Climate Change Impacts on Water Resources of Somaliland and Puntland

Basic Analysis to Support Assessment and Management of Water Resources in Drought-Prone Areas to Mitigate Climate Change

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Executive Summary

Identifying, assessing and developing groundwater resources is an urgent priority for emergency relief and long-term development in the countries of the Horn of Africa affected by drought and water scarcity. As a response to this context, UNESCO, in May 2012, launched the initiative "Strengthening Capacity to Combat Drought and Famine in the Horn of Africa: Tapping Groundwater Resources for Emergency Water Supply" through support of the Government of Japan. The overall project aims to map-out drought-resilient groundwater resources in affected areas and strengthen regional capacities in managing groundwater for drought-preparedness. In order to take advantage of the established network and experienced profile of UNESCO's partner FAO-SWALIM (Somalia Water and Land Information Management) in Somalia, an agreement of this UNESCO-FAO partnership was formalized that governs the framework of the overall project.

SWALIM's primary objective within the overall project is to contribute to better decisions on the use of Somali water and land resources by providing reliable and up-to-date information. The main stakeholders are Somali administrations, UN organizations, development agencies and NGOs. The project was set up in view of the overwhelming lack of structured and accessible information on water and land resources and with the need to develop an overview in water and land resources, in order to improve policies and interventions in support of improved rural livelihoods.

The objective of this report and related analysis comprises a desk review and stakeholder consultations to capture the impacts of climate change on groundwater recharge in Somaliland and Puntland, to compile related information and identify vulnerabilities and opportunities related to the water resources situation. Based on a situational analysis an understanding of the current situation and aspects where suitable management could be used to improve water availability through aquifer recharge as well as through mitigation and planning aspects considering both bulk supply and drought situations. Respectively the objective includes the development of technical aspects and policy recommendations and the dissemination of study results. The methodology used to achieve these results includes desk studies and an analysis of existing data, stakeholder workshops as well as meetings with the respective analysis of the collected information and presentation in this report.

As a baseline description of conditions in the area of interest, the climate in the different areas of Somaliland and Puntland as well as the groundwater and surface water resources are described in a situational analysis. Further to the physical conditions including quality aspects, current sources and means of ground- and surface water use are described and water demand and availability compared and the available data described.

Climate change which has an important input into the study is described in detail both regarding the physical background as well as the impacts that are expected for Somaliland and Puntland. Summarizing the analysis of global climate model results as generated by IPCC and evaluated by UNDP, the expected change in temperature,

rainfall and event intensity as well as the expected impacts on evaporation, runoff and infiltration and respective impacts on resource availability are shown.

Rising temperatures More extreme rainfall events	Increased evaporation Increased downpour intensities	Reduction in infiltration Increased runoff ➔ more water reaching streams and riverbeds ➔ less water available for plant growth ➔ opportunity for point recharge where water is needed

Based on the surface- and groundwater resources assessment as well as climate change information and expected impacts, vulnerabilities, sustainability limits and recharge possibilities were assessed. The importance to consider anthropogenic drivers like population growth with respectively increasing water demand and resulting reduction of per-capita water availability as well as the limitation imposed to any study due to the extreme limited data situation were expressed. In order to draw up the potential for situational improvement, groundwater recharge possibilities including sand dams, underground dams, check dams, infiltration ponds, contour trenching, soil bunding and tillage are presented and described in detail. Based on the geology of the area with respective impacts on recharge capacity as well as water quality, the suitability of different areas for groundwater recharge is described and application examples in form of case studies given for Boosaaso, Hargeysa and Qardho. These show the possibilities but also the difficulties related to groundwater recharge.

Following the physical and engineering aspects to improve the water supply situation in Somaliland and Puntland, the institutional situation was assessed with each a distinguished look into the rural and urban areas. The existing institutional situation and capacity for implementation of policies was described and improvements suggested both on policy as well as execution levels. It was found that problems are not related to missing policies but rather related to missing ability to implement policy aspects and enforce changes. Respectively recommendations did focus on implementation guidelines and the need to involve the private sector, but also highlighted the need for licensing of the use of natural resources including water, pasture and forest resources. The latter two are especially important with regards to drought management where it is not so much the lack of water but the lack of pasture that is causing problems. The drivers in this regard are found in population growth with the resulting increasing livestock numbers and respectively increasing pressure on pasture resources. The situation is exacerbated by the need for alternative livelihoods of people that drop out of the pastoralist lifestyle due to natural resources limitations and who move into tree cutting for charcoal burning and who in this way have a detrimental effect on the resource situation.

An important aspect in developing mitigation mechanisms to deal with the resource scarcity is to acknowledge the current limitations to enforce policies by the authorities and the respective need to have consensus within the population for any successful interventions. The following aspects were found to be of use:

Urban centres

- Possibilities for improving the supply situation depend much on the particular conditions for the respective area. As an example, Boosaaso could benefit from sand dams or underground dams that can be built in the sandy riverbeds that discharge water from the coastal range. In other locations, especially on the plateau, such possibilities are not available
- Population growth in the urban centres (average 4.3%, partly over 20% annually, e.g. in Hargeisa) is very high. Given the capacities of the authorities and the economy it will therefore not be possible to quickly improve the supply and distribution situation from boreholes through a supply network. Water tankers could anyhow be used more efficient to flexibly deal with the water supply needs of the population until grid based solutions have been developed and system losses reduced

Rural areas

- A strategic grid of boreholes, where necessary of very deep boreholes is seen as a basic necessity to provide water on a spatial scale. This borehole grid should also be introduced in areas where water is currently supplied by Berkads in order to overcome the direct dependence on seasonal rainfall.
- A well organized fleet of water tankers will be necessary to flexibly supply water in rural areas and to react to water shortage emergencies that are expected to increase in the future.
- The introduction of rangeland management principles, tailored to the specific conditions in Somaliland and Puntland, to ensure the sustainable use of pasture resources and avoid tree cutting as well as control land grabbing is seen as an essential step for sustainable resource management. Especially with a denser borehole grid and more organized water supply in place, pressure and resulting damage of pasture resources will increasingly become an issue.
- Migration will still play a major role in adjusting to a changing water and pasture situation, respectively land ownership needs to be controlled.
- Enforcement is a problematic issue especially in the rural areas. Education and consensus building in the local population is therefore essential to be able to introduce new rules. The traditional systems should as much as possible be used and adapted to implement the rangeland management principles
- Market reforms will be needed to be able to reduce livestock numbers during droughts

As a supplementary tool for emergency preparedness groundwater monitoring would be an important aspect to monitor resource availability and avoid over-exploitation. In addition to the monitoring an early warning system should be developed and introduced, aiming at long term forecasts by considering global meteorological patterns. Respective potential approaches, i.e. including Sea Surface Temperature fluctuations with their respective El-Nino and La-Nina effects have been described in detail.

Glossary of Somali Terms

Balleh dam	Surface dam
Berkad	Traditional water basins which collect surface water
Deyr	Second transition period, an important rainy season from October to November
Gu	Transition period, an important rainy season from April to May
Haffir dam	Surface dam on relatively flat terrain for water harvesting
Jilaal	Northeast monsoon, a dry and hot season from December to March
Qat/Mirah	Plant native to the horn of Africa used as a stimulant
Xagaa	Southwest monsoon, a dry and hot season from June to September

List of Abbreviations

AR4	Assessment Report Number Four (IPCC)
DEM	Digital Elevation Model
DG	Director General
ENSO	El Nino-Southern Oscillation
ET	Evapotranspiration
ETa	Actual Evapotranspiration
ETp	Potential Evapotranspiration
FAO	Food and Agriculture Organization
HADMA	Humanitarian Affairs and Disaster Management Agency
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System of USACE
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
IPCC	International Panel on Climate Change
LAT	Latitude
LON	Longitude
MMD	Multi Model Data
MMEWR	Ministry of Mining, Energy and Water Resources
NAPA	National Adaptation Program for Action
NDVI	Normalized Difference Vegetation Index
NERAD	National Environment Research and Disaster-Preparedness Agency
NGO	Non Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
PET	Potential Evapotranspiration
PPP	Public Private Partnership
PSAWEN	Puntland State Agency for Water, Energy and Natural Resources
RH	Relative Humidity
SRES	Special Report on Emissions Scenarios
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
SWALIM	Somalia Water and Land Information Management
SWIMS	Somalia Water Sources Information Management System
SWL	Surface Water Level
TRMM	Tropical Rainfall Measuring Mission
UN	United Nations
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children´s Fund
UNO	United Nations Organization
UNOPS	United Nations Office for Project Services
USACE	United States Army Corps of Engineers

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1. Introduction

Identifying, assessing and developing groundwater resources is now an urgent priority for emergency relief and long-term development in all countries in the Horn of Africa affected by drought and water scarcity. As a response to this context, UNESCO, in May 2012, launched the initiative "Strengthening Capacity to Combat Drought and Famine in the Horn of Africa: Tapping Groundwater Resources for Emergency Water Supply" through support of the Government of Japan. The overall project aims to map-out drought-resilient groundwater resources in affected areas and strengthen regional capacities in managing groundwater for drought-preparedness. In order to take advantage of the established network and experienced profile of UNESCO's partner FAO-SWALIM (Somalia Water and Land Information Management) in Somalia, an agreement of this UNESCO-FAO partnership was formalized that governs the framework of the overall project. As part of this project, SWALIM has recently finalized a hydrogeological survey and assessment in selected areas of Somaliland and Puntland which has come up with a wealth of information on potential groundwater resources which supplements SWALIMS previous activities in Somali water and land resources information management.

For the work described in this report, SWALIM's primary objective is to contribute to better decisions on the use of Somali water and land resources by providing reliable and up-to-date information (FAO SWALIM, 2010). The main stakeholders are Somali administrations, UN organizations, development agencies and NGOs. The project was set up in view of the overwhelming lack of structured and accessible information on water and land resources and with the need to develop an overview in water and land resources, in order to improve policies and interventions in support of improved rural livelihoods.

Until now the three phases of SWALIM project were completed. In Phase I "Broad Vision and Medium Term Implementation Strategy for Water and Land Information" was developed, supplemented by additional resources for SWALIM professional service. The work in Phase II focused on collection and interpretation of available and accurate information on water and land resources. Phase III took over responsibility for River Basin Management (RBM) and carried out an aerial photography survey that has produced very high accuracy digital aerial photographs, a digital elevation model and near infrared images of the riverine areas (Juba, Shabelle) in south-central Somalia as well as several in-the-field studies including a water points inventory. The information was stored in a GIS database. The information collected and processed includes:

- rainfall and other climatic parameters
- river levels and stream flow data
- geological, topographic and soil characteristics
- land cover, land use and land suitability features
- previous studies, maps and data series on water and land resources

SWALIM is currently in Phase IV which is designed to "address capacity building of Somali institutions to manage natural resources information with future transfer of activities to the field and applied information management services" and includes a hydrogeological assessment of Somaliland and Puntland. The main objective of the hydrogeological assessment is to create a base for sustainable groundwater use and development. To achieve this, extensive field surveys and trainings have been carried out and a systematic approach for compiling the existing information has been taken for classifying the aquifer systems and evaluating the water resources.

The objective of this report and related analysis comprises a desk review and stakeholder consultations to capture the impacts of climate change on groundwater recharge in Somaliland and Puntland, to compile related information and identify vulnerabilities and opportunities related to the water resources situation. Based on a situational analysis an understanding of the current situation and aspects where suitable management could be used to improve water availability through aquifer recharge as well as through mitigation and planning aspects considering both bulk supply and drought situations. Respectively the objective includes the development of technical aspects and policy recommendations and the dissemination of study results.

2. Methodology

The methodology utilized for developing this report includes key contact interviews, desk literature review, stakeholder workshops with authority officials and stakeholders from Somaliland and Puntland and analysis of available datasets with regards to climate, surface water and groundwater. A list of main stakeholders is provided in the Annex.

2.1 Key contact interviews

The stakeholder workshops were complemented by individual meetings with authorities and stakeholders in Hargeysa as well as with agency officials from Puntland in order to discuss specific aspects in more detail. Meetings include:

- DG Water Resources, Ministry of Mining, Energy and Water Resources, Somaliland
- Hargeysa Water Agency, Somaliland
- Representatives from PSAWEN, Puntland
- UNICEF Hargeysa
- IFAD Hargeysa
- NERAD Hargeysa

2.2 Desk literature review

Desk literature reviews included a thorough screening of literature that has previously been developed by SWALIM as well as other literature sources. An overview is given in the literature list.

2.3 Stakeholder workshops

Two workshops were carried out in Hargeysa, Somaliland, to which authority officials as well as stakeholders from water utilities and international organizations were invited. An initial workshop was carried out at the beginning of the assignment after a first literature review was completed and a baseline situation was presented to the participants as a base to discuss problems and possible solutions. The second workshop was carried out towards the end of the assignment and findings were presented, discussed and refined together with the participants.

2.3.1 Inception workshop

A three day inception workshop was carried out in Hargeysa, Somaliland, with participants from Somaliland and Puntland from 28.-30.09.2012. A participants list is shown in the Annex.

Presentations and interaction with stakeholders and workshop participants

Current knowledge based on the results of various studies, including FAO-SWALIM work, was presented to the stakeholders in the workshop. The presentation was split into a geophysical part, explaining the current water situation in Somaliland and Puntland, a climate change part where the expected impacts for the region as well as the related uncertainties were explained and a policy part where the currently existing policies were discussed. The presentations were held interactively and included feedback and updating of slides as well as group work and presentations on selected topics by the participants.

Presented facts included the information mapped by SWALIM, including drainage network, strategic water sources, hydrogeology and groundwater quality as well as the data obtained during field surveys including water quality testing and borehole yields and –depths. Climate change presentations focused on a description of the recent- and current climate, climate change projections, the involved uncertainties as well as the potential impacts of climate change on water availability and environment (including soil moisture and recharge). The absence of official documents for Somalia, as prepared with UNDP or UNFCCC support elsewhere, was highlighted.

The water availability situation was further assessed in cooperation with the participants highlighting different types of water resources, their distribution and sustainability. In addition the pasture situation and development was discussed. Considering the water users development and behaviour it was concluded that while climate change has an increasing effect, the driver and main booster of the problem of reducing per-capita water availability is the population growth, directly through increasing water demands of the growing population and indirectly through the increasing needs for livelihoods with related water and pasture demand for livestock as well as the trend for alternative livelihoods like tree cutting for charcoal burning. In general the participants reported a trend of decreasing sustainability of the society's way of live – caused by population pressure. Especially the aspects of unsustainable use of water sources, overgrazing and related destruction of vegetation and tree cutting for charcoal burning were named. The problem is exacerbated in and around urban centres.

Stakeholder and workshop participants' consultation results

Main results from stakeholder consultations during the workshop as well as obtained during individual meetings show the following:

- Population is growing rapidly leading to increasing pressure, competition and overuse of natural resources
- Per capita water availability is reducing due to increasing population numbers
- Animal numbers have increased with the growing population leading to increased pressure on pasture and water resources

- Overgrazing is now common and seriously damages the pasture. Rain/dry season grazing area separation does not exist anymore in many places but areas are grazed throughout without times for regeneration
- Per family herd sizes are reducing as a result of population growth and respective splitting of herds as well as due to reducing per capita pasture- and water availability (based on land bearing capacity limits reached) leading to increasing pressure and increasing vulnerability
- Livelihoods change away from pastoralist lifestyle to alternative, mostly unsustainable livelihoods
- Deforestation is increasing due to charcoal production by people needing alternative livelihoods
- Qat/Mirah is a main problem
- Increased consumptive behaviour of the population especially for Qat is resulting in increased need for income (charcoal)
- Land grabbing is taking place, mainly by people that have abandoned the pastoralist lifestyle, causing problems for the remaining pastoralists
- Urban population growth that much exceeds rural population increase is seen as a challenge fur future sustainable supply. The current Hargeysa wellfield could be at its limit judging from its slightly declining levels
- The mostly hard groundwater found in Somaliland and Puntland is a problem as not well suited for human and partly even animal consumption
- Water trucking is the current main adaptation mechanism to cope with droughts though not sustainable
- Groundwater levels have not yet been reported to decline significantly though the aquifer supplying Hargeysa is reported to be slightly overused
- The institutions in Somaliland and Puntland lack strength to implement policies and control development (e.g. land grabbing). In addition the traditional structures have been weakened and are less functional
- Policies have been put in place but implementation seems difficult
- Management of water sources is a main issue, especially Haffir dams need proper construction and management of use
- Currently there is limited industry in the country. Current developments (e.g. tanneries around Hargeysa) do not have to follow environmental regulations and could potentially have a significant potential for water pollution and resulting reduction in water availability
- Conflicts arising between pastoralists and charcoal burners show the increasing population pressure on resources

As opportunities some alternatives for increasing water availability were named

- Sand dams have been shown as excellent assets for locally increasing water availability. Water currently discharged to the sea could be retained and used in this way
- Balleh dams for shallow groundwater recharge in relatively flat areas through construction of broad retention structures and collector drains which would promote concentrated water infiltration

- Boreholes – though only after detailed assessments followed by test drilling to avoid dry or salty boreholes. Borehole construction would need to be accompanied by well organized trainings of sufficient time to allow for sustainable operation of the boreholes
- Rainwater harvesting from roofs should be promoted
- Drought planning and preparedness is necessary. As boreholes when put in place attract settlements to form, a possible way forward could be boreholes that will be used in emergencies only – though it could be expected that a “permanent emergency” state would be reached soon, resulting in the borehole to be used permanently

2.3.2 Second stakeholder workshop – presentation of results

A two day stakeholder workshop was held in Hargeysa, Somaliland, during 28.-29.11.2012. The workshop focussed on both technical as well as institutional and policy aspects with an agenda as follows:

Technical aspects including potential for implementation

1. Background, recap from last workshop, drivers of problems
2. Present and discuss situational analysis and inventory of
   - areas suitable for management of aquifer recharge and
   - aquifer recharge techniques including indigenous approaches;
3. Present and discuss draft plan for establishing a groundwater monitoring and early warning system in Somaliland and Puntland

Institutional and policy aspects

1. Policy background, current situation
2. Present and discuss
   - components for a draft policy on the use of groundwater in emergency situations for Somaliland and Puntland considering rural and urban areas
   - proposed actionable strategies and policies for drought management, with specific consideration of vulnerabilities, opportunities and potentials for adaptation
3. Present and discuss inventory of existing knowledge and capacities in Somaliland and Puntland for drought mitigation and planning

Participants contributed excellently to the aspects discussed in the workshop and provided significant input especially on the questions what recommendations would- and what would not work under the local conditions

2.4 Data analysis and projections

Available datasets were collected, sorted, checked for consistency and analyzed with regards to the study objectives, the results are presented in this report.

The situational analysis which forms a main part of the assignment was carried out by holistically evaluating the available information and data to compile a picture of the current situation. A respective section structure in this report was used for a logical presentation of the results.

3. General area description

An overview of the areas of Somaliland and Puntland is given in Figure 1. Somaliland is situated in north-west, with a land area of 137,600 km^2. Puntland is situated in north-east, and occupies a total land area of 212,510 km^2. Some of the main towns in the region are: Hargeysa (>500,000 inhabitants), Boosaaso (>110,000), Burco (>100,000), Boorama (>80,000), Garowe (>35,000), and Gaalkacyo, Ceerigaabo, Laas Caanood (all over 30,000) (SWALIM, 2012). The entire region faces high population growth with on average 4.3%, calculated based on UNDP figures between 1999 and 2005. For the urban centres the situation is exacerbated with annual growth rates of partly over 20% for example in Hargeisa.

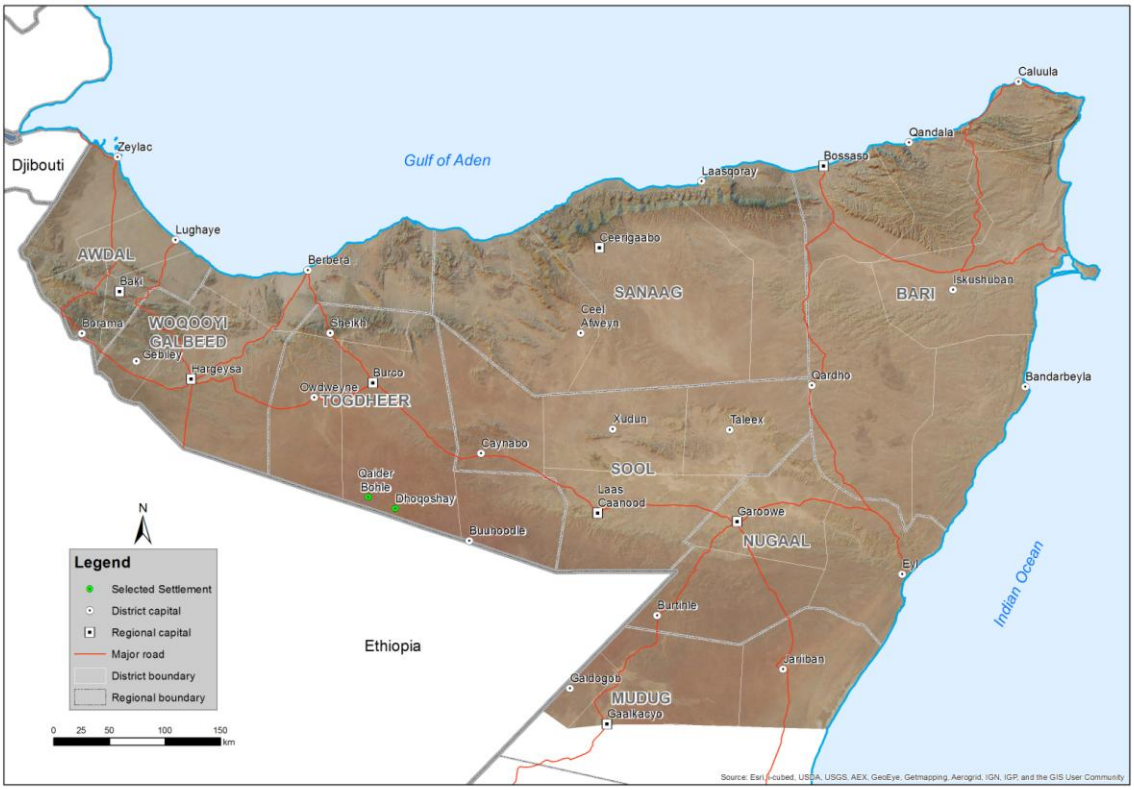

Figure 1: Map of Somaliland and Puntland

Somaliland and Puntland have a varying topography featuring coastal plains, mountain ranges and a plateau. Altitude ranges between sea level and 2,400m.

Faillace & Faillace (1986) stated that the region can be divided into three major physiographic provinces which again are divided into seven sub-divisions (hydrogeological provinces) with similar hydrogeological characteristics:

1. The coastal belt and sloping plain
   a. Gulf of Aden Coast
   b. Sloping Plains
2. The mountainous zone incised by the numerous Toggas

    a. Mountainous Zone
3. The plateaus and valleys which include the large undulated Hawd and Sool plateaus and the Nugaal and Dharoor valleys
    a. Dharoor Depression
    b. Hawd Plateau
    c. Taleex Plateau and Nugaal Valley
    d. Sool-Hawd and Sool Plateaus

The limits between some provinces are not always well defined. In fact, the geological formations of the Hawd, Sool-Hawd, and Sool plateaus belong to the Eocene and are widely exposed in these areas. At a regional scale the movement and discharge of groundwater is better defined within the subdivision of the area according to the three major physiographic provinces than within the seven hydrogeological provinces. The respective geology of the area was described extensively by Faillace & Faillace (1986).

3.1 Climate

The climate in the region varies from desert in the north-eastern parts of the coastal areas of the Gulf of Aden basin and some areas in the Dharoor basin in the north-east; to arid and semi arid in much of the Gulf of Aden basin.

SWALIM Technical Report No. W-01 provides an overview of the climate of Somaliland and Puntland. The area is characterized as arid and semi-arid (moist semi-arid climate is prevailing in the mountainous areas of the Gulf of Aden) and rainfall is generally low and erratic. There is a significant spatial variation in the rainfall in the area as studied by Basnyat (2007). The mountain region in the western part of the Gulf of Aden basin receives more than 500 mm of annual rainfall e.g. Boorama (543 mm) and in Sheikh (515 mm). However, the coastal areas in the northern part of the Gulf of Aden receive very little annual rainfall (less than 20 mm in Berbera, Caluula and Boosaaso. The catchment areas in the Dharoor basin also receive little water (e.g. Iskushuban 72 mm) The western part of the Nugaal basin near the mountains receive about 240 mm (e.g.Burco) and further east it decreases to about 110 mm (e.g. Qardho). The Somali areas of Ogaden basin receive from 205 mm (Ceelbuur) to 170 mm (Gaalkacyo). In addition the temporal variation (annual and inter-annual) is high and erratic.

The distribution of rainfall is linked to the four seasons:
- Jilaal the northeast monsoon, a dry and hot season from December to March
- Gu a transition period, an important rainy season from April to May
- Xagaa the southwest monsoon, a dry and hot season from June to September
- Deyr second transition period, an important rainy season from October to November.

Climate shifts towards very hot and very arid regime during Jilaal and Xagaa seasons and at the beginnings of rainy seasons, particularly the Gu season. Despite Deyr wet character the areal percentage of rainfall can be quite low as in the Gulf of Aden. The mountainous western region of the Gulf of Aden basin e.g. Boorama receives a good amount of rainfall in Xagaa compared to Deyr and other seasons. Rainfall in Gu and Xagaa seasons is good for rain-fed agriculture. The locations in the coastal regions (stations Caluula, Boosaaso and Berbera) receive very little rain. Basnyat (2007) noticed that in the case of basins out of the coast, about 50% and 30% of the annual rainfall occur in the Gu and Deyr seasons, respectively. He also noticed that in terms of the seasonal variations of the rainfall, there is an exponential correlation between elevations and Xagaa rainfall and inverse- exponential correlation between elevation and Deyr rainfall. In higher elevations especially in the north-western regions there is more Xagaa rainfall than in other regions and less of Deyr rainfall. However, no correlation was seen in the % of rainfall falling in Jilaal and Gu seasons.

Annual Potential Evapotranspiration (PET) exceeds 2,000 mm in the northern basins and is even as high as 3000 mm in the Gulf of Aden. In most locations, PET exceeds rainfall in all months of the year. Except for few locations in the extreme northwest, even 0.5 PET exceeds rainfall in all months giving zero values for the longest vegetation growing period in most of the areas. This is why most areas in the northern basins are not suitable for agriculture (Basnyat, 2007).

The mean air temperatures are generally high: in the range of about 25° C to more than 35° C in the northern coastal regions (e.g. Berbera and Boosaaso) while it is cooler in the north-western mountain region (e.g. Shiekh) where it varies from about 15° C to about 23° C. In the inland areas of the Dharoor, Togdheer/Nugaal basins, it varies between 22° C to about 33° C. The mean temperature is highest from June to August in the Gulf of Aden basin areas whereas the peak temperature occurs from May to September in the inland areas of the Dharoor, Togdheer/Nugaal and Ogaden basins. In the eastern coastal areas of the Central Coastal basin, the mean temperature is cooler than the inland and northern coastal regions and is more or less constant between 25° C to about 28° C throughout the year.

Somaliland and Puntland are likely exposed to the climate variations and changes more than some other parts of African continent. Hemming (1966, cited by German Agro-Action, 2005) stated that Somaliland has been in a state of ecological change for many decades if not hundreds of years, and practically all the changes have been towards a reduction in the vegetation cover. This assessment suggests that the most recent process of climatic change has been one of decreasing rainfall and that desertification has proceeded considerably in the last 500 years. Butzer (1961) has constructed a map indicating the percentage rainfall decrease during the period 1911-1940 and he places most of Somaliland between 20 and 25% reduction. A significant portion of the reduction in vegetation cover and desertification can anyhow be attributed to the growing population with respective increase in grazing pressure.

Details of the climatic conditions for the different basins are described in the following Sections, based on SWALIM, 2009. An overview of the basins is shown in Figure 2.

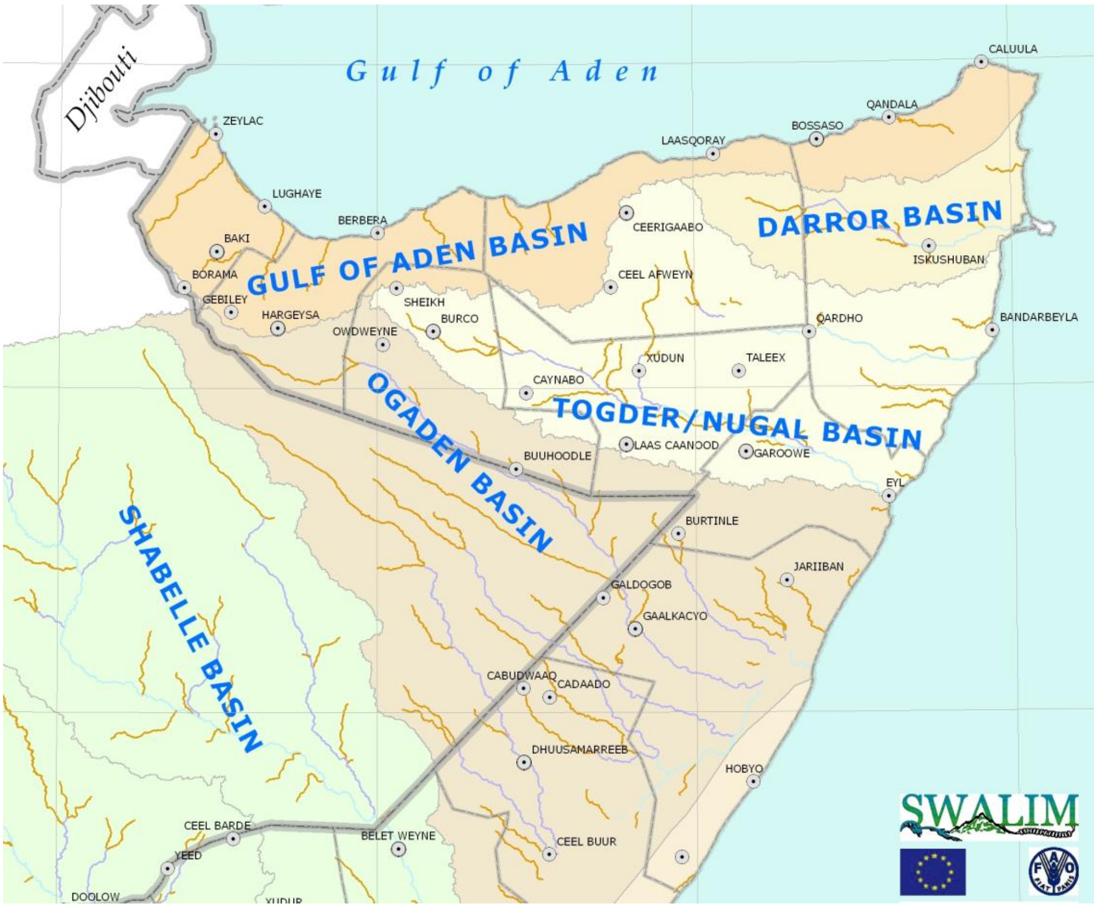

Figure 2: Major drainage basins in Somaliland and Puntland

3.1.1 Climate of the Gulf of Aden drainage basin

The climate in this basin is very varied. Mostly arid and semi-arid though subhumid in pockets. The coastal strip is classified as desert climate owing to its low rains. An overview of climatic conditions is shown in Table 1.

The rainfall in the drainage basin is low and erratic with 210 mm/year in average. The coastal region receives less than 100 mm (less than 20 mm in Caluula, Boosaaso and Berbera) of annual rainfall. The rainfall increases inland where up to more than 500 mm annual rainfall is received e.g. Boorama (543 mm) and in Sheikh (515 mm). The basin 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 distinct seasons of dry periods: Jilaal and Xagaa 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. The Gu rains start to reduce in June in most parts of the basin save for the mountainous areas around Boorama 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 2,700 to 3,000 mm per annum in the north-east coastal regions (Caluula and Berbera) whereas it is only 1,460 to 1,630 mm per annum inland. The rate of evaporation is generally higher than rainfall throughout the year.

Mean temperature is high in the range of about 25°C to more than 35°C in the northern coastal regions (e.g. Berbera and Boosaaso) while it is cooler in the north-western mountain region (e.g. Hargeysa) where it varies from about 15°C to about 23°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 (Caluula and Berbera) is higher (70-75%) than inland.

Table 1: Mean monthly meteorological conditions for the Gulf of Aden basin

Weather parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	4	7	15	39	25	12	21	33	30	10	11	4
PET (mm)	164	140	176	176	209	274	282	284	238	179	146	141
Mean Temp (°C)	23	23	25	27	28	31	31	30	29	26	24	23

3.1.2 Climate of the Dharoor drainage basin

Within the Dharoor drainage basin, climate is mostly desert with less than 100 mm of rainfall per year 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 may cause localized flooding and soil erosion in the steeper mountainous areas in the northern and southern parts of the basin. An overview of climatic conditions is shown in Table 2.

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 rainfall. 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 °C of mean daily temperature. December and January are the coolest months of the year; 20 to 23 °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 2,700 mm per annum with maximum evaporation rates taking place in the months of June to September.

Table 2: Mean monthly climate statistics in Dharoor drainage basin

Weather parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	0	0	3	22	21	2	0	5	7	6	5	1
PET (mm)	174	151	198	201	273	315	301	310	288	208	165	171
Temperature (°C)	26	26	29	32	35	35	34	34	34	31	28	27

3.1.3 Climate of the Togdheer/Nugaal drainage basin

Rainfall in the Togdheer/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. However, some areas around Burco, and the mountainous areas of Ceerigaabo receive and average of up to 400mm per annum and is classified as semi arid areas. The central areas of the basin including Qardho, Laas Caanood 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 Xagaa 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 Xagaa season is very important for rain fed agriculture which is common in some parts of the basin. An overview of climatic conditions is shown in Table 3.

Potential evapotranspiration (PET) ranges from about 2,100 mm in Burco to 2,700 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° C to more than 33° 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.

Table 3: Mean monthly climate statistics in Nugaal drainage basin

Weather parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	0	0	3	22	21	2	0	5	7	6	5	1
PET (mm)	174	151	198	201	273	315	301	310	288	208	165	171
Mean Temp (°C)	26	26	29	32	35	35	34	34	34	31	28	27

3.1.4 Climate of the Ogaden drainage basin

Rainfall in Ogaden drainage basins is low and erratic. There are both seasonal as well as 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 semi arid climate zone. The area to the south of the basin bordering the Shabelle basin in southern Somalia is also semi arid with annual rains of up to 400 mm/year. The rest of the basin which includes the central parts is largely classified as desert.

Potential evapotranspiration (PET) ranges from about 2,100 in Burco to 3,000 mm in the coastal regions. In general the evaporation is higher than rainfall throughout 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° C to more than 33° C. March and April are the hottest months of the year in this basin.

3.2 Groundwater resources

3.2.1 Groundwater situational analysis

While locally varying, the general hydrogeological conditions in Somaliland and Puntland can be described as challenging with regards to water availability and water quality. Climatic conditions range from semi-arid to arid and surface water availability as well as shallow groundwater levels fluctuate with the rainfall intensities in the different seasons. High salt concentrations in the groundwater of many wells render them marginally suitable or unsuitable for humans and/or livestock. Groundwater, being the primary source of water supply, is generally obtained from boreholes, dams, dugwells and springs. An overview of the distribution of these water sources is shown in Figure 3.

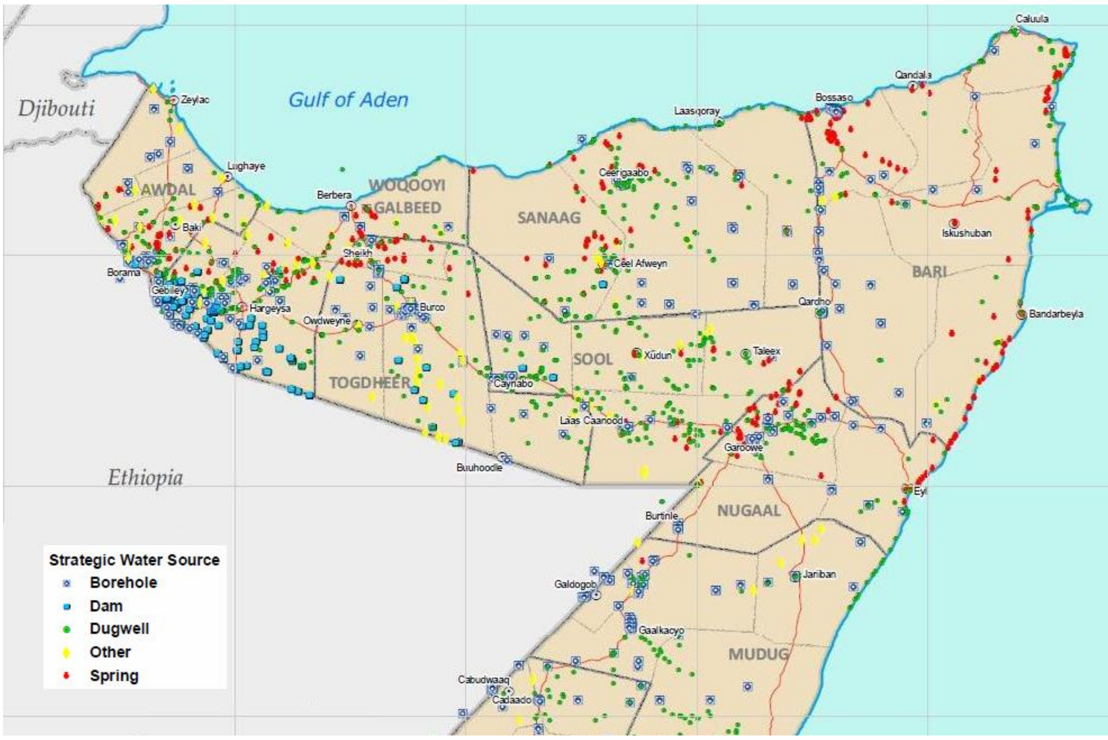

Figure 3: Distribution of strategic water sources

Previous hydrogeology surveys

The water resources situation in Somaliland and Puntland is characterized by water scarcity and low water quality, affecting livestock and human population by restricted water availability. Respectively, a variety of hydrologic and hydrogeologic surveys have been conducted to investigate the situation. Investigations were fragmented and results, due to the civil war, were lost and scattered but have been collected by SWALIM as far as possible. Most information was anyhow collected during recent surveys. The results of the most recent work, as well as a summary of previous work has been included in the final SWALIM Phase IV report "Hydrogeological Assessment of Somaliland and Puntland", 2012.

Hydrogeology

As part of the SWALIM (2012) "Hydrogeological Assessment of Somaliland and Puntland", a classification of main geological formations in accordance with their permeability and groundwater potential has been carried out. Further details regarding the hydrogeological characteristics of the main geological formations have been described by SWALIM (2012). A thumbnail of the available geological map is shown in Figure 4.

1. Basement Complex (Proterozoic): ortogneiss, schists, quartzites, marbles, paragneiss intruded by granites. Fissured aquifer to aquitard of low permeability. Locally used.

2. Jurassic (J): thick sequences of continental deposits – sandstones (J1) followed by marine limestones beds (>1,000m) slightly sandy in terminal sections. Well permeable and karstified aquifer, productive wells.
3. Cretaceous (K): in NE regions, neritic limestones and thick continental sandstones (Nubian facies, >1,700m). Forming barrier along Togga beds. Fissured aquifer, low to moderate permeability. Low productive wells.
4. Lower Eocene E1 – Auradu Formation.: white, grey massive limestones (Hargeysa, Burco, Ceerigaabo, Qanadala). Max. thickness 380m. In upper parts Allahkajid beds are gypsiferous and chalky. Well karstified, fresh groundwater reservoir of great importance.
5. Middle Eocene E2 - Taleex Formation. (Sool region etc.). Evaportic rocks from arid lagoonal depositional environment (~250m). Gypsum, anhydrite to limestones, well bedded. Fissured – karstic aquifer, low to moderate permeability, often with saline groundwater.
6. Upper Miocene E3 – Karkar Formation. Bedded marly limestones and marls (> 200m). N of Shiikh Daban series of lagoonal sandstones is replacing Karkar limestones. Fissured-karstic aquifer moderate to well permeability.
7. Oligocene/Miocene – Ol,M: Upper Daban Formation. of thick gypsiferous sandstones (>2,000m!) and Iskushuban Formation. Along Ocean of coarse sandstones and limestones. Fissured aquifer of low permeability.
8. Pleistocene basalts. Fissured aquifer, cover of younger formations, well permeable.
9. Quaternary – recent deposits: Togga's alluvium, sand dunes, beach sands, red soils, calcrete – lateritic crusts.

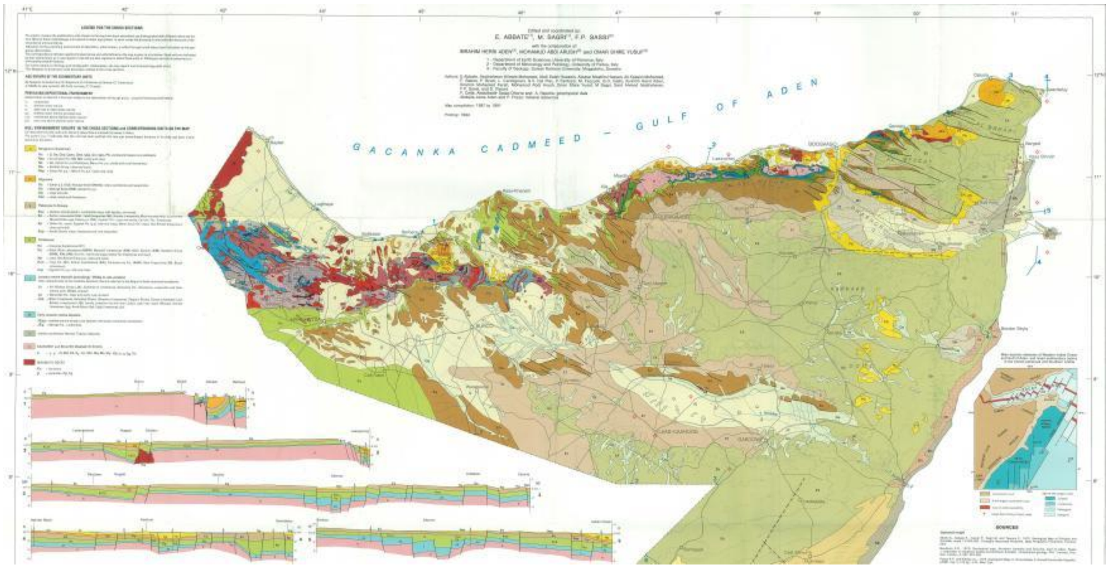

Figure 4: Geological map of Somaliland and Puntland

Groundwater sources and use

Water resources used in Somaliland and Puntland include Berkads and small dams for surface water catchments, while springs, shallow wells and boreholes are used for tapping the groundwater resources. They are distributed according to suitability with regards to terrain, water resource availability and aquifer characteristics. Groundwater yields vary widely. While surface catchments rely on the quantity, intensity and frequency of rains, groundwater yields depend on the aquifer characteristics including yield, recharge and water quality. Pumping tests carried out in boreholes throughout the region were described by Milanovic (2012), showing characteristics as shown in Table 4. The results indicate a widely varying extraction potential considering the required extraction efforts (depth) and possible safe yield.

Table 4: Borehole characteristics in Somaliland and Puntland based on pumping tests in 27 boreholes (Milancovic, 2012)

	Borehole depth m	Water depth m	Drawdown m	Duration h	Discharge l/s
Min	91	2	2	0	2
Max	403	215	163	48	20
Average	179	56	34	-	10

* pumping duration varying between zero and 48 hours depending on yield

Groundwater aquifers

Groundwater aquifers in Somaliland and Puntland are characterized by strongly changing conditions regarding depths, yields and quality aspects. Recharge to the aquifers is limited as dependent on the surface rainfall and evaporation as well as runoff characteristics. Areas of groundwater potential considering water quality and aquifer depth can be tabulated as follows (Milanovic, 2011):

- Water quality fair to good, well depths shallow to moderate
    - shallow aquifers in the sand dunes in the central coastal belt
    - northern coastal regions
    - along the streams in the mountainous areas and sloping escarpment
    - coastal belt along the Gulf of Aden
- Water quality very poor and wells drilled often very deep
    - deep aquifers in the Mudug – Galgaduud plateau
    - plateaus and valleys in Dharoor basin
    - plateaus and valleys in Togdheer/Nugaal basins
    - plateaus in Hawd and Sool plateaus and valleys

Milanovic (2011) further summarized that potentially productive aquifers occur extensively throughout Somaliland and Puntland. Shallow perched aquifers are often found in the alluvial sediments within the dry river beds and adjacent flood plains. The water table configuration varies between 2 – 20 m. Shallow dug wells are developed within these perched aquifers and used by a majority of both the rural and urban populations in Somaliland and Puntland.

Deep water aquifers are often found in alluvial deposits within the old river bed channels, the Karkaar, Taleh (Taleex), and Auradu formations. The water table profile varies between 30 – 450 m. The majority of wells drilled within these materials from later geologic times produce hard water often with a high content of sulphates, bicarbonates, carbonates, chlorides, etc. Nonetheless, these aquifers serve as the main sources of water in the region. The many productive water wells which have been drilled over the years attest to this fact.

Groundwater quality

Groundwater quality was studied by Milanovic (2011) who describes groundwater quality as related to the chemical composition of geological formations through which the water has passed, as well as to the balance between recharge and discharge. Concentrations of chemical components in groundwater vary widely within the Somaliland and Puntland areas, depending on the location and type of hydrogeological objects (spring, dug well, drilled well). Generally, groundwater quality in the study area is poor and usually does not meet all WHO guidelines for acceptable drinking water.

In general, very few groundwater sources in Somaliland and Puntland will conform to international standards. The salt content of the water commonly exceeds 1 g/l, which under normal circumstances is the upper limit for human consumption. In Somaliland and Puntland anyhow, acceptance of water with relatively high ion concentrations is a necessity, as there is usually no alternative.

Suitability limits have been defined as follows (WHO):

TDS (gr/l)	Suitability
0 – 1.0:	Suitable for all normal purposes
1.1 – 3.0:	Suitable for livestock, marginal for human consumption
3.1 – 5.0:	Suitable for livestock, unsuitable for human consumption
5.1 – 7.0:	Suitable for camels, marginal for other livestock
7.1 – 10.0:	Suitable for camels, marginal for goats and sheep, unsuitable for cattle
10.0 – 15.0:	Marginal for camels, only in emergencies for goats and sheep
> 15:	Unsuitable for any domesticated animal life

In addition Milanovic (2012) observed that shallow aquifers are often bacteriologically contaminated and may cause epidemics like cholera, diarrhoea and dysentery.

The quality of the groundwater varies by region and depends mainly on the underlying rock formations and their thickness. Some examples:

- Bari region: The EC varies between approximately 1,139 to 4,000 μS/cm with pH ranges of 7.4 – 7.8
- Sanaag, Nugaal, Sool and Mudug regions: The EC varies between approximately 2,100 to 5,500 μS/cm with a pH in the range of 7.6 – 8.0
- Awdal, Galbeedand Togdheer regions: The EC ranges between 417 to approximately 4,000 μS/cm with a pH in the range of 7.0 – 7.6

The water quality of main deep aquifers as found within the Karkaar, Taleh (Taleex), and Auradu formations is very poor. In the majority of the boreholes drilled within these formations, the salinity levels go beyond the potable drinking standards. Nevertheless, in an arid landscape like Somaliland and Puntland, where water is scarce, it is difficult to maintain water quality standards and thus define areas where water can be used for different purposes. Water quality acceptance is subject to availability and the habits of the people. Respectively the consumption of saline water is customary and tolerated in the region.

Water demand and availability

Water demand and availability was analyzed by Stevanovic (2012) based on field research and previous studies by different authors. Given the lack of perennial streams and the mostly arid climate with little rainfall in Somaliland and Puntland, groundwater represents the sole reliable water resource in most of the study area. However, aquifers are limited, mostly deep and often highly saline or low yielding compared to the rising demand that is driven by population growth.

Hargeysa, the capital of Somaliland is an example for this excessive growth. It is located at the edge of the Hawd Plateau. Its population has increased considerably, particularly during the last half century. From a small village with 2,000 in habitants in 1930, Hargeysa today is home to nearly one million inhabitants, or around one quarter of the total population of Somaliland according to the 2009 census. While being fed from hand dug wells along the water courses in its early stages, Hargeysa is today fed by an external water source from the Geed Deeble alluvial sedimentary basin, about 25 km north-northwest of Hargeysa with a total yield of 4,000 m^3/day. The recharge in this wellfield has been observed by Faillace & Faillace (1986) who reported that water level observation in some boreholes show that a certain amount of recharge occurs during the rainy season. Fluctuations of 3.12 and 3.60 m were observed in boreholes K1 and K12 respectively. Recharge in boreholes K1 and K2 is very fast, as was observed in March 1982, when water levels rose 1.80 and 0.70 m respectively, after 82 mm of rain had fallen on the Geed Deeble valley. The water level however fell rapidly once the flood subsided. Overall, the groundwater balance, calculated on the basis of the yearly water level fluctuation and on the amount of abstraction, shows that the hydrological balance in 1976 and 1977 was positive due to limited abstraction whereas after 1976-1977 it was always negative. According to the Chinese Well Drilling Team (1986), about 1,200 m^3/day were exploited in excess of the daily recharge of the basin and the annual drop of the water level in the valley was 1.25 m. Today abstraction has increased even further into unsustainable conditions. The situation is representative for many parts of the country in Boorama (Awdal) for example, drawdown rates have accelerated from 0.2-0.3 m/year in 1986 to 3-4 m/year after 2004 (Petrucci, 2008).

Based on their regional assessment using field data and existing reports, Stevanovic (2012) concluded that if the amount of around 60 l/capita/day is considered an adequate standard for water requirement in urban areas of Somaliland and Puntland (this figure is debatable given the general low water availability), the total water demands for 2.5 million residents are 150 x 103 m^3, which is equivalent to 1.77 m^3/s. Considering the fact that the current extraction rate for these settlements is 0.74 m^3/s (according to information provided by the water utilities), there is a shortage of around 1 m^3/s, or, in other words, 60% of actual water needs for 12 cities are not being met.

Faillace and Faillace (1986) also describe the difficulties with regards to groundwater drilling in Somaliland and Puntland, quoting Macfadyen (1951). “Four boreholes were drilled for the military in 1903-1904, between Shiikh (Sheikh) and Buuhoodle; all failed to find water. Altogether about 3,200 meters were drilled. The depth of these exploratory boreholes ranged from 6 to 135 m. Out of the 46 boreholes, only 9 were deeper than 100 m; the deepest borehole was drilled in Hargeysa. Results were very unsatisfactory: 22 boreholes were dry, 8 had a yield ranging from 1.1 to 1.4 m^3/h, and 7 had a yield ranging from 3.3 to 9 m^3/h. A borehole drilled in Seylac, 74 m deep, struck salt water. Macfadyen also reports six boreholes drilled in the Hawd Plateau: three were drilled in Qaidr Boleh, one in Sigr Adr, and one in Dughoshe. The deepest was a borehole drilled in Qaidr Boleh which was 175 m deep; it found only little water and was abandoned. The other boreholes were dry. In the late 1950s 12 exploratory boreholes were drilled for the water supply of Hargeysa. The deepest reached 335 m. Eight were dry, three yielded marginal water in little amounts, and one yielded water of good quality but had a small yield. To solve the water supply problem of Hargeysa 16 boreholes were drilled by the Chinese in Geed Deeble in 1970 and in 1982; 12 are production wells with yields ranging from 39 to 90 m^3/hr; the depth of these production wells ranges from 90 to 207 m. All wells were drilled in old alluvial deposits.”

In the recent years some updated information about water sources and points resulted from the survey conducted by UNICEF and FAO/SWALIM (2009). UNICEF has undertaken a number of inventories in 1999 on the water sources in Puntland and Somaliland. FAO/SWALIM, with the help of partner agencies, was also collecting data on the water sources for creating a database called the Somalia Water Source Information Management System (SWIMS). Next to collecting existing data, an inventory of the strategic water sources was created through extensive field work.

3.2.2 GW database

Groundwater data for Somaliland and Puntland is stored in FAO-SWALIM´s Soil and Water source information management system (SWIMS). Data is scarce and only available for a few years and few boreholes and wells. Groundwater measurements with regards to water tables with a wider spatial coverage are available from two measuring campaigns in 2008 and 2012. The datasets are not entirely matching so a comparison has been conducted based on spot examples as shown in Table 5 and Table 6. Results show a decline in water levels both in the shallow wells as well as in the boreholes over the four year period. The declining levels are seen in most boreholes, even in rural locations. An overview is shown in Figure 5. Comparing the values the different dates and the relation of the shallow water tables to the season needs to be considered. The 2008 mission was conducted in May/June, i.e. at the end of the Gu rains, the 2012 mission took place in January, i.e. in the Jilaal dry season and more than two month after the end of the not so heavy Deyr rains. Lower water levels can therefore be expected in the second campaign due to increased abstraction as well as possibly links to recharge, the reason for the reduced water levels can respectively not be clearly allocated to the well utilization.

Table 5: Water tables in selected shallow wells
data from 2009 SWMIS and 2012 hydrogeological survey conducted by SWALIM

SOURCENAME	LAT	LON	DATE	SWL (m)	DATE	SWL (m)	Delta (m) 08-12
Badhan	10.7139	48.3364	14.06.08	1.7	23.01.12	4.6	-2.9
Ceel Af Weyne	9.9211	47.2199	18.05.08	1.5	17.01.12	1.0	0.5
Ceel Dhaab	8.9395	46.4969	15.05.08	2	03.01.12	4.5	-2.5
Fadhi Gaab 1	9.6688	47.0158	18.05.08	0.5	12.01.12	3.0	-2.5
Hali Bixisay	8.9589	46.6091	17.05.08	0.5	03.01.12	0.3	0.2
Higlo	9.0987	46.0858	15.06.08	3	03.01.12	5.0	-2.0
Lawyo Cado	11.4325	43.2950	15.05.08	3	21.01.12	3.5	-0.5
Sin Carro	9.4766	47.0756	18.05.08	12	11.01.12	16.5	-4.5
Tokhoshi	11.3291	43.4190	14.05.08	2	22.01.12	3.0	-1.0
Udaan	9.7033	43.8853	15.06.08	0.5	02.01.12	1.0	-0.5
Ulasan 1	9.0265	46.1864	15.06.08	6	03.01.12	6.0	0.0
Yufle	10.3813	47.1954	26.06.08	2	19.01.12	6.0	-4.0
						Av.	**-1.6**

Table 6: Water tables in selected boreholes
data from 2009 SWMIS and 2012 hydrogeological survey conducted by SWALIM

SOURCENAME	LAT	LON	DATE	SWL (m)	DATE	SWL (m)	Delta 08-12 (m)
Afraaga	9.9432	43.0761	24.05.08	101	10.01.12	106	-5.0
Darar Weyne	9.5797	47.5210	06.10.08	190	16.01.12	190	0.0
Dila 2	9.7685	43.3359	18.06.08	33	09.01.12	35	-2.0
Jidhi	10.6253	43.0719	15.05.08	30	20.01.12	34	-4.0
						Av.	**-2.8**

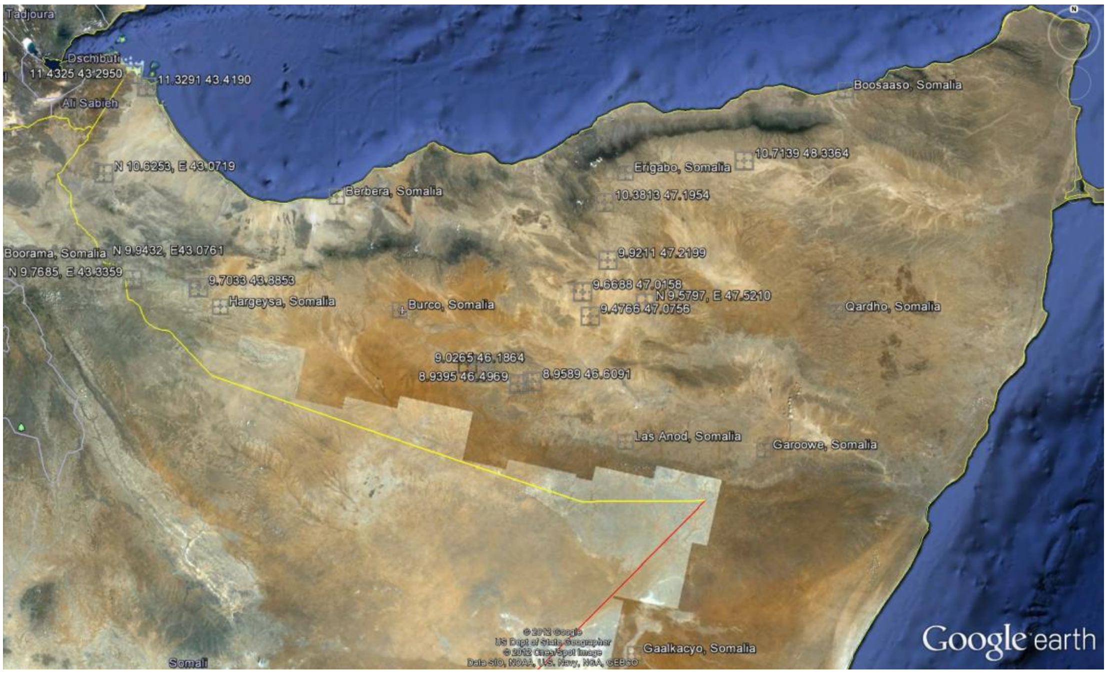

Figure 5: Groundwater observation locations for 2008 and 2012
Campaign carried out by FAO SWALIM

3.3 Surface water

The surface waters of Somaliland and Puntland have been described in the SWALIM Technical Report No. W-11 and belong to three major river basins:

- Gulf of Aden basin
- Daroor basin
- Togdheer/ Nugaal basin

There are no any perennial streams in the region. The rivers and drainages have surface water only after periods of heavy rainfall. There are, however, many small streams called Toggas (Wadis) originating from the plateaus and mountains that have perennial flows in some stretches and at other stretches have a complex surface-water groundwater interaction (subsurface flow) where there is groundwater recharge. After intense rainfall, most of these small streams can carry high floods as well as sediment and debris. The surface runoff lasts from a few hours to a few days.

The drainage network, which is influenced by local topography, rainfall, and geology, is dense to very dense in the northern mountains. It is very thin or virtually non-existent in large parts of the central basin. Runoff in Somaliland and Puntland basins generally takes place in seasonal streams (Toggas) and in addition to infiltration, it replenishes stream bed and flood plain aquifers. Runoff only occurs after heavy rainfalls in the form of spate flows, which may last from a few hours to a several days. In their mountainous sections, particularly in reaches where bedrock is exposed, the flow may be permanent in some springs along the mountains such as Iskushuban spring. In sandy fans and in valley bottoms in the gently rolling topography large quantities of water are infiltrated into the aquifers. Evaporation and overland flows are also high in these plains. It could be said that little runoff reaches the seas

Surface water resources are limited so the population largely relies on shallow and deep groundwater resources, problems occur where groundwater is brackish or saline. Aquifers have been investigated by various organizations mainly using geo-electric resistivity (vertical electrical sounding) tests though problems exist with regards to result analysis and accuracy as pointed out by Melchioly (2011), leading to partly questionable results and recommendations and respectively dry boreholes drilled.

3.3.1 Surface water situational analysis

The surface water situation for Somaliland and Puntland has been comprehensively described by SWALIM (2009) in their “Inventory of Drainage Basins of Northern Somalia”. Information is extracted in the following sections.

The major drainage basins in the region are: the Gulf of Aden Basin, Dharoor Basin, Togdheer/Nugaal Basin and Ogaden Basin (Figure 6). 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.

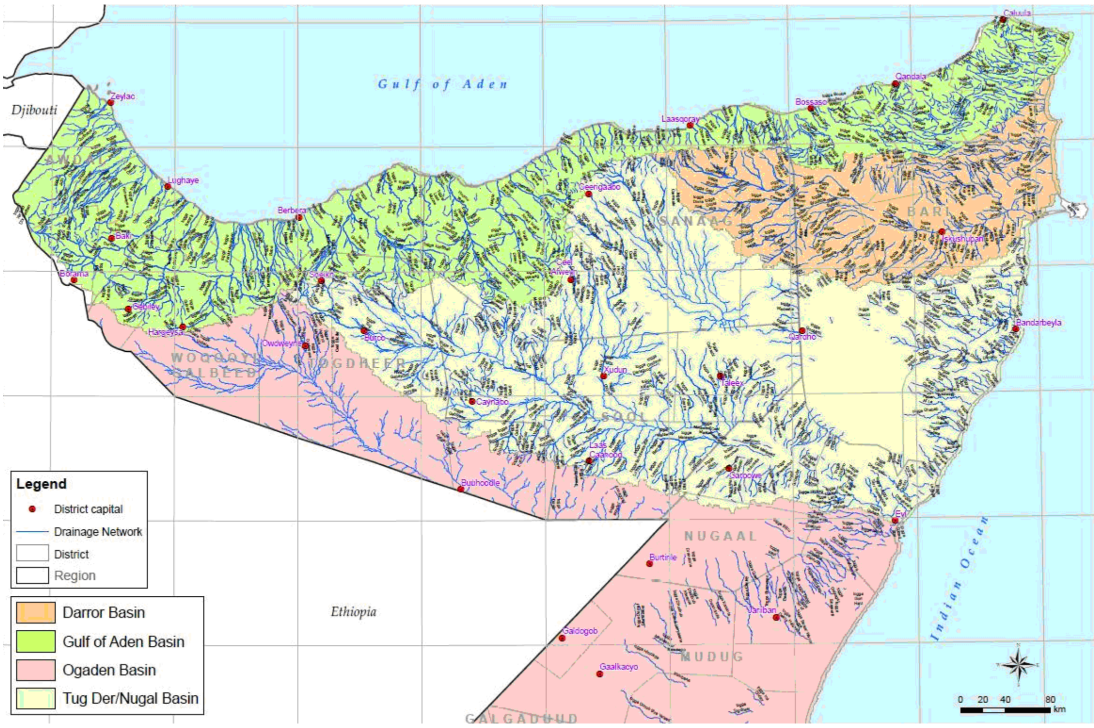

Figure 6: Drainage basins and drainage network in Somaliland and Puntland

The drainage 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.

Gulf of Aden drainage basin

The Gulf of Aden basin, situated in the northern parts, covers the areas drained by the small Wadis and Toggas that originate from the gently sloping plateau and pass through the mountain range extending in an east-west direction. The drainage area is spread over five administrative regions - Awdal, Waqooyi Galbeed, Togdheer, Sanaag and Bari.

Population estimates (UNDP 2008) in some of the towns include; Boorama (82,921), Hargeysa (422,515), Berbera, Ceerigaabo (31,098), Boosaaso (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. The Gulf of Aden basin includes a variety of morphological features, such as accentuated relief, escarpment, steep slopes, coastal plains, internal plateaus and valleys. 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. The water from the Toggas barely reaches the seas but infiltrates in the coastal plains.

Watershed delineation by SWALIM from 90m DEM (Figure 4) 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 Boorama, Hargeysa and from Sheikh to Ceerigaabo 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 (Ballehs). Flows in Toggas mostly occur as spates which transport large amount of sediment. The Wadis and Toggas, as seasonal streams, 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.

Only few and short term surface water monitoring has been done in any of these Wadis and Toggas. Assessments were conducted, e.g. by Sogreah who investigated that, on average, for unit drainage areas of 100 km^2 on the plateau, the runoff threshold is 24 mm of rainfall 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.

Dharoor drainage basin

The Dharoor 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 Togdheer/Nugaal basin. The basin lies within central parts of Bari administrative region and another small portion falling in the eastern parts of Sanaag region. There is only one major town in this basin which is Iskushuban. 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.

Dharoor drainage basin is drained by a fairly dense network of seasonal streams. Much of the surface water of the Dharoor basin is ephemeral and commonly appearing as seasonal ponds (Ballehs). 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 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, the small streams can carry high floods and debris.

Togdheer/Nugaal drainage basin

The Togdheer/Nugaal basin lies within five administrative regions: 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 Laas Caanood, Burco, Ceerigaabo and Qardho.

Togdheer and Tog Nugaal 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 Tog Nugaal drains the Nugaal region and parts of the Togdheer and Sool regions. The Sool Plateau is a nearly featureless plain covered by limestone and marls which lies between the Dharoor and Nugaal valleys. A large part of the drainage basin is made up of gently sloping plains such as the Sool Plateau, Sool Hawd and Qardho Plateaus, and the Karman and Gubato plains. An interesting part of this drainage basin is the Xingalool internal drainage basin which receives water from the Sool Hawd Plateau.

In the Togdheer/Nugaal drainage basin, some surface water records are available for Togdheer at Burco 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 per year, equivalent to about 22 mm in the 1500 km^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.

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).

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 90m 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 only major urban centre (town) within the Somalia part of the drainage basin (in Puntland) is Gaalkacyo.

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 the north 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 or perennial river of any importance reaches the Indian Ocean.

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.

3.3.2 Surface water database

Surface water data for Somaliland and Puntland is limited. Hydrometric information on the basins and catchments is limited to three gauges only, from beginning 2011. While the data is not sufficient for longer term analysis it shows the peaky nature of the runoff events in the torrential riverbeds. Some basins like the Ogaden and Dharoor have never been investigated. The last larger assessment was carried out by SOGREAH in 1981 for some selected sub catchments only. The scarcity of data makes it very difficult to understand the hydrological systems and inhibits planning for any water resources investments for which an increased level of monitoring would be essential. As an example, the design and successful operation of sand dams or other water related assets requires good knowledge about the stream flows, ideally including bed flows, of strategic riverbeds without which a potential water yield cannot be assessed with sufficient accuracy.

4. Climate change

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. The United Nations Framework Convention on Climate Change (UNFCCC, 1992) defines climate change as, “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. The UNFCCC thus makes a distinction between "climate change" attributable to human activities altering the atmospheric composition, and "climate variability" attributable to natural causes. Climate change respectively has to be differentiated from climate variability.

Climate Variability is a variation in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. The term is often used to denote deviations of climatic statistics over a given period of time (e.g. a month, season or year) from the long-term statistics relating to the corresponding calendar period. In this sense, climate variability is measured by those deviations, which are usually termed anomalies. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

A well understood occurrence of climate variability is the naturally occurring phenomenon known as the El Nino-Southern Oscillation (ENSO), an interaction between the ocean and the atmosphere over the tropical Pacific Ocean that has important consequences for the weather around the globe. The ENSO cycle is characterized by coherent and strong variations in sea-surface temperatures, rainfall, air pressure, and atmospheric circulation across the equatorial Pacific. El Nino refers to the warm phase of the cycle, in which above-average sea-surface temperatures develop across the east-central tropical Pacific. La Nina is the cold phase of the ENSO cycle. The oscillations of the ENSO cycle typically occur on a time scale of a few years. These changes in tropical rainfall affect weather patterns throughout the world. Because of the importance of ENSO, NOAA has established a special ocean - atmosphere observing system in the tropical Pacific; this enables forecasts of El Nino events to be made well in advance.

A key difference between climate variability and change is in persistence of "anomalous" conditions. In other words, events that used to be rare occur more frequently, or vice-versa. In statistical terminology, the frequency distribution representing the probability of specific meteorological events is changed. The frequency may be either modified in amplitude or shifted about a new mean, or both.

Care must be taken not to confuse variability with change. Many regions of the world experience greater variability, than others. In some parts of the world, or in any region for certain time periods or parts of the year, the variability can be weak (i.e. there is not much difference in the conditions within that time period). In other places or time periods, the conditions can swing across a large range considering both temperatures and rainfall and exhibit strong variability.
Climate change impacts on water resources are encountered through different mechanisms. Rising temperatures will lead to an intensification of the hydrological cycle, resulting in dryer dry seasons and wetter rainy seasons, and subsequently heightened risks of more extreme and frequent floods and drought. Changing climate will also have significant impacts on the availability of water, as well as the quality and quantity of water that is available and accessible. Potential evapotranspiration rises with temperature. Consequently, even in areas with increased precipitation, higher ET rates may lead to reduced runoff, resulting in a reduction in renewable water supplies. Climate change impacts will further increase a region's susceptibility to a variety of factors, including:

- Flooding
- Droughts
- Rate of soil erosion
- Mass movement of land
- Soil moisture availability

In areas that are already vulnerable due to their limited groundwater storage availability, climate change is expected to impact the runoff-infiltration-evaporation pattern. The increasing intensity of events will lead to less infiltration and more runoff. The rising temperatures will lead to increasing evaporation. As a rule of thumb evaporation increase by approximately 10% per degree temperature rise i.e. by a total of 25-30% given the temperature projections for the horn of Africa region. Considering current rainfall numbers, this could be about 400 mm, depending on the area. The projected increase in rainfall by 15-20% though with a high uncertainty will on the other hand only yield 50-100 mm more rain in average. The conditions will lead to less soil moisture and respective reduction in plant growth, less infiltration with respectively reduced groundwater recharge but more runoff, i.e. more water will be running off in streambeds with the possibility to utilize this water for shallow groundwater recharge at carefully selected locations. Water availability is likely to be further exacerbated by poor management, elevated water tables, overuse from increasing populations, and an increase in water demand primarily from increased agricultural production (IPCC 2007).

4.1 Climate change situational analysis

Current situation

Somaliland and Puntland feature an arid to semi-arid climate, changing with location and topography.

Mean daily maximum temperatures throughout the region range from 30°C to 40°C, except at higher elevations and along the Indian Ocean coast. Mean daily minimum temperatures vary from 20°C to more than 30°C. The region experiences the greatest temperature extremes, with readings ranging from below zero in the highlands in December to more than 45°C in July in the coastal plain skirting the Gulf of Aden.

There are four main seasons, dictated by shifts in the monsoon wind patterns.

Jilaal	from December/January to March	the harshest dry season of the year
Gu	April to May/June	the main rainy season
Xagaa	Jun/July to September	the second dry season
Deyr	October to November/December	the shorter and less reliable rainy season

Most of the area receives less than 500 mm of rain annually, and a large area receives as little as 50 to 150 mm. Certain higher areas however receive more than 500mm a year. Generally, rainfall takes the form of showers or localized torrential rains and is extremely variable. A climate chart for Hargeysa is shown in Figure 7. The rainfall station network is generally widely spaced (Figure 8).

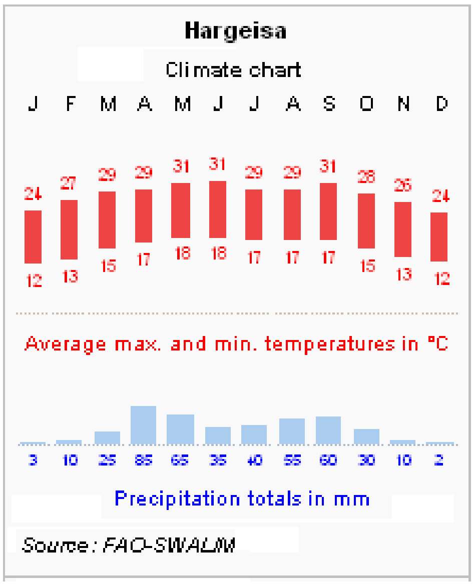

Figure 7: Climate chart for Hargeysa

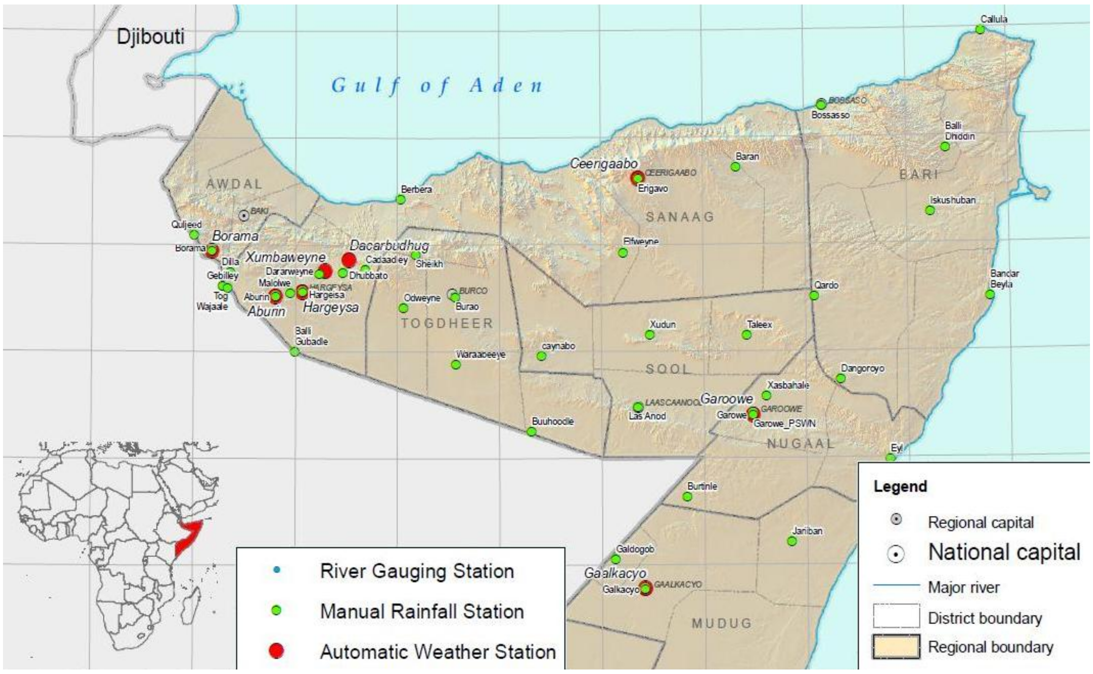

Figure 8: Overview of rainfall stations in Somaliland and Puntland

Current trends in rainfall are difficult to establish. Evaluation of annual rainfall totals show a mixed signal, which is strongly influenced by data availability and possibly data quality. Example rainfall charts are shown in Figure 9. The interrupted timeseries indicate very different trends if used without careful selection and consideration of influence of gaps leading to a high uncertainty.

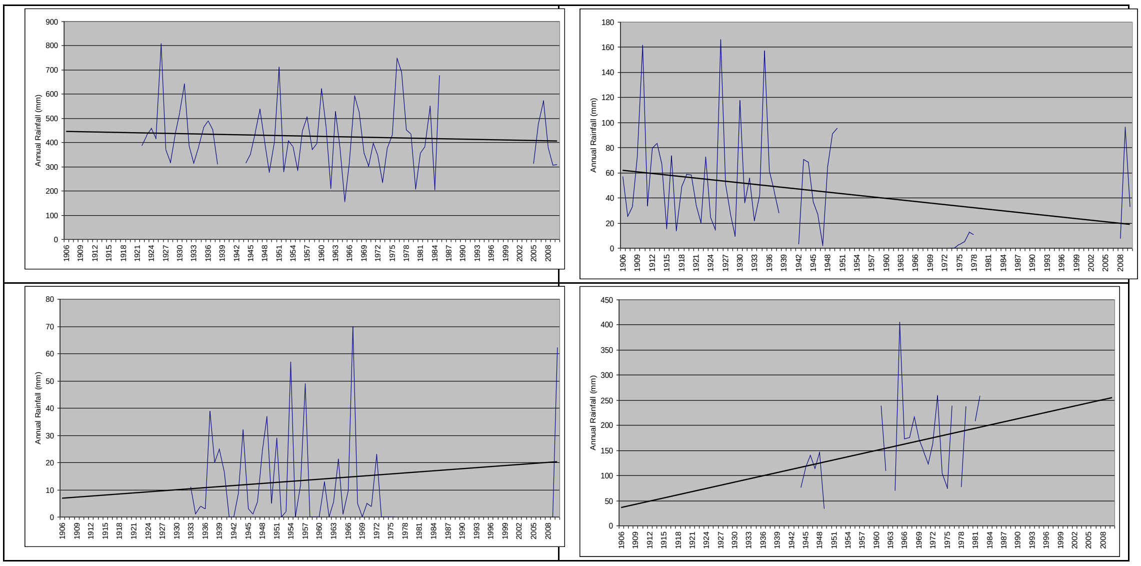

Figure 9: Annual rainfall totals 1906-2010
Hargeysa (top-left), Berbera (top-right), Boosaaso (bottom-left) and Gaalkacyo (bottom-right) showing strongly diverging trends. Especially the Gaalkacyo graph indicates the dependency of the analysis on the quality of the time series and shows that careful manual selection is needed to obtain usable results. The shown trend line in that graph is biased due to the gaps in the data series and is not representative

Stakeholders, during discussions hinted that over time the main rains may have shifted from Gu to Deyr rainy season. Evaluating measured rainfall data for different stations in Somaliland and Puntland this trend could not be confirmed. Figure 10 shows an example for Hargeysa.

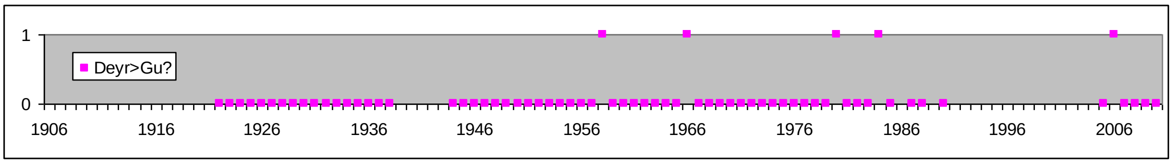

Figure 10: Analysis of strength of rainy seasons in Hargeysa
The graph indicates instances where the Deyr rains have been stronger than the main Gu rains (1). In total, Deyr only exceeded Gu in quantity of rainfall during five times in measured history. In the post-war period only one out of six years has seen the stronger rains during Deyr. Other stations show a similar pattern

Predictions

Climate predictions for Somaliland and Puntland are based on global circulation models and carry their uncertainties. Detailed analysis or regional downscaling is not available for the region so information has been based on the IPCC AR4 projections (Figure 11).

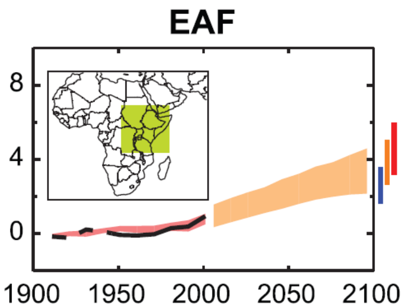

Figure 11: Temperature anomalies for East Africa
with respect to 1901 to 1950 reference period for 1906 to 2005 (black line) and as simulated (red envelope on left) by MMD (Multi Model Data) models incorporating known forcing; and as projected for 2001 to 2100 by MMD models for the A1B scenario (orange envelope on right). The right hand side bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red). The black line is dashed where observations are present for less than 50% of the area in the decade concerned.

Detailed evaluation of the regional climate predictions (Figure 12) show the following picture for Somaliland and Puntland for 2099:

- Annual mean temperature is projected to rise by 2.5-3.0 °C

- Annual mean precipitation is projected to rise by 15-20% (15-30% in winter, 5-15% in summer)
- There is a certain agreement between the models that precipitation will increase on an annual basis though with more confidence in the winter month and high uncertainty in the summer months

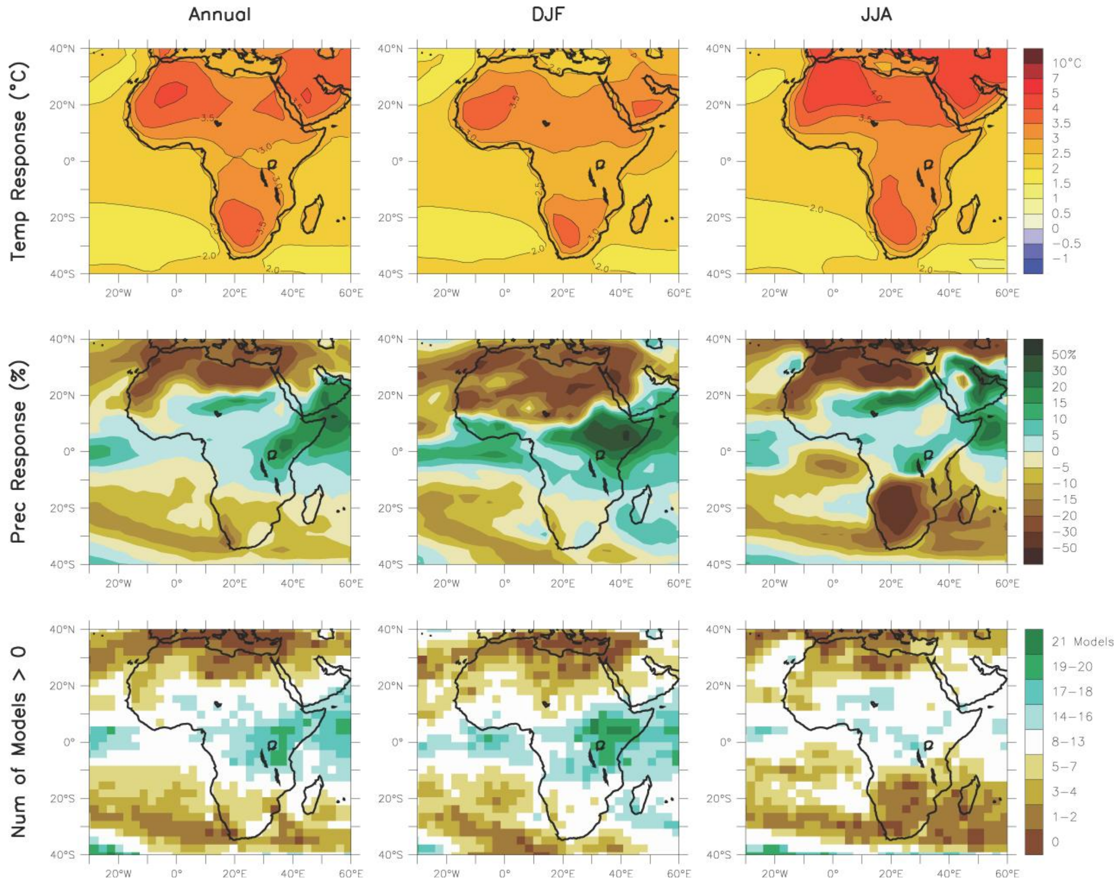

Figure 12: Temperature and precipitation changes over Africa from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.

UNDP (2010) in their climate change country profiles based on IPCC data analysis have not analyzed Somalia as such but have produced a report for Ethiopia that also covers most parts of Somalia in its spatial analysis. The results (annual values) are tabulated in Table 7 and shown in Figure 13, providing the most accurate publicly available information

Table 7: Summarized climate predictions from UNDP Climate Change Country Profiles Ethiopia (2010), for representative cells for Somaliland and Puntland (annual means, inland regions) based on SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999.

Somaliland				
Year	Temp change °C	Rain change mm	Rain change %	Heavy events %
2030	0.8 1.3 1.5	-2 +4 +10	-7 +15 +38	
2060	1.9 2.6 3.0	-4 +1 +26	-10 +6 +48	-4 +5 +14
2090	3.0 4.1 4.9	-2 +6 +29	-6 +21 +52	-2 +7 +20
Puntland				
Year	Temp change °C	Rain change mm	Rain change %	Heavy events %
2030	0.9 1.1 1.4	-1 +4 +14	-6 +18 +61	
2060	1.8 2.5 2.8	-6 0 +28	-17 +2 +57	-2 +5 +13
2090	2.9 3.5 4.6	-5 +6 +37	-18 +22 +81	-1 +6 +24

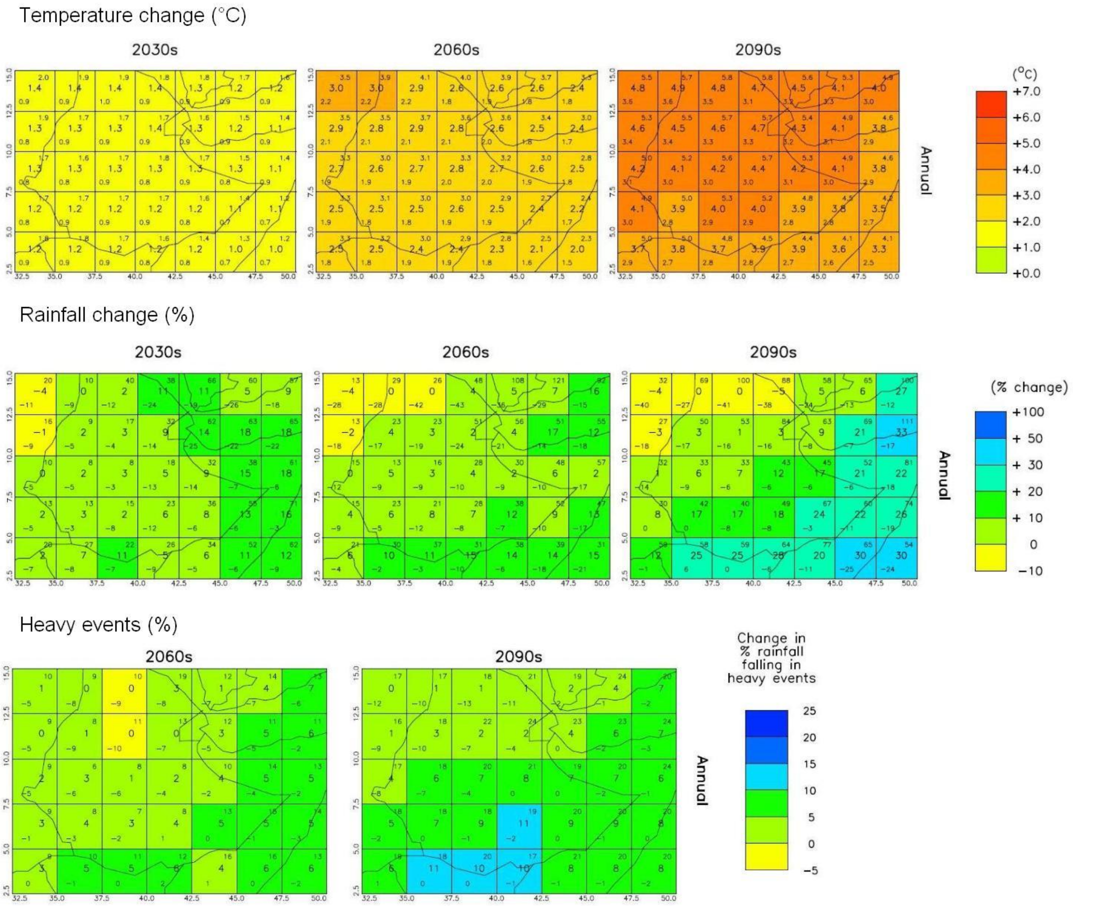

Figure 13: Climate change projections for Ethiopia and Somalia
Annual means for 10 year periods for 2030, 2060 and 2090 under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999.

4.2 Climate change impacts on aquifers

Climate change impacts on aquifers have to be separated into immediate impacts on the directly rainfall-recharge linked shallow aquifers and delayed impacts on the slowly recharging or non-rechargeable aquifers.

Shallow aquifers that are located in alluvial pockets above the rock foundations as well as in sandy riverbeds are fed directly from rainfall events and groundwater level fluctuations can be monitored nearly instantly following a precipitation event. Deep aquifers that are mostly embedded in fractured or porous rock formations and, if at all, recharge through slowly percolating surface water as well as through groundwater movements. Respectively these deep groundwater resources show a much delayed effect on climate change and may also be affected by changes on a wider aquifer scale rather than by changes on a surface basin scale.

Reactions of aquifers obviously need to be understood as a combined signal of reduced recharge as well as partly strongly increased abstraction due to increasing population and livestock numbers. Inhomogeneities in the geological formations with resulting differences in porosity are another aspect to be considered as shallow as well as deep aquifers are influenced by different percolation rates and groundwater flow rates. Shallow aquifers are specifically influenced by groundcover, soil types and slope that have an influence on the distribution of runoff and infiltration.

Based on the data situation, especially the limited information on groundwater extraction quantities as well as the hydraulic conductivity of the aquifers, it is not possible to separate the influence of abstraction and recharge on groundwater levels. To what extent the current behaviour of groundwater levels is based on current climate trends can therefore not be assessed. What can be analyzed anyhow is the potential change in recharge that can be expected with climate change. The projected rising temperatures will lead to increased evaporation with respective reduction in infiltration and percolation. While future rainfall amounts are uncertain there is a general consensus that events will become more extreme, leading to a situation where increased downpour intensities occur that cause increased runoff which is expected to lead to more water reaching streams and riverbeds and potentially the sea. The increased runoff leads to less infiltration on a spatial scale with respective reduction of water availability for plant growth. On the one hand the increased runoff leads to more water availability and recharge in riverbeds with the additional potential to enhance recharge artificially.

As a result of the above assumptions it can be projected that recharge on a spatially distributed scale will reduce due to increased evaporation as well as more intense rainfall events that result in increased runoff. Recharge on a local scale through riverbeds may increase as runoff from storm events is likely to increase. On an aquifer scale it may be assumed that recharge is reducing as also in areas with higher rainfall (e.g. the Ethiopian escarpments) infiltration will decrease due to increased evaporation and runoff. As an example, it is estimated that per degree increase in temperature potential evaporation will increase by about 5%.

rising temperatures	increased evaporation	reduction in infiltration
more extreme rainfall events	increased downpour intensities	increased runoff ➔ more water reaching streams and riverbeds ➔ less water available for plant growth ➔ opportunity for point recharge where water is needed

While the influence of climate change on deep aquifer recharge is difficult to calculate based on the available data and monitoring possibilities, an assessment of the impacts of climate change on shallow aquifers would be possible with limited resources. While the current data situation only allows for very approximate analysis, efforts to establish impact data based on a range of representative conditions would be possible with limited efforts. Details are described in Box 1.

Box 1: Pilot projects to establish climate change impacts on shallow groundwater resources through understanding of recharge mechanisms and quantities under different scenarios

The understanding of climate change impacts on shallow groundwater resources would need a twofold modelling and fieldwork analysis. The assessments should be carried out in a number of characteristic catchments to ensure applicability of the results in a variety of conditions and secondly allow for some duplication under similar conditions to test viability of the results. It is suggested that the works are carried out in about 20 small catchments under different conditions. Such different conditions could possibly include:

- Sand Dams in Wadis
- Perennial streams or permanent reservoirs
- Ephemeral streams (Wadis) with deep sand beds
- Shallow groundwater areas in hilly terrain
- Shallow groundwater areas in flat terrain
- Springs
- (in addition areas of different soil types can be selected to cover different infiltration abilities of these different soil types)

For all shallow groundwater areas the potential sources of groundwater recharge should be assessed and noted to ensure that actually the right mechanisms are considered in the rainfall-runoff calculations and analysis.

1. Monitoring in catchment areas

Meteorological as well as in-stream monitoring will be important to understand conditions and events in the pilot catchments. Meteorological monitoring as a minimum needs to include temperature and precipitation (other parameters could be estimated for evaporation calculation purposes). In-stream observations should include flow gauges (of different type) at a number of locations in a catchment that would have to be identified individually based on catchment conditions.

2. Analysis and modelling of catchment rainfall-runoff-groundwater characteristics

Scenario development is a key component in the analysis of catchment rainfall runoff characteristics. Based on the physical conditions in the different pilot catchments the scenarios need to include rainfall events of different magnitude, duration and spatial coverage, different states of soil pre-saturation as well as different temperatures. ETp and ETa would then need to be calculated based on FAO Penman- Monteith formula to establish the evaporation component.

Groundwater recharge of a certain investigation area could be based on local rainfall (e.g. in very flat terrain) or based on rainfall in an entire surface water catchment (e.g. where streams occur and water is running off rapidly). The goal of the modelling would be to depict the processes in the catchment under different conditions (scenarios) and to establish the respective shares of runoff, infiltration and evaporation after rainfall events. Due to the scarce data situation it is recommended to use custom built modelling software.

3. Groundwater fluctuation monitoring

Two pre-requirements for assessing groundwater behaviour as a result of rainfall events are the suitability of the catchment to sustain shallow groundwater resources (infiltration possibility and presence of a shallow aquifer) and the understanding of abstraction activities and respective abstraction quantities. It is therefore necessary to either select pilot areas with a shallow aquifer where groundwater abstraction is marginal or where the abstraction quantities are monitored.

For observing the expected groundwater fluctuations observation wells that are not used for abstraction are then needed. The wells should be monitored on a daily basis. Ideally several wells would be installed in the monitoring area (depending on catchment type they could be spread over the area in flat catchments or placed in certain focus areas in catchments with defined water courses).

4. Establishment of baseline conditions and correlation of calculated infiltration quantities with groundwater fluctuations

Goal of the analysis is to establish the relation between rainfall events with a respective range of potential infiltration quantities (influenced by vegetation, topography and soil type as well as pre-saturation, intensity, duration and amount of rainfall and temperatures with groundwater fluctuations considering magnitude, responsiveness and time lag of groundwater fluctuations.

Target aquifers as can be identified based on

1. shallow aquifers only
2. accessibility
3. small enough to show changes
4. extraction gauged (or possibility to gauge or estimate abstraction

5. rainfall and streamflow gauged or gauging and reading possible
6. ideally aquifers in different conditions are investigated, e.g. coastal plain, hilly terrain, plateau, etc.

At the same time as climate change impacts are assessed the pilot project may also give an idea about recharge rates if conducted over a long enough period. As the currently used figure of 20% of rainfall going into recharge is purely estimated (SWALIM, no date), monitoring over several years would be needed for the deep aquifers to show climate change impacts and the assessment may lead to inaccurate results due to the unknown aquifer interactions and slow flow processes.

4.3 Climate change database

The following data was used for climate change projections for Somalia. Scenario aspects are described in Box 2.

- UNDP country profiles available for Ethiopia
- IPCC global climate study with regional analysis: Christensen et al. (2007) IPCC Working Group I Report: 'The Physical Science Basis', Chapter 11 (Regional Climate projections): Section 11.2 (Africa)
- A UNFCCC National Adaptation Program for Action (NAPA) is not exiting but such, or a similar document, would be highly beneficial to identify priority actions in the area

Box 2: The different IPCC climate change scenarios

IPCC scenarios are developed as scenario families. In the Fourth Assessment Report, A1FI, A1B, A1T, A2, B1, and B2 are used. The IPCC did not state that any of the scenarios were more likely to occur than others.

The A1 scenarios are of a more integrated world, characterized by rapid economic growth, a global population that reaches 9 billion in 2050 and then gradually declines, the quick spread of new and efficient technologies and converging ways of life. There are subsets to the A1 family based on their technological emphasis:
- A1FI - An emphasis on fossil-fuels (Fossil Intensive)
- A1B - A balanced emphasis on all energy sources
- A1T - Emphasis on non-fossil energy sources

The A2 scenarios are of a more divided world, characterized by independently operating, self-reliant nations, continuously increasing population and regionally oriented economic development

The B1 scenarios are of a world more integrated, and more ecologically friendly, characterized by rapid economic growth as in A1, but with rapid changes towards a service and information economy, a population rising to 9 billion in 2050 and then declining as in A1, reductions in material intensity and the introduction of clean and resource efficient technologies and an emphasis on global solutions to economic, social and environmental stability

The B2 scenarios are of a world more divided, but more ecologically friendly, characterized by continuously increasing population, but at a slower rate than in A2, emphasis on local rather than global solutions to economic, social and environmental stability, intermediate levels of economic development and less rapid and more fragmented technological change than in A1 and B1.

5. Surface- and groundwater vulnerability, sustainability limits and recharge possibilities

Surface and groundwater resources are essential for the life of people and their herds. Both, surface and groundwater resources are used, albeit with different priority depending on area characteristics.

Surface water is collected in Berkads and dams which are mostly privately owned. Water availability depends in rainfall in the preceding rainy season. Typically Berkads can provide water for a few months. Surface water dams are fed by collected surface water as well and are mainly used for livestock watering. Water is lost from these dams through evaporation and infiltration as in most case these dams are not lined. In general Berkads and dams are most often used in areas with a geology where limestone or anhydrite renders groundwater saline with respective implications for use as drinking water depending on salinity. For small scale application Rainwater harvesting has been used.

Groundwater resources are extensively used throughout Somaliland and Puntland and are seen as the only reliable water sources. Extraction traditionally takes place from springs and shallow wells. Today most newly developed wells are deeper boreholes where water is extracted by diesel generator driven electrical pumps. The recharge rate especially of the deeper aquifers is slow and not well understood but assumed to be driven by rainfall in its spatial extents.

Groundwater recharge has historically been understood by the Somali population and has been utilized through shallow wells next to streambeds and extraction wells constructed next to surface catchment dams. There are examples where damming seasonal streams has been used to increase groundwater recharge in streambeds and respectively increase availability. Due to the pastoral nature of the Somali communities, recharge techniques that need more elaborate or maintenance approaches (as they are found in settled communities) have anyhow not been used historically. In recent times with a larger proportion of the Somali communities settling, groundwater recharge mechanisms have been increasingly utilized, mainly driven by efforts from international organizations. These efforts include sand dams, underground dams, check dams, retention through soil bunding and other means. It is understood that active groundwater recharge is limited by the depth of the aquifers and the differing geology due to salinity reasons.

5.1 Surface and groundwater vulnerability and sustainability limits

Surface- and groundwater resources in Somaliland and Puntland are vulnerable to both anthropogenic influences as well as climate change. Anthropogenic influences are driven by population growth and mainly seen in over-abstraction of groundwater resources as well as catchment degradation leading to increased runoff. Climate change influence is mainly expected in rising temperatures and respective increase in

evaporation as well as to some extent through intensification of rainfall events. As shown in Section 5.2 groundwater levels are declining to some extent in both shallow wells and deeper boreholes. The trend is expected to continue and possibly increase with further population pressure and climate change in future.
Sustainability limits for groundwater extraction are difficult to establish without detailed groundwater information. Considering the fact that the population in the region is growing there is potentially not much chance to reach a sustainable situation as already now groundwater levels are decreasing. Problems will increase as long as the population is growing.

5.2 Groundwater recharge possibilities

There are a variety of groundwater recharge possibilities available for situations as found in Somaliland and Puntland. Given the environment and local capacities, low tech, rigid and low maintenance possibilities have to be selected. All techniques are geared towards slowing down runoff and allowing time for infiltration. Recharge should aim at the shallow groundwater while deep groundwater may be recharged in a secondary way from the shallow aquifer.

Recharge possibilities largely depend on the topography of the terrain, soil type and vegetation cover as well as respectively the runoff coefficient. Low gradients with coarse sediments promote infiltration and recharge. The following options that can be implemented as single structures, series of structures or in combination, are generally available and suitable for the conditions in Somaliland and Puntland:

- Sand dams
- Check dams
- Infiltration wells
- Underground dams

The choice of recharge structure needs to be carefully checked based on the water needs as well as soil and geological situation on site. Depending on river morphology, targeted recharge for specific areas can be achieved. Next to recharge being used to store excess storm water runoff, recharge may also be used to mitigate or control saltwater intrusion into coastal aquifers.

An aspect that should be considered in designing and implementing recharge assets are its impacts on the hydrology and respectively the ecosystem. Both local as well as downstream aspects are of importance and a holistic approach needs to be taken in order to design a sustainable asset. In line with these considerations, ecosystems can also be enhanced and promoted in support of infiltration assets, e.g. for slope protection and erosion control where vegetation often performs better than rigid engineering structures.

Infiltration structures require minimal maintenance, consisting mostly of avoiding clogging of the surfaces with fine less permeable silt and avoiding excessive sedimentation of fine sediments in the basins and canals.

Where fine material persists, maintenance of infiltration structures has to deal with the fact that runoff from open soil areas can carry large loads of sediment, which may be deposited in the structures In cases where the sediments are coarse they may be left in the structures as pore space still allows to accommodate significant amounts of water with the added benefit of reduced evaporation (sand dams). Large deposits of fines anyhow substantively reduce storage capacity and need to be removed.

5.2.1 Sand dams

Regions with highly erratic rainfall often have rivers with seasonal sandy streambeds. They only experience runoff for short periods of time after rains or during times in the rainy season. Depending on the soil structure and vegetation cover, large quantities of sand can transported downstream during such flow periods.

Sand dams are typically constructed in sediment carrying riverbeds and are a possibility to retain coarse sediment upstream and to construct or improve an artificial aquifer. The sand collected behind the dam wall provides a means of underground water storage with much lower evaporation as compared to traditional reservoirs. The actual amount of water that can be stored in a sand dam depends on the grain size distribution of the trapped sediments. In general, the coarser and the more uniform the grains of the sediments are, the more water can be stored. A typical sand dam is shown in Figure 14.

Sand dams are typically constructed from concrete, clay soil or stone masonry. They are constructed across the river channel at specific sites to trap and hold back coarse sand during flooding while fines are washed away with the flow. The dams need to be overtopping resistant and need to withstand the abrasive power of the sediments which get washed over them during flood flows.

Suitable conditions

Several steps are required to identify suitable conditions for a sand dam. Possible dam locations can initially be identified considering sufficient water flow and quality as well as coarse sediment transport in a river at a location of need. Expert input is then required to determine a suitable dam site and design for a sand dam and to ensure the project will perform, considering mainly geology and hydraulics but also available construction technologies and materials as well as maintenance needs and possibilities. The main aspects in this regard are the environmental suitability, structural stability and sustainable operation of the dam.

Generally, the dam requires a sandy riverbed in a hilly area. Preferably the riverbed consists of coarse sands laid on impermeable bedrock. The river should be seasonal with a (possibly underground) base flow.

Design

The dam needs to be designed in a way that it is connected to the river banks and that it can overflow in a controlled manner. Both overflow over the entire dam width as well as over specific spillway sections are possible. The overflow sections need to be overtopping resistant and withstand the erosive forces of the flows, especially under high flood conditions with respective sediment transport. Wing walls can be used to avoid bank erosion. The design needs to take into account hydrological characteristics of the catchment as well as hydraulic aspects of the flood flows.

The base of the dam needs to be connected to the rock base of the riverbed to prevent seepage and underground erosion. Where the rock or another impermeable foundation can not be reached the filter stability as well as seepage rates of the underground need to be assessed to ensure structural stability of the dam foundation as well as to establish seepage losses to identify the viability of the dam. The potential importance of baseflow for downstream areas needs to be considered in the design as the dam may have adverse impacts on water availability and ecosystems downstream during the dry season. Depending on the situation, controlled seepage from the dam may be allowed.

Construction

Timing is important: sand dams need to be built during the dry season. In most cases sand dams will be constructed in stages over different years in order to allow coarse sediments to accumulate behind the dam wall while fines will be washed away with the overtopping flood flows. The height of wall built before each flood event or flood season should not exceed accumulation rate of coarse to medium sand during that flood event, otherwise ponding & silt deposition will occur, which can lower the storage volume and respectively lead to limited extraction potential. Accumulation rate and therefore height of the dam varies according to local conditions and should be adjusted site specifically based on either previous experience or after the first flood event demonstrates the rate of accumulation. Height per stage will probably be between 0.3 metre and 1.0 metre according to experience from other projects. Some silt deposition especially on the surface will always occur as velocities decrease toward the end of the flood event; the idea is to limit its quantity by ensuring no ponding occurs.

Downstream erosion may be a problem for sand dams. Downstream slope and toe protection is very important and needs to be designed and implemented carefully

Considerations

While sand dams increase water availability in an area in normal years they are dependent on rainfall and respective runoff events for replenishment. Longer term meteorological droughts therefore can strongly affect water availability in sand dams, leading to a reduction in recharge and respectively water yield.

The construction of sand dams in cascades improves total storage and efficiency along the river and also ensures water availability at different points along the river when there is a risk of cutting off baseflow.

Figure 14: Sand dam after flood and dry, filled with sediment

5.2.2 Underground dams

The construction of a sub-surface dam in naturally occurring alluvium soils is a possibility to create upstream groundwater storage. The effect is similar to a sand dam, just using an already existing sand deposit for storage. Construction requires added effort in creating the trench in which the dam is built but on the other hand the dam can be constructed more slender as it is supported by the sand depositions that continue downstream. Once completed the water table gradually rises behind the dam. Evaporation losses are prevented and the stored groundwater is generally of fairly good quality as the water is stored under ground. The volume of stored water is determined by the effective porosity of the sediments and reaches 10 to 30% of the volume of the reservoir.

Suitable conditions

Suitable conditions for an underground dam are found where thick coarse sand deposits are found in riverbeds overlying a rock bed and the river exhibiting sufficient annual discharge, either as surface or subsurface flows. The thickness of the deposits should be matching with excavation abilities so that the rock bed or other respectively impervious material can be reached. Water quality obviously needs to be taken into consideration.

Design

Underground dams are of slender design as the dam is supported by the backward sand deposits. The impervious dam wall can be constructed from clay, concrete, plastic or other impervious materials, also depending on expected flows in the river bed and respective bed mobilization. The impervious wall should not reach the surface of the sand deposits but typically stop a meter below in order to allow for bed mobilization actions during high flow events. The dam wall needs to be well connected to the bedrock in order to reduce seepage. As many rivers feature a year round underground baseflow, dewatering by motor pumps or slurry stabilized excavation may be necessary. The availability of such technologies needs to be considered in site location selection and design. Typical depths are 3-4 m. As with the sand dams, downstream water needs of riparians and ecosystems especially during the dry season should be considered in the design.

Construction

A sub-surface dam is generally constructed across a valley in a seasonally dry sandy riverbed by digging a trench down to the bedrock or other impervious layer. The dam, which is placed in the trench, must consist of an impervious wall or screen. Subsequently it is covered with the excavated material until it is completely concealed. Dewatering with motor pumps or slurry stabilized excavation may be necessary. In very dry, sandy alluvium, banks with low cohesion may constantly collapse, making excavation difficult and requiring the use of a trenching shield or other type of support to prevent slumping of the trench walls.

5.2.3 Check dams (Balleh dams)

A check dam is a small dam, built across a minor channel or drain. Check dams reduce erosion and gully formation in the channel and allow sediments to settle and water to infiltrate. They also lower the speed of water flow during storm events. Check dams retard runoff, store surface water and help in ground water recharge of the area. An example is shown in Figure 15.

Suitable conditions

Check dams can be built under a variety of conditions of different slopes, channel sizes or hydrological conditions. Check dams may as well be built on relatively flat terrain or connected with collector drains to promote localized infiltration.

Design

Main design criteria for check dams is overtopping resistance as well as stability against seepage-, bank- and toe erosion as well as sliding. Similar conditions as for check dams apply

Construction

Check dams can be built from a variety of materials including wood, soil, masonry and concrete. Similar conditions as for check dams apply

Figure 15: Small check dam on a relatively plain area in an erosion gully

5.2.4 Infiltration wells

Infiltration wells, also called interception wells, are shallow wells which are connected to a natural aquifer. They are often found where surface runoff exists but where the surface soils are not sufficiently permeable to allow surface infiltration but where there are highly conductive shallow aquifers underneath the less permeable surface layers. Infiltration wells can be used in both ways to infiltrate as well as to extract water, albeit this is only recommendable in very sanitary conditions and should generally not be followed. The wells may be open or may also be filled with porous media like coarse gravel including a filter pack on top. Such arrangement may reduce periodic maintenance needs.

Suitable conditions

Suitable conditions are characterized by a water table within a highly conductive shallow aquifer. As infiltration capacity is limited infiltration wells are normally suitable for smaller communities with relatively low water demand. The wells may be combined with surface retention facilities (check dams) in order to allow more time for infiltration but also to remove sediments by settling prior to injecting the water into the wells. Avoiding contamination is a key aspect of infiltration wells. As surface water is infiltrated into the groundwater the respective catchments need to be kept clean and should be for restricted from contamination.

Design

Site selection is an important aspect for the successful implementation of infiltration wells. The shallow aquifer that is intended to be recharged needs to be understood regarding its current recharge mechanism, its capacity and hydraulic conductivity.

Based on this understanding as well as the surface hydrology and topography, depth and numbers of infiltration wells can be designed. For the infiltration wells as such the porous fill as well as filter pack and collector structures including possible sediment traps or check dams need to be designed.

Construction

Construction of the infiltration wells is carried out at identified locations. Using standard shallow well digging technologies including securing the well walls below the water table caisson has to be used to stabilize the well walls. Typical diameters are 1.0-1.5 m. The wells are ideally constructed during the dry season when water levels are lower. Once completed, the well is filled with porous material, e.g. coarse gravel as well as a filter pack towards its top. The filter pack serves the purpose of retaining sediment and debris that is washed into the infiltration well during recharge. The filter is respectively easier to clean as if the debris would be washed into the coarser porous fill material. The top of the infiltration well is connected to a collector structure from masonry or concrete which has to be shaped to fit the local conditions, similar to a Berkad intake.

Considerations

Infiltration wells, in their capacity to recharge groundwater, are directly dependent on rainfall in the area and therefore vulnerable to meteorological droughts.

5.2.5 Infiltration ponds

Infiltration ponds (also called infiltration basins or percolation ponds) are large excavated open water ponds or depressions. They store rainwater but with the main aim of infiltrating the water to aquifers where it can be extracted using boreholes, hand-dug wells, or nearby springs. They are constructed in areas where the base of the pond is permeable and where the aquifer to be recharged is at or near the surface. An example is shown in Figure 16.

Suitable conditions

The aquifer to be recharged needs to be at or near the surface. The base of the pond needs to be permeable. The aquifer should be of good water quality with no detrimental effect on water quality.

Design

Ponds are generally 1-4 m deep, but pond size should be decided according to catchment area and number of fillings possible per year. In order to efficiently capture runoff in a catchment, contour trenches or collector drains can be employed to guide water to the infiltration pond.

Construction

Construction can be using manual labour or machine support, depending on available technology and funding.

Considerations

Infiltrations are prone to siltation and encroachment of vegetation. Drinking animals may be detrimental to keeping the pond clean, fencing should be considered. Maintaining infiltration ponds requires communal effort and organization. Catchment management is important to reduce sediment yield and sedimentation as much as possible in order to reduce maintenance needs. Sedimentation basins or check dams may be employed to reduce sediment input. Infiltration rates may reduce over time due to fines that form a less permeable silt layer. This layer has to be removed from time to time to maintain infiltration rates

Figure 16: Infiltration pond

5.2.6 Contour trenching, soil bunds and tillage

Contour trenching or soil bunding is a means for localized improvement of infiltration. The trenches or soil bunds act as trap for the water and reduce runoff and soil erosion. The trenches or bunds do not need to be very large to be effective but need to be designed for the expected surface runoff capacities in order to be effective and to avoid them being washed away with high frequency. Trenches and bunds should be staggered on the slope so that water is slowed evenly across the entire slope without larger volumes aggregating that may wash out the system. The trenches and bunds, provided they are built on a wider scale increase spatial infiltration which is mainly benefiting the local vegetation.

5.2.7 Reservoirs

Reservoirs (Figure 17), though mostly not built for this purpose, have a strong effect on groundwater recharge in their area. Construction is often more sophisticated, depending on height and local conditions, and evaporation as well as siltation leads to a reduction of benefits over time.

Figure 17: Reservoir in arid area

5.3 Areas suitable for groundwater recharge

Considering the aquifer recharge techniques as presented in Section 5.2 as well as the geological conditions, recharge of sandy stream- and riverbeds is the preferred option of groundwater recharge in Somaliland and Puntland. The main constraining factor for recharge in other areas is the surface geology with large areas of anhydrite/gypsum/limestone material that leads to immediate groundwater quality deterioration. Details about the different geological and hydrogeological areas are shown in Faillace & Faillace, 1987, as well as in the Hydrogeological Assessment of Somaliland and Puntland Report by SWALIM, 2012. Nevertheless, as accepting below standard water quality is the only means of access to water in large areas of Somaliland and Puntland, shallow groundwater recharge in stream- and riverbeds remains the sole suitable technique for improving bulk water accessibility.

Stream- and riverbeds are well distributed over nearly the entire region of Somaliland and Puntland as shown in Figure 18. The stream- and riverbeds are seasonal in nature and flows, including baseflow and in-bed flow, entirely depend on the actual rainfall situation which exhibits strong seasonal as well as inter-annual variations. It is therefore essential to understand that efforts for recharging shallow groundwater locally will show varying success depending on the actual rainfall situation in the upstream areas and respective runoff conditions. In order to make thorough use of the shallow aquifer recharge potential it is therefore essential to develop a widespread system of low maintenance recharge structures that can respectively improve the shallow groundwater situation considering the spatial rainfall variability.

The main improvement that can be achieved through shallow groundwater recharge from streambeds is the localized improvement of infiltration and respectively increasing shallow groundwater availability. For the selection of infiltration sites, i.e. for construction of recharge assets four conditions need to be considered:

- Vicinity to settlement or suitable pastoral access point
- Sufficient runoff in streambed

- Physical condition suitable for asset construction and recharge (including geological suitability
- Streambed conditions suitable for low maintenance and sustainable operation with coarse sediment yield being the most important parameter

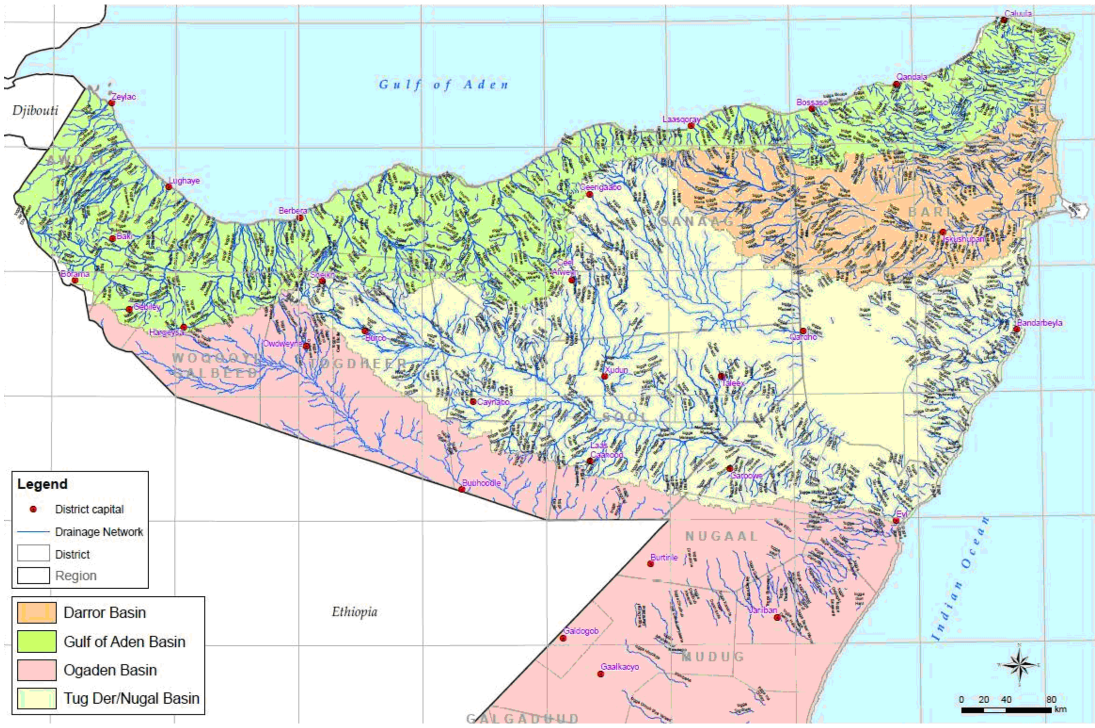

Figure 18: Stream network in Somaliland and Puntland representing the potential for shallow groundwater recharge

For all undertakings that aim at shallow groundwater recharge, a detailed feasibility study, followed by a detailed design study should be carried out to assess local conditions, quantify water quantities that could be used for recharging, estimate the recharge potential and respectively the potential quantities that could be abstracted.

5.4 Application examples for groundwater recharge

5.4.1 Boosaaso

Boosaaso is located at the Gulf of Aden coast on the coastal plain. It is bordered by the coastal range escarpment to the south from which several rivers drain into the Gulf of Aden. Water management in Boosaaso is carried out by GUMCO, a private water utility. The city currently has a deficit in supply considering both household connections as well as water supplied through alternative means, e.g. water tankers. Current water sources used include boreholes and shallow wells as the main sources. Decreasing water quality due to salinization, likely from seawater intrusion due to decreasing groundwater tables, has been reported for the downstream boreholes.

The streambeds around Boosaaso (Figure 19) have a high potential for groundwater recharge. While the streams are not gauged there is narrative evidence collected during stakeholder discussions that discharge from the riverbed often reaches the sea. On the other hand, remote sensing analysis of the streambeds indicates that there is a high potential for underground dams as well as sand dams to be constructed at multiple locations which could significantly improve groundwater availability, i.e. provide additional water resources as well as improve water quality through lifting groundwater tables.

Detailed studies would be necessary to identify the exact recharge potential, the quantities that could be abstracted as well as the infrastructure necessary to retain and deliver the water to Boosaaso.

Figure 19: Stream patterns around Boosaaso

5.4.2 Hargeysa

The water resources situation in Hargeysa is characterized by an undersupply and reducing per capita water availability due to population growth. The cities water network is supplied by groundwater from Geed Deeble wellfield with currently 10,000 m^3/d extracted from an alluvial aquifer in medium depth. Water supply is managed by the Hargeysa Water Agency, a private water utility that manages the water grid. The water supply is augmented by private water trucking businesses that supply water to not connected inhabitants from a variety of boreholes and shallow wells in the vicinity of the city.

A masterplan for Hargeysa has been developed and aims for the supplementation of Geed Deeble through additional wellfields and respective water conveyance infrastructure to satisfy the demand that has been estimated with 30,000 m^3/day, i.e. closing a 20,000 m^3/day gap.

The possibilities to improve groundwater recharge around Hargeysa are limited, especially considering the identified deficit. While Hargeysa features a developed stream network with sand deposits that could be used for groundwater recharge, the streams do not carry significant runoff. Though a seasonal behaviour of the aquifers has been reported, the recharge would rather benefit decentralized smaller scale water sources that use the upper aquifers rather than recharging the main deeper aquifers that are currently used or are planned to be developed for bulk water supply in Hargeysa. Possibilities are therefore twofold:

- Development of widespread water retention and infiltration assets in the overall aquifer basin that promotes infiltration on a broader scale but without aiming at developing exploitable local aquifers. The recharge would benefit the deeper aquifer and could potentially support family level water sources.
- Development of a limited number of locally recharged shallow aquifers using the more pronounced stream network upstream of Hargeysa (Figure 20). Downstream the city the development of local recharge assets is not recommended for pollution reasons.

In addition to the above measures pollution prevention measures through respective legislation would be essential as a point of concern In this regard is the expected industrial development around Hargeysa with the expected surface- and groundwater pollution fur which currently no legislation exists. Industrial pollution may in this regard have a serious effect on groundwater quality, especially considering the alluvial nature of the main aquifer in the region.

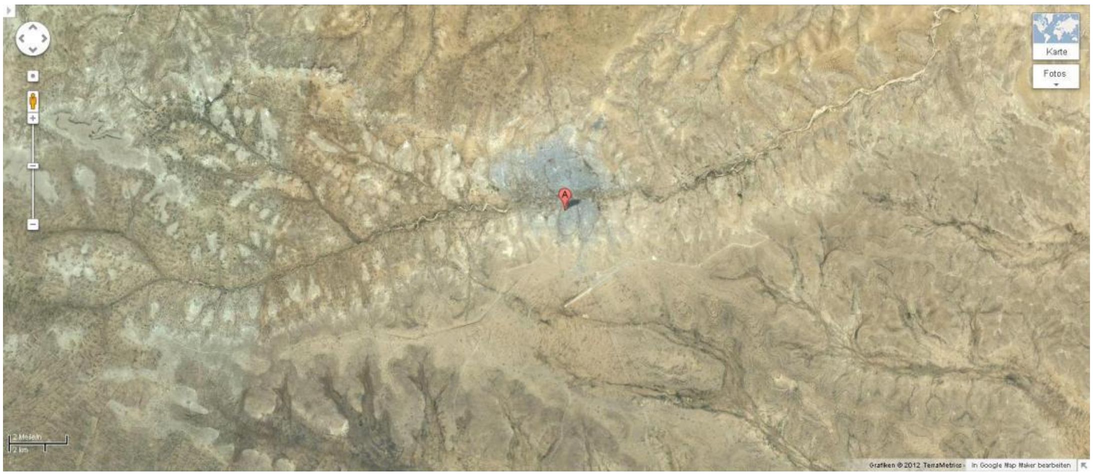

Figure 20: Stream pattern at Hargeysa

As runoff in the drainage system around Hargeysa is not gauged it is currently not possible to estimate the amount of recharge that can be achieved with the interventions.

5.4.3 Qardho

Qardho is located on Puntlands plateau area (Figure 21) which features arid conditions and a geology based on anhydrite and limestone with respective impacts on water quality. Streambeds that are rich in sediment deposits that could be effectively recharged do not exist. The potential for water catchment therefore rather lies in rainwater retention in the uppermost parts of the catchments which have been reported to have a less detrimental effect on the water quality. Small reservoirs with respective pipe systems for water delivery seem to be practical solutions to improve rural water availability. Considering expected evaporation losses investments would anyhow need to consider the temporal nature of such water supplies. In the lower parts of the catchment surface water retention using lined ponds (Haffirs) are an option to maintain water quality though siltation and maintenance will be major issues.

As grazing is a limiting factor in the Qardho area, benefits could be achieved through runoff retention on a spatial scale that would benefit the vegetation rather than going into groundwater recharge for domestic water purposes. Runoff retention in this regard could be achieved through scarifying and contouring of large areas to reduce runoff. Check dam series could be used in erosion gullies and runoff trenches. Such measures could significantly contribute to increased soil water availability and respective plant growth. The interventions would require significant maintenance as e.g. contour trenches will smoothen over time and measures will have to be repeated.

Figure 21: Qardho and surrounding area

Where wells exist adjacent to streambeds (independent of groundwater quality) check dams in the streams could contribute to runoff retention and promote local groundwater recharge. Due to the reported low coarse sediment availability the check dams would need to be designed as weirs and maintenance to remove fine sediments would be required periodically.

6. Policy aspects

Population growth and the increasing migration of people to the urban centres is leading to an increasing decline in per capita water availability and a decline in per capita pasture resources. This trend is directly increasing the vulnerability of the population to droughts. Traditionally drought was defined as a reduction of the water resource. Today the driver for increasing drought impacts is rather found in the increasing population numbers that result in reduced flexibility and increasing demand that is stretching the resource base. Meteorological conditions, which in previous years have not caused an emergency state, would today result in emergency conditions due to the already stressed per capita water availability.

Emergency preparedness and emergency intervention plans are therefore increasingly important to cope with the situation and mitigate drought effects. Current drought interventions are mainly reactions to emergencies and driven by individual decisions, the private sector and international organizations, rather than being planned interventions by the authorities. For effective management and mitigation of droughts it would respectively be essential to develop implementable policies and capacities in the authorities to deal with the problems.

6.1 Existing situation

Scarcity of water resources is an accepted problem in Somaliland and Puntland with respective efforts to improve the situation. To date the resource base with regards to groundwater, its recharge and streamflow are only understood to a limited extent due to lack of monitoring though the situation is improving. On the user side the area faces an increasing drop in per capita water availability due to population growth and a respective deterioration of the situation.

Based on the above situation water resources management is an important aspect in Somaliland and Puntland which has been addressed through the setup of respective agencies dealing with water resources management as well as by developing respective policy documents that guide the work of these agencies.

Somaliland

The water resources sector in Somaliland is lead by the Ministry of Mining, Energy and Water Resources (MMEWR). The National Environment Research and Disaster-preparedness Agency (NERAD) is in charge for related emergency aspects.

Somaliland has introduced the following documents with regards to water resources management:

- National Water Policy (description of overall goal)
- National Water Strategy (description of role sharing & actions)
- National Water Act (description of legal framework)

- National Water Regulations (description of implementation arrangements through by-laws)

Somaliland has further developed a water masterplan for Hargeysa which describes the resource base and needed infrastructure developments to satisfy the cities water demand. This masterplan is currently being followed and funding possibilities are searched for implementation of the respective infrastructure works. A masterplan for Burco is currently under development. A masterplan for water resources development for the whole of Somaliland is planned but has not yet been started.

In addition to the directly water related documents Somaliland has introduced a National Environmental Policy which is of importance considering the expected industrial development with respective water consumption and water pollution aspects of respective industries which could potentially have a severe impact on the available water resources.

Next to the MMEWR as the line ministry, the Ministry of Planning & Development is an important stakeholder in the institutional setup of the water resources sector.

Considering institutional capacities to implement the developed policies and plans, Somaliland has limited human and financial resources available which is reflected in the state of implementation of the plans. In addition to these shortcomings clear distribution of responsibilities and coordination between the different involved players are lacking and are significantly hindering the work. A clear organizational setup, clear responsibilities as well as chains of command and chains of reporting including respective templates to be used by executing officers would significantly improve the situation.

In order to overcome financial shortcomings alternative approaches could be utilized, e.g. use of mobile phones for reporting.

Puntland

The water resources sector in Puntland is lead by the Puntland State Agency for Water, Energy and Natural Resources (PSAWEN) with the Humanitarian Affairs and Disaster Management Agency (HADMA) being in charge for emergency aspects.

Puntland has developed a water policy that describes the overall goals in the water sector as promoting the construction of water infrastructure for sustainable use & access.

Authorities in Puntland face similar problems like their counterparts in Somaliland with limited financial and human resources as well as a weak framework of coordination and cooperation between authorities and organizations. To improve the situation a clear framework for water resources management is needed including a clear organizational setup, clear responsibilities, chains of command and chains of reporting as well as respective templates to be used by executing officers. For sustainable implementation capacity building of key staff and the development of a simple resource database would be another priority need as currently implementation of tasks follows emergency requirements rather than a planned approach. To support implementation identification of main problem areas followed by the development of masterplans would be a starting point for improving the situation.

6.2 Capacity for policy implementation

In both Puntland and Somaliland implementation of new policies are difficult due to the low human capacity and low executive powers of the authorities as well as the society which is not used to authority interventions into their daily business.

Puntland with its slender authority structure has the benefit of direct links between authorities and the private sector which has proven to be a functioning implementation mechanism. Somaliland on the other hand has developed a higher bureaucracy and limited abilities to involve the private sector.

Both Somaliland and Puntland have agencies in place that are set up to deal with emergencies (NERAD/Somaliland, HADMA/Puntland) though the current interventions are response- rather than planning oriented. The capacity of these agencies would need to be significantly improved to function effectively, especially considering preparedness and pre-planning. Currently a large portion of emergency interventions is carried by individuals rather than the agencies.

Requirements for effective interventions and policy implementation would not only increasing the capacity and executive powers of the agencies involved but would also include knowledge (through detailed studies for understanding the resource base), new policies (for land resource/rangeland management) and especially implementation guidelines for implementing water resources and land use policies by the involved agencies. Implementation would then need to aim at building an understanding in the population for acceptance of the interventions which, to promote implementation, would require a good spatial coverage and presence of the agencies especially for the rural areas. As this is difficult to achieve in a short time, implementation in pilot areas which receive focused attention could be used as model examples to show the benefits of the interventions. This second approach would probably be more in line with the available capacities for policy implementation.

6.3 Suggested policy input

6.3.1 Strategies

Both Puntland and Somaliland have set up authorities and developed policies to deal with the water resources sectors and their respective problems. Observing the situation it is evident that implementation lacks much behind the gazetted goals and that an emergency response strategy rather than a planned development approach is followed. It is therefore less missing policy aspects or background documents but rather implementation aspects that are missing to improve the situation.

The following elements would be the main step stones for improvement:
- Clarification of institutional organization and responsibilities
- Implementation guidelines for officers in charge
- Ability for monitoring and enforcement of regulations

Strategies that need to be pushed forward are twofold
1. Long term development strategies
2. Strict emergency management strategies

Long term development strategies

Long term development strategies related to the water sector need to ensure a sustainable and holistic approach to regulate aspects that are influenced by the water sector. These mainly include:
- land management
- livestock management
- water resources management

With regards to land management, ownership issues, overgrazing and tree cutting for charcoal burning are main issues that exacerbate meteorological droughts as they reduce pasture availability. Considering the nature of the area principles of rangland management need to be developed and applied for a sustainable use of the resources and to avoid catchment degradation. Main aspects would be the control of herd sizes and tree cutting activities through e.g. respective licensing. Measures need to be implemented and enforced. These strategies can only be implemented with full backup from the population which to achieve requires respective involvement and education.

For the urban areas the development of sufficient and sustainable water resources combined with a water tariff system that enables the sustainable operation of the water supply network would be a priority intervention. This need has been identified e.g. in Hargeysa and a respective masterplan has been developed. Implementation is anyhow hampered by missing financial resources. For other areas masterplans would be the next logical step for situation improvement as well and such planning documents may be a good base for finding funding as well.

Emergency management strategies

In addition to long term development strategies, abilities for better drought coping need to be developed. As droughts mainly affect the livestock herds and only to a lesser extent humans, mechanisms need to be found to reduce herd sizes based on drought forecasts or at the onset of droughts while they still have a good market value. The current market mechanisms anyhow only allow the sale of livestock at specific times of the year. New mechanisms have to consider the fact that cold storage is not available and that it is life animals that have to be dealt with. On the other hand new methods like e.g. dry meat preparation that can be implemented in rural areas, while at the same time being a potential export product, could be considered. Current strategies like transporting of livestock to areas with better pasture available or water tankering have been successful as short term mitigation strategies but have also proven to damage pasture through overgrazing. If these strategies - which have proven their validity - are taken forward, mechanisms need to be found to utilize them sustainably without damaging the pasture resource base.

Considering the relatively weak role of the authorities, communities need to be strengthened and given a major role in drought management, ideally considering traditional management mechanisms that can be updated with current knowledge but be used as accepted coping mechanisms. An important aspect in this regard is the management of the communities' resource base: water and pasture. As water has been explained to be a common good that cannot be denied to people and their herds which are searching for water, the only possibility to avoid concentrations with resulting pasture damage is the development of a denser water source network, ideally rather considering shallow wells which have lower running costs over boreholes with respective higher capital cost and running costs and maintenance needs. This obviously depends on the local conditions that need to be assessed before interventions though aspects like the previously described shallow groundwater recharge techniques could be utilized for improvements.

An aspect that has been brought up in discussions is that currently a good amount of interventions are organized through the private sector. Water tankering and livestock transport are the main examples. While currently expensive and ad-hoc based, these private activities could form the basis of a more organized intervention possibility though details would need to be assessed. It also needs to be taken into consideration that Puntland and Somaliland have to be looked at under consideration of their own particularities with regards to potential interventions, especially with regards to implementability. While some aspects can be handled similar, some aspects need to be looked at very distinctively. Puntland has a rather slender structure and needs a less bureaucratic system for interventions. For Somaliland note needs to be taken of the existing four policy documents and how they can be taken on board and improved.

A further point of consideration is the base on which policies should be built. In rural areas traditional water and land regulations are still strong and should be used, developed and strengthened as a base for implementable policies. In urban centres on the other hand traditional practices may not work due to the societal changes and much denser and heterogeneous population so more modern policy implementation tools need to be adopted for successful management. Especially the economy driven private sector – with respective regulation – is a chance in this regard.

6.3.2 Policy needs

Puntland policy needs

Puntland needs no new policies but an agenda for action that focuses on implementation plans taking on board and strengthening the existing players, i.e. the agencies and to a large extent also the private sector. Plans should be shaped in a masterplan containing the following information:

1. List of actions
2. Prioritization
3. Implementation plan
4. Responsibilities
5. Budget estimate

As currently many of the related activities are carried out by the private sector and this has proven to be successful, the private sector and private investments should be further promoted, based on the above masterplan(s). Using the masterplans a further achievement would be the prevention of “wrong” developments that may be beneficial in the short term but have been identified as potentially causing future problems. Main aspects in this regard are the pollution of water resources, uncontrolled land grabbing and uncontrolled tree cutting for charcoal burning. As especially for the last point controls are difficult and there is a huge market demand for charcoal, endeavours for restriction could rather aim at bulk sellers, e.g. through ban of transport by truck which can be controlled through roadblocks or through ban of export with respective control possibilities at harbours or strategic land locations. These interventions will not eliminate the problem but may be a first step in improving the situation. The masterplan(s) should not only deal with infrastructure development but also with the required regulatory and monitoring aspects of sustainable water resources management.

Asset control is another aspect for consideration in planning the future needs for Puntland. While initiatives, e.g. through SWALIM are ongoing, there is still a huge need for more detailed understanding of the resource base in order to have a better picture of water availability and trends, considering both aquifer behaviour as well as abstraction quantities. Licensing of water abstraction together with requirements to measure and report abstraction quantities and water table behaviour would provide this needed knowledge.

A strategy for development of a strategic water sources grid considering community water sources (boreholes and shallow wells) as well as the private Berkad network and private water tankering undertakings would provide a widespread and flexible water supply system. Such systems could possibly be run in form of supplier cooperations in order to maintain accessibility but also sustainable operation and management regarding physical and economic aspects. As part of this strategy maintaining mobility of herds would still be a requirement in order to be able to act or react on forecasted or experienced droughts. This undertaking should go hand in hand with assessing and promoting rangeland management possibilities in order to avoid that the increased water availability and security will lead to pasture damage and respective problems from that side. With rangeland management in its modern form being unknown in Somaliland and Puntland, an assessment of the traditional grazing systems would be needed to establish ways how to develop the traditional systems in a sustainable manner which would increase the chances for successful implementation.

Recommend consultancies

- Development of visions for major towns and districts (as a basis for masterplans)
- Detailed resources assessments
- Detailed needs assessments
- Masterplan development Puntland (Overall and rural areas) including strategy for water source grid
- Masterplans for urban centres
- Institutional coaching, capacity building and coordination between government agencies and private sector
- Development of implementable rangeland management plan including destocking possibilities, allocation of grazing rights and grazing management while maintaining mobility
- Market development and adaptation
- Development of implementable licensing system for natural resources management (water, trees, land)
- Development of structured implementation guidelines and pushing forward of pipeline projects based on masterplans as well as building the consensus of the communities
- Development of monitoring and enforcement strategies (pollution, over-abstraction, overgrazing, charcoal)

Somaliland policy needs

The main missing aspect in Somaliland with regards to its policy framework is its implementation due to a respective missing link between policy makers and the private sector who can take over practical implementation. While there is a comparably strong document base with regards to water policy, water act, etc. Implementation seems to be rather complicated. The identified needs therefore include:

- guidelines for involvement of private sector
- an organizational structure including responsibilities, chains of command and chains of reporting shown in an organigram
- multi agency workshops for bringing on board the different players and agree on responsibilities to avoid confusion regarding competencies and blocking
- Identification of lead agencies for specific tasks with agreed powers and how they need to be supported from other agencies
- guidelines and templates to be used by officers to carry out their tasks (e.g. licensing)

- setup of a low-tech, easy to use and easy to update data centre with the respective capacity building
- reporting and filing structure
- approval structure and licensing agreements
- improved coordination between capital and districts
- coordination between involved ministries
- utilize opportunities in modern technologies including mobile phones for reporting, SMS services for alerting, radio broadcasting and mobile reporting
- easy to disseminate technical guidelines for water resource improvement e.g. for rainwater harvesting, infiltration, GW recharge or similar
- licensing system for natural resources use aiming at sustainable resource management and avoiding over-exploitation

A further main aspect for improving the rural situation in Somaliland, workshop participants identified the potential for improving and better organizing water trucking as a means to flexibly react to shortcomings.

Further to the organizational and managerial aspects a strategic water source grid and rangeland management efforts would significantly improve the rural supply situation. These aspects have been described in more detail already in the Puntland section.

With a stronger government structure in place in Somaliland, the financial sustainability of the administrative system is an issue. While currently external aid as well as donations from wealthier citizens plays a major role in carrying the financial burden, for the long term an implementable tax system would need to be established. The design of the system would need to consider the particularities of the Somali communities and engage where taxes can fairly be collected and chances for tax evasion are limited.

Policy needs for use of groundwater in emergency situations

The difficulty with regards to planning for groundwater use in emergency situations is the problem of latent or permanent emergency conditions during elongated periods and the respective danger of a water source that is meant to be for emergency supply to become permanent. The general water scarcity in large parts of Puntland and Somaliland has lead to a situation where most available water resources are being exploited with high intensity and without consideration of sustainability aspects, i.e. in a way that would normally be expected to be tolerated in emergencies but not under consideration of sustainable resource management principles. This being a fact in Somaliland and Puntland, only long term planning and improvement can seriously improve the situation. Furthermore, groundwater use in emergency situations has to be separated into use in urban- and in rural areas.

Emergency groundwater use aspects in rural areas are driven by meteorological droughts that lead to a reduction in surface water availability (impacting on Berkads) as well as to a reduction of pasture availability. The drought situation has traditionally been coped with by migration into areas where rains have been richer and water and pasture are available. Where this could not be found part of the herds were starving and losses of livestock occurred and had to be accepted. Under modern conditions with boreholes and water trucking available, water scarcity can often be mitigated, while lack of pasture has more serious consequences that can not as easily be coped with through technological means. Migration, partly under utilization of trucks to transport animals is still the only mitigation mechanism. A possibility to improve the drought situation in rural areas is seen in the development of a widespread grid of reliable water sources (boreholes) especially in areas where currently Berkads are the only water source. The difficulty in this approach is anyhow the uncertain aquifer situation which would require serious investigations and potentially deep drilling to reach suitable groundwater. The borehole grid would provide water availability on a spatial scale including areas where currently Berkads are used. An aspect to be considered in this regard as expressed by workshop participants is the danger of overgrazing due to blurring the differences between wet season and dry season grazing areas due to widespread water availability. The benefits of a borehole grid should therefore carefully be assessed considering rangeland management aspects as well as implementability of any rules or restrictions that would go in line with the development of the system.

Emergency groundwater use aspects in urban areas are driven by the strongly increasing urban population with respective reduction in per capita water availability considering the current water distribution systems. Currently only a fraction of the urban population is supplied from piped networks and most urban inhabitants are dependent on water trucking. While more expensive the water trucking system has the benefit of higher flexibility to react to increasing demand and resource availability from different water sources around the cities so is respectively the best means to quickly fill supply gaps in emergencies. Nevertheless long term planning is needed to sustainably improve the urban water supply situation. Main aspects include assessments to establish good quality high- and sustainably yielding groundwater sources that can be utilized through a water supply network. Needs and implementation steps would need to consider population growth projections. Such a supply systems can only be implemented with significant financial efforts so that for immediate drought preparedness and groundwater use in emergencies in cities a well organized water tanker fleet that can draw on well assessed groundwater resources should have priority. The water tankers would have the added benefit of being flexibly deployable in different parts to react to local problems. Long term planning of piped systems should anyhow not be forgotten.

Policy needs for drought management

Drought, as previously discussed, mainly affects surface water resources (Berkads) for water availability as well as with even stronger impact pasture availability for livestock. Drought impacts with regards to pasture availability are exacerbated by high livestock numbers as well as reduced migration potential of the pastoralists due to population growth and land grabbing aspects.

Ways for mitigation of surface water scarcity have already been discussed in previous sections (borehole grid), the main improvement potential is anyhow found in pasture related aspects. Possibilities for adjusting the situation are plentiful but all come at a cost and they are not easy to implement:

1. Implementation of rangeland management principles
    - Herd management (bearing capacity of area)
    - Licensing to control herd sizes
2. Monitoring and forecasting system to allow early migration or reduction of herd sizes
    - Seasonal forecasts of potential drought conditions
    - Spatial monitoring of pasture availability and promotion of migration
3. Market transformation
    - Enable sale of animals off-season
    - Introduce new meat conservation technologies (e.g. dry meat)
4. Land resources management
    - Control of land areas with regards to land grabbing, overgrazing, deforestation
    - Control of illegal sales of land products (e.g. charcoal) in suitable ways
5. Pasture improvement
    - Improve soil moisture through promoting infiltration on a spatial scale (trenches, bunds, soil texture improvements)
    - Introduce drought resilient or higher yielding fodder plants

For all interventions and the introduction, implementation and enforcement of respective policies the consent of the population will be needed. Strong education campaigns and pilot schemes that prove the economic viability of the interventions may serve as a means to achieve this consent.

The above proposed interventions would need to be carefully assessed for their suitability and potential to gain consensus. Based of the results of such feasibility studies implementation plans on a pilot scale may be developed.

7. Groundwater monitoring and early warning system

A groundwater monitoring system would require a series of well distributed gauging locations where periodic measurements are taken and the data evaluated. There are various possibilities how such a system could be set up. Given the drawdown that wells experience when being exploited, it would be ideal to install pressure transducers in observation wells that are not used for production purposes. As groundwater levels behave slowly, daily measurements would be sufficient to observe tendencies. Water extraction rates from nearby wells would need to be recorded together with the groundwater level readings. For shallow aquifers a system of rain gauges within the aquifer basin in order to identify interrelations and delays in recharge as described in Box 3 would be ideal. This second aspect of correlation and delay between rainfall and groundwater level behaviour, corrected by the gauged abstraction will be important for the early warning aspect of the system.

Early warning time will depend on the delay between rainfall events and aquifer reaction. The reliability of the system will depend on the spatial accuracy of the rainfall measurements as well as the groundwater movements in the observed aquifer.

Box 3: Requirements of a groundwater monitoring and early warning system

Requirements
- Distributed well gauging system (observation wells)
- Recording of water abstraction quantities
- System of rain gauges within the aquifer basin

Analysis
- Correlation of rainfall, abstraction and GW level behaviour for
  - seasonal forecasting
  - demand driven forecasting
- Early warning time will depend on delay of aquifer reaction to rainfall events
- Reliability of system will depend on spatial accuracy of rainfall measurements as well as groundwater mobility

To further expand the monitoring and early warning system, longer term and larger scale climate patterns would need to be taken into consideration. Sea surface temperature (SST) fluctuations have been found as a parameter that can provide information on seasonal trends in this regard. In particular, sea surface temperature fluctuations have been monitored and identified as being connected to El Nino and La Nina effects, having an impact on global meteorological conditions and effecting the hydrological cycles.

The El Nino phenomenon causes wetter than normal conditions in the eastern African region while the La Nina phenomenon results in dryer than normal conditions. With this trend being identified, the establishment of detailed correlations and time lags between SST fluctuations and precipitation conditions could be analyzed and a relation established that could be used for respective forecasting.

Based on historic SST fluctuations as monitored by the NOAA as well as spatial rainfall data for Somalia, there would be a potential for long term (seasonal) drought forecasts based on an offset correlation of sea surface temperature fluctuations and rainfall patterns. The results would provide valuable input to judge the effects of global atmospheric cycles on the regional hydrologic conditions and related drought aspects and could be developed into an early warning tool.

As an example for groundwater monitoring data as obtained for Geed Deeble has been analyzed. Data for this location is available for approximately two years. Datasets that are available include rainfall data, groundwater level data and groundwater abstraction data. Groundwater abstraction over the monitoring period has been relatively stable, averaging 7261 m^3/d. In Figure 22 a plot of monthly rainfall against monthly groundwater levels is shown. The figure indicates that while a potential relation between rains and rising groundwater levels can be seen, a detailed analysis is difficult given the short monitoring periods of two years. Longer timeseries would be necessary for a detailed assessment. For other wellfields or boreholes such data is not available at all

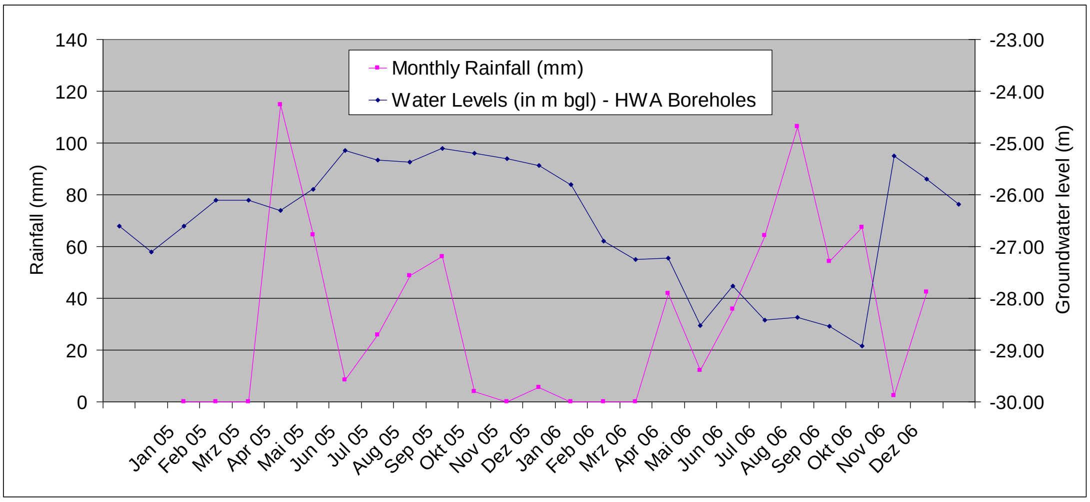

Figure 22: Problematic correlation between rainfall and groundwater level data due to limitations in data that is only available for a 2 year period. The groundwater abstraction with its relatively stable abstraction rates is not expected to have much influence

8. Conclusions and Recommendations for future work

8.1 Conclusions

Groundwater resources in Somaliland and Puntland can be expected to react directly on climate change. While deep groundwater will react slowly and mechanisms are not understood due to the limited data situation, shallow groundwater will react more quickly and diverse. The main impacts of climate change that have an effect on shallow groundwater are:

- Increased temperatures leading to increased evaporation and respective water losses
- Increased rainfall intensities leading to less spatial infiltration and increased runoff and erosion.
    - On a spatial scale infiltration will respectively decrease, resulting in less groundwater recharge and less water availability in the surface layers, impacting vegetation.
    - On the other hand there is an opportunity resulting from the increased runoff to promote streambed infiltration at specific locations to supply urban centres.
- Secondary effects include reduction of grazing and more variable water availability with respective impacts on livestock herding and related livelihoods.

Next to the climate change aspects it needs to be understood that the main driver of reducing per-capita water availability is not climate change but to a much larger extent the uncontrolled population growth that directly leads to lower per-capita water availability, increased resource competition and destruction of natural resources. The destruction is mainly caused by resource overuse (overgrazing) and people falling out of the traditional sustainable livelihood patterns, resorting to alternative unsustainable activities (charcoal burning).

8.2 Recommendations

In order to prepare Somaliland and Puntland for the future a number of activities are recommended.

Knowledge generation

1. Ensure ongoing monitoring of parameters and at locations where monitoring has started
2. Expand monitoring network considering groundwater levels, groundwater production quantities, surface water levels and –flows including bedflows, rainfall, temperatures and other meteorological data

3. Develop drought forecasting system building on SST fluctuation data, using either spatial rainfall products (e.g. TRMM) to look at rainfall impacts or secondary approaches like NDVI response (see report for details)
4. Assess detailed climate change impacts for the region by either downscaling global climate data statistically (e.g. using a delta change approach for existing stations followed by rasterizing through delta change interpolation) or through the use of a regional climate model (e.g. PRECIS)
5. Conduct detailed assessment of recharge mechanisms of shallow aquifers through water balance modelling with e.g. HEC-HMS
6. Conduct a landcover study on a spatial scale based on remote sensing data to identify the current situation as well as changes in landcover over time (i.e. based on current as well as historic remote sensing data.

Water resources masterplans

7. Development of visions for major towns and districts (as a basis for masterplans)
8. Detailed resources assessments
9. Detailed needs assessments
10. Masterplan development for rural areas including strategy for water source grid
11. Masterplanning for urban centres
12. Plans for private sector involvement
13. Development of monitoring and enforcement strategies (pollution, over-abstraction, overgrazing, charcoal)

Rangeland management plans

14. Ensure community participation for implementable rangeland management plan
15. Develop destocking possibilities, allocation of grazing rights and grazing management while maintaining mobility
16. Develop of implementable licensing system for natural resources management (water, trees, pasture, land)
17. Market development and adaptation to develop off-season livestock sale possibilities or alternative meat conservation techniques (dry meat)
18. Consider utilization of alternative fodder or firewood generating plant species
19. Pilot implementation of rangeland management plans

Situational improvement

20. Develop National Adaptation Program for Action (NAPA) type of document specific to the water and land sectors that details implementation aspects
21. Institutional coaching, capacity building and coordination between government agencies and private sector
22. Development of structured implementation guidelines and pushing forward of pipeline projects based on masterplans as well as building the consensus of the communities

9. Literature list

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Annexes

Main stakeholders

Government Agencies
- Ministry of Mining, Energy and Water Resources, Somaliland
- Ministry for Livestock, Somaliland
- Ministry for Agriculture, Somaliland
- Ministry of Agriculture and Livestock, Puntland
- Ministry of Planning, Somaliland
- NERAD, National Environment Research and Disaster Preparedness and Management Authority, Somaliland
- PSAWEN, Puntland State Agency for Water, Energy and National Resources, Puntland
- HADMA, Humanitarian Aid for Disaster Management Agency, Puntland

UNO´s
- UNICEF
- IFAD
- FAO-SWALIM
- UNESCO
- UNOPS
- UNDP
- ILO

NGO´s
- Caritas – rural water, sanitation
- SRC – rural water (currently no projects)
- Oxfam (currently no projects)
- Care – rural water /emergency
- Worldvision (currently no projects)
- Terra Solidali – rural & urban water, groundwater

Academic Institutions
- Hargeysa University (civil engineering)
- Golis University (civil engineering, agriculture, environment)
- Amoud University (civil engineering, agriculture)

Water Utilities
- Hargeysa Water Agency (water utility)
- Shaba (Boorama water utility, established by UNICEF under PPP)
- Gumco (Puntland, Boosaaso water utility)
- Nuwaco (Puntland, Garowe water utility)
- Galwa (Gaalcacyo water utility)
- Hodman (Qardho water utility)
- Samsam (Gebiley water utility)
- Tawakal (Lughaya water utility)
- Berbera water agency (utility)
- Burco water agency (utility)

- Ceerigaabo water agency (utility)
- Galdogob water company
- Bacaadweyn water company

Companies / Consultants (partly ministry staff)

- Shaac, Jigjiga (Ethiopia)
- Somaliland Engineering Association, Hargeysa
- Many small drillers

List of Stakeholder Workshop Participants, Hargeysa, 27.-29.08.12

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11.	Abdullahi Ahmed Abdalla	UNICEF	Somaliland
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17.	Mohamed Dahir Cabsiye	MMEWR	Somaliland
18.	Mukhatar Daud Kaline	MMEWR	Somaliland
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21.	Mohamed Liiban Ismail	Ministry of Agriculture	Somaliland
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MMEWR Ministry of Mining, Energy and Water Resources
MERD Ministry of Environment & Rural Development
MOA Ministry of Agriculture
MOL Ministry of Livestock
HWA Hargeysa Water Agency

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6.	Abdihakim Tshir	MMEWR	Somaliland
7.	Ibrahim Ali Hussein	MERD	Somaliland
8.	Mohamed Libaan Ismail	MOA	Somaliland
9.	Farhan Ahmed	MOL	Somaliland
10.	Ahmed Ibrahim Suldan	HWA	Somaliland
11.	Mutai Josiah	Cartitas/INGO	
12.	Mohamed Jirde	Terra Solidali/INGO	
13.	Aden Ali Mohamed	Islamic Relief/INGO	
14.	Ali Ismail	FAO SWALIM	Hargeysa/Somaliland

MMEWR	Ministry of Mining, Energy and Water Resources
MERD	Ministry of Environment & Rural Development
MOA	Ministry of Agriculture
MOL	Ministry of Livestock
HWA	Hargeysa Water Agency