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Potential of Rainwater Harvesting in Somalia

A Planning, Design, Implementation and Monitoring Framework

Technical Report No. W-09

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

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Preamble

In 2004, the Food and Agriculture Organization of the United Nations (FAO) established a project entitled Somalia Water and Land Information Management Systems, SWALIM. SWALIM's objective is to contribute to improved water and food security in Somalia by:

- collecting data needed for water and land resources management
- generating user-friendly information from the data
- storing the information in easily accessible databases and disseminating it through conventional and electronic media
- building capacity among Somali authorities to take over these functions in the future.

In March 2007, FAO-SWALIM signed a memorandum of understanding with ICRAF with the aim of producing a number of outputs. These include rainwater harvesting (RWH) classification scheme and definition system; identifying traditional water conservation systems; identifying technical and socio-economic factors for evaluating, planning and designing RWH projects; assessing the potential of RWH practices for increased agricultural or livestock production; and creating links between national institutions and international bodies or networks involved in RWH. The final output is a common framework for planning, designing, implementing and monitoring RWH projects.

To achieve these objectives and outputs, two rounds of trips were organized for fact-finding missions and consultative workshops in April and May 2007. These events took place in Puntland, Somaliland and Southern Somalia, drawing participants from relevant line ministries in government, UN agencies, international non-governmental organizations and community-based organizations. The draft framework was presented in Nairobi for ratification in June 2007. It is envisaged that the final products that include the framework document and assessment report on the potentials of RWH technologies shall act as reference material for policy makers to prioritize and guide community, government and external support agencies, on RWH investment options.

Table of Contents

List of Figures

List of Plates

List of Annexes

List of Tables

Acronyms

ACZ	Agro-climatic Zone
AfDB	African Development Bank
CA	Conservation Agriculture
CBO	Community-Based Organization
DEM	Digital Elevation Model
FAO	Food and Agriculture Organization of the United Nations
ICRAF	The World Agroforestry Centre
ITCZ	Inter-Tropical Convergence Zone
RELMA	Regional Land Management Unit
RWH	Rainwater Harvesting
SWALIM	Somalia Water and Land Information Management Systems
SWC	Soil and Water Conservation
UN	United Nations
UNECA	United Nations Economic Commission for Africa
USD	United States Dollar

Local terms

balli	A natural depression on flatter silt soils that collect surface runoff with water-holding capacity ranging from less than 1000 m^3 to more than 100,000 m^3.
war	A stock pond excavated either by hand, and within the last 15 years by machinery, in heavy sealing soils whose capacity for holding water ranges from less than 100 m^3 to more than 10,000 m^3.
berkad	A concrete-lined reservoir roofed either with corrugated iron sheets or shaded with small bushes suspended over the tanks with nets. Its capacity ranges from 30 to 400 m^3.
xurfad	Either a water pond or earth dam.
ceel	A hand-dug well.
berkad guri	Roof water harvesting.
majaroor	Roof water harvesting.
naxaroor	Soil bunds constructed to conserve both soil and water.
xadhig	Soil bunds constructed to conserve both soil and water.
il	Natural spring
doox xidh	A sub-surface dam constructed in sandy rivers
deshek	Flood-diversion techniques used for delivering flood water for irrigation purposes
mugsid	An underground reservoir

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GIS support:
Craig von Hagen, Alex Koton and Meshack Nyabenge

Computer graphics
Evans Oduor, Pixiniti Studios

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Pollyne Wangari, Amos Nyaoro and Christine Kenyao

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1. Introduction

1.1 Background and general context

Somalia covers an area of 637,657 km^2 with the population in 2003 estimated at 7.5 million inhabitants. Somalia's economy is predominantly agricultural (crops and livestock, the latter being a major mainstay). The economy depends highly on water availability, which in turn is reliant on rainfall. Rainfall in Somalia is not only low, below 100 mm per year in some areas, but has a high temporal and spatial variability (annexes 1 to 5). The annual average rainfall ranges from 215 mm in the North-eastern regions to approximate 550 mm in the South-Central regions (SWALIM, 2007). The water balance for the country depicts potential evapotranspiration greater than rainfall in the entire country. In addition, other hydro-physical conditions that negatively impact on the availability of freshwater include land degradation and siltation of water bodies. The situation has been compounded by 16 years of civil strife, especially in the southern regions. A number of local and international organizations have initiated civil reconstruction, environmental conservation and livelihood-support programmes.
Experts estimate that Somalia is among the 13 African countries that will face water scarcity by 2025. A country is said to be water scarce when its annual per capita water availability falls below 1000 m^3. Already, Somalia has less than 500 m^3/per capita/year (UNECA, 2000). This is attributed to erratic spatial and temporal distribution of rainfall with average annual amounts falling between 100 and 800 mm, high evaporation, and human activities that exacerbate land degradation.

Annexes 6 and 7 show the agro-ecological zones for Somalia. The dry and moist semi-arid zones in the South, South-Central and North-western regions are conducive to agricultural production. In these regions the length of crop growing season ranges from 60 to 120 days, and in situ water conservation measures and rainwater harvesting techniques can be practised.

A survey carried out by FAO-SWALIM in 2006; found that land degradation requires serious attention. According to the technical report Name and year produced by the SWALIM land team, rangeland degradation, which constitutes about 50% of land degradation, is the most serious form of land degradation. Land degradation is exacerbated by prolonged droughts and the charcoal trade, which is widespread in the country. The report further states that the rate of soil nutrient loss alone in Somalia is 88 kg ha^{-1}yr^{-1}. Rangelands also constitute the largest runoff water domain. Proper management of soil and water resources is therefore a big challenge.

The agricultural and livestock sectors play a key role in food security, natural resources management and environmental protection. Many districts have no permanent sources of water supply. The human population and livestock depend on surface water harvesting structures such as dams and *berkads*. These however dry up in the middle of the dry season resulting in serious shortage of water that causes deaths of livestock and sometimes humans. Water trucking is common in such districts during prolonged droughts. The waters in these reservoirs are polluted with organic matter, silt and sometimes garbage. There is also high likelihood of biological contamination.

Despite all these problems, Somalia still has potential to harvest rainwater for domestic, agricultural and livestock use in areas where considerable runoff is generated. The principles and technologies applicable to rainwater harvesting are discussed in detail in chapter 3 of this report.

Definition of rainwater harvesting and management systems

A rainwater harvesting and management system is broadly defined as the collection, concentration and management of runoff water from roofs or ground catchments for the production of crop, pasture/fodder, trees, livestock and/or domestic water (Ngigi, 2006). Surface runoff from roofs or rock outcrops is collected and stored in plastic or concrete tanks of about 4–20 m^3. Surface runoff from ground catchments is harnessed and stored in soil or in ponds with capacities of about 1000 m^3 and in dams with higher capacities.

1.2 Problem statement

Although many organisations are involved in water-related activities, the capacity of the community and government is still inadequate to take advantage of the potential that rainwater harvesting offers in mitigating the effects of water scarcity in most parts of Somalia.

The Governments of Puntland, Somaliland and South-Central Somalia are still in the early stages of developing water policy. Rainwater harvesting is not adequately mainstreamed in policy documents. The governments will need the support of experts to incorporate RWH in its programmes and projects.

1.3 Objectives of the assessment

The objective of the Food and Agriculture Organization's Somalia Water and Land Information Management (FAO-SWALIM), is to improve water and food security and support the sustainable use of natural resources through information management. In March 2007, SWALIM signed a memorandum of understanding with The World Agro-forestry Centre (ICRAF) to collaborate on the production of *"A common framework for planning, designing, implementation and monitoring of rainwater harvesting projects in Somalia"*. The aims of the mission included:

- Producing a rainwater harvesting classification scheme;
- Identifying traditional water conservation systems
- Identifying technical and socio-economic factors for evaluating, planning and designing RWH projects
- Assessing the potential of RWH practices for increased agricultural and livestock production
- Creating links between national institutions with regional and global networks involved in RWH.

1.4 Methodology

Consultative meetings and workshops

Two rounds of trips were made to Hargeisa in Somaliland, Garowe in Puntland and Baidoa in South-Central Somalia. Workshops and consultative meetings were held in the three regions where participants drawn from government line ministries, UN agencies, international and local NGOs deliberated on criteria for mapping and determining the potential for agricultural, livestock and domestic RWH and conservation systems. In total six workshops were held, two in each region. Participants were split into technology and policy working groups to deliberate on rainwater harvesting for Somalia. These discussions form the framework document.

Plate 1: Participants during consultative workshops in Garowe, Hargeisa and Baidoa

Outcome of the consultative meetings and workshops

There was acknowledgement and consensus that runoff that flows un-tapped to the Red sea and the Gulf of Oman goes to waste. It also emerged that many organizations practice rainwater harvesting in Somaliland, Puntland and South-Central Somalia, though its definition is not clearly understood by some of the practitioners.

Common water harvesting and related activities currently in place include dam construction, shallow wells, spring development, watershed management, pasture development, sinking of boreholes and construction of berkads.

To benefit in the cross-fertilization of knowledge and experiences, the governments of the three regions were interested to liaise with FAO-SWALIM in networking with and joining the Southern and Eastern Africa Rainwater Network (SearNet). Somaliland has a watershed management association formed to address for rainwater harvesting and land degradation issues.

The governments have policies that touch directly or indirectly on rainwater harvesting but which are still at various stages of development.

Classification of RWH and conservation technologies for Somalia

The technology working groups deliberated on indigenous rainwater as well as other water conservation technologies, identified the local names for these practices and produced a classification chart for each region (see sections 3.1 to 3.3).

Developing the mapping criteria

The original plan was to map development domains for rooftop; ponds, pans and small earth dams; in situ water conservation; rock catchment systems and sand/sub-surface dams (see annex 8 for the description of classes for these criteria). However, due to lack of information on some criteria, mapping was done for rooftop water harvesting potential, runoff water domains for agricultural areas and runoff water domains for rangelands.

Criteria for mapping rooftop water harvesting potential depended on the availability of data on settlements (roof area coverage), population density and rainfall as shown in the classes in annex 8. Owing to lack of demographic data, especially population density, mapping for rooftop water harvesting potential was instead produced with support of roof area coverage data provided by UN Habitat. FAO-SWALIM provided rainfall data.

Criteria for mapping agricultural and rangelands development domains depended on the availability of GIS baseline datasets such as those for climate (rainfall and evaporation) and elevation models. These were provided by FAO-SWALIM and ICRAF.

Design of RWH systems

Information compiled from the missions to Somalia and from the FAO-SWALIM office was used as base data for developing designs for Somalia RWH systems. Three categories of rainwater use were considered—livestock production, crop production and domestic use. Suggestions were made on maintenance aspects and how to improve on the systems.

1.5 Challenges, opportunities and benefits of RWH in Somalia

Somalia receives low rainfall and very high temperatures, hence high evaporation from surface reservoirs. This means that large tracks of land are required as catchment areas to generate adequate runoff for ponds or dams. The other problem is silt deposits along conveyance channels. After the rains huge deposits of silt are transported to the reservoirs. This not only reduces the lifespan of the reservoir, but also hikes maintenance costs through manual or mechanical desiltation. NGOs such as the Agricultural Development Cooperation in Hargeisa cite costs of desilting ranging from USD 20,000 to USD 30,000 for ponds with surface areas of approximately 1000 m^2.

Most concrete storage structures such as the berkads have cracks. According to Foerch (2003), the quality of berkad construction changed drastically since the 1950s (see figure 1). This was attributed to the combined effects of war, absence of maintenance during the displacement years and poor workmanship. Quality declined drastically during the 1970s. The motto at the time was to build a berkad as fast and as cheaply as possible (15-day construction period). This resulted in imprecision, carelessness and poor quality of construction. From the rural water supply assessment carried out by SWALIM, more than half of the berkads are currently broken. The challenge is to develop standards for their design, construction and maintenance.

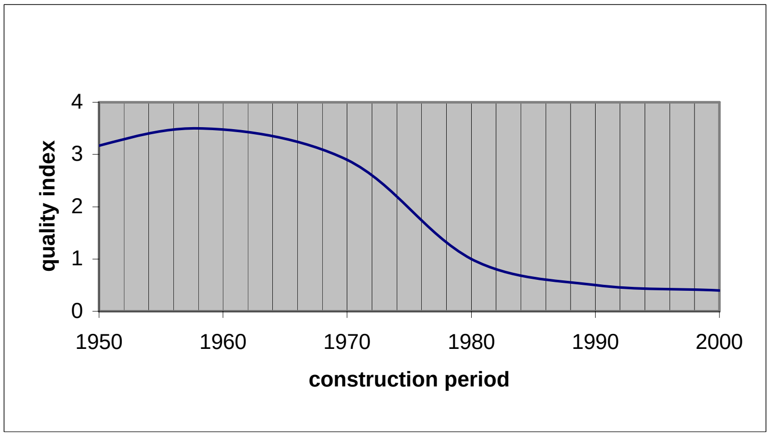

Figure 1: Change in construction quality over time

Unlike other countries in the region that have networks of rainwater harvesting associations composed of diverse disciples relevant to the technology, Somalia is just beginning to establish its own structure. So far, government authorities are taking the lead with the inter-ministerial forums that are looking into policy and regulatory aspects of water management. There is interest to establish watershed management associations that would also include rainwater harvesting in their agenda.

Rainwater harvesting is mostly practised by NGOs and UN agencies show-casing or proving to governments and key donors that the technology is a viable investment. So far, information on costs and benefits is insufficient for econometricians to use in assessing the viability of RWH.

In addition to the above, participants at the consultative workshop said there was insufficient human capacity to implement rainwater harvesting in Somalia. The challenge is to develop a capacity-building framework that will prepare Somalia in upscaling and outscaling RWH projects and programmes implemented by governments, international NGOs and UN agencies.

RWH presents opportunities which communities can take advantage of to enhance their livelihoods. These include taking advantage of runoff water to boost human health (since rainwater from roof and rock catchment is fairly clean and safe); boosting agricultural productivity and thus food security; involving local communities in planning and implementing RWH projects and creating jobs for local artisans and fabricators. RWH complements other water sources. It saves energy and time because its infrastructure is close to its utilization points. RWH mitigates against the devastating effects of climate change as water stored during floods is stopped from creating havoc in the lowlands, and it becomes useful for irrigation and livestock production during the dry periods.

Somalia receives approximately 209 km^3 of fresh renewable rainwater annually. This water is unevenly distributed in space and time. Using RWH as a means of addressing this spatial and temporal rainfall variability would contribute to coping with droughts and floods, thus enabling communities to invest in livelihood activities. The twin challenges of droughts and floods can be mitigated by constructing huge reservoirs to store flood water, which is later availed during the dry periods for irrigation, livestock and domestic use.

1.6 Expected outcome

The major output from this exercise is a framework document that policy and decision makers can use for planning, designing and implementing RWH projects in Somalia.

2. Climatic and Hydro-physical Factors Influencing Rainwater Harvesting in Somalia

2.1 Rainfall

Rainfall in Somalia is low and erratic caused primarily by the descending motion of the air and low humidity. Somalia is also located at the leeward side of the Kenya–Ethiopia highlands, thus subjecting it to further low rains. Somalia has a bimodal rainfall distribution—*gu* and *deyr*. The timing of the seasons varies across the country. The first main season, gu, occurs between March and July and the second, deyr, from August to November (annexes 2 to 5). The months of highest rainfall within these seasons are generally from April–June and October–November. The two dry seasons in the country are *jilaal* and *haggai,* which occur between December and March and July and August, respectively.

Based on the annual average rainfall pattern, Somalia has a desert to dry subhumid climate. Rainfall is influenced greatly by the inter-tropical convergence zone (ITCZ) and the Somali jet. Orographic and coastal influences are also significant and cause a high degree of variability across the country.

High rainfall areas occur in the Shabelle and Juba Basins with annual averages of approximately 460 and 427 mm respectively (SWALIM, 2007). Rainfall reduces further inland to the south with Upper Shabelle (Hiran and surrounding) receiving up to 400 mm per year while the area between Shabelle and Juba valley receive relatively high rainfall of about 500–700 mm per year. The amount of rainfall received annually reduces further to the north except for areas around Sheikh, Hargeisa and Borama that receive between 500 mm and 600 mm per year. The area around Ceerigavo receives up to 400 mm annually. The northern coastline is characterized by low rains of less than 100 mm per year. The same is experienced around the inland of north-eastern coast (Lasanod, Qardo and Scuscuban). The rest of the northern region and central Somalia receive an annual mean of 200 to 300 mm. This situation is further exemplified in figures 2 to 4. Figure 2 shows the area per region, figure 3 shows the rainwater potential per region computed as a volumetric product of average annual rainfall depth with the area, while figure 4 shows the rainwater potential per unit area for every region. From the three charts, it is clear that the southern regions of Juba, Shebelle, Mogadishu and Bay have the highest rainwater water potential in Somalia.

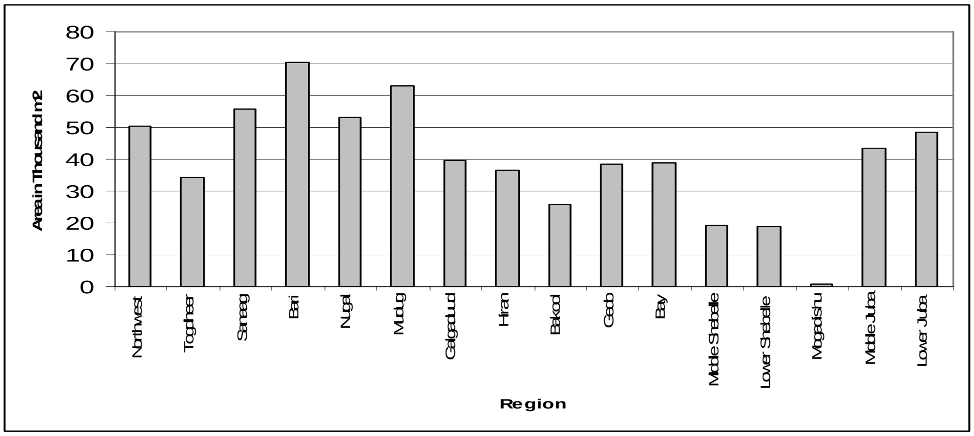

Figure 2: Area per region

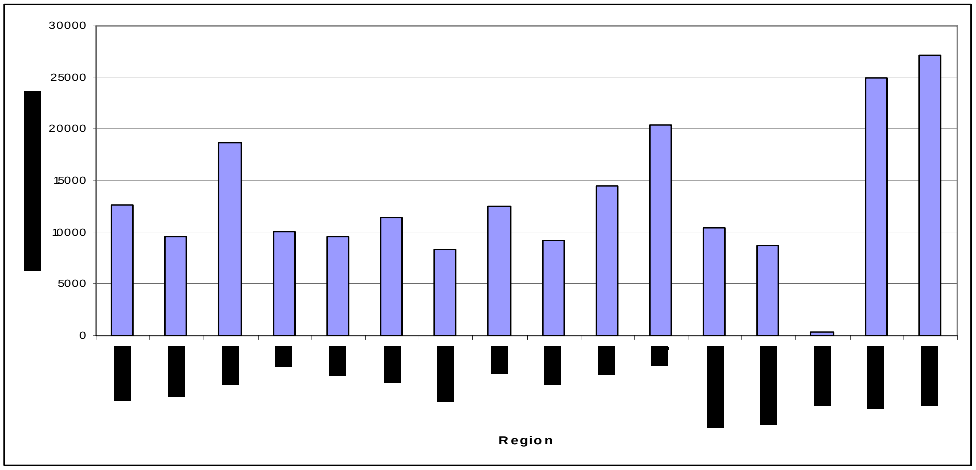

Figure 3: Rainwater potential per region prior to partitioning

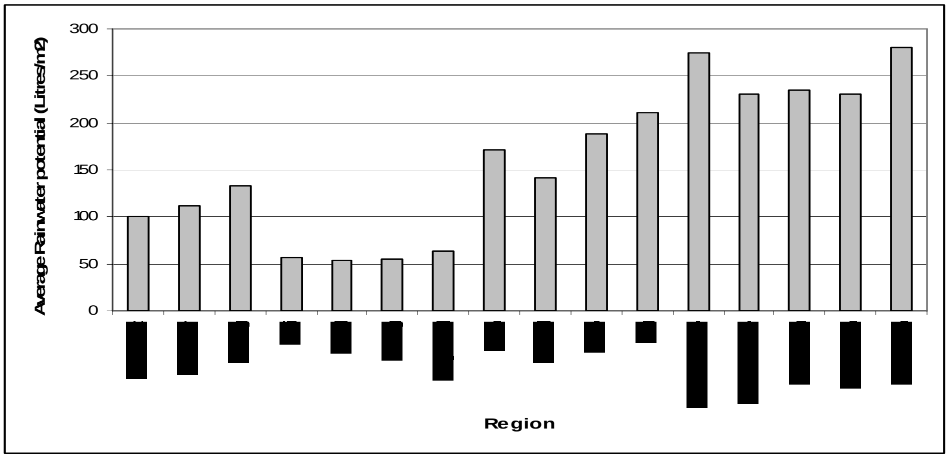

Figure 4: Rainwater potential per unit area

Since its inception, FAO-SWALIM has put together all the available historical rainfall data of Somalia. In addition, it is facilitating the installation and management of rain gauges across the country. So far 70 manual 24-hour rain gauges have been installed.

2.2 Potential evaporatranspiration

Evaporation in Somalia is very high, exceeding rainfall in all regions. Annual potential evapotranspiration ranges from 1000 mm around Lower Juba region, to 3000 mm in West Galbeed and Togdheer regions (see annex 9). The southern regions are thus more suitable to open surface water reservoirs compared to the northern and north-eastern regions.
Potential evapotranspiration is important especially when designing in situ rainwater conservation structures. The rainfall potential evaporation ratios help in identifying suitable locations for sand and subsurface dams which is < 0.6 for drylands and > 0.6 in wetlands.

2.3 Air temperature and wind speed

Air temperature and wind speed are important especially in designing open RWH reservoirs or tanks, particularly when considering losses due to evaporation. The mean air temperatures in Somalia are generally high all the year round throughout the country. Average monthly temperatures reach as high as 31–33^0 C in March around Bardheere, Luuq and Afmadow in the south, and 36–38^0 C in the north around Berbera (annex 10). The local communities in some areas have observed higher temperatures. These have not been recorded and have not been used in this report.

December to March are the hottest months in Southern Somalia. Temperatures are greatest at the Kenya, Somalia and Ethiopia borders (over 30^0 C) gradually decreasing towards the ocean (28^0 C). July and August are the coolest months in Southern Somalia. The Somali low-level jet is coincidentally strongest over southern Somalia during this period thus contributing to the cooling effects in the region.

The hottest weather in the north is experienced between June and September especially around Awdal and Bosasso areas. The North gets cooler in January and February. Between 1963 and 1990 the highest mean maximum value that was recorded is 42^0 C in June and July at Berbera, with the lowest mean minimum temperature being 6^0 C at Erigavo in January.

Wind speeds are generally from about 2 m/s to 8.5 m/s on average and strongest during the south-westerly monsoon (June to August). It is during such times that care needs to be taken especially on evaporation losses from open surface reservoirs. On average the lowest values of wind speed occur between April and November in the country coinciding with the peaks of the two rainy seasons gu and deyr respectively. Losses due to evaporation are enhanced with increased temperatures and further accelerated with higher wind speeds. Where possible for open water bodies, the losses due to evaporation can be reduced by planting wind-breaking trees on the side of the reservoir from whose direction the winds emerge. Figure 5 shows the temporal distribution of wind speed from selected stations across the country.

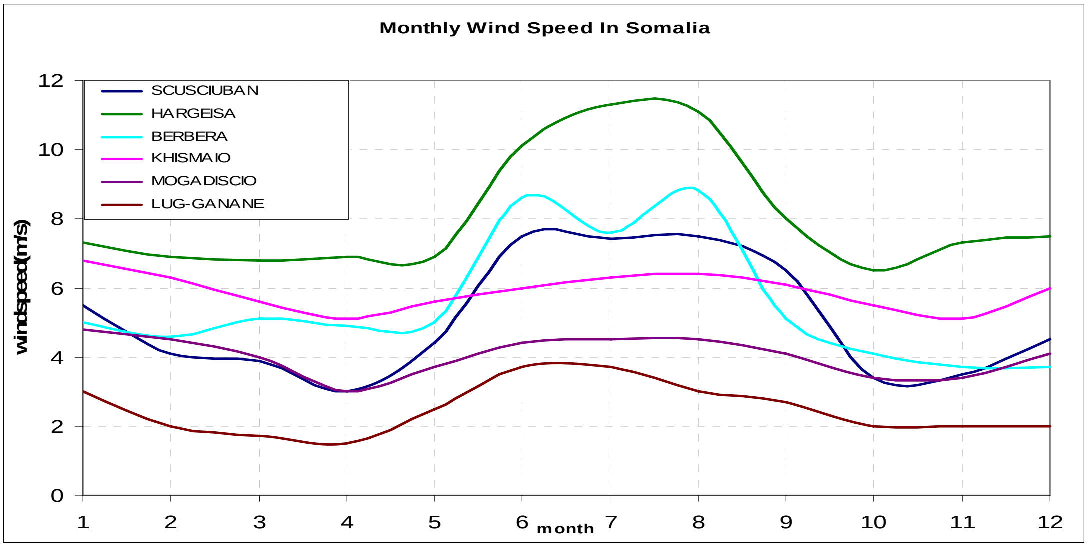

Figure 5: Wind speed at some stations

2.4 Landforms and vegetation cover

The elevation gradient, determined from digital elevation models including the degree and length of slope, influences the amount of runoff generated from a given rainfall event. The steeper or longer the slope, the more the runoff. Most of Somalia is made up of gentle to undulating landforms. Annexes 11 and 12 show the digital elevation model and landforms for Somalia.

Vegetation cover is determined by the inherent physiographic factors and the type of land use of a given area. Areas with high rainfall have more biomass and hence dense vegetation cover. Somalia is largely arid and semi-arid with sparse vegetation. A decrease in vegetation results in corresponding decrease in interception, retention and infiltration and increased runoff. Continuous denudation of land through practices such as deforestation results in less infiltration and more runoff.

2.5 Soil types

Soil type is important in determining whether the water harvesting system will depend on direct rainfall or runoff. Soils with poor infiltration capacities are can be used with runoff-based systems while those with good infiltration and water-holding capacities, whether natural or induced, are good for in situ water conservation systems.

3. Historical Development and Technological Options of RWH in Somalia

3.1 Water resources in various regions of Somalia

Rainwater harvesting is not the only technique for availing water to Somali communities, but rather it complements other sources of water. Consultative workshops held in Puntland, Somaliland and South-Central Somalia in May 2007 identified and developed a nomenclature of water sources for the three regions. Table 1 shows these water sources with minor variations in the local names of some technologies.

Table 1: Nomenclature of water sources in various regions of Somalia

Somaliland		Puntland		S. Somalia	
Technology	**Local name**	**Technology**	**Local name**	**Technology**	**Local name**
Cement water tank	*Berkad*	Underground water tank	*Berkad*	Cement water tank	*Berkad*
Bund	*Naxaroor/Xadhig*	Natural water pond	*Balli*	Underground reservoir	*Ceel/Mugsid*
Water pond/earth dam	*Balley*	Water pond/earth dam	*Xurfad*	Water pond/earth dam	*War*
Hand well behind a dam	*Ceel*	Well	*Ceel*	Natural water course	*Tog*
Spring	*IL*	Spring	*IL*	Flood diversion	*Deshek*
Roof water harvesting	*Majaroor*	Roof water tank	*Berkad Guri*	Natural depression	*Gal*
Subsurface dam	*Doox xidh*				
Underground reservoir	*Ceel/Mugsid*				
Natural ditch	*Dhiijan*				
Flood channel	*Deshek*				
Terrace					
Plastic pond					
Pit					

3.2 Indegenous technologies

Rainwater harvesting is not new to Somalia. It has been in place since time immemorial. The existence of *berkads, waro and xadlings* are testimony to a long history of harnessing rainwater for domestic, livestock and crop use. During jilal (dry season), people migrate with camels for long distances in search of water and fodder for their animals. The camels were used to carry water fetching it twice weekly in the dry seasons, and once monthly in the rainy seasons. Shoats were kept only in areas with adequate water, for example, in rivers or shallow wells.

With the introduction of berkads, which are privately owned especially in Northwest region of Somaliland, more and more people are settling down. The first berkads in the region were built in the 1950s when Somaliland was still under British colonial rule (Foerch, 2003). The idea was first introduced by one Xaaxi in 1952, who built the first berkad near Odweyne. It is likely the idea was taken from existing examples in Sudan at that time. It was not until 1964 when major construction started. Construction continued even after the Italians occupied the South and the British protectorate in the North merged and became independent in 1960. More and more people settled in the Haut region and the demand for water increased tremendously. As a result, an intense period of construction began. This continued until the civil war broke out between 1988 and 1991 pitting the North and the South of Somalia, and thus halting construction.

3.3 Current RWH technologies in Somalia

Rainwater harvesting and management systems in Somalia are classified according to rainwater use. Three categories were identified during the consultative workshops: crop production systems; livestock production systems; and domestic water harvesting and conservation systems (Figure 6).

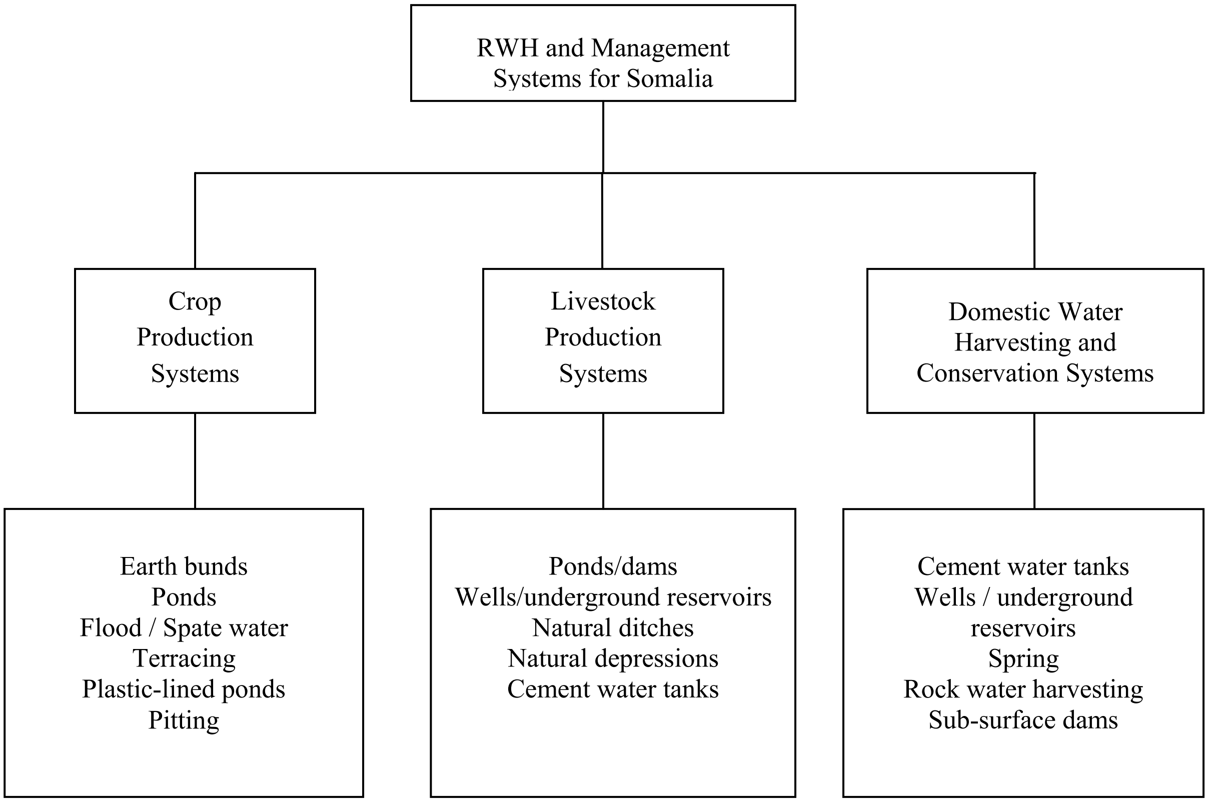

Figure 6: Classification of rainwater harvesting and conservation systems for Somalia

Crop production systems
These are either water harvesting or water conservation systems that capture runoff water that is stored in reservoirs for later use, or direct rainfall for in situ soil moisture conservation. Technologies that benefit from direct runoff and that are either used for supplementary or full irrigation include earth dams, ponds, dams and flood/spate water. These technologies are common in south-central and southern districts and some parts of north-western regions. Other areas, such us the southern riverine environs benefit from floodwater flowing mainly from the Juba and Shabelle River basins.

Livestock production systems
These are systems that make use of runoff or underground water for livestock production. Runoff water is collected and stored in natural depressions or man-made reservoirs such

as ponds, berkads and dams. Quite often, the stored water is shared for crop production and domestic use. Areas with shallow groundwater also abstract water for animal use.

Domestic water harvesting and conservation systems

Domestic water harvesting and conservation systems harness either direct rainwater or ground water. From roof or rock catchments rainwater is collected and later stored in concrete water tanks, known locally as *berkad guri*. Rainwater is also conserved in sandy river beds in areas with sufficient rainfall also conserve rainwater. Water for domestic use can also be drawn from shallow wells and springs.

3.4 Technological options for RWH and conservation systems in Somalia

All the RWH systems have six components: the catchment area, conveyance mechanism, storage and treatment, abstraction mechanism and utilization components (see annex 13 for details). Systems with fewer components are more technologically efficient and cost efficient. Losses are fewer and so are impurities from outside their domain area. Domestic roof or rock catchment and in situ water conservation systems such as conservation agriculture, are good examples of short-component systems. In situ systems are even much better as the hydrologic cycle is closed at very small scales. Storage mechanisms are the most expensive of all components. This calls for proper planning and design to reduce the cost without compromising structural strengths.

3.4.1 Ex situ agricultural RWH systems

The agricultural (crop and livestock) systems get their water from direct runoff or flood (both ex situ) and direct rainfall (in situ). Ex situ rainwater harvesting is the provision of runoff water from external catchments for supplementary irrigation to sustain crops through the entire growing period, or for livestock drinking. Runoff water that collects on the ground in homesteads, farms, paths and rural roads is channelled via mitre drains into already existing channels with silt traps. Immediately after the silt traps, the runoff water is conveyed to surface or underground reservoirs. The underground reservoirs are either closed or open. Closed reservoirs include sausage or spherical tanks while open ones are either lined or unlined ponds and tanks. Water from these ponds or tanks is abstracted using simple rope and washer or treadle pumps for supplementary irrigation. Figure 7 shows the components of an ex situ agricultural water harvesting system for crop production. Livestock systems use mainly surface reservoirs such as ponds.

Information gathered during consultative workshops organised by FAO-SWALIM in May 2007, shows that ponds are constructed using bulldozers at unit volumetric costs of USD 5 per m^3; a 500-m^3 reservoir costs approximately USD 2500. The cost of hiring machinery to construct new balleys ranges from USD 70 to USD 100 per day.

Siltation is a major problem calling for annual desiltation. Within 2 to 3 years, the community maintains the structure by providing labour. Only those who contribute to the maintenance of these structures have rights to the use of water from the balleys. There are no restrictions on amount or quota for those eligible to use balley water.

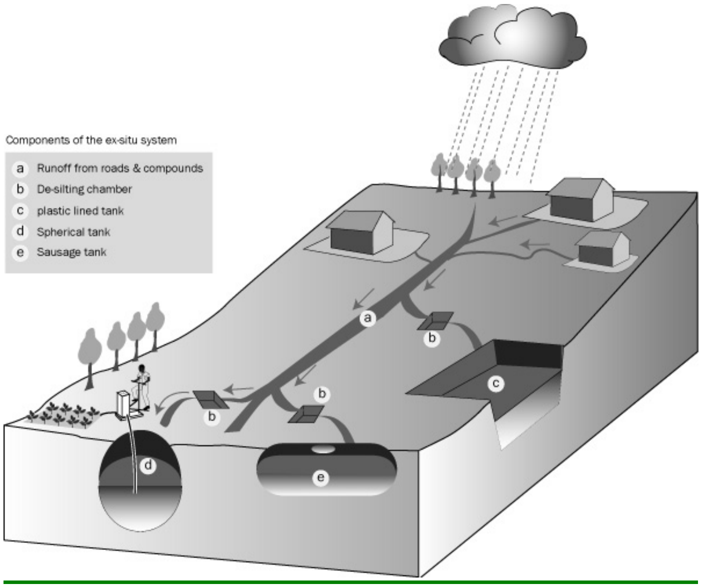

Figure 7: Rainwater harvesting components for agricultural system

3.4.2. In situ water conservation

In situ rainwater conservation technologies aim at conserving rainfall where it falls in the cropped or pasture areas by holding rainwater and prolonging the time for infiltration. In situ water conservation is achieved mainly using conservation agriculture and micro-catchments. This technology can be practiced in areas with low topography in arid or semiarid climates such as Somalia. Conservation farming involves minimizing soil disturbance through reduced or zero tillage, maximizing soil cover, and using crop rotations or associations. Indeed, conservation farming refers to the simultaneous practice of all three through ripping, tied ridges, basins, strip tillage, etc., as a gateway to progressively achieve minimal soil disturbance.

Table 2: Profile of some conservation farming practices[1]

Type	**Technical description**	**Development domain**	**Advantages**	**Limitation**	**Costs**
Planting Pits (a) Zai holes	-Holes measuring 10–30 cm wide,5–15cm deep and spaced 75–90 cm (inter-row) -Ideal for cereal crops (millet, sorghum, maize, etc.)	-Successful in areas receiving 200–750 mm annual rainfall -Does best in silt clay soil on gentle slopes Composed/manure fertilizer very necessary	-Traps moisture and increase soil water Reduces soil erosion	Labour intensive Animal draft not applicable	8 man days/acre 2 man days/ 0.25acre @ USD 2 + USD 4

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[1] Source: Wilfred Miriithi (2007)

Type	Technical description	Development domain	Advantages	Limitation	Costs
(b) Tumbukiza	Holes measuring 2x2x2 ft to 3x3x2. Holes spacing based on specific crop. Ideal for Napier maize (multiple seeding), pawpaw, mangoes and other fruit trees	Ideal for all slopes/rainfall regimes in dry areas. Topsoil must be mixed with manure, fertilizers	Act as micro-catchments Can harvest water from external catchments	Labor intensive Animal draft not applicable	10 holes/ person/day 75 holes/0.25acre 8md x USD 2 = USD 16
Semi-circular bands	Earth bands in the shape of a semi-circle (eye brows) Holes (planting) dug to specific crop recommendation Bands vary from structure with radius 2–30 m. Ideal for fruit trees and fodder crops Staggered in arrangement to get spill over	Suitable on gentle slopes with 200–250 mm rainfall Soil should not be too shallow or saline	Easy to construct Suitable for uneven terrain Increase soil moisture Control soil erosion	Animal draft not applicable Requires regular maintenance	32md/acre 8md/1/4 acre 8xUSD 2 USD 16
Retention ditch	Laid along contour Measures 0.3x0.6 m deep, 0.5–1 m wide Ends are closed May be a trench or a hole Capture runoff from ext. catchments	Suitable on flat gentle/steep slopes On permeable, deep and stable soils	Reduces soil erosion. Holds runoff for use by crops and ground recharge Guards other structure down stream	Labour demanding Requires regular maintenance Risk some erosion/processes Prone to overflow	USD 0.75 /meter of excavation 20 m= USD 15
Cover crop	Usually creeping legumes e.g. *Mucuna, Dolichos lablab,* etc. Used to cover the ground below widely spaced tall crop	Used for deep-rooted crop to avoid competition for nutrients	Improve soil fertility Suppress weeds Regulates soil temperatures	Competes for water with shallow rooted crops	Cost of establishing = . USD 4.2 = per 0.25acre
Conservation tillage Agriculture	Entails minimal soil disturbance Permanent soil cover Crop rotations/associations	Herbicides selection based on type of weed and crop	Reduces labour, lost energy needed to increase SWC water.	Selective use of herbicides	USD 4.2 = per 1/4 acre

Type	Technical description	Development domain	Advantages	Limitation	Costs
			Improves infiltration		
Ripping (in CA)	Ripper works by ripping the soil and therefore cracking it It breaks any paw (hard)that may have developed Magoye ripper - used in place of mould board on ox-driven ploughs	On gentle flat terrain On field free of rocks and tree roots	Breaks hard pan Moisture stored in root zone. Soil nutrients are accessible by the plant. Productivity increase by 78% compared to conventional farming practices	Only applicable where animal draft power is used	- USD 3 per 0.25 acre

The benefits of these include improved soil structure and moisture storage. Soil cover is maximized through cover cropping, intercropping and the use of crop residues or mulch. Conservation agriculture enhances moisture conservation, suppresses weeds, reduces erosion and soil temperature variation and also enhances soil fauna and micro-organisms. Crop rotations and associations enhance nutrient replenishment and uptake; control of weeds, pests and diseases; integration of livestock, carbon sequestration and food security (RELMA, 2004). In situ water conservation promotes improved management practices when cultivating corn, cotton, sorghum and other drought-tolerant crops. In Somalia, it can be practised in areas with annual rainfall above 200 mm (annex 5). The areas include Gabiley District of Woqooyi Galbeed region, Bay, Hiram, Galgadud, Middle and Lower Shebelle. Table 2 profiles of some of the in situ farming practices.

3.4.3 Rainwater management for agro-forestry systems

Selection of agro forestry trees and shrubs

Sunshine is not a problem in these areas; the growing season and sunny days are long. Therefore, maximizing the shading effect of the trees and shrubs is what benefits most. However, one cannot choose broad-leaved trees and shrubs because they will minimize the Albedo (reflectivity) and trigger higher evapotranspiration. What is needed is the maximization of reflectivity at the top canopy layer so that heat absorption is reduced to the minimum. Hence the target species, especially in the most top canopy hierarchy must be those with small pinnated leaves that quiver and cause air ventilation to the species in the lower canopy layers. Most of the *Acacia* and *Ziziphus* species, *Pithecellobium dulce, Parkinsonia aculeate, Schinus molle, Salix subserata, Sclerocarya birrea, Moringa oleifera, Commiphora erythraea, Ximenia americana, Celtis africana, Balanites aegyptiaca, Boswellia rivae, Securidaca longepedunculaat,* and many others belong to this group.

One additional important factor is looking for those agroforestry trees and shrubs, which have got broader leaves but at the same time are aided either with thin film that covers the stomata of the leaves or have leathery leaves for reduced evapotranspiration. *Sarcocephalus latifolius, Calotropis procera, Annona senegalensis, Celtis toka, Piliostigima thonningii, Agave Americana, etc.,* few examples of such species aided by nature.

The trees and shrubs listed above are among the few of many agroforestry trees and shrubs that fit the agroclimatic conditions of Somalia. But what t tree or shrub species to use will depend on the use and purpose of the intervention. These and other species have varied benefits that range from shade provision, industrial milk production to soil fertility replenishment medicinal use, and providing nutrition in the form of edible fruits. Bekele Tesemma (2007) gives detailed information on the species best suited for dry, hot lowland agroclimatic conditions.

Configuration of agro forestry trees and shrubs
Specifically in the agro-climatic zones of Somalia, where evapotranspiration far exceeds precipitation, benefits from agro forestry systems are highly correlated to the configuration of the trees and shrubs over the landscape. Components need to be mixed and arranged carefully even regardless of the intended use of the farming system itself. Good knowledge of the prevailing wind direction and aspect, slope extent and orientations, amount of rainfall, soil depth and status of soil fertility of the site is important. The tree/shrub configurations in agro forestry systems need to consider the type and nature of the site preparation activities as well. Agro forestry systems in flat lands can benefit from water harvesting if the size of the dish-like micro-basins (in the case of flat lands) takes into account the amount of rain and for how many consecutive days. For instance, where annual rainfall is only 600 mm and potential evapotranspiration is 1600 mm doubling the diameter of the micro basins from 60 cm to 120 cm increases the survival of agro forestry trees and shrubs by 250%.

Site preparations can take many shapes depending on the nature of the micro-site where the agro forestry intervention is to take place. Micro basins, retention ditches, different types of terraces may be used. In a flat site, circular dish-like micro basins are preferred to crescent–shaped micro basins, the latter or better suited to sites with gentle to undulating topography. If the same land is shallow in soil depth, shrubs are preferred over trees. If the soil of the micro site is weak in organic matter, deciduous trees and shrubs are more suitable. Knowing the hydro physical conditions of the area is important to maximize the shading effect of the agro forestry system when it is practised along irrigation canals to minimize evapotranspiration loss. The same is true when the agroforestry system is designed to support and benefit from other rainwater harvesting measures such as hillside reservoirs.

We recommend training development facilitators, who in turn train farmers, of the essence and issues of agroforestry innovations that suit such environments. The training should be supported with demonstrations and practicals. The trainers should prior understanding of the different micro-sites so that they can customize lessons and practicals to real conditions of the area. Similarly there should be an understanding of the communities' interests about the main purpose and function of the agroforestry system to be established and cared by them. Having a thorough understanding of complementary development efforts such as rainwater management is quite necessary. The impact of such community support can be effectively rooted if primary and high school teachers are trained with development facilitators on how to re-tool their teaching syllabus to accommodate agroforestry interventions that work in the different agroclimatic conditions of Somalia. I recommend that specific agroforestry innovations be designed taking into account the specific site conditions and community interests. For the pool of agroforestry innovations, from which candidate interventions can be selected, read Bekele-Tesemma (2007).

3.4.4 Rainwater for livestock production

A successful livestock enterprise requires a good water supply, both in terms of quantity and quality. There are generic approaches for determining the quantity of water needed for livestock production, however, the major concern is the quality of water that livestock consume. The minimum amount of water required to produce feed that can produce one tropical livestock unit (TLU) is 450 m^3 (Peden et al., 2002). This is 50 to 100 times more than water required for drinking. This information is important in designing livestock production and water consumption systems. The two components of rainwater for livestock production are rainwater management for pasture production and rainwater management for livestock consumption. In the latter case, water quality is a critical issue.

Systems for livestock water consumption

These are systems that aim at producing adequate and clean water for livestock. Runoff ponds and dams are examples of such systems with multiple uses for both livestock, human and if in plentiful supply, crop irrigation. To avoid animals contaminating water sources also used by humans, structures such as drinking troughs should be constructed separately for livestock. This will prevent animals polluting domestic water supplies and transmitting water-borne diseases. In the case of ponds, the water can be abstracted using simple pumping devices such as treadle or suction pumps. This water should be lifted on raised tanks and allowed to flow by gravity through sand filtration galleries before release to the troughs.

Systems for livestock production

These are systems that aim at increased fodder production through efficient green water management. For ex situ systems, spreading floodwater over the pasture area is one way of achieving high productivity especially if the pasture fields are fertilized with organic manure. The other option is to plant fodder trees or grasses using pot-holing techniques. The holes should be fertilised with composted manure.

3.4.4 Domestic water harvesting systems in Somalia

As shown in figure 6, water for domestic use is drawn from rock or roof catchments. When it rains, runoff water generated on the catchments flow into gutters, which convey the water to the tanks. The water collected in the tanks is abstracted either by gravity or using buckets. Plate 2 shows the components of a domestic rainwater harvesting system using roof catchments. This technological option is viable in urban settlement areas where rainfall is sufficient to generate runoff. However, roof runoff is not the only source of water. The Somali community also depends on wells, springs and sandy riverbeds to access water for domestic use.

Plate 2: A typical Berkad guri depicting the catchment, conveyance and storage components

3.4.6 Water conservation in sandy river beds

Somalia has ephemeral streams that yield adequate amounts of sand that could be used to conserve water for domestic, livestock and irrigation purposes (see Plate 3 and annex 31). Identifying areas whose rainfall to potential evapotranspiration ratio is above 0.6 is necessary to indicate positions for installing sand dams, sub-surface dams or even infiltration galleries. The advantage of these systems is that the water is hidden underneath the sand layers and thus evaporation is reduced. The water also goes through natural treatment where the *schmutzdecke* micro-organisms kill harmful bacteria and other pathogens found in the water.

Infiltration galleries are a low-cost, low-skilled technology that require local construction materials and labour to abstract groundwater via horizontally perforated pipes. Such systems are in use in India, the Falkland Island, Barbados, Kenya and the USA. However, their improvision by MS (Mesfin Shenkut) Consultants in Gambella, Ethiopia, is what attracted international accolades. According to MS Consultants, the main advantage of the galleries is the high acceptability of the bacteriological, chemical and physical status of the infiltrated water devoid of conventional treatment mechanisms. In addition, the gallery works with only one operator whose job is merely to start and shut off pumps.

Plate 3: A typical ephemeral stream with a sandy riverbed in Somaliland

4. Design of RWH Systems

4.1 Introduction

Designing a RWH system requires adequate knowledge on rainfall characteristics (intensity and distribution). There should be spatial and temporal rainfall data series to determine distribution patterns and rainfall-runoff processes. There are three zones determined by rainfall distribution patterns in Somalia: 1) Southern, with annual averages between 300–500 mm; 2) Central and North-Eastern zone, with mean annual rainfall decreasing from >200 mm in the south to <100 mm in the North East, and 3) Northern Mountain zone with annual averages of >500 mm at high altitudes, that decreases towards the southern valleys (Kammer and Tin, 1987). Hutchinson and Polishchouk (1989) concluded that what makes a difference to annual rainfall over Somalia is not the type of intensity but the number of rain days. Rainfall factors used in the design of RWH systems include:

- The number of days when rain surpasses threshold values of 5 mm per event for domestic purposes, or 20 mm for agricultural purposes
- Probability and occurrence of the mean monthly rainfall
- Probability and reoccurrence for the minimum and maximum monthly rainfall
- Distribution frequency of storms of different specific intensities

domestic RWH systems as shown in annexes 14 and 15. Agricultural systems mainly depend on surface runoff water bodies such as ponds, dams and berkads, and quite often share the same source for crop, livestock and to some extent human use. Ponds and berkads are a lot more common and hence this section will dwell on their design aspects.

4.2 Design considerations for agricultural systems - ponds

These are open surface reservoirs constructed by communities (Plate 4). They consist of a catchment area, an inlet canal and an appropriate live fencing to break the wind and protect animals and humans. During the consultative workshops, the technology working groups estimated that surface area for ponds is approximately 1000 m^2 with depths ranging from 2.5 to 6 m. The height of the embankments ranges from 2 to 3 m.

Plate 4: A balley filled with water during the rainy season

4.2.1 The catchment area

This is the area where runoff is generated before it is conveyed for storage. In ex situ systems, the catchment, and in some cases, the conveyance mechanisms are located outside the farming area. A number of issues need to be considered during the risk analysis in the planning stage. One major issue is the size of the catchment. Arid to semi-arid regions with low rainfall need large catchments to draw runoff water. Such expansive areas traverse communal or private property and thus the farmer has no control with regard to catchment conservation. External problems such as massive siltation have to be sorted out.

The catchment to cultivated area ratio formula helps determine the size of the catchment needed to generate runoff that can meet crop water requirements. This ratio is computed using the formula below:

$$\frac{C}{C_A} = \frac{CWA - P}{P * C_r * E_f}$$

Where C/C_A = Catchment to cultivated area ratio (dimensionless)
CWA = Crop water requirement (mm)
P = Design rainfall (in millimetres at Probability of 67%)
C_r = Runoff coefficient (assumed as 0.25 for long catchment with low slopes when data on slope, soil type, vegetation cover, antecedent moisture, design rainfall and duration are lacking)
E_f = Efficiency factor (taken as 0.5 for long slopes)

For example, the crop water requirement for a millet crop is 475 mm. To grow millet at Burhakaba in Bay region with design rainfall of 335 mm, the C/C_A ratio is determined as follows:

$$\frac{C}{C_A} = \frac{475 - 335}{335 * 0.25 * 0.5} = 3.34$$

This means that the catchment area should be about three times the size of the cultivated area to guarantee sufficient water to grow millet.

Generating runoff is important for rainwater harvesting. The average annual rainfall usually gives a wrong impression if used directly for computing runoff harvesting potential. For instance, the mean annual rainfall for Borama calculated for 41 years (between 1925 to 1987) is 536 mm.

However, the annual averages for storms that have threshold of 20 mm, deemed sufficient to cause runoff is 266 mm, all received on an average of 6 days annually (see annex 16). The latter value is more dependable when computing runoff for agro-pastoral purposes.

4.2.2 Conveyance mechanisms

Conveyance mechanisms are natural or man-made channels or waterways that convey runoff generated from catchment areas to storage structures. The channels are dug along rather than grading them across the slope using tractor-drawn implements (Plate 5). When it rains, a lot of erosion occurs culminating in gully formation (Plate 6). The channels develop into rills or gullies, conveying large amounts of silt to storage structures. The biggest challenge in runoff conveyance is how to contain the large amount of silt that is washed into storage structures.

Plate 5: Runoff conveyance channel during construction

Plate 6: Runoff conveyance channel in north-west Somalia after having developed into a gully and conveying a lot of silt to the pond

Siltating of the *waro* or *balleys* can be mitigated by designing shallow but wide waterways with side slopes of 1:3. Vegetating such waterways with grass would be ideal but since it is difficult to establish grass given the low rainfall and high evaporation in most parts of Somalia, stone pitched filter strips would be sufficient wherever possible (figures 8 and 9).

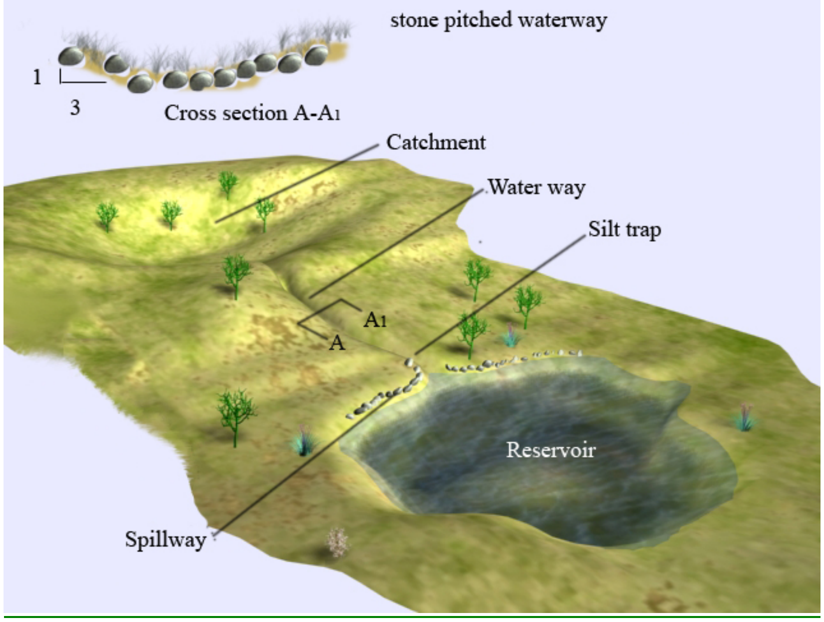

Figure 8: Pictorial depiction of a pond design

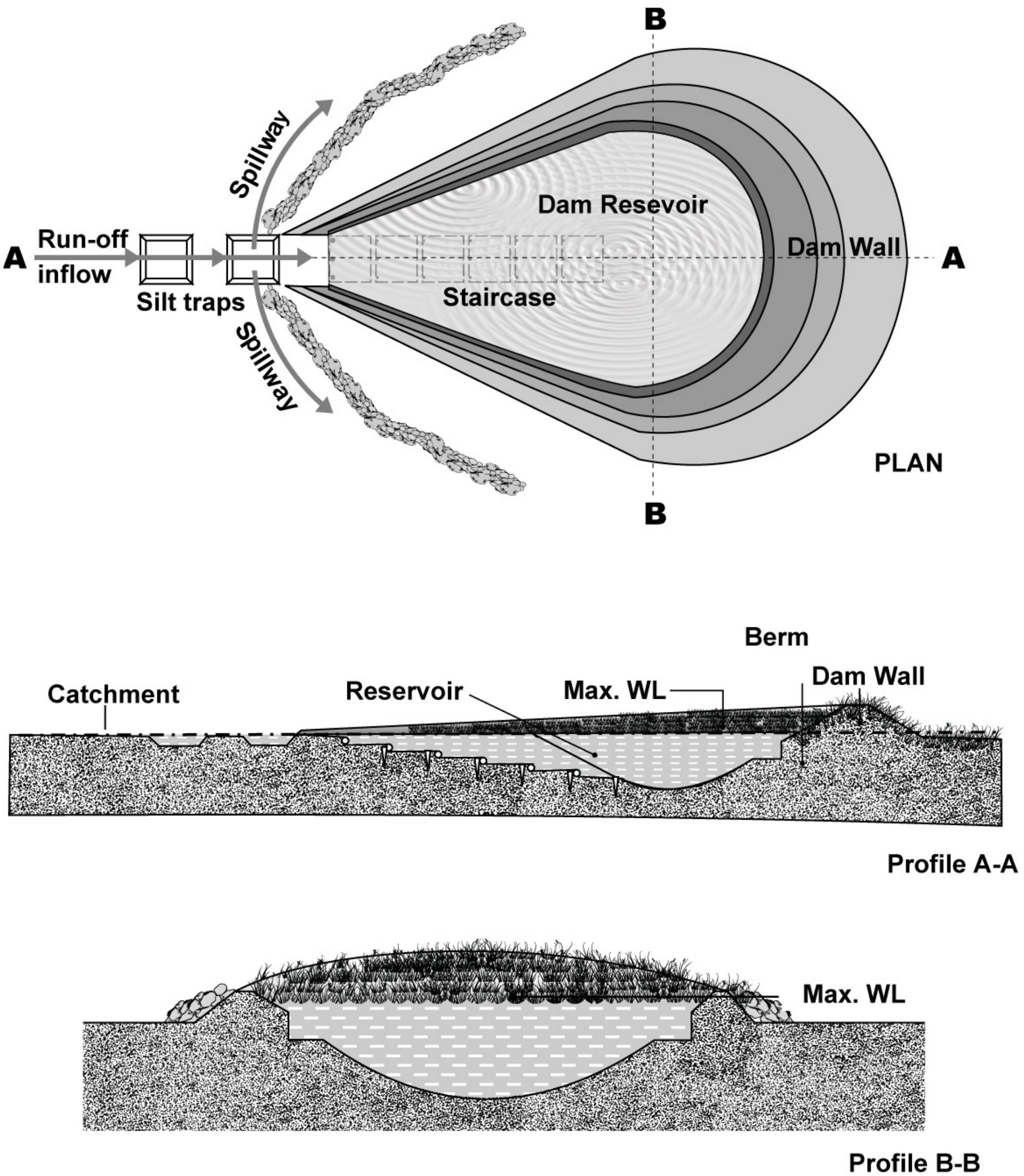

Figure 9: Bird's eyeview of a pond design

Determining size, depth and number of ponds based on the Soil Conservation Curve Number method

Issues to consider when designing pond reservoirs are structural strength, siltation, the cost of construction and the sizing of its capacity. With runoff already determined, Senay and Verdin (2004) further developed a methodology for computing the recommended pond depth, required watershed areas, potential number of ponds in a given area, and number of ponds per family as shown below.

Supply-based approach to pond sizing

To estimate the size, the soil conservation curve number method (SCS-CN) is employed by getting the product of runoff generated with the area of the upstream watershed. The SCS-CN is used in hydrological and crop models to evaluate the effects of soil management or surface conditions on runoff, erosion, and water balance. Runoff is computed using the formula below:

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \tag{1}$$

$$S = \frac{25400}{CN} - 254 \tag{2}$$

$$\text{Therefore Pond volume} = (Q \times A) \times 10^{-3}\ (m^3) \tag{3}$$

Where P = Average annual rainfall (mm)
Q = Runoff (mm)
S = Potential maximum soil storage (mm)
I_a = Initial moisture abstraction (assumed as 0.2)
CN= Dimensionless curve number shown in Table 3

The watershed should be divided into a maximum of five sub-catchments represented by different curve numbers. Then, the overall curve number and total area is weighted. The Weighted curve number is computed from:

$$A = A_1 + A_2 + A_3 + A_4 + A_5$$
$$CN = \tfrac{1}{A}[A_1(CN_1) + A_2(CN_2) + A_3(CN_3) + A_4(CN_4) + A_5(CN_5)]$$

Where A = Area or watershed
An = Area of sub-catchment

Table 3: *Runoff Curve Numbers*

Description of land use	**Hydrologic soil groups**			
	A	**B**	**C**	**D**
Paved parking lots, roofs, driveways	98	98	98	98
Streets and roads				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Cultivated (agricultural crop) land*:				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contours)	62	71	78	81
Pasture or range land				
Poor (<50% ground cover or heavily grazed)	68	79	86	89
Good (50–75% ground cover; not heavily grazed)	39	61	74	80

Description of land use	**Hydrologic soil groups**			
	A	**B**	**C**	**D**
Meadow (grass, no grazing, mowed for hay)	30	58	71	78
Brush (good, >75% ground cover)	30	48	65	73
Woods and forests				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83
Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77
Open spaces (lawns, parks, golf courses, cemeteries, etc.):				
(grass covers 50–75% of area)	49	69	79	84
Good (grass covers >75% of area)	39	61	74	80
Commercial and business districts (85% impervious)	89	92	94	95
Industrial Districts (72% impervious)	81	88	91	93
Residential areas				
0.05 ha plots, about 65% impervious	77	85	90	92
0.1 ha plots, about 38% impervious	61	75	83	87
0.2 ha plots, about 25% impervious	54	70	80	85
0.4 ha plots, about 20% impervious	51	68	79	84

Source: Chow et al., 1988

The hydrologic soil group A to D in the table refers to the infiltration potential of the soil after prolonged wetting.

Group A Soils:	High infiltration (low runoff). Sand, loamy sand, or sandy loam. Infiltration rate > 0.75 cm/hr when wet.
Group B Soils:	Moderate infiltration (moderate runoff). Silt loam or loam. Infiltration rate 0.375 to 0.75 cm/hr when wet.
***Group C Soils*:**	Low infiltration (moderate to high runoff). Sandy clay loam. Infiltration rate 0.125 to 0.375 cm/hr when wet.
Group D Soils:	Very low infiltration (high runoff). Clay loam, silty clay loam, sandy clay, silty clay, or clay. Infiltration rate 0 to 0.125 cm/hr when wet.

The Agricultural Development Organization based in Hargeisa, stressed that it takes about three to four tractor hours to construct one balley. The embankments are often inadequately compacted leaving room for flush floods to destroy them (see Plate 7). For example, the Allaybaday reservoirs, where more than 87 cascades of balleys were destroyed during the onset of gu rains in April 2007. The balleys also lack adequate spillways to dispose of excess water.

Plate 7: A section of a balley embankment destroyed by 2007 Gu rains

Determining recommended pond depth
This is calculated according to the following water balance equation:

$$D = 1 + E - P + S \tag{4}$$

Where D = Recommended pond depth (m);
E = Annual evaporation (m)
P = Average annual rainfall (m), and
S = Annual seepage (m).
Wherever D is negative, it is set to a minimum depth of 1 m.

Example:
If we take the case of Baidoa District whose annual rainfall is about 500 mm with an assumed evaporation of 1900 mm and seepage of 2.5 mm/day for 20 storm events (50 mm). Then recommended pond depth for Baidoa would be

$$\begin{aligned} D &= 1 + E - P + S \\ &= 1 + 1.9 - 0.5 + 0.05 \\ &= 2.45 \text{ m} \end{aligned}$$

To yield a minimum depth of 1 m net supply of pond water in Baidoa region, one would need a recommended design depth of 2.45 m. Thus 1.45 m is lost to seepage and evaporation. A map for minimum pond depths can be produced for Somalia if the rainfall, evaporation and seepage values are known.

Required upstream watershed area (drainage basin)
This is given by the equation below:

$$WA = D\frac{(1000)}{Q}0.0001 \tag{5}$$

Where WA = required watershed area (ha)
D = recommended pond depth (m);

Q = average annual runoff (m), and
1000 is the net desired pond volume (m^3)
0.0001 is the conversion factor from m^2 to hectares

Continuing with the Baidoa example, the watershed area can be computed by substituting the values of *D* and *Q* in the equation above. Recommended depth has already been obtained in the previous example as 2.45 m. The map on RWH potential also indicates that average annual runoff for Baidoa is approximately 0.02 m. From computations, the watershed area is 12.25 ha.

$$WA = 2.45\frac{(1000)}{0.02}0.0001 \qquad (6)$$

Here again, a map for Somalia can be produced to depict required watershed areas needed to generate runoff water for the 1000-m^3 ponds (see example for Africa in the annex 17).

Potential number of ponds
Once the gross capacity of the pond has been estimated, the potential number of ponds in a given watershed is estimated by dividing the runoff volume by the gross pond capacity.

$$NP = \frac{Q*TWA}{D*1000} \qquad (7)$$

$$NP = \frac{TWA}{WA}$$

Where TWA = Total watershed area (ha).
D = recommended pond depth (m);
WA = Required watershed area (ha)
Q = Average annual runoff (m), and
1000 is the net desired pond volume (m^3)

If the total watershed area is 200 ha, then the number of ponds is given by
$NP = \frac{200}{12.25}$ = 16.33, or approximately 17 ponds.

Number of ponds per family
Computation of number of ponds per family is important as a planning tool for spacing water points. When the value goes below one, then it denotes sharing of the resource. This is especially important for the pastoralist community who gather around the only available water source in the event of drought. Such congregations have impacted negatively on the surrounding areas owing to soil erosion caused by cattle tracks and deforestation by humans. Large amounts of silt are washed into ponds reducing their longevity. The formula below shows how to compute the number of ponds per family.

$$NP_{f^{-1}} = \frac{NP_{km^{-2}}}{p_\rho} f_s \tag{8}$$

Where $NP_{f^{-1}}$ = Number of ponds per family

$NP_{km^{-2}}$ = Number of ponds per square kilometre

f_s = Average family size, and

p_ρ = Population density

As an example for Baidoa, assuming a population density of 34 people per square kilometre, the number of ponds per family is then determined by;

$$NP_{f^{-1}} = \frac{NP_{km^{-2}}}{p_\rho} f_s \quad = \quad NP_{f^{-1}} = \frac{((17*(100/200))}{34} 8$$

$$NP_{f^{-1}} = 2$$

The number of ponds per household with a family size of six is thus 2.

4.3 Design considerations for berkads

Berkads are cuboid-shaped ground or above-ground tanks made of concrete or ferrocement and are common in most parts of Somalia (Plate 8). They consist of an inlet canal, masonry lining and a live fencing. Fencing is done as a security measure for water conservancy or against dangers to livestock and human beings who may fall and get injured, sometimes fatally. Their volumes vary, but majority range from 300–500 m^3. In some cases, silt traps are provided to check siltation. At the entrance of the berkads, stairs are constructed to facilitate access inside the tank. Berkads receive runoff water from upstream ground catchments via mitre drains or stone bund diversion and silt traps. Water conserved in berkads is mainly for livestock and domestic use.

Plate 8: A typical berkad in Somalia

4.3.1 The catchment area

The catchment area is usually big enough to generate enough runoff that can fill a berkad. The size is therefore demand based. However, if the watershed boundary is known, then the soil conservation curve number method (see formula 1) can be used to compute its potential runoff generation capacity, which can then be used to design the berkad.

4.3.2 Conveyance mechanism

Unlike ponds, the conveyance mechanism for berkads does not use machine excavated channels. Instead, runoff from upstream catchments or roads is directed via mitre drains to the reservoirs. Owing to silt being washed into the berkads (Plate 9), silt traps are constructed just before the entrance. This is an on-stream approach to control siltation, but it is not a good approach. Instead, an off-stream approach to silt management should be adopted.

Off-stream design entails converging runoff to a waterway that is positioned besides the berkad. When the inflow rate is low, a 'tongue', constructed at the entrance to the mitre drain directs water to the berkads via the silt traps (figure 10). The same mitre drain acts as a spillway and will discharge excess runoff back to the waterway. However, with high flow rates, most of the runoff simply 'jumps' over the tongue, carrying with it heavy silt away from the berkads.

Plate 9: Siltation of a berkad

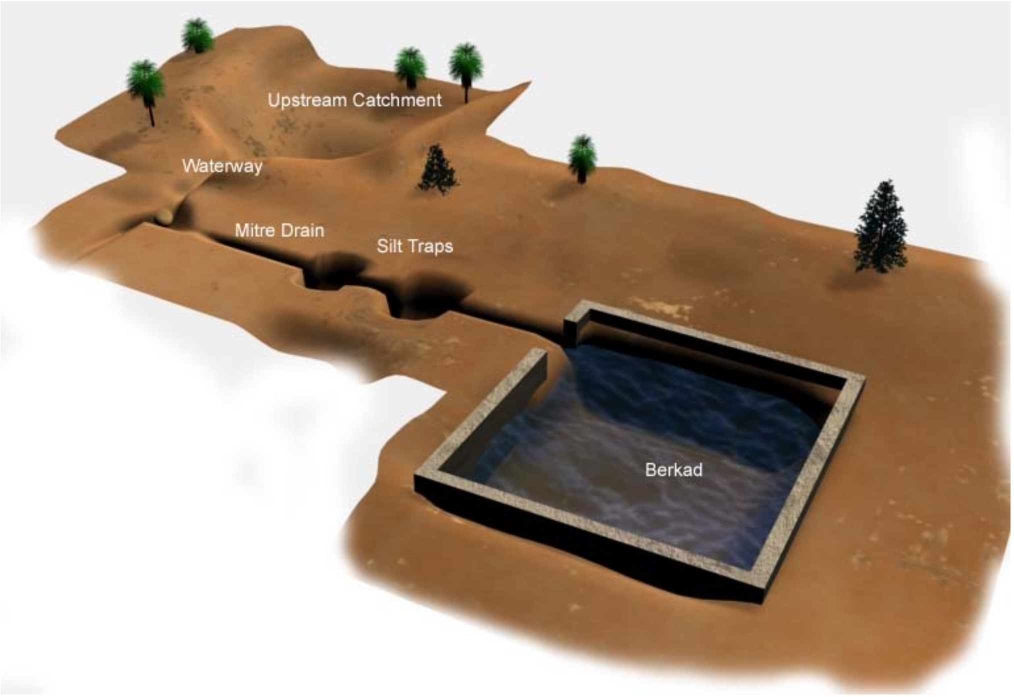

Figure 10: Off-stream conveyance mechanism for berkads

4.3.3 Design considerations for storage

Design of the berkad capacity or volume could either be supply or demand based. In a supply-based approach, the soil conservation curve number method could be used as highlighted in section 4.2.3 and 4.3.1. In a demand-based approach, consideration has to be made for the dry periods for which this water shall be needed as well as the daily water requirements for domestic use that includes animals and humans. Table 4 is an example for determining berkad size based on water demand and a six-month dry period.

Table 4: Berkad size based on water demand

Item	Population	Consumption rate (Litres/day)	Total/day (Litres/day)	(m3/day)	Dry days	Total /dry period (m3)
People	5	x 20	100	0.1	180	18
Camels	5	x 15	75	0.1	180	13.5
Cattle	8	x 15	120	0.1	180	21.6
Sheep/goats	20	x 3.5	70	0.1	180	12.6
Donkeys	2	x 15	30	0.0	180	5.4
Berkad volume			395	0.4		71.1

Source: Adopted from RELMA Technical Handbook No. 32

From the volumes determined either in supply- or demand-based approaches, the dimensions of the berkads can be iterated. Care should be taken not to have a large surface area due to evaporation losses. Instead, a narrow, long and deep shape for cuboidal designs would be prefferable. From the volume in the example of table 4, iteration would give dimensions of approximately 3 m by 5 m (top area) by 4.73 m (depth). The problem with cuboidal shapes is that they are more prone to cracking, especially at the corners. Cylindrical shapes would therefore be preferrable although they require more skill in construction. Again, the surface area should be minimized to reduce evaporation losses while not compromising the maximum depth for water abstraction. The current practice to mitigate evaporation losses is to cover the surface of the tanks using vegetative material such as grass placed over a mesh of wires (Plate 10). There is need to ensure that all the sides of the tank are reinforced with appropriate wire mesh and British re-inforced concrete depending on the size to avoid cracking (Plate 11).

Plate 10: Mitigating evaporation losses from berkads using grass covers

Plate 11: Cracking of a berkad

4.3.4 Abstraction of water for animal or domestic use

The current practice is to abstract water or silt from the berkads using rope and buckets (figure 11). After the bucket is dipped in water, it is pulled by hand and brought to the ground level to pour out the water. This technique is not good as it is prone to contamination. An alternative is to install a rope-and-washer pump, which delivers water via a spout (figure 12). This pump should be installed at one of the berkad corners as shown in figure 14, to facilitate easy abstraction. The water drawn using this technique should be allowed to pass through a layer of quick sand and later to either a tank for domestic use, or a trough for animal drinking. NB: The current practice by the Somalis of separating the area where water is drawn to the area where animals drink using live fences is good and should be adopted and incorporated in the designs. This is also clearly demonstrated in figure 14.

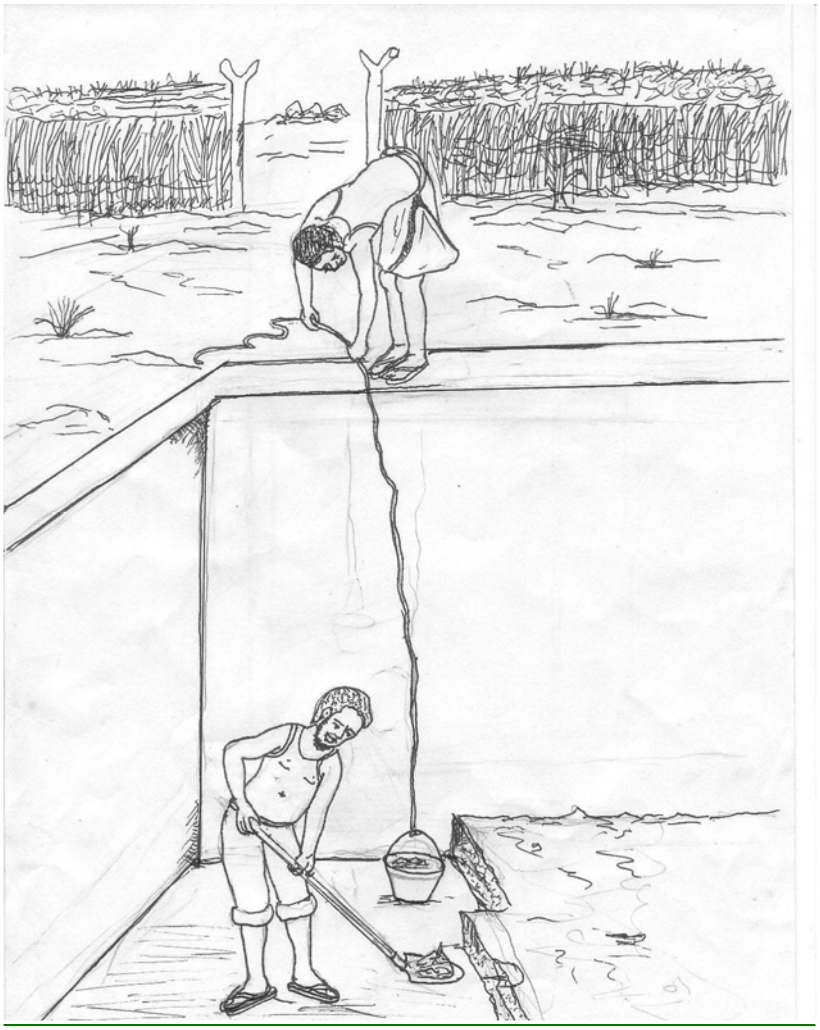

Figure 11: Use of rope and bucket to desilt or abstract water from berkads[2]

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[2] *Adopted from* Caritas Switzerland, Luxemburg, COOPI, OXFAM GB & SCF-UK

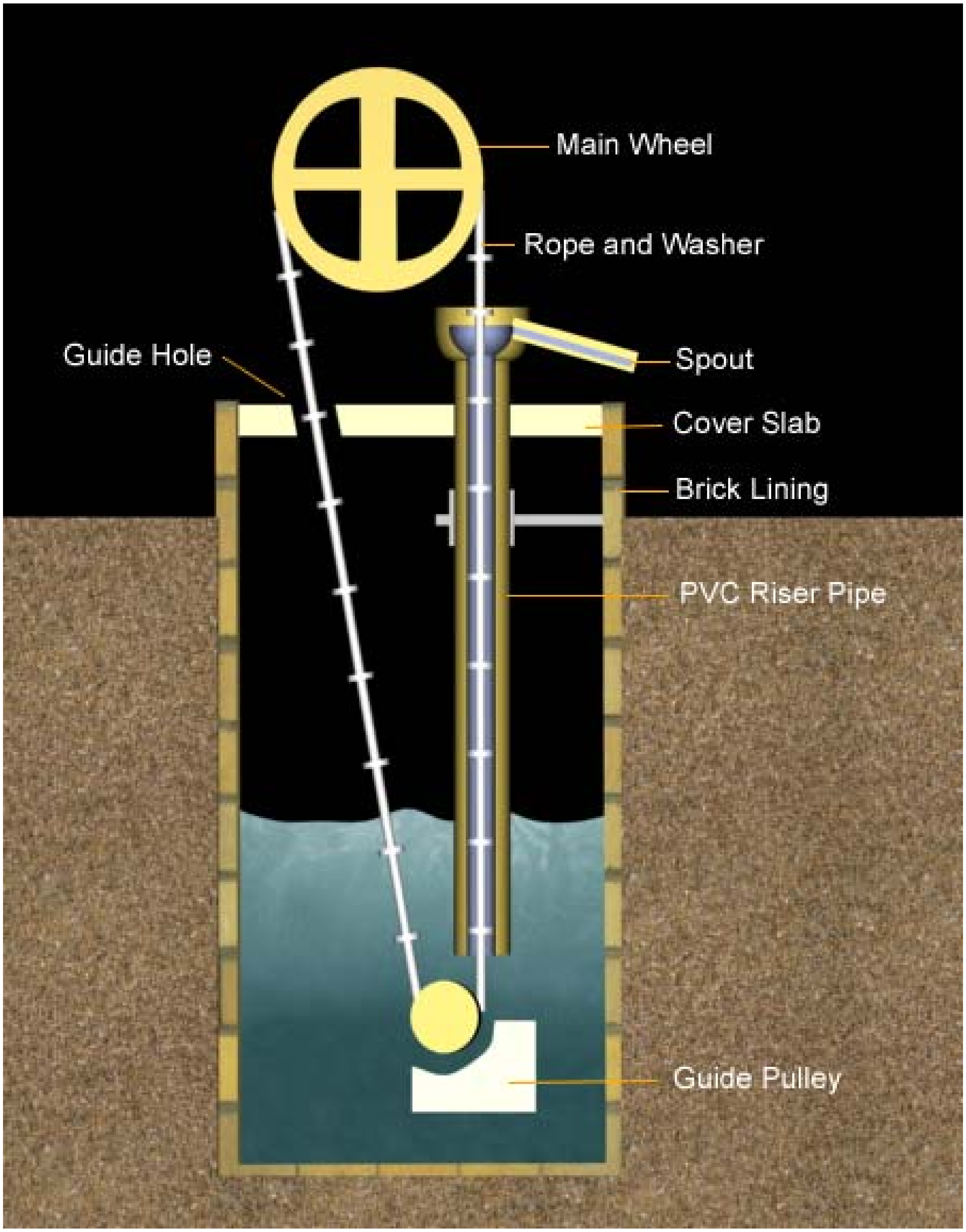


Figure 12: Rope and washer pump

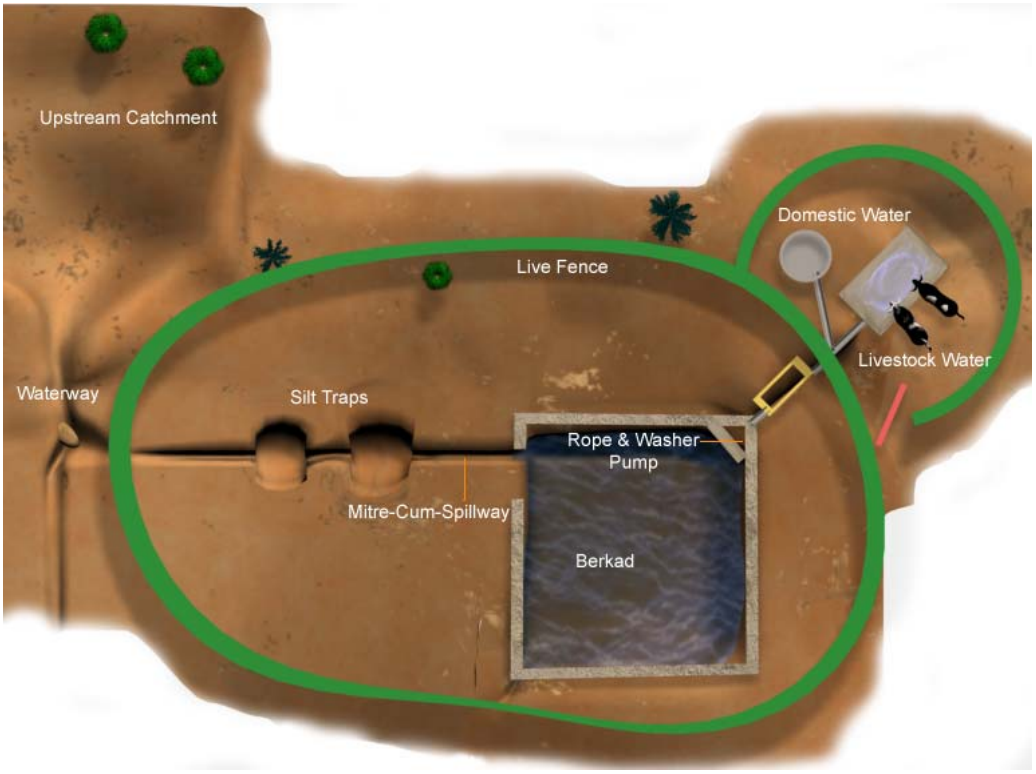


Figure 13: A Berkad runoff harvesting system depicting trough for animal drinking

4.4 Design of roof water harvesting systems: the case of berkad guris

Berkad guris are cuboid-shaped above-ground tanks made of concrete or ferrocement (Plate 12). Their rainwater harvesting systems consist of a roof catchment, gutters, down pipes and the tank itself. They are covered using corrugated iron sheets with a small opening that also serves as a manhole to access the interior to maintain and abstract water from the tank. They are best applied in urban settings with rainfall above 200 mm.

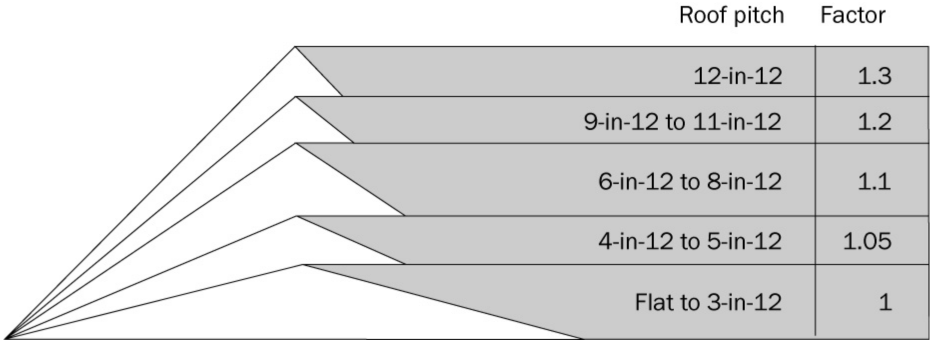
Plate 11: A Berkad guri showing the roof runoff harvesting components

4.4.1 Design considerations and aspects for roof catchments

In designing roof catchment systems, the following factors have to be taken into account: rainfall, area/size of the roof surface, surface conditions, roof pitch and presence of settlements. Annex 8 expounds on the criteria for domestic water harvesting.

Areas with rainfall above 200 mm per annum are considered suitable for roof water harvesting. The nature of roofing material or surface will determine how much runoff is generated. The smoother the surface, the higher the runoff coefficient. Most buildings especially in urban areas of Somalia use corrugated galvanised iron sheets for roofing whose coefficients range from 0.8–0.9. The roof pitch, which denotes the slope defined by the vertical height of a roof truss to its half-length is gentle, estimated at 4 to 12 (figure 14). The roof pitch factor for such ratio is 1.05. The relationship between roof pitches and roof runoff losses due to splashing effect is that the sharper the pitch, the lower the losses due to smooth flow of water and vice versa. For the internally displaced persons (IDPs) however, canvass and polythene are the preferred roofing materials. Given their hemi-spherical shapes, it is difficult to determine their roof pitches. However, since they are vertically oriented towards the ground level, an assumption of 1.2 for the roof pitch could be used. An issue of concern for the roof is dust blown by wind and deposited on the roofs.

Runoff generation for roofwater harvesting systems requires lower threshold values as compared with that for agriculture. The threshold of 5 mm is sufficient to create runoff from corrugated iron-roofed catchments, which are common in Somalia urban settings. Using the example of Borama, the mean annual rainfall for Borama calculated between 1925 and 1987 is 500 mm. However, the annual averages for storms that have threshold of 5 mm, deemed sufficient to cause runoff is 489 mm, all received on an average of 30 days annually (annex 18).



Roof pitch	Factor
12-in-12	1.3
9-in-12 to 11-in-12	1.2
6-in-12 to 8-in-12	1.1
4-in-12 to 5-in-12	1.05
Flat to 3-in-12	1

Figure 14: Roof pitch factors

4.4.2 Conveyance, by pass and filtering mechanisms

Conveyance mechanisms consist of gutters and down pipes made of poly vinyl chloride (PVC), galvanised iron sheet (gauge 20–22) or bamboo trunks cut vertically in half. The gutters should be laid on an appropriate 1% gradient (10 cm in 10 m) to drain water from roof to tank. They can either be semi-circular or rectangular in shape. With data on average rainfall intensities for Somalia, it is possible to develop a guide for estimating pipe diameters for known roof areas.

In the case of grass thatched or hemi-spherical round houses (common in IDP camps), it is difficult to install conventional gutters. For grass-thatched houses, circular trenches can be dug and positioned to receive runoff directly below the roof eves (figure 15), and trench gutters dug around hemispherical houses (figure 16). The mitre drain from the trench gutters should be positioned on the side or at the back of the house to be accessible. The mitre drains convey runoff into an underground tank (figures 15 and 16).

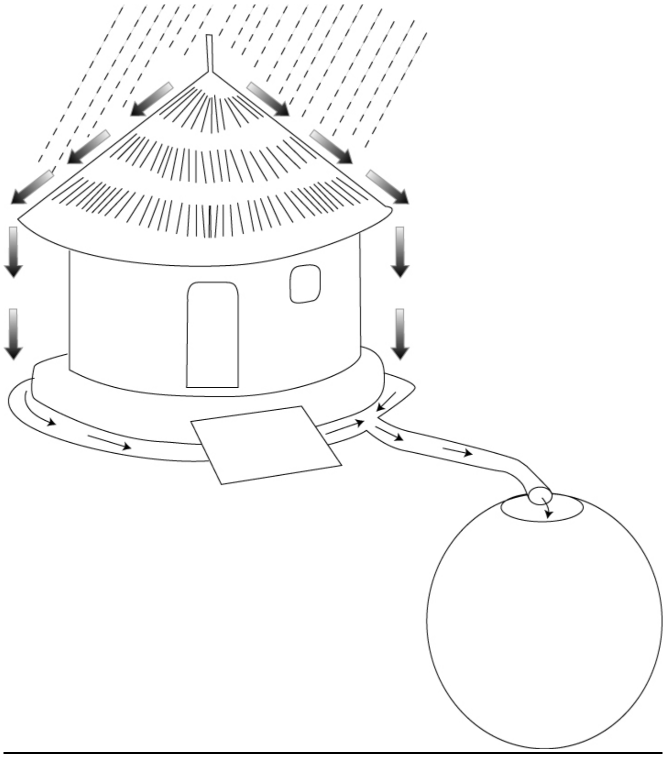


Figure 15: Illustration of RWH system for grass-thatched house

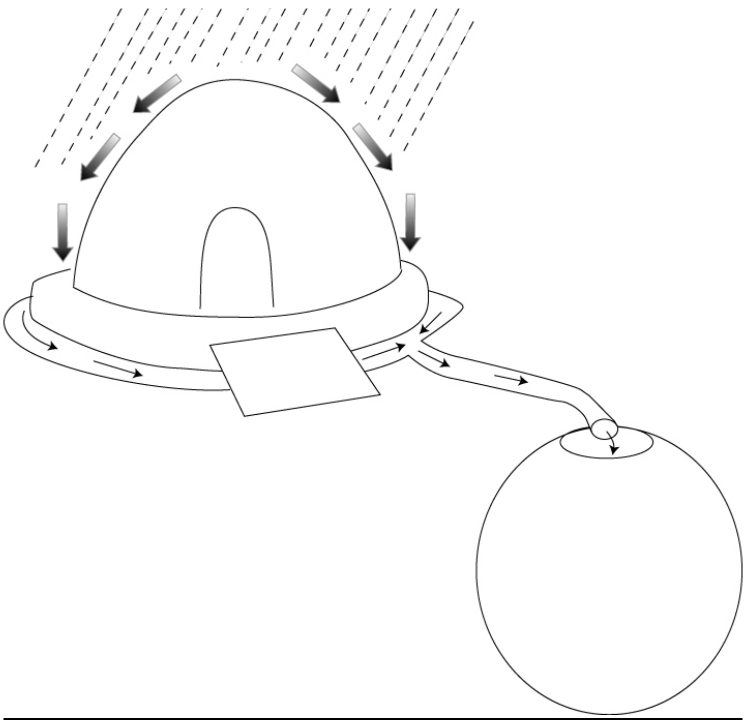


Figure 16: Illustration of RWH system for a hemi-spherical house

4.4.3 Storage and abstraction

Storage tanks collect rainwater for later use. In Somalia, they are often cuboid or rectangular in shape. Most of the tanks are placed above the ground with overflow provisions. Stairs are made in some cases to access the top of the tank. This allows for the use of buckets or jerry cans to draw water. Dipping jerry cans or buckets in and out of the tanks is an un-hygienic practice that introduces impurities and pathogens in the stored water (Plate 13). Instead, provisions should be made for a tapping station to draw water from the tank through gravity (figures 19 and 20).

Plate 12: Current practice of drawing water from the berkad guris

4.4.4 Demand-based approach to sizing a berkad guri

A demand-based approach to determining the size of a berkad guri is dependent on the per capita basic water requirement (BWR) taken as 20 litres/capita/day. Getting the product of BWR with a number of people in a household and the number of dry days gives the tank capacity. For instance, in a house of 8 people inhabiting a location with 180 dry days, tank capacity is given as:

Tank capacity = BWR x 8 x 180 litres
= 20 x 8 x 180 litres
= 28,800 litres or 28.8 m^3

4.4.5 Total annual available rainwater from roof catchments

The total annual available rainwater is dependent on the size of the roof. Tank capacity is computed by getting the product of total roof area with average annual rainfall, the roof pitch and runoff coefficient. For example, for a house roofed with GI sheets in a town covering an area of 60 m^2, with annual rainfall of 400 mm the tank capacity is calculated as follows:

Tank capacity = Area x rainfall depth x runoff coefficient x roof pitch
= 60 x (400/1000) x 0.85 x 1.05 litres
= 60 x 0.4 x 0.85x 1.05

$= 21.42\ m^3$ or 21,420 litres

Using the formula in Section 4.4.5, it is possible to develop a guide table for estimating harvestable rainwater from varied roof sizes and rainfall in Somalia.

Plate 13: A guide for harvestable domestic roof water

Rainfall (mm)	100	200	300	400	500	600	700	800
Roof area (m2)	Harvestable rainwater from rooftop (m^3)							
20	1.79	3.57	5.36	7.14	8.93	10.71	12.50	14.28
30	2.68	5.36	8.03	10.71	13.39	16.07	18.74	21.42
40	3.57	7.14	10.71	14.28	17.85	21.42	24.99	28.56
50	4.46	8.93	13.39	17.85	22.31	26.78	31.24	35.70
60	5.36	10.71	16.07	21.42	26.78	32.13	37.49	42.84
70	6.25	12.50	18.74	24.99	31.24	37.49	43.73	49.98
80	7.14	14.28	21.42	28.56	35.70	42.84	49.98	57.12
90	8.03	16.07	24.10	32.13	40.16	48.20	56.23	64.26
100	8.93	17.85	26.78	35.70	44.63	53.55	62.48	71.40
150	13.39	26.78	40.16	53.55	66.94	80.33	93.71	107.10
200	17.85	35.70	53.55	71.40	89.25	107.10	124.95	142.80
250	22.31	44.63	66.94	89.25	111.56	133.88	156.19	178.50
300	26.78	53.55	80.33	107.10	133.88	160.65	187.43	214.20
400	35.70	71.40	107.10	142.80	178.50	214.20	249.90	285.60
500	44.63	89.25	133.88	178.50	223.13	267.75	312.38	357.00
1000	89.25	178.50	267.75	357.00	446.25	535.50	624.75	714.00
2000	178.50	357.00	535.50	714.00	892.50	1071.00	1249.50	1428.00
3000	267.75	535.50	803.25	1071.00	1338.75	1606.50	1874.25	2142.00

Table 5: Optimizing tank size using mass curve analysis method

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Amount	0	0	45	64	60	21	5	0	26	43	38	0
Cum amount (mm)	0	0	45	109	169	190	195	195	221	264	302	302
Supply from RWH (m^3)	0	0	6	14.6	22.6	25	26	26	30	35	40	40
No of days	31	28.0	31	30	31.0	30	31	31	30	31	30	31
Monthly Water deman (m)	3	2.80	3	3.00	3.10	3	3	3	3	3	3	3
Cum water demand (mm)	3	5.90	9	12.00	15.1	18.1	21.2	24.3	27.3	30.4	33.4	36.5
Absolute difference (m^3)	3	5.90	3	2.60	7.50	7.30	4.9	1.8	2.3	4.9	7	3.9

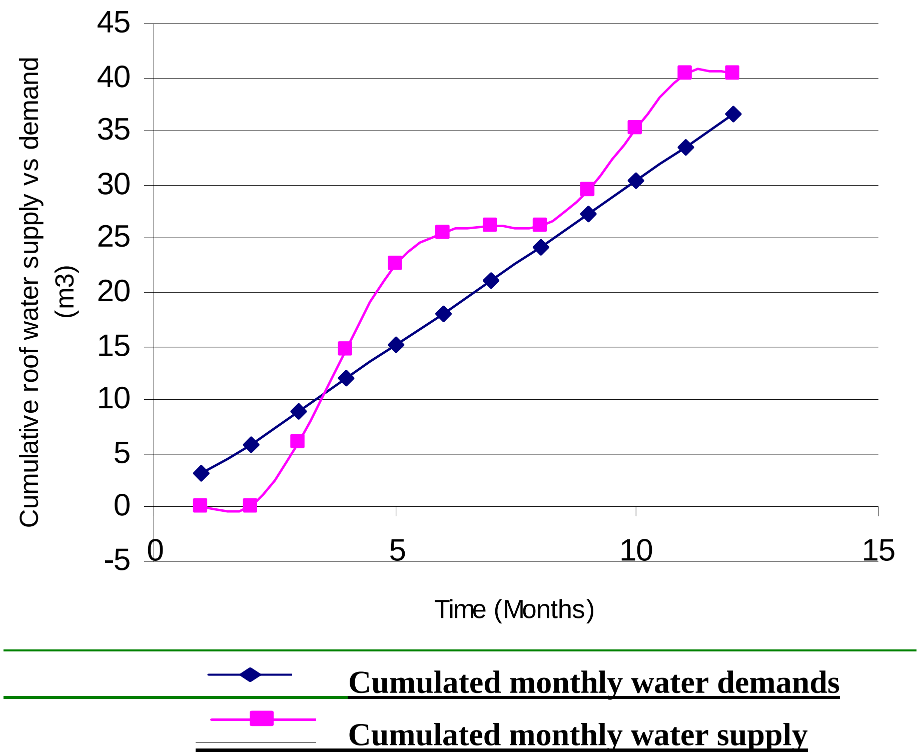


Figure 17: Optimizing tank size using mass curve analysis method

4.4.7 Sizing roof rainwater tanks using nomographs

Jomo Kenyatta University of Agriculture and Technology in Kenya developed a nomograph that uses computer-based spreadsheet performance calculator to size roofwater harvesting tanks in Kenya at a reliability of 67%. This was in collaboration with the World Agroforestry Centre where, nomographs for 50 stations covering a wide range of agroecological zones were developed.

The monograph is a simple tool that can be understood by most people and can only be applied in areas with similar rainfall. It helps in determining the mean daily runoff for particular areas. To determine the tank size using a nomograph, the daily family water demand should be determined. For instance, for a family of five at a basic water requirement of 20 litres per day, the total demand for the family will be 100 litres. If the roof area is 80 m^2, then for the example of Moyale town given in figure 19, the MDR is 140 l/d. From the nomograph, this means that there is sufficient water to supply the needs of the family with a balance still left of 40 litres for other uses.

Somalia too, could develop similar nomographs for selected towns based on the performance calculator developed by Jomo Kenyatta University of Agriculture and Technology.

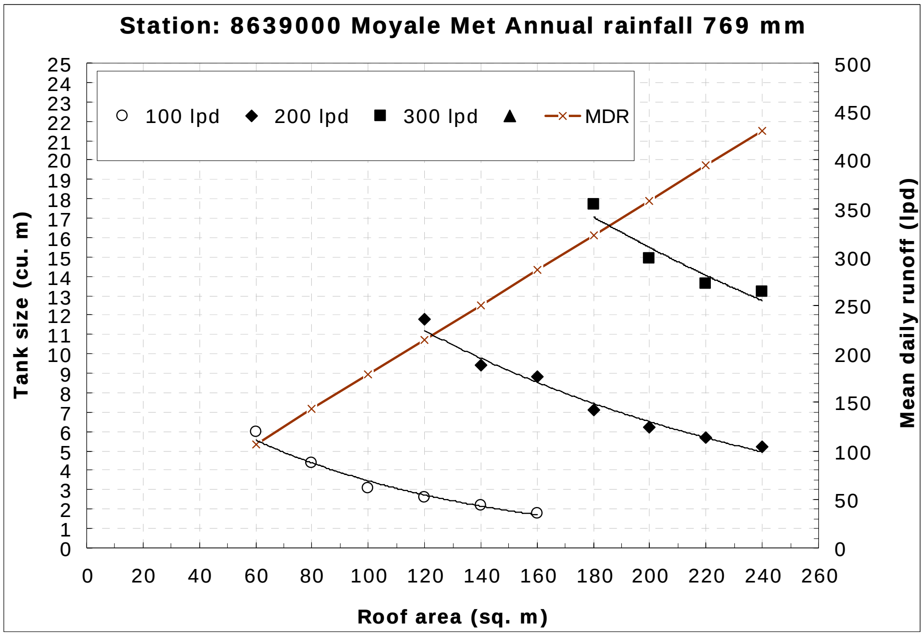


Figure 18: An example of a nomograph for estimating required tank size[3]

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[3] Source: Malesu et al. (2005)

5. Quality Aspects of Stored Rainwater

5.1 Introduction

In areas that are fairly clean and unpolluted such as rural settings with low industrialization, rainwater is a clean and safe resource. However, once it hits the roof surface, the rainwater collects impurities and washes down bacteria, moulds, algae, protozoa and other contaminants into the tank (UN Habitat, 2005). Health concerns related to bacteria such as *Salmonella*, *Escherechia coli* and *Legion ella* are the primary criteria for analysing the quality of drinking water. Rainwater for household use should be filtered and disinfected.

Virtually all ex situ runoff water is led to open storage structures. As the runoff flows to the reservoirs, it carries with it silt and organic impurities. If the surrounding areas are denuded following cutting down of trees to produce charcoal, high siltation and pollution of the water bodies occur. There is also a danger of such water harbouring mosquitoes or snails that are hosts to malaria and bilharzia. Typhoid is common when the people, livestock and other domestic animals use water un-hygienically.

5.2 Domestic water treatment techniques

5.2.1 Leaf screening

At the roof catchment level, large organic matter such as leaves deposited on the roof surfaces by wind can be removed using leaf screens (plate 14). These are placed at the lower edges of the roofs and extended over the gutters. During initial rainfall events, runoff water flows into the gutters carrying with it minute particles. The leaves cannot enter the fine mesh covering the gutters and will thus go over the gutters and fall to the ground.

Leaf screening can also be achieved along down pipes. A section of the pipe is cut in a slanting manner and a fine mesh placed over it. Runoff flowing on the pipe will pass through the mesh leaving behind the large organic matter such as leaves, which will slide to the ground.

Plate 14: Screening leaves from roof runoff water

5.2.2 Manual foul flush mechanisms

This is a plastic by-pass mechanism which is initially positioned to allow foul flush to flow away as wastewater. After about five minutes of a rainfall event, it is manually changed so that clean water is re-routed to the tank (Plate 15). The disadvantage of this system is that the operator has to be around to re-position the foul flush gadget so that it receives clean water after a few minutes of the rainfall event.

Plate 15: Manual foul flush mechanism

The alternative to the manual mechanism is the automatic one shown in Plate 16 and figures 20 and 21. Here, roof runoff is directed to the down pipe which has an extended pipe that separates the foul flush from on-coming cleaner runoff. The volume of foul flush is calculated to fill the separator pipe. Thereafter, oncoming runoff is blocked by a non-return valve and instead re-routed to the treatment chamber. This water is forced through layers of sponge and sand. A space on the top portion of the chamber acts as a sump upon which treated pool water collects and discharges into the berkad (see top right and bottom Plates 16). The advantage of this system is that it takes care of the physical (using the separator) and biological impurities (using the sand filtration) simultaneously.

Top left

Top right

Bottom left

Bottom right

Plate 16: Use of separator and filtering mechanisms to treat roof runoff water

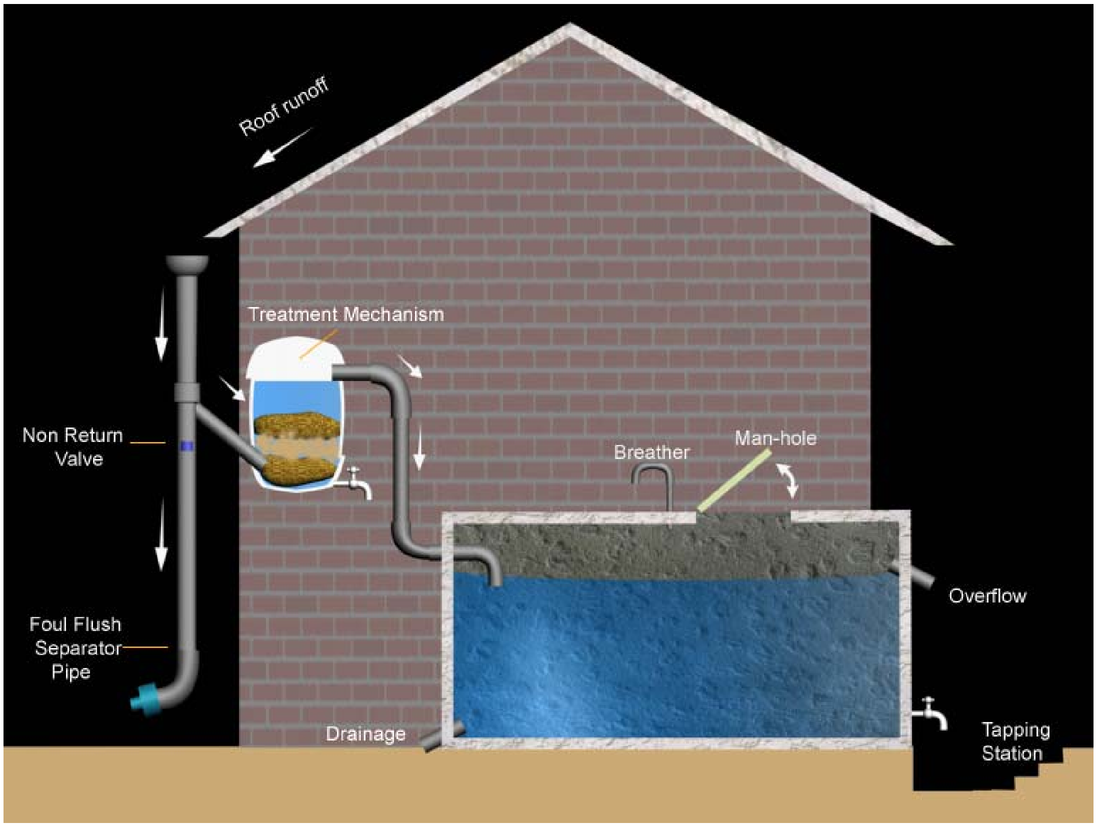

Figure 19: Use of separator and filtering mechanisms to treat roof runoff water

The alternative to the use of separator extension pipe (figure 18) is the use of a floating ball technique (figure 19). In this technique, initial runoff flows into a container with conical ends. The container has a ball that floats and rises with the filling water. When full, this chamber is automatically blocked by the ball. At this stage, clean water will be rerouted into the berkad. The advantage of this method is that the operator doesn't have to be around during a rainstorm. He can remove the foul flush after the rainfall event.

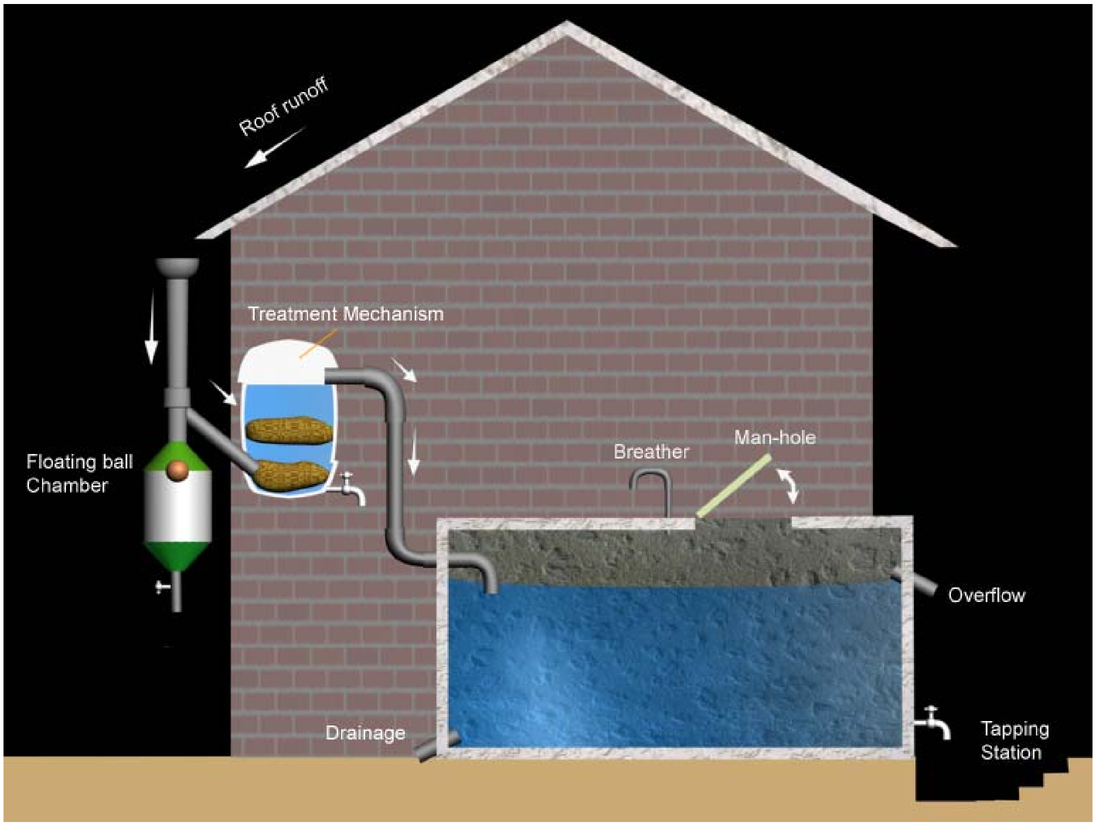

Figure 20: Floating ball technique in foul flush treatment

5.2.3 Filtration

A number of filtration mechanisms are in use—gravity, pressure and sand- based filters. Given the abundance of sand in Somalia, the sand-based filter is highlighted.

Sand-based filters remove turbidity (suspended particles), colour and even micro-organisms. Depending on availability of different materials, layers of sand are arranged as shown in figure 21.

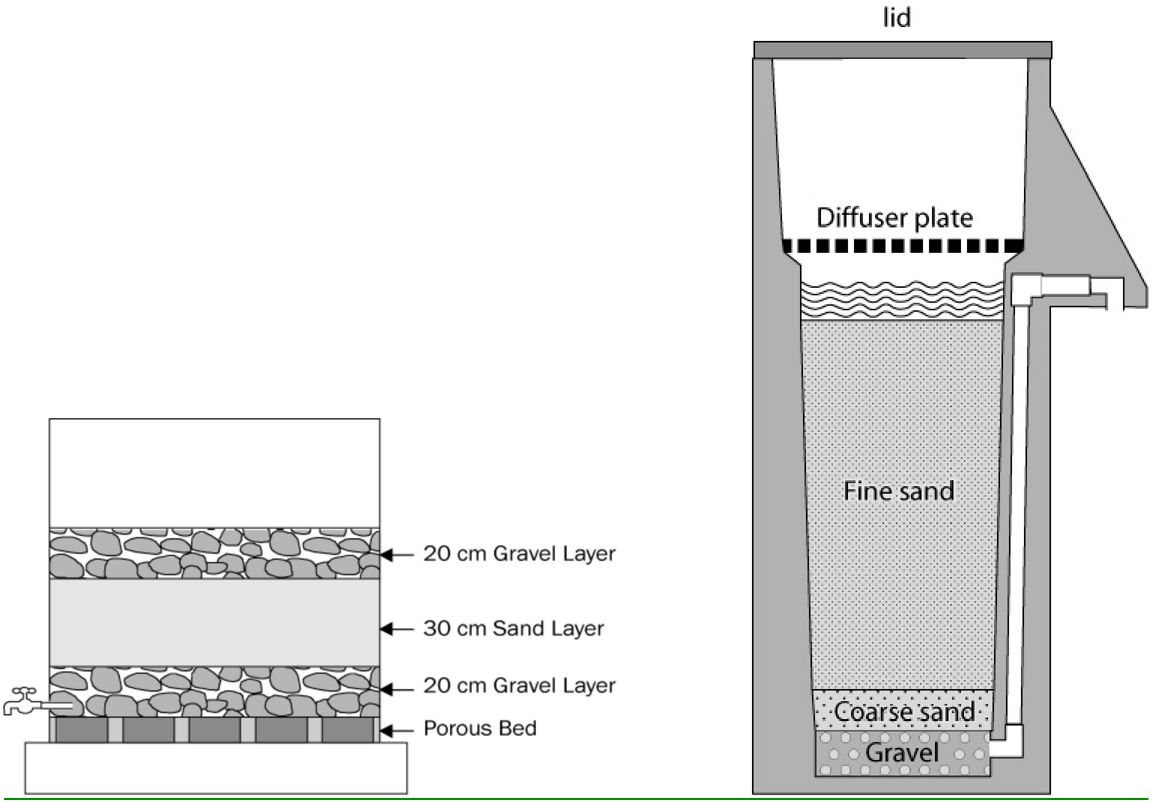

Figure 19: Sand and gravel- based water filters

5.2.4 Disinfection

Disinfection consists of boiling water and using chemicals and ultra-violet light. Boiling water for 10 to 20 minutes is sufficient to remove all biological contaminants (UN Habitat, 2005). Chlorination is done using calcium hypochlorite ($CaOCl_2$), known as bleaching powder, at a mix of 1 g per 200 litres of water to kill all types of bacteria. Alternatively, chlorine tablets can be used at a mix of 0.5 g to treat 200 litres of water. Table 5 summarizes water treatment along various components of a domestic roof water harvesting system.

At the collection conveyance stage, physical treatment through leaf screening is done. This is followed by a physical and biological stage especially when automatic foul flush gadgets are used together with sand. Finally, at the storage and utilization stage, water must be boiled and chemicals applied to kill harmful micro-organisms.

5.2.5 Monitoring water quality

The World Health Organization has developed standard chemical and biological tests that guide users in monitoring water quality. Chemical tests are carried out for chemical oxygen demand, biological oxygen demand, turbidity, conductivity, iron, manganese, calcium, magnesium, sodium, aluminium, chlorides, fluoride, ammonia, sulphate, phosphorus, total dissolved solids, zinc, cadmium and lead. Biological tests include bacteriological, viral and protozoa tests. Somalia needs to develop a strategy and framework for the monitoring of water quality. Since these tests cost money (see table 6 as an example), a study should be carried out to determine the on which parameters are relevant parameters for monitoring so that appropriate laboratories are set up either in government, parastatal or university colleges. When establishing monitoring infrastructure, twinning of a Somali institution with that of a counterpart in a neighbouring country such as Kenya or Yemen, is desirable especially if the latter have advanced technologies. The Public Health, Pharmacology and Toxicology Department at the University of Nairobi undertakes water quality tests.

Table 6: Example of current costs for charges of various parameters for water testing at the University of Nairobi

Tests	Parameter	Cost per sample (USD)
Chemical tests	PH	3.0
	Chlorides (mg/l)	9.0
	Fluoride (mg/l)	27
	Ammonia (mg/l)	22.5
	Copper (mg/l)	22.5
	Phosphorus (mg/l)	22.5
	Cadmium (mg/l)	22.5
	Lead (mg/l)	22.5
	Arsenic (mg/l)	22.5
	Flourides	27
Microbiological tests	Coliforms/E-coli	22.5
	Faecal Strephtococci	15
	Salmonella	22.5
	Clostridium Perfrigens	22.5

5.3 Agricultural water quality management

Water for agricultural use is polluted from non-point sources, i.e. it is difficult to pin-point precisely where particular pollutants come from, especially if the catchment is located in an area with intensive farming or livestock rearing. In Somalia, the major problem is siltation of water bodies. To mitigate this problem, there is need to come up with policies that encourage catchment management through soil and water conservation. Terracing is recommended wherever applicable as noted in parts of Bay region and Somaliland, as is the use of silt traps and waterway treatment (section 4.2.2).

5.4 Livestock water quality requirement

Given that the origin of all waters is rainwater, livestock have no problem drinking water drawn from surface or ground reservoirs. However, the water quality of water may be affected by the presence of nitrates and sulphates, alkalinity, salinity, bacterial contamination, other toxic elements and stagnant water.

Nitrates

Nitrate poisoning in cattle results from eating forage with a high nitrate content. The nitrates themselves are not toxic, but bacteria in the rumen reduce the nitrates to nitrites, which then get into the bloodstream. There, the nitrites convert the red pigment, haemoglobin, which is responsible for carrying oxygen from the lungs to the tissues, to a dark brown pigment, methaemoglobin, which will not carry oxygen. When this conversion is about 50% complete, animals become distressed and short of breath, and when conversion reaches 80% or more, they usually die of suffocation.

Table 6: Guide to the use of water containing nitrates for livestock and poultry

Nitrate content (ppm nitrate nitrogen)	Comments
Less than 100	Experimental evidence to date indicates that this water should not harm livestock or poultry.
100 to 300	This water should not by itself harm livestock or poultry. When feeds contain nitrates, this water could add greatly to the nitrate intake and be dangerous. This could be of some concern in the case of cattle or sheep during drought years and especially with waters containing levels of nitrates that approach the upper limits.
Over 300	This water could cause typical nitrate poisoning in cattle and sheep, and its use for these animals is not recommended. Because this level of nitrate contributes significantly to salinity, and also because experimental work with levels of nitrate nitrogen in excess of this are meagre, the use of this water for swine, horses or poultry should also be avoided.

Sulphates

Both sodium and magnesium sulphates are well-known laxatives. Water containing up to 3,000 ppm sulphates has no harmful effects on the rate or efficiency of weight gain or on faecal consistency, in gestating or lactating sows or on their litters up to 28 days of age. Water containing above 3,000 ppm, will harm livestock.

Alkalinity

Waters with alkalinities of less than 1,000 ppm are considered satisfactory for all classes of livestock and poultry. Adults may not be harmed at concentrations of less than about 2,500 ppm unless the concentration of carbonates exceeds the concentration of bicarbonates. Most waters have alkalinities of less than 500 ppm, and are not harmful. Excessive alkalinity in water can cause physiological problems and digestive upsets in livestock.

Bacterial contamination

Bacterial contamination in water for livestock use drinking water does not usually cause problems. Most water consumed by livestock has some degree of contamination from being impounded stored in depressions, tracks, dugouts or ponds. However, producers should be concerned if bacteria contaminate farm water supplies. become contaminated by bacteria. The source of contamination should be determined and eliminated, particularly if humans also consume water from the system. Waters with alkalinities of less than 1,000 ppm are considered satisfactory for all classes of livestock and poultry. Adults may not be harmed at concentrations of less than about 2,500 ppm unless the concentration of carbonates exceeds the concentration of bicarbonates.

Salinity

At high salt concentrations, water consumption increases. At very high salinities, animals may at first refuse to drink water for a few days, then drink large quantities at a go. This leads to sudden sickness or even death. Below is a table that gives a guide for salinity levels in water for livestock.

Table 7: Guide to the use of saline water for livestock and poultry

Total dissolved solids (parts/million)*	Total dissolved solids (parts/million)*
Less than 1,000	This water should is be excellent for all classes of livestock.
1,000 to 2,999	This water should be satisfactory for all classes of livestock. Water approaching the upper limit may cause some watery droppings in poultry, but should not adversely affect the health or production of birds.
3,000 to 4,999	This water should be satisfactory for livestock. If not accustomed to it they may refuse to drink it for a few days, but they will adapt to it in time. If sulphate salts predominate, animals may show temporary diarrhoea, but this should not harm them. It is, however, a poor to unsatisfactory water for poultry. It may cause watery faeces and, particularly near the upper limit, it may cause increased mortality and decreased growth, especially in turkeys.
5,000 to 6,999	This water can be used for livestock, except those that are pregnant or lactating, without seriously affecting their health or productivity. It may have some laxative effects and animals may be refuse to take it d by the animals until they become accustomed to it. It is unsatisfactory for poultry.
7,000 to 10,000	This water should not be used for poultry or swine. It can be used with reasonable safety for older, low-producing ruminants or horses that are not pregnant or lactating.
Over 10,000	This water is considered unsatisfactory for all classes of livestock.

** Electrical conductivity expressed in micromhos per centimetre at 25°C can be substituted for total dissolved solids without introducing a great error in interpretation.*

Other factors

Although toxic elements such as arsenic, mercury, selenium and cadmium may harm animals, the major concern is that their accumulation in meat, milk or eggs makes them unsafe for human consumption. Occasionally, heavy algal growths occur in stagnant or slow-flowing water bodies. Under some circumstances, a few of these species can be toxic. As there are no tests for these toxins at present, stagnant water should not be used for livestock.

6. Assessment of RWH Potential for Somalia

6.1 Introduction

Given that at less than 500 m^3 per capita per year, Somalia already faces water scarcity, every effort should be made to use all available and accessible freshwater to sustain livelihoods. Somalia currently depends on livestock and rainfed and irrigated agriculture to produce food. To cope with the low and erratic rainfall, the current practice is to grow drought-resistant crops or to abstract water from ephemeral or permanent rivers for irrigation. Pastoralists are forced to shift with their animals to new areas in search of green pasture and water during droughts. The situation is not different for water for domestic use. In most areas with low annual rainfall, the government and resident communities use either boreholes or trucking to supply water.

Rainstorms come in short and intense events and usually cause flooding both in the rural and urban areas. Such untapped potential if under-utilized poses great danger to people and the environment. Rainwater harvesting could complement and ease not only the scarcity problem, but contribute to environmental conservation too. Emphasis should be on the runoff which otherwise goes to waste.

6.2 Assessement of RWH potential for Somalia

FAO-SWALIM and ICRAF collaborated with US Geological Survey to estimate runoff using the soil conservation service curve number technique and satellite-derived rainfall estimates. This follows experience from a previous similar study conducted by Senay and Verdin (2004) for Africa. For Somalia, watersheds were delineated from digital elevation model data sets in a GIS environment. Annual runoff volumes were estimated as the product of the watershed area and runoff excess estimated from the SCS–CN method (section 4.2.3).

The average rainfall values for Somalia were used to produce three runoff potential maps of the following ranges; low (0–10 mm), medium (10–20 mm) and high (over 20 mm). By determining the areas for these regimes using GIS, the product of the runoff and areas provided an estimate of runoff water harvesting potential (volumes in km^3). Annex 19 shows runoff water harvesting potential estimated as follows: desert areas with annual rainfall below 200 mm having less than 1,393 M m^3 (million cubic metres); regimes with low rainfall (200–400 mm) generating between 2,246 to 4,492 M m^3; and medium-rainfall regimes generating above 5,309 M m^3. Using GIS, the runoff harvesting potential for Somalia is therefore estimated to be 11,194 M m^3. FAO-Africover aggregated rangelands and agriculture data sets were used to extract runoff for the agricultural lands and rangelands (annexes 19 to 21). By determining the areas covered under these domains using GIS, the runoff potential for agriculture and rangeland sectors were was estimated (table 8).

Table 8: Runoff potential in volumes for the agriculture and rangeland sectors

Rainwater Harvesting domain	Rainfall regimes	Area (Million ha)	Runoff depth (mm)	Runoff volume (M m3)
Rainfed Agriculture	Desert	0.15	<10	<15.38
	Low	1.77	10 – 20	177.83 - 355.66
	Medium	1.15	>20	230.74
	TOTAL	3.08		601.78
Irrigated herbaceous fields & tree crops	Desert	0.04	<10	<3.95
	Low	0.71	10 – 20	70.73 – 141.5
	Medium	0.16	>20	32.15
	TOTAL	1.01		177.6
Rangelands	Desert	14.3	<10	1433
	Low	4.67	10 – 20	467 – 935
	Medium	1.79	>20	357
	TOTAL	7.89		2725
Overall	Desert	14.49	<10	1452.33
	Low	7.15	10 – 20	1432.16
	Medium	3.9	>20	619.89
	TOTAL	11.98		3504.38

From table 8, it is clear that at 7.89 Million hectares (M ha), rangelands constitute the biggest area generating 2,725 M m^3 of runoff water. This is in comparison to rainfed agriculture, covering an area of 3.08 M ha with runoff water harvesting potential of about 602 M m^3, and irrigated areas covering 1 M ha with runoff water harvesting potential of 178 M m^3. The total amount of runoff generated in the whole of Somalia is thus approximately 3,504 M m^3 (3.5 km^3).

6.2.1 Roof water harvesting potential

According to UNECA (2000), a human ideally requires about 1,700 m^3 of freshwater per year, equivalent to 4,660 litre per day for drinking, dietary and industrial needs. Of these, the daily domestic water needs alone constitute 3.33%, or 155 litres per capita, with dietary needs taking 86.7% equivalent to 4,040 litres, and industry the remaining 10% equivalent to 466 litres. Table 9 shows water needs in comparison to the Somalia allocations in litres per capita per day.

Table 9: Global water needs in comparison to the Somalia per capita allocation

Category of water situation	Amount (m3)	Domestic water 3% of amount (Litres/cap/day)
Ideal global	>1700	>155
Water stressed	1000-1700	82 - 155
Water scarce	<1000	< 82
Somalia		
Current	<500	41
Basic Water Requirement	242	20

On average, per capita daily water availability for Somalia is about 41 litres/capita/day. ICRAF and FAO-SWALIM determined the RWH potential for selected towns. Roof coverage of these towns is shown in annexes 22 to 30. The formula below was used to compute roof water harvesting potential (RWH_{pot}) for selected towns (see table 10):

$$RWH_{pot} = P \times C_d \times \Sigma A_d \times \eta \times R_p$$

Where P = Average annual rainfall (mm)

C_d = Runoff coefficient dependent on the common roof material used (See annexes 23 to 31)

ΣA_d = The sum of all roof surfaces in a given town (m^2)

η = Rainfall reliability (assumed as 0.67 for the East African region dependent on the monsoons)

R_p = Roof pitch, taken as 1.05 for Somalia buildings

Table 10: Roof water harvesting potential for selected towns in Somalia

Example of urban settings	R_fWH_{pot} (Million litres)	Approximate population[4] (2007)	Basic water requirement (litre/cap/day)	Duration of supply per year (months)
Garoowe	33	60,000	20	.1
Hargeisa	1200	500,000	20	3
Hargeisa	1200	500,000	20	2
Jowhar	352	60,000	20	10

Analysis of the results shows that rainwater harvesting alone is not adequate to meet the basic daily water requirements. Nevertheless, it complements conventional municipal supplies.

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[4] Population figures are obtained from UN Habitat, Hargeisa office

7. Institutional and Policy Aspects in RWH Projects

7.1. Overview of current status

Although the governments have established lead ministries to coordinate other line ministries in water policy management, RWH has not received adequate attention in government programmes and projects unlike in irrigation or groundwater resources. In addition, management capacity to operate and maintain water supply facilities is inadequate in Somalia (PSAWEN, 2001) following 16 years of civil strife. This has prompted the governments to start institutional and policy development initiatives. The policies are still in their development stages and are yet to be implemented. Examples of the draft policies include:

- The Water Supply Policy Green Paper: a discussion paper for to be reviewed by Puntland State for Water, Energy and Natural Resources Corporation
- The Draft National Water Plan by Puntland State for Water, Energy and Natural Resources Corporation
- The Draft Water Act for Somaliland

On-going water policy reforms in Puntland, Somaliland and the Transitional Federal Government recognise the Ministry of Water as the lead agency in charge of water resources. Depending on the state or region, the water ministry coordinates a task force drawing its members from line ministries and key local or external agencies. At the moment, most of the RWH activities are carried out by international NGOs.

7.2 Excerpts from existing water policies

7.2.1 Somaliland Water Act

The Ministry of Water and Mineral Resources (MWMR) prepared the Draft Water Act for Somaliland in collaboration with UNICEF and the Danish Royal Government. The MWMR is responsible for implementing this water act. Its purpose is to improve water availability and access in a sustainable and equitable way for all types of uses, in a manner that is environmentally safe. The specific objectives are to:

- recognise, legitimise, empower, and endorse the Somaliland's customary laws and institutions and Somaliland's traditional leaders in water-related administrative, fiscal, and judicial affairs;
- manage water resources and provide water services by implementing and enforcing the Water Code, its laws and regulations;
- develop a national water strategy, and translate it into national water plans;
- enable multi-disciplinary planning and evaluation of water resources, programs and projects;
- coordinate government ministries and autonomous agencies which are concerned with the development and administration of water resources and water rights; and,
- define the rights and obligations of persons, both social and economic, and harmonise them with the general welfare.

7.2.2 Puntland Green Water Paper

The objective of the Green Water Paper is to set out the policy for the Puntland State for Water, Energy and Natural Resources Corporation, (PSAWEN). PSAWEN is positioned to be the lead technical agency to direct and coordinate sector activities, policy development, guidelines, standards, monitoring and evaluation, surveys, create database, training and advice on financing. The green paper and the input from a review process must be endorsed by parliament for it to be accepted as a white paper on water policy.
The institutional framework for PSAWEN will involve a range of other agencies, notably provincial and local government as well as other interested parties such as the private sector and NGOs. PSAWEN has the following institutional goals for water supply services:

- In the long term, the goal is that services provided to consumers should be based on full cost recovery.
- In the medium term, the objective of the government is to support institutional development at local and national and local levels.
- In the short term, the immediate goal is to maintain service delivery to build institutions and ‘gear’ up to achieve medium-term goals.

7.2.3 Pre-war National Water Policy

Prior to the imposition of colonial rule, each Somali clan was an independent entity, which owned water sources and exercised grazing rights (PSAWEN, 2001). During the colonial and UN Trust Territory period (1880–1960), some systems were started to supply only the small, ruling and wealthy elite of the towns. Since the 1960s, traditional dug wells and reservoirs have been constructed and then controlled by individual families along lineage groups or clans. Drilling of boreholes on a large scale begun in the 1970s under the authority of different government agencies.

A national water committee was formed comprising various ministries and general managers of the autonomous Water Development Agency (WDA) and the National Range Agency. One required their approval before constructing a borehole to ensure that strategic and environmental concerns were addressed. There were four autonomous centres in the water sector—Mogadishu, Hargeisa, Kismayo and the WDA—responsible for rural water supply, while responsibility for urban water supply was given to regional authorities. In 1978, the responsibility for the urban water supply was transferred to WDA.

7.3 Role of local and external support agencies

The rate of population growth for humans and livestock far surpasses water supply capacity from surface and ground water bodies by various governments in Somalia. The response to this has been the creation of NGOs and the entry of international organizations to contribute to mitigating water scarcity for various sectoral uses. These agencies and NGO’s contribute in the mitigation of the problems enumerated above by addressing other socio-economic issues such as lack of employment, by granting financial support to job creation within the available programs or projects.

7.4 Roles of government and local community

The role of central government in the water sector is to manage the nation's water resources in the public interest and ensure that all citizens have access to adequate water services. This is achieved through;

- strong and enforced policies and regulations relating to water, land use and environment
- creating a secure environment for humanitarian interventions & investments
- developing a national strategic plan of for integrated water resource management (IWRM) (rainwater harvesting, ground water and shallow wells) RWH,GW & SW) for different uses and users
- coordinating different stakeholders
- ensuring sustainability

The community's role is to manage shared primary resources—water and pasture—mainly through conflict resolution at the behest of elders, chieftains and religious leaders. Members of society who flout rules or regulations governing the use of the shared resources are penalized by confiscating their domestic animals as compensation. The community gets assistance from the Diaspora through contributions in gifts and financial aid.

8. Planning, Implementation and Monitoring of RWH Interventions

The basis for implementing RWH interventions is the principle of integrated water resources management (IWRM), which states that water is an economic, social and environmental good, and policies and options that guide water resources management should be analyzed within a comprehensive framework. IWRM provides a good entry point for balanced interventions using programmatic rather than project approach to achieve greater chance of sustainability. Its central objective is to promote efficient, equitable, and sustainable development using institutional, technical, economical, social and environmental strategies. The following excerpts adopted from the African Development Bank (2007) have relevance in the implementation of RWH projects at various scales.

Having been convinced of the importance of RWH for livelihood support and environmental conservation, the Governments of Puntland, Somaliland and Southern Somalia need to develop national masterplans that spell out where, how and what needs to be done. This can be achieved by engaging expertise drawn locally or abroad. The experts shall estimate the potential of RWH for given technologies identified here as RWH for agriculture and livestock, roofwater harvesting, sand and sub-surface dams and runoff water harvesting; identify suitable areas for implementing such domains; and advise governments on the investment costs of implementing various RWH programmes and projects. The governments can use the masterplans as reference documents to solicit funding through various means such as proposal writing.

The next major step is to establish an institutional structure that will coordinate, implement and monitor RWH programmes or projects. So far, the Ministries of Water are taking the lead in streamlining RWH in their programmes. This is a good move that needs support and strengthening especially in policy formulation, which forms the backbone of project management. There should be institutional acceptance of RWH as a viable water supply option in areas with limited water sources. RWH as a water supply option should feature prominently in national water policies and strategies. Otherwise, the techniques and use will continue to be restricted to NGOs and sporadic interventions by some bilateral donors.

Initial RWH interventions should be operationalized from existing policy and consider legislative, administrative and institutional frameworks. Rainwater harvesting for crop or animal production should consider providing field extension services, and credit and marketing facilities, while that for domestic use should consider integrating water supply sources. Below are examples of specific RWH-related projects at local, national and, regional levels:

Local level

- Carry out demonstration projects and research on efficiency of RWH interventions
- Integrate RWH in ongoing projects
- Support farmers developing RWH techniques

- Support communities engaging in RWH activities
- Improve extension services and training on RWH
- Improve/ensure access to markets for the necessary RWH materials.
- Build capacity of local authorities on RWH

National and regional level

- Map traditional RWH practices and experiences
- Map potential of RWH
- Support policy analysis and implementation strategy formulation related to RWH
- Include RWH in national policies in water, agriculture, land, livestock, rural development, urban development and environment
- Operationalise and institutionalise policies, and formulate regulations and legislation
- Provide enabling environment for RWH and water-related businesses
- Develop frameworks for standard designs for RWH systems
- Develop RWH curriculum for technical educational institutions
- Support the development of efficient monitoring systems on performance of RWH.
- Support a networking knowledge base among stakeholders on RWH

8.1 RWH projects implementation

From the mapping of RWH technologies, it is easy to decide on which areas or technologies to introduce in selected areas. Once this is done, the community needs to be sensitized and their approval sought. The government should organise or conduct a training needs assessment (TNA). The TNA report will be useful in developing staff and community training curricula and manuals which can later be used to build capacity of extension personnel, artisans, fabricators and farmers.

In introducing RWH in a given locality, specific sites for scaling up best practices should be identified using GIS tools. With support of external agencies, the government should procure a quickbird image to expedite hydrologic delineation of the selected area as well as develop a digital elevation model and describe its biophysical features. These are important baseline data for the planning of RWH projects.

Local ownership and participation are important issues when seeking to establish sustainable RWH measures. Sustainable RWH technologies are those that are developed and managed by local farmers themselves. These farmers must be involved in identifying technically feasible, sustainable and acceptable technologies. One of the main prerequisites is social and economic sustainability that considers cost recovery and willingness of the community to contribute cash or labour. Central to involving communities is the inclusion of gender issues in planning and implementing projects. Women play a crucial role in water provision as they are the ones who fetch water. They will often have the greatest interest and the most to gain from water supply projects, thus their views and conditions must be included in the implementation activities.

Specialists such as engineers will need these baseline data to design particular interventions identified from the map earlier developed. Technicians and artisans will use these costed designs to introduce these technologies to community members and provide them with skills training for future uptake and sustainability.

8.2 RWH projects monitoring and evaluation

During implementation of RWH interventions, data should be continuously collected on amounts, quality and utilization of harvested rainwater through testing of the designs. Reports from monitoring missions will be useful in preparing follow-up plans and providing technical backstopping or adjusting various techniques to improve their performance. From these reports, precise operational and maintenance plans can be developed.

Monitoring of roof catchment systems
For roof water harvesting systems, trees planted close to buildings should be monitored to ensure that leafy branches do not spread towards or over the roofs. If this happens, organic matter will be deposited on the roofs that and may impede conveyance of runoff water. Such branches should be trimmed. Just before the onset of rains, the roofs and gutters should be cleaned. Gutter gradient should be evaluated by measuring the slope that has to conform to the original design and checked for any leakages and consequently repaired.

During the rainy season manual foul flush mechanisms have to be carried out to drain the dirty runoff water after every each rainfall event.

Storage tanks should be monitored for any leaks that may arise from poor concrete workmanship or faulty pipes (taps or drainage plugs). If noticed, repairs should be done immediately. To monitor water quality, random samples should be taken at least once a year for analysis and where necessary appropriate treatment mechanisms put in place.
Overall, the entire system should be evaluated for its sufficiency and cost effectiveness.

Monitoring of agricultural systems
Agricultural systems are a lot more complex than the domestic ones. Monitoring them requires a good understanding of land use and hydrologic processes that influence generation of runoff. The catchment area is often beyond the control of the user. Its misuse therefore results in externalities that may pose big challenges to the reservoir's life. If communally owned, however, then inhabitants may come up with conservation measures. Land-use trends should therefore be keenly monitored.

Conveyance mechanisms that include waterways, channels and silt traps should be closely monitored to ensure that siltation is reduced or impeded. Re-designs and repairs should be done carried out before the onset of rains.

Regarding storage, losses due to seepage and evaporation have to be monitored constantly. Monitoring can be enhanced by carrying out a water balance audit to monitor water use for irrigation or livestock. The siltation rate should also be evaluated to plan for frequency of desiltation.

9. Conclusions and recommendations

1. There is inadequate capacity in the designing, constructing on and maintaining rainwater-harvesting infrastructure. Local and international NGOs complain of frequent cases of collapsing infrastructure. There is need to develop a capacity-building framework that looks at all aspects of training and skills development for various components of RWH as well as for the different categories of practitioners. In particular, capacity building for government officials on formulating and regulating RWH policy should be considered.
2. The inter-ministerial efforts by various governments on to develop policy development are laudable and should be supported. Support to policy formulation and implementation should be provided through developing guidelines, standards, and procedures and, study tours, and through identifying demonstration sites for RWH best practices.
3. Due to inadequate rainfall and population data, it was not possible to produce maps that show areas suitable for particular RWH technologies. Instead, mapping was done for the broad categories of agricultural and domestic water use. FAO-SWALIM should continue with compiling hydro-physical and climatic data to be used for this purpose.
4. RWH associations should be established and linked to regional, continental and global networks: The Southern and Eastern Africa Rainwater Network (SearNet) could should assist with information on how such networks are established. Interim committees' should be formed to follow up on the establishment of these associations. In Somaliland, proposed names interim officials for the of national watershed management policy networking are: Ali Ismail (Interim Chairman), Abdirashid D. Farah and Sadia Musse Ahmed and, Abdirahman Abdisalan. Puntland and S. Somalia should also name interim officials.
5. FAO-SWALIM in collaboration with the relevant government ministries should take the lead in sharing pertinent information on monitoring hydro-climatic data. They should also continue supporting capacity building to generate improved data sets. FAO-SWALIM should compile data on average rainfall intensities for Somalia to enable the development of a guide for designing RWH infrastructure.
6. FAO-SWALIM should commission a study on cost- benefit analysis for the current rainwater practices in Somalia. Information gathered from such studies will be useful in the assessing the viability of RWH projects or practices as well as acting as reference material for planning and re-designing RWH technologies.

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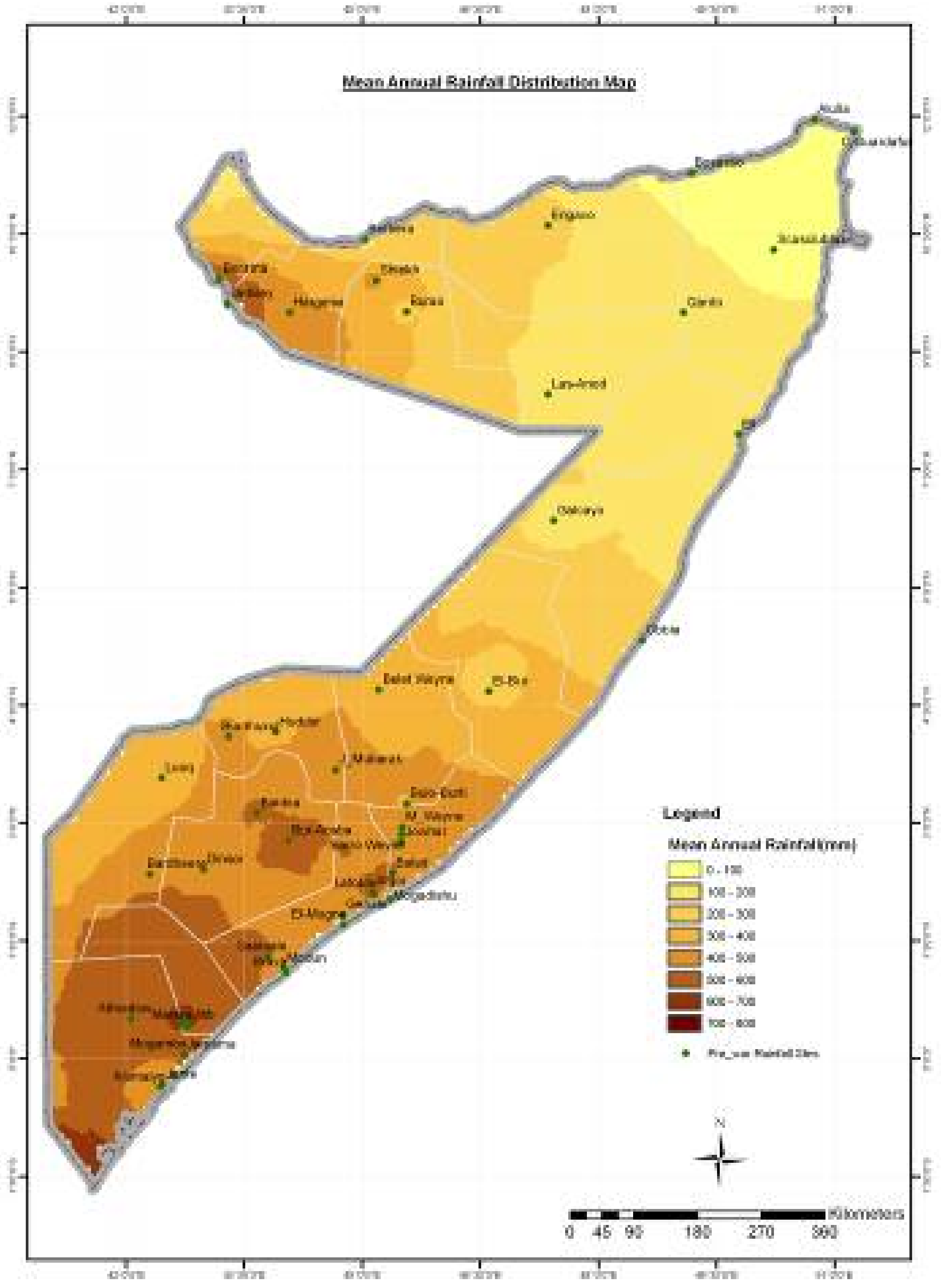
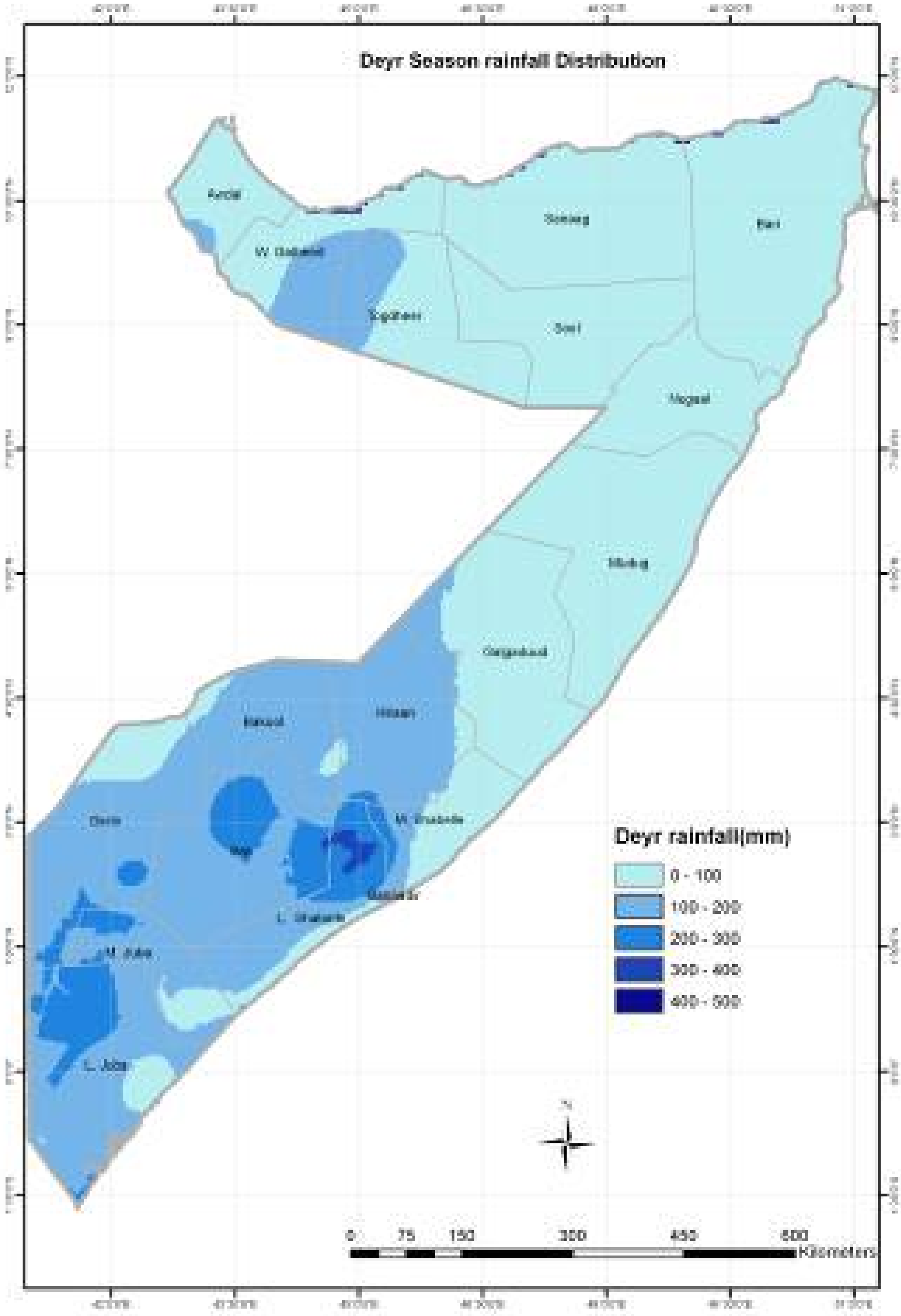
Annexes

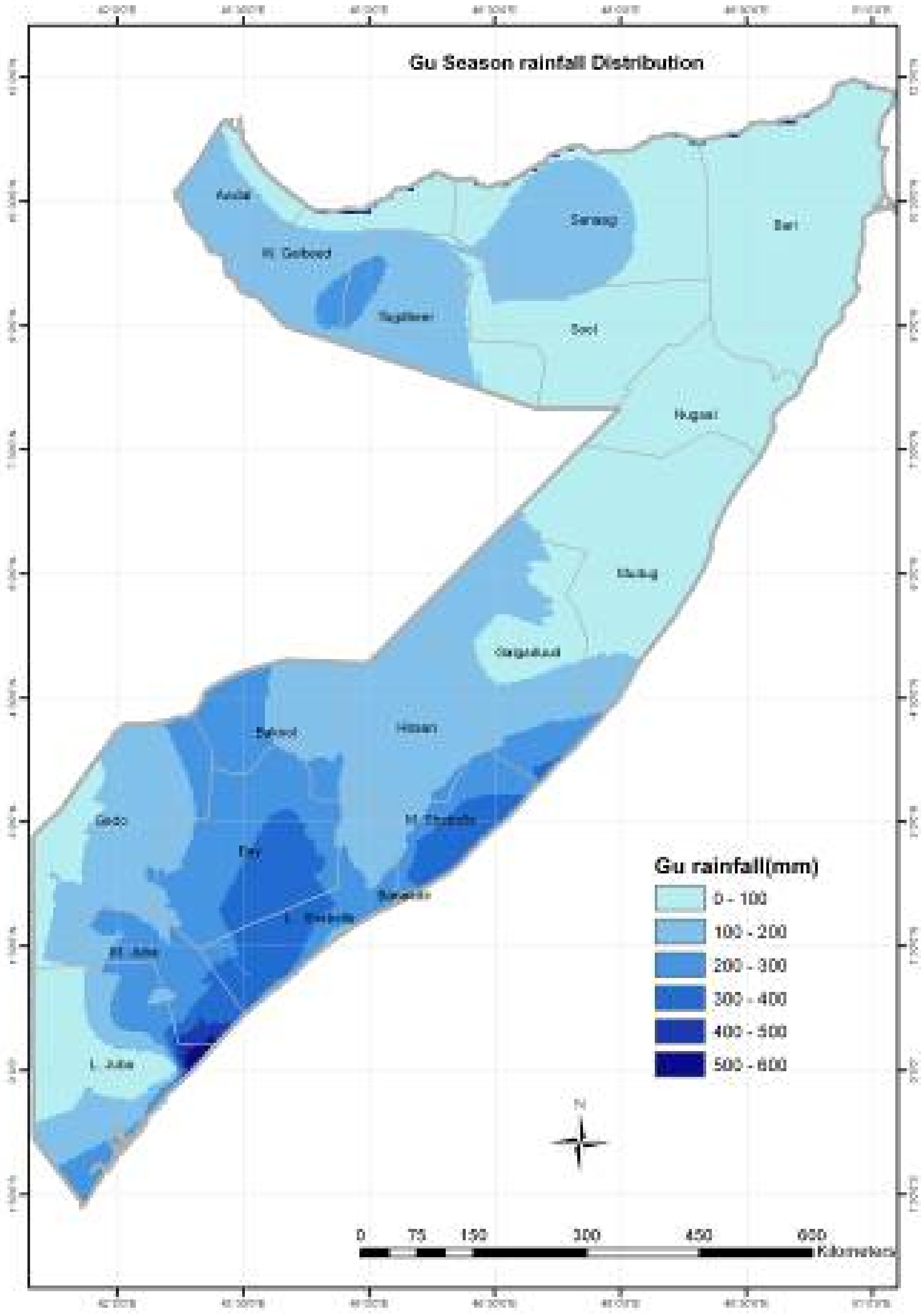
Annex 1: Mean annual, rainfall distribution for Somalia



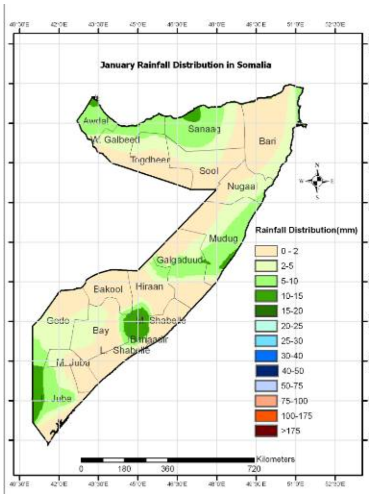
Annex 2: Deyr seasonal rainfall for Somalia

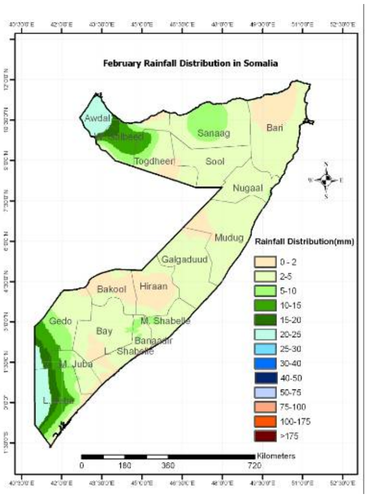


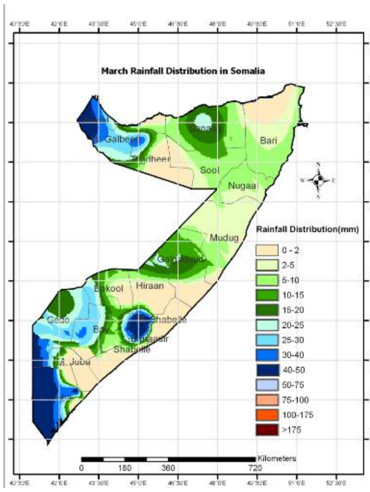
Annex 3: Gu seasonal rainfall for Somalia

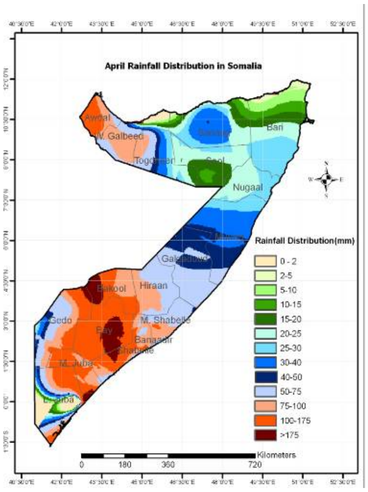


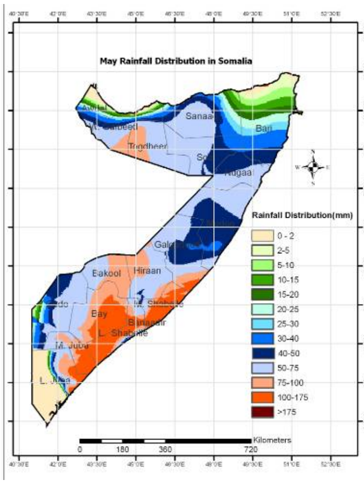
Annex 4: Monthly rainfall distribution patterns for Somalia: January to June

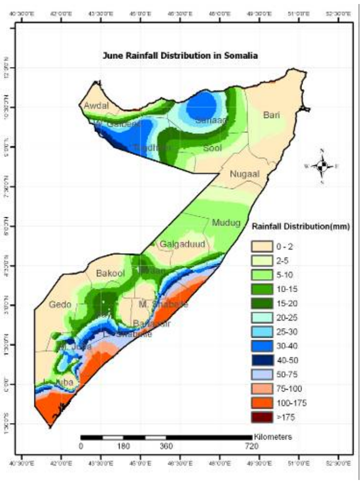




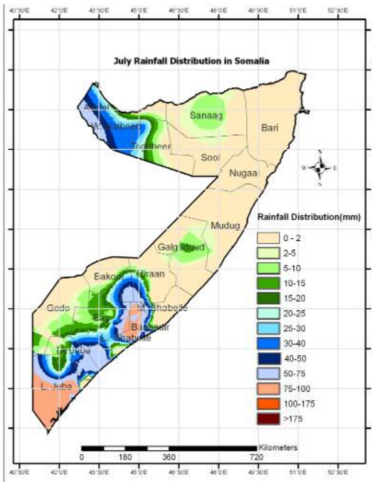


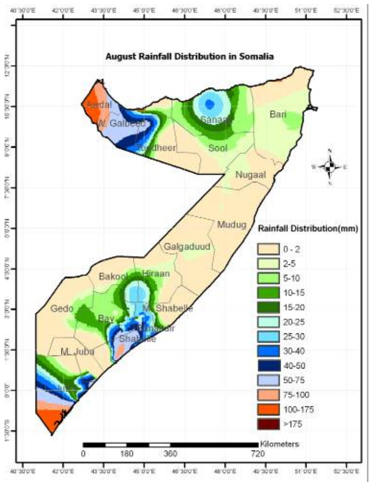


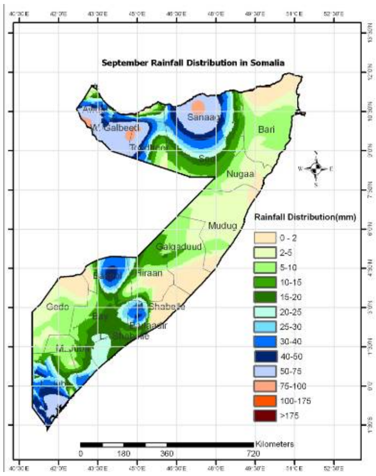


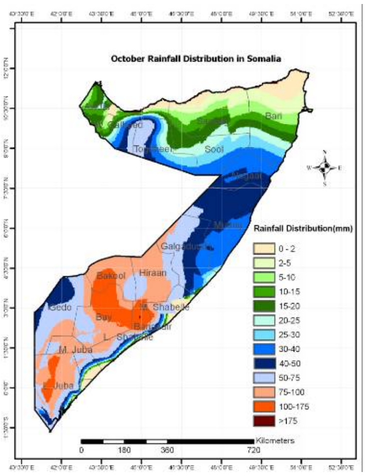


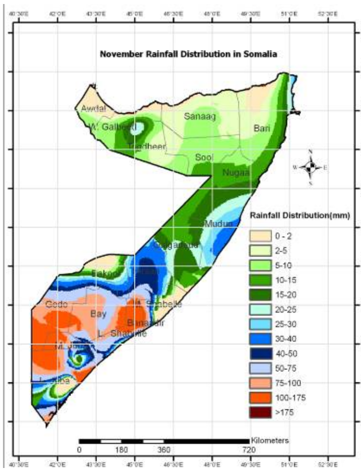
Annex 5: Monthly rainfall distribution patterns for Somalia: July to December

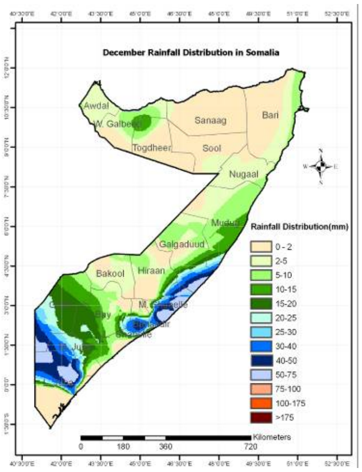




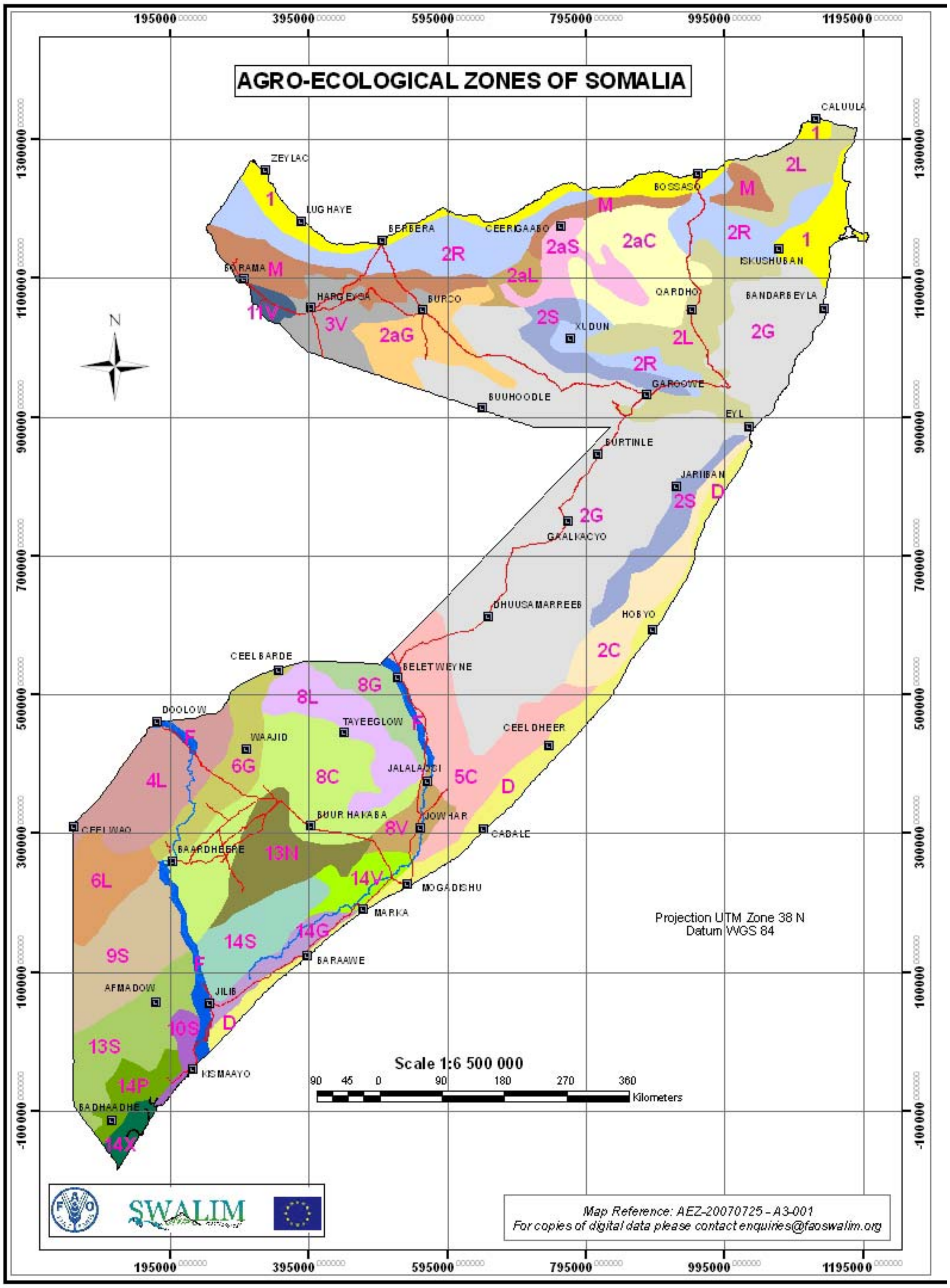




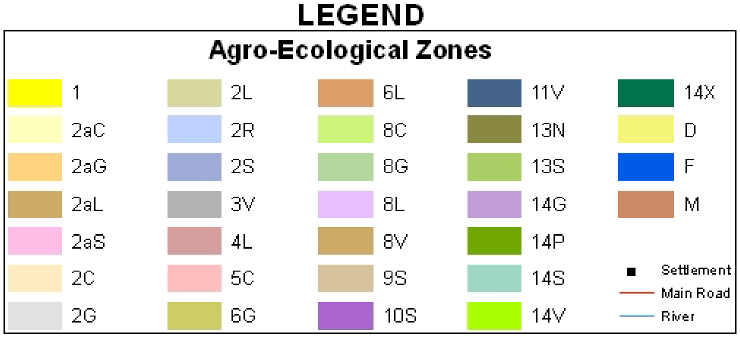




Annex 6: Agro-ecological Zone map for Somalia



Annex 7: Legend of the AEZ map for Somalia



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

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

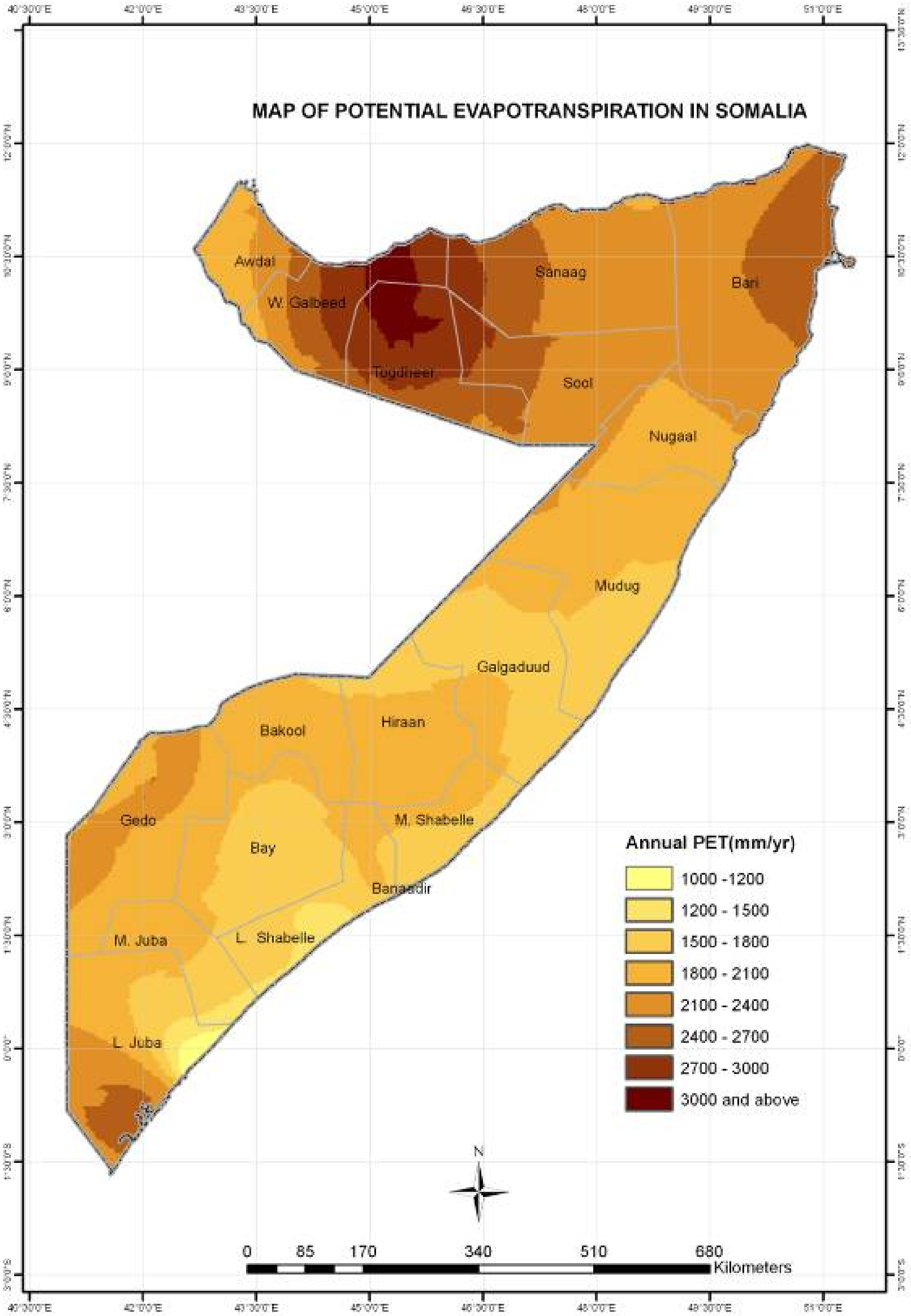
Annex 8: Criteria for mapping of RWH technologies

Development domain	Criteria	Classes	Comments
1. Rooftop	• Presence of settlement • Population density >10/km^2 • Rainfall in sufficient amount	**Rainfall** Desert: 0 – 200 mm Low 200 – 400 mm Medium 400 – 800 mm **Population** Low 10/km^2 Medium 10 - 100/km^2 High > 100/km^2 **Development domains** *Compute areas for:* Low rainfall low population Low rainfall medium population Low rainfall high population Medium rainfall low population Medium rainfall medium population Medium rainfall high population	Obtain base maps for: • Rainfall • Human settlement Compute RWH_{pot} and R_fWH_{pot} (see notes below)
2. Ponds, pans & small earth dams	• Rainfall > 200 mm • Slope • May include areas with low human population but having livestock & wildlife	**Rainfall** Desert: 0 – 200 mm Low 200 – 400 mm Medium 400 – 800 mm **Slope** Flat: < 2% Undulating: 2 – 8 % Steep > 8% **Development domains** *Compute areas for:* Flat & low rainfall Flat & medium rainfall Undulating & low rainfall Undulating & medium rainfall Steep & low rainfall Steep & medium rainfall	Obtain base maps for: • Rainfall • Digital Elevation Models Compute RWH_{pot} and R_nWH_{pot} (see notes below)

Development domain	**Criteria**	**Classes**	**Comments**
3. In-situ RWH systems (All types of on-farm sytems, micro and macro catchments	Landuse Rainfall	**Rainfall** Desert: 0 – 200 mm Low 200 – 400 mm Medium 400 – 800 mm High > 800 mm **Land use** Agricultural lands, YES Other lands, NO **Development domains** *Compute areas for:* Flat & low rainfall Flat & medium rainfall Undulating & low rainfall Undulating & medium rainfall Steep & low rainfall Steep & medium rainfall	Obtain base maps for: • Rainfall • Landuse maps depicting all agricultural activities Compute RWH_{pot} and R_nWH_{pot} (see notes below)
4. Rock catchment systems	• Rainfall • Rock outcrops • May include areas with low human population but having livestock & wildlife	**Rainfall** Desert: 0 – 200 mm Low 200 – 400 mm Medium 400 – 800 mm **Development domains** *Compute areas for:* Rock outcrops in desert conditions Rock outcrops with low rainfall Rock outcrops with medium rainfall	Obtain base maps for: • Rainfall • Rock outcrops Compute RWH_{pot} and R_kWH_{pot} (see notes below)
5. Sand dams & Sub-surface dams	Ephemeral sand river beds suited to drylands	**Ephemeral rivers: Yes** Drylands P/ET < 60% Wetlands P/ET > 60%	Obtain base maps for: • Rainfall • Rock outcrops Compute RWH_{pot} and R_kWH_{pot} (see notes below)

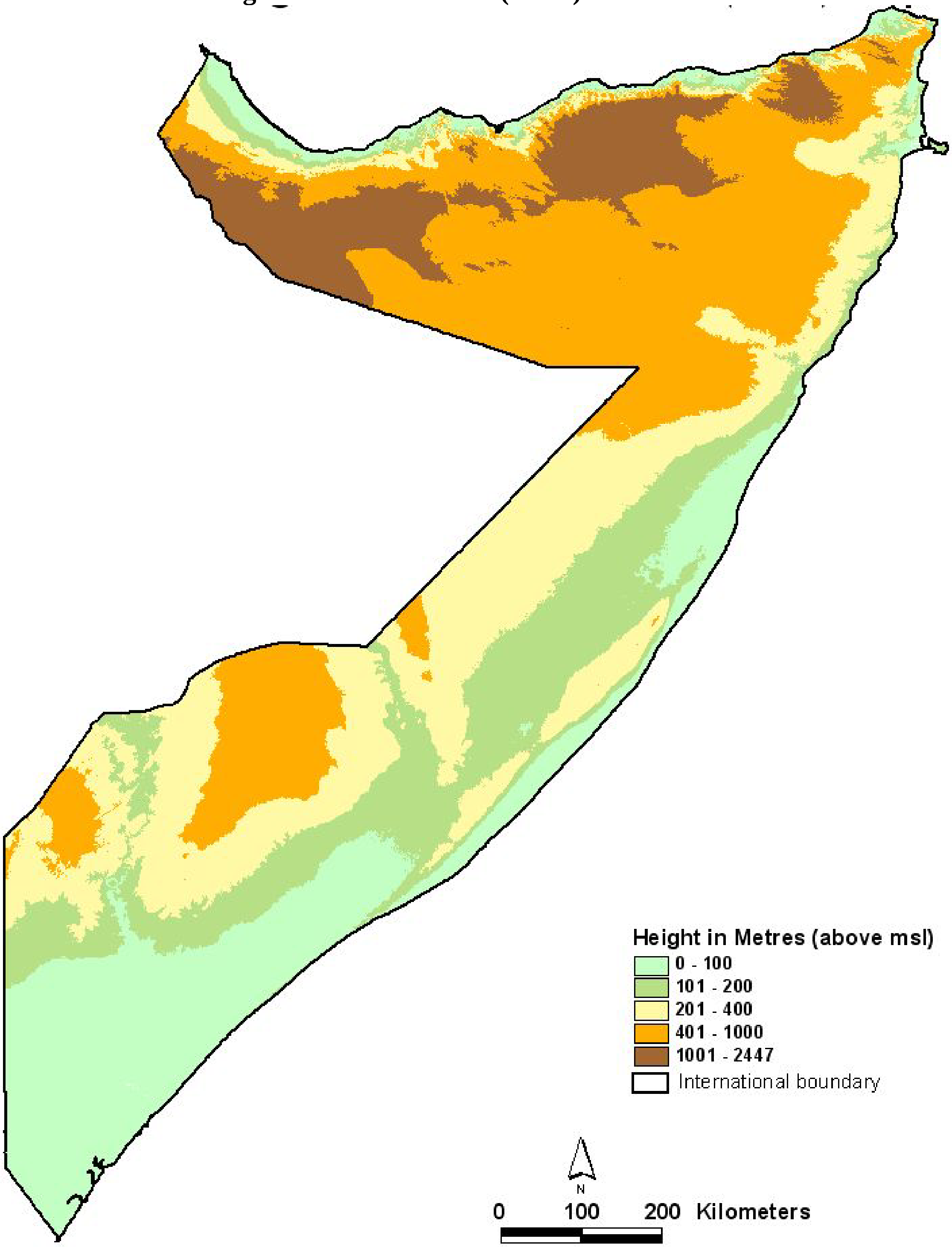
Source: Adopted from Mati et.al., 2006.

Annex 9: Potential evapotranspiration for Somalia

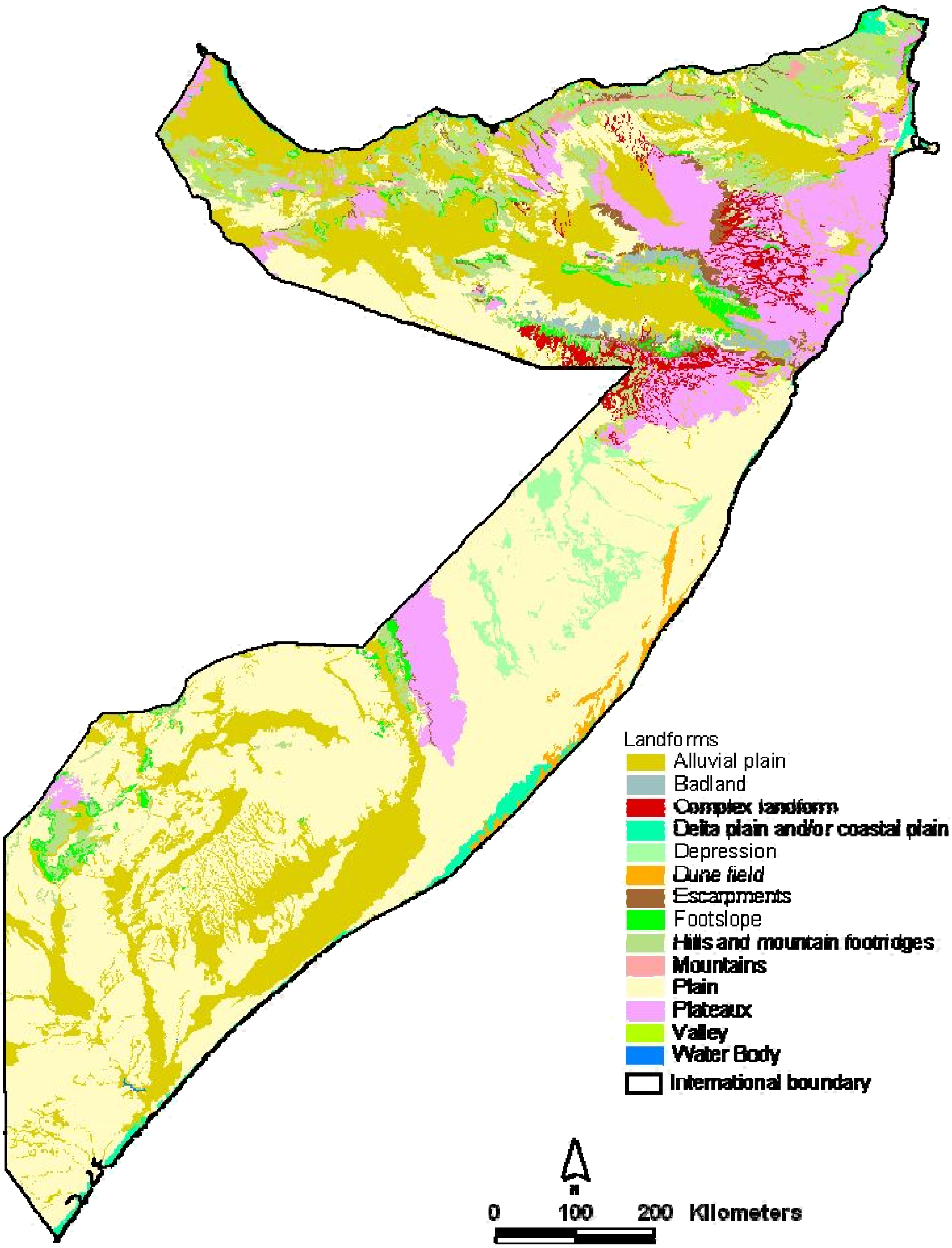


Annex 10: Mean annual temperatures for Somalia

Annex 11: Somalia Digital Elevation Model (DEM)



Annex 12: Somalia landforms



Annex 13: Rainwater harvesting systems for domestic, agricultural & livestock use

	Technological Option by use		
RWH Component	**Domestic**	**Agricultural (Crops)**	**Livestock**
Catchment	Roof cover	Ground	Open ground
	GI sheets	Roads	Roofs
	Grass	Paths	Rock
	Tiles	Cropland	Treated ground
	Asbestos	Open ground	
	Rock catchment	Terraces	
	Open ground		
	Treated ground		
	Roof pitch		
Conveyance	Gutters	Waterways	Waterways
	Chains	Trenches	Trenches
	Ropes	Pipes	Pipes
		Soil profile	
Storage	Cylindrical Tanks	Ponds/pans	Ponds/pans
	Ferrocement	Small earth dams	Small earth dams
	Brick tank	Soil profile	Soil profile
	Rubble stone	Sausage tanks	Sausage tanks
	Sausage tanks	Spherical tanks	Spherical tanks
	Spherical tanks	Plastic lined tanks	Plastic lined tanks
		Wells	Cylindrical tanks
			Wells
Treatment	Mechanical	Silt traps	As in Agricultural
	Foul flush by-pass	Waterways	and domestic use
	Bio-physical	*Grasses*	
	Sand filters	*Stone pitching*	
	Chemical	*Tractor tread patterns*	
	Aluminium sulphate		
	Chlorine		
Abstraction	Gravity	Gravity	As in Agricultural
	Pumping	Rope & Washer pump	and domestic use
		Treadle pump	
		Siphoning	
Utilization	*Drinking*	*Crop production*	*Livestock production*
	Cooking	*Agro-industries*	*Ground water recharge*
	Kitchen gardening	*Ground water recharge*	
	Sanitation		

Annex 14: Factors to consider in the planning, design, and implementation of agricultural RWH systems

RWH Component	Factors to consider in		
	Planning	Design	Implementation
Catchment	Catchment conservation	Catchment area	Catchment committees
	In-situ vs. Ex-situ systems	Runoff coefficient	Policy on conservation
	Rainfall regime/characteristics	Catchment characteristics	Community participation
	Estimation of the potential	Runoff generation	in afforestation
Conveyance	Availability of labour/skills on conveyance mechanisms	Availability of labour/skills on conveyance mechanisms	
Storage	Water quality	Livestock water use	Artisan entrepreneurship
	Capacity optimization (cost/m3)	Crop water requirement	Community contributions
	Rainfall regime/characteristics	Rainfall	esp in labour & local mtrls
	Labour imlications	Evaporation	Machinery hire construction
	Technical know-how	cascading systems	
	Suitability mapping		
Treatment	Health of livestock	Silt traps	Tractor hire to desilt
	Reduced siltation of reservoirs	Water ways	Human labour for desiltation
Abstraction	Water resources prospecting	Consider:	Training of Technicians
	Costs comparisons in abstraction	Mechanical (Treadle pump)	and pump fabricators
		Gravity	
		Fuel driven & cost implications	
		Supply management	
Entire system	Awareness creation/study tours	Potential estimation	Demonstrations
	CIG formation	Suitability mapping	Upscaling
	Training/capacity building		maintanance
	Institutional arrangements		Technical backstopping
	Monitoring & Evaluation		

Annex 2: Factors to consider in the planning, design, and implementation of domestic RWH systems

RWH Component	Factors to consider in		
	Planning	**Design**	**Implementation**
Catchment	Catchment type	Catchment area	Artisan entrepreneurship
	Water demand	Runoff coefficient	
	Catchment design to maximize harvest	Roof pitch (domestic)	
	Cost implications	Rainfall characteristics	
		Ground slope (Agric/livestock)	
Conveyance	Technological option	Optimum gutter width (50-70mm)	Artisan entrepreneurship
	Conveyance type/material	Cross sectional area	Fabricator entrepreneurship
	Cost implications	Roughness coefficient	
	training of technicians/fabricators	Conveyance gradient	
Storage	Water quality	Reservoir/hydraulic pressures	Artisan entrepreneurship
	Capacity optimization	Potential storage/estimations	Community contributions
	Rainfall regime/characteristics	Reservoir capacity, Volume (V)	
	Cost implications	V=A*Roof Pitch*Cr*P	
	Artisan training	Mass curve analysis	
	Suitability mapping		
Treatment	Skill/training needs	Knowledge on chemistry	As in Agricultural
	Cost implications	of treatment agents	and domestic use
	Health implications/hazards	Knowledge on mechanics	
		of foul flush gadgets & filters	
Abstraction	Water resources prospecting	Consider:	Training of Technicians
	Costs comparisons in abstraction	Mechanical (Treadle pump)	and pump fabricators
		Gravity	
		Fuel driven & cost implications	
		Supply management	
Utilization	Consumer demand information	Demand management	Awareness creation on
	Population/demographic data	Rationing	water conservancy
	Lifestyles		

DRWH = Domestic Rainwater Harvesting

Annex 163 Analysis for Borama 20mm Rainfall threshold

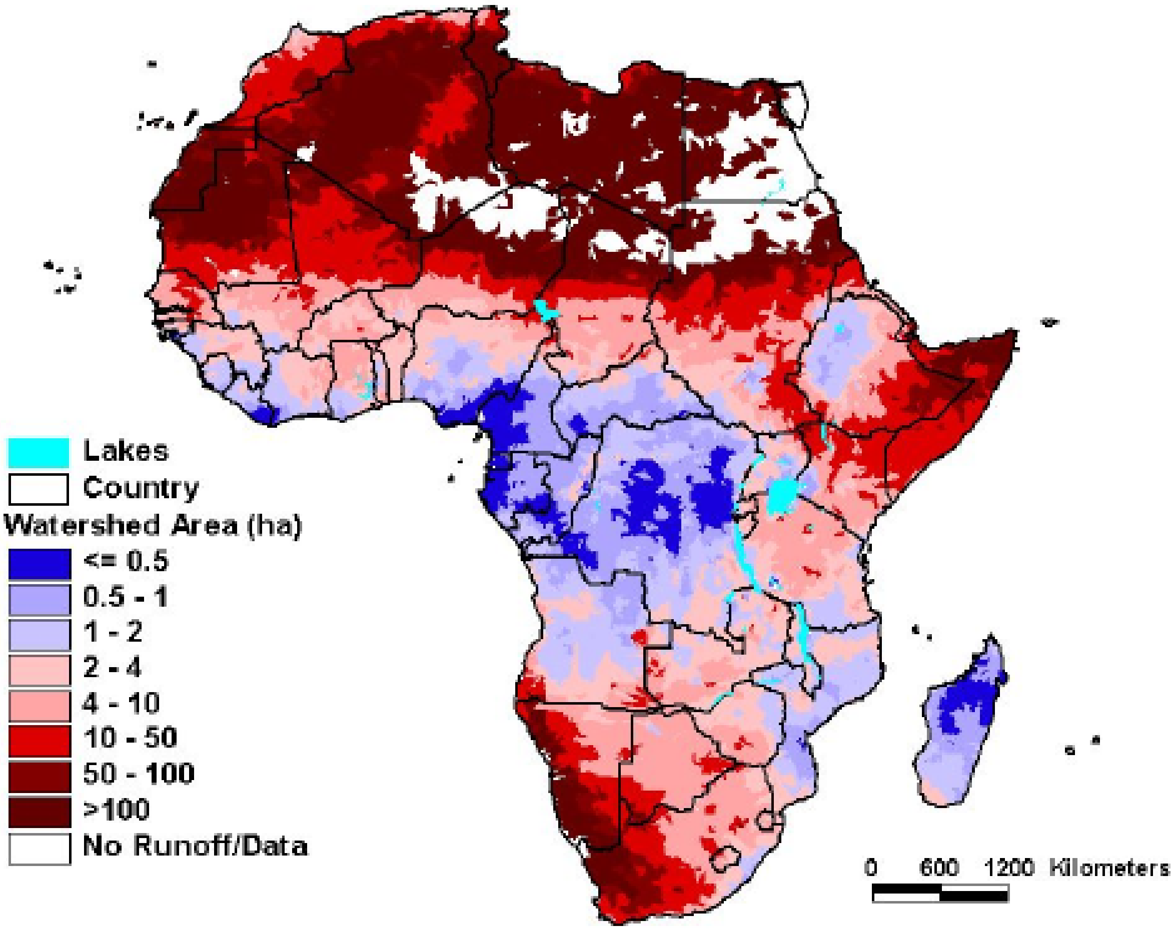
Number of days with rainfall more than 20mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	0	0	0	0	0	0	1	4	1	1	0	0	7
1968	0	1	0	1	0	2	1	0	1	0	0	0	6
1969	0	0	0	1	1	0	0	1	0	0	0	m	m
1970	m	m	m	1	0	0	3	2	0	0	0	0	m
1971	0	0	0	3	0	0	1	1	2	0	0	0	7
1972	0	1	1	1	2	0	1	1	1	0	0	0	8
1973	0	m	m	2	1	0	0	0	0	0	0	0	m
1974	0	0	1	0	0	0	1	1	0	0	0	0	3
1975	0	0	1	3	0	0	0	2	0	0	0	0	6
1976	0	0	0	2	0	0	1	0	0	1	0	0	4
1977	0	0	0	0	0	0	0	1	0	1	0	0	2
1978	0	2	0	0	0	0	2	2	5	1	0	0	12
1979	1	0	1	2	2	0	0	1	1	0	0	0	8
1980	0	0	0	0	0	0	1	1	0	0	0	0	2
1981	0	0	2	3	0	0	0	2	0	0	0	0	7
1982	0	0	3	0	3	1	0	1	4	0	0	0	12
1983	0	0	0	1	1	0	0	1	1	1	0	0	5
1984	0	0	0	1	2	0	0	0	1	0	0	1	5
1985	0	0	1	3	1	0	0	0	2	0	0	0	7
1986	0	m	0	3	1	0	0	2	0	0	0	0	m

Total rainfall with more than 20 mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	0	0	20	22.7	22	11.5	124.4	183	62.7	26.5	27.5	0	500.3
1968	0	101.3	0	122.8	17.5	60	43.5	91.9	52.5	0	20.5	0	510
1969	0	77.5	17.5	74	43.5	11	65	122.5	16.5	10.5	12	m	m
1970	m	m	m	33.5	0	0	117	134.5	32	0	0	0	m
1971	0	0	31	108.5	66	18.8	31	85.5	84	0	12	0	436.8
1972	0	32	52	102.5	91	5	38	63.5	55.5	5	0	0	444.5
1973	0	m	m	124	47.5	29.5	59.5	91.5	30.5	19	0	0	m
1974	0	0	114	0	41	45	59	62	43.5	0	0	0	364.5
1975	0	0	37	135	5	24.5	37	106.5	84	6	0	0	435
1976	12	0	0	103	39	34	87	111	16	28	50	0	480
1977	0	6	10	54.5	40	10	45	119	40	57	0	0	381.5
1978	0	133	0	0	0	22	157	76	210	29	0	0	627
1979	74	0	69	78	143	31	42	89	64	0	0	0	590
1980	0	0	0	18	23	8	80	91	55	15	8	0	298
1981	0	7	97.5	98.1	40.5	6	57	172.6	125	0	0	0	603.7
1982	5	15	150	71.2	117.9	50	51	107.6	123.6	25.7	0	0	717
1983	0	0	0	127.7	131.7	23	20.9	67.9	91.7	63.4	20.9	0	547.2
1984	0	0	0	26.4	122.7	0	13.5	0	31.4	0	0	77.5	271.5
1985	0	0	55.8	253.4	55.4	0	31.7	103.7	76.8	0	0	0	576.8
1986	0	m	15.2	138.7	43	32.9	16.3	112.1	82.3	0	0	0	m

Annex17: Required watershed area for collecting 1,000 m^3



Source: Senay G. B., Verdin J. P. 2004.

Annex 18 Analysis for Borama 5 mm Rainfall threshold

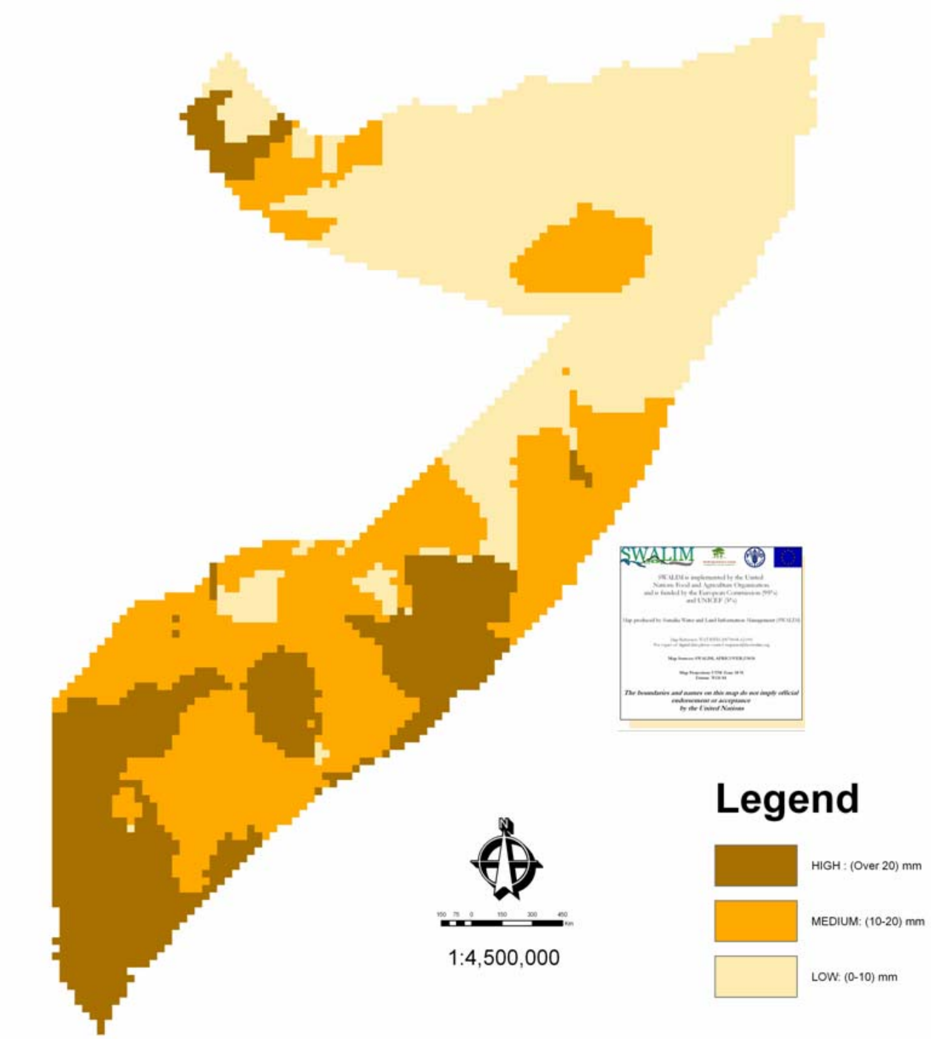
Number of days with rainfall more than 5 mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	0	0	1	1	1	1	9	11	4	1	4	0	33
1968	0	8	0	7	1	3	3	10	3	0	1	0	36
1969	0	5	1	5	3	1	6	8	2	1	1	m	m
1970	m	m	m	1	0	0	7	8	3	0	0	0	m
1971	0	0	3	4	5	3	2	7	3	0	1	0	28
1972	0	1	3	7	3	0	2	4	4	0	0	0	24
1973	0	m	m	8	2	2	6	7	3	1	0	0	m
1974	0	0	7	0	4	3	3	4	3	0	0	0	24
1975	0	0	1	7	0	2	3	5	4	1	0	0	23
1976	1	0	0	6	4	3	7	7	1	1	2	0	32
1977	0	1	1	4	3	1	4	7	4	4	0	0	29
1978	0	6	0	0	0	2	10	4	10	1	0	0	33
1979	6	0	2	2	8	2	3	6	4	0	0	0	33
1980	0	0	0	1	1	1	5	6	4	1	1	0	20
1981	0	1	8	5	3	1	3	11	10	0	0	0	42
1982	0	1	3	5	5	3	3	8	5	2	0	0	35
1983	0	0	0	8	6	1	3	6	5	3	3	0	35
1984	0	0	0	1	6	0	2	0	2	0	0	3	14
1985	0	0	2	8	4	0	4	8	5	0	0	0	31
1986	0	m	1	8	2	3	2	8	6	0	0	0	m

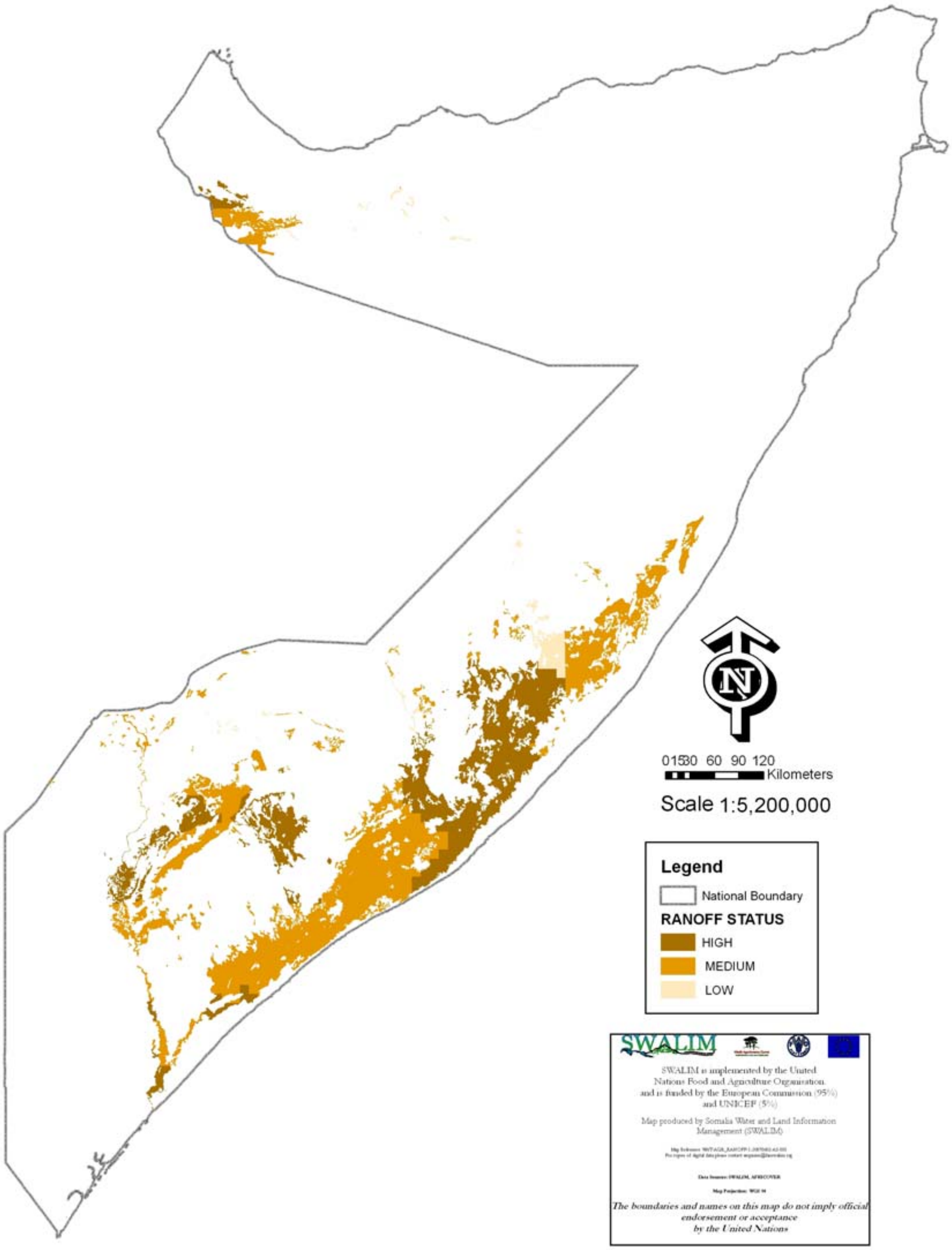
Total rainfall with more than 5 mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1967	0	0	20	22.7	22	11.5	124.4	183	62.7	26.5	27.5	0	500.3
1968	0	101.3	0	122.8	17.5	60	43.5	91.9	52.5	0	20.5	0	510
1969	0	77.5	17.5	74	43.5	11	65	122.5	16.5	10.5	12	m	m
1970	m	m	m	33.5	0	0	117	134.5	32	0	0	0	m
1971	0	0	31	108.5	66	18.8	31	85.5	84	0	12	0	436.8
1972	0	32	52	102.5	91	5	38	63.5	55.5	5	0	0	444.5
1973	0	m	m	124	47.5	29.5	59.5	91.5	30.5	19	0	0	m
1974	0	0	114	0	41	45	59	62	43.5	0	0	0	364.5
1975	0	0	37	135	5	24.5	37	106.5	84	6	0	0	435
1976	12	0	0	103	39	34	87	111	16	28	50	0	480
1977	0	6	10	54.5	40	10	45	119	40	57	0	0	381.5
1978	0	133	0	0	0	22	157	76	210	29	0	0	627
1979	74	0	69	78	143	31	42	89	64	0	0	0	590
1980	0	0	0	18	23	8	80	91	55	15	8	0	298
1981	0	7	97.5	98.1	40.5	6	57	172.6	125	0	0	0	603.7
1982	5	15	150	71.2	117.9	50	51	107.6	123.6	25.7	0	0	717
1983	0	0	0	127.7	131.7	23	20.9	67.9	91.7	63.4	20.9	0	547.2
1984	0	0	0	26.4	122.7	0	13.5	0	31.4	0	0	77.5	271.5
1985	0	0	55.8	253.4	55.4	0	31.7	103.7	76.8	0	0	0	576.8
1986	0	m	15.2	138.7	43	32.9	16.3	112.1	82.3	0	0	0	m

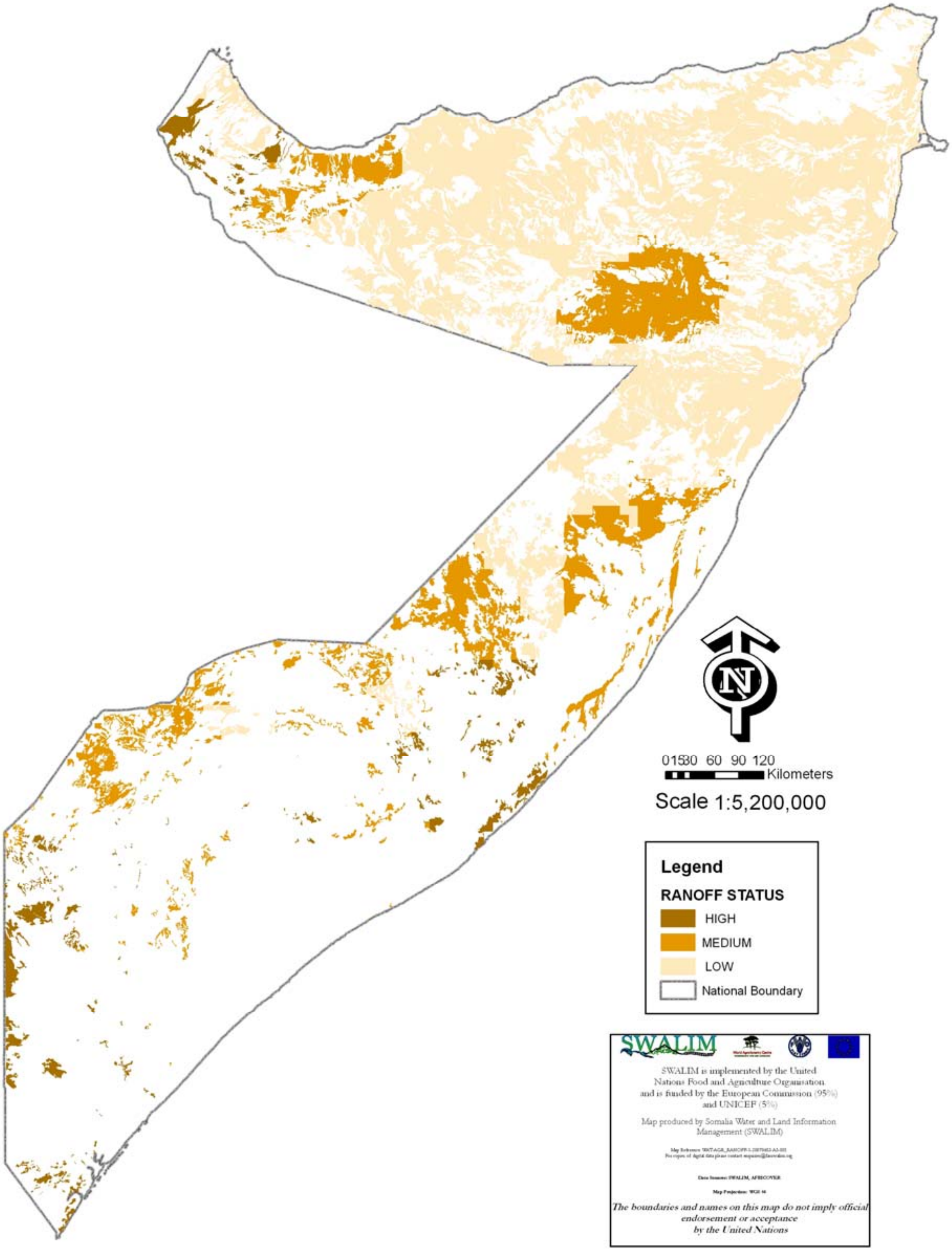
Annex 4: Runoff water harvesting potential for agriculture and rangelands



Annex 20: Runoff water domains for agricultural areas



Annex 21: Runoff water domains for rangelands



Annex 5: Rainwater Harvesting Potential for Garoowe

Annex 6: Rainwater Harvesting Potential for Garowe

Annex 7: Rainwater Harvesting Potential for Hargeisa

Annex 8: Rainwater Harvesting Potential for Borama

Annex 9: Rainwater Harvesting Potential for Borama

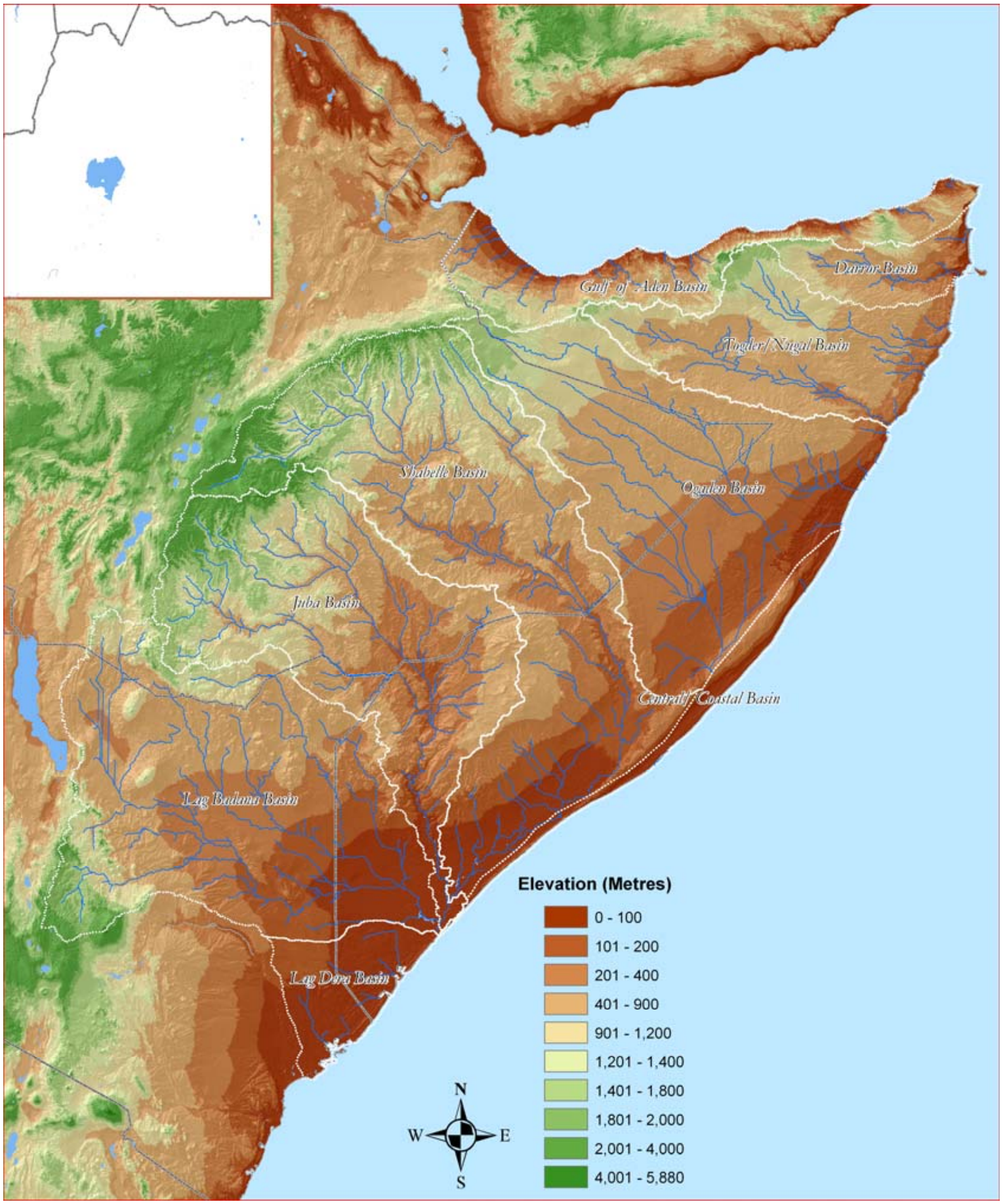
Annex 10: Rainwater Harvesting Potential for Bossaso

Annex 11: Rainwater Harvesting Potential for Bossaso

Annex 12: Rainwater Harvesting Potential for Jowhar

Annex 30: Rainwater Harvesting Potential for Jowhar

Annex 13: Streams feeding into for Somalia



Annex 32 Participats in consultative workshops

Baidoa

Hargeisa

Garowe