0.65	24.40	16.36	2.66	1.40	1.80	100	25.50
309	2135	B	20-70	28.0	14.0	58.0	**C**		0.39	0.05	5.10	8.28	1.30	16.80	15.23	3.43	1.08	1.25	100.0	29.00
309	2136	C	70-120	24.0	10.0	66.0	**C**		0.27	0.04	4.70	8.12	1.65	20.00	16.75	4.47	0.32	2.65	100.0	29.50
316	2140	A	0-20	34.0	16.0	50.0	**C**	1.48	0.47	0.07	10.00	8.20	0.35	25.40	16.49	4.22	0.84	1.35	100	22.50
316	2141	Bt	20-85	32.0	12.0	56.0	**C**		0.30	0.05	9.70	8.47	0.35	16.80	16.53	4.76	0.64	2.35	100.0	22.50
316	2142	C	85-120	22.0	16.0	62.0	**C**		0.22	0.04	7.70	8.38	1.00	28.60	19.32	4.99	1.96	3.45	100.0	26.50
321	2146	Ap	0-15	38.0	4.0	58.0	**C**	1.36	0.65	0.09	11.50	8.03	0.70	20.40	9.79	2.98	0.76	1.20	100	26.00
321	2147	A2	15-40	20.0	22.0	58.0	**C**		0.55	0.12	10.50	7.85	2.50	21.40	10.53	3.53	0.60	1.65	100	24.00
321	2148	Bt1k1	40-80	24.0	12.0	64.0	**C**		0.38	0.11	14.70	7.98	2.35	22.40	10.71	3.88	0.70	2.15	100	26.50
321	2149	Bt2k2	80-135	22.0	16.0	62.0	**C**		0.27	0.08	18.80	8.00	2.20	23.60	19.83	7.59	0.78	2.25	100.0	29.00
321	2150	Ck	135-155	18.0	16.0	66.0	**C**		0.23	0.07	15.40	8.09	2.15	27.20	12.27	5.26	1.16	2.65	100	32.50
323	2151	A1	0-10	6.0	32.0	62.0	**C**	1.41	0.52	0.07	18.00	8.06	0.55	25.40	5.02	1.21	0.28	0.20	100	24.00
323	2152	A2	10-25	6.0	32.0	62.0	**C**		0.46	0.08	7.10	7.98	1.20	32.00	15.71	4.80	0.80	1.80	100	23.00
323	2153	B1	25-50	10.0	38.0	52.0	**C**		0.51	0.11	7.30	7.81	3.50	20.60	10.97	3.20	0.42	1.35	100	22.50
323	2154	B2	50-110	8.0	34.0	58.0	**C**		0.41	0.10	5.60	7.84	4.00	21.80	10.89	5.92	0.68	2.35	100	25.00
323	2155	C	>140	12.0	26.0	62.0	**C**		0.29	0.09	9.30	7.90	3.50	29.40	6.09	9.20	1.40	1.30	100	25.50
325	2162	Ap	0-20	32.0	12.0	56.0	**C**	1.34	1.28	0.11	6.10	7.97	0.35	27.60	31.27	2.73	1.30	1.55	100.0	19.50
325	2163	Btk	20-75	30.0	12.0	58.0	**C**		0.88	0.07	10.00	7.84	0.55	27.00	36.86	4.11	1.10	1.55	100.0	21.00
325	2164	Ck	75-110	24.0	12.0	64.0	**C**		0.64	0.05	4.60	8.13	0.95	21.60	12.96	4.61	0.50	2.30	100	27.50
326	2165	Ap	0-15	34.0	12.0	54.0	**C**	1.43	1.09	0.06	7.30	7.92	0.35	26.40	22.73	2.88	1.44	1.55	100.0	19.00
326	2166	AB	15-30	30.0	12.0	58.0	**C**		0.81	0.07	4.90	7.96	0.35	32.00	25.40	3.88	1.10	1.30	100	23.00
326	2167	Btk	30-110	24.0	14.0	62.0	**C**		0.53	0.04	4.20	8.13	0.50	21.20	18.11	8.24	0.96	1.65	100	25.00
326	2168	Ck	>110	22.0	12.0	66.0	**C**		0.14	0.04	6.40	8.24	0.90	25.00	14.73	8.59	0.68	2.80	100.0	28.00
328	2169	Ap	0-20	14.0	18.0	68.0	**C**	1.31	1.76	0.11	6.00	7.97	0.40	41.40	27.10	5.71	0.86	0.85	100.0	22.00
328	2170	Bt	20-90	14.0	12.0	74.0	**C**		0.92	0.05	6.20	8.46	0.75	45.32	19.37	9.82	0.76	3.10	100	26.00

328	2171	C	90-160	12.0	12.0	76.0	**C**		0.04	0.03	7.70	8.28	4.00	26.40	20.21	6.64	0.40	4.55	100.0	29.50
329	2172	Ap	0-25	16.0	14.0	70.0	**C**	1.16	0.02	0.14	4.40	7.82	0.60	33.70	13.24	4.63	1.10	1.05	100	25.00
329	2173	Bt	25-110	14.0	8.0	78.0	**C**		0.02	0.03	5.90	8.63	1.55	25.40	11.93	3.44	0.96	1.95	100	31.50
329	2174	C	110-140	10.0	10.0	80.0	**C**		0.01	0.02	7.00	8.50	3.50	27.00	12.96	6.41	1.00	8.55	100	30.50
Average values for Vertisols			140+	27	14.5	58	**C**	1,40	0.62	0.07	9.48	8.2	1.1	21.8	21.8	4.8	0.87	1.94	100	25.7
Range values for Vertisols				6-64	4-38	12-80		1.16-1.55	0.01 1.76	0.02 0.19	2.1 35.5	7.81 8.8	0.14 4.0	7.28 45.32	5.02 86.29	0.3 10.93	0.10 1.76	0.2 8.55		14.85 34.15

Table 10: Soil laboratory results of the Vertisols

The Vertisols in the study area have low stable porosity, and a predominance of fine pores. The topography is usually flat or gently sloping throughout the alluvial plain, and the most common soil erosion type is slight sheet wash, but rill and gully erosion occur on the upper slope of the dissected plateaus around the Borama/Gebiley catchments.

A Gilgai microrelief is often a peculiar sign of the Vertisols; in this study this feature was not found, although many sinkholes were observed.

Soil physical properties

The bulk density of the vertisols in the study area can be broadly characterised as available data is limited to the surface horizons and it is recognised that clay content increases with soil depth. Bulk densities are usually very widely distributed and occur in a moderately low range between 1.16 - 1.54g/cm^3. These variations are caused by swelling and shrinking with changes in soil moisture content. Bulk density is high when the soils are dry and low when wet. Water infiltration is moderately slow.

In the dry season, surface horizons are characterised by grumic and granular structure (forming surface mulch) at intervals of 10 - 20 cm which often cover up wide, deep vertical cracks in the soil. In the subsoil there are strongly developed prismatic, angular to sub-angular structures separated from each other by cracks of various sizes. In the wet season all the structures are almost completely destroyed, reducing the surface horizon to a massive block. Shiny pressure faces and/or well-developed slickensides were also observed in the profiles. Porosity is limited, except for the cracks developed during the dry season and occasional root channels. In the lower horizons the plant roots are confined to cracks and slickenside faces.

The vertisols in the study area have a relatively high water storage capacity in the root zone of the upper 1m of the soil profile, due to their depth and high clay content. The soil moisture content in the deeper layers is lower, apparently due to compression effects on metric potential. As this study area is characterised by uncertain rainfall, the water stored in the soil profile is very important for survival of crops during the growing season until the end of the rainy season.

Soil chemical properties

In an arid and semi-arid climate it is recognised that the major chemical factors limiting crop production are usually related to the increase of soluble salts in the soil. Therefore attention is always focused on chemical analyses to assess the types and amount of soluble salts and amount of exchangeable sodium associated with the soil clay. Consequently, all the soil horizons of the sampled profiles were subjected to detailed chemical analyses.

Chemical analysis of vertisols in the study area (Table 10) show them to be rich in clay content, moderately alkaline in reaction and moderately base saturated (for the interpretation, see Annex 2). Salinity values are uniformly low throughout the soil profile. The levels of exchangeable sodium are generally very low. These characteristics are favourable for crop production.

Soil Fertility

The results of tests on organic matter and total nitrogen in the surface horizons of the soil profiles show values of less than 1% and 0.1% respectively, indicating that levels of organic matter and total nitrogen are lower than deficient. These low values are probably a result of the arid and semi-arid climates, but a major factor is also the lack of soil management practices in relation to the agricultural and pastoral systems. Therefore, nitrogen fertilizer will be necessary to maintain or increase crop yields under present farming systems.

Phosphorus (P) was determined to be the "available" form. The measured values of phosphorus indicate it is irregular in terms of content and distribution in almost all the profiles. Phosphorus values vary from site to site, and similarly downwards in the soil profile, ranging between 3.5 - 35.5 ppm. Rating of P according to guidelines for interpretation by Olsen's method (Landon, 1984) suggests that values < 5 ppm can be considered low and 5 - 15 ppm as medium. Values > 15 ppm are considered excessive. As pH values of soils in the study area are moderately alkaline to strongly alkaline, phosphorous is subject to fixation or formation of poorly soluble calcium phosphate, suggesting that application of phosphate fertilizer is required and likely to improve production in intensive cultivation systems.

Management and use
The vertisols in this semi-arid region are used for different purposes, but primarily for rain-fed agriculture through smallholder post-rainy season crop cultivation, mainly sorghum, maize, millet, cowpeas and Qat, and extensive grazing and wood collection.

Crop management practices are mainly directed towards building soil bunds for water harvesting, in combination with soil conservation in order to store more water in the soil. Neither manure nor mineral fertilizers are not applied to crops.

Fluvisols (Profiles: 103, 106, 107, 113, 200, 201, 206)
Fluvisols are young soils developed on parent material of recent alluvial plains, river fans and tidal marshes which are periodically flooded by seasonal rivers which are very common within the Al Mountains, Highlands and Dissected Plateaus, mostly in the central part of the study area. Soil profiles show stratification and a weak subsoil horizon differentiation due to successive flooding and deposition of soil material.

The climate is arid and semi-arid, similar to that of the Vertisols. Topography is a flat to gently undulating surface. The natural vegetation varies from general open trees with shrubs, sparse shrubs with a herbaceous layer, general open shrubs and bare soil. The fluvisols in the study area are very important because they are used for irrigated orchards along the alluvial plains of the main rivers and *toggas*.

Physical and chemical properties
In arid and semi-arid climates, it is recognised that the major physical and chemical factors limiting crop production usually relate to soil texture, alkalinity, sodicity and levels of salinity. Therefore, attention is always focused on physical and chemical analyses to assess important parameters associated with soil characteristics. Consequently, all soil horizons of the sampled profiles were physically and chemical analysed, and described as follows:

Fluvisols in the study area all have diverse texture classes which change within the soil profile and in different spatial areas. The majority of these soils have good water drainage and water holding capacities, and are periodically flooded. They have variable bulk density ranging from 1.30 - 1.67, which is fairly high. The pH ranges from moderately alkaline to strongly alkaline, varying with depth or spatially.

Salinity is not a major hazard in these soils. Results obtained from the analyses show that a limited number of sites' lower horizons have a moderate degree of salinity and may cause salinity problems in the long term if irrigation is applied to inadequately drained land.

The analytical value of the total sums of CEC in the fluvisols of the study areas are variable and range from low (5 - 15 meq/100g) to medium (15 - 25meq/100g) and with an irregular distribution within the profiles. This is due to the diverse nature of the stratification layers and their content of colloidal material clay and organic matter. The base saturation is high or moderate. The dominant exchangeable cations are calcium and

magnesium. There is no sodium hazard and the soils are strongly calcareous. All the fluvisols are deficient in organic carbon and nitrogen, and phosphorus values are also low. Available potassium is adequate. Application of organic manure or inorganic nitrogen can yield better crop responses in terms of yield.

Management and use
The fluvisols of the study area are developed in river plain landscapes and have good natural fertility. They are usually suitable for all uses, but in the project area are commonly used for irrigated crops or grazing and woodcutting for fuelwood.

Calcisols (Profiles: 110, 114, 115, 118, 119, 124, 129, 135, 136, 138, 310, 311, 317)
The calcisols are soils commonly developed in the study area and are characterised by having a substantial secondary accumulation of lime. They principally occur in dissected plateaux and some piedmonts of the study area. Deep fluvial incisions form areas of bare rock at the upper surface part of the landscape, generally causing high and intense degradation. They are developed in highly calcareous parent material mainly in the Fossiliferrous limestone and Yesomma sandstones. The parent material in the lower parts of the landscape is mostly alluvial and colluvial, consisting of base-rich weathered deposits consisting mainly of highly calcareous sands and gravel of colluvial and alluvial soil deposits.

The natural vegetation consists of general open shrubs with open herbaceous, sparse trees and different herbaceous cover. Most of these soil units are used for rainfed agriculture and livestock grazing.

Physical and chemical properties
The majority of the calcisols have a clayey texture which varies slightly with soil depth (see Table 11). These soils are strongly calcareous throughout the soil profiles, moderately alkaline to strongly alkaline, non saline, have adequate to high CEC, high to adequate or rarely excessive content of phosphorus and are deficient in organic matter and total nitrogen (for interpretation see Annex 2).

Management and use
The vast majority of the calcisols are under shrubs, grasses, herbs and sparse tree cover and are used for general grazing. Some calcisols are used for production of isolated rainfed fields of herbaceous crops (single or multiple), sorghum and maize where arable farming is not hindered by surface stoniness or a shallow petrocalcic horizon.

Cambisols (Profiles: 108)
These are soils with an initial stage of subsurface soil horizon differentiation. They occur in slopes, denudational surfaces and in some alluvial deposits in the study area. The parent material is derived from a wide variety of rocks, the most common of which is fossiliferous limestone. The profiles are characterised by slight transformation of the parent material and evidence changes in soil structure, colour and clay content, but there is an absence of appreciable quantities of illuviated clay or carbonate content, organic matter, Al and/or Fe compounds. The topography varies from flat to gently sloping surfaces of alluvial deposits.

Table 11: Soil laboratory results of the Calcisols, Fluvisols, Regosols, Cambisols, Arenosols

PROFILE	LAB_CODE	HORIZON	DEPTH	SAND %	SILT %	CLAY %	TEXTURE	Bulk_density (g/cm)	C_%	N_%	P_ppm	PH(H2O)	EC mS/cm	CECm_meq/100g	Ca++	Mg++	K+	Na+	PSB_%	CaCO3_ %
110	1861	A1k	0-10	18.0	34.0	48.0	**C**	1.46	0.42	0.04	15.20	8.15	0.78	19.12	72.84	3.82	0.79	1.05	100.0	36.65
110	1862	A2k	10-20	22.0	20.0	58.0	**C**		0.77	0.06	16.30	8.03	0.33	26.39	32.84	0.47	1.03	1.20	100	27.65
110	1863	Ck	20-90	34.0	18.0	54.0	**C**		0.30	0.02	15.40	8.14	0.58	11.60	112.74	4.46	0.28	3.47	100	28.15
114	1867	A1	0-19	52.0	30.0	18.0	**SL**	1.66	0.65	0.04	11.70	8.03	2.19	19.16	14.82	1.79	1.27	0.97	100.0	6.65
114	1868	AB	19-35	44.0	30.0	26.0	**L**		0.66	0.05	11.60	8.14	0.60	11.38	20.47	2.29	1.37	2.00	100.0	8.65
114	1869	Bt	35-60	40.0	32.0	28.0	**CL**		0.64	0.05	15.60	8.19	0.29	12.36	23.81	2.94	1.00	2.53	100	9.65
114	1870	Ck	60-120	40.0	30.0	30.0	**CL**		0.59	0.03	12.40	8.17	0.23	13.76	20.35	3.01	0.28	2.17	100	14.65
115	1871	Ap	0-15	36.0	16.0	48.0	**C**	1.48	1.16	0.10	10.80	8.00	0.15	18.96	23.40	2.36	1.27	1.23	100	18.65
115	1872	Bt	15-60	44.0	16.0	40.0	**CL**		0.80	0.08	10.20	8.42	0.80	20.96	23.04	37.00	0.73	0.57	100	15.65
115	1873	Ck1	60-80	32.0	18.0	50.0	**C**		0.87	0.09	9.60	8.08	0.70	26.56	32.16	3.68	0.73	0.73	100.0	20.65
115	1874	Ck2	80-145	32.0	16.0	52.0	**C**		0.60	0.06	14.70	8.15	0.35	18.54	26.91	3.24	0.57	0.70	100.0	30.65
118	1880	Ap	0-15	54.0	14.0	32.0	**SCL**	1.45	0.60	0.05	7.20	8.26	0.22	15.60	15.11	2.69	1.16	0.80	100.0	12.50
118	1881	A2	15-28	52.0	10.0	38.0	**SC**		0.56	0.06	17.40	8.14	0.52	8.68	32.21	2.13	0.72	0.75	100.0	12.50
118	1882	Bt1	28-65	40.0	10.0	50.0	**C**		0.72	0.07	6.10	8.26	0.25	15.62	17.50	2.20	0.71	0.75	100.0	20.00
118	1883	Bt2k1	65-118	32.0	14.0	54.0	**C**		0.52	0.05	6.40	8.33	0.30	12.99	10.99	2.07	0.64	0.80	100.0	26.50
118	1884	Ck2	118-150	60.0	10.0	30.0	**SC**		0.39	0.03	39.40	8.58	1.16	10.64	11.18	3.04	0.58	1.45	100.0	31.00
119	1885	A1	0-20	30.0	14.0	56.0	**C**	1.65	0.58	0.08	7.00	8.37	0.16	12.00	15.03	2.51	0.56	1.45	100.0	13.00
119	1886	A2	20-42	44.0	12.0	44.0	**C**		0.71	0.07	7.20	8.22	0.52	18.60	42.05	3.24	0.56	0.85	100.0	21.50
119	1887	C1	42-65	36.0	12.0	52.0	**C**		0.44	0.04	6.50	8.35	0.35	16.40	24.53	4.58	0.40	0.85	100.0	30.00
119	1888	C2k	65-150	40.0	12.0	48.0	**C**		0.26	0.02	11.30	8.17	0.29	11.00	9.61	1.30	0.40	0.95	100.0	29.50
124	2090	A1	0-23	20.0	12.0	68.0	**C**	1.39	1.01	0.14	10.60	8.08	0.35	30.88	34.66	4.02	1.18	1.05	100.0	25.85
124	2091	A2	23-45	56.0	4.0	40.0	**SC**		0.53	0.06	13.60	8.23	0.27	14.28	30.18	3.92	0.24	0.50	100.0	19.35
124	2092	Ck1	45-65	52.0	6.0	42.0	**SC**		0.27	0.05	9.10	8.23	0.45	14.48	38.48	4.68	0.30	0.70	100.0	21.35
124	2093	Ck2	>65	50.0	6.0	44.0	**SC**		0.21	0.03	8.40	8.30	0.55	11.08	23.72	4.96	0.24	0.60	100.0	22.85
129	2094	ACk1	0-25	24.0	34.0	42.0	**C**	1.36	0.29	0.04	13.10	8.27	0.25	17.32	32.54	1.71	0.48	0.95	100.0	26.85
129	2095	Ck2	25-40	22.0	36.0	42.0	**C**		0.25	0.09	3.50	7.87	3.50	16.28	21.02	3.47	0.38	0.50	100.0	31.35
135	2096	A	0-25	48.0	12.0	40.0	**SC**	1.33	0.50	0.05	5.60	8.42	2.40	15.08	30.89	2.16	0.32	1.20	100.0	20.35
135	2097	Ck1	25-65	46.0	12.0	42.0	**SC**		0.38	0.05	2.70	8.01	2.30	13.48	17.71	2.02	0.16	0.85	100.0	25.85
135	2098	Ck2	65-80	44.0	12.0	44.0	**C**		0.28	0.04	4.40	8.13	2.45	15.08	30.10	4.13	0.28	1.80	100.0	30.85
136	2099	Ac	0-25	58.0	8.0	34.0	**SCL**	1.39	0.43	0.07	2.20	8.25	0.21	11.32	32.67	2.29	0.26	0.45	100.0	25.85
136	2100	Ck	25->75	42.0	16.0	42.0	**C**		0.42	0.04	2.20	8.55	0.24	18.12	10.08	4.81	0.24	0.70	100	37.35
138	2101	A	0-20	58.0	10.0	32.0	**SCL**	1.73	1.03	0.08	2.60	8.11	0.24	20.12	21.35	1.45	1.04	1.05	100.0	16.35
138	2102	Bt	20-75	38.0	10.0	52.0	**C**		0.74	0.09	9.90	8.10	0.40	23.08	18.31	2.67	0.92	0.95	100	19.35
138	2103	Ck	>75	44.0	8.0	48.0	**C**		0.35	0.04	2.30	8.24	0.29	13.68	36.62	2.41	0.52	0.75	100.0	23.85
310	2137	A	0-35	76.0	6.0	18.0	**SL**	1.58	0.31	0.05	11.80	8.17	0.20	10.20	17.99	2.06	0.80	0.55	100.0	7.50
310	2138	B	35-75	68.0	6.0	26.0	**SCL**		0.27	0.05	5.20	8.11	0.50	10.00	18.51	2.16	0.36	0.75	100.0	14.00
310	2139	C	75-140	18.0	14.0	68.0	**C**		0.18	0.05	9.50	8.14	4.00	27.80	13.76	5.95	0.60	3.95	100	29.50
317	2143	A	0-10	34.0	18.0	48.0	**C**	1.38	0.62	0.07	10.10	8.17	0.35	29.40	35.73	3.78	0.88	1.60	100.0	24.00
317	2144	AB	10-20	24.0	22.0	54.0	**C**		0.94	0.07	9.40	8.35	0.30	33.40	18.75	3.98	0.36	1.70	100	27.00
317	2145	Bt	20-65	22.0	20.0	58.0	**C**		0.68	0.07	13.60	8.31	0.70	26.40	17.35	3.03	0.28	2.30	100	27.00
Average values for Calcisols			99	40.65	16	43.5	**SCL**	1.48	0.54	0.06	10.04	8.20	0.76	17.29	27.05	3.86	0.62	1.20	100	22.2
Range values for Calcisols			0-150	18-68	4-36	18-68		1.33-1.73	0.18 1.16	0.02 0.14	2.2 39.4	7.87 8.42	0.15 4.0	8.68 33.4	9.61 112.74	0.47 37.0	0.16 1.37	0.45 3.95		6.65 37.35

PROFILE	LAB_CODE	HORIZON	DEPTH	SAND %	SILT %	CLAY %	TEXTURE	Bulk_density (g/cm)	C_%	N_%	P_ppm	PH(H2O)	EC mS/cm	CECm_meq/100g	Ca++	Mg++	K+	Na+	PSB_%	CaCO3_ %
103	1653	A1	0-40	10.0	52.0	38.0	**SICL**	1.35	0.50	0.04	14.20	8.30	1.30	15.60	19.5	1.7	0.3	2	100.0	23.00
103	1654	E	40-60	12.0	74.0	14.0	**SIL**		0.40	0.05	8.60	7.90	4.07	7.40	28.1	2.9	0.3	2	100.0	10.00
103	1655	B1	60-90	16.0	60.0	24.0	**SIL**		0.70	0.11	4.30	7.70	8.91	21.10	24.3	0.4	0.8	7	100.0	21.00
103	1656	B2	90-110	22.0	64.0	14.0	**SIL**		0.20	0.02	11.30	8.20	3.73	6.30	14.3	1.6	0.2	2	100.0	9.00
103	1657	C1	110-120	12.0	46.0	42.0	**SICL**		0.40	0.04	8.80	7.90	10.60	14.00	17.5	3.1	0.3	11	100.0	23.00
106	1758	A	0-20	54.0	34.0	12.0	**SL**	1.65	0.82	0.07	10.30	8.10	0.16	9.20	12	0.7	1.2	1	100	13.00
107	1759	A1	0-20	68.0	14.0	18.0	**SL**	1.63	0.37	0.01	12.00	8.30	0.11	11.10	11.2	0.6	0.5	0.5	100	9.00
107	1760	C1	20-110	66.0	18.0	16.0	**SL**		0.18	0.01	6.40	8.40	0.12	9.90	9.9	0.7	0.1	0.2	100	10.00
107	1761	C2	110-120	78.0	12.0	10.0	**SL**		0.71	0.01	6.50	9.00	0.16	17.90	18.3	1.6	0.1	1	100	8.00
113	1864	A1	0-35	46.0	34.0	20.0	**L**	1.45	0.85	0.08	10.00	8.27	0.23	11.16	22.34	1.63	0.67	0.77	100.0	8.15
113	1865	A2	65-75	34.0	42.0	24.0	**L**		0.61	0.06	8.80	8.40	0.24	13.39	26.21	2.00	0.39	0.60	100.0	12.65
113	1866	C	75-150	20.0	42.0	38.0	**SiCL**		0.57	0.07	6.80	8.17	0.47	15.92	27.83	3.22	0.40	0.70	100.0	13.65
200	1762	A	0-15	72.0	14.0	14.0	**SL**	1.57	0.13	0.02	7.30	8.50	0.12	11.20	14.5	1	0.5	0.5	100	8.00
200	1763	C	15-200	74.0	12.0	14.0	**SL**		0.14	0.01	5.90	8.40	2.48	14.10	16.4	1.8	0.2	4	100	6.00
201	1764	A1	0-10	88.0	8.0	4.0	**S**	1.67	0.24	0.02	8.20	8.40	0.07	10.50	5.3	0.3	0.2	0.2	100	2.00
201	1765	A2	10-45	88.0	6.0	6.0	**S**		0.21	0.02	7.60	8.50	0.07	23.30	10.2	0.4	0.2	1	100	1.00
201	1766	C	45-100	88.0	6.0	6.0	**S**		0.16	0.01	6.50	8.50	0.10	11.90	12.8	0.3	0.1	0.2	100	5.00
206	1897	A	0-35	22.0	16.0	62.0	**C**	1.30	0.48	0.05	8.30	8.53	1.51	23.86	14.56	7.85	0.70	3.25	100.0	30.00
206	1898	C1	35-65	90.0	4.0	6.0	**S**		0.13	0.01	6.00	8.61	0.28	5.40	8.61	1.33	0.12	0.10	100.0	14.50
206	1899	C2	65-94	90.0	4.0	6.0	**S**		0.13	0.01	8.50	8.51	0.26	6.60	8.88	0.79	0.18	0.25	100.0	16.00
206	1900	C3	>94	92.0	6.0	2.0	**S**		0.09	0.00	7.70	8.61	0.30	10.60	10.57	0.96	0.18	0.30	100.0	14.50
Average values for Fluvisols			114	54.3	27	18.5	**SL**	1.51	0.38	0.03	8.28	8.34	1.68	12.87	15.87	1.66	0.36	1.83	100	12.25
Range values for Fluvisols			0-200	10-92	4-74	2-62		1.30-1.67	0.09 0.85	0.00 0.11	6.0 14.2	7.7 9.0	0.07 10.6	5.4 23.86	5.3 28.1	0.3 7.85	0.1 0.67	0.1 7		1.0 30
105	1755	A1	0-10	74.0	18.0	8.0	**SL**	1.70	0.63	0.05	15.30	8.10	0.28	6.60	11.8	1.1	1	1	100.0	7.00
105	1756	A2	10-65	76.0	10.0	14.0	**SL**		0.34	0.03	9.30	8.10	0.14	7.80	17.7	1.2	0.3	0.4	100.0	8.00
105	1757	Ck	65-150	72.0	12.0	16.0	**SL**		0.19	0.03	7.20	8.30	0.12	23.80	13.7	1.4	0.3	1	100	11.00
203	1854	A1	0-30	66.0	24.0	10.0	**SL**	1.61	0.51	0.05	13.50	8.76	0.40	13.57	13.67	1.16	0.17	0.36	100.0	5.65
203	1855	A2	30-60	60.0	24.0	16.0	**SL**		0.64	0.12	8.50	8.34	1.30	11.52	10.47	1.06	0.09	0.10	100.0	5.65
203	1856	C1	60-125	62.0	22.0	16.0	**SL**		0.63	0.06	13.70	8.14	0.35	32.58	16.46	1.22	0.17	0.36	100	11.15
203	1857	C2	125-170	72.0	16.0	8.0	**SL**		0.31	0.03	0.50	8.11	2.30	9.96	11.37	1.47	0.11	0.10	100.0	4.65
Average values for Regosols			160	68.8	18	12.5	**SL**	1.65	0.46	0.05	9.71	8.26	0.69	15.11	13.59	1.23	0.3	0.47	100	7.58
Range values for Regosols				60-76	12-24	8-16		1.61-1.7	0.19 0.64	0.03 0.12	0.5 15.3	8.1 8.76	0.12 2.3	6.6 32.58	10.47 17.7	1.06 1.47	0.09 0.3	0.1 1		4.65 11.15
108	1767	A	0-15	52.0	20.0	28.0	**SCL**	1.39	0.47	0.05	7.70	8.20	1.24	30.80	21.4	2.8	0.2	1	100	14.00
108	1768	B	15-35	40.0	26.0	34.0	**CL**		0.57	0.04	7.80	7.90	3.00	24.00	22.5	5.2	0.3	2	100	16.00
108	1769	C1	35-70	36.0	38.0	26.0	**LS**		0.38	0.03	7.70	7.90	2.30	25.50	19.40	4.90	0.20	2.00	100	14.00
108	1770	C2	70-140	50.0	26.0	24.0	**SCL**		0.39	0.04	7.40	8.10	1.30	29.90	23.40	5.20	0.20	2.00	100	10.00
Cambisols																				
Arenosols																				
104	1658	A1	0-25	76.0	18.0	6.0	**LS**	1.60	0.20	0.01	3.20	8.80	0.08	1.30	6.6	0.3	0.2	0	100.0	4.00
104	1659	A2	25-75	78.0	16.0	6.0	**LS**		0.10	0.00	3.30	8.80	0.07	0.70	10.5	0.4	0.2	0.2	100.0	4.00
104	1660	AC	75-85	88.0	8.0	4.0	**S**		0.10	0.00	2.40	9.20	0.15	0.60	11.9	0.3	0.2	0.7	100.0	5.00
104	1661	C1	85-110	64.0	28.0	8.0	**LS**		0.10	0.00	1.60	9.80	0.40	2.70	12.9	0.7	0.5	1	100.0	4.00
104	1662	C2	110-120	92.0	4.0	4.0	**S**		0.10	0.00	34.60	10.00	0.40	1.10	11.7	0.3	0.2	0.5	100.0	4.00

The soils are covered by wide range vegetation from general open trees with shrubs, dense shrubs and herbaceous cover. The main use of these soils is for livestock grazing and in small cases for rainfed agriculture purposes.

Physical and chemical properties
Soil analysis data of cambisols examined in the project area show that soil texture is within loamy classes and of low bulk density. These soils are moderately alkaline in soil reaction, non saline to moderately saline, high to moderate CEC, high base saturation and strongly calcareous. They are deficient in nutrients, specifically nitrogen and phosphorus.

Management and use
Due to insufficient rainfall moisture conditions, these soils are commonly used for grazing and wood harvesting. Small irrigated fields of fruit trees and herbaceous crops (pulses and vegetables) are practiced beside the water sources.

Arenosols (Profile: 104)
The Arenosols comprise soils developed on the coastal plain, which is commonly flat with small, slightly sloping surfaces towards the Red Sea. The coastal plain is intersected by broad rivers forming deltas, accumulating seawards. Seasonal flush floods originating in the hills and Al Mountains occur in large parts of the area.

Parent material of soils in the coastal plain consist of mixed unconsolidated deposits from sandy aeolian beach deposits (consisting of quartz particles and mica flakes) with finer materials from loam to silty clay texture of recent alluvial deposits. The soil profile shows no sign of development or horizon differentiation.

Natural vegetation cover varies from bare soil with scattered vegetation, to general open herbaceous and closed strips of exotic trees (*Prosopsis* sp.) along the streams.

Physical and chemical properties
The arenosols of the study area have a loamy sand texture class and moderately high bulk density. This indicates that these soils are highly permeable and have low water storage capacity.

The soils are strongly alkaline in reaction, not saline, low in CEC and deficient in soil nutrients, particularly organic matter, nitrogen and phosphorus.

Management and use
The arenosols are found in the arid coastal plain where annual rainfall is lower than 150 mm. They are characterised by a common sandy class texture, high permeability and low water holding capacity, low nutrient storage and high sensitivity to wind erosion. They do not favour cultivation of crops. The most common land use is transhumance grazing and sedentary pastoralism. The most common grazing animals are goats and camels.

Leptosols (Profiles: 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 33, 35, 37, 38, 39, 42, 46, 51)
Leptosols are the dominant soils in the study area, occurring mainly in the northern central part of the study area on the Al Mountains, but are also present in the Plateau and dissected plateaus. Their landscapes include isolated mountain blocks or successions of mountains of differing elevations, rugged or more or less dissected surfaces as a result of tectonic faulting and folding activity, volcanic activity, the effects of climatic weathering, drainage and plants and animals. There are recently developed steep-sided trenches or channels (classified as gully and rills) of varying widths and depths) in poorly consolidated bedrocks, and weathered sediments or soil on sloping lands in response to intense run-off events. The mountain surfaces are made up of stony and rocky formations without soil development. Dominant rocks are Fossiliferrous limestone,

sandstone, biotite and amphibole, schists, sand and gravel of colluvial and small alluvial deposits in narrow river beds.

They are very shallow soils over continuous rock, and soils that are extremely gravelly or stony. These characteristics make these soils of limited suitability for agriculture.

Vegetation cover is variable, consisting of general open shrubs, general open trees with shrubs and general open herbaceous with shrubs.

Due to the limited amount of soil material in Leptosols, soil profiles were difficult to dig and no soil samples were taken.

Management and use
Leptosols have the most resource potential as areas for wet season grazing and as woodland. Erosion is the greatest threat to large areas of these soils in the study area, due to increasing overexploitation for grazing and wood collection by transhumance and semi-sedentary pastoralism, which appear to determine very high levels of surface stoniness.

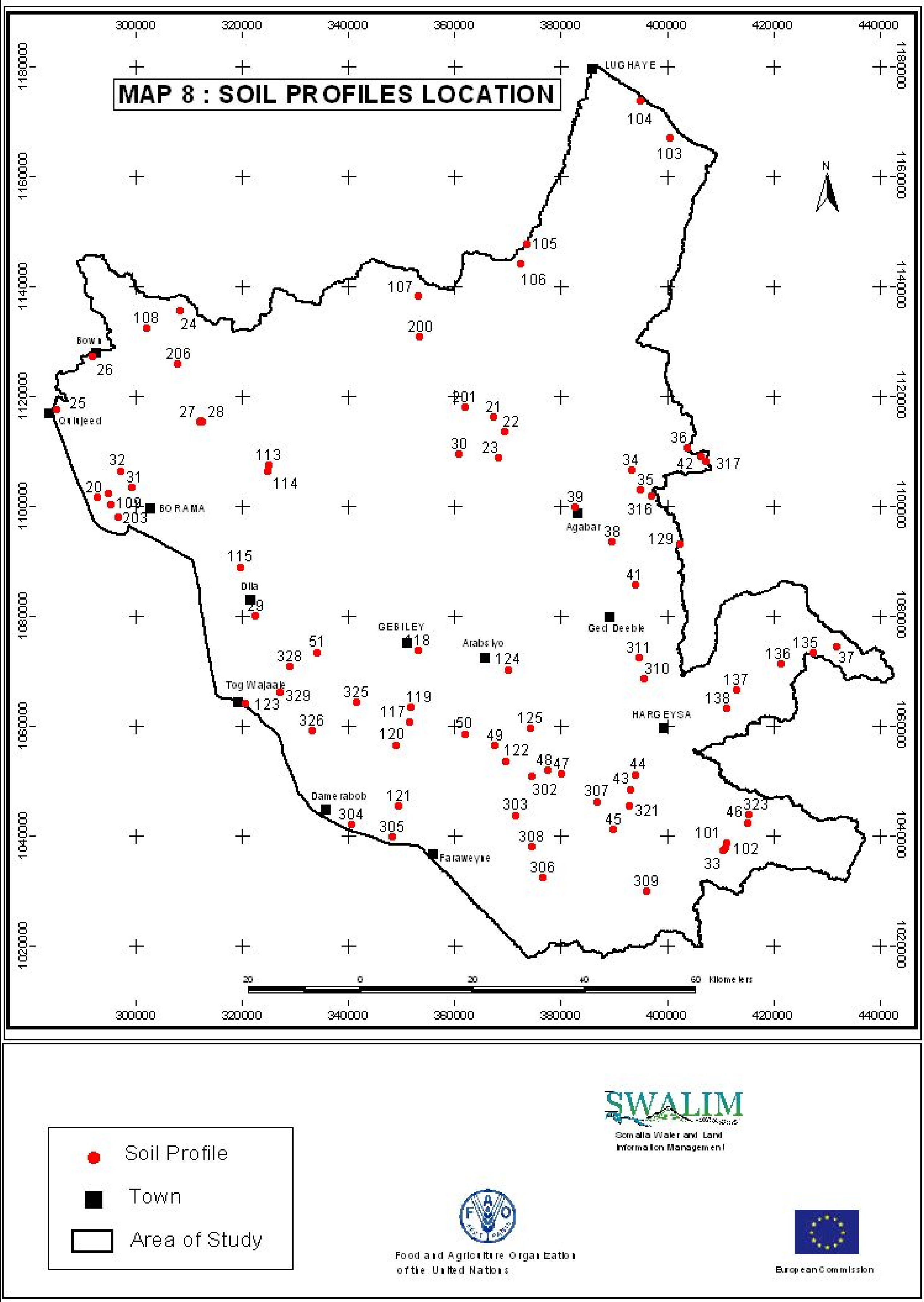
Solonchaks (Profiles: no profiles available, bibliographic information)
Solonchaks are soils with a high concentration of soluble salts at certain times of the year. They are located in the playas in the southern part of the study area on the border with Ethiopia. Land cover in the area is mainly bare soil with scattered vegetation, allowing very marginal levels of grazing activity.

Regosols (Profiles: 20, 26, 36, 40, 41, 43, 44, 45, 47, 105, 137, 203)
Regosols comprise all the soils that can not be referred to any of other Reference Soil Groups. These soils are characteristic of arid and semi-arid environments, and due to their aridity the soil profiles do not show diagnostic horizons that may be referred to any of the previous RSG. These soils occur in variable relief types in the landscape, particularly on planation surfaces, slopes, denudational surfaces, mesas and pediments of dissected plateaus; the topography is generally undulating to hilly. The parent material consists of unconsolidated fine-grained material originating from different rock types, including basement complexes, limestone and sandstone.

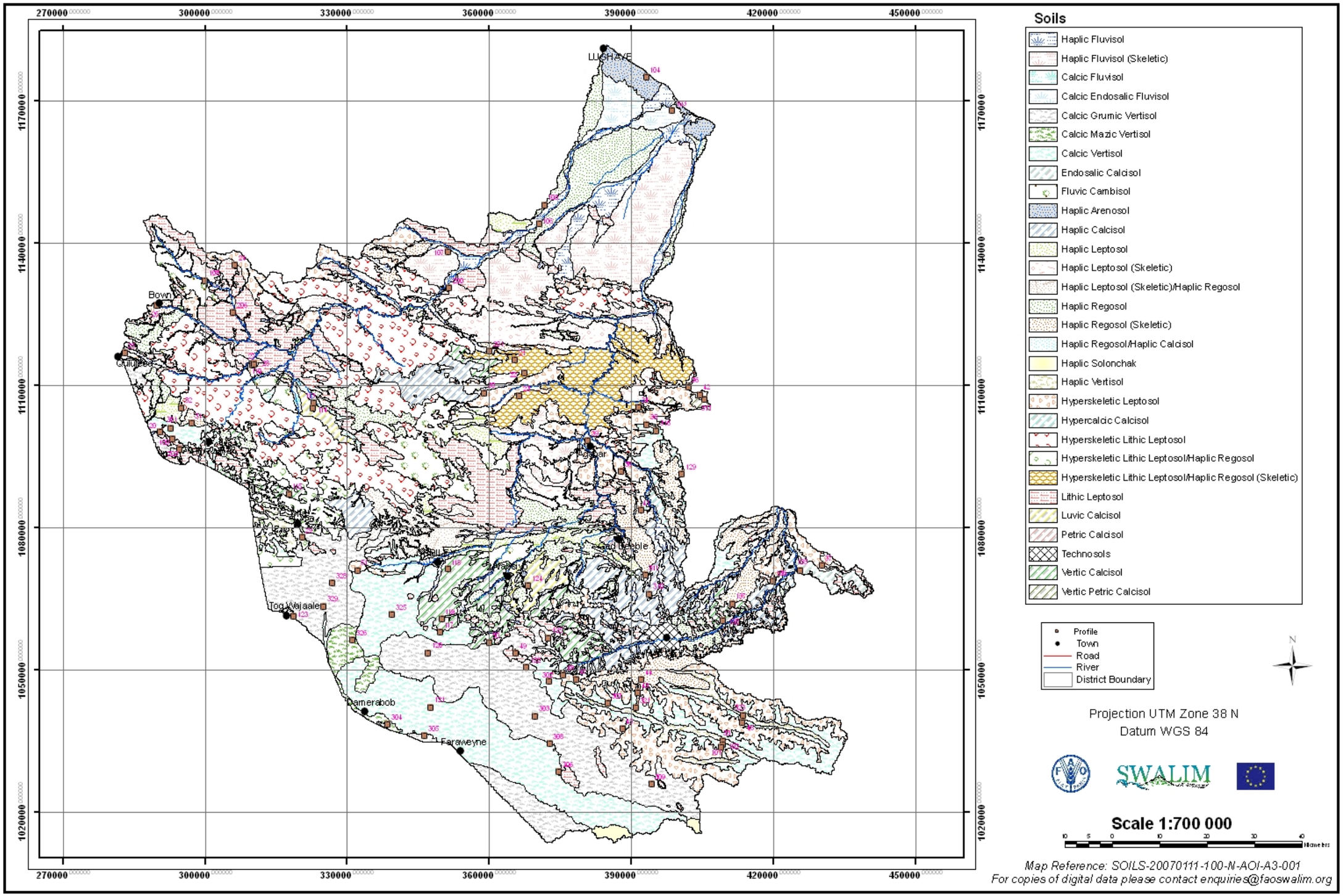
Vegetation cover of the Regosols in the study area varies from place to place, generally being open shrubs, sparse trees with shrubs, sparse shrubs or general open herbaceous.

Physical and chemical properties
A limited number of soil profile samples were examined for physical and chemical analysis as most of these soils in the study are shallow. The data of the tested soil profiles indicate a uniform sandy loam texture and moderately high bulk density, a strongly to moderately alkaline reaction, are non saline, have high CEC, high base saturation, are strongly calcareous and deficient in nitrogen and phosphorus.

Management and use
Due to the low rainfall and fragile land surface and low moisture-holding capacity of this soil, the Regosols in the study area have minimal agriculture significance, as do the Leptosols. They are used as communal grazing lands and for wood collection.


MAP 8 : SOIL PROFILES LOCATION
LUGHAYE
Bown
Quljeed
BORAMA
Dila
GEBILEY
Arabsiyo
Tog Wajaale
Agabar
Ged Deeble
HARGEYSA
Damerabob
Faraweyne
Kilometers
Soil Profile
Town
Area of Study
SWALIM
Somalia Water and Land Information Management
Food and Agriculture Organization of the United Nations
European Commission

Map 9: Soils at Prefix Level



Prefix qualifiers

According to WRB 2006, the Prefix qualifiers are typically associated qualifiers and intergrade qualifiers; the sequence of the intergrade qualifiers follows that of the RSGs in the WRB Key, with the exception of Arenosols; this intergrade is ranked with the textural suffix qualifiers. The qualifiers should be used before the reference group and give the specific soil diagnostic property that characterises the soil class.

Table 12: Prefix qualifiers

PREFIX	Interpretation
Calcic	Having a calcic horizon or concretions of secondary carbonates between 50 and 100 cm from the soil surface.
Endosalic	Having a salic (salt) horizon starting within 100 cm of the soil surface.
Fluvic	Having fluvic material (fluviatile, marine and lacustrine sediments) in a layer, 25 cm or more thick, within 100 cm of the soil surface.
Grumic	Having a surface layer with a 3 cm or more with a strong structure finer than very coarse granular.
Haplic	Having a typical expression of certain features (typical in the sense that there is no further or meaningful characterisation) and only used if none of the preceding qualifiers applies.
Hypercalcic	Having a strong calcic horizon or concentrations of secondary carbonates starting within 100 cm of the soil surface.
Hyperskeletic	More than 40% (by volume) gravel or other coarse fragments averaged over a depth of 100 cm from the soil surface or to continuous rock or a cemented or indurated layer, whichever is shallower.
Lithic	Having continuous rock starting within 10 cm of the soil surface (in Leptosols only).
Luvic	Having an argic horizon that has a CEC of 24cmol$_c$/kg clay or more throughout or to a depth of 50 cm below its upper limit, whichever is shallower, either starting within 100 cm of the soil surface, or within 200 cm of the soil surface if the argic horizon is overlain by loamy sand or coarse textures throughout, and a base saturation (by1 M NH4OAc) of 50 percent or more in the major part between 50 and 100 cm from the soil surface
Mazic	Having a massive structure and hard to very hard consistency in the upper 20 cm of the soil
Petric	Having a strongly cemented or indurated layer starting within 100 cm of the soil surface.
Vertic	Having a vertic horizon (clayey subsurface horizon that, as a result of shrinking and swelling, has slickensides and wedge-shaped structural aggregates) or vertic properties starting within 100 cm of the soil surface.

4.2.2 General accuracy of the map

After running verification and validation processes, the following results were obtained:

Verification of the map

Forty random points were used for assessing the map quality. The table below shows the 40 random points with the soil classes inferred by the model, and the expected soil classes according to a soil scientist's expert knowledge.

Table 13: Error matrix using Expert Knowledge

Random Point	X	Y	Inferred	Expected (expert knowledge)
1	379840.0027483	1078626.1741585	leptosols_regosols	✓
2	339596.7945320	1053978.0190246	vertisols	✓
3	304946.6938532	1136464.0262495	leptosols	✓
4	415523.3487644	1035286.3300710	leptosols_regosols	✓
5	297413.2196331	1141212.7533854	leptosols_regosols	✓
6	321808.4816118	1120208.3726447	fluvisols	✓
7	333048.0564785	1104790.4273984	regosols	✓
8	304461.6021455	1135302.5410409	leptosols	✓
9	397972.7307810	1023301.4472995	vertisols	✓
10	393369.2104752	1135831.8904944	regosols	✓
11	380349.3490414	1094270.2492684	regosols	✓
12	331752.8616190	1041438.0902243	vertisols	✓
13	395493.9121548	1028163.2393672	vertisols	✓
14	313183.5510494	1065865.2548096	vertisols	✓
15	347241.8398449	1078996.2048444	fluvisols	✓
16	301682.0266606	1115423.6703033	leptosols	✓
17	334527.5861869	1077176.8873053	vertisols	✓
18	418225.3095762	1066821.1674149	calcisols	✓
19	294953.8046752	1137101.3013197	regosols	cambisols
20	293382.1075424	1121308.1860723	leptosols	✓
21	327576.2220160	1098242.9399838	leptosols	✓
22	380635.5531489	1033924.4115742	vertisols	✓
23	316365.7526517	1112088.2548150	fluvisols	✓
24	361265.8411136	1042198.7088564	vertisols	✓
25	401848.6135252	1160233.3585043	leptosols	regosols
26	408790.2758620	1053936.9045040	fluvisols	vertisols
27	373490.1522949	1030660.9464971	vertisols	✓
28	418341.7315860	1062478.4461705	regosols	leptosols
29	387227.9494561	1055458.1417683	regosols	cambisols
30	356094.7635099	1098803.1253277	leptosols_regosols	✓
31	366325.3477726	1112242.4342675	leptosols	✓
32	311388.7117311	1094912.6636537	leptosols	✓
33	381329.2342908	1120285.4623710	leptosols_regosols	✓
34	327687.7931087	1053073.4995702	vertisols	✓
35	343807.3905546	1130923.8445910	leptosols_regosols	✓
36	390099.6923655	1157802.4624704	regosols	✓
37	301861.5105924	1109271.9101500	leptosols	✓
38	420820.5502122	1071909.0893461	leptosols	✓
39	371229.6249372	1079566.6688185	leptosols	✓
40	371578.8909667	1094542.6329678	leptosols	✓

The above error matrix gives an overall accuracy level of 87.5% according to expert knowledge. This is due to the general scale of 1:100.000 which controls the predictive process.

Validation of the map

Eighty two soil profiles collected in the field were used to validate the inferred soil map. These profiles were compared with the predicted or inferred soil classes in the same area. Table 12 shows the error matrix obtained through this process.

The error matrix (Table 14) gives an overall accuracy level of 80.4% which is the accuracy at which the map was produced. This demonstrates that the map represents the soil variability of the area under 80.4%.

Table 14: Error matrix of the validation process

Random Point	X	Y	Inferred	Observed
101	409401	1035093	✓	vertisol
109	293311	1098830	✓	vertisol
122	367873	1050614	✓	vertisol
125	372534	1056758	calcisol	vertisol
303	369736	1040302	✓	vertisol
305	346450	1036186	✓	vertisol
307	385163	1042931	✓	vertisol
309	394299	1025995	✓	vertisol
306	374743	1028580	✓	vertisol
308	372823	1034437	✓	vertisol
323	413625	1040462	✓	vertisol
329	325151	1063458	✓	vertisol
117	349804	1057946	calcisol	vertisol
121	347691	1042124	✓	vertisol
301	292822	1100951	✓	vertisol
120	347168	1053619	✓	vertisol
123	318826	1061372	✓	vertisol
302	372635	1047616	✓	vertisol
325	339591	1061629	calcisol	vertisol
316	395353	1100459	calcisol	vertisol
328	327021	1068371	✓	vertisol
102	409341	1034321	✓	vertisol
304	338710	1038520	✓	vertisol
321	391024	1042029	✓	vertisol
326	331228	1056257	✓	vertisol
21	365559	1115328	✓	leptosol
22	367560	1112638	✓	leptosol
48	375690	1048891	✓	leptosol
49	365711	1053553	✓	leptosol
50	360083	1055854	✓	leptosol
29	320610	1077927	✓	leptosol
34	391524	1105374	✓	leptosol
23	366453	1107790	✓	leptosol
24	306412	1135355	✓	leptosol
25	283245	1116868	✓	leptosol
27	310171	1114385	✓	leptosol
28	310527	1114503	✓	leptosol
30	359084	1108407	✓	leptosol
31	297269	1102062	vertisol	leptosol
33	408925	1033739	✓	leptosol
35	393304	1101974	✓	leptosol
37	430334	1072201	vertisol	leptosol
38	387949	1091887	✓	leptosol
39	380900	1098346	✓	leptosol
42	404513	1108059	✓	leptosol
46	413469	1038976	✓	leptosol
51	332301	1071046	✓	leptosol
110	310471	1114683	leptosol	calcisol
115	317848	1087121	✓	calcisol
118	351351	1071426	✓	calcisol
119	350035	1060743	✓	calcisol
124	368316	1067811	✓	calcisol
138	409433	1060397	✓	calcisol
136	419844	1068808	✓	calcisol
310	393828	1066010	✓	calcisol
114	322951	1105225	cambisol	calcisol
129	400736	1091345	✓	calcisol
135	425758	1071008	✓	calcisol
311	392999	1069972	fluvisol	calcisol
317	405573	1107070	✓	calcisol
105	371735	1148073	✓	regosol
137	411317	1064026	✓	regosol
203	294676	1096493	✓	regosol
20	290726	1100306	leptosol	regosol
26	289966	1126844	✓	regosol
36	402059	1109679	✓	regosol
40	380109	110031	Leptosol-regosol	regosol
41	392178	1083747	✓	regosol
43	391422	1045205	leptosol	regosol
44	392237	1048008	✓	regosol
45	388196	1037591	leptosol	regosol

47	378378	1048095	leptosol	regosol
106	370641	1144179	./	fluvisol
107	351437	1138236	./	fluvisol
200	351673	1130587	./	fluvisol
201	360137	1117240	./	fluvisol
206	306076	1125322	leptosol	fluvisol
103	398704	1167944	./	fluvisol
113	323089	1106253	./	fluvisol
104	393211	1175039	./	arenosol
108	300192	1132129	fluvisol	cambisol

4.3 Soil map at 1:50 000 scale

A 1:50 000 soil map was produced only for the Agricultural areas of the study area due to the higher number of soil profiles available (from a high sampling density), which were basically the Dur-Dur and Gebiley valleys. The level of classification used in this map was the suffix which gives clearly specific soil attributes or properties to the main soil reference group and prefix level. This study area mainly comprises Vertisols, Calcisols, Fluvisols and Leptosols.

Table 15: Extent of the soil classes

Soil Type	Area (ha)	Area (km^2)	%
Calcaric Grumic Vertisol (Chromic)	31020.46	310.20	46.3
Calcaric Grumic Vertisol (Calcaric)	4152.51	41.52	
Calcaric Grumic Vertisol (Hyposodic, Chromic)	9686.29	96.86	
Calcic Grumic Vertisol (Calcaric, Hyposodic)	2468.84	24.68	
Calcic Grumic Vertisol (Hyposalic, Hyposodic, Chromic)	21861.51	218.62	
Calcic Mazic Vertisol (Bathyhyposalic, Bathyhyposodic)	1708.32	17.08	
Calcic Mazic Vertisol (Chromic)	7738.72	77.39	
Calcic Vertisol (Bathyhyposalic, Bathyhyposodic)	33475.76	334.76	
Calcic Vertisol (Calcaric, Hyposalic)	22215.79	222.16	
Calcic Vertisol (Calcaric, Hyposodic)	65496.53	654.97	
Calcic Vertisol (Calcaric, Hyposodic, Chromic)	26709.23	267.09	
Calcic Vertisol (Chromic)	39912.59	399.13	
Calcic Vertisol (Hyposodic, Chromic)	3254.69	32.55	
Haplic Vertisol (Calcaric, Chromic)	18248.77	182.49	
Endosalic Calcisol (Aridic, Clayic)	5231.17	52.31	15.7
Haplic Calcisol (Aridic, Clayic)	31481.25	314.81	
Haplic Calcisol (Episkeletic, Clayic)	12506.03	125.06	
Petric Calcisol (Episkeletic, Arenic)	1878.40	18.78	
Hypercalcic Calcisol (Aridic, Clayic)	4269.14	42.69	
Vertic Calcisol (Aridic, Clayic)	42279.16	422.79	
Haplic Regosol (Aridic)	3993.57	39.94	17.3
Haplic Regosol (Calcaric)	2116.78	21.17	
Haplic Regosol (Calcaric, Arenic)	1967.37	19.67	
Haplic Regosol (Calcaric, Aridic)	15914.75	159.15	
Haplic Regosol (Skeletic)	37008.50	370.08	
Haplic Regosol (Calcaric)/Hyperskeletic Lithic Leptosol(Calcaric)	29578.75	295.79	
Haplic Regosol (Calcaric, Arenic)/Haplic Leptosol (Skeletic)	17115.26	171.15	
Haplic Leptosol (Skeletic)	3535.02	35.35	14.9
Hyperskeletic Leptosol	59429.81	594.30	
Hyperskeletic Lithic Leptosol	5660.02	56.60	
Lithic Leptosol	6336.74	63.37	

Lithic Leptosol (Calcaric)	17631.41	176.31	
Calcic Fluvisol (Aridic, Siltic)	420.75	4.21	4.5
Haplic Fluvisol (Calcaric, Aridic)	27297.12	272.97	
Haplic Solonchak	2546.69	25.47	0.42
Fluvic Cambisol (Calcaric)	865.050	8.65	0.15
Technosols	4456.08	44.56	0.73
TOTAL	**621468.93**	**6214.69**	**100**

The soils dominating agricultural areas in the Dur-Dur and Gebiley area are the Vertisols (46.3%) the majority of which are used for agriculture. Calcisols, Leptosols and Regosols are found in similar proportions, with calcisols used for agriculture and leptoslols and regisols for grazing and other marginal land uses. Fluvisols are distributed along the rivers and alluvial plains and are used mainly for irrigated orchards. Few Cambisols and Solonchaks are present in the study area.

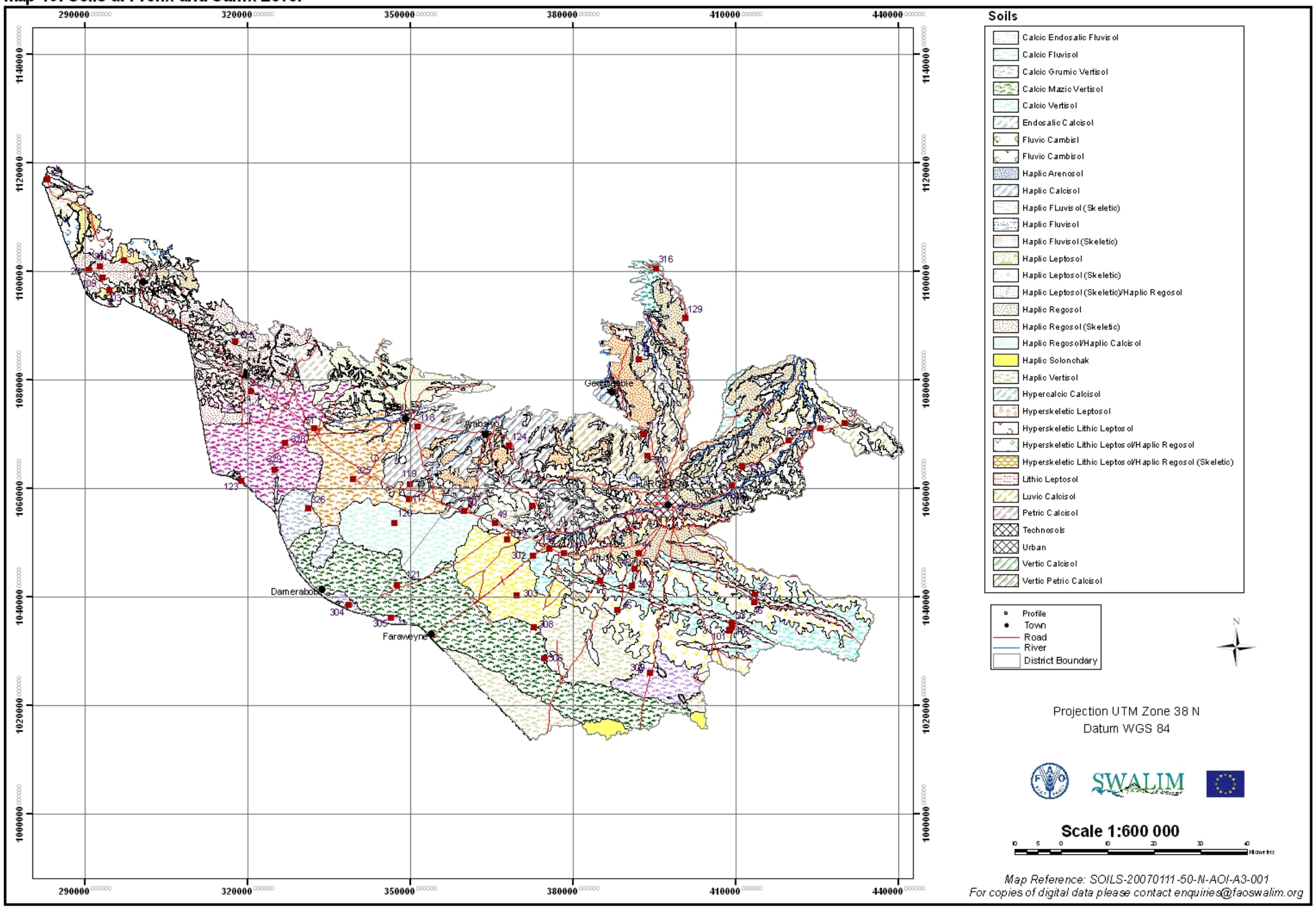
4.3.1 Technical description of the Suffix qualifiers used in the classification

The soils were first characterised at Reference Group level and also at Prefix qualifier level. The Suffix qualifiers were now included which, according to the WRB 2006, are qualifiers aimed at describing diagnostic horizons, properties or materials. They can also be qualifiers relating to chemical and/or physical characteristics. Descriptions of Suffix qualifiers used are found in Table 16.

Table 16: Suffix qualifiers and its technical meaning

SUFFIX	TECHNICAL MEANING
Aridic	Having *aridic* properties without takyric or yermic horizon. Aridic properties combine a number of properties that are common in surface horizons of soils occurring under arid conditions and where pedogenesis exceeds new accumulation at the soil surface by Aeolian or alluvial activity.
Arenic	Having a texture of loamy fine sand or coarser in a layer, 30 cm or more thick, within 100 cm of the soil surface.
Bathyhyposalic	Salic (salt) horizon starting between 100 - 200 cm from the surface.
Bathyhyposodic	Sodic horizon having more than 6% saturation with exchangeable sodium between 100 - 200 cm from the surface.
Calcaric	Having *calcaric* material between 20 - 50 cm from the soil surface or between 20 cm and a continuous rock or a cemented or indurated layer, whichever is shallower. Calcaric material applies to material that contains 2% or more calcium carbonate equivalent.
Chromic	Having within 150 cm of the soil surface a subsurface layer, 30 cm or more thick, that has a Munsell hue redder than 7.5YR or that has both, a hue of 7.5 YR and a chroma, moist, of more than 4.
Clayic	Having a texture of clay in a layer, 30 cm or more thick, within 1,000 cm of the soil surface
Dystric	Having a base saturation (by 1 M NH_4OAc) of less than 50% in the major part between 20 - 100 cm from the soil surface or between 20 cm and continuous rock or a cemented or indurated layer, or, in Leptosols, in a layer, 5 cm or more thick, directly above continuous rock
Epihyposodic	Having 15% or more exchangeable Na plus Mg on the exchange complex within 50 cm of the soil surface.
Episkeletic	Having 40% or more (by volume) gravel or other coarse fragments averaged within 50 cm of the soil surface.
Hyposalic	Having an ECe of 4 dSm^{-1} or more at 25° C in some layer within 100 cm of the soil surface.
Hyposodic	Having 6% or more exchangeable on the exchange complex in a layer, 20 cm or more thick, within 100 cm of the soil surface.
Siltic	Having a texture of silt, silt loam, silty clay loam or silty clay in a layer, 30 cm or more thick, within 100 cm of the soil surface.
Skeletic	40% or more (by volume) gravel or other coarse fragments averaged over a depth of 100 cm from the soil surface or to continuous rock or a cemented or indurated layer, whichever is shallower.

Map 10: Soils at Prefix and Suffix Level



4.4 Technical assessment of the soil resource in the study area

Table 17 gives a general idea of the main properties of the different soil classes at Reference group level. The potentialities and limitations of each soil class were expressed on a theoretical basis (soil reference books and the author's experience) and expert knowledge.

Table 17: Technical assessment of the soil resource

SOIL CLASS	PHYSICAL PROPERTIES	CHEMICAL PROPERTIES	RECOMMENDED LAND USE	LIMITATIONS
Vertisols	➢ Located on flat to slightly sloping surfaces. ➢ Low bulk density ➢ Dark colours ➢ Clayey texture ➢ Grumic/granular surface structure. ➢ Deep soils ➢ Angular/subangular blocky, prismatic subsurface horizons. ➢ Deep and wide vertical cracking structure. ➢ Wedge-shaped structure and slickenside development in lower layers. ➢ Churning or pedoturbation. ➢ Slow water conductivity ➢ Relatively high water holding capacity. ➢ Very hard below the surface horizon when dry; plastic and sticky when wet.	➢ Low organic matter content ➢ Low content of nitrogen and phosphorus nutrients. ➢ pH: slightly to moderately alkaline. ➢ EC: Negligible or slightly saline. ➢ Low Exchangeable sodium. ➢ CEC: Moderate ➢ High base saturation. ➢ High accumulation of lime. ➢ Dominant cations calcium and magnesium.	➢ Considered fertile soil where most agricultural land is found. ➢ Good potential production under specific soil management practices.	➢ Very susceptible to erosion: sheet, rill, and gully erosion, especially under poor water harvesting practices. ➢ Soil crusting at the surface is frequent. ➢ Soil severely waterlogged during high rainfall periods. ➢ Difficult to plough with oxen-drawn implements. ➢ Difficult to cultivate with heavy machinery. ➢ Poor trafficability when wet. ➢ Sub-surface piping through cracks and sinkholes.
Calcisols	➢ Well drained ➢ Good water holding capacity.	➢ Good amount of soil nutrients. ➢ Highly calcareous	➢ Good alternative for agriculture use due to their physical properties.	➢ Stoniness of the surface or close to the surface in some parts. ➢ Aridity ➢ Salinity in lower horizons. ➢ High pH and/or high calcium content limits the availability of some nutrients.
Fluvisol	➢ Located on flat to gently undulating surface. ➢ Young soils along rivers ➢ Good water conductivity	➢ Irregular organic content with depth. ➢ Salinity in lower layers locally.	➢ Good drainage conditions. ➢ Accumulation of yearly fertile soil material.	➢ Periodical flooding ➢ No major soil development.

	➢ Mainly light soil texture classes.			
Leptosols	➢ Very shallow soils ➢ High soil stoniness ➢ Excessive internal drainage.	➢ Very poor fertility	➢ Not suitable for any specific use. Mainly conservation.	➢ Shallow depth. ➢ Soil stoniness and gravel content.
Cambisols	➢ Loamy textures	➢ Medium fertility	➢ Irrigated farming ➢ Extensive grazing land	➢ Severe eroding land in mountain areas.
Regosols	➢ Weakly developed mineral soil in unconsolidated material. ➢ Shallow or stony soil	➢ Poor fertility	➢ Extensive grazing	➢ Delicate and severely eroding soils. ➢ Poor fertility ➢ Erosion and soil stoniness.
Arenosols	➢ Sandy soils developed in active sand dunes. ➢ Extremely drained	➢ Very poor fertility ➢ Saline soils	➢ Extensive nomadic grazing.	➢ Wind erosion ➢ Salinity ➢ Soil texture (sandy)
Solonchaks	➢ Heavy texture soils ➢ Low water conductivity	➢ Very saline soils	➢ Conservation	➢ Salinity ➢ Texture

The main aspects that should be highlighted with regard to soil resources in the study area are related to:

Soil erosion

Soil erosion is the primary problem in the study area. Water and wind erosion are present all over the territory and have a huge influence on the status of the soil resource and the overall environment. Sheet, rill and gully erosion are present at different levels of severity. Soil erosion problems as observed in the field and according to land users, can be attributed to natural conditions and to land mismanagement, especially increased levels of livestock grazing (overstocking), increases in numbers of water points (hand-wells, boreholes and underground water reservoirs or berkado), increasing devegetation (tree cutting, forage cutting) and some water harvesting techniques applied in agricultural areas. As the severity of soil erosion in agropastoral areas was noticed previously, two soil conservation and water harvesting projects were implemented during the 1980s and in 2000. Specifically, soil bunding was practiced in all the agricultural areas in the Plateau and dissected plateau between Hargeisa, Gebiley and Borama. In some areas it is very common to see old and unmaintained soil contour bunds together with gullies and rills, sometimes partly reduced in height through time either inside or around the fields. These soil bunds were reported as being established in the 1980s by the North-west Agricultural Development Project [24], which included soil water conservation programmes. Several newer bunds were recently made both in support of farmers practicing soil conservation, but mainly for water harvesting purposes.

It is noteworthy that wind erosion problems are severe and no conservation measures are in place.

Much of the erosion problems are recent, but they have advanced significantly during the past 20 years and more intensively after the end of the civil war in 1991. During this period the majority of pastoralists in the region altered their livelihood from nomadic herding to sedentary agropastoralism as a primary source of livelihood. The open grazing lands have been reduced both in extent and access, and traditional grazing has mostly been substituted by private farming, with permanent enclosures created without legal

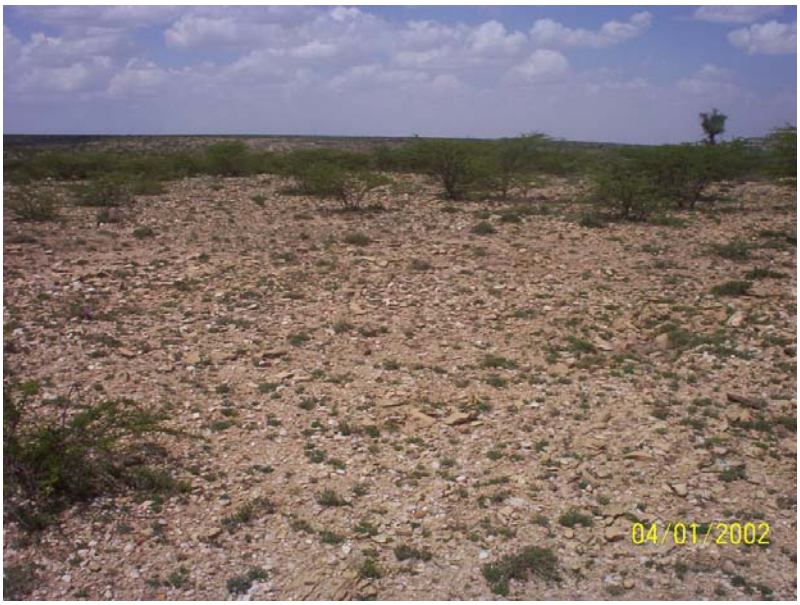
restrictions or grazing controls. Privately acquired lands are used for grazing family stock or used for grass harvesting or wood collection. The ever-increasing pressure on land resources is aggravated by an increased number of water points (wells and berkeds), and a lack of knowledge and skills amongst new farmers.

Deep soils as a natural resource are limited in the study area due to its arid and semi-arid climate. Soil formation is a very slow process, and the small existing amounts of soil are being washed away, making the situation even worse for land users.

Picture 1: Consequences of lack of maintaince of a soil bunding

Soil stoniness

A result of soil erosion is an increase in stoniness on the soil surface. Approximately, 45% of the soils in the study area are graded between “Many” (15 - 40% of coverage) and “Abundant” (40 - 80% of coverage) classes of soil stoniness. Soil stoniness is one of the main indicators for assessing land degradation as it is a sign of several degradational processes, usually in an advanced stage, occurring on the land. Its presence constrains cropping, grazing, forest development and even wildlife.



Picture 2: Soil stoniness

Soil fertility

Soil fertility is one of the main soil resources available in the study area especially for agropastoralism. According to laboratory results (Table 18) the soils of the study area are below the standard deficiency level (see Annex 2) which clearly shows the poor fertility status of the different soil classes.

Table 18: Fertility levels

SOIL CLASS	FERTILITY LEVELS					SALINITY	CALCIUM CARBONATE
	Organic matter	Nitrogen	Phosphorus	Potassium	pH		
Vertisols	Deficient	Deficient	Deficient	Low	Moderately to strongly	Non saline to slightly saline	Strongly calcareous
Fluvisols	Deficient	Deficient	Deficient to rarely adequate	Low	Moderately to strongly	Non saline	Strongly calcareous
Calcisols	Deficient	Deficient	Deficient to adequate	Low	Moderately alkaline	Non saline	Strongly calcareous
Cambisols	Deficient	Deficient	Adequate	Low	Moderately alkaline	Non saline	Strongly calcareous
Regosols	Deficient	Deficient	Deficient	Low	Moderately alkaline	Non saline	Calcareous to strongly calcareous
Arenosols	Deficient	Deficient	Deficient	Moderate to high	Strongly alkaline	Non saline	Calcareous to strongly calcareous
*Leptosols**	*not analyzed due to their natural limitations for sampling.						
Solonchack	Deficient	Deficient	Deficient	Low	Strongly alkaline	Saline to strongly saline	Strongly calcareous

Fertility problems occur in all soil classes in the study area but particularly in those used for agriculture, due to the unfavourable arid and semi-arid environment and also the fact that farmers do not replace minerals taken from the soil after harvest. Very few or no mineral or organic fertilizers are used, and available manure is kept outside fields because farmers feel that incorporating fresh manure into fields causes the appearance of weeds, making farming more difficult. They also fear the ticks that are present in the manure (Picture 3).

All soil classes in the study area are calcareous due to the underlying parent material. This fact doesn't have significant implications for the soil behaviour as such, but these soils are vulnerable to soil erosion because of their physical and chemical properties.

Salinity is not a problem in the area, with the exception of two small areas in the southern part where saline soils are found.

Picture 3: Available manure that is not used in the fields

5 CONCLUSIONS AND RECOMMENDATIONS

This study produced soil data using a multiscale and multi-user approach so that users dealing with natural resources management and other applications might make ready use of the different types of soil data presented here.

Most soils in the study area belong to a class denoting very limited soil development. 45% of the study area is composed by rocky/stony soils which have limitated use for agriculture. The origins of these type of soils are due to their natural geographic context expressed by a hilly terrain and arid climate, and to some human activities which further diminish the existing limited soil resources.

Soil stoniness is a common feature in the study area, particularly where soil erosion is high both in extent and severity. It is advisable that this process be studied in detail under a comprehensive Land Degradation Assessment of the study area. This will determine the main causes and will also find integrated solutions as part of a Natural Resources Management (NRM) strategy.

Soil fertility in the study area is low. Soils are being degraded continuously in the agro-pastoral areas, where almost no organic or inorganic fertilizers are applied. Present and future extension service activities should include the creation of awareness amongst farmers of serious declining soil fertility, and development of strategies to improve practices in the present farming systems. Research into the management and application of manure appropriate for the area is required.

A soil management strategy should be proposed in relation to a NRM strategy that can later be adopted by land users in the study area, otherwise soil degradation will continue to increase both in extent and severity, resulting in very low productivity and direct negative effects in terms of socio-economic and environmental status.

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ANNEXES

Annex 1: Soil data collection form

Annex 2: Soil analysis laboratory results

Annex 3: Soil profile description

Annex 1: Soil data collection form

Annex 2: Ranges for the soil attributes assessment

Nutrient	Deficiency level	Adequate level	Excessive level	Reference

SWALIM

PROFILE AND TRANSECT CODE

SOILS

SOIL PROFILE DESCRIPTION

DESCRIPTION OF THE SOIL SURFACE

DATE OF DESCRIPTION:

SURVEYOR:

LOCATION:

COORDINATES

X

Y

Elevation:

Slope:

LANDFORM UNIT

According to map:

According to field:

SURFACE CRUSTING/SEALING

SURFACE STONINESS

ROCK OUTCROPS

PRESENCE OF SALTS

PRESENCE OF CRACKS

SOIL DRAINAGE CLASS

SURFACE HUMIDITY

SOIL PROFILE

	1			2			3			4			5		
HORIZON															
LOWER BOUNDARY															
BOUNDARY	DISTIN		TOPO	DISTIN		TOPO	DISTIN		TOPO	DISTIN		TOPO	DISTIN		TOPO
MOISTURE STATUS															
LITHOLOGY															
COLOUR (moist)															
COLOUR (dry)															
ROCK FRAGMENTS	AB	SZ	SH	AB	SZ	SH	AB	SZ	SH	AB	SZ	SH	AB	SZ	SH
TEXTURE	TP	SZ	GR	TP	SZ	GR	TP	SZ	GR	TP	SZ	GR	TP	SZ	GR
STRUCTURE															
$CACO_3$(HCL)															
pH															
ELECTRIC CONDUCTIVITY															
ORGANIC MATTER															
ROOTS	ABUN		SZ	ABUN		SZ	ABUN		SZ	ABUN		SZ	ABUN		SZ
COATINGS	AB	LOC	NAT	AB	LOC	NAT	AB	LOC	NAT	AB	LOC	NAT	AB	LOC	NAT
MOTTLES	AB	SZ	LIM	AB	SZ	LIM	AB	SZ	LIM	AB	SZ	LIM	AB	SZ	LIM
Colour															
CEMENTATION	NAT	ST	CO	NAT	ST	CO	NAT	ST	CO	NAT	ST	CO	NAT	ST	CO
MINERAL CONCENTRATIONS	SZ-SH	AB	K/N	SZ-SH	AB	K/N	SZ-SH	AB	K/N	SZ-SH	AB	K/N	SZ-SH	AB	K/N
VOIDS	TP	SZ	AB	TP	SZ	AB	TP	SZ	AB	TP	SZ	AB	TP	SZ	AB
POROSITY															
BIOLOGICAL FEATURES	ABUN		KIN	ABUN		KIN	ABUN		KIN	ABUN		KIN	ABUN		KIND

cm 0, 25, 50, 75, 100, 125, 150, 175, 200

SOIL EROSION CLASS:

SOIL EROSION SEVERITY:

SOIL EROSION EXTENT:

LAND USE:

VEGETATION:

MICRORELIEF:

FLOODING:

Draw a transect and the position where your profile is located.

WRB SOIL CLASIFICATION

Phosphorus (Olsen method) (ppm)	< 10	10.0-15.0	> 15.0	Olsen and Dean (1965)
Total nitrogen (%)	< 0.2	0.2-0.5	> 0.5	Landon J. R. (1991)
Total organic carbon (%)	< 1.33 1.33-2.65 moderate	2.66-5.32	> 5.32	NARL

pH	Rating	Reference
Below 4.5	Extremely acid	Landon J. R. (ed.) 1991. Booker tropical soil manual. Modified for NARL
4.5 - 4.9	Strongly acid	
5.0 - 5.9	Moderately acid	
6.0 - 6.6	Slightly acid	
6.7 - 6.9	Near neutral	
7.0 - 7.4	Slightly alkaline	
7.5 - 8.4	Moderately alkaline	
8.5 - 8.9	Strongly alkaline	
Above 9.0	Extremely alkaline	

EC mS/cm	Classification	Reference
0 - 1.2	non saline	Kenya Soil Survey Staff. Manual for soil survey and land evaluation. Miscellaneous soil paper No. M24, 1987
1.2 - 2.5	slightly saline	
2.5 - 5.0	moderately saline	
5.0 - 10.0	strongly saline	
> 10.0	excessively saline	

Carbonate content %	Carbonate class	Reference
< 0.5	Trace	Kenya Soil Survey Staff. Manual for soil survey and land evaluation. Miscellaneous soil paper No. M24, 1987
0.5 - 2	Slightly calcareous	
2 - 5	Calcareous	
> 5	Strongly calcareous	

CEC me/100g	Rating	Reference
> 40	Very high	Landon J. R. (ed.) 1991. Booker tropical soil manual.
25 - 40	High	
15 - 25	Medium	
5 - 15	Low	
< 5	Very low	

Annex 3: Soil profile descriptions

SOIL PROFILE DESCRIPTION

Profile code : 20	**Date :** 2006-05-23

Location : Sararka	**Coordinates :** 09º56'54" / 43º05'28"
Authors : Ronald Vargas	**Soil climate :** Aridic
WRB 2006 Soil classification: Haplic Regosol (Skeletic**)**	**Land form :** Valley
Land use : Animal husbandry	**Drainage :** Excessively
Effective soil depth: 0 -25cm	**Moisture conditions :** Dry
Rock outcrops : Few	
Surface stoniness : Dominant	**UTM coordinates**: 290726 - 1100306

Remarks :	Profiles are impossible because this soil is dominated by stones. Usually located in valleys surrounded by hills. Soil erodes away due to overgrazing. Rock outcrops are present. The area is used for grazing and many succulent plants are present. Mineral soil with lithic contact developed in sandstone with highly $CaCO^3$ and metamorphic rocks. This soil type is spread through the whole area.

Horizon	**Depth cm**	**Description**
A	0-20	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 21	**Date :** 2006-05-31

Location : Lebida	**Coordinates :** 10º05'14" / 43º46'23"

Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil classification: Lithic Leptosol	**Land form :** Hill
FAO 90 classification :	**Land element :** Slope
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Common	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 365559 - 1115328

Remarks :	This soil is found under a basement complex material in hilland. There are no salts and the presence of rock outcrops is usual. There is a very little soil development between the rocks. The site corresponds to the shoulder of the slope.

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 22	**Date :** 2006-05-31

Location : Between Garbada and Ali Haydh	**Coordinates :** 10º03'47" / 43º47'29"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil classification: Lithic Leptosol	**Land form :** Mountain

FAO 90 classification :	**Land element :** Slope
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Abundant	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 367560 - 1112638.
Remarks :	Mountain block, ridge, upper slope. The parent material is basement complex. with little or no soil development taking place. The specific position where the soil was described is the Backslope.

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 23	**Date :** 2006-06-01

Location : Cali Xayolh	**Coordinates :** 10º01'09" / 43º46'53"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil classification: Hyperskeletic Leptosol	**Land form :** Mountain
Rock outcrops : Common	**Land element :** Ridge
Surface stoniness : Dominant	**Drainage :** Well
	Moisture conditions : Dry
UTM coordinates: 366453 - 1107790	
Remarks : Soil located in a mountain, dissected ridge and iniated in a basement complex. There is insignificant soil development.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 24	**Date :** 2006-06-04

Location : Hadha Godan	**Coordinates :** 10º15'57" / 43º13'56"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil classification: Hyperskeletic Leptosol	**Land form :** Hill
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Common	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 306412 - 1135355
Remarks : No soil at the site, plenty of large boulders, but small quantities of soil can be found in spaces between the rocks. The lithology consists of limestone in a hill/ridge.	

Horizon	**Depth cm**	**Description**
R	0-50	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 25	**Date :** 2006-06-05

Location : Near Qohyeed	**Coordinates :** 12º48'32" / 43º00'11"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006Soil Classification: Hyperskeletic Leptosol	**Land form :** Hill
Effective soil depth: 0 -25cm	**Land element :** Ridge
Rock outcrops : Common	**Drainage :** Well
Surface stoniness : Dominant	**Moisture conditions :** Dry
UTM coordinates: 283245 - 1416868	
Remarks : Lithology is sandstone, and the site is located in the shoulder. Very little soil development, partly as a result of soil erosion due to overgrazing.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 26	**Date :** 2006-06-05

Location : Near Bown	**Coordinates :** 10º11'17" / 43º04'58"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil classification: Haplic Regosol (Skeletic)	**Land form :** Pediment

Land use : Not used and not managed	**Land element :** Slope
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Very few	**Moisture conditions :** Dry
Surface stoniness : Dominant	**Vegetation :** Xeromorphic shrub
UTM coordinates: 289966 - 1126847	
Remarks : This is a slightly-developed soil located in a Piedmont/Planation surface. Grazing is the land use.	

Horizon	**Depth cm**	**Description**
A	0-12	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 27	**Date :** 2006-06-11

Location : Xeego	**Coordinates :** 10º04'35" / 43º16'03"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB2006 Soil classification: Hyperskeletic Leptosol	**Land form :** Pediment
Effective soil depth: 0 -25cm	**Drainage :** Well
Surface stoniness : Dominant	**Moisture conditions :** Dry
UTM coordinates: 310171 – 1114385	
Remarks : Very little soil development, in a Piedmont/pediment. Boulders and stones are present.	

Horizon	Depth cm	Description
R	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 28	**Date :** 2006-06-11

Location : Xeego	**Coordinates :** 10º04'39" / 43º16'15"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Pediment
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Many	**Moisture conditions :** Dry
Surface stoniness : Abundant	**UTM coordinates:** 310527 - 114503
Remarks : Soil with no development located in a Piedmont, pediment.	

Horizon	Depth cm	Description
R	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 29	**Date :** 2006-06-14

Location : Dudwayne	**Coordinates :** 09º44'51" / 43º21'52"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Lithic Leptosol (Calcaric)	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Surface stoniness : Many	**Moisture conditions :** Dry
UTM coordinates: 320610 - 1077927	
Remarks : Little soil developement, in a plateau/hill complex under limestone.	

Horizon	Depth cm	Description
A	0-25	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 30	**Date :** 2006-06-01

Location : Xiriiro, west of Ali Xayah	**Coordinates :** 10º01'28" / 43º42'51"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Hill
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Surface stoniness : Common	**Moisture conditions :** Dry
UTM coordinates: 359084 - 1108407	
Remarks : Stony soil located in a Hilland/hill complex. No soil development is present.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 31	**Date :** 2006-06-06

Location : Carra Garanug	**Coordinates :** 09º57'52" / 43º09'02"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil classification: Hyperskeletic Leptosol	**Land form :** Pediment
Surface stoniness : Dominant	**Drainage :** Well
	Moisture conditions : Dry
UTM coordinates: 297269 - 1102062.	
Remarks : Gravelly surface located in a Piedmont/Pediment, denudational surface.	

Horizon	Depth cm	Description
R	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 32	**Date :** 2006-06-06

Location : Fulunful	**Coordinates :** 09º59'36" / 43º07'53"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Leptosol (Skeletic)	**Land form :** Mountain
Surface stoniness : Abundant	**Drainage :** Well
	Moisture conditions : Dry
UTM coordinates: 295187 - 1105258	
Remarks : Located in a mountain/dissected ridge.	

Horizon	Depth cm	Description
R	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 33	**Date :** 2006-05-20

Location : Toon-maadhyaal	**Coordinates :** 09º21'02" / 44º10'14"
Authors : Ronald Vargas	**Land form :** Plateau
WRB 2006 Soil classification: Hyperskeletic Leptosol	**Land element :** Slope
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Common	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 408925 - 1033739
Remarks : This profile is located in the denudational surface of the plateau. The entire profile is full of stones and very little soil can be found down to 20 cm. There is evidence of soil erosion. Is a shoat grazing area.	

Horizon	Depth cm	Description
A	0-15	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 34	**Date :** 2006-07-13

Location : Galnidhiqeed	**Coordinates :** 09º59'53" / 44º00'37"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Lithic Leptosol	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Dominant	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 391524 - 1105374

Remarks : No soil profile development, the parent material is mica and schist located in a Dissected Plateau/Pediment. Rocky soil.

Horizon	Depth cm	Description
R	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 35	**Date :** 2006-07-12

Location : Illinta Qoryale	**Coordinates :** 09º57'55" / 44º01'36"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Surface stoniness : Dominant	**Moisture conditions :** Dry
UTM coordinates: 393304 - 1101743	
Remarks : Dissected plateau/hill complex. The parent material of this undeveloped soil is conglomerate. No cracks or salts are present.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 36	**Date :** 2006-07-14

Location : Gacan Waashay	**Coordinates :** 10º02'14" / 44º06'22"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Skeletic)	**Land form :** Plateau
Rock outcrops : Few	**Drainage :** Excessively
Surface stoniness : Dominant	**Moisture conditions :** Dry
UTM coordinates: 402059 - 1109679	
Remarks : Dissected plateau/Pediment, marginal grazing land. Soil observation located in a toeslope formed by basalt.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 37	**Date :** 2006-07-16

Location : Diingal	**Coordinates :** 09º41'51" / 44º21'50"
Authors : Musse Shaie	**Soil climate :** Aridic

WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Pediment
Effective soil depth: 0 -25cm	**Land element :** Ridge
Surface stoniness : Dominant	**Drainage :** Excessively
	Moisture conditions : Dry
UTM coordinates: 430232 - 1072033	
Remarks : Stony soil with no profile under sandstone. Located in a Piedmont/Badland.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 38	**Date :** 2006-07-12

Location : East Agabar	**Coordinates :** 09º52'34" / 43º58'41"
Authors : Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Pediment
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 387949 - 1091887
Remarks : Undeveloped soil located in a Piedmont/denudational surface under tuff parent rock. No samples.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 39	**Date :** 2006-07-13

Location : Agabar	**Coordinates :** 09º56'03" / 43º54'49"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Pediment
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 380900 - 1098346
Remarks : Undeveloped soil under complex parent material composed of sandstones located in a piedmont/dissected ridge.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 40	**Date :** 2006-07-13

Location : North of Agabar	**Coordinates :** 10º02'24" / 43º54'21"
Authors : Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Skeletic)	**Land form :** Mountain
Effective soil depth: 0 -25cm	**Land element :** Ridge
Surface stoniness : Dominant	**Drainage :** Excessively
	Moisture conditions : Dry
UTM coordinates: 380109 - 1110031	
Remarks : Very little-developed soil located in a Mountain/Dissected ridge under a complex parent material.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 41	**Date :** 2006-07-13

Location : North of Dirato	**Coordinates :** 09º48'09" / 44º01'01"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Skeletic)	**Land form :** Pediment
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Abundant	**UTM coordinates:** 392178 - 1083747
Remarks : This soil observation is located in a Piedmont/Denudational surface under limestone and granite parent material.	

Horizon	Depth cm	Description
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 42	**Date :** 2006-07-14

Location : North of Illinta Dhexe	**Coordinates :** 10º01'22" / 44º07'43"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 404513 - 1108059
Remarks : Soil observation located in a Dissected plateau/Pediment under sandstone parent rock.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 43	**Date :** 2006-07-17

Location : North of Cunagabad	**Coordinates :** 09º27'14" / 44º00'39"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Skeletic)	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Common	**UTM coordinates:** 391422 - 1045205
Remarks : Soil observation located in a Dissected plateau/denudational surface under limestone.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 44	**Date :** 2006-07-17

Location : South of Hargeisa	**Coordinates :** 09º28'46" / 44º01'06"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Skeletic)	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Common	**Moisture conditions :** Dry
Surface stoniness : Many	**UTM coordinates:** 392237 - 1048008
Remarks : Soil observation located in a Plateau/mesa under limestone parent rock.	

Horizon	Depth cm	Description
R	0-50	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 45	**Date :** 2006-07-17

Location : South of Canagabad	**Coordinates :** 09º23'06" / 43º58'54"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic

WRB 2006 Soil Classification: Haplic Regosol (Skeletic)	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Well
Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Many	**UTM coordinates:** 388196 - 1037591
Remarks : Soil observation located in a Dissected plateau/denudational surface under limestone.	

Horizon	**Depth cm**	**Description**
A	0-20	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 46	**Date :** 2006-07-16

Location : Sharmaarke	**Coordinates :** 09º23'53" / 44º12'43"
Authors : Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Well

Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 413469 - 1038976
Remarks : Soil observation located in a Dissected plateau/Denudational surface under limestone parent rock.	

Horizon	Depth cm	Description
A	0-20	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Position

SOIL PROFILE DESCRIPTION

Profile code : 47	**Date :** 2006-07-17

Location : Fahda	**Coordinates :** 09º28'47" / 43º53'31"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Skeletic).	**Land form :** Plateau
Rock outcrops : Few	**Drainage :** Excessively
Surface stoniness : Many	**Moisture conditions :** Dry
UTM coordinates: 378378 - 1048095	
Remarks : Soil observation located in a limestone parent rock in a Dissected plateau/Denudational surface.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 48	**Date :** 2006-07-17

Location : Garyogol	**Coordinates :** 09º29'13" / 43º52'03"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Lithic Leptosol (Calcaric).	**Land form :** Plateau
Effective soil depth: 0 -25cm**:**	**Drainage :** Excessively
Rock outcrops : Common	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 375690-1048891
Remarks : Soil observation located in a Dissected plateau/Denudational surface in a limestone parent rock.	

Horizon	Depth cm	Description
R	0-20	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 49	**Date :** 2006-07-17

Location : Harcadaad	**Coordinates :** 09º31'44" / 43º46'35"

Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Lithic Leptosol (Calcaric).	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Many	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 365711 - 1053553
Remarks : Soil observation located in a Dissected plateau/Hill under limestone.	

Horizon	Depth cm	Description
R	0-20	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

Profile code : 50	**Date :** 2006-07-17

Location : Xidhinta	**Coordinates :** 09º32'54" / 43º43'30"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil classification: Lithic Leptosol (Calcaric).	**Land form :** Plateau
Effective soil depth: 0 -25cm	**Drainage :** Excessively
Rock outcrops : Many	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 360073 - 1055724

Remarks :	Soil observation located in a Dissected plateau/Hill under limestone.

Horizon	**Depth cm**	**Description**
R	0-20	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 51	**Date :** 2006-07-22

Location : Kalabaydh	**Coordinates :** 09º41'08" / 43º28'17"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hyperskeletic Leptosol	**Land form :** Plateau
Rock outcrops : Nil	**Drainage :** Excessively
Surface stoniness : Dominant	**Moisture conditions :** Dry
UTM coordinates: 332301 – 1071046	
Remarks : Soil observation located in a Dissected plateau/Hill under limestone.	

Horizon	**Depth cm**	**Description**
A	0-10	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

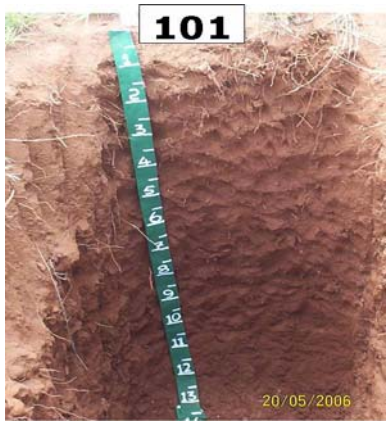
Profile

SOIL PROFILE DESCRIPTION	
Profile code : 101	**Date :** 2006-05-19
Location : Toon-maadh Yaal	**Coordinates :** 09º21'47" / 44º10'30"
Authors : Omar Haji Duale, Ronald Vargas, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Vertisol (Calcaric, Chromic).	
Land use : Mixed farming	**Land form :** Valley
Parent material : Alluvium	
Effective soil depth: 100-150cm	**Drainage :** Moderately well
Rock outcrops : Nil	**Moisture conditions :** Moist
Surface stoniness : Nil	**UTM coordinates:** 409401 - 1035093

Remarks :	The area is covered by sinkholes and cracks.

Horizon	Depth cm	Description
A1	0-35	Reddish brown (5YR 4/4) (moist); no mottles; clay; moderate medium subangular blocky structure; no cutans; many Voids fine; no rocks; strongly calcareous; few biological activity; common fine roots; Field pH: 8.2; clear smooth boundary.
A2	35-65	Dark reddish brown (5YR 3/4) (moist); no mottles; clay; weak medium subangular blocky structure; no cutans; medium porosity, many Voids fine; no rocks; strongly calcareous; few biological activity; very few very fine roots; Field pH: 8.4; gradual smooth boundary.
Bt	65-130	Reddish brown (5YR 4/4); no mottles ; clay; weak coarse subangular blocky structure; common pressure faces; low porosity, very few Voids very coarse; no rocks; strongly calcareous; few biological activity; very few very fine roots; Field pH: 8.7.

HORIZON	A1	A2	Bt		
LOWER BOUNDARY	35	65	130		
SAND %	28.0	24.0	24.0		
SILT %	14.0	16.0	14.0		
CLAY %	58.0	60.0	62.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.26	1.26	1.26		
C (%)	0.60	0.50	0.30		
N (%)	0.03	0.03	0.03		
P (ppm)	8.90	35.50	11.50		
pH	8.20	8.40	8.70		
EC (mS/cm)	0.22	0.20	0.25		
CEC (me/100g)	14.80	11.80	0.30		
Ca^{++}	24.6	18.8	17.3		
Mg^{++}	1.6	0.3	0.3		
K^{+}	1.4	1.1	0.8		
Na^{+}	2	1	2		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	28.00	30.00	31.00		



Profile

SOIL PROFILE DESCRIPTION

Profile code : 102	**Date :** 2006-05-20

Location : Toon-maadhyaal	**Coordinates :** 09º21'21" / 44º10'27"
Authors : Omar Haji Duale, Musse Shaie, Ali Ibrahim Ismail	**Land form :** Valley
WRB2006 Soil Classification: Calcic Vertisol (Chromic)	**Land element :** Slope
Land use : Shifting cultivation	**Drainage :** Well
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Surface stoniness : Nil	**Vegetation :** Grassland
UTM coordinates: 409341 - 1034321	
Remarks : Very hard soil located at the talus slope of a valley, very close to profile 201. Soil is clayed but is very compacted and dry, so, many properties were difficult to see. Although the soil texture is clay, there is no evidence of cracks. Gilgai microtopography was found.	

Horizon	Depth cm	Description
A1	0-20	Dark brown (7.5YR 4/4) (dry); no mottles; clay; weak very fine granular structure; no cutans; many Voids fine; no rocks; extremely calcareous; common fine-medium roots; gradual smooth boundary.
A2	20-30	Reddish brown (5YR 4/4) (dry); no mottles; clay; moderate medium granular structure; no cutans; few Voids fine; no rocks; extremely calcareous; common fine roots; gradual smooth boundary.
B1	30-50	Dark reddish brown (5YR 3/3) (dry); no mottles; clay; moderate medium subangular blocky structure; many pressure faces; very few, very fine Voids; no rocks; extremely calcareous; common very fine roots; gradual smooth boundary.
B2	50-65	Brown (7.5YR 4/3) (dry); no mottles; clay; moderate medium angular blocky structure; many pressure faces; no voids; no rocks; extremely calcareous; common very fine roots; gradual smooth boundary.
C	65-130	Brown (7.5YR 4/3) (dry); no mottles; clay; massive structure; no cutans; no voids; no rocks; extremely calcareous; very few very fine roots.

HORIZON	A1	A2	B1	B2	C
LOWER BOUNDARY	20	30	50	65	130
SAND %	38.0	24.0	24.0	20.0	22.0
SILT %	16.0	20.0	20.0	22.0	20.0
CLAY %	46.0	56.0	56.0	58.0	58.0
TEXTURE CLASS	**C**	**C**	**C**	**C**	**C**
BULK DENSITY (g/cm^3)	1.46	1.46	1.46	1.46	1.46
C (%)	0.70	0.50	0.70	0.40	0.40
N (%)	0.05	0.04	0.03	0.03	0.03
P (ppm)	2.60	8.50	14.10	12.80	10.80
pH	8.30	8.10	8.20	8.20	8.20
EC (mS/cm)	0.23	0.98	1.30	1.50	2.20
CEC (me/100g)	16.20	17.80	17.60	17.60	16.60
Ca^{++}	22.5	25.8	24.1	15	19.4
Mg^{++}	2.2	2.6	4.4	3.1	4.4
K^{+}	1.9	1.2	1.2	0.7	0.52
Na^{+}	2	2	3	3	3
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	30.00	31.00	30.00	24.00	28.00

Profile

SOIL PROFILE DESCRIPTION

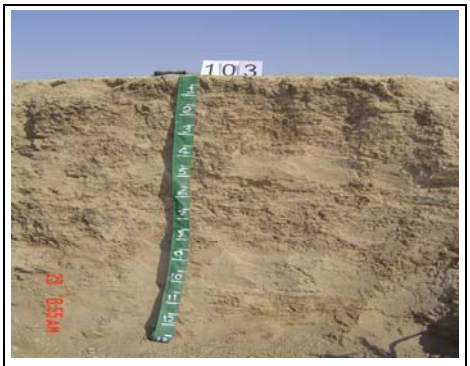
Profile code : 103	**Date :** 2006-05-23

Location : Caloolane	**Coordinates :** 10º33'51" / 44º04'26"
Authors : Musse Shaie, Omar Haji Duale, Ali Ibrahim Ismail	**Land form :** Coastal plain
WRB 20006 Soil Classification: Calcic Endosalic Fluvisol (Aridic, Siltic)	**Drainage :** Well
Land use : Animal husbandry	**Moisture conditions :** Dry
Effective soil depth: 100-150cm	**Vegetation :** Xeromorphic forest
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates:** 398704 - 1167944

Remarks : Floodingis frequent. Presence of surface sealing and crusting. This profile is located in the northern coastal plain, delta. Dried *Xudhur* sp. is common. Toward the coast there are many well established *Prosopsis* sp.

Horizon	Depth cm	Description
A1	0-40	Pale brown (10YR 6/3) (dry); no mottles; silty clayloam; weak fine and medium platy structure; no cutans; no voids; no rocks; extremely calcareous; no roots; clear wavy boundary.
E	40-60	Light grey (2.5Y 7/2) (dry); no mottles; siltloam; massive structure; no cutans; no voids; no rocks; extremely calcareous; no roots; clear smooth boundary.
B1	60-90	Light olive brown (2.5Y 5/3) (dry); no mottles; siltloam; strong medium angular blocky structure; no cutans; no voids; no rocks; extremely calcareous; no roots; clear smooth boundary.
B2	90-110	Pale brown (10YR 6/3) (dry); no mottles; siltloam; massive structure; no cutans; no voids; no rocks; extremely calcareous; no roots; clear wavy boundary.
C1	110-120	Brown (10YR 5/3) (moist); no mottles; silty clay; massive structure; no cutans; no voids; no rocks; extremely calcareous; no roots.

HORIZON	A1	E	B1	B2	C1
LOWER BOUNDARY	40	60	90	110	120
SAND %	10.0	12.0	16.0	22.0	12.0
SILT %	52.0	74.0	60.0	64.0	46.0
CLAY %	38.0	14.0	24.0	14.0	42.0
TEXTURE CLASS	**SICL**	**SIL**	**SIL**	**SIL**	**SICL**
BULK DENSITY (g/cm^3)	1.35	1.35	1.35	1.35	1.35
C (%)	0.50	0.40	0.70	0.20	0.40
N (%)	0.04	0.05	0.11	0.02	0.04
P (ppm)	14.20	8.60	4.30	11.30	8.80
pH	8.30	7.90	7.70	8.20	7.90
EC (mS/cm)	1.30	4.07	8.91	3.73	10.60
CEC (me/100g)	15.60	7.40	21.10	6.30	14.00
Ca^{++}	19.5	28.1	24.3	14.3	17.5
Mg^{++}	1.7	2.9	0.4	1.6	3.1
K^{+}	0.3	0.3	0.8	0.2	0.3
Na^{+}	2	2	7	2	11
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	23.00	23.00	22.00	22.00	23.00



Profile

SOIL PROFILE DESCRIPTION

Profile code : 104	**Date :** 2006-05-24
Location : Beeyo Macaan	**Coordinates :** 10º37'41" / 44º01'25"
Authors : Omar Haji Duale, Ali Ibrahim, Ismail Musse Shaie	**Soil climate :** Aridic aridic
WRB 2006 Soil Classification: Haplic Arenosol (Calcaric, Aridic).	**Land form :** Coastal plain
Effective soil depth: 100-150cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 393211 - 1175039

Remarks : This profile is located in the northwest coastal plain, on the sandy coast of Somalia. Grazing is the only land use present. No flooding hazard.

Horizon	Depth cm	Description
A1	0-25	Pale brown (10YR 6/3) (dry); no mottles; loamy sand; massive structure; no cutans; no voids; no rocks; extremely calcareous; many very fine roots; clear wavy boundary.
A2	25-75	Light grey (10YR 7/2) (dry); no mottles; loamy sand; massive structure; no cutans; no voids; no rocks; strongly calcareous; many very fine roots; clear wavy boundary.
AC	75-85	Pale red (10R 7/2) (dry); no mottles; sand; massive structure; no cutans; no voids; no rocks; slightly calcareous; many very fine roots; abrupt smooth boundary.
C1	85-110	Light brownish grey (10YR 6/2) (dry); no mottles; loamy sand; massive structure; no cutans; no voids; no rocks; slightly calcareous; very few medium roots; abrupt smooth boundary.
C2	110-120	Light brownish grey (10YR 6/2) (dry); no mottles; sand; massive structure; no cutans; no rocks; slightly calcareous; very few medium roots.

HORIZON	A1	A2	AC	C1	C2
LOWER BOUNDARY	25	75	85	110	120
SAND %	76.0	78.0	88.0	64.0	92.0
SILT %	18.0	16.0	8.0	28.0	4.0
CLAY %	6.0	6.0	4.0	8.0	4.0
TEXTURE CLASS	**LS**	**LS**	**S**	**LS**	**S**
BULK DENSITY (g/cm^3)	1.60	1.60	1.60	1.60	1.60
C (%)	0.20	0.10	0.10	0.10	0.10
N (%)	0.01	0.00	0.00	0.00	0.00
P (ppm)	3.20	3.30	2.40	1.60	34.60
pH	8.80	8.80	9.20	9.80	10.00
EC (mS/cm)	0.08	0.07	0.15	0.40	0.40
CEC (me/100g)	1.30	0.70	0.60	2.70	1.10
Ca^{++}	6.6	10.5	11.9	12.9	11.7
Mg^{++}	0.3	0.4	0.3	0.7	0.3
K^{+}	0.2	0.2	0.2	0.5	0.2
Na^{+}	0	0.2	0.7	1	0.5
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	4.00	4.00	5.00	4.00	4.00

Profile

SOIL PROFILE DESCRIPTION

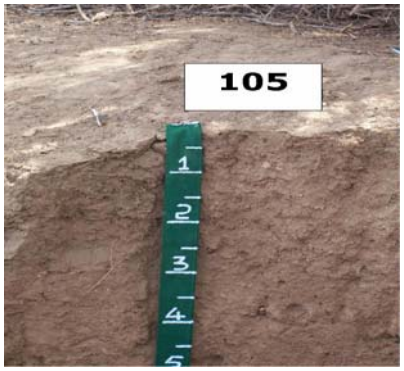
Profile code : 105	**Date :** 2006-05-29

Location : Lurega Meygaaga	**Coordinates :** 10º23'01" / 43º49'42"
Authors : Musse Shaie	**Land form :** Pediment
WRB 2006Soil Classification: Haplic Regosol (Calcaric, Aridic)	**Drainage :** Moderately well
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Few	**UTM coordinates:** 371735 - 1148073

Remarks : Piedmont, alluvial plain. Grazing land use. Soils are very little developed under Limestone. There are no salts and there are soil cracks (fine width and very widely spaced). The landform is a braided valley.

Horizon	Depth cm	Description
A1	0-10	Brown (7.5YR 5/2) (moist) and Pale brown (10YR 6/3) (dry); no mottles; sandy loam; massive structure; no cutans; ; few Voids medium; no rocks; slightly calcareous; common fine roots; clear smooth boundary.
A2	10-65	Brown (7.5YR 4/3) (moist) and Brown (7.5YR 5/3) (dry); no mottles ; sandy loam; massive structure; no cutans; few Voids coarse; common fine and medium subrounded rocks; moderately calcareous; few medium-coarse roots; clear smooth boundary.
Ck	65-150	Brown to dark brown (7.5YR 4/2) (moist) and Brown (7.5YR 5/3) (dry); no mottles; sandy loam; massive structure; no cutans; very few Voids very coarse; no rocks; strongly calcareous; no roots.

HORIZON	A1	A2	Ck		
LOWER BOUNDARY	10	65	150		
SAND %	74.0	76.0	72.0		
SILT %	18.0	10.0	12.0		
CLAY %	8.0	14.0	16.0		
TEXTURE CLASS	**SL**	**SL**	**SL**		
BULK DENSITY (g/cm^3)	1.70	1.70	1.70		
C (%)	0.63	0.34	0.19		
N (%)	0.05	0.03	0.03		
P (ppm)	15.30	9.30	7.20		
pH	8.10	8.10	8.30		
EC (mS/cm)	0.28	0.14	0.12		
CEC (me/100g)	6.60	7.80	23.80		
Ca^{++}	11.8	17.7	13.7		
Mg^{++}	1.1	1.2	1.4		
K^{+}	1	0.3	0.3		
Na^{+}	1	0.4	1		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	7.00	8.00	11.00		



Profile

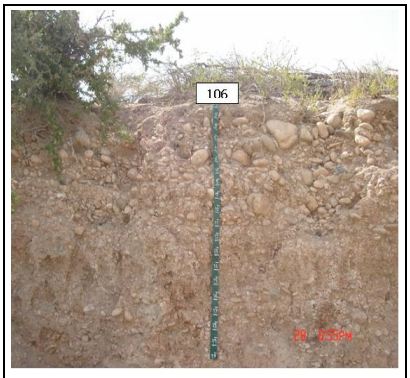
SOIL PROFILE DESCRIPTION

Profile code : 106	**Date :** 2006-05-29

Location : Ilka Weyn Colful	**Coordinates :** 10º20'54" / 43º49'06"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Fluvisol (Calcaric, Skeletic).	**Land form :** Valley
Effective soil depth: 25-50cm	**Land element :** Valley floor
Surface stoniness : Dominant	**Drainage :** Well
	Moisture conditions : Dry
UTM coordinates: 370641 - 1144179	
Remarks : Grazing area in a valley, braided river plain. Soil influenced by the fluvial deposits, where old alluvial materials are found. There are no salts and very few soil cracks.	

Horizon	Depth cm	Description
A	0-20	Pinkish grey (7.5YR 7/2) (dry); no mottles ; sandy loam; weak medium subangular blocky structure; no cutans; ; few Voids medium; common fine angular rocks; extremely calcareous; few fine roots; clear wavy boundary.
C	-	.

HORIZON	A				
LOWER BOUNDARY	20				
SAND %	54.0				
SILT %	34.0				
CLAY %	12.0				
TEXTURE CLASS	**SL**				
BULK DENSITY (g/cm^3)	1.65				
C (%)	0.82				
N (%)	0.07				
P (ppm)	10.30				
pH	8.10				
EC (mS/cm)	0.16				
CEC (me/100g)	9.20				
Ca^{++}	12				
Mg^{++}	0.7				
K^{+}	1.2				
Na^{+}	1				
PSB (%)	100				
CaCO3 (%)	13.00				



Profile

SOIL PROFILE DESCRIPTION

Profile code : 107	**Date :** 2006-05-30

Location : Diriye Malayste-West Garbadadar	**Coordinates :** 10º17'38" / 43º38'36"
Authors : Musse Shaie	**Elevation :** 466
WRB 2006 Soil Classification: Haplic Fluvisol (Calcaric, Aridic)	**Land form :** Pediment
Effective soil depth: 50-100cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates**: 351437 - 1138236

Remarks : Soil located in a piedmont, lower pediment, on a fluvial plain. No salts and cracks. Calcium carbonate nodules or concretions present in second and third horizons. Land use is grazing.

Horizon	Depth cm	Description
A1	0-20	Brown (7.5YR 5/3) (moist) and Light brown (7.5YR 6/3) (dry); no mottles; sandy loam; massive structure; no cutans; very few, very fine Voids; no rocks; strongly calcareous; common fine-medium roots; gradual wavy boundary.
C1	20-110	Dark brown to brown (10YR 4/3) (moist) and Pale brown (10YR 6/3) (dry); no mottles; sandy loam; massive structure; no cutans; no voids; no rocks; common calcareous concretions medium; strongly calcareous; clear wavy boundary.
C2	110-150	Dark brown to brown (10YR 4/3) (moist) and Pale brown (10YR 6/3) (dry); no mottles; sandy loam; massive structure; no cutans; no voids; no rocks; common calcareous concretions medium; strongly calcareous; gradual wavy boundary.

HORIZON	A1	C1	C2		
LOWER BOUNDARY	20	110	120		
SAND %	68.0	66.0	78.0		
SILT %	14.0	18.0	12.0		
CLAY %	18.0	16.0	10.0		
TEXTURE CLASS	**SL**	**SL**	**SL**		
BULK DENSITY (g/cm^3)	1.63	1.63	1.63		
C (%)	0.37	0.18	0.71		
N (%)	0.01	0.01	0.01		
P (ppm)	12.00	6.40	6.50		
pH	8.30	8.40	9.00		
EC (mS/cm)	0.11	0.12	0.16		
CEC (me/100g)	11.10	9.90	17.90		
Ca^{++}	11.2	9.9	18.3		
Mg^{++}	0.6	0.7	1.6		
K^{+}	0.5	0.1	0.1		
Na^{+}	0.5	0.2	1		
PSB (%)	100	100	100		
CaCO3 (%)	9.00	10.00	8.00		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 108	**Date :** 2006-06-04

Location : Near Xalimale	**Coordinates :** 10º14'11" / 43º10'32"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Fluvic Cambisol (Calcaric, Dystric).	**Land form :** Pediment
Effective soil depth: 100-150cm	**Drainage :** Well
Surface stoniness : Many	**Moisture conditions :** Dry
UTM coordinates: 300192 - 1132129	
Remarks : Soil located in a Piedmont, pediment. Soil with no surface cracks or salts. Shrubs and grazing area.	

Horizon	Depth cm	Description
A	0-15	Reddish grey (5YR 5/2) (dry); no mottles; sandy clayloam; moderate coarse granular structure; no cutans; few Voids fine; no rocks; common nodules calcareous fine; extremely calcareous; few fine roots; diffuse wavy boundary.
B	16-35	Reddish grey (5YR 5/2) (moist); clayloam; moderate fine granular structure; common clay on pedfaces Cutans; few Voids fine; no rocks; few fine calcareous nodules; extremely calcareous; few fine roots; clear wavy boundary.
C1	35-70	Reddish grey (5YR 5/2) (moist); no mottles; loam; moderate medium subangular blocky structure; no cutans; very few Voids fine; no rocks; very few fine calcareous nodules; extremely calcareous; few very fine roots; gradual smooth boundary.
C2	70-140	Reddish grey (5YR 5/2) (moist); no mottles; sandy clayloam; weak fine subangular blocky structure; no cutans; very few Voids very coarse; no rocks; very few fine calcareous nodules; extremely calcareous; few fine roots; diffuse wavy boundary.

HORIZON	A	B	C1	C2	
LOWER BOUNDARY	15	35	70	140	
SAND %	52.0	40.0	36.0	50.0	
SILT %	20.0	26.0	38.0	26.0	
CLAY %	28.0	34.0	26.0	24.0	
TEXTURE CLASS	**SCL**	**CL**	**LS**	**SCL**	
BULK DENSITY (g/cm^3)	1.39	1.39	1.39	1.39	
C (%)	0.47	0.57	0.38	0.39	
N (%)	0.05	0.04	0.03	0.04	
P (ppm)	7.70	7.80	7.70	7.40	
pH	8.20	7.90	7.90	8.10	
EC (mS/cm)	1.24	3.00	2.30	1.30	
CEC (me/100g)	30.80	24.00	25.50	29.90	
Ca^{++}	21.4	22.5	19.40	23.40	
Mg^{++}	2.8	5.2	4.90	5.20	
K^{+}	0.2	0.3	0.20	0.20	
Na^{+}	1	2	2.00	2.00	
PSB (%)	84	100	100	100	
CaCO3 (%)	14.00	16.00	14.00	10.00	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 109	**Date :** 2006-06-07

Location : Abu Qays	**Coordinates :** 09º56'06" / 43º06'53"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Epihyposodic).	**Land form :** Pediment
Effective soil depth: 50-100cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 293311 - 1098830

Remarks : Soil developed in an old piedmont/pediment. Presence of some fine very closely spaced cracks, from surface to depth of 90 cm.

Horizon	Depth cm	Description
A1	0-10	Brown to dark brown (7.5YR 4/2) (moist) and Brown (7.5YR 5/3) (dry); no mottles; weak fine granular structure; no cutans; few very fine Voids; no rocks; extremely calcareous; common fine-medium roots; diffuse boundary.
A2	10-45	Brown to dark brown (7.5YR 4/2) (moist); no mottles; strong medium and coarse prismatic structure; few clay on pedfaces Cutans; very few Voids fine and very fine; no rocks; extremely calcareous; common fine roots; diffuse
Bk	45-100	Dark brown (7.5YR 3/2) (moist); no mottles; strong medium and coarse angular and subangular blocky structure; many clay on pedfaces Cutans; ; very few Voids fine and very fine; no rocks; extremely calcareous; very few fine roots.

HORIZON	A1	A2	Bk		
LOWER BOUNDARY	10	45	100		
SAND %	52.0	24.0	18.0		
SILT %	4.0	20.0	22.0		
CLAY %	44.0	56.0	60.0		
TEXTURE CLASS	**SC**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.51	1.51	1.51		
C (%)	1.08	0.44	0.62		
N (%)	0.09	0.03	0.06		
P (ppm)	11.00	11.80	10.90		
pH	8.15	8.04	8.13		
EC (mS/cm)	0.14	0.24	2.07		
CEC (me/100g)	39.22	18.16	26.22		
Ca^{++}	36.22	86.29	20.31		
Mg^{++}	3.68	4.57	7.95		
K^{+}	0.91	0.57	0.60		
Na^{+}	3.97	1.60	1.03		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	25.65	34.15	28.15		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 110	**Date :** 2006-06-11

Location : Xeeqo	**Coordinates :** 10º04'45" / 43º16'13"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Calcisol (Aridic, Clayic).	**Land form :** Pediment
Effective soil depth: 25-50cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Very few	**UTM coordinates:** 310471 - 1114683

Remarks : Piedmont, pediment. Presence of fine and very closely spaced cracks.

Horizon	Depth cm	Description
Ak1	0-10	Reddish grey (5YR 5/2) mottled (dry); no mottles ; weak fine subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; dominant very fine calcareous concretions; extremely calcareous; common fine-medium roots; diffuse smooth boundary.
Ak2	10-20	Weak red (2.5YR 5/2) (dry); no mottles; moderate medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; dominant nodules calcareous very fine; extremely calcareous; common medium roots; gradual smooth boundary.
Ck3	20-90	Light red (10R 7/6) (dry); no mottles; strong very coarse platy structure; dominant clay on pedfaces Cutans; ; very few, very fine Voids; no rocks; dominant calcareous very fine; extremely calcareous; very few fine roots.

HORIZON	A1k	A2k	Ck		
LOWER BOUNDARY	10	20	90		
SAND %	18.0	22.0	34.0		
SILT %	34.0	20.0	18.0		
CLAY %	48.0	58.0	54.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.46	1.46	1.46		
C (%)	0.42	0.77	0.30		
N (%)	0.04	0.06	0.02		
P (ppm)	15.20	16.30	15.40		
pH	8.15	8.03	8.14		
EC (mS/cm)	0.78	0.33	0.58		
CEC (me/100g)	19.12	26.39	11.60		
Ca^{++}	72.84	32.84	112.74		
Mg^{++}	3.82	0.47	4.46		
K^{+}	0.79	1.03	0.28		
Na^{+}	1.05	1.20	3.47		
PSB (%)	100.0	100	100		
CaCO3 (%)	36.65	27.65	28.15		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 113	**Date :** 2006-06-12

Location : Dijaamaley	**Coordinates :** 10º00'13" / 43º23'29"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Fluvisol (Aridic, Siltic).	**Land form :** Valley
Effective soil depth: 100-150cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Very few	**UTM coordinates:** 323089 - 1106253

Remarks : Soil developed under unconsolidated sediment in a Valley, braided river plain. Fine and very closely spaced cracks.

Horizon	Depth cm	Description
A1	0-35	Dark reddish grey (5YR 4/2) (moist); no mottles; weak fine subangular blocky structure; no cutans; very few, very fine Voids; no rocks; strongly calcareous; many very fine roots; gradual smooth boundary.
A2	35-75	Reddish brown (5YR 4/3) (moist); no mottles; moderate medium subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; strongly calcareous; common fine roots; clear wavy boundary.
C	75-150	Dark reddish brown (5YR 3/2) (moist); no mottles ; massive structure; no cutans; ; very few Voids medium; no rocks; few fine calcareous nodules; strongly calcareous; common fine roots.

HORIZON	A1	A2	C		
LOWER BOUNDARY	35	75	150		
SAND %	46.0	34.0	20.0		
SILT %	34.0	42.0	42.0		
CLAY %	20.0	24.0	38.0		
TEXTURE CLASS	**L**	**L**	**SiCL**		
BULK DENSITY (g/cm^3)	1.45	1.45	1.45		
C (%)	0.85	0.61	0.57		
N (%)	0.08	0.06	0.07		
P (ppm)	10.00	8.80	6.80		
pH	8.27	8.40	8.17		
EC (mS/cm)	0.23	0.24	0.47		
CEC (me/100g)	11.16	13.39	15.92		
Ca^{++}	22.34	26.21	27.83		
Mg^{++}	1.63	2.00	3.22		
K^{+}	0.67	0.39	0.40		
Na^{+}	0.77	0.60	0.70		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	8.15	12.65	13.65		

Profile

SOIL PROFILE DESCRIPTION

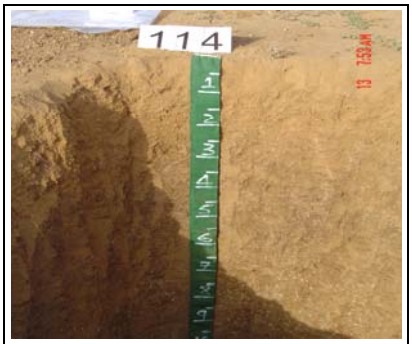
Profile code : 114	**Date :** 2006-06-13

Location : Dhijaamley	**Coordinates :** 09º59'39" / 43º23'05"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Luvic Calcisol (Aridic, Siltic).	**Land form :** Pediment
Effective soil depth: 100-150cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 322951 - 1105225

Remarks : Soil located in a Piedmont/pediment. Land use is grazing. There are no salts. Fine very closely spaced cracks.

Horizon	Depth cm	Description
A1	0-19	Brown (7.5YR 4/3) (moist) and Light brown (7.5YR 6/4) (dry); no mottles; weak very fine granular structure; no cutans; ; very few, very fine Voids; no rocks; abundant nodules calcareous medium; extremely calcareous; many fine-medium roots; gradual smooth boundary.
AB	19-35	Dark brown (7.5YR 3/2) (moist) and Brown (7.5YR 5/4) (dry); no mottles; moderate very fine granular structure; no cutans; ; very few, very fine Voids; no rocks; abundant nodules calcareous medium; extremely calcareous; many fine-medium roots; gradual irregular boundary.
Bt	35-60	Dark brown (7.5YR 3/2) (moist) and Brown to dark brown (7.5YR 4/2) (dry); no mottles; strong fine and medium subangular blocky structure; abundant clay on pedfaces Cutans; ; very few, very fine Voids; no rocks; abundant nodules calcareous medium; extremely calcareous; common fine roots; diffuse boundary.
Ck	60-120	Brown (7.5YR 4/3) (moist) and Light brown (7.5YR 6/3) (dry); no mottles; massive structure; no cutans; ; very few, very fine Voids; no rocks; abundant nodules calcareous medium; extremely calcareous; very few fine roots.

HORIZON	A1	AB	Bt	Ck	
LOWER BOUNDARY	19	35	60	120	
SAND %	52.0	44.0	40.0	40.0	
SILT %	30.0	30.0	32.0	30.0	
CLAY %	18.0	26.0	28.0	30.0	
TEXTURE CLASS	**SL**	**L**	**CL**	**CL**	
BULK DENSITY (g/cm^3)	1.66	1.66	1.66	1.66	
C (%)	0.65	0.66	0.64	0.59	
N (%)	0.04	0.05	0.05	0.03	
P (ppm)	11.70	11.60	15.60	12.40	
pH	8.03	8.14	8.19	8.17	
EC (mS/cm)	2.19	0.60	0.29	0.23	
CEC (me/100g)	19.16	11.38	12.36	13.76	
Ca^{++}	14.82	20.47	23.81	20.35	
Mg^{++}	1.79	2.29	2.94	3.01	
K^{+}	1.27	1.37	1.00	0.28	
Na^{+}	0.97	2.00	2.53	2.17	
PSB (%)	100.0	100.0	100	100	
CaCO3 (%)	6.65	8.65	9.65	14.65	



Profile

SOIL PROFILE DESCRIPTION

Profile code : 115	**Date :** 2006-06-14

Location : Jarahoroto	**Coordinates :** 09º49'49" / 43º20'20"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Land use : Annual field cropping	**Drainage :** Imperfect
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates:** 317848-1087121

Remarks : Soil site located in a plateau, flat valley floor under unconsolidated sediments. No salts but some fine very closely spaced cracks.

Horizon	Depth cm	Description
Ap	0-15	Dark brown (7.5YR 3/3) (moist) and Pale brown (10YR 6/3) (dry); no mottles; moderate fine and medium granular structure; no cutans; ; very few, very fine Voids; no rocks; extremely calcareous; common fine roots; clear wavy
Bt	15-60	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles ; moderate medium subangular blocky structure; few clay on pedfaces Cutans; ; very few, very fine Voids; no rocks; extremely calcareous; many fine roots;
Ck1	60-80	Dark brown (7.5YR 3/2) (moist) and Brown to dark brown (7.5YR 4/2) (dry); no mottles ; moderate coarse subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; common nodules calcareous fine; extremely calcareous; very few very fine roots; gradual irregular boundary.
Ck2	80-145	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; massive structure; no cutans; ; very few, very fine Voids; no rocks; many nodules calcareous medium; extremely calcareous; no roots.

HORIZON	Ap	Bt	Ck1	Ck2	
LOWER BOUNDARY	15	60	80	145	
SAND %	36.0	44.0	32.0	32.0	
SILT %	16.0	16.0	18.0	16.0	
CLAY %	48.0	40.0	50.0	52.0	
TEXTURE CLASS	**C**	**CL**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.48	1.48	1.48	1.48	
C (%)	1.16	0.80	0.87	0.60	
N (%)	0.10	0.08	0.09	0.06	
P (ppm)	10.80	10.20	9.60	14.70	
pH	8.00	8.42	8.08	8.15	
EC (mS/cm)	0.15	0.80	0.70	0.35	
CEC (me/100g)	18.96	20.96	26.56	18.54	
Ca^{++}	23.40	23.04	32.16	26.91	
Mg^{++}	2.36	237.00	3.68	3.24	
K^{+}	1.27	0.73	0.73	0.57	
Na^{+}	1.23	0.57	0.73	0.70	
PSB (%)	100	100	100.0	100.0	
CaCO3 (%)	30.65	20.65	15.65	18.65	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 117	**Date :** 2006-06-17

Location : Ijaara	**Coordinates :** 09º34'04" / 43º37'53"
Authors : Omar Haji Duale Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Calcaric, Hyposodic).	**Land form :** Plateau
Land use : Agriculture	**Drainage :** Imperfect
Effective soil depth: 100-150cm	**Moisture conditions :** Moist
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates:** 349804 - 1057946

Remarks : Soil located in a flat cultivated dissected plateau/denudational surface. Soil with fine, very closely spaced cracks. The soil is very moist, so difficult to determine soil structure.

Horizon	Depth cm	Description
Ap	0-15	Brown (7.5YR 4/3) (moist); no mottles; granular structure; no cutans; ; very few, very fine Voids; no rocks; extremely calcareous; few burrows; many fine-medium roots; diffuse boundary.
AB	15-40	Dark brown (7.5YR 3/2) (moist); no mottles; no cutans; very few, very fine Voids; no rocks; extremely calcareous; few burrows; many fine-medium roots; diffuse boundary.
Bt1	40-75	Dark brown (7.5YR 3/2) (moist); no mottles; angular blocky structure; common clay on pedfaces Cutans; very few, very fine Voids; no rocks; extremely calcareous; common fine-medium roots; gradual wavy boundary.
Bt2	75-96	Dark brown (7.5YR 3/2) (moist); no mottles; no cutans; very few, very fine Voids; no rocks; few fine calcareous nodules; extremely calcareous; common fine and very fine roots; diffuse irregular boundary.
C	96-135	Yellowish red (5YR 4/6) (moist) and Brown (7.5YR 4/3) (moist); no mottles; no cutans; very few, very fine Voids; no rocks; strongly calcareous; few fine and very fine roots.

HORIZON	Ap	AB	Bt1	Bt2	C
LOWER BOUNDARY	15	40	75	96	135
SAND %	32.0	28.0	26.0	20.0	20.0
SILT %	20.0	16.0	14.0	26.0	14.0
CLAY %	48.0	56.0	60.0	64.0	66.0
TEXTURE CLASS	**C**	**C**	**C**	**C**	**C**
BULK DENSITY (g/cm^3)	1.44	1.44	1.44	1.44	1.44
C (%)	1.20	0.98	0.91	0.66	0.44
N (%)	0.13	0.11	0.09	0.05	0.04
P (ppm)	10.00	6.30	12.50	9.20	7.90
pH	8.13	8.06	8.20	8.29	8.51
EC (mS/cm)	0.58	0.58	2.98	0.30	1.80
CEC (me/100g)	16.88	21.11	21.98	22.56	22.12
Ca^{++}	25.25	38.99	20.19	22.56	17.08
Mg^{++}	3.10	4.72	6.41	9.23	8.22
K^{+}	1.57	1.15	1.00	0.53	0.78
Na^{+}	1.50	1.13	1.40	2.43	4.70
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	20.65	26.65	30.65	31.65	35.65

Profile

SOIL PROFILE DESCRIPTION

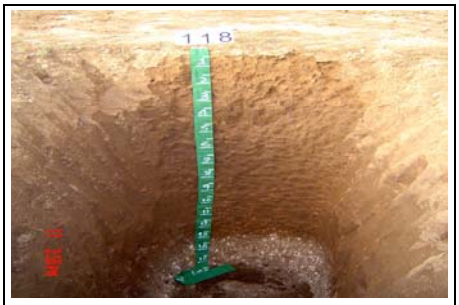
Profile code : 118	**Date :** 2006-06-17

Location : Gebiley	**Coordinates :** 09º41'23" / 43º38'42"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Effective soil depth: 100-150cm	**Drainage :** Imperfect
Rock outcrops : Nil	**Moisture conditions :** Slightly moist
Surface stoniness : Nil	**UTM coordinates**: 351351 - 1071426

Remarks : Soil developed in a plateau/denudational surface. There is no presence of cracks because is moist and also compacted.

Horizon	Depth cm	Description
Ap	0-15	Dark brown (7.5YR 3/2) (moist); no mottles; massive structure; no cutans; ; many Voids fine and very fine; no rocks; strongly calcareous; many fine roots; clear smooth boundary.
A2	15-28	Brown (7.5YR 5/3) (moist); no mottles; massive structure; no cutans; ; many Voids fine and very fine; no rocks; strongly calcareous; few fine-medium roots; clear smooth boundary.
Bt1	28-65	Dark reddish brown (5YR 3/2) (moist); no mottles; massive structure; many clay on pedfaces Cutans; no voids; no rocks; strongly calcareous; few fine roots; clear wavy boundary.
Bt2k1	65-118	Dark reddish brown (5YR 3/3) (moist); massive structure; many clay on pedfaces Cutans; no voids; no rocks; many calcareous concretions medium; strongly calcareous; few fine roots; clear wavy boundary.
Ck2	118-150	Dark brown (7.5YR 3/3) (moist) and Reddish brown (5YR 5/4) (dry); no mottles; massive structure; no cutans; no voids; no rocks; dominant calcareous concretions medium; extremely calcareous; no roots.

HORIZON	Ap	A2	Bt1	Bt2k1	Ck2
LOWER BOUNDARY	15	28	65	118	150
SAND %	54.0	52.0	40.0	32.0	60.0
SILT %	14.0	10.0	10.0	14.0	10.0
CLAY %	32.0	38.0	50.0	54.0	30.0
TEXTURE CLASS	**SCL**	**SC**	**C**	**C**	**SC**
BULK DENSITY (g/cm^3)	1.45	1.45	1.45	1.45	1.45
C (%)	0.60	0.56	0.72	0.52	0.39
N (%)	0.05	0.06	0.07	0.05	0.03
P (ppm)	7.20	17.40	6.10	6.40	39.40
pH	8.26	8.14	8.26	8.33	8.58
EC (mS/cm)	0.22	0.52	0.25	0.30	1.16
CEC (me/100g)	15.60	8.68	15.62	12.99	10.64
Ca^{++}	15.11	32.21	17.50	10.99	11.18
Mg^{++}	2.69	2.13	2.20	2.07	3.04
K^{+}	1.16	0.72	0.71	0.64	0.58
Na^{+}	0.80	0.75	0.75	0.80	1.45
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	12.50	12.50	20.00	26.50	31.00



Profile

SOIL PROFILE DESCRIPTION

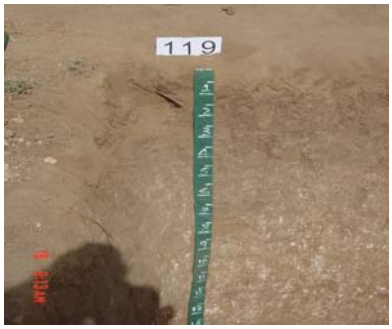
Profile code : 119	**Date :** 2006-06-18

Location : Ijjara	**Coordinates :** 09º35'35" / 43º38'04"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Land use : Agriculture	**Drainage :** Moderately well
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Very few	**UTM coordinates:** 350035 - 1060743

Remarks : Soil developed in a plateau/denudational surface under limestone. Fallow agricultural land. Fine very closely spaced cracks. No salts are present.

Horizon	Depth cm	Description
A1	0-20	Dark brown (7.5YR 3/2) (moist) and Brown (7.5YR 5/3) (dry); no mottles; weak very fine granular structure; no cutans; very few, very fine Voids; no rocks; strongly calcareous; many fine-medium roots; clear wavy boundary.
A2	20-42	Dark brown (7.5YR 3/2) (moist) and Brown (7.5YR 5/3) (dry); no mottles ; moderate medium subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; few fine calcareous nodules; strongly calcareous; few earthworms; few medium roots; clear wavy boundary.
C1	42-65	Brown (7.5YR 4/3) (moist) and Brown (7.5YR 5/3) (dry); no mottles; moderate medium subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; many calcareous concretions medium; extremely calcareous; no roots; clear irregular boundary.
C2k	65-150	Strong brown (7.5YR 4/6) (moist) and Strong brown (7.5YR 5/6) (dry); massive structure; no cutans; very few, very fine Voids; no rocks; abundant calcareous concretions medium; extremely calcareous; no roots.

HORIZON	A1	A2	C1	C2k	
LOWER BOUNDARY	20	42	65	150	
SAND %	30.0	44.0	36.0	40.0	
SILT %	14.0	12.0	12.0	12.0	
CLAY %	56.0	44.0	52.0	48.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.65	1.65	1.65	1.65	
C (%)	0.58	0.71	0.44	0.26	
N (%)	0.08	0.07	0.04	0.02	
P (ppm)	7.00	7.20	6.50	11.30	
pH	8.37	8.22	8.35	8.17	
EC (mS/cm)	0.16	0.52	0.35	0.29	
CEC (me/100g)	12.00	18.60	16.40	11.00	
Ca^{++}	15.03	42.05	24.53	9.61	
Mg^{++}	2.51	3.24	4.58	1.30	
K^{+}	0.56	0.56	0.40	0.40	
Na^{+}	1.45	0.85	0.85	0.95	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	13.00	21.50	30.00	29.50	



Profile

SOIL PROFILE DESCRIPTION

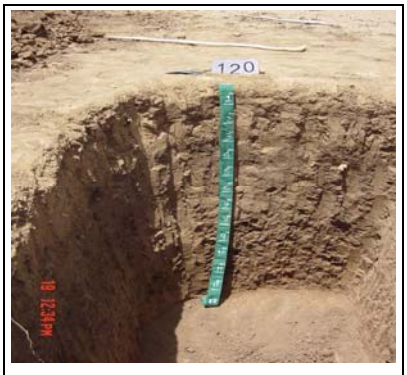
Profile code : 120	**Date :** 2006-06-19

Location : North of Laaye	**Coordinates :** 09º31'43" / 43º36'27"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Calcaric, Hyposalic)	**Land form :** Pediment
Effective soil depth: 50-100cm	**Drainage :** Poor
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 347168 - 1053619

Remarks : Soil profile located in a piedmont/denudational slope composed of alluvial clay. Fine very closely spaced cracks.

Horizon	Depth cm	Description
A1	0-10	Dark reddish brown (5YR 3/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; moderate medium granular structure; no cutans; ; very few, very fine Voids; no rocks; strongly calcareous; many fine roots; clear smooth boundary.
A2	10-40	Dark reddish brown (5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; strong medium and coarse subangular prismatic structure; no cutans; few Voids coarse; no rocks; strongly calcareous; few coarse roots; clear smooth boundary.
Bt1	40-75	Dark reddish brown (5YR 3/2) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; strong medium prismatic structure; abundant clay on pedfaces Cutans; very few, very fine Voids; no rocks; strongly calcareous; few fine roots; clear wavy boundary.
Bt2	75-100	Dark reddish brown (5YR 3/2) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; massive structure; many clay on pedfaces Cutans; very few, very fine Voids; no rocks; few fine calcareous nodules; strongly calcareous; very few very fine roots.

HORIZON	A1	A2	Bt1	Bt2	
LOWER BOUNDARY	10	40	75	>75	
SAND %	30.0	30.0	28.0	72.0	
SILT %	22.0	18.0	14.0	16.0	
CLAY %	48.0	52.0	58.0	12.0	
TEXTURE CLASS	**C**	**C**	**C**	**LS**	
BULK DENSITY (g/cm^3)	1.42	1.42	1.42	1.42	
C (%)	1.56	1.06	0.87	0.87	
N (%)	0.18	0.11	0.08	0.04	
P (ppm)	30.40	9.30	14.70	9.90	
pH	8.16	8.22	8.45	8.37	
EC (mS/cm)	0.33	0.40	2.65	0.20	
CEC (me/100g)	9.86	21.24	18.80	11.00	
Ca^{++}	13.43	24.80	19.08	20.68	
Mg^{++}	2.40	4.72	5.99	2.07	
K^{+}	1.08	1.38	1.06	0.48	
Na^{+}	1.05	1.65	3.00	0.50	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	23.50	25.00	26.00	22.00	



Profile

SOIL PROFILE DESCRIPTION

Profile code : 121	**Date :** 2006-06-20

Location : Diini Goobaale	**Coordinates :** 09º25'29" / 43º36'45"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Calcaric, Hyposodic).	**Land form :** Pediment
Effective soil depth: 100-150cm	**Drainage :** Imperfect
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 347691 - 1042124

Remarks : Soil developed under a clayed parent material in piedmont/pediment.

Horizon	Depth cm	Description
A1	0-20	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 5/4) (dry); no mottles; weak fine and medium granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; common medium roots; clear smooth boundary.
A2	20-45	Dark brown (7.5YR 3/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak fine and medium subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; extremely calcareous; few fine-medium roots; diffuse wavy boundary.
Bt	45-80	Dark reddish brown (5YR 3/2) (moist) and Brown to dark brown (7.5YR 4/2) (dry); no mottles; strong medium and coarse prismatic structure; many clay on pedfaces Cutans; ; very few, very fine Voids; no rocks; few fine calcareous nodules; extremely calcareous; very few fine roots; diffuse boundary.
Ck	80-140	Dark reddish brown (5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; massive structure; no cutans; very few, very fine Voids; no rocks; few,very fine calcareous nodules; extremely calcareous; no roots.

HORIZON	A1	A2	Bt	Ck	
LOWER BOUNDARY	20	45	80	140	
SAND %	30.0	28.0	28.0	20.0	
SILT %	24.0	14.0	14.0	14.0	
CLAY %	46.0	58.0	58.0	66.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.54	1.54	1.54	1.54	
C (%)	1.56	0.59	0.88	0.51	
N (%)	0.19	0.06	0.09	0.05	
P (ppm)	22.60	12.60	22.30	13.90	
pH	8.21	8.46	8.18	8.47	
EC (mS/cm)	0.31	0.32	1.23	1.37	
CEC (me/100g)	11.00	26.60	19.80	19.06	
Ca^{++}	14.50	25.64	22.86	11.29	
Mg^{++}	2.92	4.52	4.52	3.18	
K^{+}	1.72	1.06	1.46	0.26	
Na^{+}	1.50	1.75	1.45	1.85	
PSB (%)	100.0	100.0	100.0	87.0	
CaCO3 (%)	27.00	20.00	25.00	30.00	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 122	**Date :** 2006-06-20

Location : Abusiin	**Coordinates :** 09º30'8" / 43º47'46"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Calcaric).	**Land form :** Pediment
Rock outcrops : Nil	**Drainage :** Imperfect
Surface stoniness : Nil	**Moisture conditions :** Dry
UTM coordinates: 367873 - 1050614	
Remarks : This profile is similar to profile 121, with little more structural development located in a Piedmont/denudational slope. Samples were not taken.	

Horizon	Depth cm	Description
A1	0-20	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 5/4) (dry); no mottles; weak fine and medium granular structure; no cutans; ; very few, very fine Voids; no rocks; extremely calcareous; common fine-medium roots; clear smooth boundary.
A2	2041-	Brown (7.5YR 4/3) (dry); no mottles; weak fine and medium subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; extremely calcareous; few fine-medium roots; diffuse wavy boundary.
Btk	41-75	Brown to dark brown (7.5YR 4/2) (moist); no mottles; strong medium to very coarse prismatic structure; many clay on pedfaces Cutans; ; very few, very fine Voids; no rocks; extremely calcareous; very few fine roots; diffuse irregular boundary.
C	75-100	Reddish brown (5YR 4/4) (moist); no mottles; massive structure; no cutans; ; very few, very fine Voids; no rocks; extremely calcareous; no roots.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 123	**Date :** 2006-06-24

Location : Togwajale	**Coordinates :** 09º35'52" / 43º20'57"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Chromic).	**Land form :** Pediment
Effective soil depth: 50-100cm	**Drainage :** Moderately well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 318826 - 1061372

Remarks : This soil profile is located in a piedmont/pediment where the parent material is unconsolidated. Rainfed farms under fallow. The presence of cracks is common; they are 1 cm wide and very closely spaced. No salt crusts are present.

Horizon	Depth cm	Description
A1	0-25	Very dark grey (7.5YR 3/1) (moist) and Brown (7.5YR 4/3) (dry); no mottles ; weak fine granular structure; no cutans; ; no voids; no rocks; extremely calcareous; many fine and very fine roots; gradual smooth boundary.
A2	25-45	Brown (7.5YR 5/2) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; moderate medium subangular blocky structure; no cutans; no voids; no rocks; extremely calcareous; common fine roots; clear wavy boundary.
Bt	45-80	Dark brown (7.5YR 3/4) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; moderate medium subangular blocky structure; abundant clay on pedfaces Cutans; ; no voids; no rocks; extremely calcareous; few fine roots; diffuse boundary.
C	80-100	Dark brown (7.5YR 4/4) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; massive structure; no cutans; no voids; no rocks; extremely calcareous; very few very fine roots.

HORIZON	A1	A2	Bt	C	
LOWER BOUNDARY	25	45	70	>80	
SAND %	26.0	24.0	22.0	14.0	
SILT %	38.0	10.0	8.0	12.0	
CLAY %	36.0	66.0	70.0	74.0	
TEXTURE CLASS	**CL**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.48	1.48	1.48	1.48	
C (%)	0.74	0.81	0.63	0.46	
N (%)	0.08	0.09	0.08	0.06	
P (ppm)	8.60	6.80	4.70	16.10	
pH	8.04	8.07	8.28	8.42	
EC (mS/cm)	0.21	0.53	1.30	1.95	
CEC (me/100g)	13.68	31.28	21.08	19.28	
Ca^{++}	26.88	37.20	17.06	12.44	
Mg^{++}	2.15	8.21	5.89	7.82	
K^{+}	0.30	0.56	0.28	0.38	
Na^{+}	0.45	1.10	1.50	2.55	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	16.35	23.35	30.85	31.85	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 124	**Date :** 2006-06-25

Location : Gogolwanaag	**Coordinates :** 09º39'28" / 43º47'59"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Effective soil depth: 50-100cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 368316 - 1067811
Remarks :	Soil profile located in a Dissected plateau/denudational surface. No surface salts found. Soil cracks can be found, fine width and very closely spaced.

Horizon	Depth cm	Description
A1	0-23	Dark brown (7.5YR 3/2) (moist) and Dark reddish grey (5YR 4/2) (dry); no mottles; weak fine granular structure; no cutans; ; no voids; no rocks; strongly calcareous; few fine and very fine roots; clear smooth boundary.
A2	23-45	Dark brown (7.5YR 3/3) (moist) and Reddish grey (5YR 5/2) (dry); no mottles; weak medium subangular blocky structure; no cutans; ; no voids; no rocks; strongly calcareous; very few very fine roots; gradual wavy boundary.
Ck1	45-65	Brown (7.5YR 4/3) (moist) and Reddish brown (5YR 5/3) (dry); no mottles; massive structure; no cutans; no voids; no rocks; abundant nodules calcareous medium; extremely calcareous; very few very fine roots; diffuse boundary.
Ck2	65-80	Dark brown (7.5YR 4/4) (moist) and Reddish brown (5YR 5/4) (dry); no mottles; massive structure; no cutans Voids; no rocks; dominant nodules calcareous coarse; extremely calcareous; very few very fine roots.

HORIZON	A1	A2	Ck1	Ck2	
LOWER BOUNDARY	23	45	65	>65	
SAND %	20.0	56.0	52.0	50.0	
SILT %	12.0	4.0	6.0	6.0	
CLAY %	68.0	40.0	42.0	44.0	
TEXTURE CLASS	**C**	**SC**	**SC**	**SC**	
BULK DENSITY (g/cm^3)	1.39	1.39	1.39	1.39	
C (%)	1.01	0.53	0.27	0.21	
N (%)	0.14	0.06	0.05	0.03	
P (ppm)	10.60	13.60	9.10	8.40	
pH	8.08	8.23	8.23	8.30	
EC (mS/cm)	0.35	0.27	0.45	0.55	
CEC (me/100g)	30.88	14.28	14.48	11.08	
Ca^{++}	34.66	30.18	38.48	23.72	
Mg^{++}	4.02	3.92	4.68	4.96	
K^{+}	1.18	0.24	0.30	0.24	
Na^{+}	1.05	0.50	0.70	0.60	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	25.85	19.35	21.35	22.85	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 125	**Date :** 2006-06-27

Location : Carra Muse Case	**Coordinates :** 09º33'29" / 43º50'19"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Calcaric).	**Land form :** Plateau
Effective soil depth: 50-100cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 372534 - 1056758

Remarks : There is no soil profile description because the surveyors considered that this profile is similar to profile 124. Without soil samples, it was not considered as a complete profile. Located on a dissected plateau/denudational surface.

Horizon	Depth cm	Description
A1	0-23	.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 129	**Date :** 2006-07-14

Location : Beeyo Baxday	**Coordinates :** 09º52'17" / 44º05'41"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Hypercalcic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Effective soil depth: 100-150cm	**Drainage :** Excessive
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Few	**UTM coordinates:** 400736 – 1091345

Remarks : Soil developed under limestone parent material located in a Plateau/Denudational surface. The soil surface is eroded. No cracks or salts.

Horizon	Depth cm	Description
ACk1	0-25	Yellowish red (5YR 4/6) (moist) and Reddish brown (5YR 5/4) (dry); no mottles ; moderate medium subangular blocky structure; no cutans; ; few Voids medium; few medium rounded rocks; very few fine-medium roots; abrupt wavy boundary.
Ck2	25-40	Yellowish red (5YR 4/6) (moist) and Light reddish brown (5YR 6/4) (dry); no mottles; no cutans; no voids; many medium rounded rocks; abundant calcareous concretions medium; extremely calcareous; no roots; abrupt wavy
Ck3	40-175	Pink (5YR 8/4) (moist) and Pinkish white (5YR 8/2) (dry); no mottles ; no cutans; ; no voids; no rocks; dominant calcareous concretions medium; extremely calcareous; no roots.

HORIZON	ACk1	Ck2			
LOWER BOUNDARY	25	40			
SAND %	24.0	22.0			
SILT %	34.0	36.0			
CLAY %	42.0	42.0			
TEXTURE CLASS	**C**	**C**			
BULK DENSITY (g/cm^3)	1.36	1.36			
C (%)	0.29	0.25			
N (%)	0.04	0.09			
P (ppm)	13.10	3.50			
pH	8.27	7.87			
EC (mS/cm)	0.25	3.50			
CEC (me/100g)	17.32	16.28			
Ca^{++}	32.54	21.02			
Mg^{++}	1.71	3.47			
K^{+}	0.48	0.38			
Na^{+}	0.95	0.50			
PSB (%)	100.0	100.0			
CaCO3 (%)	26.85	31.35			

Profile

SOIL PROFILE DESCRIPTION

Profile code : 135	**Date :** 2006-07-16

Location : Sabaad	**Coordinates :** 09º41'17" / 44º19'23"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Endosalic Calcisol (Aridic, Clayic).	**Land element :** Slope
	Drainage : Excessive
UTM coordinates: 425758 - 1071008	
Remarks : Soil profile located in a Piedmont/Denudational surface. Lithology is limestone, conglomerate.	

Horizon	Depth cm	Description
A	0-25	Brown to dark brown (7.5YR 4/2) (moist) and Brown (7.5YR 5/3) (dry); no mottles ; fine and medium granular structure; no cutans; ; few very fine Voids; no rocks; slightly calcareous; common fine-medium roots; clear smooth boundary.
Ck1	25-65	Dark brown (7.5YR 4/4) (moist) and Brown (7.5YR 5/4) (dry); no mottles ; weak medium and coarse prismatic structure; no cutans; ; few very fine Voids; common fine rounded rocks; common calcareous concretions; strongly calcareous; few fine roots; abrupt wavy boundary.
Ck2	65-80	Brown (7.5YR 4/3) (moist) and Pinkish white (7.5YR 8/2) (dry); no mottles ; no cutans; ; no voids; many medium rounded rocks; dominant calcareous concretions; extremely calcareous; no roots.

HORIZON	A	Ck1	Ck2		
LOWER BOUNDARY	25	65	80		
SAND %	48.0	46.0	44.0		
SILT %	12.0	12.0	12.0		
CLAY %	40.0	42.0	44.0		
TEXTURE CLASS	**SC**	**SC**	**C**		
BULK DENSITY (g/cm^3)	1.33	1.33	1.33		
C (%)	0.50	0.38	0.28		
N (%)	0.05	0.05	0.04		
P (ppm)	5.60	2.70	4.40		
pH	8.42	8.01	8.13		
EC (mS/cm)	2.40	2.30	2.45		
CEC (me/100g)	15.08	13.48	15.08		
Ca^{++}	30.89	17.71	30.10		
Mg^{++}	2.16	2.02	4.13		
K^{+}	0.32	0.16	0.28		
Na^{+}	1.20	0.85	1.80		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	20.35	25.85	30.85		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 136	**Date :** 2006-07-16

Location : Burcada	**Coordinates :** 09º40'05" / 44º16'09"

Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Calcisol (Episkeletic, Clayic)	**Land element :** Slope
Effective soil depth: 25-50cm	**Drainage :** Excessive
Surface stoniness : Common	**Moisture conditions :** Dry
UTM coordinates: 419844 - 1068808	
Remarks : Young calcaric soil developed from Limestone & quartzite parent rocks located in a Piedmont/Denudational surface. No cracks or salts.	

Horizon	Depth cm	Description
AC	0-25	Pink (7.5YR 7/3) (dry); no mottles; weak medium subangular blocky structure; no cutans; many very fine Voids; no rocks; strongly calcareous; common fine-medium roots; clear wavy boundary.
Ck	25-75	Pink (7.5YR 8/4) (dry); no mottles; massive structure; no cutans; few very fine Voids; no rocks; dominant calcareous concretions medium; extremely calcareous; few fine roots.

HORIZON	Ac	Ck			
LOWER BOUNDARY	25	>75			
SAND %	58.0	42.0			
SILT %	8.0	16.0			
CLAY %	34.0	42.0			
TEXTURE CLASS	**SCL**	**C**			
BULK DENSITY (g/cm^3)	1.39	1.39			
C (%)	0.43	0.42			
N (%)	0.07	0.04			
P (ppm)	2.20	2.20			
pH	8.25	8.55			
EC (mS/cm)	0.21	0.24			
CEC (me/100g)	11.32	18.12			
Ca^{++}	32.67	10.08			
Mg^{++}	2.29	4.81			
K^{+}	0.26	0.24			
Na^{+}	0.45	0.70			
PSB (%)	100.0	87.0			
CaCO3 (%)	25.85	37.35			

Profile

SOIL PROFILE DESCRIPTION

Profile code : 137	**Date :** 2006-07-16

Location : Halleeya	**Coordinates :** 09º37'29" / 44º11'30"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol	**Drainage :** Excessive

(Calcaric, Arenic).	
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	**Local soil classification (serie) :**
Surface stoniness : Nil	**UTM coordinates:** 411317 – 1064026
Remarks : This profile is located in a surface where local sand dunes are formed due to wind erosion. Piedmont landscape and Gully/rill erosion surface relief. No soil samples.	

Horizon	Depth cm	Description
A	0-140	Light brown (7.5YR 6/4) (dry); no mottles; massive structure; no cutans; common Voids very coarse; no rocks; strongly calcareous; many fine roots; abrupt smooth boundary.
c	140-160	Massive structure; no cutans; common Voids very coarse; no rocks; strongly calcareous; common fine roots.

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 138	**Date :** 2006-07-16

Location : Halleeya	**Coordinates :** 09º35'31" / 44º10'29"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Effective soil depth: 50-100cm	**Drainage :** Excessive
Surface stoniness : Few	**Moisture conditions :** Dry
UTM coordinates: 409433 - 1060397	
Remarks : Soil developed from limestone parent rock in a Plateau/Denudational slope. No salts; no cracks.	

Horizon	Depth cm	Description
A	0-20	Brown (7.5YR 4/3) (moist) and Light brown (7.5YR 6/4) (dry); no mottles ; weak fine and medium subangular blocky structure; no cutans; ; many medium Voids ; few fine rounded rocks; extremely calcareous; few burrows; many coarse roots; gradual wavy boundary.
Bt	20-75	Dark brown (7.5YR 3/4) (moist) and Brown to dark brown (7.5YR 4/2) (dry); strong coarse prismatic structure; no cutans; ; few very fine Voids; few fine rounded rocks; extremely calcareous; few burrows; common medium-coarse roots; gradual wavy boundary.
Ck	75-100	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; massive structure; no cutans; ; no voids; no rocks; extremely calcareous; few fine roots.

HORIZON	A	Bt	Ck		
LOWER BOUNDARY	20	75	>75		
SAND %	58.0	38.0	44.0		
SILT %	10.0	10.0	8.0		
CLAY %	32.0	52.0	48.0		
TEXTURE CLASS	**SCL**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.73	1.73	1.73		
C (%)	1.03	0.74	0.35		
N (%)	0.08	0.09	0.04		
P (ppm)	2.60	9.90	2.30		
pH	8.11	8.10	8.24		
EC (mS/cm)	0.24	0.40	0.29		
CEC (me/100g)	20.12	23.08	13.68		
Ca^{++}	21.35	18.31	36.62		
Mg^{++}	1.45	2.67	2.41		
K^{+}	1.04	0.92	0.52		
Na^{+}	1.05	0.95	0.75		
PSB (%)	100.0	99.0	100.0		
CaCO3 (%)	16.35	19.35	23.85		

Profile

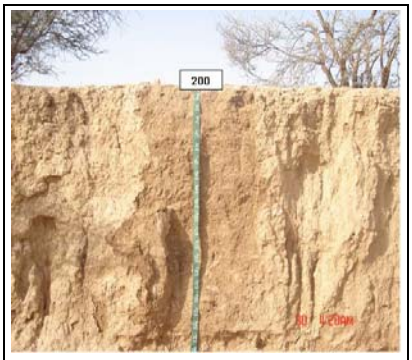
SOIL PROFILE DESCRIPTION

Profile code : 200	**Date :** 2006-05-30
Location : Dhagax Galalaan	**Coordinates :** 10º13'29" / 43º38'44"
Authors : Omar Haji Duale Ali Ibrahim Ismail	**Soil climate :** Aridic

WRB 2006 Soil Classification: Haplic Fluvisol (Calcaric, Aridic).	**Land form :** Pediment
Effective soil depth: >150	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Few	**UTM coordinates:** 351673 - 1130587
Remarks :	This soil is located in a Piedmont, dissected pediment, fluvial in origin due to presence of many seasonal rivers. There are few soil cracks in the surface and no salts. As for most of this area, the land is used for grazing.

Horizon	Depth cm	Description
A	0-15	Brown (7.5YR 5/3) (dry); no mottles; sandy loam; strong coarse granular structure; no cutans; few Voids fine; no rocks; few fine calcareous nodules; strongly calcareous; no roots; diffuse smooth boundary.
C	15-200	Brown (7.5YR 5/3) (dry); no mottles ; sandy loam; massive structure; no cutans; ; very few, very fine Voids; few fine subrounded rocks; common nodules calcareous coarse; strongly calcareous; very few very fine roots.

HORIZON	A	C			
LOWER BOUNDARY	15	200			
SAND %	72.0	74.0			
SILT %	14.0	12.0			
CLAY %	14.0	14.0			
TEXTURE CLASS	**SL**	**SL**			
BULK DENSITY (g/cm^3)	1.57	1.57			
C (%)	0.13	0.14			
N (%)	0.02	0.01			
P (ppm)	7.30	5.90			
pH	8.50	8.40			
EC (mS/cm)	0.12	2.48			
CEC (me/100g)	11.20	14.10			
Ca^{++}	14.5	16.4			
Mg^{++}	1	1.8			
K^{+}	0.5	0.2			
Na^{+}	0.5	4			
PSB (%)	100	100			
CaCO3 (%)	8.00	6.00			



Profile

SOIL PROFILE DESCRIPTION

Profile code : 201	**Date :** 2006-05-31
Location : Dabago	**Coordinates :** 10º06'16" / 43º43'24"
Authors : Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Fluvisol (Aridic, Arenic)	**Land form :** Valley
Effective soil depth: 50-100cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry

Surface stoniness : Common		**UTM coordinates:** 360137 - 1117240
Remarks :	Soil located in a braided river plain. There are no salts or cracks. Purely sandy soil.	
Horizon	**Depth cm**	**Description**
A1	0-10	Brown (7.5YR 4/3) (moist) and Light brown (7.5YR 6/3) (dry); no mottles; sand; massive structure; no cutans; ; few Voids fine; slightly calcareous; few burrows; common fine-medium roots; diffuse smooth boundary.
A2	10-45	Brown (7.5YR 4/3) (moist) and Brown (7.5YR 5/3) (dry); no mottles; sand; no cutans; ; few Voids fine; non calcareous; few burrows; common fine-medium roots; diffuse smooth boundary.
C	45-	Brown (7.5YR 5/3) (moist); no mottles; sand; massive structure; no cutans; ; few Voids fine; few stones and boulders subrounded rocks; non calcareous; very few very fine roots.

HORIZON	A1	A2	C		
LOWER BOUNDARY	10	45	100		
SAND %	88.0	88.0	88.0		
SILT %	8.0	6.0	6.0		
CLAY %	4.0	6.0	6.0		
TEXTURE CLASS	**S**	**S**	**S**		
BULK DENSITY (g/cm^3)	1.67	1.67	1.67		
C (%)	0.24	0.21	0.16		
N (%)	0.02	0.02	0.01		
P (ppm)	8.20	7.60	6.50		
pH	8.40	8.50	8.50		
EC (mS/cm)	0.07	0.07	0.10		
CEC (me/100g)	10.50	23.30	11.90		
Ca^{++}	5.3	10.2	12.8		
Mg^{++}	0.3	0.4	0.3		
K^{+}	0.2	0.2	0.1		
Na^{+}	0.2	1	0.2		
PSB (%)	56	49	100		
CaCO3 (%)	2.00	1.00	5.00		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 203	**Date :** 2006-06-07

Location : Hancadley	**Coordinates :** 09º54'50" / 43º07'38"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Regosol (Dystric, Aridic)	**Land form :** Plateau
Effective soil depth: >150	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Very few	**UTM coordinates:** 294676 - 1096493

Remarks : Soil developed under unconsolidated material located in a plateau/piedmont, denudational slope.

Horizon	Depth cm	Description
A1	0-30	Dark brown (7.5YR 3/2) (moist) and Brown to dark brown (7.5YR 4/2) (dry); no mottles; massive structure; no cutans; few Voids medium; no rocks; moderately calcareous; few burrows; common fine roots; diffuse smooth boundary.
A2	30-60	Very dark greyish brown (10YR 3/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; massive structure; no cutans; very few, very fine Voids; no rocks; strongly calcareous; many fine and very fine roots; gradual wavy boundary.
C1	60-125	Very dark grey (10YR 3/1) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; massive structure; no cutans; very few, very fine Voids; no rocks; abundant nodules calcareous medium; strongly calcareous; few fine roots; gradual wavy boundary.
C2	125-170	Brown to dark brown (7.5YR 4/2) (moist); no mottles; massive structure; no cutans; very few, very fine Voids; common fine and medium rocks; slightly calcareous; no roots.

HORIZON	A1	A2	C1	C2	
LOWER BOUNDARY	30	60	125	170	
SAND %	66.0	60.0	62.0	72.0	
SILT %	24.0	24.0	22.0	16.0	
CLAY %	10.0	16.0	16.0	8.0	
TEXTURE CLASS	**SL**	**SL**	**SL**	**SL**	
BULK DENSITY (g/cm^3)	1.61	1.61	1.61	1.61	
C (%)	0.51	0.64	0.63	0.31	
N (%)	0.05	0.12	0.06	0.03	
P (ppm)	13.50	8.50	13.70	0.50	
pH	8.76	8.34	8.14	8.11	
EC (mS/cm)	0.40	1.30	0.35	2.30	
CEC (me/100g)	13.57	11.52	32.58	9.96	
Ca^{++}	13.67	10.47	16.46	11.37	
Mg^{++}	1.16	1.06	1.22	1.47	
K^{+}	0.17	0.09	0.17	0.11	
Na^{+}	0.36	0.10	0.36	0.10	
PSB (%)	100.0	100.0	56.0	100.0	
CaCO3 (%)	5.65	5.65	11.15	4.65	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 206	**Date :** 2006-06-12

Location : Badanbed	**Coordinates :** 10º10'33" / 43º13'46"
Authors : Musse Shaie	**Land form :** Valley
WRB 2006 Soil Classification: Haplic Fluvisol (Calcaric, Aridic, Arenic).	**Drainage :** Excessively
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 306050 - 1125383

Remarks : Soil developed under its bedrock limestone located in a Valley/braided river plain. There are no cracks, no salts and no stoniness.

Horizon	Depth cm	Description
A	0-35	Light brown (7.5YR 6/3) (dry); no mottles; massive structure; no cutans; very few Voids medium; no rocks; strongly calcareous; few burrows; common fine-medium roots; diffuse smooth boundary.
C1	35-65	Brown (10YR 5/3) (dry); no mottles; massive structure; no cutans; no voids; no rocks; strongly calcareous; common fine roots; diffuse smooth boundary.
C2	65-94	Pale brown (10YR 6/3) (dry); no mottles; massive structure; no cutans; no voids; no rocks; strongly calcareous; few medium-coarse roots; diffuse irregular boundary.
C3	94-180	Pale brown (10YR 6/3) (dry); no mottles; massive structure; no cutans; no voids; no rocks; strongly calcareous; few fine roots.

HORIZON	A	C1	C2	C3	
LOWER BOUNDARY	35	65	94	>94	
SAND %	22.0	90.0	90.0	92.0	
SILT %	16.0	4.0	4.0	6.0	
CLAY %	62.0	6.0	6.0	2.0	
TEXTURE CLASS	**C**	**S**	**S**	**S**	
BULK DENSITY (g/cm^3)	1.30	1.30	1.30	1.30	
C (%)	0.48	0.13	0.13	0.09	
N (%)	0.05	0.01	0.01	0.00	
P (ppm)	8.30	6.00	8.50	7.70	
pH	8.53	8.61	8.51	8.61	
EC (mS/cm)	1.51	0.28	0.26	0.30	
CEC (me/100g)	23.86	5.40	6.60	10.60	
Ca^{++}	14.56	8.61	8.88	10.57	
Mg^{++}	7.85	1.33	0.79	0.96	
K^{+}	0.70	0.12	0.18	0.18	
Na^{+}	3.25	0.10	0.25	0.30	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	30.00	14.50	16.00	14.50	

Profile

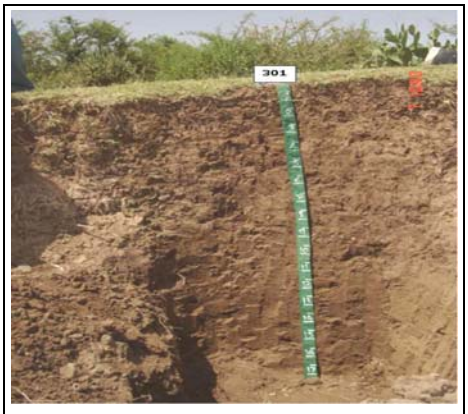
SOIL PROFILE DESCRIPTION

Profile code : 301	**Date :** 2006-06-07
Location : Shebeeley	**Coordinates :** 09º57'15" / 43º06'36"
Authors : Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Calcaric, Hyposodic)	**Land form :** Pediment
Effective soil depth: 100-150cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 292822 - 1100951

Remarks : Soil located in a Piedmont/pediment as general unit; however, the facet is an alluvial plain. No salts and very few cracks are present.

Horizon	Depth cm	Description
A1	0-30	Dark brown (7.5YR 3/2) (moist); no mottles ; strong medium granular structure; no cutans; ; very few, very fine Voids; few fine subrounded rocks; extremely calcareous; many medium-coarse roots; clear wavy boundary.
A2	30-70	Brown to dark brown (7.5YR 4/2) (moist); no mottles; strong medium subangular and angular blocky structure; no cutans; few Voids fine; common medium subrounded rocks; common nodules calcareous fine; extremely calcareous; few fine roots; clear smooth boundary.
Btk	70-160	Dark brown (7.5YR 3/2) (moist); no mottles; strong medium subangular and angular blocky structure; common pressure face Cutans; very few, very fine Voids; no rocks; common nodules calcareous fine; extremely calcareous; very few very fine roots.
C	160-170	Dark brown (7.5YR 3/2) (moist); no mottles; moderate subangular and angular blocky structure; very few pressure face Cutans; very few, very fine Voids; no rocks; strongly calcareous; no roots.

HORIZON	A1	A2	Btk	C	
LOWER BOUNDARY	30	70	160	170	
SAND %	30.0	28.0	32.0	12.0	
SILT %	22.0	22.0	22.0	28.0	
CLAY %	48.0	50.0	46.0	60.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY	1.38	1.38	1.38	1.38	
C (%)	0.77	0.54	0.53	0.41	
N (%)	0.10	0.10	0.04	0.06	
P (ppm)	10.90	11.90	7.50	8.70	
pH	8.25	8.32	8.28	8.80	
EC (mS/cm)	1.04	0.45	0.21	0.39	
CEC (me/100g)	19.80	29.18	24.20	14.53	
Ca^{++}	16.88	8.08	26.80	21.26	
Mg^{++}	4.54	3.57	1.12	7.70	
K^{+}	0.10	0.80	1.06	0.86	
Na^{+}	1.65	1.25	1.10	3.75	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	20.50	17.50	18.00	23.50	



Profile

SOIL PROFILE DESCRIPTION

Profile code : 302	**Date :** 2006-06-29
Location : Gadhgogol	**Coordinates :** 09º28'38" / 43º50'23"
Authors : Ali Ibrahim Ismail, Musse Shaie, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Chromic)	**Land form :** Plateau
Effective soil depth: 100-150cm	**Drainage :** Well
Surface stoniness : Nil	**Moisture conditions :** Dry
UTM coordinates: 372635 - 1047816	
Remarks : Soil located in a Dissected plateau/Pediment. Few cracks are present but no salt crusts. The soil profile is located in a flat floor valley.	

Horizon	Depth cm	Description
Ap	0-15	Dark reddish brown (5YR 3/2) (moist) and Brown (7.5YR 5/4) (dry); no mottles; weak medium granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; many fine-medium roots; clear wavy boundary.
A2	15-45	Dark reddish brown (5YR 2.5/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; common fine-medium roots; clear smooth boundary.
Btk	45-65	Dark reddish brown (5YR 3/2) (moist) and Brown to dark brown (7.5YR 4/2) (dry); no mottles ; moderate medium angular blocky structure; many pressure face Cutans; very few, very fine Voids; no rocks; few,very fine calcareous nodules; extremely calcareous; few termite channels; few coarse roots; clear smooth boundary.
Ck	65-130	Dark reddish brown (5YR 3/3) (moist) and Reddish brown (5YR 4/3) (dry); no mottles; moderate medium angular blocky structure; no cutans; very few, very fine Voids; no rocks; abundant nodules calcareous coarse; extremely calcareous; no roots.

HORIZON	Ap	A2	Btk	Ck	
LOWER BOUNDARY	15	45	65	>130	
SAND %	48.0	40.0	42.0	36.0	
SILT %	10.0	10.0	4.0	8.0	
CLAY %	42.0	50.0	54.0	56.0	
TEXTURE CLASS	**SC**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.39	1.39	1.39	1.39	
C (%)	1.31	0.90	0.67	0.35	
N (%)	0.15	0.13	0.11	0.04	
P (ppm)	19.30	10.30	4.60	12.70	
pH	8.01	7.86	8.07	8.38	
EC (mS/cm)	0.70	1.20	0.65	0.65	
CEC (me/100g)	19.08	18.88	22.08	16.08	
Ca^{++}	31.85	25.89	37.50	23.43	
Mg^{++}	1.93	3.36	5.54	4.35	
K^{+}	1.24	0.92	0.58	0.32	
Na^{+}	1.50	0.80	0.95	1.95	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	14.85	19.85	17.85	25.85	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 303	**Date :** 2006-06-29

Location : Abdisamad	**Coordinates :** 09º24'33" / 43º48'49"
Authors : Musse Shaie, Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Hyposodic, Chromic).	**Drainage :** Well
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	**UTM coordinates:** 369736-1040302
Surface stoniness : Nil	
Remarks : Soil developed in a Piedmont/Denudational slope which parent material is a re-deposited natural material. Very closely-spaced cracks of medium width are present. No surface salts.	

Horizon	Depth cm	Description
Ap	0-20	Dark reddish brown (5YR 3/3) (moist) and Brown (7.5YR 5/4) (dry); no mottles; weak medium granular structure; no cutans; no voids; no rocks; extremely calcareous; many fine-medium roots; clear smooth boundary.
A2	20-39	Dark reddish brown (5YR 3/3) (moist) and Reddish brown (5YR 4/3) (dry); no mottles; moderate medium subangular blocky structure; no cutans; few Voids fine; no rocks; extremely calcareous; many fine-medium roots; diffuse
Bt1	39-65	Dark reddish brown (5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; strong medium angular blocky structure; abundant pressure face Cutans; no voids; no rocks; extremely calcareous; many fine roots; clear wavy boundary.
Bt2	65-115	Yellowish red (5YR 4/6) (moist) and Reddish brown (5YR 4/4) (dry); no mottles; strong coarse angular blocky structure; abundant pressure face Cutans; no voids; no rocks; extremely calcareous; few fine-medium roots; clear smooth boundary.
Ck	115-130	Reddish brown (2.5YR 4/4) (moist) and Yellowish red (5YR 4/6) (dry); no mottles; moderate medium angular blocky structure; no cutans; no voids; no rocks; extremely calcareous; no roots.

HORIZON	Ap	A2	Bt1	Bt2	Ck
LOWER BOUNDARY	20	39	65	115	>115
SAND %	42.0	28.0	26.0	26.0	18.0
SILT %	4.0	10.0	10.0	8.0	10.0
CLAY %	54.0	62.0	64.0	66.0	72.0
TEXTURE CLASS	**C**	**C**	**C**	**C**	**C**
BULK DENSITY	1.39	1.39	1.39	1.39	1.39
C (%)	0.96	0.69	0.54	0.51	0.30
N (%)	0.09	0.07	0.06	0.05	0.04
P (ppm)	10.30	10.90	11.80	8.00	7.70
pH	8.14	8.29	8.57	8.70	8.34
EC (mS/cm)	0.27	0.35	0.45	0.80	2.80
CEC (me/100g)	18.12	24.28	19.28	15.48	20.48
Ca^{++}	28.40	31.54	17.86	16.03	8.83
Mg^{++}	3.68	2.52	7.17	8.08	3.24
K^{+}	1.36	1.24	0.80	0.40	0.14
Na^{+}	1.45	1.60	2.45	3.30	2.10
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	23.35	28.85	29.35	30.85	32.85

Profile

SOIL PROFILE DESCRIPTION

Profile code : 304	**Date :** 2006-07-02

Location : Allaybaday	**Coordinates :** 09º23'31" / 43º31'52"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Mazic Vertisol (Bathyhyposodic, Bathyhyposalic).	**Land form :** Alluvial plain
Effective soil depth: 100-150cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 338710 - 1038520

Remarks : Parent material is silt, clay and loam located in a Piedmont/Alluvial plain. No salt crusts are present, instead soil cracks of fine width and very closely spaced are present.

Horizon	Depth cm	Description
A1	0-15	Dark brown (7.5YR 3/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak fine granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; many very fine roots; clear wavy boundary.
A2	15-40	Dark brown (7.5YR 3/2) (moist) and Dark brown (7.5YR 3/3) (dry); no mottles; moderate medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; few very fine roots; clear smooth boundary.
Bt	40-100	Dark brown (7.5YR 3/2) (moist) and Dark brown (7.5YR 3/3) (dry); no mottles; strong coarse angular blocky structure; common pressure face Cutans; very few, very fine Voids; no rocks; extremely calcareous; very few very fine roots; diffuse smooth boundary.
C	100-130	Dark brown (7.5YR 3/3) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles; moderate medium angular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; no roots.

HORIZON	A1	A2	Bt	C	
LOWER BOUNDARY	15	40	100	130	
SAND %	32.0	26.0	26.0	20.0	
SILT %	8.0	12.0	8.0	8.0	
CLAY %	60.0	62.0	66.0	72.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.33	1.33	1.33	1.33	
C (%)	0.92	0.77	0.55	0.40	
N (%)	0.13	0.11	0.06	0.05	
P (ppm)	8.90	8.30	5.90	4.60	
pH	8.20	8.09	8.42	8.46	
EC (mS/cm)	0.50	1.65	2.15	2.70	
CEC (me/100g)	21.08	21.68	25.08	27.28	
Ca^{++}	38.11	26.98	22.41	18.53	
Mg^{++}	4.05	6.54	9.93	7.87	
K^{+}	1.40	0.90	0.32	0.22	
Na^{+}	1.70	1.95	1.95	2.15	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	24.85	28.35	30.85	33.35	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 305	**Date :** 2006-07-02

Location : Wadda Makasuil	**Coordinates :** 09º22'16" / 43º36'06"
Authors : Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Hyposodic, Chromic).	**Land form :** Alluvial plain
Effective soil depth: 100-150cm	**Land element :** Terrace
Rock outcrops : Nil	**Drainage :** Moderately well
Surface stoniness : Nil	**Moisture conditions :** Dry
UTM coordinates: 346450 - 1036186	
Remarks : Soil developed under clay, silt and loam in a Piedmont/Alluvial plain. Presence of fine width and very closely spaced soil cracks. No salts.	

Horizon	Depth cm	Description
A1	0-10	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak very fine granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; very few very fine roots; clear smooth boundary.
A2	10-35	Dark brown (7.5YR 3/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak fine granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; very few fine roots; clear wavy boundary.
B1	35-85	Dark brown (7.5YR 3/3) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; strong very coarse subangular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; very few very fine roots; clear smooth boundary.
B2	85-140	Reddish brown (5YR 4/4) (moist) and Strong brown (7.5YR 4/6) (dry); no mottles; strong medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; no roots.

HORIZON	A1	A2	B1	B2	
LOWER BOUNDARY	10	35	85	140	
SAND %	32.0	26.0	28.0	24.0	
SILT %	12.0	14.0	10.0	10.0	
CLAY %	56.0	60.0	62.0	66.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.45	1.45	1.45	1.45	
C (%)	0.95	0.92	0.61	0.44	
N (%)	0.11	0.10	0.07	0.05	
P (ppm)	4.50	2.10	3.50	8.20	
pH	8.19	8.20	8.70	8.78	
EC (mS/cm)	0.35	0.35	0.40	0.90	
CEC (me/100g)	25.07	25.48	22.28	14.08	
Ca^{++}	37.22	30.23	27.17	13.63	
Mg^{++}	3.27	4.43	9.49	10.93	
K^{+}	1.30	0.98	0.44	0.16	
Na^{+}	1.30	1.15	2.20	1.45	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	24.85	25.85	27.85	31.85	

Profile

SOIL PROFILE DESCRIPTION

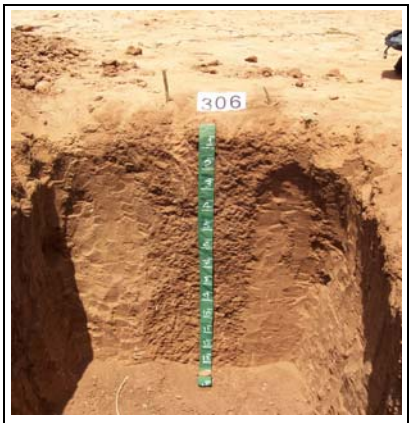
Profile code : 306	**Date :** 2006-07-04

Location : Seyla Galbeed	**Coordinates :** 09º18'18" / 43º51'34"
Authors : Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Chromic).	**Land form :** Pediment
Effective soil depth: 100-150cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:**374743 - 1028780

Remarks : Parent material consists of gravel, clay and loam in a Piedmont/Pediment. No salts but there are fine width and very closely spaced cracks.

Horizon	Depth cm	Description
A	0-23	Reddish brown (5YR 4/3) (moist) and Dark reddish brown (5YR 3/3) (dry); no mottles ; moderate medium granular structure; no cutans; ; no voids; common fine subrounded rocks; strongly calcareous; common fine roots; gradual smooth boundary.
AB	23-40	Dark reddish brown (5YR 3/3) (moist) and Dark reddish brown (5YR 3/2) (dry); no mottles ; moderate medium subangular blocky structure; no cutans; ; no voids; few fine subrounded rocks; common very fine calcareous concretions; extremely calcareous; few fine roots; clear smooth boundary.
Btk	40-85	Dark reddish brown (5YR 3/3) (moist) and Dark reddish brown (5YR 3/2) (dry); no mottles; strong medium subangular blocky structure; common pressure face Cutans; no voids; no rocks; many very fine calcareous concretions; extremely calcareous; no roots; diffuse boundary.
Ck	85-130	Dark reddish brown (5YR 2.5/2) (moist) and Reddish brown (5YR 4/3) (dry); no mottles; moderate medium subangular blocky structure; no cutans; no voids; no rocks; abundant very fine calcareous concretions ; extremely calcareous; no roots.

HORIZON	A	AB	Btk	Ck	
LOWER BOUNDARY	23	40	85	>85	
SAND %	42.0	46.0	46.0	38.0	
SILT %	6.0	4.0	6.0	10.0	
CLAY %	52.0	50.0	48.0	52.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.35	1.35	1.35	1.35	
C (%)	0.56	0.66	0.50	0.40	
N (%)	0.08	0.08	0.06	0.04	
P (ppm)	8.30	11.90	5.20	5.10	
pH	8.19	8.01	8.15	8.32	
EC (mS/cm)	0.40	1.15	1.00	0.75	
CEC (me/100g)	21.08	22.48	23.88	23.48	
Ca^{++}	33.60	25.92	21.95	16.97	
Mg^{++}	2.99	8.49	1.24	5.58	
K^{+}	1.68	0.80	0.56	0.68	
Na^{+}	1.80	0.80	0.70	1.95	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	16.35	17.50	19.00	21.00	



Profile

SOIL PROFILE DESCRIPTION

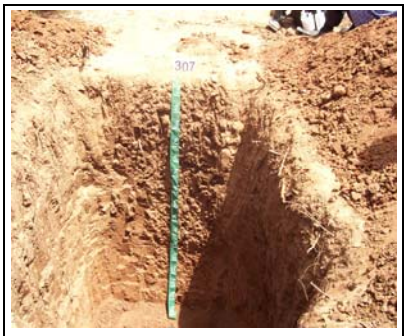
Profile code : 307	**Date :** 2006-07-06

Location : Garabis	**Coordinates :** 09º25'60" / 43º57'14"
Authors : Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Hyposodic, Chromic).	**Land form :** Valley
Effective soil depth: 100-150cm	**Drainage :** Moderately well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 385163 - 1042931

Remarks : Soil developed under alluvium parent material located in a Valley/Pediment. Soil covers without salt crusts and with fine width and very closely spaced cracks.

Horizon	Depth cm	Description
A1	0-15	Dark reddish brown (5YR 3/3) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; weak fine granular structure; no cutans; no voids; no rocks; few soft segregation calcareous fine; extremely calcareous; many fine-medium roots; clear smooth boundary.
A2	15-30	Dark reddish brown (5YR 3/3) (moist) and Dark brown (7.5YR 3/3) (dry); no mottles; moderate medium granular structure; no cutans; no voids; no rocks; many soft segregation calcareous fine; extremely calcareous; few fine roots; clear smooth boundary.
Btk	30-110	Dark brown (7.5YR 3/3) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles; strong medium angular and subangular blocky structure; no cutans; no voids; no rocks; extremely calcareous; very few fine roots; diffuse smooth boundary.
Ck	110-160	Reddish brown (5YR 4/4) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; hard prismatic structure; no cutans; no voids; no rocks; common soft segregation calcareous fine; extremely calcareous; no roots.

HORIZON	A1	A2	B2k	Ck	
LOWER BOUNDARY	15	30	110	160	
SAND %	26.0	30.0	20.0	64.0	
SILT %	10.0	10.0	12.0	4.0	
CLAY %	64.0	60.0	68.0	32.0	
TEXTURE CLASS	**C**	**C**	**C**	**SCL**	
BULK DENSITY (g/cm^3)	1.35	1.35	1.35	1.35	
C (%)	0.72	0.68	0.40	0.22	
N (%)	0.09	0.08	0.06	0.04	
P (ppm)	7.00	9.10	4.70	2.90	
pH	8.23	8.49	8.63	8.34	
EC (mS/cm)	0.29	0.40	1.55	1.60	
CEC (me/100g)	25.08	26.48	20.08	7.28	
Ca^{++}	37.82	34.01	18.12	12.34	
Mg^{++}	5.11	6.18	5.45	2.12	
K^{+}	1.68	1.76	0.48	0.20	
Na^{+}	2.20	2.65	3.00	0.70	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	25.00	27.50	30.50	18.00	



Profile

SOIL PROFILE DESCRIPTION

Profile code : 308	**Date :** 2006-07-06

Location : Sheik Moodhle	**Coordinates :** 09º21'22" / 43º50'31"
Authors : Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Hyposalic, Hyposodic, Chromic)	**Drainage :** Well
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates:** 372823 - 1034437

Remarks : Soil profile located in a Piedmont/Denudational slope where the parent material is an alluvium. No salts and fine width very closely spaced cracks are present.

Horizon	Depth cm	Description
A1	0-10	Dark reddish brown (5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak fine granular structure; no cutans; no voids; no rocks; extremely calcareous; common very fine roots; clear smooth boundary.
A2	10-25	Dark reddish brown (5YR 3/2) (moist) and Brown (7.5YR 4/3) (dry); no mottles; moderate medium granular structure; no cutans; no voids; no rocks; extremely calcareous; few very fine roots; diffuse smooth boundary.
Bk	25-85	Dark reddish brown (5YR 3/3) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles; strong coarse subangular and angular blocky structure; no cutans; no voids; no rocks; extremely calcareous; very few very fine roots; clear smooth boundary.
Ck	85-130	Reddish brown (5YR 4/3) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles; strong coarse subangular and angular blocky structure; no cutans no voids; no rocks; extremely calcareous; no roots.

HORIZON	A1	A2	Bk	Ck	
LOWER BOUNDARY	10	25	85	130	
SAND %	42.0	34.0	34.0	26.0	
SILT %	10.0	12.0	8.0	12.0	
CLAY %	48.0	54.0	58.0	62.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.53	1.53	1.53	1.53	
C (%)	1.00	0.79	0.41	0.33	
N (%)	0.10	0.09	0.05	0.04	
P (ppm)	9.70	5.70	1.50	2.80	
pH	8.20	8.11	8.56	8.51	
EC (mS/cm)	0.45	0.90	1.80	2.40	
CEC (me/100g)	14.08	24.08	21.08	20.08	
Ca^{++}	22.90	25.23	22.98	23.71	
Mg^{++}	2.28	3.55	9.54	8.38	
K^{+}	1.02	0.90	0.52	0.40	
Na^{+}	1.20	1.20	2.60	2.70	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	19.50	23.50	25.50	30.00	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 309	**Date :** 2006-07-09

Location : Daba Mayagaag	**Coordinates :** 09º16'49" / 44º02'15"
Authors : Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Hyposodic, Chromic)	**Land form :** Pediment
Effective soil depth: 100-150cm	**Drainage :** Moderately well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 394299 - 1025995

Remarks : Soil profile located in the toeslope of a piedmont/pediment. Fine width very closely spaced cracks are present. No salt crusts.

Horizon	Depth cm	Description
A1	0-15	Reddish brown (5YR 4/4) (moist) and Strong brown (7.5YR 5/6) (dry); no mottles; weak fine granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; many very fine roots; clear smooth boundary.
a2	15-20	Dark reddish brown (5YR 3/3) (moist) and Strong brown (7.5YR 4/6) (dry); no mottles; moderate medium granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; common very fine roots; diffuse smooth boundary.
B	20-70	Dark reddish brown (5YR 3/4) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles ; strong medium subangular blocky structure; no cutans; ; very few, very fine Voids; no rocks; few crystals salt fine; extremely calcareous; very few fine roots; clear smooth boundary.
C	70-120	Dark reddish brown (5YR 3/4) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles; medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; few crystals salt fine; extremely calcareous; no roots.

HORIZON	A1	A2	B	C	
LOWER BOUNDARY	15	20	70	120	
SAND %	34.0	30.0	28.0	24.0	
SILT %	16.0	14.0	14.0	10.0	
CLAY %	50.0	56.0	58.0	66.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.55	1.55	1.55	1.55	
C (%)	0.71	0.58	0.39	0.27	
N (%)	0.06	0.07	0.05	0.04	
P (ppm)	8.30	8.30	5.10	4.70	
pH	8.33	8.16	8.28	8.12	
EC (mS/cm)	0.24	0.65	1.30	1.65	
CEC (me/100g)	19.64	24.40	16.80	20.00	
Ca^{++}	26.74	16.36	15.23	16.75	
Mg^{++}	2.51	2.66	3.43	4.47	
K^{+}	1.20	1.40	1.08	0.32	
Na^{+}	1.40	1.80	1.25	2.65	
PSB (%)	100.0	91.0	100.0	100.0	
CaCO3 (%)	26.50	25.50	29.00	29.50	

Profile

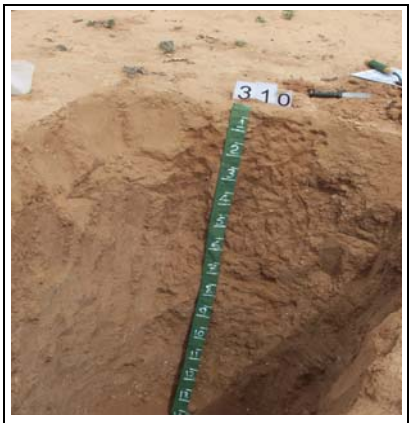
SOIL PROFILE DESCRIPTION

Profile code : 310	**Date :** 2006-07-11

Location : Gumbur Shiikhdon	**Coordinates :** 09º38'32" / 44º01'56"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Haplic Calcisol (Aridic, Clayic).	**Land form :** Plateau
Rock outcrops : Nil	**Drainage :** Well
Surface stoniness : Nil	**Moisture conditions :** Dry
UTM coordinates: 393828 - 1066010	
Remarks : Soil developed under limestone parent rock and located in a Dissected Plateau/Denudational surface. Fine width very closely spaced cracks.	

Horizon	Depth cm	Description
A	0-35	Dark brown (7.5YR 4/4) (moist) and Strong brown (7.5YR 4/6) (dry); no mottles; moderate medium granular structure; no cutans; no voids; no rocks; extremely calcareous; many very fine roots; clear smooth boundary.
B	35-75	Dark brown (7.5YR 4/4) (moist) and Strong brown (7.5YR 4/6) (dry); no mottles; moderate medium subangular blocky structure; no cutans; no voids; no rocks; few fine calcareous nodules; extremely calcareous; very few very fine roots; clear wavy boundary.
C	75-140	Brown (7.5YR 4/3) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; moderate medium subangular blocky structure; no cutans; no voids; no rocks; many nodules calcareous medium; extremely calcareous; no roots.

HORIZON	A	B	C		
LOWER BOUNDARY	35	75	140		
SAND %	76.0	68.0	18.0		
SILT %	6.0	6.0	14.0		
CLAY %	18.0	26.0	68.0		
TEXTURE CLASS	**SL**	**SCL**	**C**		
BULK DENSITY (g/cm^3)	1.58	1.58	1.58		
C (%)	0.31	0.27	0.18		
N (%)	0.05	0.05	0.05		
P (ppm)	11.80	5.20	9.50		
pH	8.17	8.11	8.14		
EC (mS/cm)	0.20	0.50	4.00		
CEC (me/100g)	10.20	10.00	27.80		
Ca^{++}	17.99	18.51	13.76		
Mg^{++}	2.06	2.16	5.95		
K^{+}	0.80	0.36	0.60		
Na^{+}	0.55	0.75	3.95		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	7.50	14.00	29.50		



Profile

SOIL PROFILE DESCRIPTION

Profile code : 311	**Date :** 2006-07-11

Location : Beeyo Doofar	**Coordinates :** 09º40'41"/ 44º01'29"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Land form :** Plateau
WRB 2006 Soil Classification: Petric Calcisol (Episkeletic, Arenic)	**Drainage :** Well
Rock outcrops : Few	**Moisture conditions :** Dry
Surface stoniness : Dominant	**UTM coordinates:** 392999 - 1069972
Remarks :	Calcaric soil located in a Dissected plateau/Gully rill erosion surface, under calcaric rock parent material. Fine width very closely spaced cracks and no salt crusts.. No soil samples were taken for soil lab analysis and there is no a complete horizon description because of soil-rock hardness

Horizon	**Depth cm**	**Description**
A	0-25	Brown (7.5YR 5/3) (dry);

HORIZON					
LOWER BOUNDARY					
SAND %					
SILT %					
CLAY %					
TEXTURE CLASS					
BULK DENSITY (g/cm^3)					
C (%)					
N (%)					
P (ppm)					
pH					
EC (mS/cm)					
CEC (me/100g)					
Ca^{++}					
Mg^{++}					
K^{+}					
Na^{+}					
PSB (%)					
CaCO3 (%)					

Profile

SOIL PROFILE DESCRIPTION

Profile code : 316	**Date :** 2006-07-14

Location : Cadayabur	**Coordinates :** 09º57'14" / 44º02'43"
Authors : Omar Haji Duale, Ali Ibrahim Ismail, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Hyposodic, Chromic).	**Land form :** Plateau
Effective soil depth: 100-150cm	**Drainage :** Moderately well
Surface stoniness : Common	**Moisture conditions :** Dry
UTM coordinates: 395353 - 1100459	
Remarks : Soil profile located in a Plateau/Denudational surface and developed under clay deposits. Fine width very closely spaced cracks are present whereas salt crusts are absent.	

Horizon	Depth cm	Description
A	0-20	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; moderate medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; many fine-medium roots; clear smooth
Bt	25-85	Dark brown (7.5YR 3/4) (moist); no mottles ; strong coarse subangular blocky structure; common pressure face Cutans; ; very few, very fine Voids; no rocks; many calcareous concretions fine; extremely calcareous; many fine roots; clear smooth boundary.
C	85-120	Dark brown (7.5YR 3/3) (moist); no mottles; moderate coarse subangular blocky structure; no cutans; very few, very fine Voids; no rocks; many calcareous concretions fine; extremely calcareous; no roots.

HORIZON	A	Bt	C		
LOWER BOUNDARY	20	85	120		
SAND %	34.0	32.0	22.0		
SILT %	16.0	12.0	16.0		
CLAY %	50.0	56.0	62.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.48	1.48	1.48		
C (%)	0.47	0.30	0.22		
N (%)	0.07	0.05	0.04		
P (ppm)	10.00	9.70	7.70		
pH	8.20	8.47	8.38		
EC (mS/cm)	0.35	0.35	1.00		
CEC (me/100g)	25.40	16.80	28.60		
Ca^{++}	16.49	16.53	19.32		
Mg^{++}	4.22	4.76	4.99		
K^{+}	0.84	0.64	1.96		
Na^{+}	1.35	2.35	3.45		
PSB (%)	90.0	100.0	100.0		
CaCO3 (%)	22.50	22.50	26.50		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 317	**Date :** 2006-07-14

Location : North of Luina Dhexe	**Coordinates :** 10º00'50" / 44º08'18"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Vertic Petric Calcisol (Aridic, Clayic).	**Land form :** Plateau
Effective soil depth: 50-100cm	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Few	**UTM coordinates:** 405573 - 1107070

Remarks : Soil profile located in a Dissected plateau/Pediment with parent material calcaric rock and limestone. Fine width very closely spaced cracks are present whereas salt crusts are absent. The C horizon constitutes a $CaCO^3$ parent rock present as a form of rocks and concretions. This horizon was not sampled.

Horizon	Depth cm	Description
A	0-10	Dark brown (7.5YR 3/2) (moist) and dark brown (7.5YR 4/4) (dry); no mottles ; weak fine granular structure; no cutans; ; no voids; few fine subrounded rocks; extremely calcareous; common fine-medium roots; clear smooth boundary.
AB	10-20	Very dark Grey (7.5YR 3/1) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; strong medium subangular blocky structure; no cutans; no voids; very few fine subrounded rocks; extremely calcareous; common fine-medium roots; gradual wavy boundary.
B	20-65	Very dark Grey (7.5YR 3/1) (moist) and Very dark Grey (7.5YR 3/1) (dry); no mottles; strong medium angular blocky structure; common pressure face Cutans; no voids; very few fine subrounded rocks; extremely calcareous; few fine roots; clear wavy boundary.
C	65-110	No mottles; dominant limestone stones and boulders subrounded fresh-slightly weathered rocks; extremely calcareous.

HORIZON	A	AB	B		
LOWER BOUNDARY	10	20	65		
SAND %	34.0	24.0	22.0		
SILT %	18.0	22.0	20.0		
CLAY %	48.0	54.0	58.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.38	1.38	1.38		
C (%)	0.62	0.94	0.68		
N (%)	0.07	0.07	0.07		
P (ppm)	10.10	9.40	13.60		
pH	8.17	8.35	8.31		
EC (mS/cm)	0.35	0.30	0.70		
CEC (me/100g)	29.40	33.40	26.40		
Ca^{++}	35.73	18.75	17.35		
Mg^{++}	3.78	3.98	3.03		
K^{+}	0.88	0.36	0.28		
Na^{+}	1.60	1.70	2.30		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	24.00	27.00	27.00		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 321	**Date :** 2006-07-17

Location : Cunagabad	**Coordinates :** 09º25'31" / 44º00'26"
Authors : Omar Haji Duale, Musse Shaie	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Mazic Vertisol (Hyposalic, Hyposodic).	**Land form :** Valley
Effective soil depth: >150	**Drainage :** Well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates:** 391024 - 1042029

Remarks : Soil profile located in a Valley/Pediment under clay deposits. Fine width very closely spaced cracks are present whereas salt crusts are absent.

Horizon	Depth cm	Description
Ap	0-15	Brown (7.5YR 4/3) (moist) and brown (7.5YR 5/4) (dry); no mottles; weak fine and medium granular structure; no cutans; very few voids very fine; no rocks; extremely calcareous; many fine roots; abrupt wavy boundary.
A2	15-40	Dark reddish brown (5YR 3/3) (moist) and Reddish brown (5YR 4/3) (dry); no mottles; moderate medium subangular blocky structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; common fine roots; diffuse boundary.
Bt1k1	40-80	Dark reddish brown (5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles ; strong medium subangular blocky structure; few slickensides on pedfaces Cutans; very few, very fine Voids; no rocks; common soft segregation calcareous; extremely calcareous; few burrows; few very fine roots; gradual wavy boundary.
Bt2k2	80-135	Dark reddish brown (5YR 3/3) (moist) and Reddish brown (5YR 4/3) (dry); no mottles ; strong medium and coarse angular blocky structure; few slickensides on pedfaces Cutans; ; very few, very fine Voids; no rocks; common soft segregation calcareous; extremely calcareous; no roots; gradual wavy boundary.
Ck	135-155	Dark reddish brown (5YR 3/3) (moist) and Reddish brown (5YR 4/4) (dry); no mottles; strong medium and coarse angular blocky structure; no cutans; very few, very fine Voids; no rocks; common soft segregation calcareous; extremely calcareous; no roots.

HORIZON	Ap	A2	Bt1k1	Bt2k2	Ck
LOWER BOUNDARY	15	40	80	135	155
SAND %	38.0	20.0	24.0	22.0	18.0
SILT %	4.0	22.0	12.0	16.0	16.0
CLAY %	58.0	58.0	64.0	62.0	66.0
TEXTURE CLASS	**C**	**C**	**C**	**C**	**C**
BULK DENSITY (g/cm^3)	1.36	1.36	1.36	1.36	1.36
C (%)	0.65	0.55	0.38	0.27	0.23
N (%)	0.09	0.12	0.11	0.08	0.07
P (ppm)	11.50	10.50	14.70	18.80	15.40
pH	8.03	7.85	7.98	8.00	8.09
EC (mS/cm)	0.70	2.50	2.35	2.20	2.15
CEC (me/100g)	20.40	21.40	22.40	23.60	27.20
Ca^{++}	9.79	10.53	10.71	19.83	12.27
Mg^{++}	2.98	3.53	3.88	7.59	5.26
K^{+}	0.76	0.60	0.70	0.78	1.16
Na^{+}	1.20	1.65	2.15	2.25	2.65
PSB (%)	72.0	76.0	78.0	100.0	86.0
CaCO3 (%)	26.00	24.00	26.50	29.00	32.50

Profile

SOIL PROFILE DESCRIPTION

Profile code : 323	**Date :** 2006-07-17

Location : Sharmarke	**Coordinates :** 09º24'42" / 44º12'48"
Authors : Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Hyposalic, Chromic).	**Land form :** Valley
Effective soil depth: >150	**Drainage :** Moderately well
Rock outcrops : Nil	**Moisture conditions :** Dry
Surface stoniness : Nil	**UTM coordinates**: 413625 - 1040462
Remarks : Soil profile located in a Valley/Flat floor valley. Fine width very closely spaced cracks are present whereas salt crusts are absent.	

Horizon	Depth cm	Description
A1	0-10	Dark brown (7.5YR 3/4) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; strong fine granular structure; no cutans; no voids; no rocks; extremely calcareous; many fine roots; clear smooth boundary.
A2	10-25	Dark brown (7.5YR 3/4) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; strong medium subangular and angular blocky structure; no cutans; no voids; no rocks; extremely calcareous; common fine-medium roots; clear wavy boundary.
B1	25-50	Dark brown (7.5YR 3/4) (moist) and Strong brown (7.5YR 4/6) (dry); no mottles; strong coarse angular and subangular blocky structure; no cutans; no voids; no rocks; extremely calcareous; few fine roots; gradual smooth boundary.
B2	50-110	Dark brown (7.5YR 3/3) (moist) and Brown (7.5YR 4/3) (dry); no mottles; weak medium subangular and angular blocky structure; no cutans; no voids; no rocks; extremely calcareous; very few fine roots; diffuse smooth boundary.
C	110-160	Dark brown (7.5YR 3/3) (moist) and Dark brown (7.5YR 3/4) (dry); no mottles; weak medium subangular and angular blocky structure; no cutans; no voids; no rocks; extremely calcareous; no roots.

HORIZON	A1	A2	B1	B2	C
LOWER BOUNDARY	10	25	50	110	>140
SAND %	6.0	6.0	10.0	8.0	12.0
SILT %	32.0	32.0	38.0	34.0	26.0
CLAY %	62.0	62.0	52.0	58.0	62.0
TEXTURE CLASS	**C**	**C**	**C**	**C**	**C**
BULK DENSITY (g/cm^3)	1.41	1.41	1.41	1.41	1.41
C (%)	0.52	0.46	0.51	0.41	0.29
N (%)	0.07	0.08	0.11	0.10	0.09
P (ppm)	18.00	7.10	7.30	5.60	9.30
pH	8.06	7.98	7.81	7.84	7.90
EC (mS/cm)	0.55	1.20	3.50	4.00	3.50
CEC (me/100g)	25.40	32.00	20.60	21.80	29.40
Ca^{++}	5.02	15.71	10.97	10.89	6.09
Mg^{++}	1.21	4.80	3.20	5.92	9.20
K^{+}	0.28	0.80	0.42	0.68	1.40
Na^{+}	0.20	1.80	1.35	2.35	1.30
PSB (%)	100.0	100.0	100.0	100.0	100.0
CaCO3 (%)	24.00	23.00	22.50	25.00	25.50

Profile

SOIL PROFILE DESCRIPTION

Profile code : 325	**Date :** 2006-07-21

Location : Boodhley	**Coordinates :** 09º36'03" / 43º32'18"
Authors : Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Chromic)	**Land form :** Plateau
Rock outcrops : Nil	**Drainage :** Well
Surface stoniness : Nil	**Moisture conditions :** Dry
UTM coordinates: 339591 - 1061629	
Remarks : Soil profile located in a Plateau/Denudational surface where the parent material is clay deposits. Fine width very closely spaced cracks are present whereas salt crusts are absent.	

Horizon	Depth cm	Description
Ap	0-20	Dark brown (7.5YR 3/3) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; weak fine granular structure; no cutans; ; no voids; no rocks; extremely calcareous; common very fine roots; clear wavy boundary.
Btk	20-75	Dark brown (7.5YR 3/2) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; strong coarse subangular blocky structure; common pressure face Cutans; no voids; no rocks; common soft segregation calcareous; extremely calcareous; common fine roots; diffuse boundary.
Ck	75-110	Dark brown (7.5YR 3/3) (moist) and Brown to dark brown (7.5YR 4/2) (dry); strong coarse subangular blocky structure; no cutans; no voids; no rocks; many soft segregation calcareous; extremely calcareous; few fine roots.

HORIZON	Ap	Btk	Ck		
LOWER BOUNDARY	20	75	110		
SAND %	32.0	30.0	24.0		
SILT %	12.0	12.0	12.0		
CLAY %	56.0	58.0	64.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.34	1.34	1.34		
C (%)	1.28	0.88	0.64		
N (%)	0.11	0.07	0.05		
P (ppm)	6.10	10.00	4.60		
pH	7.97	7.84	8.13		
EC (mS/cm)	0.35	0.55	0.95		
CEC (me/100g)	27.60	27.00	21.60		
Ca^{++}	31.27	36.86	12.96		
Mg^{++}	2.73	4.11	4.61		
K^{+}	1.30	1.10	0.50		
Na^{+}	1.55	1.55	2.30		
PSB (%)	100.0	100.0	93.0		
CaCO3 (%)	19.50	21.00	27.50		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 326	**Date :** 2006-07-21

Location : Idhanka Deerayaharka	**Coordinates :** 09º33'07" / 43º27'44"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Mazic Vertisol (Chromic)	**Land form :** Pediment
Land use : Agriculture	**Drainage :** Well
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates**: 331228 - 1056257

Remarks : Soil profile located in a Piedmont/Pediment where a clay deposit is the parent material. Wide width very closely spaced cracks are present whereas salt crusts are absent.

Horizon	Depth cm	Description
Ap	0-15	Dark brown (7.5YR 3/2) (moist) and dark brown (7.5YR 3/2) (dry); no mottles; weak fine granular structure; no cutans; no voids; no rocks; extremely calcareous; common very fine roots; clear smooth boundary.
AB	15-30	Very dark Grey (7.5YR 3/1) (moist) and dark brown (7.5YR 3/2) (dry); no mottles; moderate medium subangular blocky structure; no cutans; ; no voids; no rocks; extremely calcareous; common very fine roots; diffuse boundary.
Btk	30-110	Dark brown (7.5YR 3/2) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; strong coarse angular blocky structure; many pressure faces on pedfaces Cutans; no voids; no rocks; few soft segregation calcareous; extremely calcareous; few very fine roots; clear smooth boundary.
Ck	110-140	Dark brown (7.5YR 3/4) (moist) and Dark brown (7.5YR 3/3) (dry); no mottles; moderate medium angular blocky structure; no cutans; no voids; no rocks; common soft segregation calcareous; extremely calcareous; no roots.

HORIZON	Ap	AB	Btk	Ck	
LOWER BOUNDARY	15	30	110	>110	
SAND %	34.0	30.0	24.0	22.0	
SILT %	12.0	12.0	14.0	12.0	
CLAY %	54.0	58.0	62.0	66.0	
TEXTURE CLASS	**C**	**C**	**C**	**C**	
BULK DENSITY (g/cm^3)	1.43	1.43	1.43	1.43	
C (%)	1.09	0.81	0.53	0.14	
N (%)	0.06	0.07	0.04	0.04	
P (ppm)	7.30	4.90	4.20	6.40	
pH	7.92	7.96	8.13	8.24	
EC (mS/cm)	0.35	0.35	0.50	0.90	
CEC (me/100g)	26.40	32.00	21.20	25.00	
Ca^{++}	22.73	25.40	18.11	14.73	
Mg^{++}	2.88	3.88	8.24	8.59	
K^{+}	1.44	1.10	0.96	0.68	
Na^{+}	1.55	1.30	1.65	2.80	
PSB (%)	100.0	100.0	100.0	100.0	
CaCO3 (%)	19.00	23.00	25.00	28.00	

Profile

SOIL PROFILE DESCRIPTION

Profile code : 328	**Date :** 2006-07-23

Location : Balliga Godan	**Coordinates :** 09º39'41" / 43º25'24"
Authors : Ali Ibrahim Ismail, Omar Haji Duale	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Vertisol (Bathyhyposalic, Bathyhyposodic)	**Land form :** Pediment
Land use : Agriculture	**Drainage :** Well
Effective soil depth: >150	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates:** 327021 - 1068371
Remarks : Soil profile developed in a Piedmont/Pediment composed of clay deposits. Wide, very closely spaced cracks are present whereas salt crusts are absent.	

Horizon	Depth cm	Description
Ap	0-20	Black (7.5YR 2.5/1) (moist) and very dark Grey (7.5YR 3/1) (dry); no mottles; weak fine granular structure; no cutans; very few, very fine Voids; no rocks; extremely calcareous; many very fine roots; clear wavy boundary.
Bt	20-90	Black (7.5YR 2.5/1) (moist) and Black (7.5YR 2.5/1) (dry); no mottles; strong coarse angular blocky structure; many slickensides on pedfaces Cutans; very few, very fine Voids; no rocks; extremely calcareous; very few fine-medium roots; clear smooth boundary.
C	90-160	Dark brown (7.5YR 4/4) (moist) and Dark brown (7.5YR 4/4) (dry); no mottles; strong coarse angular blocky structure; many pressure face Cutans; very few, very fine Voids; no rocks; many soft segregation calcareous; extremely calcareous; no roots.

HORIZON	Ap	Bt	C		
LOWER BOUNDARY	20	90	160		
SAND %	14.0	14.0	12.0		
SILT %	18.0	12.0	12.0		
CLAY %	68.0	74.0	76.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.31	1.31	1.31		
C (%)	1.76	0.92	0.04		
N (%)	0.11	0.05	0.03		
P (ppm)	6.00	6.20	7.70		
pH	7.97	8.46	8.28		
EC (mS/cm)	0.40	0.75	4.00		
CEC (me/100g)	41.40	45.32	26.40		
Ca^{++}	27.10	19.37	20.21		
Mg^{++}	5.71	9.82	6.64		
K^{+}	0.86	0.76	0.40		
Na^{+}	0.85	3.10	4.55		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	22.00	26.00	29.50		

Profile

SOIL PROFILE DESCRIPTION

Profile code : 329	**Date :** 2006-07-23

Location : Mashrunca Wajale	**Coordinates :** 09º37'07" / 43º24'24"
Authors : Omar Haji Duale, Ali Ibrahim Ismail	**Soil climate :** Aridic
WRB 2006 Soil Classification: Calcic Grumic Vertisol (Bathyhyposodic, Chromic)	**Land form :** Pediment
Land use : Agriculture	**Drainage :** Imperfect
Effective soil depth: 100-150cm	**Moisture conditions :** Dry
Rock outcrops : Nil	
Surface stoniness : Nil	**UTM coordinates:** 325151 - 1063458

Remarks : Soil profile located in a Piedmont/Pediment composed of clay deposits. Wide width, very closely spaced cracks are present whereas salt crusts are absent.

Horizon	Depth cm	Description
Ap	0-25	Dark brown (7.5YR 3/2) (moist) and grey (7.5YR 6/1) (dry); no mottles; strong fine and medium granular structure; no cutans; no voids; no rocks; extremely calcareous; many fine roots; clear wavy boundary.
Bt	25-110	Brown (7.5YR 4/3) (moist) and Dark brown (7.5YR 3/2) (dry); no mottles; strong coarse angular blocky structure; many slickensides on pedfaces Cutans; no voids; no rocks; extremely calcareous; common very fine roots; gradual irregular boundary.
C	110-140	Brown (7.5YR 4/3) (moist) and dark brown (7.5YR 3/4) (dry); no mottles; moderate medium angular blocky structure; no cutans; no voids; no rocks; common crystals salt; extremely calcareous; no roots.

HORIZON	Ap	Bt	C		
LOWER BOUNDARY	25	110	140		
SAND %	16.0	14.0	10.0		
SILT %	14.0	8.0	10.0		
CLAY %	70.0	78.0	80.0		
TEXTURE CLASS	**C**	**C**	**C**		
BULK DENSITY (g/cm^3)	1.16	1.16	1.16		
C (%)	0.02	0.02	0.01		
N (%)	0.14	0.03	0.02		
P (ppm)	4.40	5.90	7.00		
pH	7.82	8.63	8.50		
EC (mS/cm)	0.60	1.55	3.50		
CEC (me/100g)	33.70	25.40	27.00		
Ca^{++}	13.24	11.93	12.96		
Mg^{++}	4.63	3.44	6.41		
K^{+}	1.10	0.96	1.00		
Na^{+}	1.05	1.95	8.55		
PSB (%)	100.0	100.0	100.0		
CaCO3 (%)	25.00	31.50	30.50		

Profile