Inventory of Drainage Basins of Northern Somalia

Technical Report No. W-18

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List of abbreviations

AEZ	Agro-Ecological Zones
DEM	Digital Elevation Model
EC	Electrical Conductivity
EU	European Union
FAO	Food and Agriculture Organisation
ITCZ	Inter tropical Convergence Zone
m.a.s.l.	meters above sea level
MDGs	Millennium Development Goals
PET	Potential Evapotranspiration
RC	Runoff coefficient
RFE	Rainfall Estimates
RH	Relative Humidity
SWALIM	Somalia Water and Land Information Management
UNDP	United Nations Development Programme
USGS	United States Geological Survey
WMO	World Meteorological Organization

1.0 INTRODUCTION

Addressing issues of natural resources requires a holistic approach that recognizes the interdependence between competing demands and limited resources. Integrated watershed management is recognized as the best instrument for dealing with water and natural resources. This would also contribute to the eradication of extreme poverty and hunger (MDG 1) through improved food security (main focus of FAO) and sustainable environmental management (MDG 7).

To enable start a process of integrated water resources management in Northern Somalia, the Somalia Water and Land Information Management (SWALIM) project has been mandated by the European Union (EU) to develop an inventory of the drainage basins of the area. A great percentage of the Somalia population relies directly on the natural resource base to meet their daily needs.

This document, "Inventory of Northern Somalia Drainage Basins" is a first attempt to develop a working document for planners in many fields in northern Somalia. This document is therefore likely to be updated and refined as information continues to flow in from actors in all the involved sectors. As a working document, there is scope for improving the accuracy and we must invest in further research and field actions. The inventory provides baseline information on climate, water resources and land resources. This information is useful for policy development, prioritization of initiatives on watershed management, coordination of actions and further assessments.

The major drainage basins in Northern regions of Somalia are: the Gulf of Aden Basin, Darror Basin, Tug Der/Nugal Basin and Ogaden Basin (Figure 1). In addition to these, the narrow strip of land along the Indian Ocean has short drainage networks and there is not much flow in these drainage channels that reaches the Indian Ocean. This narrow strip has been discussed in this report.

Unlike the Juba and Shabelle river basins in southern Somalia which originate in the Ethiopian and Kenyan highlands, the northern Somalia basins have little surface runoff and rainfall in the basins are mostly lost through infiltration and evaporation. There are, however, some short streams (toggas) especially in the mountainous regions in the north that flow throughout the year in some stretches. There is a complex surface water-groundwater interaction along the toggas, whereby in some stretches there is surface runoff and in others there are mostly sub-surface interflows and recharging of groundwater aquifers. Natural springs are also common in the mountainous regions of the north where the rocky outcrops intersect the groundwater tables. Sub-surface flows along the toggas and groundwater available in springs (mountainous areas) and in shallow and deep aquifers are an important source of water for people and livestock in these drainage basins. Catchment rainwater harvesting through dams(wars) and berkads is also prevalent.

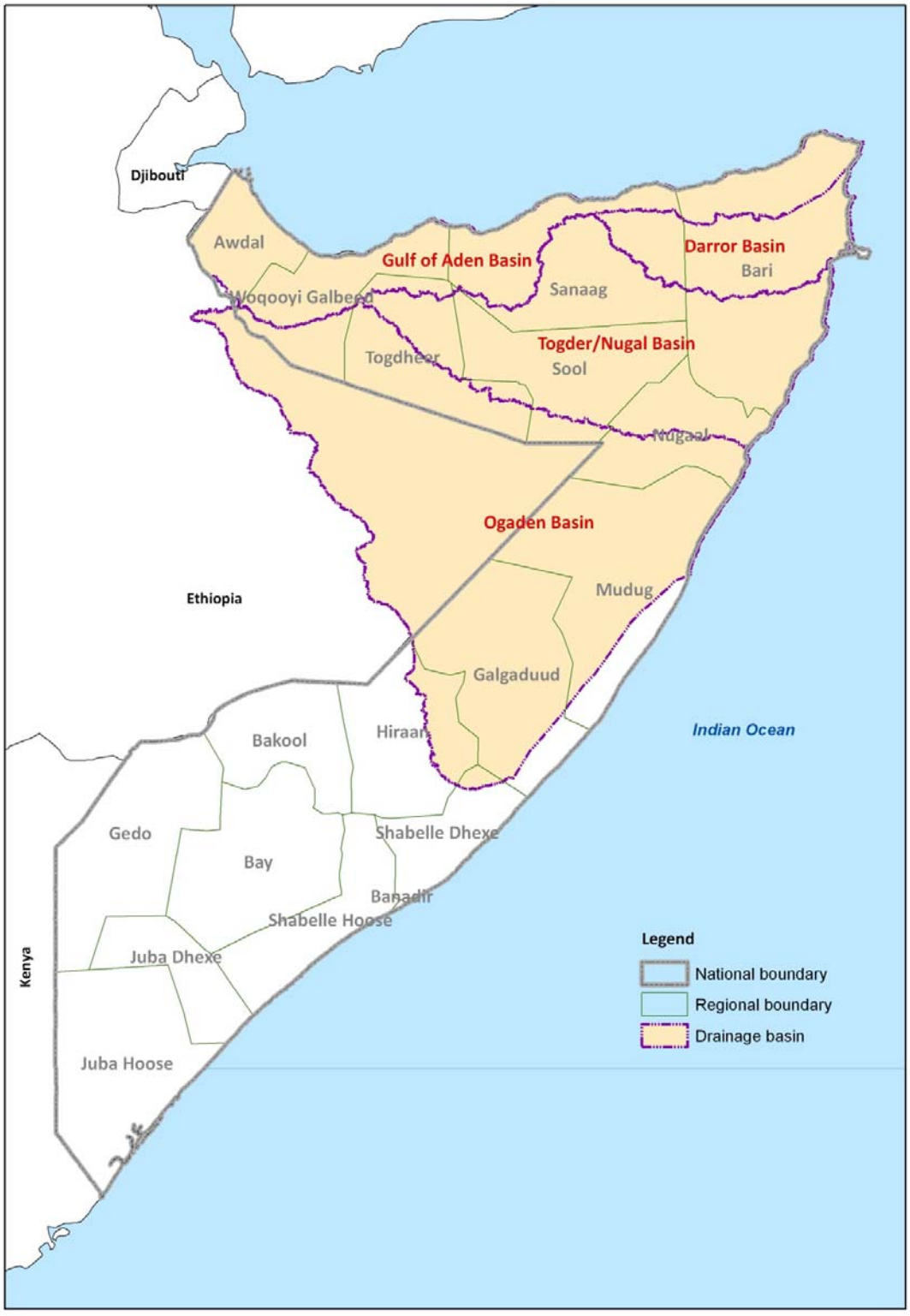


Figure 1: Map of drainage basins in northern Somalia

1.1 Data Availability

General Description Data:

The general description data used in this report consists of settlement data, and physical environment of each drainage basin. The settlement data was derived from United Nations development Programme (UNDP) datasets. While the physical environment data was derived from the United States Geological Survey (USGS) global 90 m Digital Elevation Model (DEM).

Climate data:

The density of climate monitoring network in Somalia has never been good enough to support a meaningful analysis of weather in the country. However, many researchers have attempted to do so, using different datasets to indicate average conditions of the climate of Somalia. Most available datasets are characterised by large gaps of missing data. The outbreak of civil war in the early nineties made the situation worse. Attempts to carry out analyses have become difficult since then, due to the loss of important datasets as well as the collapse of monitoring networks. SWALIM and other partner NGOs have been trying to revive the climate monitoring network. No significant weather observation was carried out between 1990 and 2004. The Somalia climate archive held within SWALIM contains data as far back as 1894 (for Kismayo) and 1904 (for Mogadishu).

In this analysis, the most recent consistent available data has been used, most of which have been extracted from the FAO global climate database for the period between 1963 - 1990. However, the database has missing information for some periods from some stations. In such cases missing data was interpolated to improve the analysis.

Water Resources

The USGS 90m DEM was used to generate the drainage network for all the watersheds. Hydrometric information on the catchment is limited and some basins like the Ogaden and Darror have never been investigated. The last intervention was carried out by SOGREAH in 1981 in some selected sub catchments. Water sources data was obtained from SWALIM's water sources inventory. The inventory holds a lot of information on thousands of water sources which were collected during the 2008/2009 point water sources survey. Ground water information was derived from historical data or records that exist within the SWALIM database. This data is to be used with caution because no further investigations have taken place since the break of civil war in Somalia.

Agro Ecological Zones (AEZ)

Agro-ecological zones (AEZ) are land resource mapping units, defined in terms of climate, landform and soils, and/or land cover, having a specific range of potentials and constraints (FAO, 1996). The purpose of Agro-ecological zoning is to give an inventory and overview of the physical agricultural potential of an area. SWALIM delineated agro-ecological zones for Somalia by mapping and defining through a combination of information on soils, landform and climate. Information on soils and landform was mainly derived from the Soil and Terrain

(SOTER) Database for north-eastern Africa (FAO, 1998), updated with recent information from the SWALIM study areas. Available data on rainfall and potential evapotranspiration (FAOCLIM, 2001) has been used to define Length of Growing Period Zones (LGP Zones)

Length of Growing Period (LGP)

The length of the growing period (LGP) as defined by FAO is the period (in days) during a year when precipitation exceeds half the potential evapotranspiration, plus a period required to transpire an assumed 100 mm of water from excess precipitation stored in the soil profile. It is a useful concept for calculating agricultural potential and can be used as a criterion for classifying areas and roughly determining crop cycle lengths. Calculation of the growing period is based on a simple water balance model, comparing precipitation with PET, using monthly values. PET and Rainfall data in SWALIM climate archive were used to calculate LGP for Somalia.

Geology and Soils Data

The existing soil classification systems suffer from considerable confusion and a lack of consistency between countries. Therefore, presenting a standardized classification is not easy. There are a number major soil groups in northern Somalia with different textural characteristics and fertility profiles for purposes of consistency with other SWALIM and generally FAO soil information, FAO SOTER datasets (at a scale of 1:1500000)(FAO, 1998) were used in this document to extract both geological and soils information.

2.0 GULF OF ADEN DRAINAGE BASIN

2.1 General Description of the Gulf of Aden Drainage Basin

The Gulf of Aden basin, situated in the northern parts of Somalia, covers the areas drained by the small *wadis* and *toggas* that originate from the gently sloping plateau and passes through the mountain range extending in an east-west direction. The drainage area covered by these small seasonal streams, collectively known as the Gulf of Aden basin, is about 74,422 km^2 (based on the 90 m SRTM DEM data). The drainage area is spread over five administrative regions - Awdal, West Galbeed, Togdheer, Sanaag and Bari. As administrative boundaries of regions do not necessarily match the basin boundaries, the drainage basin covers only parts of some of these regions. The drainage area lies roughly between 42^o 42' and 51^o 22' East and between 9^o 28' and 12^o 1' North. Figure 2 shows the administration boundaries within the basin and the location of major towns. The figure also shows the distribution of settlements in the basin with majority of the settlement being around the major town centres. Population estimates (UNDP 2008) in some of the towns include; Borama (82,921), Hargeisa (422,515), Berbera, Ceerigavo (31,098), Bosasso (107,181). No population data is available for other towns.

The elevation varies from sea level in the coastal areas to over 2000 m a.s.l in the mountain ranges that extend from the east to the west of the basin. The area slopes from the south to the north with the drainage flowing towards the Gulf of Aden. 42% of the area is below 500 m a.s.l, 94% below 1500 m a.s.l and 5% of the area lies between 1500 m a.s.l to 2000 m a.s.l. The highest peak is Mt. Surud; with an elevation of 2,408 m a.s.l. Figure 2 shows the topography within the basin.

The Gulf of Aden basin includes a variety of morphological features, such as accentuated relief, escarpment, steep slopes, coastal plains, internal plateaus and valleys (Figure 2). The high mountain range runs parallel to the shore of the Gulf of Aden. The mountain range is constituted by crystalline rocks which are deeply incised by numerous *toggas* that flow towards the Gulf of Aden. Some of the major *toggas* include Tug Jangarra (3700 km^2), Tug Hodmo (3 800 km^2) and Tug Belgeabbili (4,800 km^2). The water from the *toggas* barely reaches the seas but infiltrates in the coastal plains.

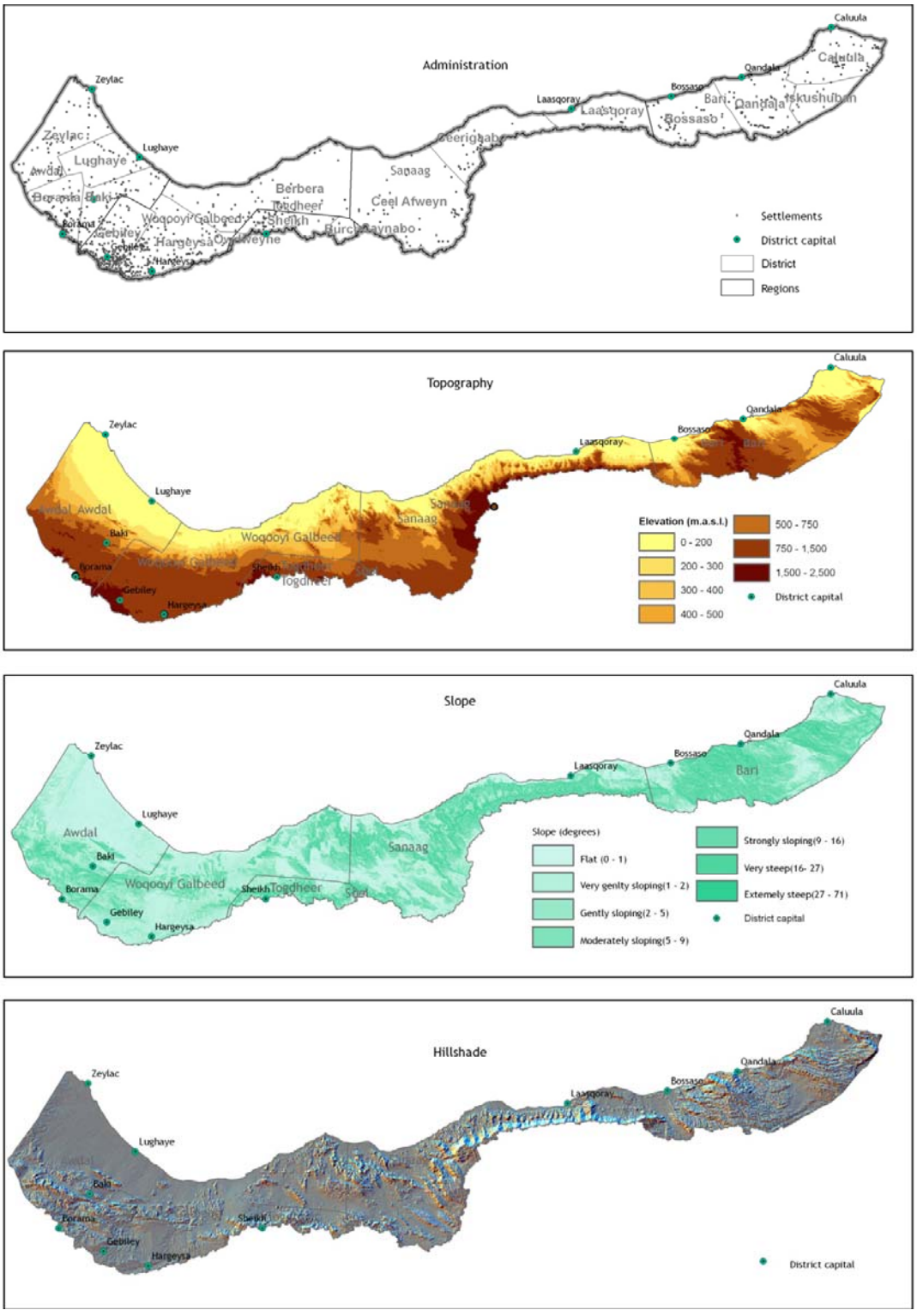


Figure 2: General description maps of Gulf of Aden drainage basin

2.2 Climate of the Gulf of Aden Drainage Basin

The climate in this basin is mostly arid and semi-arid. The coastal strip is classified as desert climate owing to its low rains. The area from Borama to Hargeisa and Sheikh are classified as humid semi arid zones (Figure 3). This area receives an average of 500 to 600 mm of rainfall annually. Rainwater harvesting through various means is common. High short duration rainfalls are found to generate "spates" of runoff often lasting for a few hours to a few days. This may however cause localized flooding and soil erosion in the steeper mountainous areas in the north-west parts of the basin. Hence, the meteorological network requirements for these areas are for rainfall (intensity and amount) and other climate data for flash flood forecasting and management, rainwater harvesting, irrigation water requirement in small patches of some mountainous areas, rain-fed agriculture in limited areas and supply or recharge of the groundwater and other water sources.

Rainfall in the drainage basin is low and erratic with a mean annual of 210 mm /year. The coastal region receives less than 100 mm (less than 20 mm in Alula, Bossaso and Berbera) of annual rainfall. The rainfall increases inland where up to more than 500 mm annual rainfall is received e.g. Borama (543 mm) and in Sheikh (515 mm). The basin, just like the rest of Somalia has a bimodal rainfall distribution, with two rainy seasons (*Gu* and *Deyr*).The first main rainy season (*Gu*) occurs in the period between April and June and the second rainy season (*Deyr*) from September to November. There are two distinctive seasons of dry periods: *Jilaal* and *Hagga* which occur in December - March and July - August, respectively. The *Gu* season dominates over the *Deyr* in quantity and reliability of rainfall and as such it is treated as the primary cropping season (Figures 3). The *Gu* rains start to reduce in June in most parts of the basin save for the mountainous areas around Borama which continues to receive a little but significant rains for rain fed agriculture in the months of July and August.

Potential Evapotranspiration (PET) ranges from about 2700 to 3000 mm per annum in the north-east coastal regions (Alula and Berbera) whereas it is only 1460 to 1630 mm per annum inland. The rate of evaporation is generally higher than rainfall throughout the year (figure 3). Mean temperature is high in the range of about 25 ^{o}C to more than 35 ^{o}C in the northern coastal regions (e.g. Berbera and Bosasso) while it is cooler in the north-western mountain region (e.g. Hargeisa) where it varies from about 15^{o}C to about 23^{o}C.

The relative humidity (RH) is higher in the coastal regions than in the inland areas. In the case of the Gulf of Aden basin which has wide topographical variations, RH in the northern coastal region (Alula and Berbera) is higher (70 - 75 %) than in the inland- mountainous.

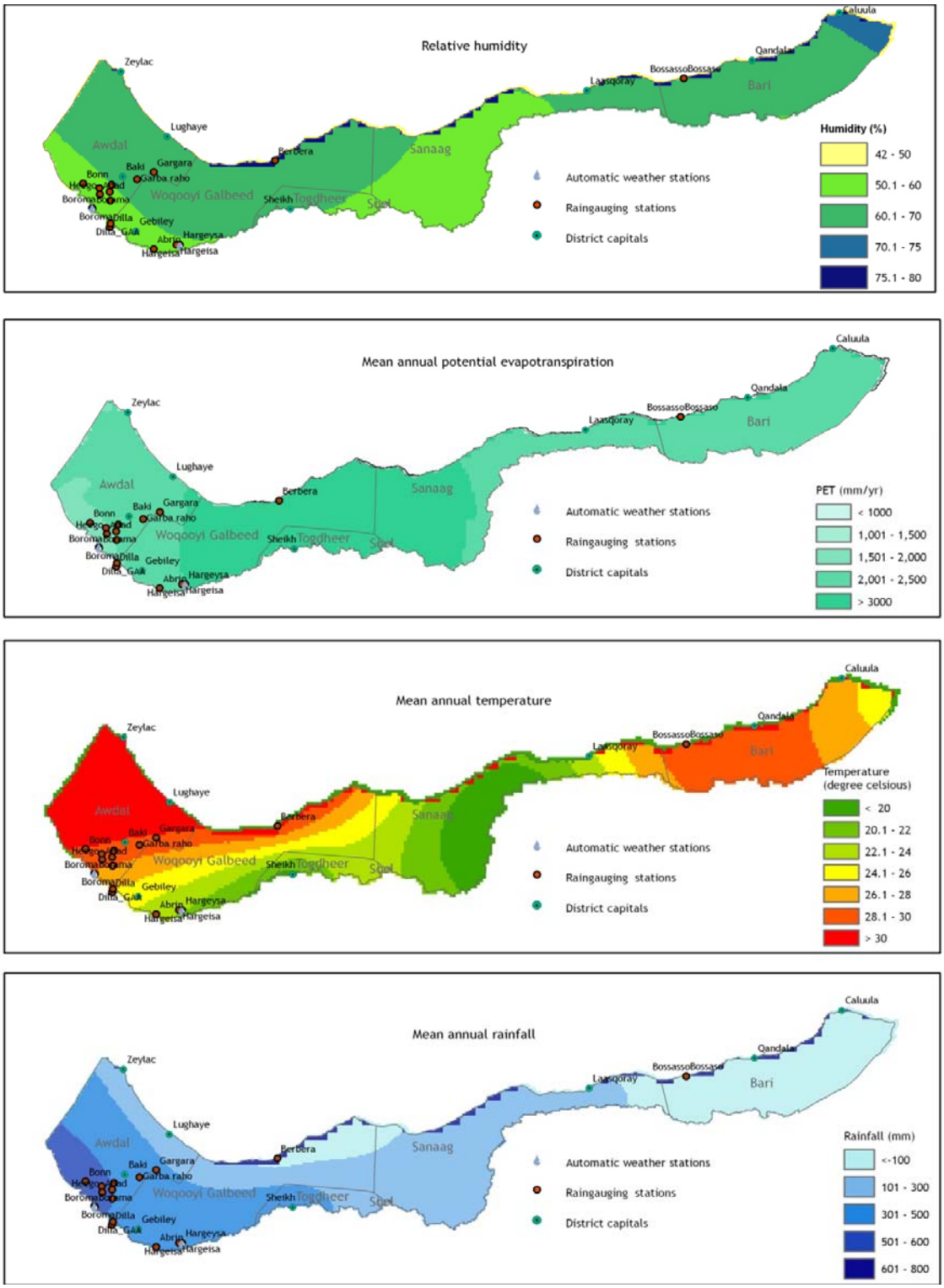


Figure 3: Mean annual weather pattern maps for Gulf of Aden

In the mountainous areas (e.g. Hargeisa) the wind speed is quite high, ranging from around 7 m/s to a peak wind speed of about 11 m/s in July and August. The northern coastal areas (e.g. Berbera and Bosasso) have wind speeds varying from around 4 m/s to a high of around 8 m/s in July and August. Like the rest of Somalia, the basin is highly vulnerable to weather related natural disasters with both flash floods and drought affecting the watershed. SWALIM together with line ministries in the respective areas are responsible for effective and timely collection, analysis and dissemination of weather information in Somalia. The weather data collected is very vital in producing weather forecasts and early warning. The weather monitoring network in Somalia was largely reduced by the break of civil war. However, SWALIM and partners have come on the frontline in efforts to revive the crucial weather monitoring network all over Somalia.

Table 1 summarises the monthly and annual average conditions for the Gulf of Aden Basin.

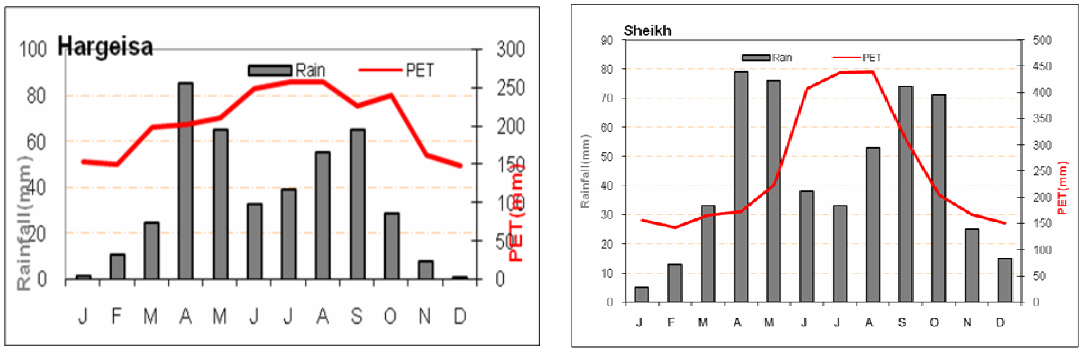


Figure 4: Monthly rainfall and PET for selected stations in Gulf of Aden Basin

Table 1: Mean Monthly Climate Statistics in Gulf of Drainage Basin

Weather Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean Annual
Rainfall (mm)	4	7	15	39	25	12	21	33	30	10	11	4	211
PET (mm)	164	140	176	176	209	274	282	284	238	179	146	141	**201**
Wind speed (m/s)	6	5	6	5	5	8	9	9	6	5	5	5	**6**
Mean Temperature (^{0}C)	23	23	25	27	28	31	31	30	29	26	24	23	**27**
Minimum Temperature (^{0}C)	17	18	20	22	23	26	26	26	25	21	18	17	**22**
Maximum Temperature (^{0}C)	31	29	30	32	34	38	37	37	36	31	29	28	**33**

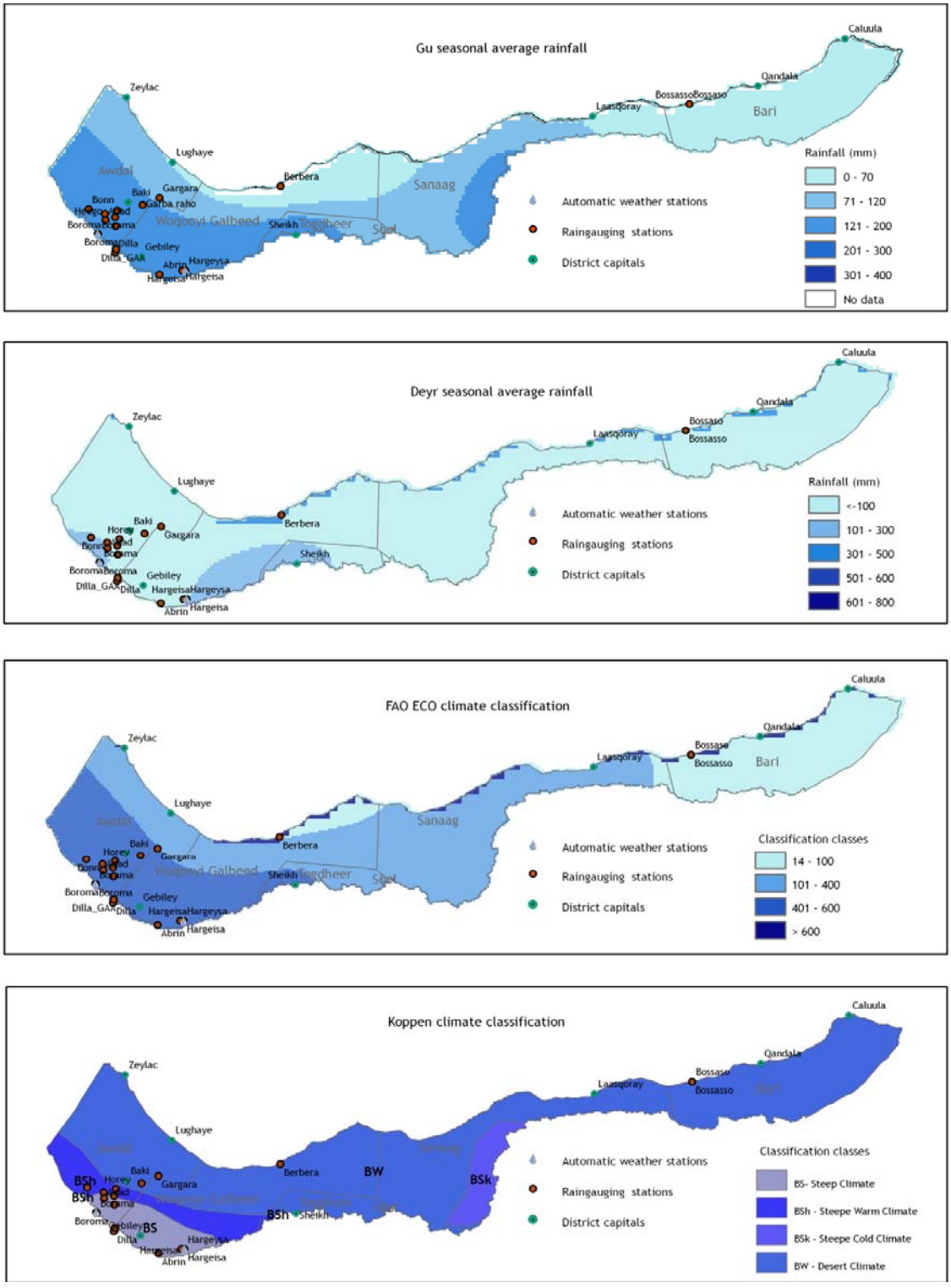


Figure 5: Climate maps for Gulf of Aden Basin

2.3 Surface Water Resources of the Gulf of Aden Drainage Basin

The hydrology of the northern parts of the country has been briefly documented by Hunt (1951), Macfadyen (1950) and Humphreys (1960). The most recent one was done in 1980 by SOGREAH and Halcrow. No much attention has been paid to such studies in the recent past despite the need to do so. A watershed delineation by SWALIM from 90m DEM shows that there are numerous short toggas dissecting the escarpment facing the Gulf of Aden. Larger toggas are located in the western parts of the basin and drain the mountain areas of Borama, Hargeisa and from Sheikh to Erigavo all discharging their water to the coastal plain of the Gulf of Aden. No perennial river of any importance exists in the basin. Much of the surface water of the Gulf of Aden basin is ephemeral and commonly appearing as seasonal ponds (balleh). Streams that flow permanently generally lie on the impervious rock of the highlands, coastal area. Streams also occur in toggas as spates which transport large amount of sediments. The wadis and toggas, the seasonal streams, where drainage networks are developed, have surface runoff only after heavy rainfall. After intense rainfall, these small streams can carry high floods and debris. The surface runoff lasts from a few hours to a few days.

No long term surface water monitoring has been done in any of these wadis and toggas. Some surface water observations were made in the small streams originating from the plateau in the western region of the Gulf of Aden basin by Sogreah in 1980 and 1981. Sogreah monitored 12 hydrometric stations, four with water level recorders and eight with staff gauge only in four main catchments in the Gulf of Aden drainage basin. In addition, nine stations were also installed in small catchments with drainage areas between 6 and 172 km^2. Sogreah (1981) also concluded that, on average, for unit drainage areas of 100 km^2 on the plateau, the runoff threshold is 24 mm and the corresponding runoff coefficient is 0.65. In the case of small catchment areas (2-3 km^2) used for rainwater harvesting, the threshold rainfall value for runoff generation was estimated at 15-20 mm.

Wars and berkads (also called bailey or water pan, ponds, dams) used for rain water (catchment) harvesting are common in Northern Somalia. The 2008 point water sources survey in northern Somalia identified 492 point water sources within the Gulf of Aden drainage basin. The study by SWALIM targeted strategic point water sources including boreholes, dugwells, springs and big dams. Most point water sources are located around the settlements and along the toggas (figure 5). The point water sources in the basin are used for both human and livestock and sometimes for irrigated agriculture. Water quality of the point water sources varies from place to place; the coastal water sources have less quality compared to the ones inland. For instance, during the SWALIM survey (2008) it was found that some wells along the coast had temperatures of about 40 ^oC and electro conductivity of about 8000 µS/cm. The pH was also beyond World Health Organisation (WHO) acceptable levels making such water unsuitable for human, livestock and agricultural purposes. Due to lack of other better available sources the community still use the wells in their poor quality.

Of the 492 water points identified 58% are dug wells (figure 6). This is the majority water point type in the basin. Dugwells are always preferred to boreholes because they are cheaper, easy to maintain and the water level is less deep. The dugwells in the catchment have a depth

of up to 30 m and are multipurpose owing to their relative good quality.

Springs are also common and comprises of 24 %. The springs are located all over the basin. These are permanent natural point water sources. In some cases the local community protect the springs by building a cover over the well and trapping the water through a pipe. This is recommended to prevent the water from contamination.

12% of them are boreholes. This is a smaller percentage even though the water quality from boreholes is always preferable over that of other well types. Boreholes are expensive to drill and maintain. Most boreholes depths range from 26 t 50 m while there are few that more than 100 m deep.

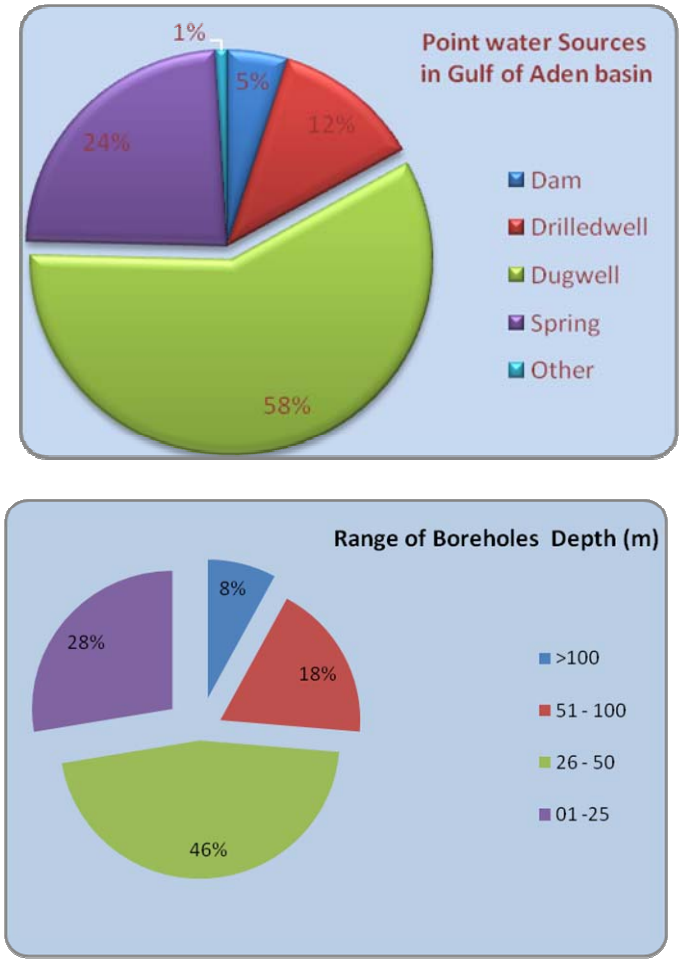


Figure 6: Point water sources representation in Gulf of Aden Basin

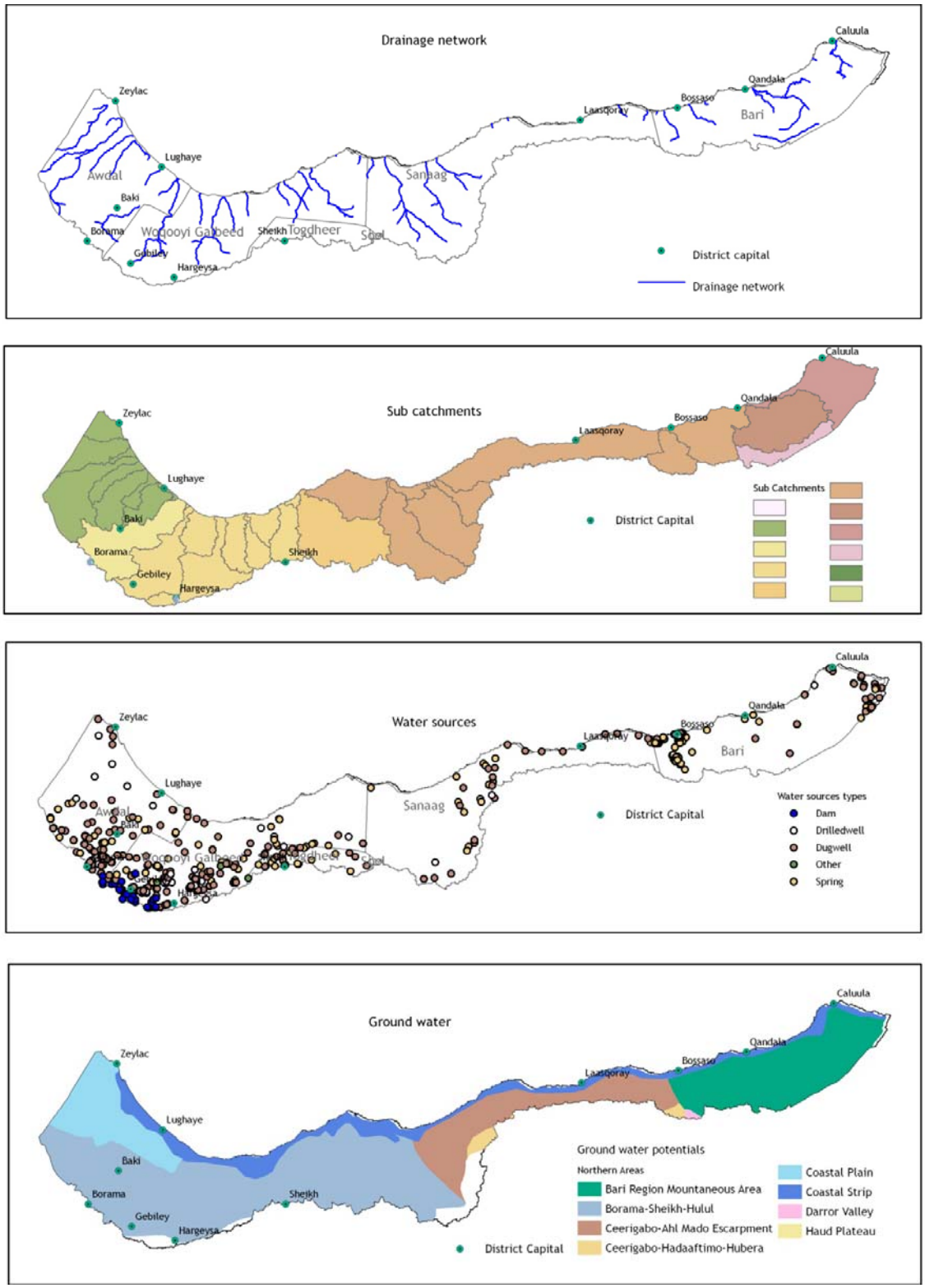


Figure 7: Water resources maps for Gulf of Aden Basin

2.4 Land Resources of the Gulf of Aden Drainage Basin

The Gulf of Aden drainage basin is mainly made up of sedimentary rocks comprising of limestone, sandstone and evaporatic rocks. Small patches of metamorphic and igneous rocks of the Precambrian and Palaeozoic age exists in the western parts of the basin. The basic structures in this basin are due to normal faulting (Macfadyen 1933) which dates back from the upper Eocene to Oligocene. Faulting of the Gulf of Aden was responsible for the uplift of the plateau found in northern Somalia which comprises of the Golis mountains that are incised by numerous togga. The coastal plain o the Gulf of Aden is about 1km in the east and 60 km wide in the west and is covered by a mantle of stony and sandy alluvium and raised beach deposits. The land surface is of quaternary age with most of the shoreline consisting of raised beaches except for the wide western side which is a basin of subsidence. About 65km west of Berbera there are extensive high dunes (8km wide) of loose sand that are the most desert like in the Gulf of Aden basin. These sands are derived from cretaceous sandstone, which are locally up to 1700 m thick (Abate et al 1993). 92 % of the underlying rock is classified as undifferentiated unconsolidated sediments

There are no recent studies of the soils. Historical studies indicate that the soils of the Gulf of Aden basin are dominantly loam and clayey loams that lie on undifferentiated unconsolidated sediments. All soils are strongly reflective of an arid to semi arid climate and the rocks upon which they have been formed, but vary within texture and composition with landform and the length of time that the surface has been exposed to biogeochemical weathering.

In the agricultural areas ranging from Baki, Gebilley, Hargeisa, down to Sheikh and Erigavo, the soils are mostly loam to clay roam and widely used for crop production. The north most region of Awdal is fully covered by sandy soils that are not suitable for crop production. The soil map of the Gulf of Aden identifies eight classes of soil; Aeronosols, calcisols, cambisols, fluvisols, leptosols, rogosols, solonchaks and vertisols.

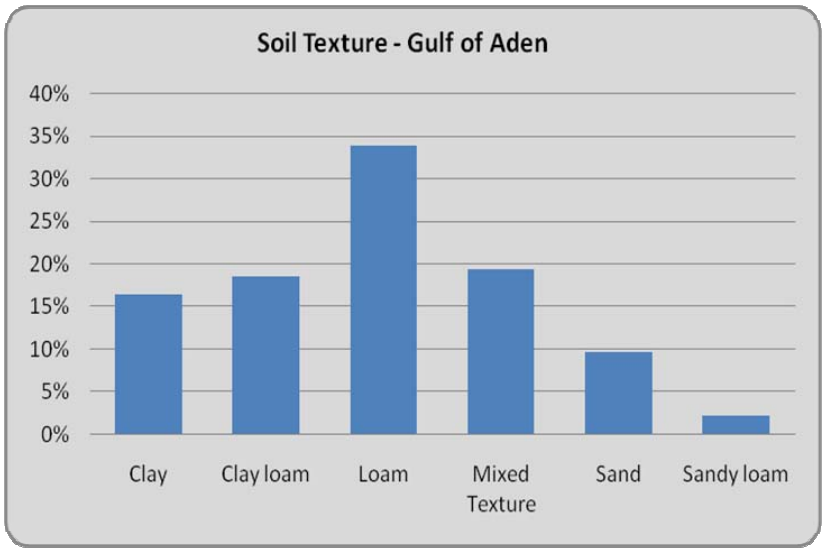


Figure 8: Soil type percentages in the Gulf of Aden Basin

Based on the agro-ecological zones for Somalia that have been defined and mapped by SWALIM, the land in the Gulf of Aden basin is categorized as not suitable for irrigated agriculture. However, some patches of areas along the toggas in the mountainous regions in North Somalia are suited for irrigated agriculture (e.g. Durdur and Gebiley watersheds within the Gulf of Aden drainage basin). Some areas in the plateau areas in the west parts of the basin (around Hargeisa) are marginally suitable for rain-fed cultivation. However, these areas are mostly moderately or marginally suitable for extensive grazing and forestry plantation. SWALIM Technical Report No. L-12 (2007) more details of the agro-ecological zones for Somalia.

SWALIM has undertaken a land suitability assessment in two main areas of interest, one in the north in the Dur Dur and Gebiley watersheds in the Gulf of Aden drainage basin in Somaliland (Technical Report L-09, 2007) and another in the riverine areas of the Juba and Shabelle rivers (Technical Report L-09, 2007). These were based on various land resources surveys carried out by SWALIM. The results of these surveys are documented in SWALIM Technical Reports Nos. L-02 (Landform), L-03 (Land cover), L-07 (Land use), and L-08 (Soils), respectively.

From SWALIM land suitability studies with the basin, it is seen that only the plateau area with relatively high rainfall is (moderately) suitable for rain fed crops. This area has two short growing periods (Gu and Deyr, respectively), separated by a short dry period (Hagaa). Farmers can follow two strategies: either grow a crop with a very short growing period in the Gu and/or Deyr period, or plant a drought resistant crop with a long growth cycle which can make use of both Gu and Deyr. Presently farmers in the area follow the latter strategy and grow a sorghum variety with a growing period of 180 days. However, an improved early maturing variety is likely to give a better yield then the traditional late maturing variety. Also, any early maturing crop gives the farmer the opportunity to plant a second sequential or relay crop on the same land within a year (SWALIM Technical Report No. L-06, 2007).
The Length of Growing Period (LGP) is the period (in days) that moisture supply exceeds half potential evapotranspiration2 ($P > 0.5PET$). The LGP is calculated over a whole year and may consist of one or more "normal" or "intermediate" Growing Periods (GP), whereby a normal GP is a period in which P exceeds full PET ($P>PET$) and an intermediate GP a period in which P exceeds half PET, but is less than PET ($0.5PET<P<PET$).
Figure 10 shows maps land resources in the Gulf of Aden Basin.

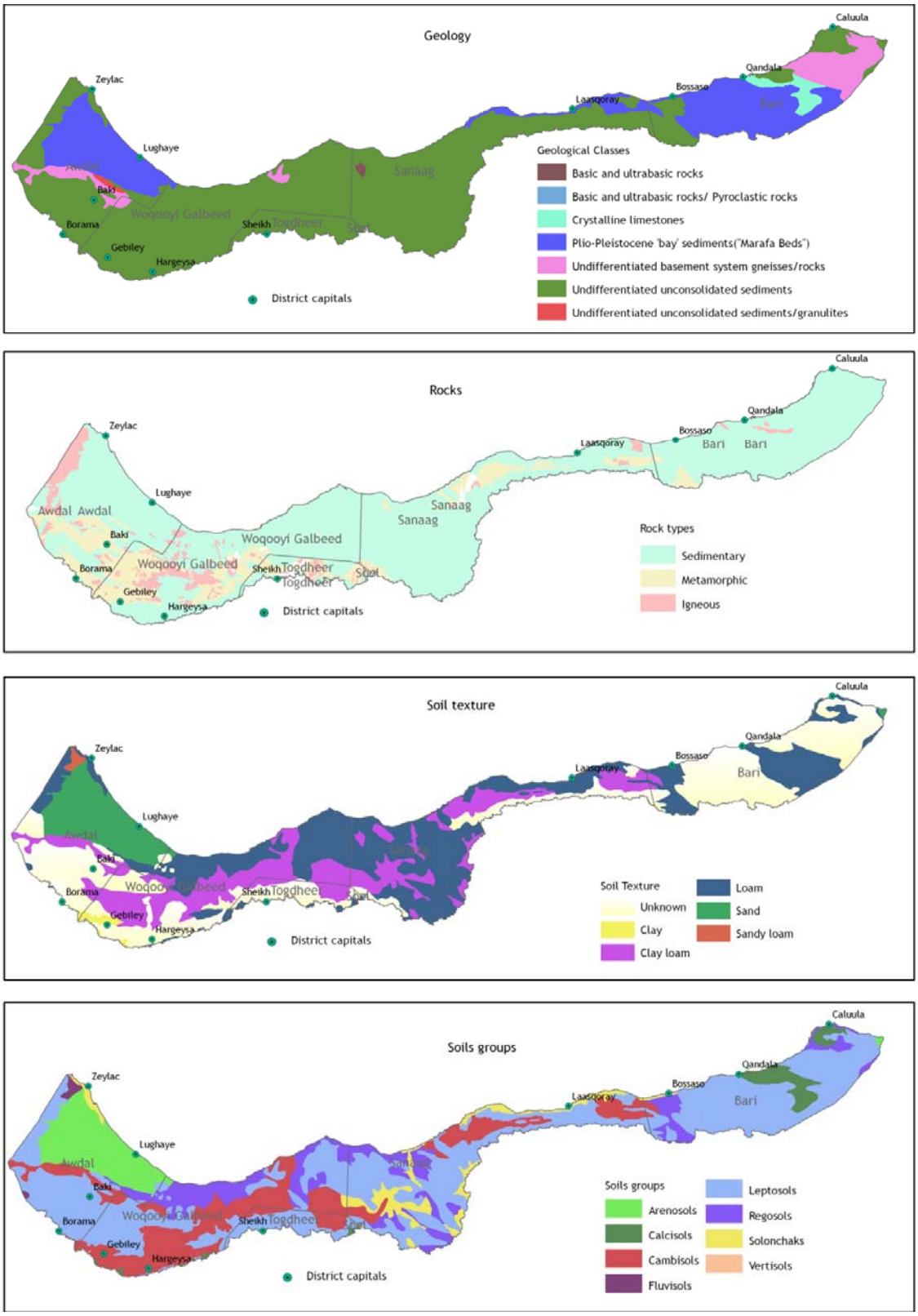


Figure 9: Geology and soil maps of the Gulf of Aden Basin

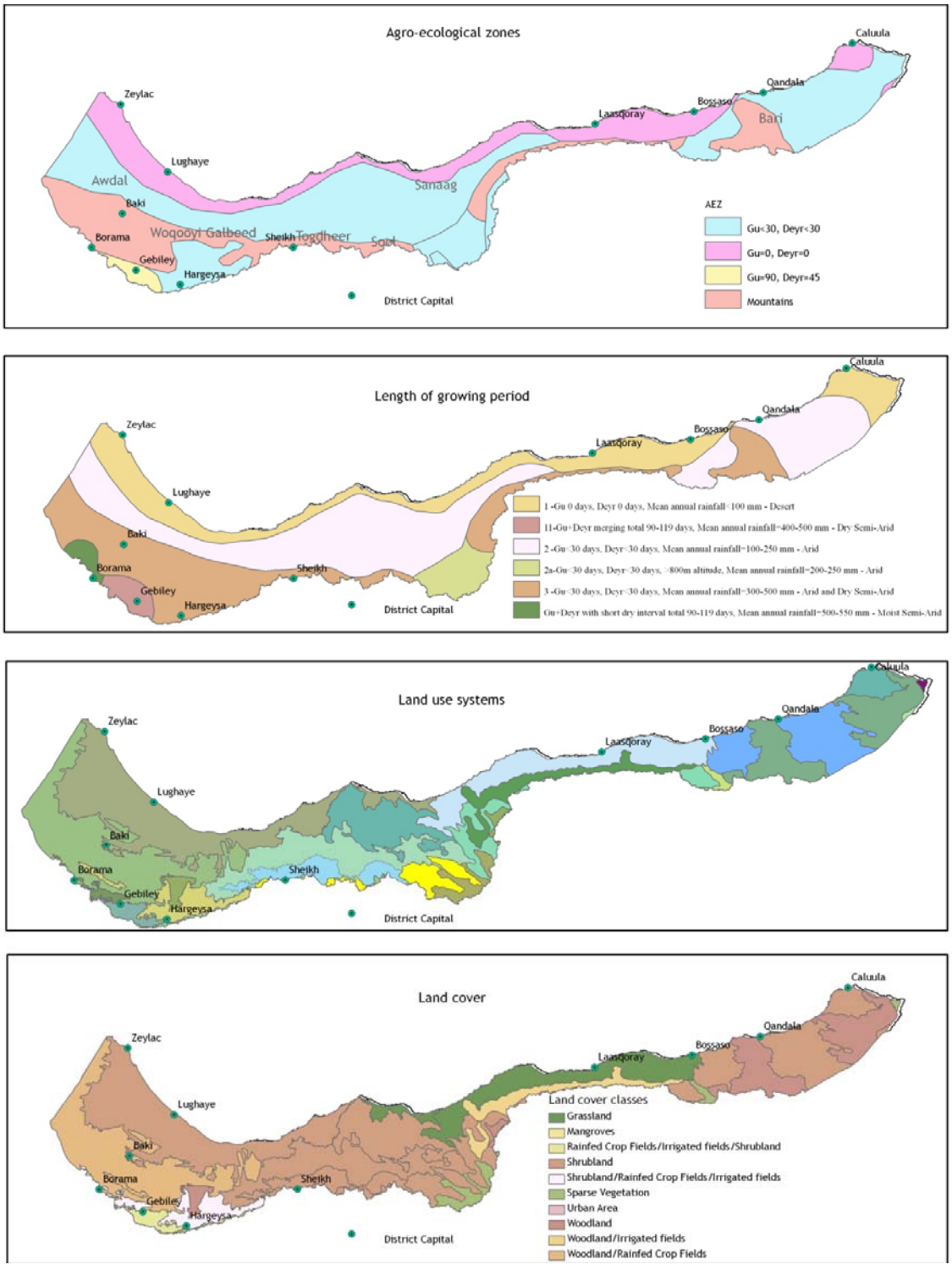


Figure 10: Land resources map for the Gulf of Aden Basin

3.0 DARROR DRAINAGE BASIN

3.1 General Description of Darror Drainage Basin

The Darror basin covers an area of 34,195 km^2. To its north is the eastern part of the Gulf of Aden basin and to its south is the featureless plateaus separating it from the Tug Der/Nugal basin. The basin lies within central parts of Bari administrative region and another small portion falling in the eastern parts of Sanag region. It is the smallest watershed in northern Somalia. There is only one major town in this basin which is Iskushban. Population in this basin is sparse and the community is mostly nomadic, this is due to the harsh climate of the area and poor land cover that may not sustain livelihoods round the year.

The Darror Valley located south of the Meskat and Madow mountains and north of the Kar Kar mountains extends from west to east over a length of about 350 km with an area of over 25,000 km^2 and average elevation of up to 300 m a.s.l. There are a number of small stream networks north of the Darror Valley that flow from west to east towards the Indian Ocean, however, this catchment does not contribute to flows in the main water course of the Darror Valley. The land here slopes towards the sea and therefore does not hold substantial amounts of water. For convenience of proximity of geography and climate, it has been grouped together while classifying the major drainage basin as the Darror basin.

The mountains (Madow, Muskat and Kar Kar) range from 1500 m a.s.l. to about 2500 m a.s.l. the rocky nature of this area also makes it impossible for most livelihood activities. Oasis farming is very common in this area within the Darror valley. The foot of the mountains are source of income through cultivation of frankincense trees for export.
Figure 11 shows the basic general information of the basin including distribution of settlements and topography.

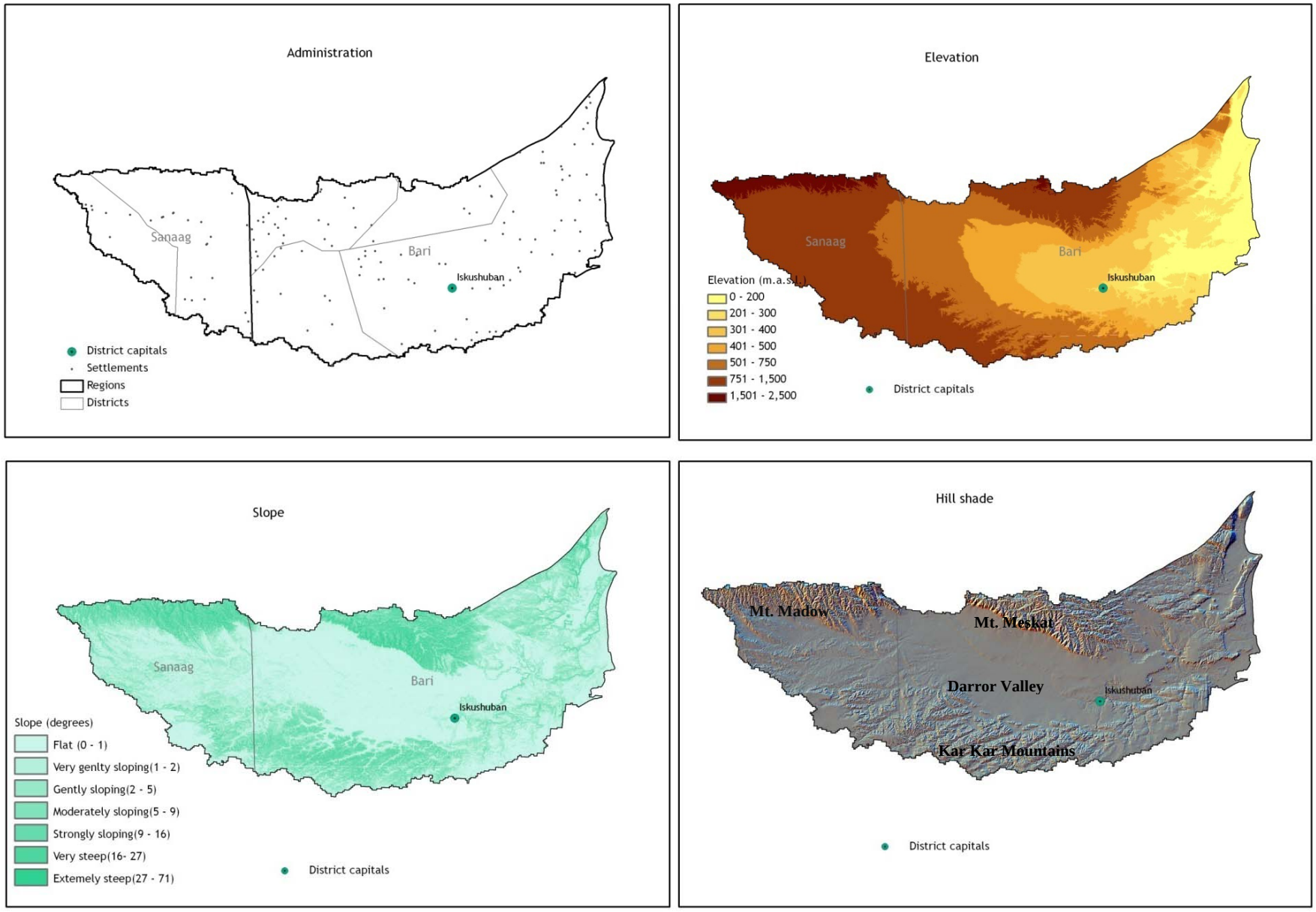


Figure 11: General description maps of Darror drainage basin

3.2 Climate of Darror Drainage Basin

Within the Darror drainage basin, climate is mostly desert with less than 100 mm of rainfall per annum with very high temperatures and high evaporation rates. It is one of the driest regions in Somalia. However, on rare occasions, high and short duration rainfalls are found to generate "spates" of runoff. These sometimes though may cause localized flooding and soil erosion in the steeper mountainous areas in the northern and southern parts of the basin. The main rainy season (Gu) is in April and May while Deyr season occurs in September to November. These seasons however do not produce any significant rain fall. The long term mean monthly rainfall in April and May do not exceed 50 mm of rainfall.

Temperatures here are very high throughout the year, June through to September are the hottest months of the year in this region ranging between 30 to 33 ^{0}C of mean daily temperature. December and January are the coolest months of the year; 20 to 23 ^{0}C of mean daily temperatures.

Evaporation rates are very high in this basin and are always higher than the rainfall throughout the year except in April and May during the rainy season. The average potential evapotranspiration (PET) in the catchment is estimated to be 2700 mm per annum with maximum evaporation rates taking place in the months of June to September.

Wind speed are also high and are in the range of about 5 m/s to more than 7 m/s in the eastern coastal regions while the wind is calm in the north-western mountain region (e.g. Baran) where it varies from about 2 m/s to 3 m/s. June through out to September experience the highest rates of wind speed while April has a mean speed of 3 m/s.

The relative humidity (RH) is higher in the mountainous areas than in the central regions within the Darror valley.

Climate maps of the drainage basin are as shown on figures 12 and 13 while table 2 and figure 14 displays the long term mean monthly weather observation within the catchment.

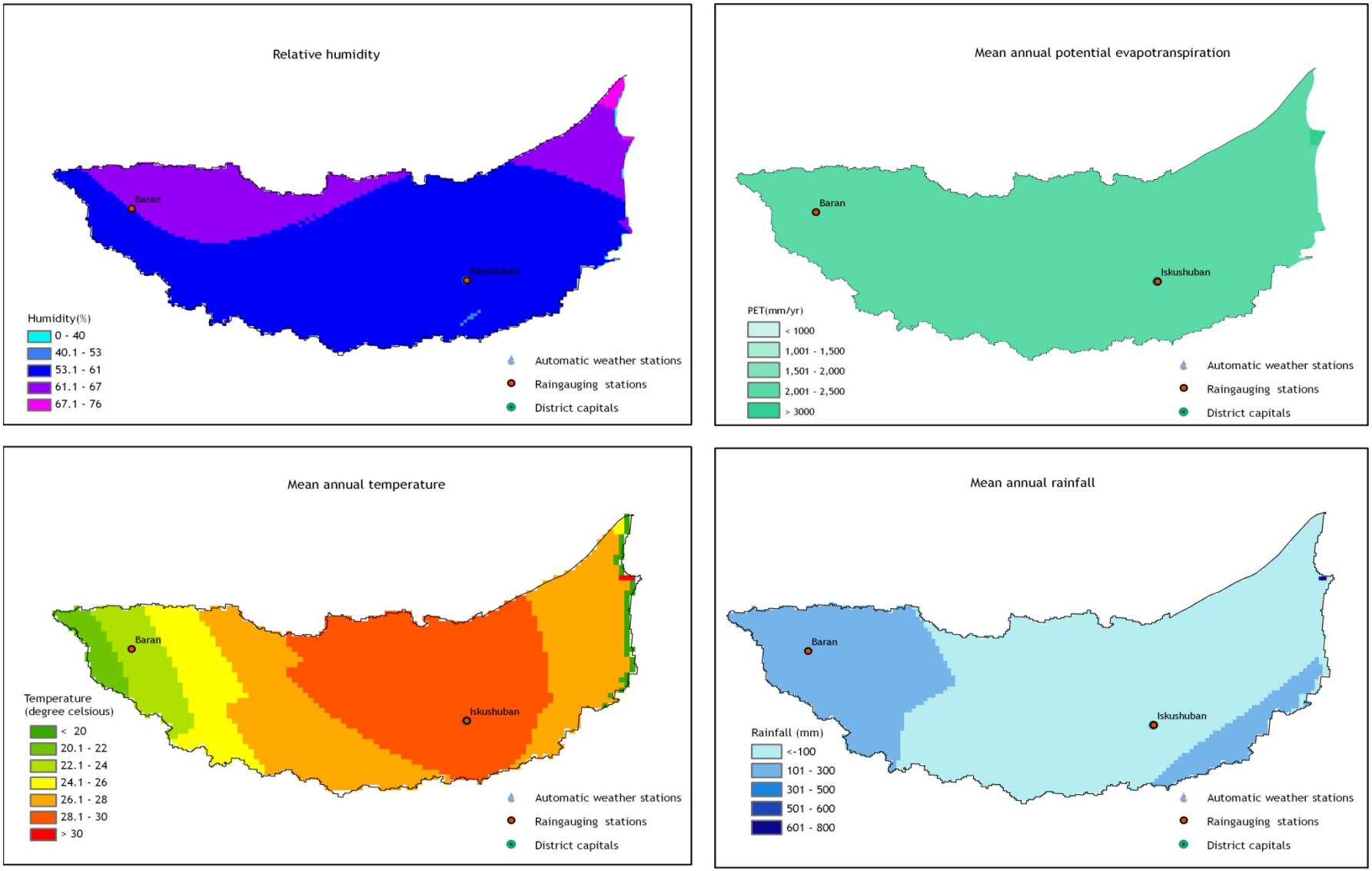


Figure 12: Mean annual weather pattern maps for Darror Basin

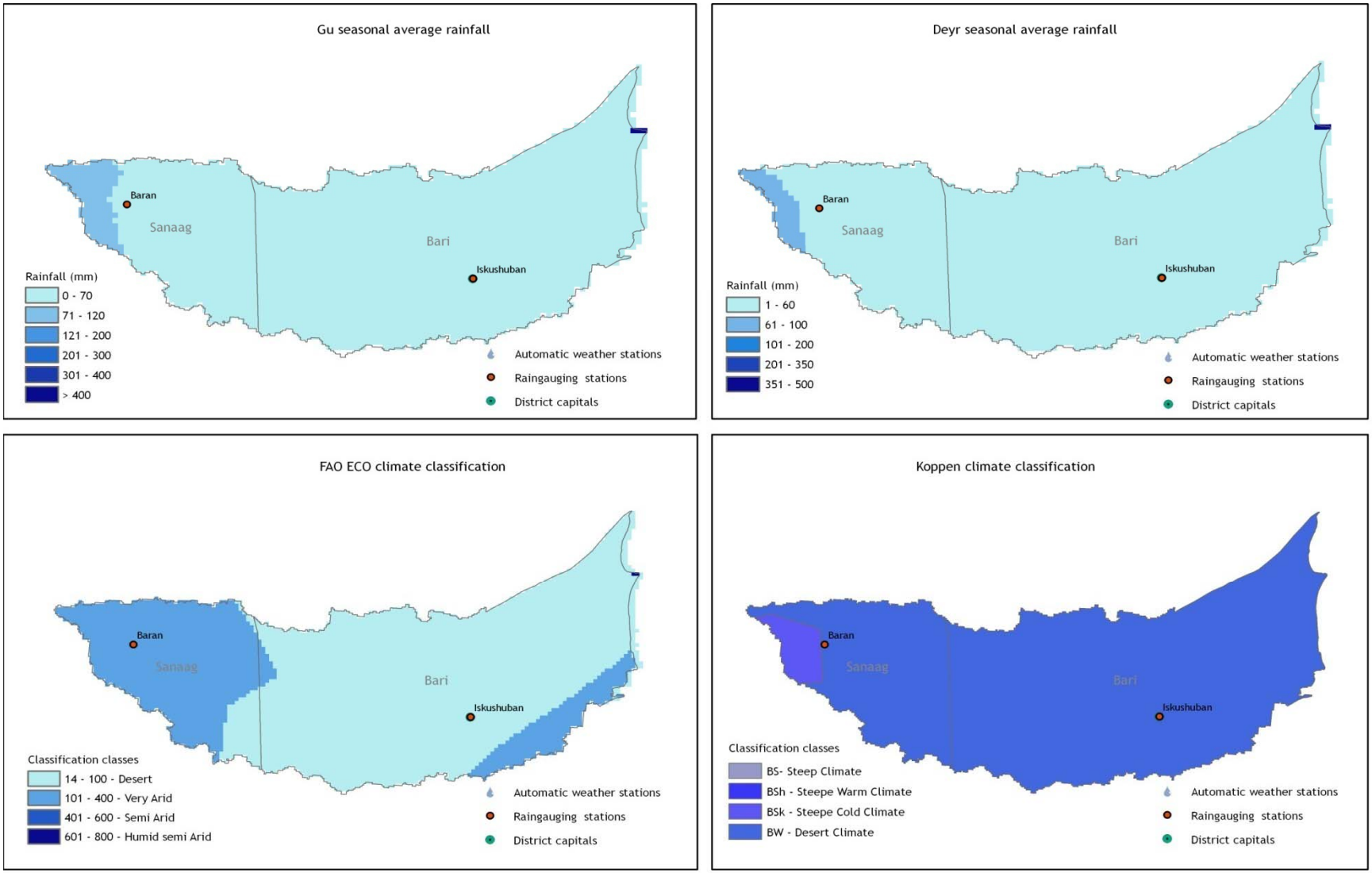
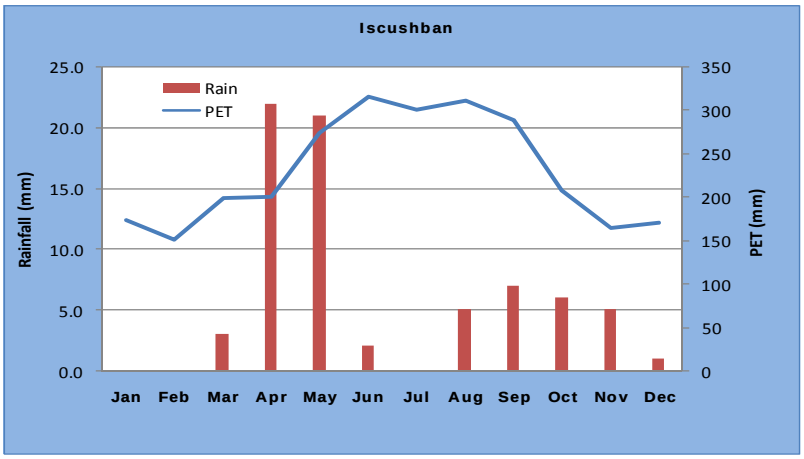


Figure 13: Climate maps for Darror Basin

Table 1: Mean Monthly Climate Statistics in Darror Drainage Basin												
Weather Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean Monthly Rainfall (mm)	0.0 0.	0 3.	0	22.0	21.0	2.0 0.	0 5.	0 7.	0 6.	0 5.	0 1.	0
Mean Monthly Vapour pressure	20.1	21.1	23.0	25.0	25.2	26.3	26.0	26.3	26.3	24.2	22.0	21.0
Monthly PET	173.6 151.	2 198.	4 201.	0 272.	8 315.	0 300.	7 310.	0 288.	0 207.	7 165.	0 170.	5
Monthly Wind speed (m/s)	5.6	4.2	3.9	3.0	4.4	7.5	7.4	7.5	6.5	3.4	3.5	4.5
Mean Daily Temperature (^{0}C)	25.9 26.	2 29.	3 31.	7 34.	9 34.	9 33.	7 34.	2 34.	4 31.	4 28.	2 27.	2
Minimum Temperature (^{0}C)	17.7	17.8	20.0	22.6	24.0	25.2	25.1	25.2	24.7	21.2	19.1	18.5
Maximum Temperature (^{0}C)	29.8 30.	1 33.	6 36.	0 40.	0 39.	5 37.	7 38.	5 39.	0 36.	2 32.	5 31.	3



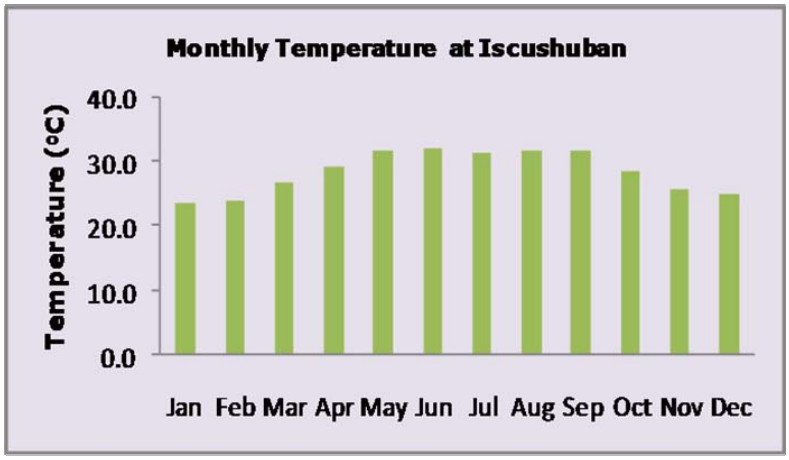


Figure 14: Mean monthly weather observations at Iscushban

3.3 Surface Water Resources of Darror Drainage Basin

Darror drainage basin is drained by a fairly dense network of seasonal streams. Much of the surface water of the Darror basin is ephemeral and commonly appearing as seasonal ponds (balleh). Streams that flow permanently generally lie on the impervious rock of the highlands, coastal area. Streams also occur in tugga as spates which transport large amount of sediments. The wadis and toggas, the seasonal streams, where drainage networks are developed, have surface runoff only after heavy rainfall at other times, the surface runoff is negligible. Infiltration is very rare due to the nature of the basin that slopes towards the sea. After intense rainfall, these small streams can carry high floods and debris. No hydrometric work has ever been carried out for this basin even during the pre war era. Probably this is due to the insignificant amount of water that flows in the seasonal river of which this occurs in times of heavy storms which are also very rare.

A Comprehensive point water sources survey carried out by SWALIM in 2008 indicates that there are about 82 strategic water points within the basin. Of these identified sources, 52% are dugwells while boreholes and springs take 21% and 27% respectively. There could be other water types of water points in the basin e.g. dams and berkads which were not covered during the survey due to their semi permanent nature tending to dry up most of the time.

Shallow dug wells are common sub-surface water sources in the area. Many of them however run dry during prolonged droughts. They are also known to have high organic contamination due to poor construction and common outlets for both livestock and humans. Shallow wells are dug along the various toggas of the mountainous regions of the drainage basins in Northern Somalia. Shallow wells are also common in the northern coastal areas but the quality of water does not meet the WHO standards for most purposes. In the plateau areas, the water tables are found to be lower and hence there are less of shallow dug wells found in these areas.

Spring water generally flows in stream channels and infiltrates rapidly in boulders and gravel after short durations. This water is of relatively good quality. There are a number of thermal springs that flows from the base of the mountain areas and faulted rock outcrops along the coast. The SWALIM survey identified 22 springs in the basin. The springs are also used for human and livestock water consumption.

Boreholes provide water through out the year. The SWALIM survey identified 22 drilled wells within the basin. These are the only permanent sources water in the catchment and therefore very crucial all year round as the y serve domestic, livestock and sometimes small scale irrigation.

A number of oases are found within the Darror valley, oases farming of horticulture is also a source of livelihood in the basin.

Figure 15 Shows the distribution of stream network, subbasins and point water sources in the basin.

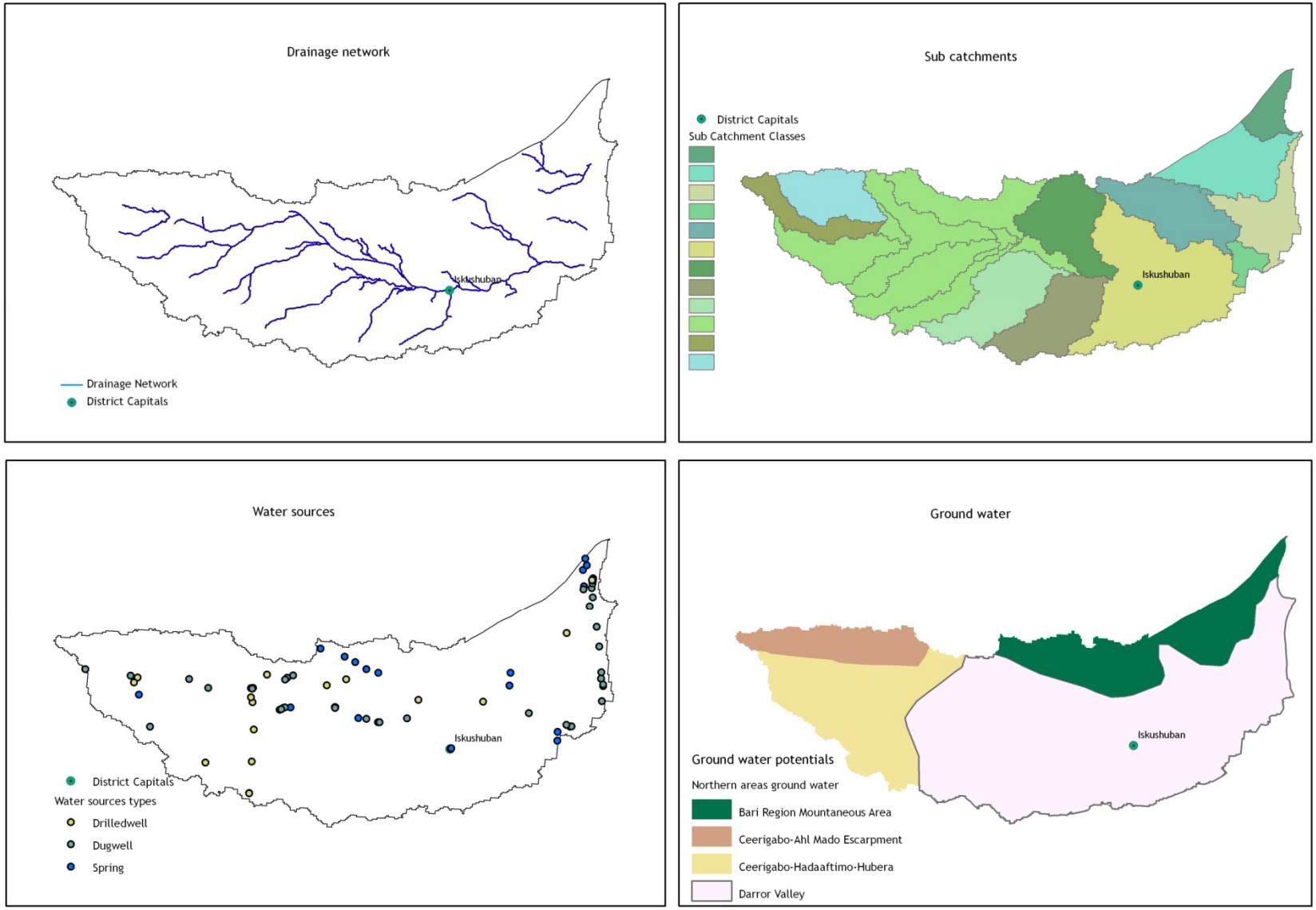


Figure 15: Water resources maps of Darror Basin

3.4 Land Resources of Darror Drainage Basin

Darror basin lies in five different types of Agro ecological zones. Most of the area lies in to the zone classified as 2ac a nd 2R. Thes e zones have a co mbination o f cambsols, lepitsols and a little o f the fluvial soils. The basin has less than 30 days of Length of Growing Period (LGP) during the two r ainy seasons. This is attributed to the fact that this is a very dry zone with rains not exceed ing 100 mm for any given season. The area east of Iskushban to th e coast is not suitable for agricu lture owing to th e poor soils and very little rains (less than 50 mm per year).

The main land use in th e basin is extensive grazing (pastoralism) and wood collection. Goats and sheep are grazed mostly on sloping areas, whereas cattle and camels are grazed on flatter areas Agro-pastoralism is also pr acticed in the mountainous areas near Erigavo with sparse irrigation of vegetables, fruits and sorghum around the toggas.

The land cover of the ba sin is co mprised mostly of natura l vegetation. Land cover classes include open Shrub lands and sp arse v egetation w ith po ckets of woodlands and ir rigated fields. More details on land cover and the vegeta tion of the area ca n be found in FAO-SWALIM Technical Report No. L-03.

The D arror V alley is located in the arid p art of northeast Som alia. Its soils are highly influenced b y the ir pare nt material, w hich consis ts mainly of evaporites, li mestone, conglomerate and alluvial de posits. The most co mmon soils in this ar ea are calcic Solonchaks, gy psic Sol onchaks, gypsic Calcis ols, hap lic Calcisols, eutric Leptos ols and calcic Ve rtisols. All soils ha ve a neutra l to w eakly alkaline pH-value and ar e v ery r ich in carbonates, often rich in gy psum, mainly saline, and their moisture content at the end of the dry season is much lower than the moisture content of th e permanent wilting point. Most of these soils have a colo ur of 7.5 YR, which beco mes redder in the subsoil. Analytical data indicate that the top soils ar e usually enriched in carbona te, whereas the sub s oils are enriched in gy psum an d/or sal t. T he soi l sali nization is m ainly due to te rtiary e vaporite formations. The composition of the soil types and texture clearly indicates that the area is not suitable for optimal land cultivation

The Darror drainage ba sin is char acterized by outcropping of the s edimentary base ment complex, which ar e made up of undifferentiated, unc onsolidated s ediments. A wide co astal dune system also occurs along th e coastal strip of the bas in. The lithology of the underly ing rocks is r elatively simple and is domi nated by calcareous formations. The sequence cons ists of thin and massive white lime stones, marls and evaporates with well developed gypsiferous layers.

Figure 16 shows land resources maps of the basin while figure 17 shows geology and soils of the drainage basin.

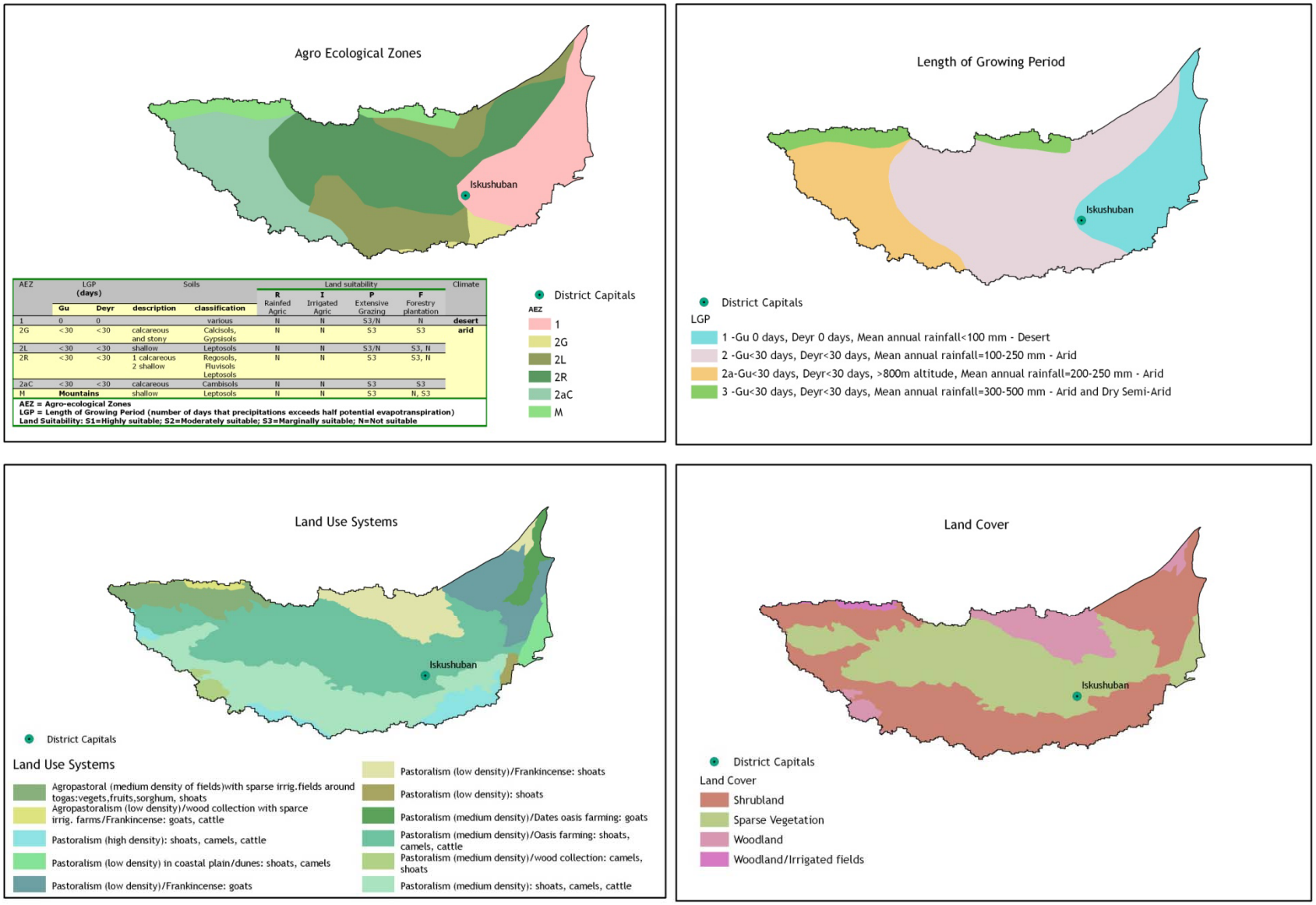


Figure 16: Land Resources Maps for the Darror Basin

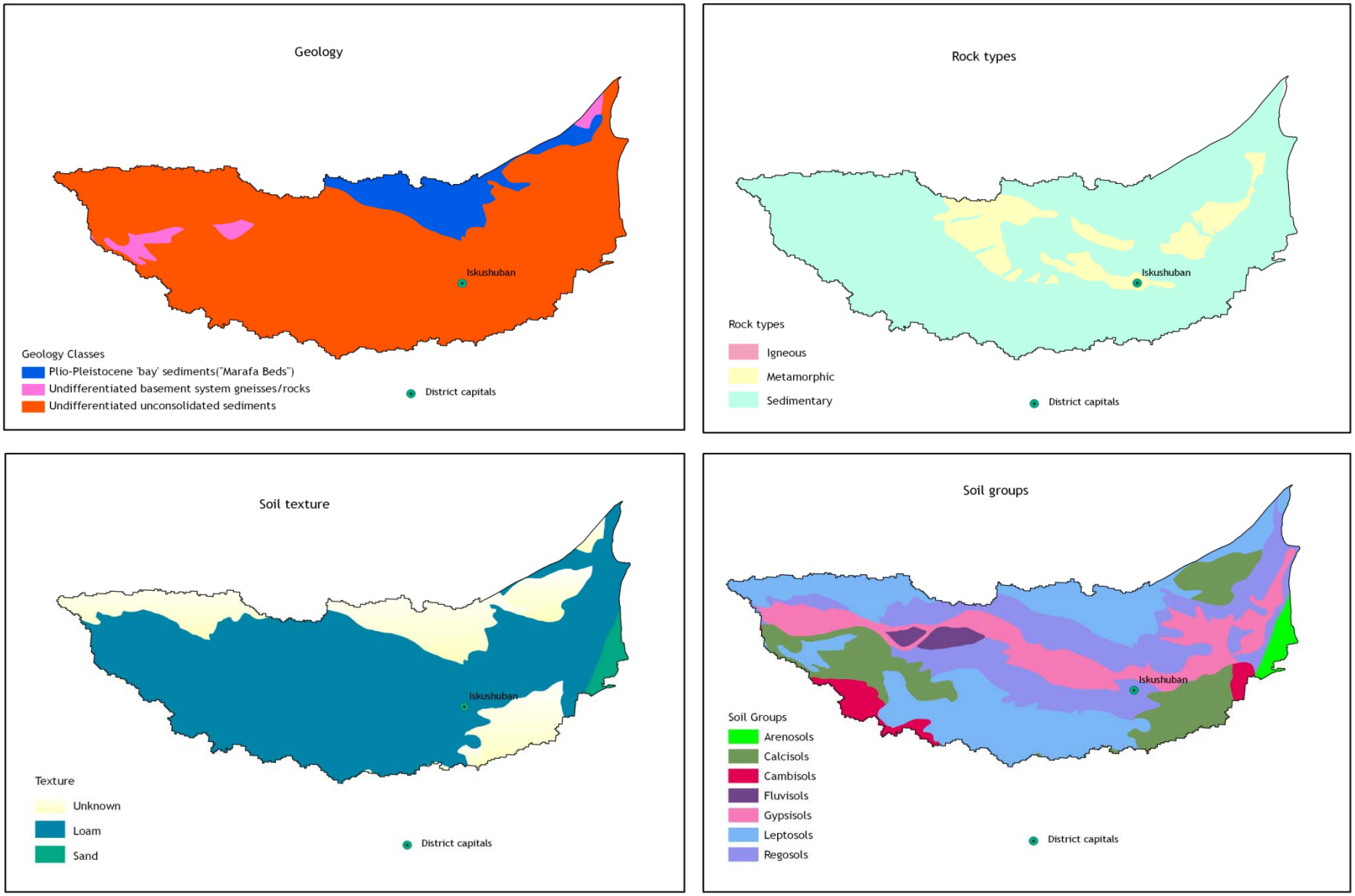


Figure 17: Geology and Soils Maps for the Darror Basin

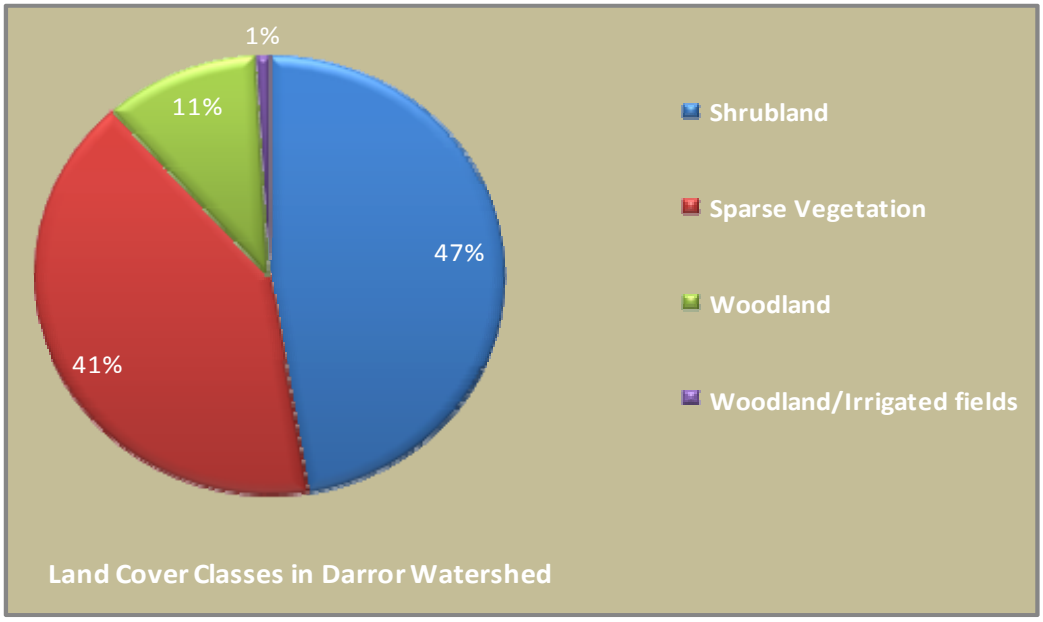


Figure 18: Representation of land cover classes in the Darror Basin

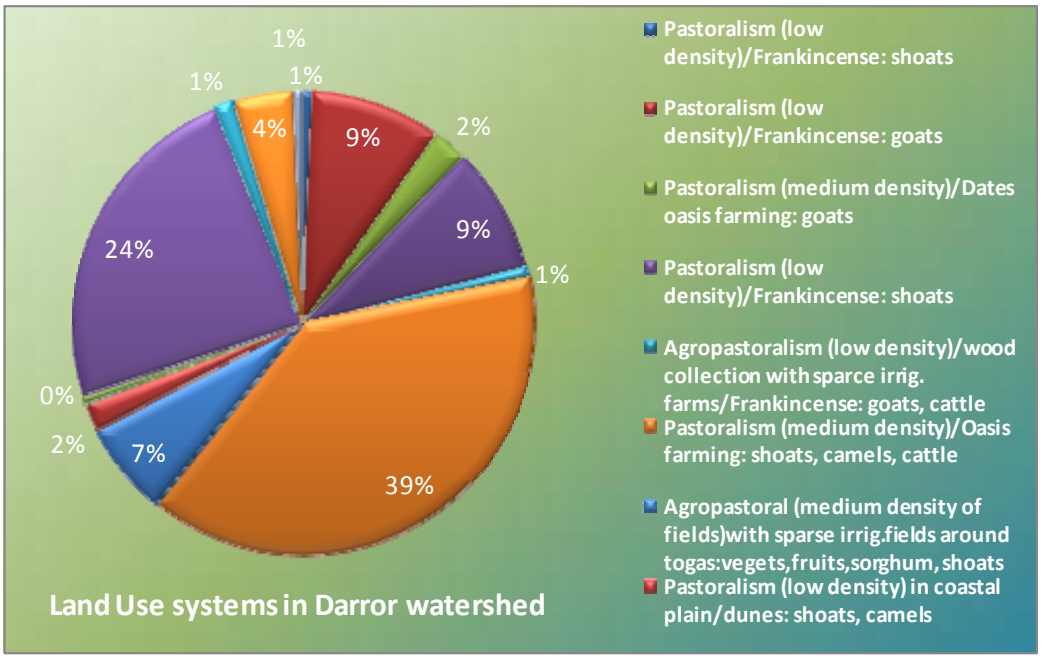


Figure 19: Representation of land use systems in the Darror Basin

4.0: TUG DER/NUGAAL DRAINAGE BASIN

4.1 General Description of Tug Der/Nugaal Drainage Basin

The Tug Der/Nugaal basin lies within five administrative regions in northern Somalia: Togdheer, Sool, Sanaag, Bari and Nugaal. The population is mainly concentrated in the town centres and along the coastline. Garowe, the headquarters of the semi autonomous Puntland state is located in this basin. Other important towns in the watershed include Las Anod, Burco, Erigavo and Qardo (Figure 20).

The Tug Nugal drains the Nugal region and parts of the Togdheer and Sool regions. The Nugal valley extends over 600 km in length with elevations varying from about sea level in the east to 1,200 m above sea level in the west. The Sool Plateau, a nearly featureless plain covered by limestone and marls, lie between the Darror and Nugal valleys. The elevations of the basin area vary from sea level in the west to over 2000 m in the mountain area of the north-east of the basin. The highest point is 2,233 m. About 24% lies below 500 m, 58% between 500-1000 m, 15% between 1000-1500 m, 3% between 1500-2000 m and a small part of the basin (<1%) is above 2000 m. A large part of the drainage basin is made up of gently sloping plains such as the Sool Plateau, Sool Haud and Qardo Plateaus, and the Karman and Gubato plains.

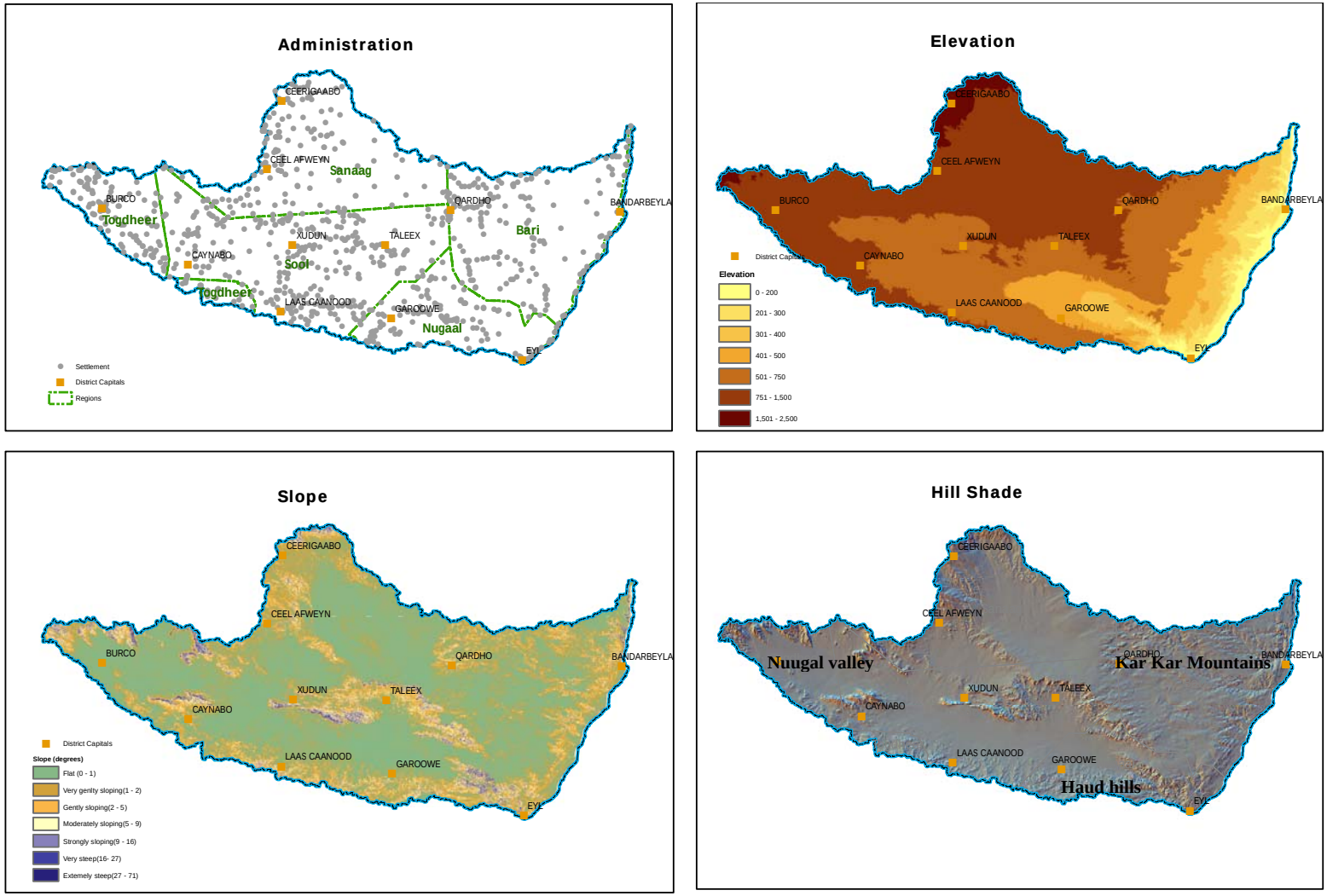


Figure 20: General description maps of Nugaal drainage basin

4.2 Climate of Tug Der/Nugal Drainage Basin

Rainfall in the Tug Der/Nugaal drainage basins is low and erratic just like the rest of the country. There are both a seasonal as well inter-annual variations in the amount of rainfall in the area. The mean annual rainfall for the basin is about 168 mm (table 3). However, some areas around Burao, and the mountainous areas of Ceeriga vo receive and average of up to 400mm per annum and is classified as humid semi arid areas. The central areas of the basin including Qardo, Laas Canood and Garoowe receive the least rains in the catchment; less than 100mm per year falling in into a very arid climate zone. Rainfall in this basin increases with increasing altitude.

About 51% and 20% of the annual rainfall occur during the *Gu* and *Deyr* seasons, respectively. The *Hagaai* season running from July to September benefits from an extension of the *Gu* rains and thus receives about 20% of the annual total rainfall. This *Hagaai* season is very important for rain fed agriculture which is common in some parts of the basin.

Potential Evapo-transpiration (PET) ranges from about 2100 mm in Burao to 2700 mm in the coastal regions. Highest monthly PET values are on different months depending on location.

The mean air temperatures are generally high in the drainage basin. Mean temperature is in the range of about 22 ^{o} C to more than 33 ^{o} C being highest from May to September in the basin. Higher differences in daily minimum and maximum temperature occur inland compared to nearer the coast.

The relative humidity here is more or less constant throughout the year and varies from a low of 40% (in Qardo) to around 70% (in Las Anod).

Wind speeds vary from a low of about 3 m/s to a high of about 7.5 m/s. Wind speeds are higher during June to August.

Table 2: Mean monthly climate statistics in Nugal drainage basin

Weather Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Rainfall (mm)	0	0	3	22	21	2	0	5	7	6	5	1
Monthly PET (mm)	174	151	198	201	273	315	301	310	288	208	165	171
Monthly Wind speed (m/s)	6	4	4	3	4	8	7	8	7	3	4	5
Mean Daily Temperature (^{0}C)	26	26	29	32	35	35	34	34	34	31	28	27
Minimum Temperature (^{0}C)	18	18	20	23	24	25	25	25	25	21	19	19
Maximum Temperature (^{0}C)	30	30	34	36	40	40	38	39	39	36	33	31

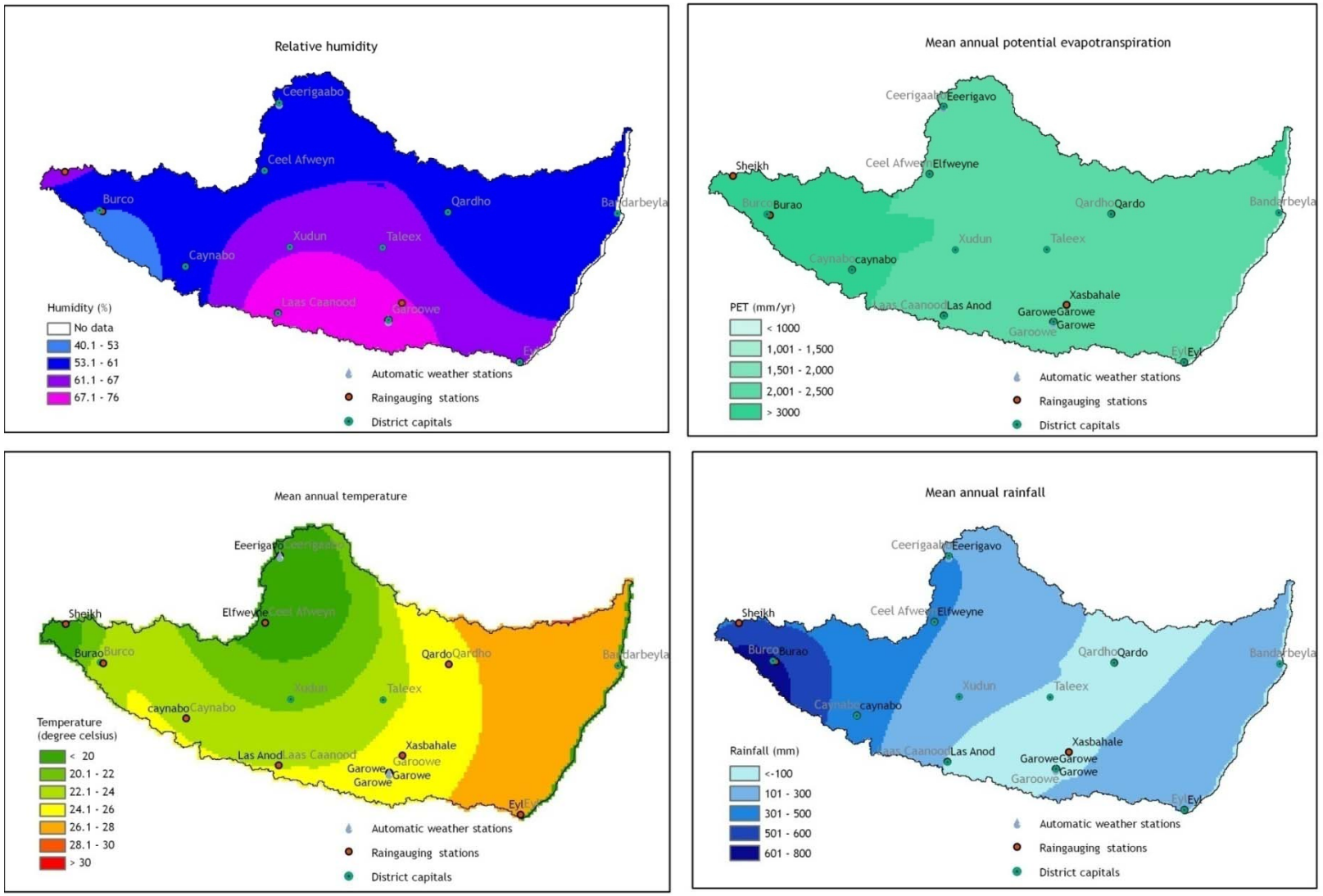


Figure 21: Mean annual weather pattern maps for Nugaal basin

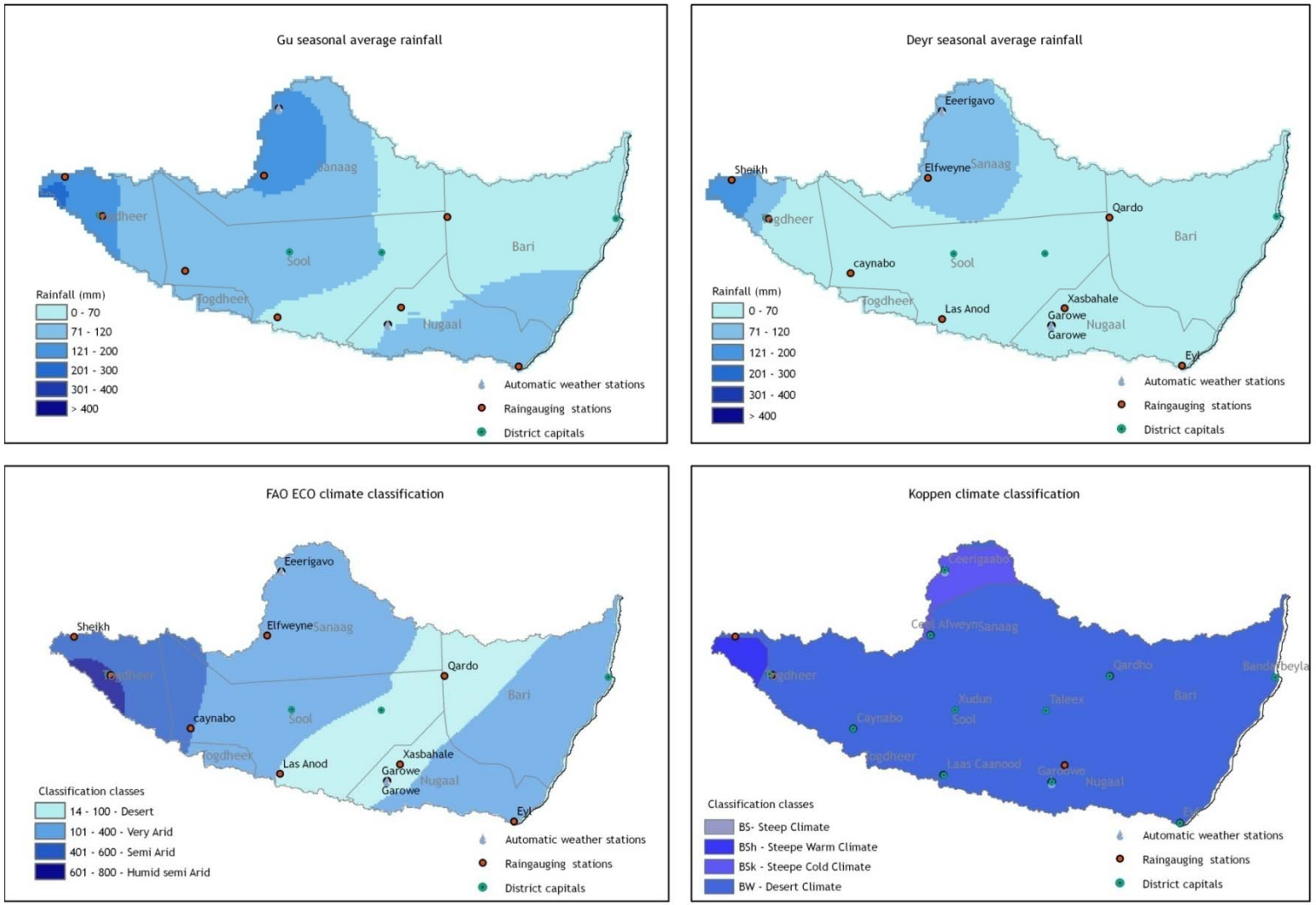


Figure 22: Climate maps for Nugaal drainage basin

4.3 Surface Water Resources of Tug Der/Nugaal Drainage Basin

Tug Der and Tug Nugal are two main drainage systems, which forms a large valley extending over 600 km in length in the southern and western parts of the drainage basin. The total catchment area of the drainage basin is about 112,231 k m^2. An interesting part of this drainage basin is the Xingalol internal drainage basin which receives water from the Sool Haud Plateau.

In the Tug Der/Nugal drainage basin, some surface water records are available for Tug Der at Burao for six years during 1945 to 1950. During this period, an average of about 33 spates was recorded per year. About 85% of these occurred during the five months from May to September. It is estimated that an average runoff of 33 million m^3 (MCM) per year, equivalent to about 22 mm in the 1500 k m^2 catchment, occurs in the area (runoff coefficient of 0.06) (*Kammer,1989*). Although some mountainous areas in the basin contain some surface water, in other plain and plateau areas most rainfall is lost and little surface water ever reaches the Indian Ocean.

The 2008 SWALIM point water sources survey identified a total of 536 strategic point water sources in the Tug Der/Nugaal basin. Dug wells are common in the basin as water especially along the dry river beds where the water table is not very low. 298 dug wells were identified which is about 56% of the total number of water sources in the catchment (figure 23). The dug wells in this basin are a few meters deep and can store water for a longer time compared to berkads and dams which run dry as soon as the rains are gone.

Boreholes are also widely used and the SWALIM survey identified a total of 198 (26%) boreholes. The boreholes are mainly along the river beds and have varying depth of up to 300 m dip. In some areas the boreholes are used for small scale irrigation when no other source is available.

Springs are mainly concentrated along the coastal strip of the basin. They comprise of 17% of the point water sources in the basin. Groundwater recharge is through direct rainfall, amount of infiltration is estimated to be not more than 5 % of the rainfall due to low and erratic rainfall (*Faillace and Faillace, 1987*).

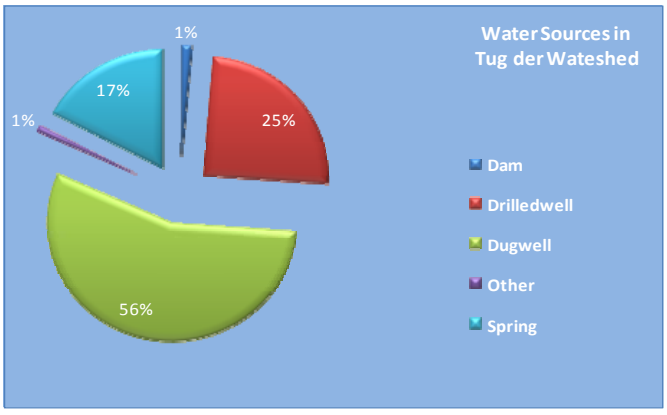


Figure 23: Representation of point water sources distribution in Nugaal drainage basin

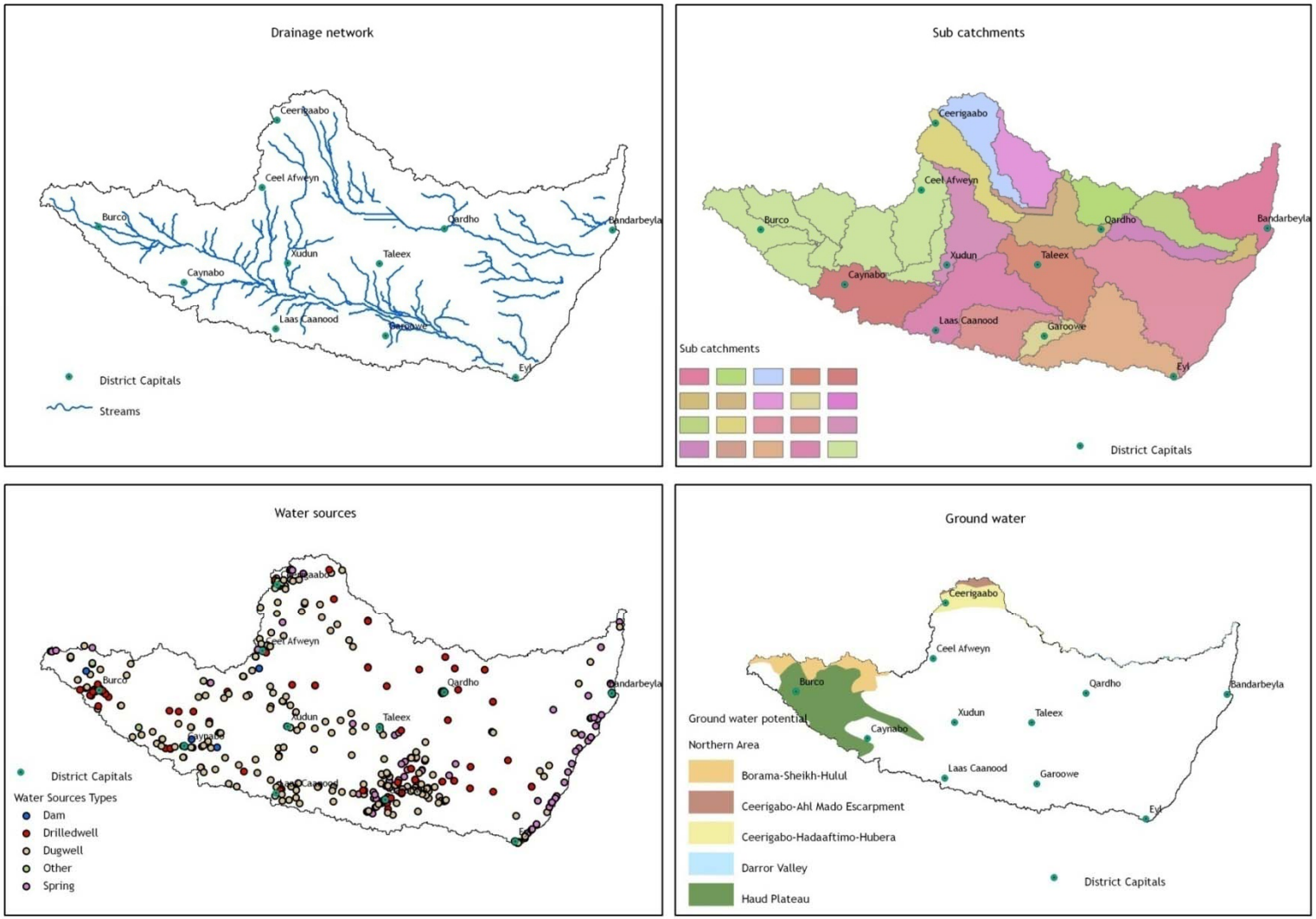


Figure 24: Water resources maps of Nugaal drainage basin

4.4 Land Resources of Tug Der/Nugal Drainage Basin

The Tug Der/Nugaal drainage basin is entirely characterized by outcropping of the sedimentary basement complex, which are made up of undifferentiated, unconsolidated sediments. Outcrops of the pre-Cambrian are only found in a small area in the coastal mountains especially around Qandala district. The most dominant formation was formed during Eococene karkar formation. This formation covers more than 75% (SAWA, 1995) of the area and consists of inter bedded lime stones and marls with some gypsum beds.

Soils are mainly loam to clay loam, the coastal area has a mixed soil texture. A wide coastal dune system also occurs along the coast.

The basin has a mixture of soil types including Fluvisols, Aerosols, Calcisols, cambisols, gypisols, leptosols and Regosols. The composition of the soil types and texture clearly indicates that the area is not suitable for optimal land cultivation. The central part of the basin is dominated by sandy soils along the coast and moderately deep loamy soils with a high content of calcium carbonate and/or gypsum further inland. Figure 25 shows the geology and soil maps of the Nugaal basin.

Defining the agro ecological zones of this basin becomes difficult owing to the high variability of weather both in space and time. Using the SWALIM AEZ classification, the basin has over ten agro ecological zones. Normally, climate and soils are the defining factors considered in agro ecological zoning. The SWALIM AEZ classification also considers land suitability. Figure 26 shows the land resources of Nugaal basin while figure 28 shows the legend of AEZ for the same basin.

The basin has less than 30 days of Length of Growing Period (LGP) during the two rainy seasons. This is attributed to the fact that this is a very dry zone with rains not exceeding 300 m for any given season. The areas around Burco and Erigavo are relatively wetter and are suitable for Agriculture.

The main land use in the basin is extensive grazing (pastoralism) and wood collection. Agro pastrolism is also practiced in the mountainous areas near Erigavo and Burao with sparse irrigation around the togas Cultivation of irrigated vegetables, fruits and sorghum . Most of the area is used for extensive grazing. Common livestock are the camels, cattle and shoats. Oasis farming is very common in the southern parts of the basin including las Anod, and Ainabo. Goats and sheep are grazed mostly on sloping areas , whereas cattle and camels are grazed on flatter areas. Land use map is on figure 26 and the legend is shown on figure 28.

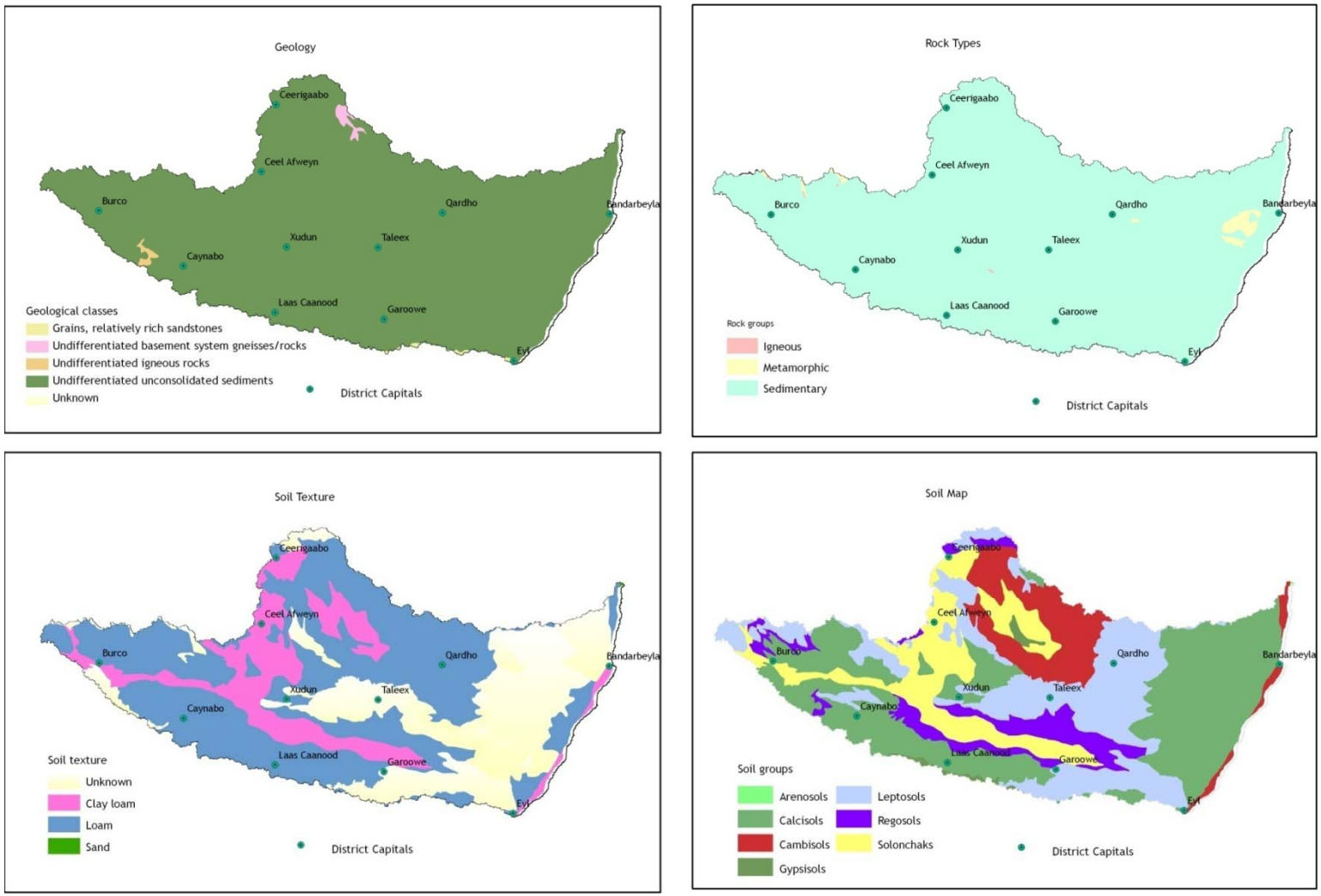


Figure 25: Geology and soil map for Nugaal drainage basin

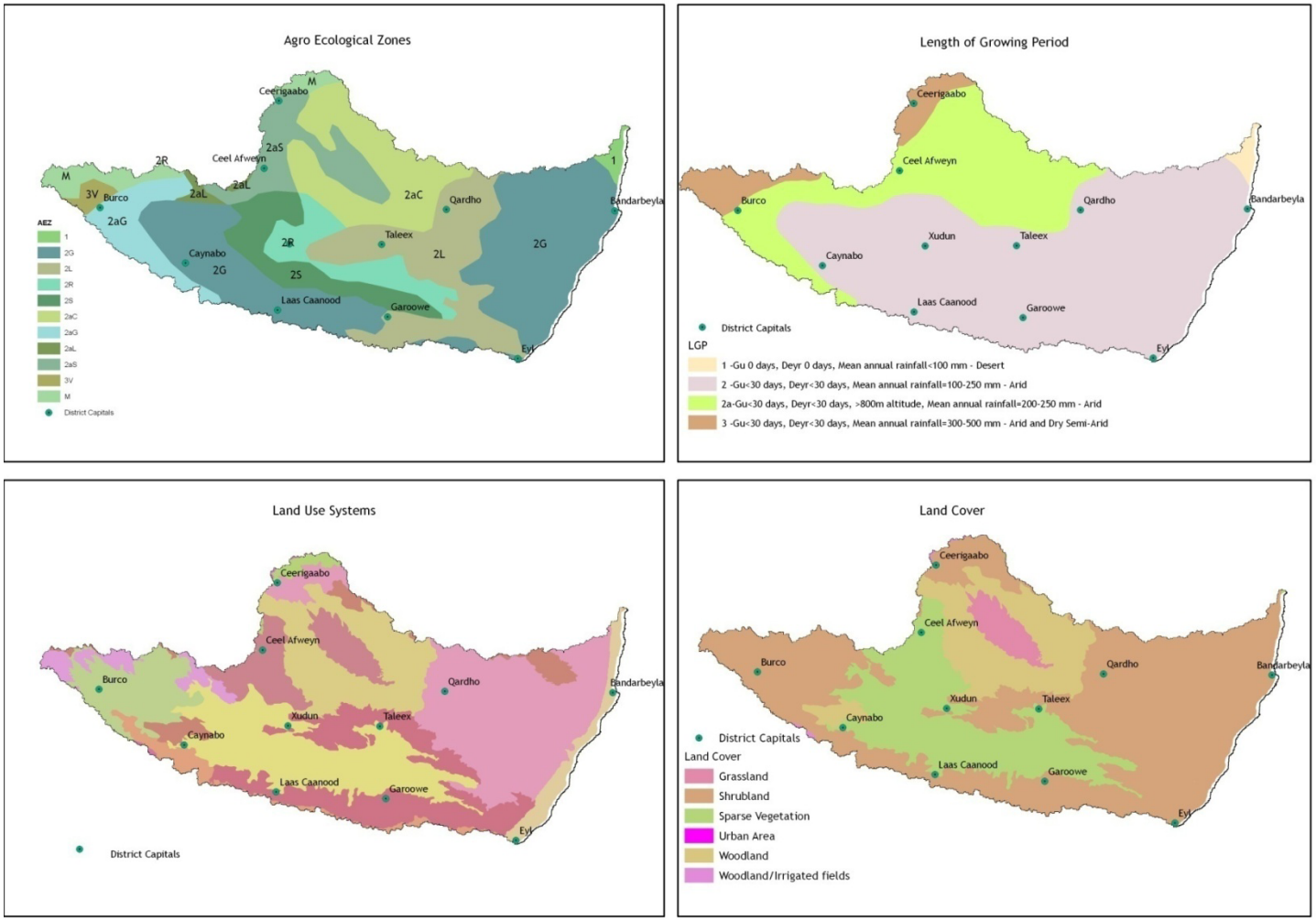


Figure 26: Land resources map for Nugaal drainage basin

AEZ	LGP		Soils		Land suitability				Climate
	Gu	Deyr	description	classification	R Rainfed Agric	I Irrigated Agric	Extensive Grazing	Forestry plantation	
1	0	0		various	N	N	S3/N	N	desert
2G	<30	<30	calcareous and stony	Calcisols, Gypsisols	N	N	S3	S3	arid
2L	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2S	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2R	<30	<30	1 calcareous 2 shallow	Regosols, Fluvisols Leptosols	N	N	S3	S3, N	
2aG	<30	<30	high lime, gypsum content	Calcisols, Gypsisols	N	N	S3	S3	arid + altitude >500m
2aL	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2aS	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2aC	<30	<30	calcareous	Cambisols	N	N	S3	S3	
3V	<30	<30	1 calcareous, clayey 2 calcareous, loamy	Vertisols Regosols	S3	N	S3	S2, S3	arid
M	Mountains		shallow	Leptosols	N	N	S3	N, S3	
Land Suitability: S1=Highly suitable; S2=Moderately suitable; S3=Marginally suitable; N=Not suitable									

Figure 27: Legend for Agro-Ecological Zones (AEZ) in Nugaal basin

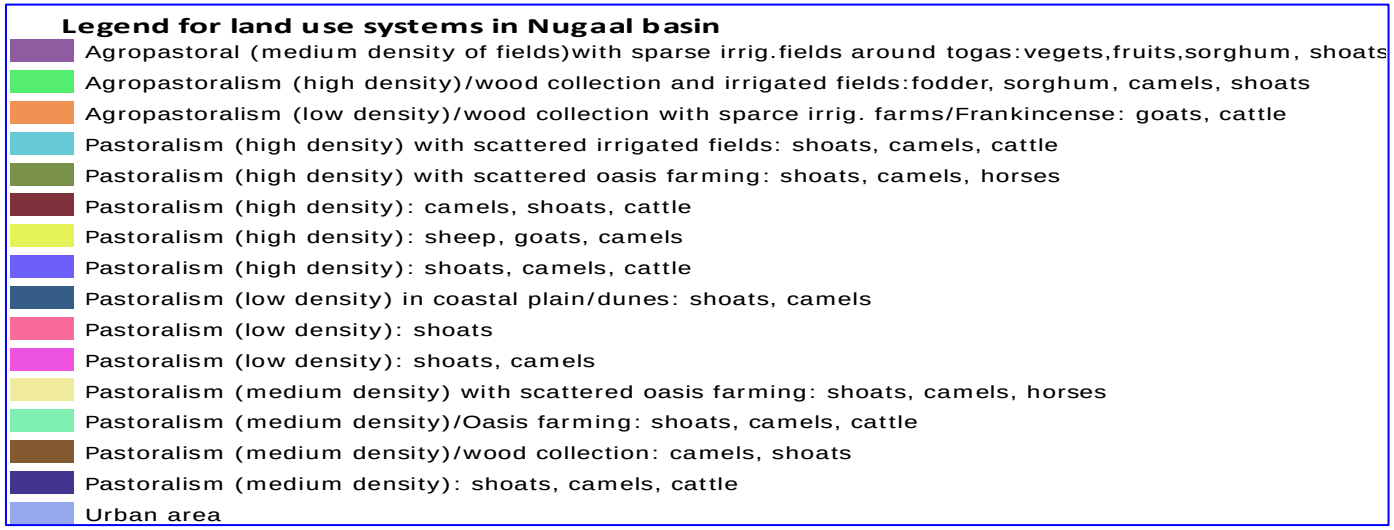


Figure 28: Legend for land use systems in Nugaal basin

5.0: OGADEN DRAINAGE BASIN

5.1 General Description of Ogaden Drainage Basin

A major part of the central region of Somalia is drained by the extension of the Ogaden desert that is considered to extend from the Ethiopian region northeast of the Shabelle River basin. Migration of communities from the war torn southern Somalia has been a major contribution to the increasing population in this basin.

The total drainage area of the Ogaden basin extending from Ethiopia to coastal areas in Somalia is about 235,000 km^2 (based on 90 m SRTM DEM data). Within Somalia, the area extends over seven regions and 20 districts within the regions and covers a total area of 149,559 km^2. The drainage area lies roughly between 42^0 45' and 49^0 55' east of the Prime Meridian and between 3^0 32' and 9^0 50' north of the Equator. The only major urban centre (town) within the drainage basin is Galkayo. Though the basin extends to Ethiopia, only the part in Somali has been considered in this analysis due to lack of information from the neighbouring country (Figure 30). This is because data from the Ethiopian side of the drainage basin was not available.

Its elevation ranges from about sea level in the east to 1,563 m in the west. About 76% of the area is below 500 m, 8% is between 500-1,000 m, 16% is over 1,000 m. The drainage network in most of the Ogaden region and central Somalia is very sparse and ill defined. The only reasonably well defined water course is in the Bokh Valley in northern Somalia which has a total length of about 180 km. In other areas, there is some occasional, localized surface runoff generated in the poorly developed seasonal streambeds, but this generally disappears quickly through evaporation and infiltration. No water reaches the Indian Ocean.

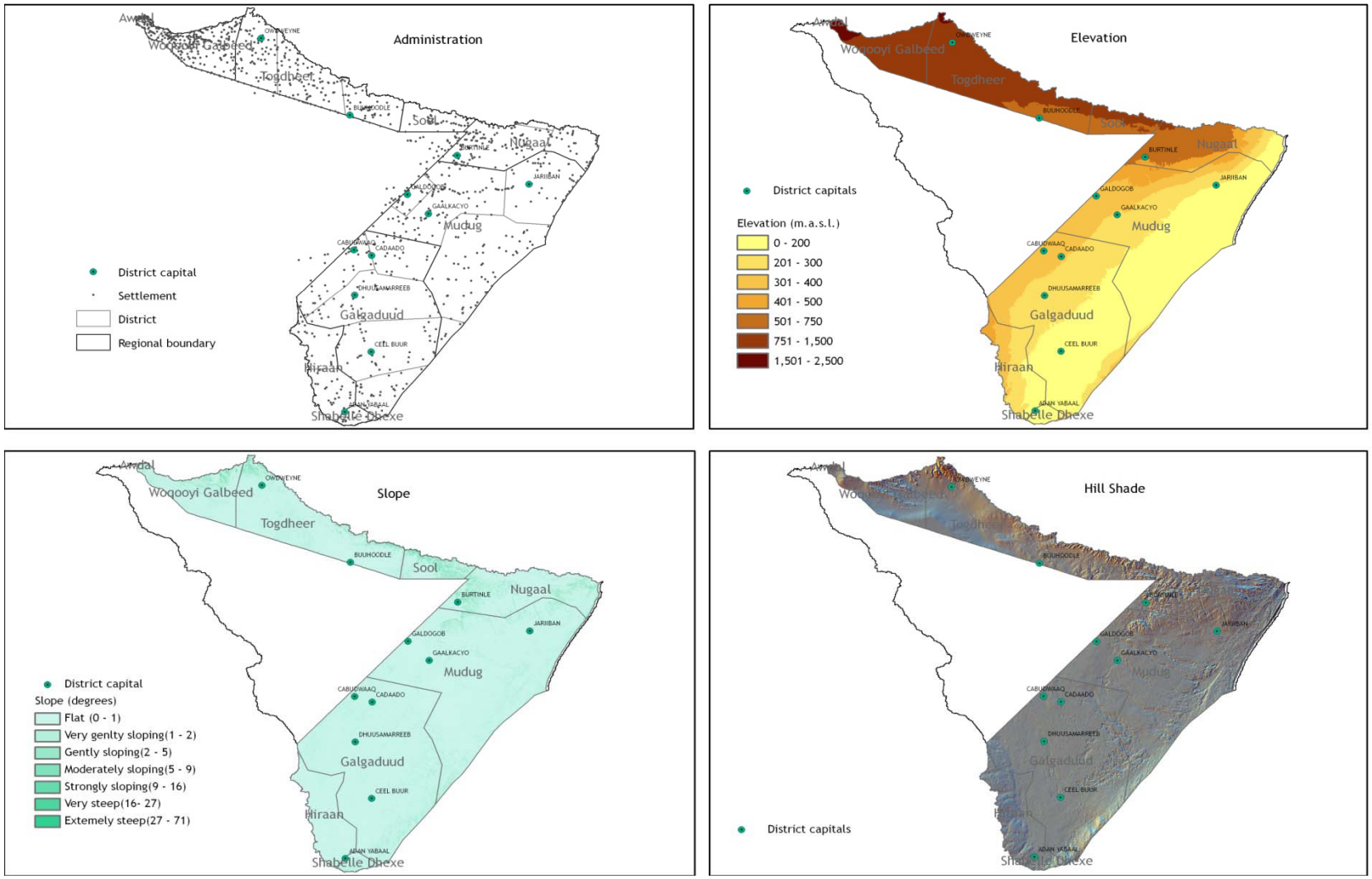


Figure 29: General description of Ogaden drainage Basin

5.2 Climate of Ogaden Drainage Basin

Rainfall in Ogaden drainage basins is low and erratic. There are both seasonal as well inter-annual variations in the amount of rainfall in the area. The mean annual rainfall for the basin is about 280 mm. However, the north western parts of the basin receive an average of up to 500 mm/year and are classified as humid to semi arid climate zone. The area to the south of the basin bordering the Shabelle basin in southern Somalia is also semi humid with annual rains of up to 400mm/year (figure 30). The rest of the basin which includes the central parts is largely classified as desert.

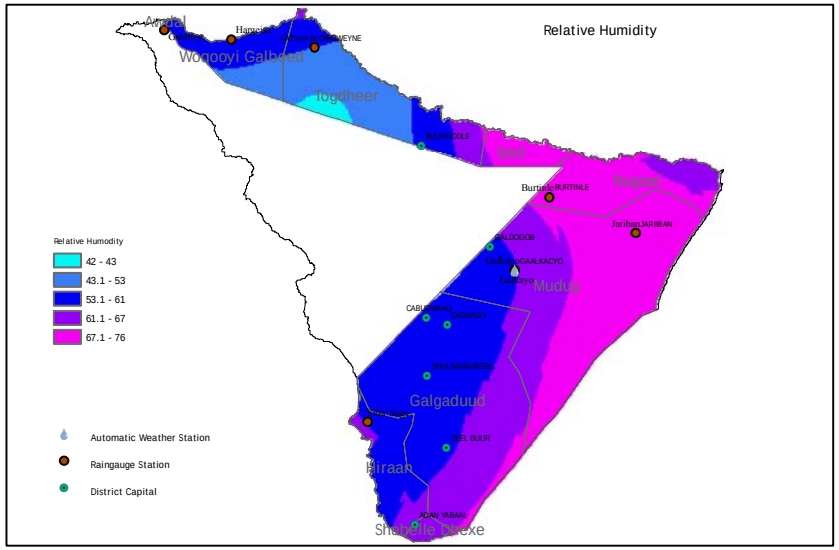
During the pre war era, only two (Galckayo and Gebilley) rainfall stations existed inside the basin. However, stations bordering the basin in other watersheds could be used to analyse the climate conditions of the Ogaden basin. Currently a number of rainfall stations exist in the basin including Odweyne, Gebilley, Burtinle, Jaribaan, Burtinle and Galckayo. Galckayo station has both the manual rain gauge and an automatic weather station. It is regrettable that there is no climate or water resources data that is available from the Ethiopian part that lies in Ogaden basin. This again calls for more collaboration between the relevant authorities.

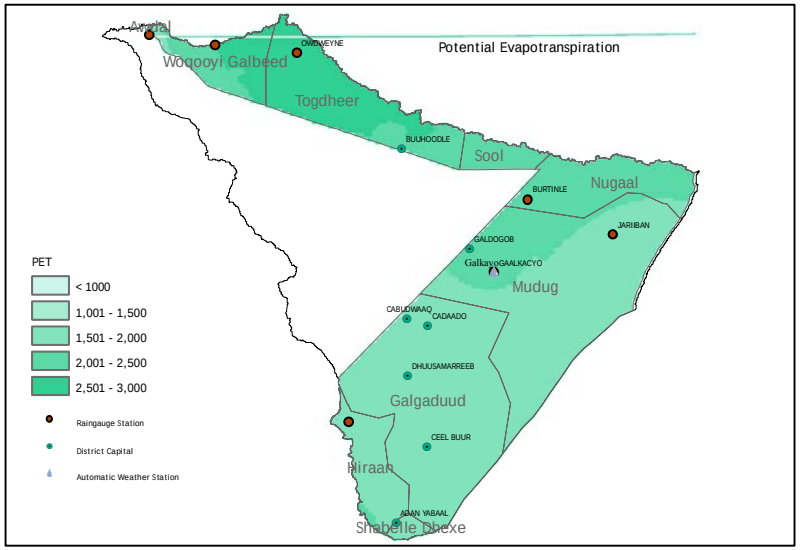
Potential Evapo-transpiration (PET) ranges from about 2100 in Burao to 3000 mm in the coastal regions. In general the evaporation is higher than rainfall through out the year except the months of May and October which happens to be the peak of *Gu* and *Deyr* rainy seasons respectively.

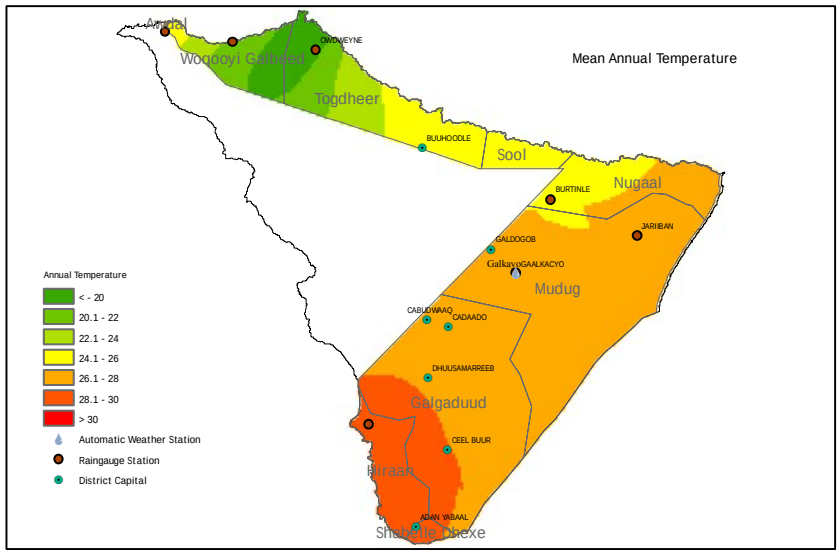
The mean air temperatures are generally high in the drainage basin. Mean temperature is high in the range of about 22^0 C to more than 33^0 C. March and April are the hottest months of the year in this basin.

The relative humidity (RH) is higher in the coastal regions (up to 70%) than in the inland (50% to 60%) areas. The southern parts of Togdheer region located in this basin is said to be the coolest area in Somalia.

Wind speeds vary from a low of about 4.2 m/s to a high of about 8.2 m/s. Wind speeds are higher during June to August. On an average the lowest values of wind speed occur in the months of April and November in the country coinciding with the peaks of the two rainy seasons, *Gu* and *Deyr*, respectively.







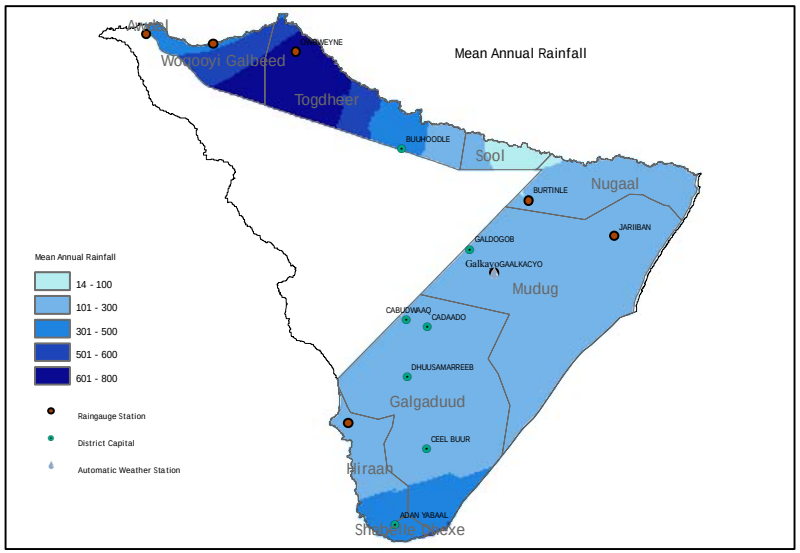


Figure 30: Mean annual weather pattern maps for Ogaden Basin

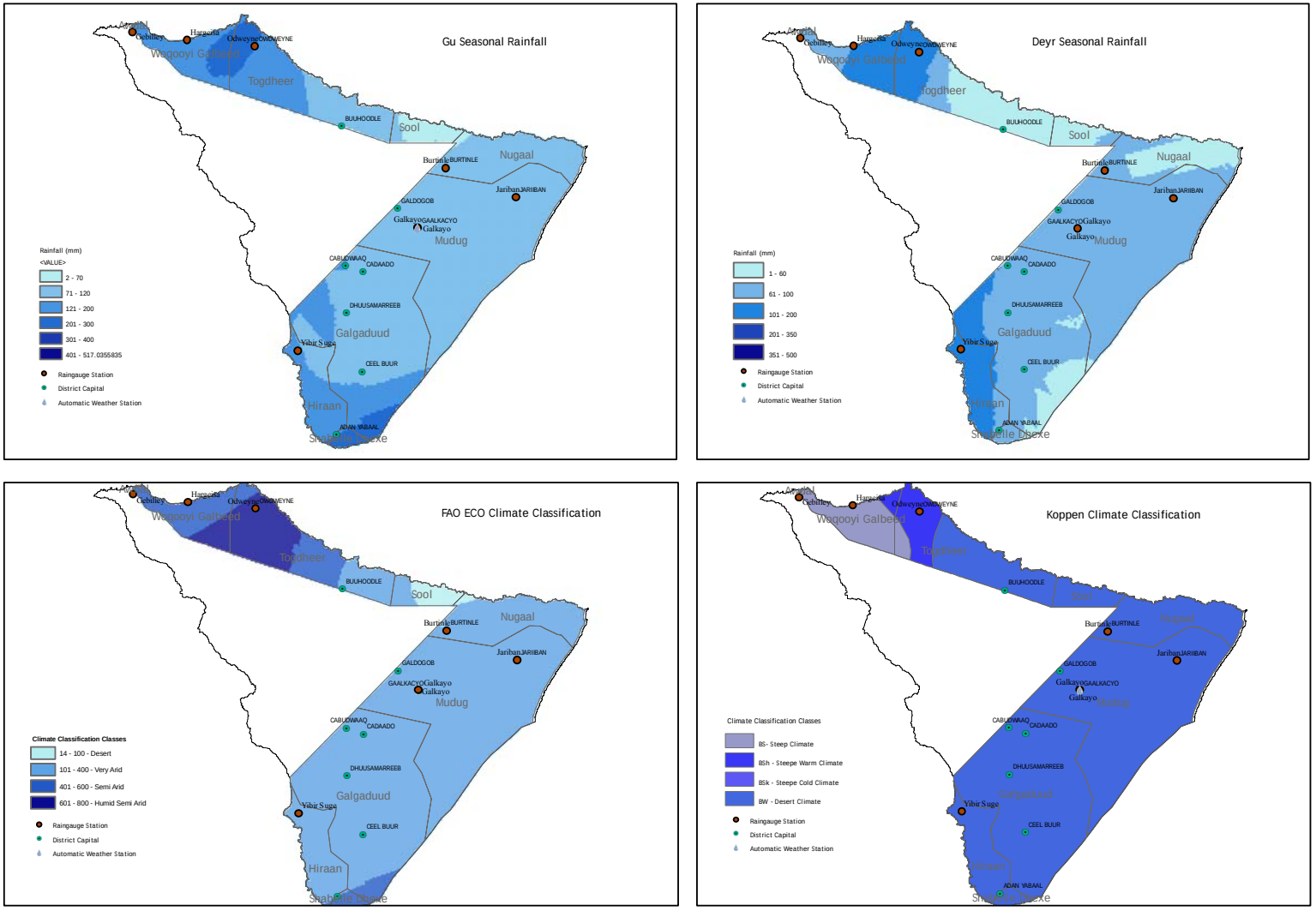


Figure 31: Climate maps of Ogaden basin

5.3 Surface Water Resources of Ogaden Drainage Basin

No perennial river of any importance exists in the basin. The wadis and toggas, the seasonal streams, where drainage networks are developed, have surface runoff only after heavy rainfall. No long term surface water monitoring has been done in any of these wadis and toggas.

The 2008/09 point water sources survey in northern and central Somalia by SWALIM identified a total of 420 point water sources within the basin. The study indicates that there are numerous such points which could not be fully covered by the surveys due to time and resources. Warsand berkads used for rain water (catchment) harvesting are not very common in Northern Somalia. The survey identified only 24 such points. These are mainly berkads and are located on the southern parts of Togdheer region. Dams are also very common south east of Galbeed region. A total of 77 dams were identified during the survey.

Dug wells and bore wells are very common in the eastern parts of the basin (Mudug and Galgadud). A total of 209 (50%) dug wells were identified. Boreholes act as the main source of water here. There are 108 (26%) of such points (Figure 32) . The dug wells and boreholes are used for all kinds of water use including small scale irrigation.

Groundwater is an important source of water to meet the needs of the human and livestock population. Data on the aquifers and groundwater systems are scattered and scarce.

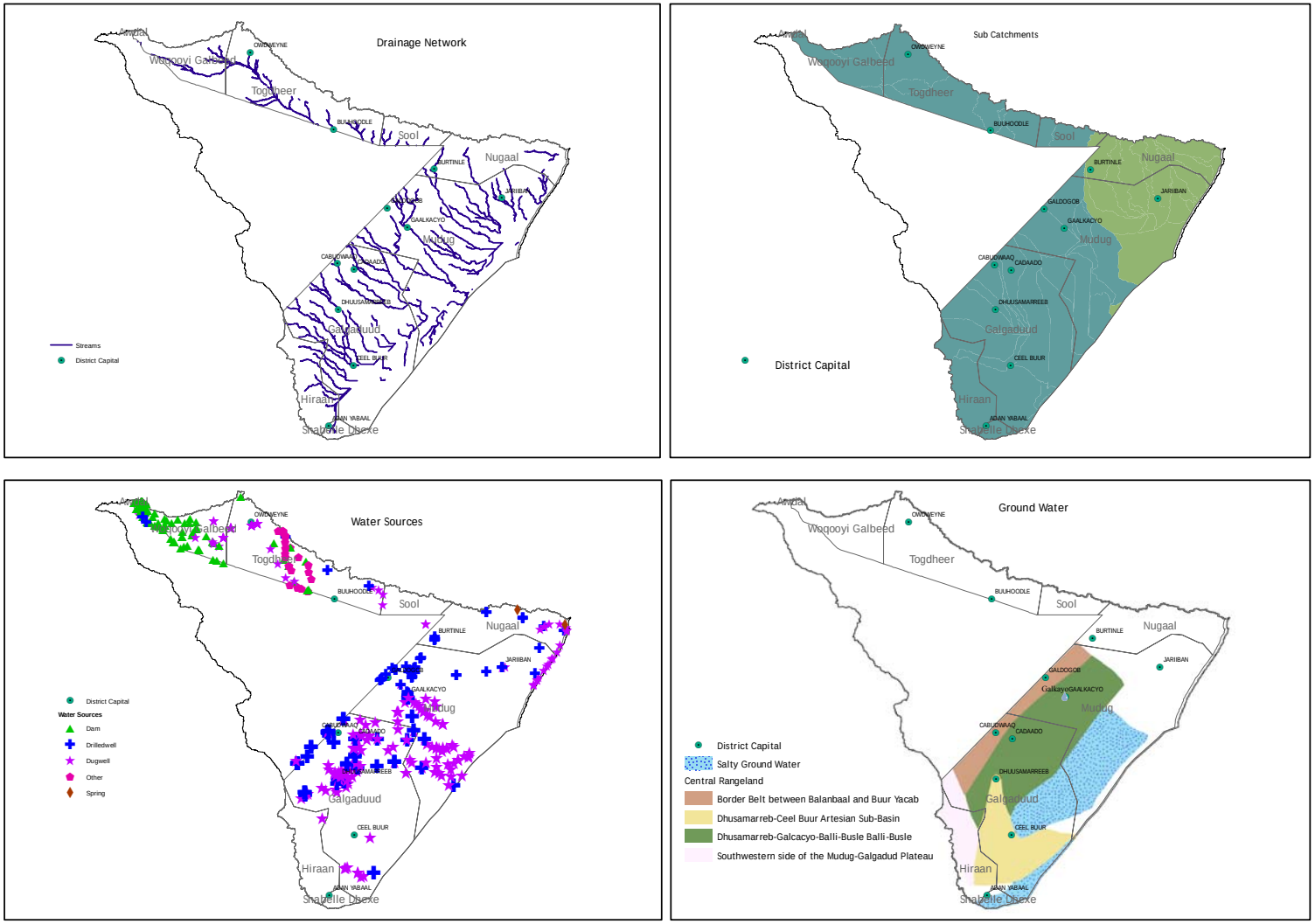


Figure 32: Water Resources maps for Ogaden basin

5.4 Land Resources of Ogaden Drainage Basin

Ogaden basin has a mix of geological classes as indicated on figure 33. The rock type in this basin is primarily sedimentary.

The basin has a mix of soil groups including Fluvisols, Arenosols, Calcisols, cambisols, gypisols, leptosols and Regosols. The central part of the basin is dominated by loam and clay soils while the coastal strip is covered by sandy soils.

The length of the growing period in the basin is less than 30 days both in gu and deyr rainy seasons owing to the low rains experienced in most parts of the drainage basin.

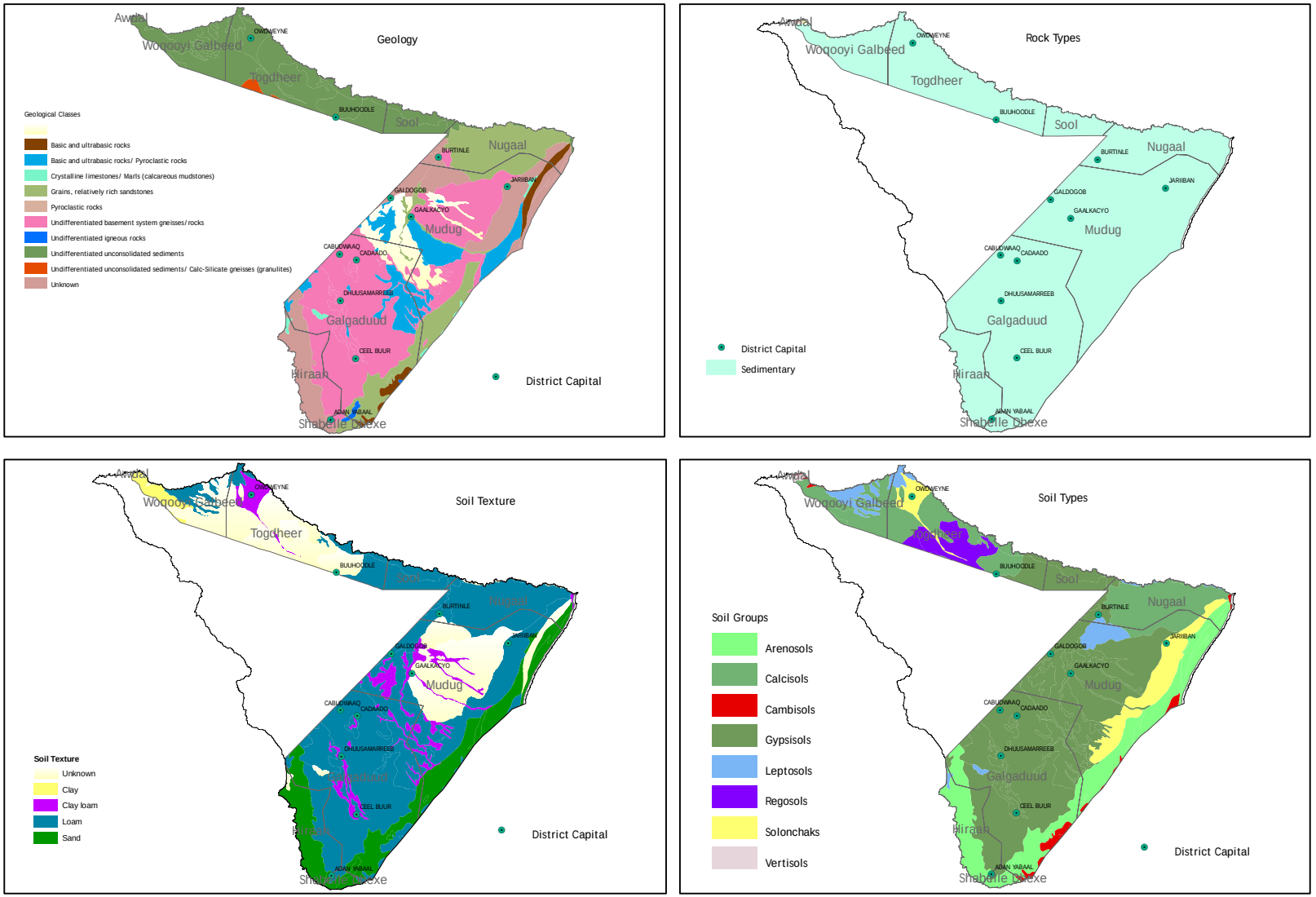


Figure 33: Geological and soil map for Ogaden basin

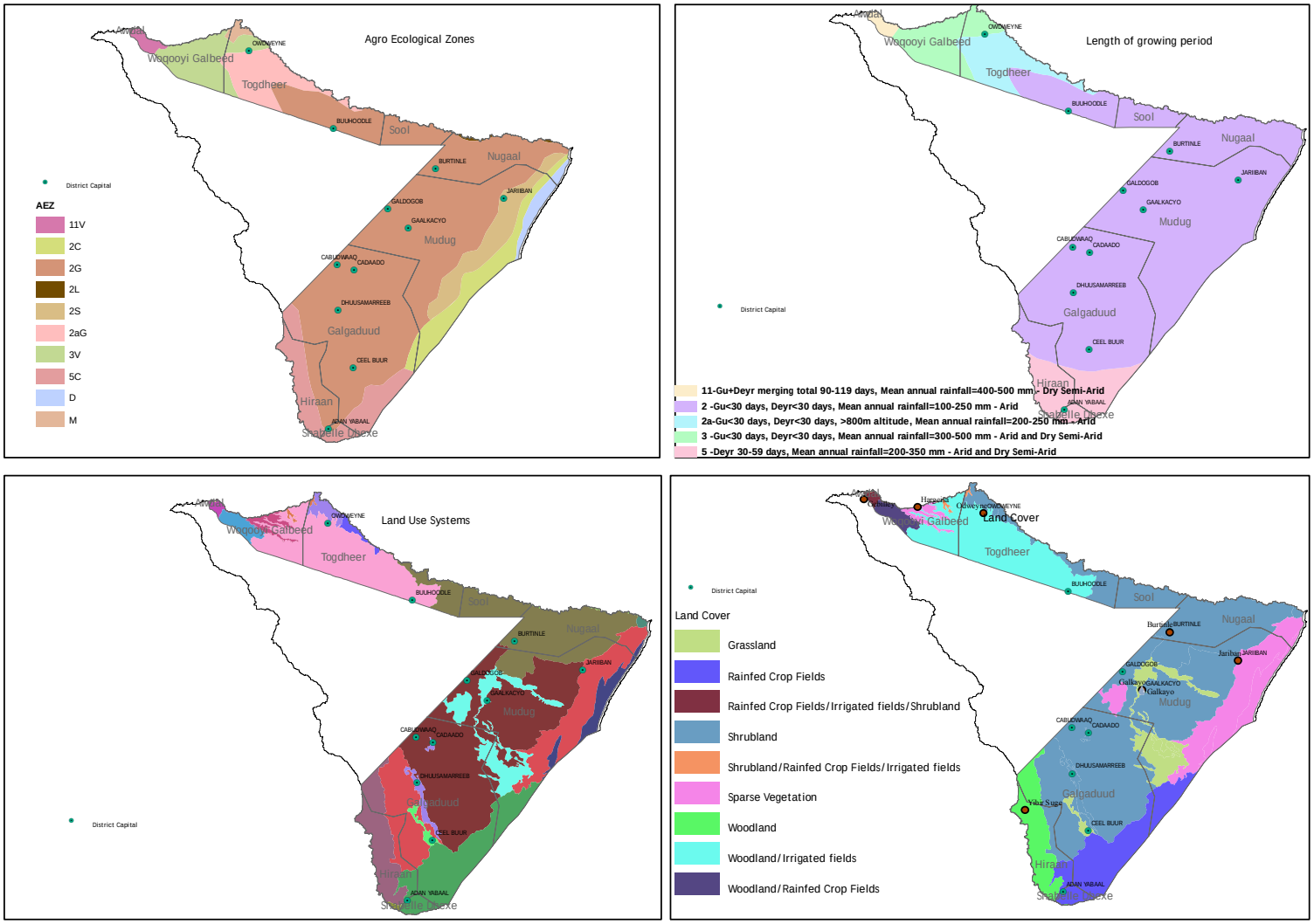


Figure 34: Land resources maps in Ogaden basin

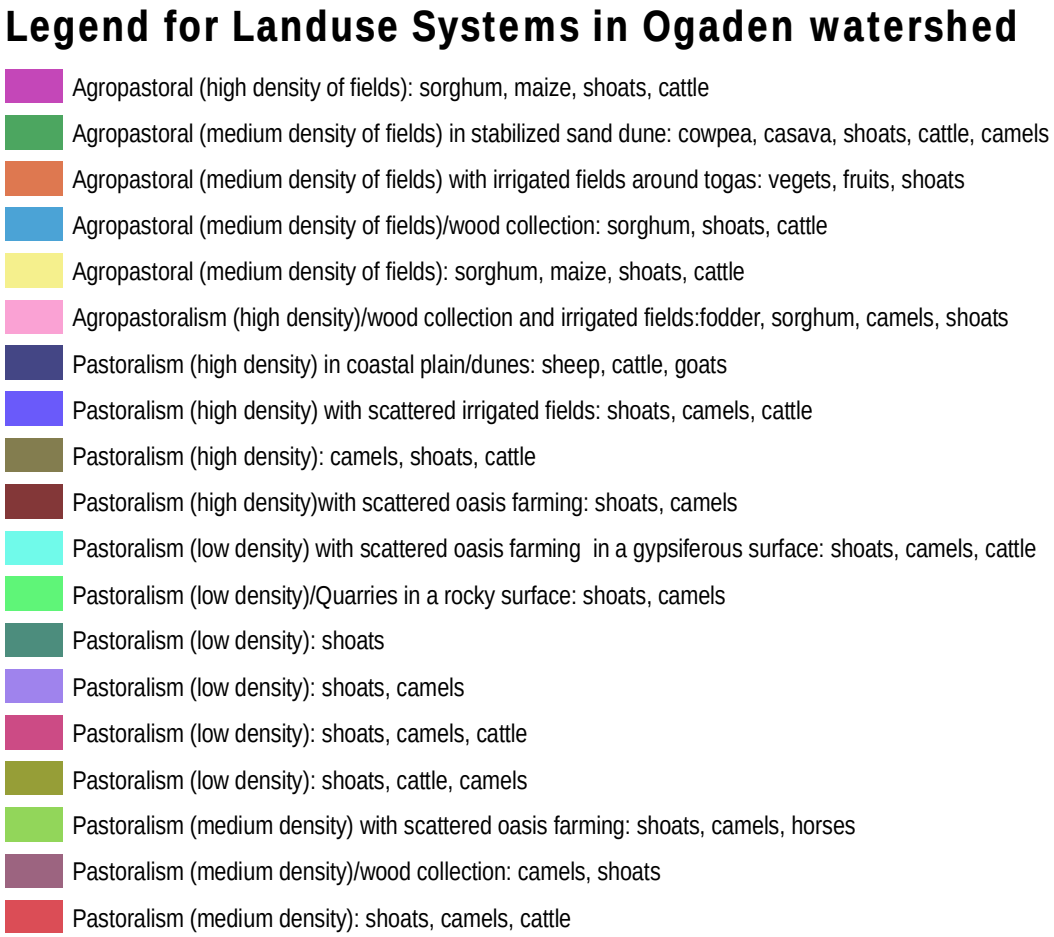


Figure 35: Legend for land use systems in Ogaden basin

References

Agrar-Und Hydrotechnik GMBH. 1990. Master Plan for Juba Valley Development. Main Report. Ministry of Juba Valley Development, Somali Democratic Republic.

Alim, M. S. 1997. Inventory Report Somalia. Internal Report No. 1. GCP/RAF/287/ITA. Food and Agriculture Organization of the United Nations.

Faillace, C. 1964. Surface Water and Underground Water Resources of the Shebeli Valley. Ministry of Public Works & Communication. Mogadishu.

Faillace, C and Faillace, E. R. 1987. Water Quality Data Book of Somalia. General Report. GTZ Project No. 80.2193.3-09.112. GTZ and Water Development Agency (WDA), Somalia.

Faillace, C. 1993. Results of a Country-wide Groundwater Quality Study in Somalia. In. Geology and Mineral Resources of Somalia and Surrounding Regions. Eds. Abbate, E., Sagri. M. and Sassi, F. P. Instituto Agronomico Per L'oltremare, Firenze. Pages: 615-632.

Faillace, C. 1993. The Need to use Simple and Appropriate Technology to Develop the Water Resources in Somalia. In. Geology and Mineral Resources of Somalia and Surrounding Regions. Eds. Abbate, E., Sagri. M. and Sassi, F. P. Instituto Agronomico Per L'oltremare, Firenze. Pages: 633-648..

Hutchinson, P. and Polishchouk, O. The Agroclimatology of Somalia. Food Early Warning Department. Ministry of Agriculture. Somali Democratic Republic. Technical Report No. 12. F.E.W.S. Project.

Kammer, D. 1989. A Brief Description of Major Drainage Basins affecting Somalia with special reference to Surface Water Resources. National Water Center, Mogadishu, Field Document No. 14. FAO/SOM/85/008, Rome.

Mbara C.J., Gadain H.M and Muthusi F.M. (2007), Status of Medium to Large Irrigation Schemes in Southern Somalia, Technical Report No W-05, FAO-SWALIM, Nairobi, Kenya.

Mink, A. 2007. Rural Water, Sanitation and Hygiene in Northwest Somalia. Technical Backstopping Mission to the EC funded Project. Caritas Luxembourg and

Switzerland and EU.

Muchiri P.W. (2007), Climate of Somalia. Technical Report No W-01, FAO-SWALIM, Nairobi, Kenya.

Muchiri, P. W. (2007), Inventory of Hydro-Meteorological Data of Somalia. Technical Report No W-03. FAO-SWALIM, Nairobi, Kenya.

Musgrave, H. 2002. Drought and Hydrological Variability in Southern Somalia. A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in the University of London. London.

Oduori, S.M., Vargas, R.R. and Alim, M.S. (2007) Land Resources Assessment of Somalia, Technical Report No L-12, FAO-SWALIM

Print, C. 2000. Development of a Water Information System for Somalia. Final Report to the SACB WSIS Committee. UNICEF Somalia.

SWALIM. 2007. Somalia Dynamic Atlas. FAO, Nairobi.

UNDP and FAO, 1968. Agricultural and Water Surveys, Somalia, Final Report, Six Volumes (Series), Water Resources (Volume II). DP/FAO/Sf:36/SOM. FAO Library Fische AN: 04002-004.

UNDP and FAO. 1973. Surface Water Resources. Report to the Government of Somalia. No. TA 3190. FAO Library Fische AN: 23906.

Venema, J.H. and Vargas, R.R. (2007), Land Suitability Assessment of Selected Area in Somaliland, Technical Report No L-06, FAO-SWALIM

Venema, J.H. and Vargas, R.R. (2007), Land Suitability Assessment of the Juba and Shabelle Riverine Areas in Southern Somalia, Technical Report N°. L-07, FAO-SWALIM