REGIONAL BASELINE MAPBOOK
of Dolo Ado Woreda, Liben Zone
Somali Region, Ethiopia

An assessment by:

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Additions and remarks are welcome via info@acaciawater.com

Regional Baseline Mapbook Dolo Ado Woreda Liben Zone Somali Region Ethiopia

An assessment towards building resilience through Ecosystem-based Disaster Risk Reduction

Dolo Ado Woreda, Somali Regional State in Southern Ethiopia, is a disaster prone area where the rural communities heavily depend on natural resources. Communities are troubled by frequent droughts, floods and diseases. Strategic ecosystem restoration and implementing landscape interventions targeting water security, food security and disaster risk reduction is key to building community resilience. To select the most effective interventions a good understanding of the landscape is essential. This mapbook supports implementation by presenting a biophysical and socio-economic background and showing the potential for Ecosystem based disaster risk reduction (Eco-DRR).

The major challenges and opportunities based on the biophysical and socio-economic background, climate data, land cover and landuse, ecosystems and water resources are explained. The assessments were made based on data from a literature study, satellite imagery and GIS analyses, field surveys, focus group discussions and interviews. Failing natural resources management turns out to be the core problem in the project area. Disasters are becoming more frequent and intense essentially because the natural system is not optimally functioning to provide DRR. The resilience of the landscape is low and a further decrease in resilience is likely due to climate change and a population increase.

But there are also many opportunities. The potential to improve access, availability and quality of water is high and there are many possibilities to protect nature and implementation of landscape interventions to for example reduce flood risk and improve water availability. Early Warning Committees and DRR Committees are already active in communities. Current adaptation strategies are also already practiced in Dolo Ado Woreda on small scales (such as trenches and area closures), though in general the focus is still too much on disaster response instead of disaster prevention. This mapbook shows that it is important to prioritize rainwater buffering in the landscape to reduce flood risk and improve water availability on the long term.

An integrated approach that addresses underlying causes is recommended. A main focus should be on capacity building to self-motivate users to manage the landscape in a sustainable manner and reach scale. Efforts can best be a combination of soft ecosystem restoration measures (regulations, capacity building, coordination etc.) and hard measures (e.g. bunds, trenches etc.). Hard measures are less effective in the long term if not combined with soft measures. Community mobilization, participatory decision-making and involvement of experts is crucial towards developing sustainable strategies at community level to reverse the degradation trend.

The project team urges all stakeholders to invest more in strengthening natural resources management, at all spatial and temporal scales. This mapbook makes a case for communities, governments and NGOs to invest in small-scale measures, rangeland and forest management, sustainable farming practices, and soil and water conservation measures.

Table of contents

1. Background

2. Disaster risks and reduction strategies

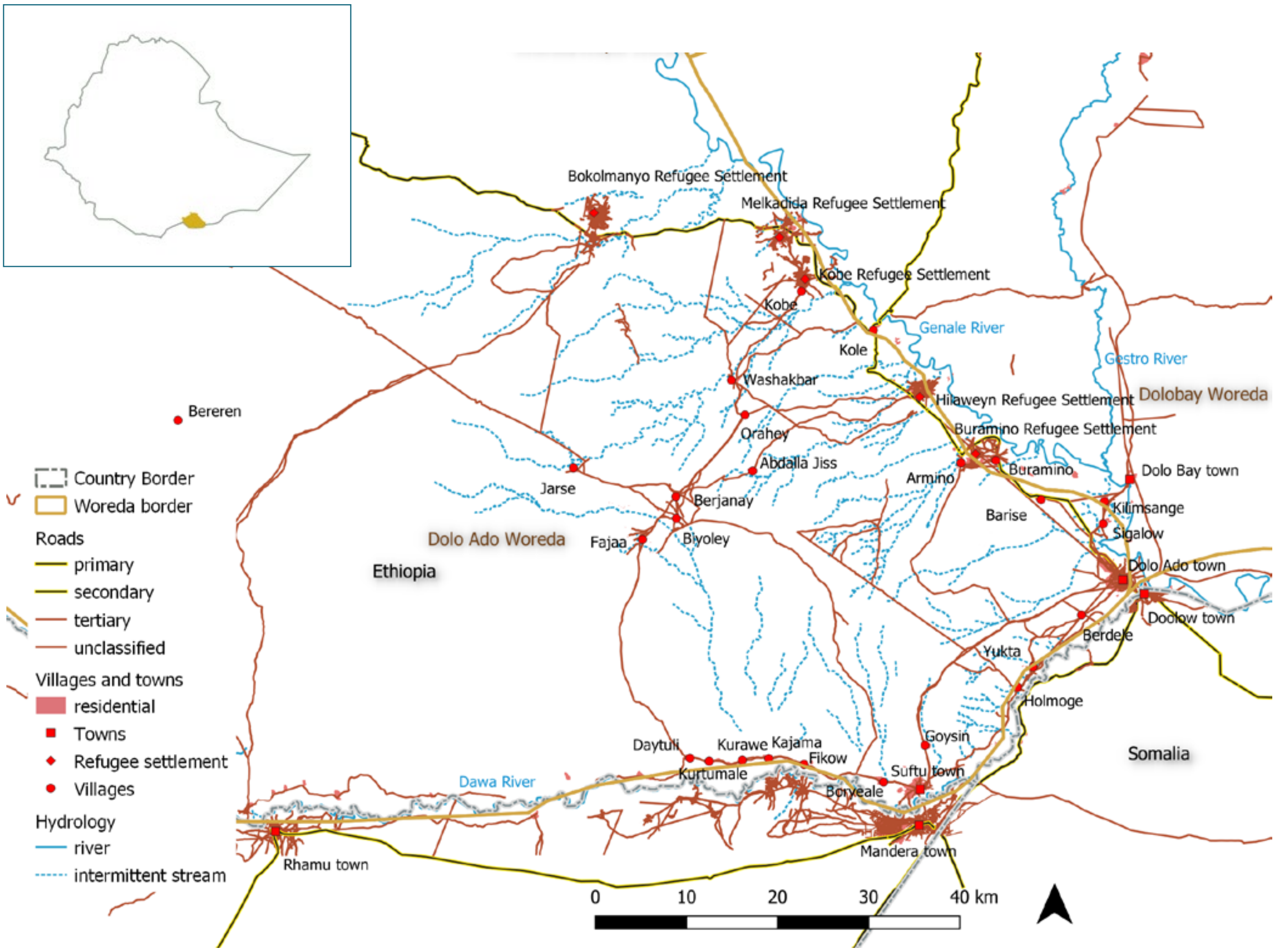
3. Land use and management

4. Water resources

5. Landscape restoration

6. Conclusions

Project area



List of acronyms and abbreviations

Birkad	Somali term for local (underground) water harvesting cistern or artificial pond
Deyr rain	Minor wet season from October to December
EC	Electrical conductivity; indication of concentration of salts and dissolved solids in water
EC-DEVCO	Directorate-General for International Cooperation and Development of the European Commission
Eco-DRR	Ecosystem-Based Disaster Risk Reduction
ET	Evapotranspiration; sum of evaporation and plant transpiration from the Earth's land
EU	European Union
EWC	Early warning committee
FTC	Farmer Training Center
Gu rain	Major wet season from March to June
ha	Hectare
ISRIC	International Soil Reference and Information Centre – World Soil Information
IWRM	Integrated Water Resources Management
Jilaal	long dry season from June to October
m asl	Meters above sea level
m bgl	Meters below ground level
NBS	Nature Based Solutions
NDVI	Normalized difference vegetation index; to determine the density of live green vegetation on a patch of land
NGO	Non-Governmental Organization
NLRC	Netherlands Red Cross
NRM	Natural Resources Management
P	Precipitation (e.g. rainfall)
PfR	Partners for Resilience
ppm	Parts per million
RACIDA	Rural Agency for Community Development and Assistance
RESET II	Resilience Building and Creation of Economic Opportunities in Ethiopia Programme of the European Union (EU)
RWH	Rain Water Harvesting
SWC	Soil and water conservation
SWOT	Strengths, weaknesses, opportunities and threats
UNHCR	United Nations High Commissioner for Refugees
WRB	World Reference Base for Soil Resources; an international soil classification system

1. Background

1.1 Introduction

Dolo Ado Woreda, located in Somali Regional State of Ethiopia, is disaster prone. Rural communities heavily depend on natural resources. There is increasing awareness about the role that ecosystems play in reducing the impacts of hazards and climate change. This includes restoring and protecting vegetation on slopes to reduce hazards such as soil erosion; landscape intervention for absorbing excess flood waters. Ecosystem-based Disaster Risk Reduction (Eco-DRR) approaches include more inclusive natural resources management (NRM) in a water catchment area. The approach recognizes the connectedness between human activities and natural resources management across landscapes, while including disaster risk reduction (DRR) and climate change adaptation activities such as early warning and prevention. In parallel, ecosystem degradation is closely linked to decreased resilience, especially in regions vulnerable to climate change impact.

With funding from the European Commission (EC-DEVCO), Partners for Resilience (PfR), coordinated by the Netherlands Red Cross (NLRC), is collaborating with UN Environment to develop and demonstrate models for upscaling Eco-DRR in 10 countries, of which Ethiopia is one. The overall goal of the project is to increase investments and uptake of Eco-DRR measures to increase community resilience. In Ethiopia the project of Cordaid focusses on Demonstrating models for scaling up community based Eco-DRR with field level implementation across selected landscapes by Rural Agency for Community Development and Assistance (RACIDA). The main focus will be on conservation of soil and water to strengthen the natural resource base in order to prevent drought, diseases and conflict over water sources.

1.2 This mapbook

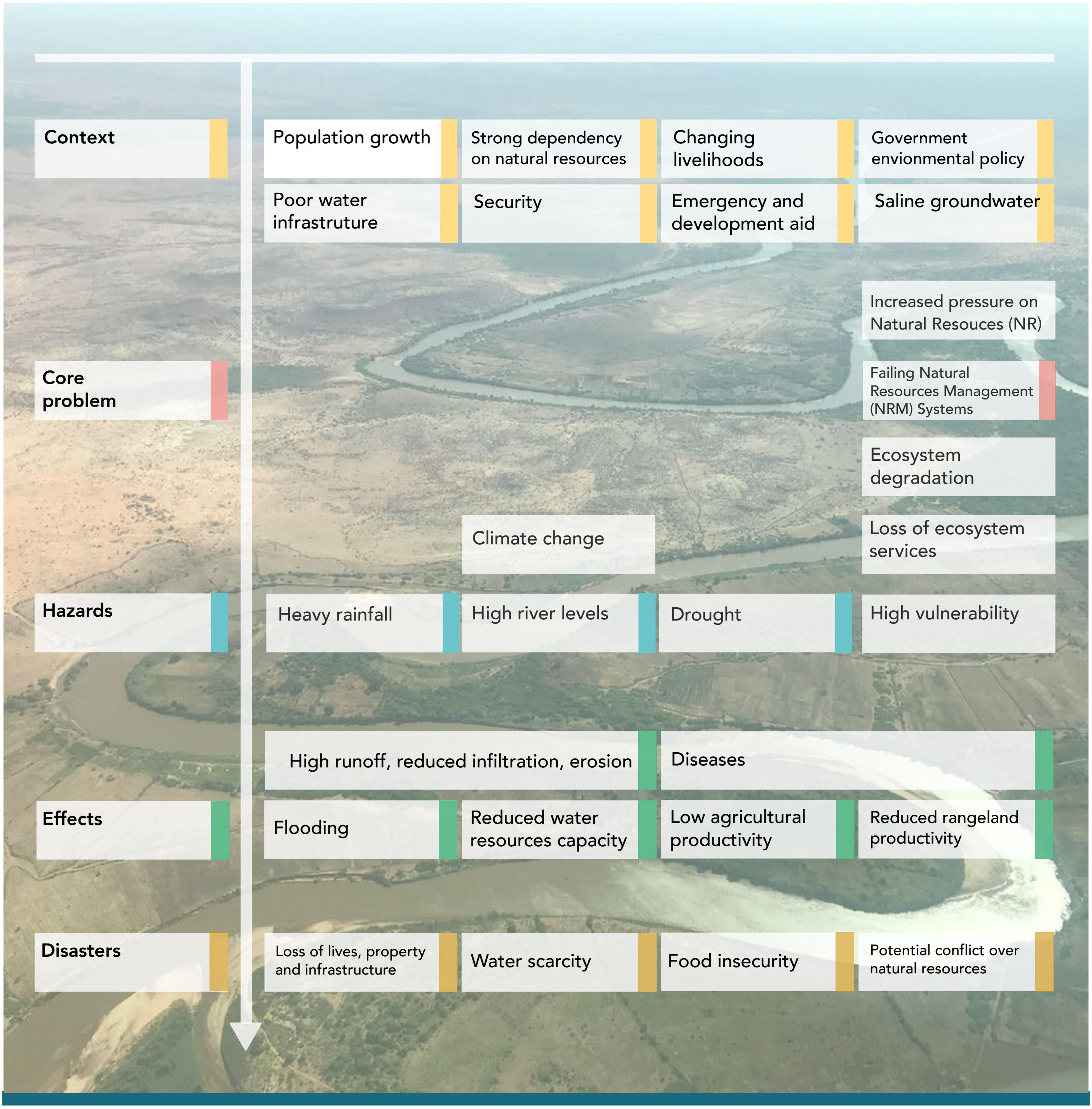
Effective and sustainable ecosystem restoration targeting water security, food security and disaster risk reduction is key to building community resilience. To select the most effective interventions a good understanding of the landscape is essential. This mapbook provides a base for the implementation of Eco-DRR interventions in Dolo Ado Woreda. The mapbook presents biophysical and socio-economic background information and shows the potential for and nature based solutions (NBS) in the landscape.
This mapbook supports mainstreaming of Eco-DRR approaches and practices into regional development.

1.3 Problem analysis

The problem analysis is based on a literature study, field data collection, key informant interviews, community interview, and focus group discussions from November 2019 until March 2020.

Cause-effect chains are key to understand the problem. Hazards, such as heavy rainfall and high river water levels, become disasters when they have a disruptive or damaging function. This often only occurs due to sever ecosystem degradation and human activities in high risk areas (e.g. agricultural activities in flooding areas). Climate conditions contribute to natural hazards becoming disasters but are not the major problem. The increasing population of Dolo Ado Woreda has a strong dependency on natural resources. Failing natural resources management (NRM) was identified as the core problem. Due to the degraded state of the landscape groundwater recharge is low enhancing the low availability of water and (native) vegetation in rangelands. The natural function of rainwater buffering in the landscape (through a good vegetation cover) is not optimal in Dolo Ado Woreda, and support from water harvesting interventions in the landscape just recently started and is not nearly sufficient.

The core problem is that the natural system is not optimally functioning to provide DRR. The natural system, and thereby ecosystems, should be supported by landscape interventions – such as nature based solutions (NBS) - to for example reduce flood risk an improve water availability.



1.4 Methodology

The assessments in this Mapbook are anchored to the Ecosystem-based DRR (Eco-DRR) (see Box 1 on the right). The assessments started with a review of readily available reports and data and preparatory GIS-analyses. These preliminary results provided a basic understanding of the biophysical and socio-economic context. Consecutive analyses of satellite imagery and field data collection were used to verify and validate the first results and fill data gaps.

Data collection in the field was organized along focus group discussions with communities, interviews with key informants, and field surveys in January 2020. Cordaid and RACIDA provided feedback during the process.

Box 1. Ecosystem-based DRR

"[...] in most places in the world, nature is the single most important input into local economies and human well-being." This role for ecosystems creates new opportunities for more flexible, systemic and responsive win–win–win outcomes that address climate change (both adaptation and mitigation), biodiversity loss and the need for improved human wellbeing. By harnessing the full potential of natural systems to ensure a sustained quality of life and by helping "[...] people, infrastructure and economies" to adapt to variable conditions. (Based on Roberts et al. 2011)

Ecosystem-Based Disaster Risk Reduction (Eco-DRR) addresses the links between climate change, biodiversity, ecosystem services and sustainable resource management and taps on ecosystem services as drivers of socio-ecological system resilience. Ecosystems provide different types of services and contribute to water security, food security and disaster risk reduction.

Data sources	Parameters, factors and/or subjects
SRTM 1-Arcsecond	Elevation, slopes, catchments, flow accumulation
Mandera meteorological station data via CLIMEXP	Daily rainfall
ARC2	Monthly rainfall
WorldClim2	Evapotranspiration
EU JRC Soil Map of Africa	Soils
RESET II Programme	Groundwater suitability map, geology, boreholes
OpenStreetMap	Administrative information
FLO1K	Annual streamflow of Genale and Dawa river

Table 1. Some of the datasets used in this project. Literature and other data sources are listed in the References.

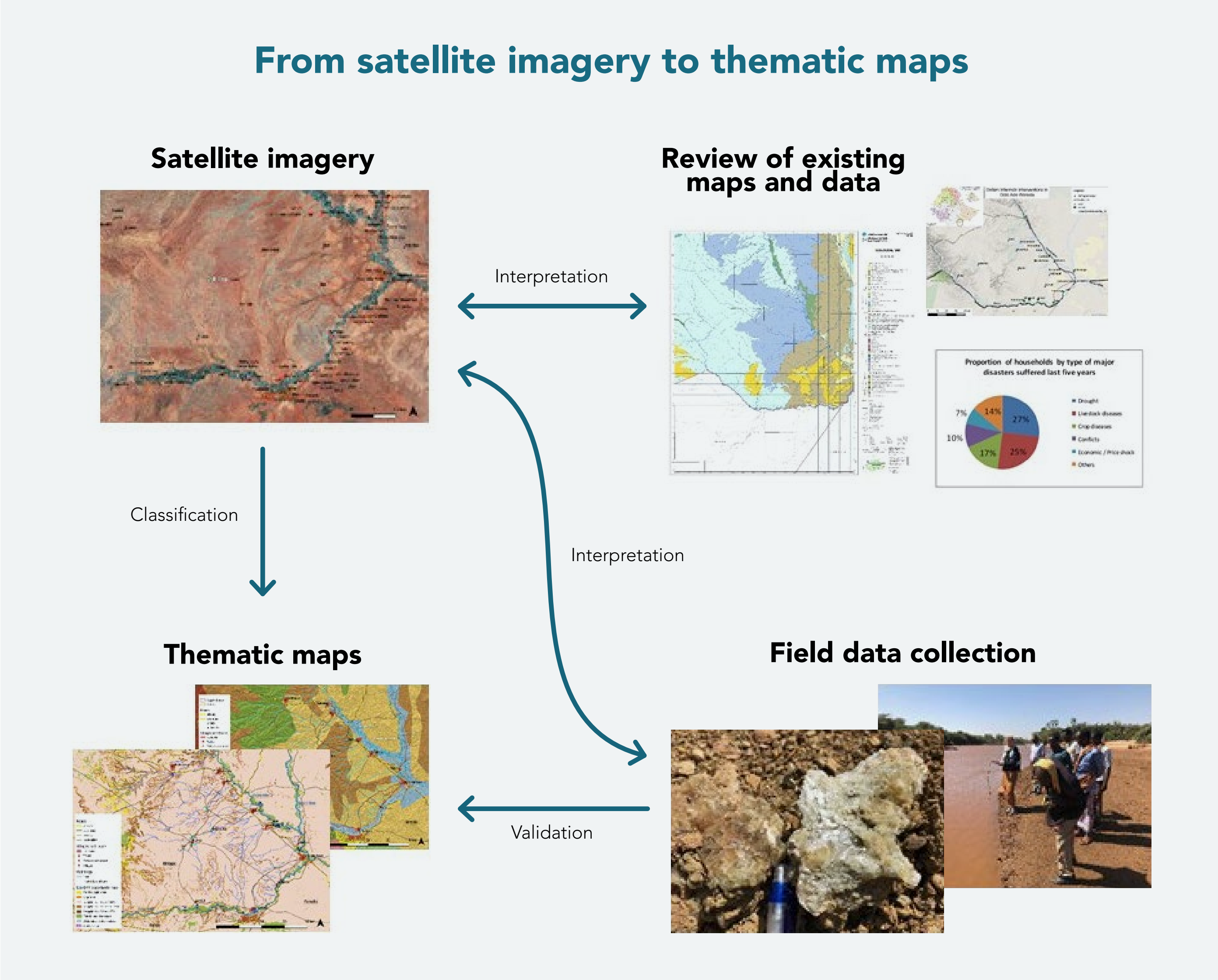


Figure 1. Steps followed to develop thematic maps.

1.5 Socio-economic analysis

Dolo Ado Woreda (also referred to as "Dolo Addo" or "Dollo Ado") is a woreda in the Somali Regional State of Ethiopia and part of the Liben Zone. Towns in Dolo Ado Woreda include Dolo Ado town and Softu. Dolo Ado town is located at the confluence of the Ganale and Dawa River, and bordered to the northwest by Filtu Woreda, on the northeast by Afder Zone, on the southeast by Somalia, and on the south by Kenya.

The total population of Dolo Ado Woreda was 150,100 in 2011 of which 37,000 living in Dolo Ado town (Woreda census data, 2011). This population census does not include the Refugee Settlements mostly situated along the Genale river: Bur-Amino, Bokolmayo, Melkadida, Kobe, and Hilaweyn. According to the United Nations High Commissioner for Refugees (UNHCR) Operational portal, there are currently 157,000 refugees living in the refugee settlements in Dolo Ado Woreda. The arrivals mostly originating from the Bay, Gedo, Middle Juba and Bakool regions since 2009 and fled to the refugee settlements from conflicts, exacerbated by the droughts in Somalia (Betts et al., 2019). Most refugees remain poor and dependent upon food aid. Only 21% of refugees have an income-generating activity, compared with 29% of the host community. The largest source of employment for both communities is with humanitarian non-governmental organizations (NGOs) and international organizations. There are approximately 40 different NGOs active in the Woreda, including the WFP, UNHCR, UNICEF, RACIDA, Cordaid, ZOA, Save the children, World Vision and COOPI (Risk Mitigation Adaptation plan, 2019).

Most host communities live of subsistence farming and their own livestock. For most refugees and host community members, the economy is based mainly on two inter-related elements: humanitarian aid and the cross-border economy. Food assistance, services such as education and health are crucial to the survival strategies of the households. Dolo Ado town is the biggest commercial hub in the area, connecting the Woreda to the economy of Somalia (via Doolow) and Kenya (Betts et al., 2019). Mandera (Kenya) is a major town of trade and only 37 km away from Dolo Ado town through Softu. Dolo Ado town hosts many businesspeople. The town also hosts the major livestock market and provides seeds for agricultural activities. Some kebeles reported poor access to Dolo Ado town market due to poor road conditions.

"Refugee-host relations within the district are exceptionally positive. They share a common 'Somali' identity and culture, language and religion, and the host population derives considerable material and perceived benefits from the presence of both refugees and international humanitarian organizations. This offers an opportunity for socio-economic integration" cited from Betts et al., 2019.

Dolo Ado town also provides health services, with several kebeles having their own health post. Major education services are provided in Dolo Ado town. The percentage of literate population in the woreda above 7 years old is 14% out of which 51% completed below 1st grade level, 32% and 16% of the population completed primary and secondary school respectively. With regard to gender parity in education, percentage of female students is higher than male students in completing 1st grade level, but dominated by male students in all other education levels (Risk Mitigation Adaptation plan, 2019).

Figure 2. Transport of wooden bedframes for sale in the central rangelands and watermelons in Dolo Ado town.

1.6 Livelihoods

Somalis have a pastoral heritage and most people keep small livestock (mainly goats and sheep). An estimated 30% of the people are pastoralists, 50% are agro-pastoralists, 15% lives in urban areas and 5% is a sedentary (i.e. a settled or location-bound) farmer. For most households, livestock ownership is (an additional) livelihood activity but also a source of food and savings. Having camels is a status symbol. Some communities in the central rangelands (the rangelands in between the Dawa and Genale river) were reported to keep camels, but most keep goats and sheep. A household has 15 – 30 goats or sheep on average. Also, the refugees keep livestock, around 55% of refugee households have livestock (Betts et al., 2019).

In the central rangelands rainfed agriculture is practiced on small pieces of land. Rainfed crops include maize, sorghum, watermelon as well as seasonal maize and sesame. During periods of drought, sesame is used for livestock fodder (very nutritious).

Along the Dawa and Genale river, irrigated agriculture is practiced. Along the river some fruits are grown such as mango, lemon, papaya and banana. After every rainy season, newly planted vegetables and fruits are grown such as tomato, onion, watermelon, and chili peppers. There are two harvest per year. The harvest is collected just before the rainy season.

Along the Genale river, Just outside Kobe and Melkadida, NGOs funded the construction of an irrigation system. In total, ~100 ha arable land was created for 210 farmers joined by a cooperative (50% for refugees and 50% host communities). They each have 0.5 ha of land and they are growing onions, maize, watermelons, and papayas, for example, depending on the season (Betts et al., 2019).

One of the main activities for the Dolo Ado Woreda Office of Agriculture is providing support to resettlement of former pastoralist to agro-pastoralist. The people who are living in pastoralist community, who have been facing lack of water, education, health, nutrition etc. are willing to resettle along the River Dawa or the River Genale. The government already provided support to approximately 17,200 households (from 15 kebeles) in total, who were being resettled over a period of 7 years. This change has been voluntarily. Each household will be given 0.5 ha of land. In the resettlement areas there are farmer training centers (FTCs) were education is going on and generators for irrigation, seeds, fertilizer and pesticides are provided if possible.

Figure 3. Below: a herd of goats at Holmoge Kebele; Above: An agricultural field with furrow irrigation to produce onion near the Dawa river.

1.7 The landscape

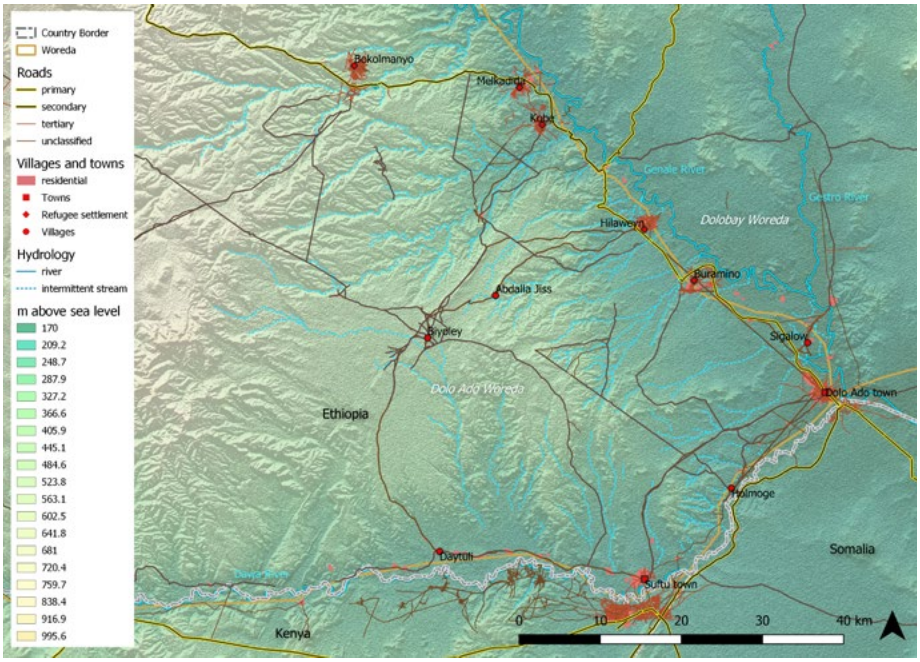


Figure 4. DEM - elevation map.

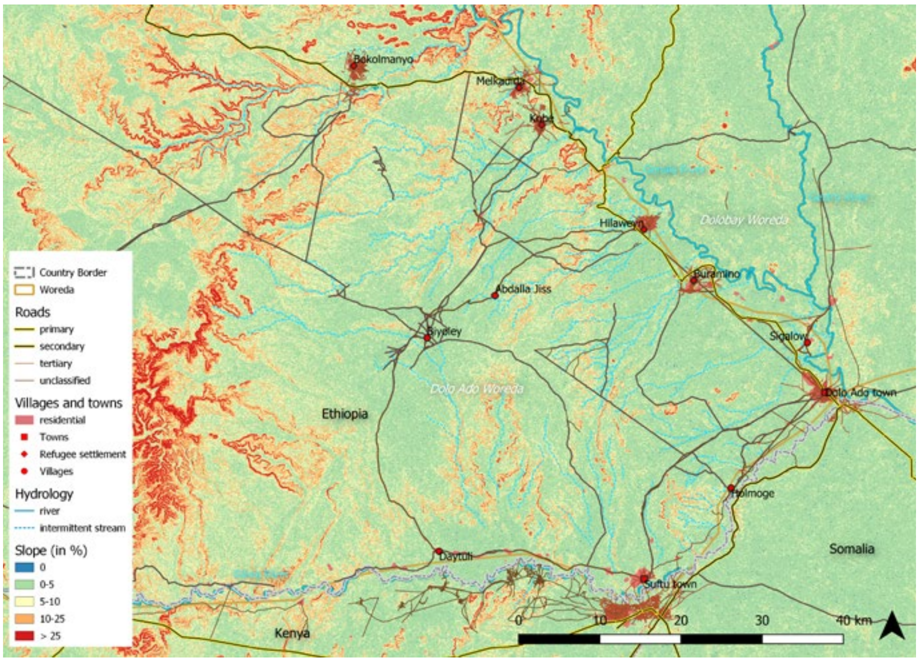


Figure 5. Slope map (%).

Central rangelands

The central rangelands (referring to the rangelands in between the Dawa and Genale river) reach up to 950 meters above sea level (m asl) in Dolo Ado Woreda. Here, population density is low and sandy rivers cross the landscape. The two rainy seasons in the year provide short seasons with green rangelands and seasonal streams. Vegetation consists of small shrubs and trees. The southern part of the rangelands drain towards the Dawa rivers, the northern part of the rangelands drain towards the Genale river. In general the topography of these wadi's are flat and open. In the central rangelands, some parts of the landscape have some ridges with steeper drops overlooking the valleys below. For example the ridges near Kobe Refugee Settlement.

Genale and Dawa river valley

Dolo Ado town is located at an elevation of 180 m asl. The meandering riverbanks and flooding areas of the Genale River, which flows from the north to south-east direction, form a diverse landscape. The first ~250m of the riverbanks of the Genale River are mostly occupied by agricultural land. The other regularly flooded land around the Genale river is covered with small trees and bushes and often used as communal grazing lands. Small depressions along the Genale river form temporary wetlands due to stagnant water.

The Dawa River, which originates from the East and forms the border of Ethiopia with both Somalia and Kenya, is less meandering. Nevertheless, its river banks are also used as agricultural land and communal shrub lands. For both the Dawa and Genale rivers, there are sections of the riverbanks and surroundings that are regularly flooding.

Figure 6. Left: Genale river with maize and beans planted on the river banks; Middle: View of the central rangelands; Right: a typical house.

1.8 Climate

The Climate of Dolo Ado is arid to Semi-arid, making it a arid to semi-arid lands. Meteorological station data is only available from one station within the project area, namely from Mandera in Kenya, which is located 35km southwest of Dolo Ado town. The average yearly rainfall is 270 mm/year (without the extreme rainfall of 1997). The rainfall pattern is bimodal whereby Dolo Ado Woreda experiences two rainy seasons per year: the Gu rain, major wet season, from March to June and the Deyr rain, minor wet season, from October to December. The communities indicated that due to climate change, the past years the Gu rains often only started in April opposed to March historically. The Gu rains are important for local livelihoods as they mark the end of the long dry season (Jilaal) replenishing river flow, beginning of agricultural production and regeneration of pastures (grasslands).

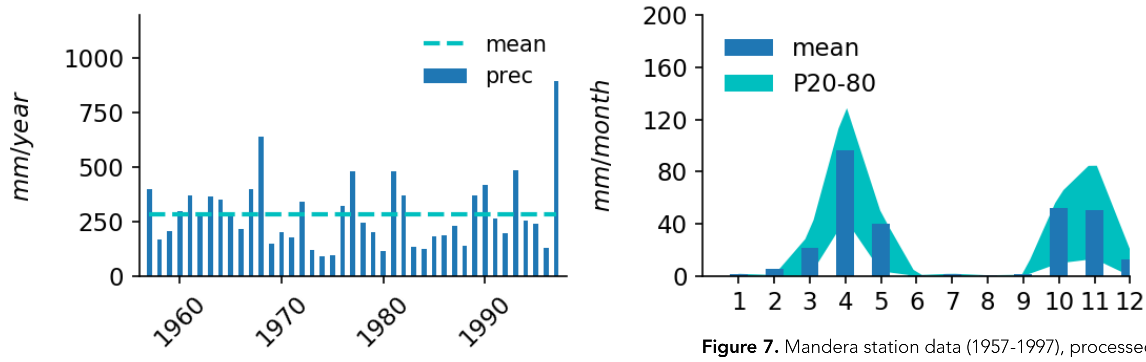


Figure 7. Mandera station data (1957-1997), processed daily rainfall data.

Close to the wadis, floods are a major threat to communities. Local rainfall is poorly stored in the landscape and causes flash floods damaging infrastructure, agricultural lands and poses threats to grazing livestock. The figure on the right shows the return period of rainfall events. The figure shows that statistically, once every year a rainfall event of 33 mm can be expected for Biyoley, and of 45 mm for Dolo Ado Town. Once every 10 years, an event of around 70 mm can be expected. These rainfall amounts are not per se very high if spread out over the day, but rainfall events are often concentrated in a short time period. This intensity causes high surface runoff (overland flow). In order to address flooding due to local rainfall, peak discharge flow in streams and rivers should be reduced or mitigated with storage and retention interventions in the landscape. Planning of these interventions could take into account these flood statistics.

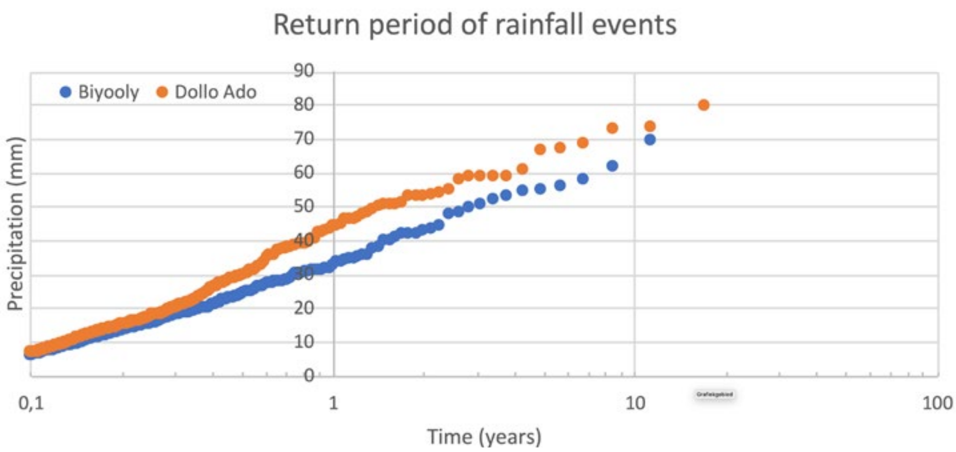


Figure 8. Return period of rainfall events for Dolo Ado Town and Biyoley kebele based on ARC2 satellite imagery. Statistically, once every year a rainfall event of 33 mm can be expected for Biyoley, and of 45 mm for Dolo Ado Town.

Variability between years (inter-annual variability) is high. Dolo Ado town receives 226 mm of rainfall in an average year. Biyoley (center of Woreda) receives just 173 mm/year. The table shows that in an extreme dry year, total annual rainfall is only one third of the amount of a normal rainfall year. In an extreme wet year, the total annual rainfall is more or less twice the amount of an average year. This excess of water can be stored in the landscape to bridge the water gap of dry years.

mm/year	Extreme wet year (one in 10 years)	Wet year (one in 5 years)	Average year	Dry year (one in 5 years)	Extreme dry year (one in 10 years)
Dolo Ado Town	423	341	226	127	86
Biyoley Village	325	294	173	114	80

Table 2. Mean annual rainfall under different climate conditions (data source: ARC2).

Rainfall comes in two seasons and has a high seasonal and intern-annual variability which results in regular floods and droughts. Figure 9 shows the mean annual precipitation for Dolo Ado Woreda.

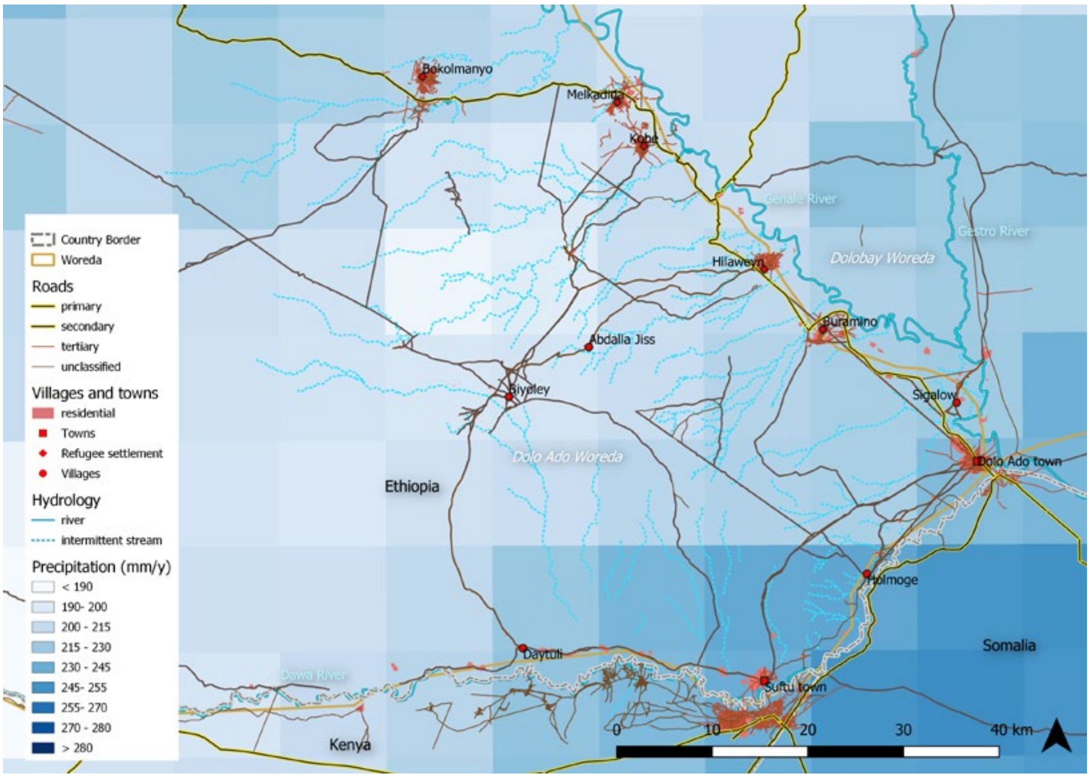


Figure 9. Mean annual precipitation (P) in mm/year (data source: ARC2).

Evapotranspiration is the sum of evaporation and plant transpiration from the Earth's land, and is an important indication for vegetation growth which is strongly influenced by water availability. Water availability is slightly higher in the far west to northwest of the Woreda, as shown in Figure 10.

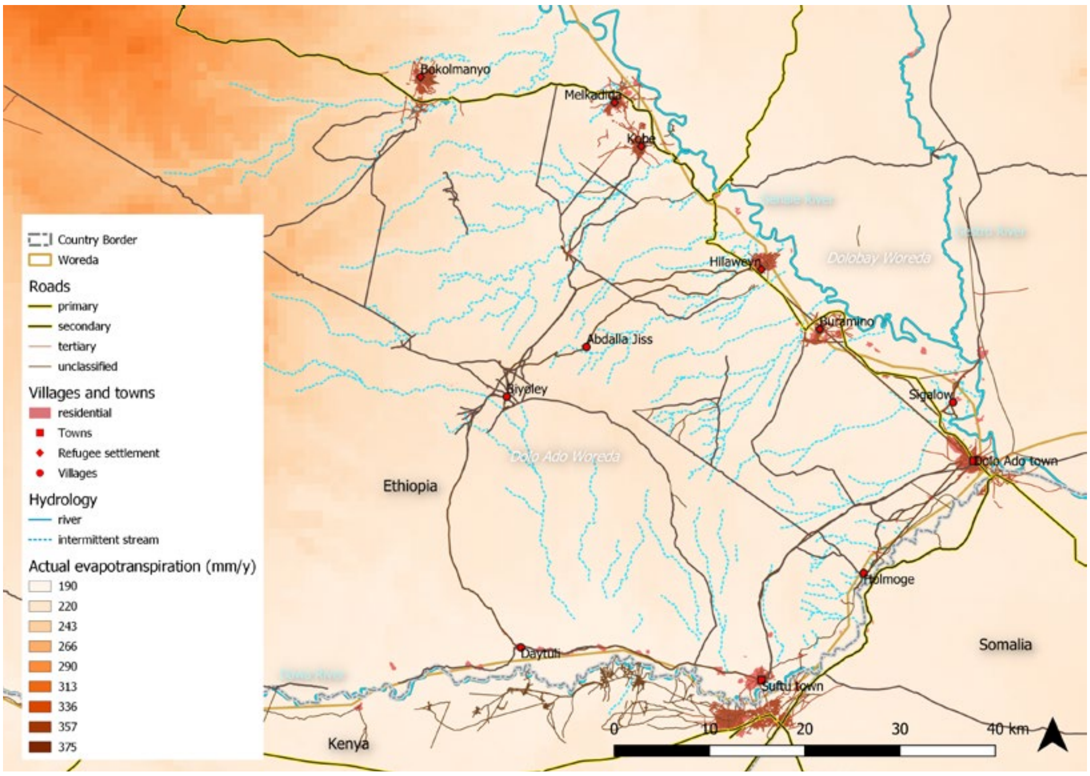


Figure 10. Mean annual actual evapotranspiration (ET) in mm/year (data source: WorldClim2).

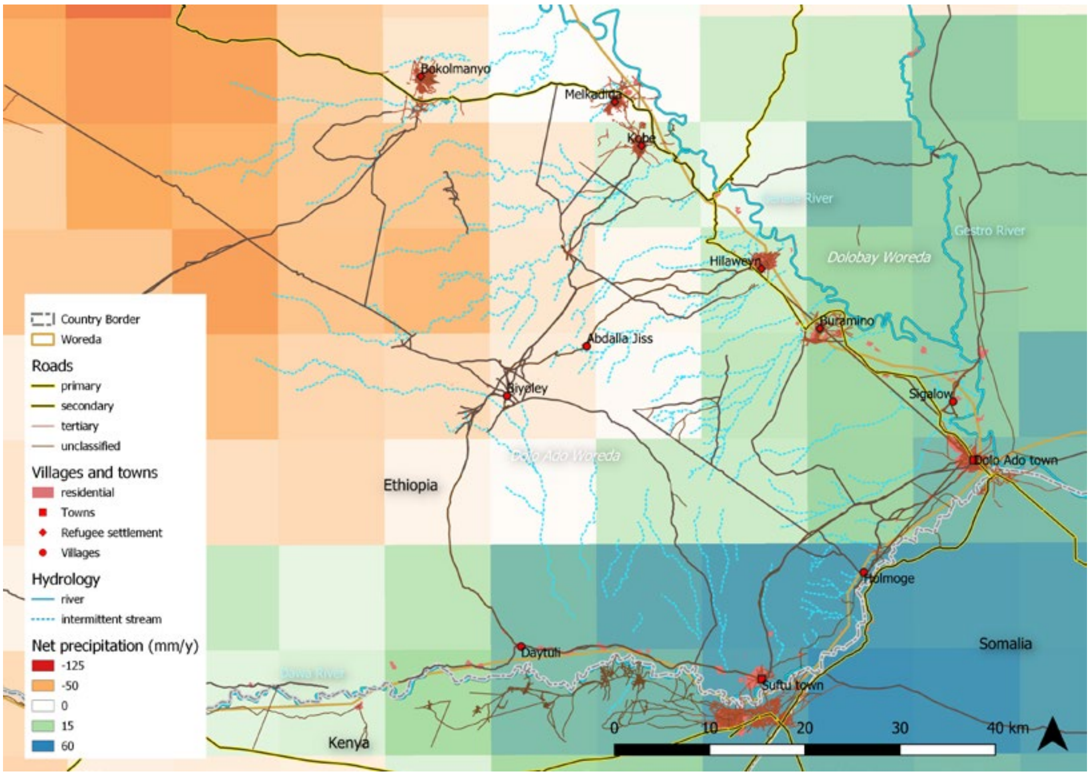


Figure 11. Net precipitation (Pnet) in mm/year, which is precipitation minus actual evapotranspiration (ETa).

The net precipitation (Pnet) is low for the rural inland area of Dolo Ado Woreda, as can be seen in Figure 11. Negative values are possible when soil moisture from deeper soil layers is evaporated. Pnet is slightly positive around Mandera and Dolo Ado town. The excess of water however is lost with high runoff rates and lost to downstream areas.

Climate change

Climate models for the 21st century predict a slight increase in annual precipitation for Dolo Ado Woreda. This could have negative effects on flood risk, as more rainfall is expected in the upstream part of the hydrological Dawa-Genale river basin. An increase in rainfall could have a positive effect on food security as long as effects of surface runoff and flooding are controlled. For food security, it is mostly important that rainfall is predictable in relation to planting and harvest. The climate simulations do not show the change in predictability, but weather is becoming more extreme. The simulation from Figure 12 show more rain compared to the two major rainy seasons and an even drier June-August period. This will have a radical impact on available growing days of crops as well as on agriculture itself in the region.

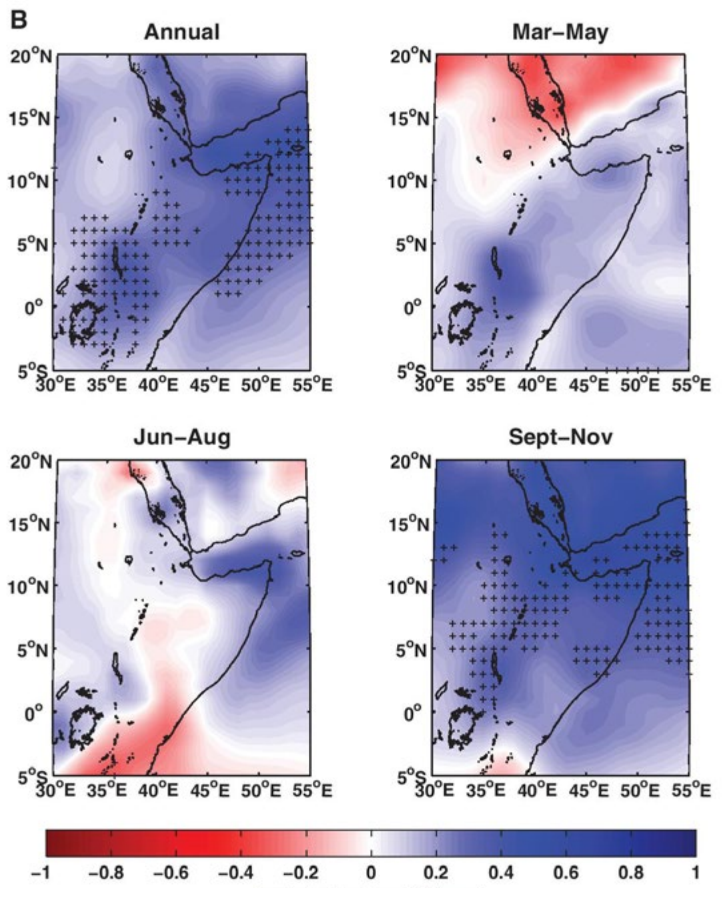
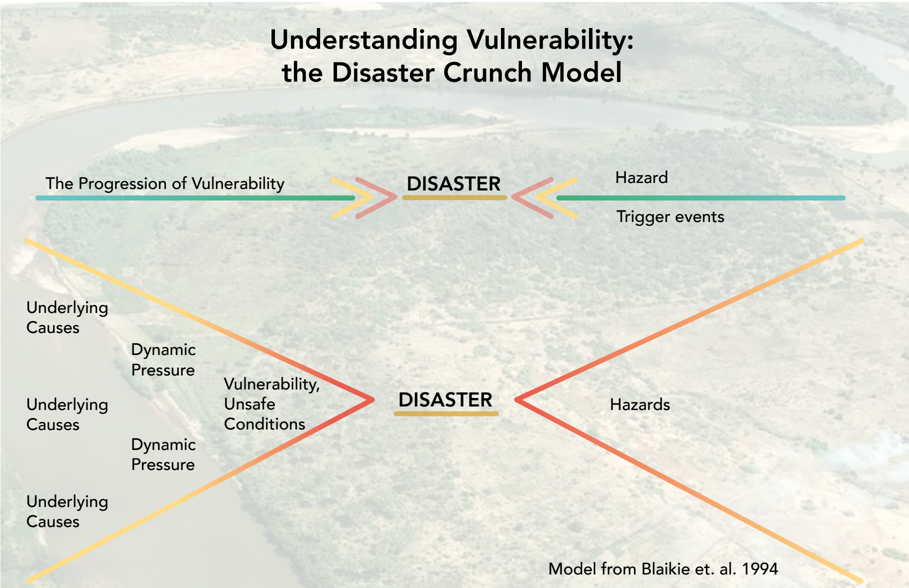


Figure 12. Average results of 23 different climate models for a simulated trend in precipitation (percent change per year) for the 21st century (2006–2099). A blue color indicated an expected increase in precipitation, a red color shows an expected decrease in precipitation. The 4 panels include the annual mean, the two major rainy seasons (March–May and September–November), and the dry season (June–August). Stippling indicates areas where at least 90% of the models agree on the sign of change. From Tierney et al. 2015.

2. Disaster risks and reduction strategies

The word ‘disaster’ is often seen as the opposite of ‘resilience’. Both disaster and resilience are states of capacity - or the lack of it - of the element at risk such as individuals, natural resources, vegetation (flora/fauna), community, society or a nation to survive, bounce back and transform the system to prevent disaster from happening. Resilience refers to the capacity of an individual and the community to bounce back from any event. A disaster only happens when specific elements at risk are unable to survive and bounce back from a hazard event (Cordaid, 2013).



Dolo Ado Woreda is extremely disaster prone. The hydro-meteorological hazards – droughts and floods - are the two major disasters risks in the woreda. Diseases (human, livestock and crop) affecting daily life in Dolo Ado Woreda throughout the year. Relatively new - and potentially incidental – are pests like locusts (grasshopper) swarms. An overview of the disasters is presented in Table 3. The communities reported that all disaster bring psychological depression and stress, economic disruption and paralyses the function of social structure such as schools.

Major disasters	Period of occurrence	Frequency	Effects of disaster
Drought	March - April & September	Every year	• Death of livestock • Loss of pasture and (safe) water • Loss of food and (agricultural) income • Increasing malnutrition • Student drop out
Flood	April - May & Nov - Oct - Dec	3 times in 5 years	• Crop damage • Livestock damage • Human death • Physical damage on houses and property • Displacement
Human diseases	Throughout the year	3 times in 5 years	• Human death (particularly vulnerable people) • Long-time illness and loss of working power • Loss of saving
Livestock diseases	Throughout the year	3 times in 5 years	• Death of animals • Reduced productivity & market trade • Loss of income
Crop pests and diseases	July - Sept	2 to 3 times in 5 years	• loss of crop production and loss of income • Pasture loss and loss of livestock • Food shortage
Locust	Likely after extreme weater	Unknown, increasing	• loss of crop production and loss of income • Pasture loss and possible earlier outward livestock migration • Food shortage

Table 3. Hazard assessment of the major disasters from the Dolo Ado Woreda Risk Mitigation Adaptation plan 2019, adapted by community Focus Group Discussion. **Note:** Frequency of these disasters is changing with changing climate & land use.

2.1 Droughts

There are two types of droughts affecting Dolo Ado Woreda:

- A below average rainfall season and.
- A later onset of the rainfall season.

Drought in terms of rainfall shortage is the major problem in the woreda, mainly affecting crop production and the rangelands resulting in food shortage. The local communities in the central rangelands are severely affected by drought as they run out of water for domestic use and grass for their cattle. During a drought, people move from the central rangelands to the riverine communities along the riverbanks, taking their herds with them. The elderly, young and lactating mothers stay behind in the village and depend on water trucking.

During a drought, water levels in the river Genale and Dawa are very low. The direct effect is that irrigation of the agricultural field with river water is not possible, resulting in a loss of income for the households. Also, there is a serious shortage of forage areas for the pastoralists. During a 'severe drought', the river Genale and Dawa stop flowing and water becomes stagnant in scattered ponds. This stagnant water becomes warm and is not suited for irrigation nor for domestic use. During drought, pressure on natural resources along the Genale and Dawa river increases as people from the central rangelands come to stay with their livestock.

Box 2. Drought in Biyoley Kebele
The respective elders recall that when they were young (~40-60 years ago) the rains where much more predictable, the droughts were less severe, and also the impact was less because there was much less population. Back then, it was possible to survive a bad year (drought), as is it was followed by several 'normal' or 'good' years.

However, these days, a drought happens every year and there is no time to recover. Also, the impact is bigger, as the large increase in population has let to overgrazing, deforestation and lower awareness of the environment, which all contributes to more severe drought. The rains used to be much more predictable and constant and not as severe as these days (heavy rains causing the wadi's to overflow).

2.2 Floods

There are two type of floods:
• ***The river overflowing its banks due to heavy rainfall somewhere upstream in the catchment.***
These floods are occurring almost every rainy season (twice per year) around the Genale river. The Dawa river is not overflowing its banks every year, only some seasons. These floods leave behind fertile soil, but it also washes away human-made dams and irrigation structures. Generally, it does not create large damages to infrastructure or fruit trees.

• ***Overflowed riverbanks in combination with local heavy rainfall.***
The local rainfall creates flash floods in the inland wadi and collides with the overflowing water near the river. This causes even higher water levels and larger areas with stagnant water. The fast flowing water in the wadis cause topsoil erosion and gully formation. Around the Dawa river it is also known that local heavy rainfall causes sediment transport from the wadis onto agricultural land. This coarse sediment is not beneficial for agricultural production.

According to respected elders from communities, the magnitude/frequency of floods has always been like nowadays. The impact only became larger. The difference is that back in the days people were pastoralist and flooding had no big impact on their herds, but in the last 20 years many people started to change to agro-pastoralism and (irrigated) agriculture on the riverbank, which is currently their most important source of income.

2.3 Diseases

According to the Dolo Ado Woreda Risk Mitigation and Adaptation plan, 2019, Malaria, Diarrhea, Dengue fever, malnutrition, measles and the common cold are the most serious hazards to humans. Anemia and excessive bleeding (during/after child birth) has also been reported. The root causes are lack of clean water, sanitation and hygiene. Severe shortages of health posts and life-saving medical supplies were also reported as root causes (Gu assessment Somali region, 2019). Floods and overflow of water sources can lead to water borne diseases; open defecation practice (more critical in districts with internally displaced persons (IDPs)); shortage of medical supplies and a low vaccination coverage are not improving the situation. An improvement in the percentage of functional water points and training in proper WASH practices could improve the situation already significantly.

Antrax, Parasites, Trypanosomiasis, LSD, Contagious Caprine Pleuropneumonia (CCPP), Foot and mouth disease and Liver fluke are the most prevalent livestock diseases in the woreda. Root causes are a shortage of pasture and water, lack of veterinary services and poor management of livestock (caring, watering, etc.). The communities are affected by a loss in income and property. Some are also depended on livestock labor for agricultural production (e.g. ploughing) (DRR plan Dolo Ado, 2019). During droughts and livestock disease outbreaks, there is a significant reduction of meat and milk productivity across the region (Gu assessment Somali

Box 3. Extreme flood 2019
In November 2019 there was an extreme flooding event along the Dawa and Genale river due to local heavy rainfall combined with the rivers breaking its banks. The flood destroyed water infrastructure, crops and submerged farms for a longer period of time. Households had a great loss of income as crops were not harvested. Mango and banana trees have survived the flood, but the other crops must be replanted. After the stagnant water retreated, agricultural fields were overgrown with grass and the farmers did not have the capacity (manpower and/or machinery) to plough all the fields in time in preparation of the next sowing. This means also a reduced income in the next harvest season.

Figure 13. The Desert Locust (Schistocerca gregaria)

region 2019). Crop diseases and pests are bacterial welt, stack borer, African Army worm, Aphids and locusts. Most farmers are working with furrow irrigation and are not applying any techniques that reduce crop pests and diseases. On the other hand, agroforestry can be a more natural resilient way of food production. Erratic rainfall makes timely sowing and harvesting challenging. Improved seeds are present in Dolo Ado, but not yet widely spread. Also government is supporting distribution and correct use of pesticides and fertilizers.

2.4 Locust swarms

Since December 2019 one of the most severe locust outbreaks is troubling the Horn of Africa. The Desert Locust (Schistocerca gregaria) is a relatively new hazard for Dolo Ado woreda.
This was the first time a swarm of locust reached the central rangelands of Dolo Ado Woreda. Along the Genale River, it was the second time a swarm of locusts crossed the land.

The locust itself is not harmful, but it poses a serious threat to food security and livelihoods in the woreda. When ecological conditions become appropriate (extreme weather conditions), these Locusts are known to give up their solitary lifestyles and convene into wide, movable, famished swarms. During the night the swarm remains still (and impossible to chase away), during daytime it can rapidly move (tens of kilometers a day). The locust feed on leaves, shoots, flowers, fruit, seeds, stems and bark. Nearly all crops, and non-crop plants, are eaten including pasture grasses. The vegetation loss caused by swarming desert locusts is a threat to food security and pastoralist livelihoods. The desert locust is not used as a source of food in Ethiopia, however the communities heard that in Somalia, the locust is fried and eaten. The government tries to eliminate the locust with chemicals with support from the FAO. Hereafter communities were informed not the eat the locusts.

2.5 Trends

Trends	Description of the trend	Impact of the trend	Coping mechanism
Rainfall	The amount and distribution of rainfall is decreasing, and the onset and cessation has been abnormal.	• Loss of pasture and (safe) water • Reduction in yield and livestock	• Water conservation • Water buffering • Shifting from cow to camel • Small scale irrigation
Temperature	Temperature has been increasing.	• More diseases	• Planting trees • Agroforestry practices • WASH practices
Deforestation	Increasing due to a high demand of trees for fuel and timber.	• Loss of buffering function of the landscape • Soil erosion • Expansion of desertification	• Planting trees • Soil and Water Conservation • Vegetation enclosures • Environmental policies • Alternative fuel • Fuel-efficient cooking stoves
Soil Erosion	Increasing due to erratic rainfall patterns (climate change) and deforestation.	• Loss of fertile soil • Damage to pasture • Change in floodwater flow path due to gully formation • Damage to crop yield	• Planting trees / Re-vegetation • Soil and Water Conservation (contour bunds, trenches) • Landscape restoration through anti-erosion measures (gully plugs, enclosures) • Watershed management (water diversion)
Population	Population has increased due to a high birth rate and migration.	• Resources competition • Shortage of land	Family planning

Table 4. Gradual changes observed and threatening the livelihoods of the community, from the Focus group discussions and the Dolo Ado Woreda Risk Mitigation Adaptation plan 2019.

2.6 Disaster coping strategies

The communities are known to provide help to each other during disasters through sharing of grazing areas and livestock, provision of money and community mobilization. Communities along the rivers are allowing a large influx of people and livestock from the central rangelands during droughts. Major coping mechanisms are a reduced expenditure on non-essential items, selling more livestock than usual, increasing working hours and consumption rather than selling of crop surplus (Dolo Ado Woreda Disaster risk adaptation plan, 2019). Government and NGOs are providing water through water trucking for the people who must stay behind in the central rangelands.

The Biyoley community mini store was constructed in 2010 (funded by USAID) and provides storage of food (for human consumption) that can be used in times of disaster. The emergency food is a good way to support disaster response but does not target the underlying causes. The storage hut contains hundreds of 50 kg bags of split yellow peas and sorghum. There are also around 50 boxes with palm oil. The roof of the storage was supported by Safe the Children but is at the point of collapsing. According to the community chairman, they have no problems with unwanted visitors like rats and mice. Individual households also create a small food storage for times of drought. During the 2019 extreme flood, rainfall washed away several of these household food storage along the Dawa riverine communities.

2.7 DRR centers in Dolo Ado Woreda

Multiple Disaster Risk Reduction (DRR) centers have been constructed by RACIDA in partnership with the local communities with funding from the European Union (EU) through Cordaid under the RESET II program. Under the same program, Rain Water Harvesting (RWH) tanks were constructed. The water in this tank is used by vulnerably people (lactating mothers, children and elderly) and in times of drought.

The DRR center is used for meetings of the communities Early Warning Committees (EWC) and the DRR Committee itself. Inside there are facilities for meetings and on the walls, the main targets and activities of the community Action plan for resilience can be found. For example, the Biyoley Community Development Action Plan for Drought includes the following (desired) activities: development of another water tank with roof catchment, environmental awareness creation within the community and Birkad (pond) rehabilitation & construction.

The DRR centers help in the awareness raising for environmental protection and disaster risk management for the communities. Also trainings can be provided on awareness raising on prevention of human diseases (RACIDA is already providing WASH trainings). Trainings have been provided to the communities on the creation of food savings for difficult times.

Figure 14. Above: Community Food storage at Biyoley kebele, containing a large stock of sorghum, split yellow peas and palm oil. Middle: Grass production in an enclosed field for the dry season. Dry prickly bushes, located in the front, are used to enclose the area from livestock. Below: DRR community centre of Daytuli, constructed by RACIDA and the community in 2018. Funded by the European Union through Cordaid under the RESET II programme. A rain water harvesting tank is connected to the roof of the DRR centre to provide water for vulnerable community members.

2.8 Main challenges and needs

Problematic months in terms of shortage of pasture and shortage of water are March and October, just before the rainy season arrives. During these months, people and livestock are very vulnerable for diseases. To reduce vulnerability with Eco-DRR interventions, it is necessary to implement structures that provide water up until these months for domestic use and support vegetation on the long term. Rain Water Harvesting tanks can store water for the dry season for the most vulnerable community members. It would be a good practice to construct RWH tanks next to all buildings with larger roofs. An improved water availability would support WASH activities during the dry season and reduce spreading of diseases. A good functioning borehole would also improve community resilience, however, in reality these are often not functioning due to technical or maintenance issues.

Droughts are becoming more frequent, which gives the community less time to recover in between. The Early Warning Committees (EWCs) are reading indicators to ensure timely warning of the community of floods and droughts. Indicators include strong winds, cloud disappearances, animal behavior, shedding of plant leaves etc. However, this is not easy and means for proper communication (radio and phones) with other EWCs are not available in every community. The Early Warning System could be improved if the EWCs are provided with communication means and an sharing of information with Woredas upstream of Dolo Ado Woreda.

Hazards		Months												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Frequency
Hazard	Drought			X	X						X			Every year
	Flood					X						X		Every three year
	Livestock diseases			X							X			During drought season
	Crop diseases					X						X		Sometimes affect the crops
	Human diseases (Malaria, Measles, Diarrhea etc.)				X	X					X	X		Every season during drought and flood out break
Problematic months	Economic/ price shock				X							X		Every year
	Shortage of pasture				X						X			Every year
	Shortage of water				X						X			It depends on the severe drought

Table 5. Hazard Calendar based on 2 focus group discussions with the communities of Biyoley and Sigalow.

Major challenges for the regional offices	Disaster prevention	Emergency response
Disaster Preparedness and Prevention Office (DPPO	• The Early Warning Committees from communities don't have the tools they need to measure or communicate with others. • Lack of actions/implementations for Risk Reduction.	The impact of the disasters is widespread. It is difficult to prioritize the response when the entire Woreda is affected. There is no capacity to support all.
Agricultural Office	There is a lack of knowledge on the importance of environmental protection. Environmental policies and enforcement are necessary.	The agricultural office is more active in disaster prevention: resettlement of pastoralists, Farmer Training Centres and landscape restoration.
Water office	• Difficult to keep all water points functional. • Siting new water sources (e.g. boreholes) is difficult due to the presence of saline groundwater.	Capacity for water trucking is limited and sources for water retrieval are far from communities with a water gap.

Table 6. Main challenges for the Woreda (district) offices.

3. Land use and management

3.1 Soils

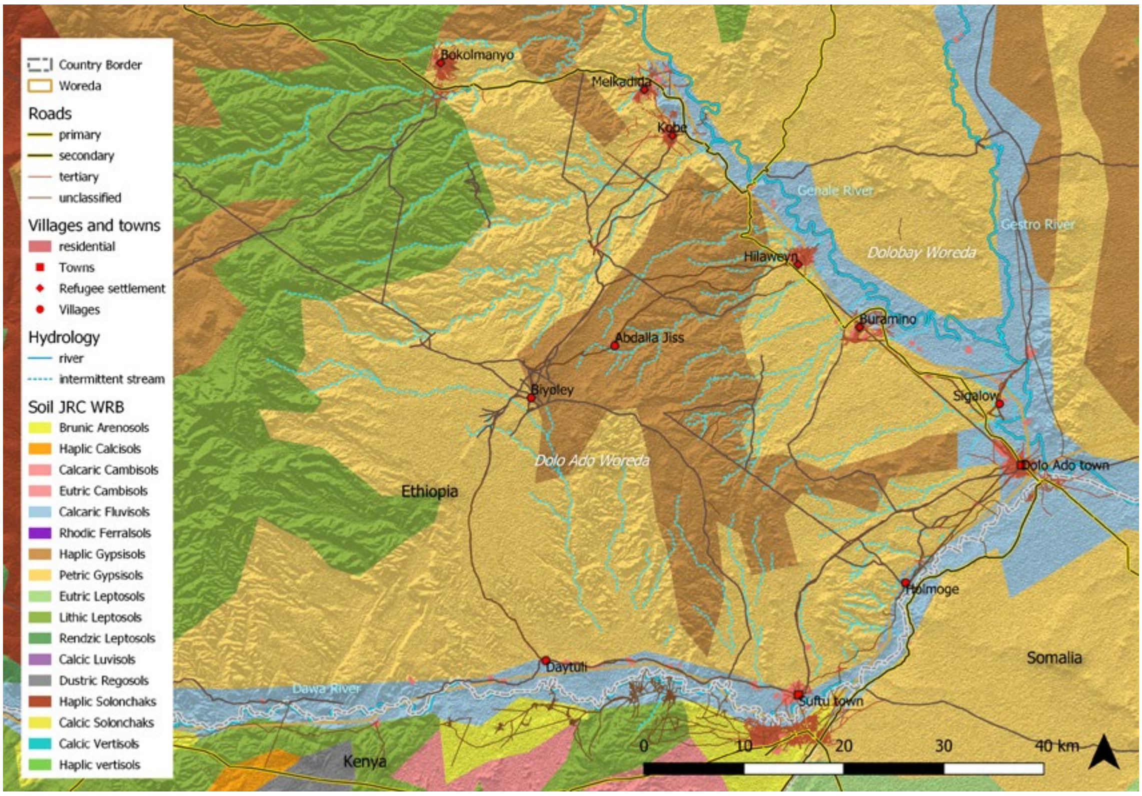


Figure 15. Soils of Dolo Ado Woreda (Source: Soil Atlas of Africa).

3.2 Soil suitability and management

Soil characteristics strongly influence surface water runoff, infiltration capacity, water buffering potential and groundwater recharge. Accurate soil maps help to identify areas prone to erosion, to assess agricultural potential and to guide land use. The map shows in figure 16 an unrefined soil map with World Reference Base for Soil Resources (WRB), which is an international soil classification system, and therefore provide an indication of the soil types present in the woreda.

Along the river Dawa and Genale, Fluvisols have been deposited by seasonal streams on the floodplains. The infiltration and moisture holding capacity of fluvisols is relatively high and, with application of proper structure and fertilization management, these soils can be suitable for a wide variety of agricultural uses. In the central rangelands Gypsisols are dominant. Haplic Gypsisols have a substantial accumulation of gypsum. The Petric Gypsisols have a high level of gypsum having a strongly cemented (also referred to as 'indurated') or impermeable layer.

In the west, Leptosols and Solonchaks are present. Leptosols are very stony, poor soils, mostly used for extensive grazing, but are best kept under forest or other permanent forms of vegetation to protect and stimulate soil development. Lithic Leptosols have a shallow soil over a hard rock with continuous hard rock near the surface. A Rendzic leptosol has a dark organic rich acid surface horizon overlying calcareous materials. Solonchaks have accumulation of salt in the soil profile.

Other soils shown on the map, but only present in Kenya outside the project area are Brunic Arenosols (sandy soils with a reddish horizon), Cambisols (young soils) and Regosols (weakly developed soils with a loose texture).
Table 7 shows an analysis of the strengths, weakness, opportunities and threats (SWOT) of typical soil types present in Dolo Ado Woreda.

Soil Type	Description	Strength	Weakness	Opportunities	Threats
Fluvisols	Soils developed in alluvial deposits, in periodically flooded areas or alluvial plains. Texture can vary from coarse sand to heavy clay.	Fluvisols are very fertile because of regular supply of nutrients. Riverine fluvisols are highly suitable for irrigation due to the proximity of water.	Flood control or drainage may be needed due to proximity to rivers. Low lying swamps, if not suitable for rice, are best left to natural conditions and extensive grazing.	High agricultural potential. High soil moisture holding capacity.	Flooding and waterlogging. Prone to urbanisation and sealing.
Gypsisols	Soils with substantial accumulation of gypsum. Developed in mostly unconsolidated deposits of base-rich weathering material.	Can support limited extensive grazing.	Gypsisols do not hold much water. The soils have a high pH, normally over 8, which creates disorder in plant nutrients. The sandy nature, alkaline character and lack of water make most soils unsuitable for cropping. Low soil moisture holding capacity.	Limited. Cultivation is possible on soils with relatively low gypsum content if irrigated.	When high amounts of gypsum are present, the soil structure may collapse under irrigation.
Leptosols	Generally young, very shallow soils over hard rock of highly calcareous material, but also deeper soils that are stony.	The provide a solid foundation for construction.	Unsuitable for growing crops. They have a limited rooting depth, a low water holding capacity and a shallow topsoil layer.	Extensive grazing and reforestation.	High erosion sensitivity.
Solonchak	A pale or grey soil type with accumulation of salt. Found in poorly drained conditions.	Supports natural habitats. Little agricultural value apart from extensive grazing.	Due to salts not directly suitable as farmland. When they dry out, the soils become very hard, making land preparation difficult.	Cultivation is possible after salts have been flushed from the soils. Irrigation must satisfy crop needs.	Salinization and wind erosion.

Figure 16. Typical soils in Dolo Ado Woreda (Photo credit: Acacia Water for Fluvisols and Leptosols, ISRIC for Gypsisols and Solonchaks.)

Table 7. SWOT analysis of the soil present in Dolo Ado Woreda (adapted from the Soil Atlas of Africa, 2013.)

3.3 Landcover

Land cover has an important impact on (micro)climate, biochemistry, hydrology and the diversity in a landscape. Securing a good understanding of how vegetation cover and land use practices are evolving is fundamental to comprehend land degradation processes, assess the status of ecosystems, and design strategic interventions at landscape level.

The land cover map (Figure 17) indicates that, in general, soil cover is sparse throughout the landscape with large areas covered with grassland and shrubs and bare land. The land along the rivers stands out as crop land and tree covered areas.

Agriculture in the central rangelands is rainfed and, thus, the decision to cultivate or not is highly dependent on rainfall. Areas may be cultivated one year, but in the following left fallow allowing grassland to establish.

Along the Dawa and Genale river, furrow irrigation is widely practiced. Land is cleared of riverine vegetation, ploughed and diverted into plots for agriculture. Hereafter the land is used to produce vegetables and fruits from two growing seasons per year. Earthen irrigation channels are dug to the main river to the agricultural fields. Pipes for water diversion are not preferred as they degrade in the sunlight. These irrigation channels need some rehabilitation after flooding.

Rural livelihoods are to a large extent dependent on products from rangelands, shrublands and (riverine) forests. Camels and goats browse the thick thorny bushes, sheep and cattle prefer the lush pastures of grasslands. Communities also cut grass and store it as fodder for the dry season. Trees provide wood for energy, livestock feed, medicines and to some extent timber, food and shelter.

Rangelands and forests are considered to be common pool resources of the communities. Agricultural land is either privately owned or managed by farmers' cooperatives.

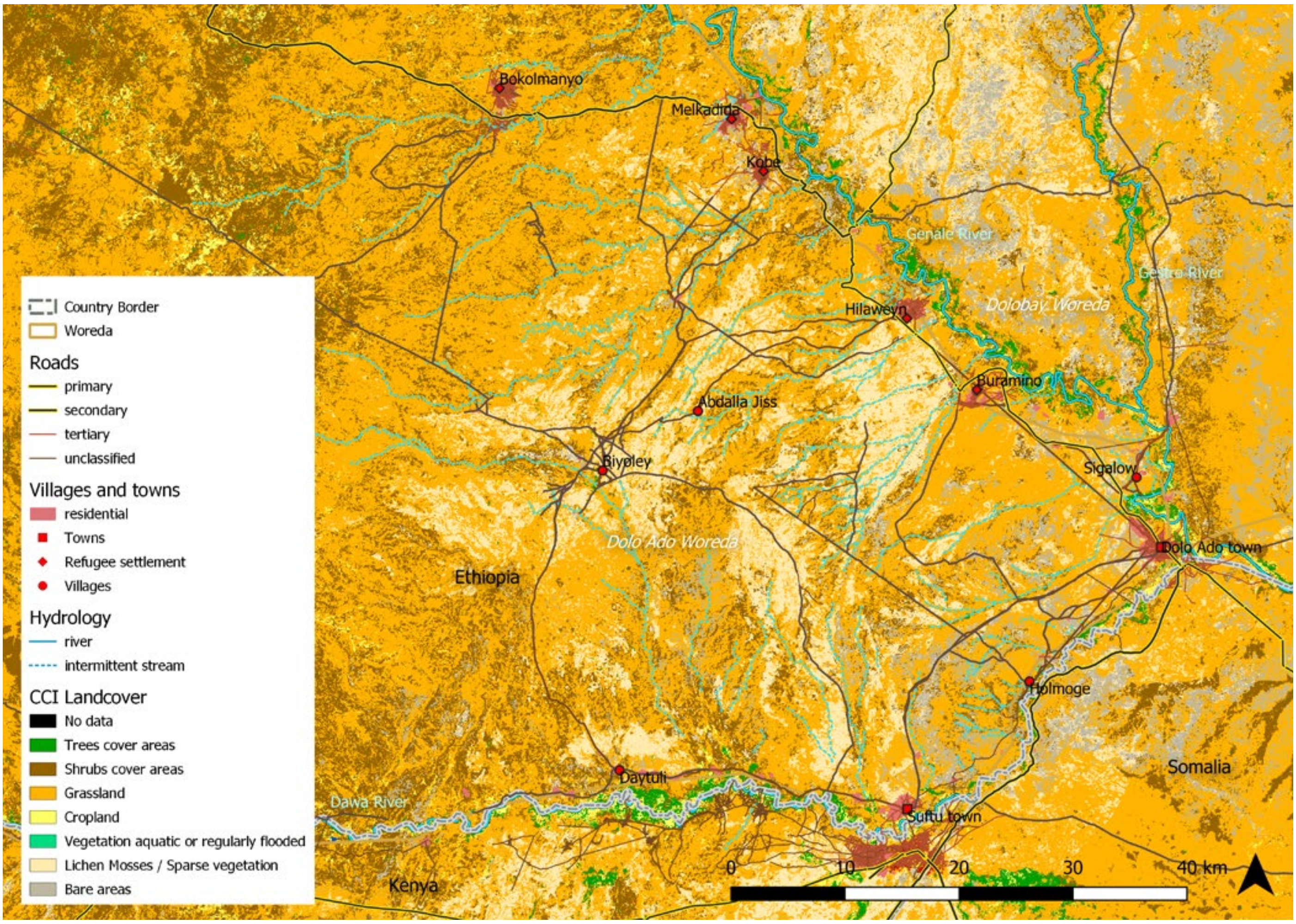


Figure 17. Landcover map of Dolo Ado Woreda.

Figure 18. Long needles of Acacia Tree in shrublands, termite hill, shaded grazing area, dry grassland, irrigated agriculture, and lush green vegetation on the riverbanks of the Dawa river.

3.4 Land use change

Uncontrolled grazing, tree-cutting, land clearing for crop production are intensifying land degradation. Vegetation cover in Ethiopia has changed over the past years (17,2% tree cover loss between 2001 and 2018; Global Forest Watch), and the vegetation cover in Dolo Ado showed a decreasing trend. Focus group discussions and interviews indicate that environmental degradation is a problem. Logging of trees near the refugee camps has been a serious problem, but also charcoal making, which is a common practice throughout the woreda (Figure 19). Reforestation is ongoing with support from the government, with a focus on Hilaweyn refugee settlement. Expansion of irrigated agricultural land is also ongoing. According to the Agricultural Office, the government used to support resettlement towards the Dawa and Genale river.

Figure 19. Location for charcoal making, as seen near Holmoge village.

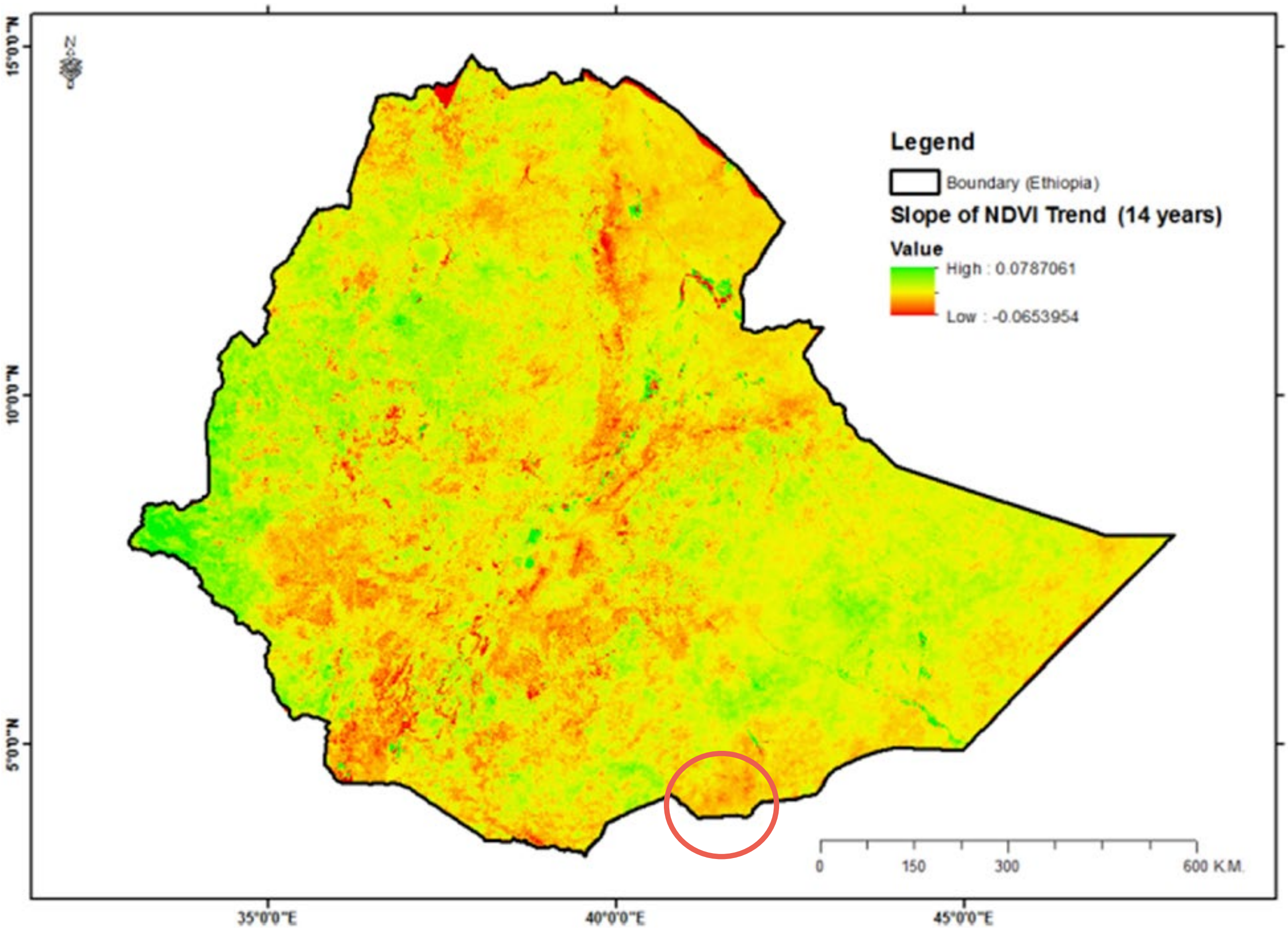


Figure 20. Map showing the change in vegetation cover over the past 14 years. Positive slope indicates an increasing trend in vegetation (green) while negative a decreasing trend (red). Source: Tenaw Geremew Workie & Habte Jebessa Debella (2018).

Figure 20 shows the change in vegetation cover for Ethiopia over the past 14 years. The slope of a linear fit into the time series of normalized difference vegetation index (NDVI) data for the period 2002–2015 shows a decrease in vegetation cover for Dolo Ado woreda. NDVI is a graphical indicator that can be used to determine the density of live green vegetation on a patch of land.

3.5 Erosion

Field observations show that topsoil erosion, wind erosion and gully erosion are all three types of erosion troubling Dolo Ado Woreda. Due to erosion of topsoil, fertile soils and vegetation is lost and agricultural productivity is reduced. Due to severe gully erosion, water flow paths can be redirected to a new gully, while infiltration and groundwater recharge are being reduced. Also, infrastructure such as roads can be destroyed as a result. Some of the above-mentioned effects increase erosion, making it a self-increasing process.

Erosion in Dolo Ado woreda is mostly seen at the larger wadis and in the center of flow paths. Years with severe local rainfall have a big impact on erosion rates. The observations and interviews indicate that erosion is largely a consequence of poor land use and management, including: overgrazing; tree cutting for wood collection, land clearing for crop production; reduced vegetation cover on poor soils and steep slopes without proper SWC measures; this in combination with heavy rainfall creates severe erosion rates. Sediment transport of coarse material downstream is not preferred for agricultural production.

In general, grazing is controlled by herders and by applying cut-and-carry systems for grass in dry times. Erosion along livestock migration paths is becoming more severe as livestock tramples the soil loose thereby exposing it to water and wind erosion. It would be better to confine livestock migration paths to a small corridor, therefore increasing soil stability.

Figure 21. Left: Erosion of topsoil in the center of the flow path towards the river Genale. Second: Erosion of topsoil severed by the migration of livestock.

Figure 22. Above: Severe gully erosion in Biyoley kebele exposing hardrock beneath. Below: erosion of wadi banks in wadi with coarse sediment.

3.6 Ecosystems and their services

A good functioning (non-degraded) ecosystem provides all kinds of services: provisioning services, regulating services, and cultural services. Provisioning services are tangible products that can be exchanged or traded, as well as consumed or used directly by people in manufacture, such as: wood, food and potable water. Regulating services are ecosystem outputs that are not consumed but affect the performance of individuals, communities and populations and their activities (e.g. climate regulation, pollination), cultural services include all non-material ecosystem outputs that have symbolic and cultural significance. Protecting biodiversity is an important aspect of ecosystem restoration as it strengthens ecosystems services delivery.

Examples of services provided by various landscapes:

- Trees promote soil stability and thereby infiltration, and as such improve water availability in the soil after the rainy season.
- Trees and shrubs minimize soil erosion on site, reduce sediment in water bodies (wetlands, ponds, lakes, streams, rivers) and trap or filter water pollutants in the forest litter.
- grass slows down runoff and promotes infiltration.
- Micro-organisms in grasslands promote bioremediation, meaning that water quality is improved.
- Numerous insect species are responsible for pollination processes for edible goods.
- Wood and charcoal serve cooking purposes and are sold in urban areas to make and additional income.
- Dry shrubland is also good for keeping bees, and as such contributes to the production of honey.
- Grasslands are important grazing areas for camels. Cattle, goats and sheep. Indirectly the ecosystem contributes to the availability of dairy products (milk, butter, yoghurt) and meat, which have a high nutritional value.
- Leaves, fruits and seeds form resources to develop natural remedies and medicines.
- Vegetation slows down water, thereby preventing flooding downstream.

Ecosystems provide different types of services and contribute to water security, food security and disaster risk reduction in different ways. The ecosystems with high contribution to DRR should be prioritized for restoration and prevention of degradation.

- A focus area for **restoration** are the upstream parts of the flooding areas where local rainfall is collected into a flash flood. A restored vegetation cover will promote infiltration of rainwater, slow down surface runoff and minimize soil erosion. This should be combined with landscape interventions such as contour bunds and stone bunds to maximize the reduction in flash floods.
- **Prevention of degradation** should be on the ecosystems with threes close to villages, towns and refugee settlements. Population is increase and the demand for fuel food and construction will increase. Reforestation will support the ecosystems. Enclosures, environmental policies and enforcement and awareness raising supports prevention of ecosystem degradation. Advantages and positive impact of alternative fuel sources or fuel-efficient cooking stoves should be disseminated and promoted.

4. Water resources

4.1 Surface water in Dolo Ado Woreda

Since annual rainfall is low and evapotranspiration is high, the drainage network in Dolo Ado Woreda consists mostly of dry riverbeds (wadis) that are filled with sand and stones and contain water only when heavy rain occurs. Exception are the seasonal Dawa river and the perennial Genale river, both originating from the Ethiopian highlands and ultimately draining into the Indian Ocean in Somalia. During the rainy season the rivers flood and form temporary swamps/wetlands. Water is stored in the sandy river beds and during the dry season this water is harvesting using hand dug wells or scoop holes for domestic use and livestock watering purposes.

Genale-Dawa river basin

In a river basin, hydrological events that occur in the upper part may have a direct influence downstream, from a few to many hundreds of kilometers away. Understanding these upstream-downstream linkages is an essential basis for integrated land and water resources management (ILWRM) and planning in a river basin. As such, in order to understand the water availability (and water quality) in Dawa River and Genale River at Dolo Ado Woreda, it is important to look at the whole river catchment. Similarly, Genale River basin accounts for more than 50% of the flow in the Jubba River downstream. Jubba River is the Somalian name of the river after the Dawa River and Genale River join at Dolo Ado town and is an extremely important river for Somalia. Hence, activities in Dolo Ado Woreda can have an effect on downstream areas in Somalia. The Genale, Gestro and Dawa rivers, three tributaries/rivers originating in the highlands of Ethiopia, merge at Dolo Bay town (Genale & Gestro) and at the point just south of Dolo Ado town (Genale & Dawa) near the Somali national boundary (Doolow town) to form the Jubba River. Jubba River ultimately combines with Shabelle River prior to emptying into the Indian Ocean, few kilometers east of the city of Kismaayo in Somalia (Figure 23). The Genale-Dawa Basin covers an area of about 172,880 km^2, which makes it the third biggest river basin in Ethiopia, and the main river has a length of about 600 km.

Upstream activities effect downstream areas

Recently, the Genale Dawa III (GD-3) Hydroelectric Power Plant was inaugurated . This GD-3 dam is constructed more than 350 km upstream of Dolo Ado town (Feasibility Study of Genale GD-6 Hydropower Project, 2009), and is part of a cascading system which is foreseen to include two more dams (GD-5 and GD-6). The initial filling of the reservoir(s) will significantly decrease the water availability in Genale river further downstream. The construction of this/these dam(s) will have a significant impact on the Genale valley farmers and agro-pastoralists who depend on these water resources for survival.

Continued urbanisation and poor land use management (including: overgrazing, tree cutting for wood collection, land clearing for crop production etc.) within Genale-Dawa River Basin leads to crusting of the soils and has decreased the storage capacity of the soils in the catchment. The low permeability of degraded soils reduces infiltration capacity. During heavy rains, this leads to increased surface runoff (instead of infiltration) and a faster responding hydrological system with more extreme river flows downstream. The combined effect is increased flooding during wet periods, and a decrease in soil moisture and river baseflows in the catchment during the dry season.

Genale River

The Genale river is a perennial river which is an important source of water for the communities and towns along the northern border of Dolo Ado Woreda, such as Sigalow, Kole and Kobe village, as well as the refugee settlements of Bokolmanyo, Buramino, Hilaweyn, Kobe and Melkadida. The water is used for domestic consumption, as well as livestock watering and small scale irrigation (Figure 24).

According to the Dolo Ado Woreda Water Office, there are no monitoring stations in the Genale River within the woreda. Measurements at Helwei station show that the mean monthly stream flow is about 50 m^3/s during the months December-March, after which it rises up to 190 m^3/s in May and 280 m^3/s in October (source: GDMP, 2007). The mean and minimum flow characteristics of the Genale river is shown in Figure 25.

This station is located near Hilaweyn Refugee Camp at Latitude N 4.22 / E 41.53 (source: Feasibility Study of Genale GD-6 Hydropower Project, 2009), where monthly streamflow measurements were taken between 1973 and 2002. Similar to the local rainfall pattern the seasonality is bimodal, but the timing and magnitude is different. While Dolo Ado Woreda experiences the Gu rain as major wet season (from March to June) and the Deyr rain as minor wet season (from October to December), the streamflow in Genale river is highest in August to November, with a minor high flow during May to July.

The FLO1K global maps of mean, maximum and minimum annual streamflow at 1 km resolution from 1960 through 2015 (Barbarossa, V et al., 2018), was used to get an indication of annual flow in Genale river at Dolo Ado town, just before merging with the Dawa river (Figure 25). FLO1K comprises mean, maximum and minimum annual flow for each year in the period 1960–2015, which represent the lowest and highest mean monthly flows for a given year. The data shows that minimum monthly flow in Genale river is around 20 m^3/s, while the maximum monthly flow can be as high as 400 m^3/s. This shows the very strong seasonality in river flow.

Figure 23. Map showing the Dawa and Genale river, as part of the Juba-Shebelle River Basin. Source: Kmusser

Figure 24. Above: The Genale river just south of Sigalow with maize and beans planted on the river bank, and a large mango tree to the right. Below: Goats drinking from the Genale river from a steep access point on the river bank.

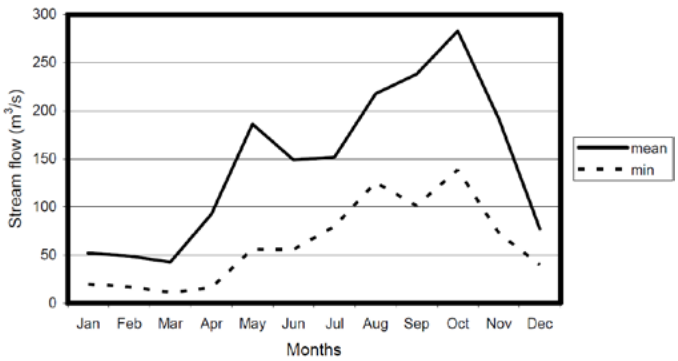


Figure 25. Monthly stream flow of Genale river at Helwei, 1973 – 2002 (source: GDMP 2007)

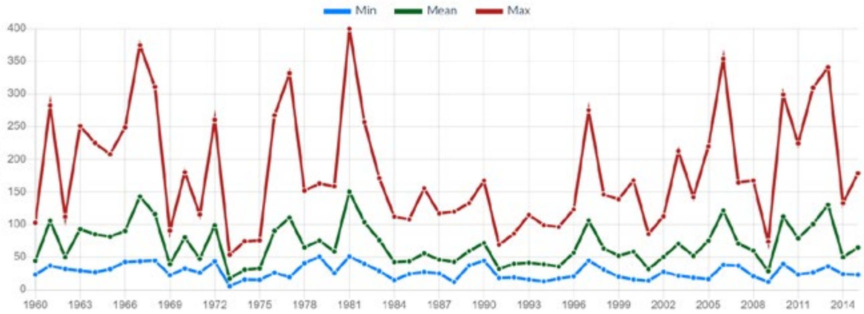


Figure 26. Mean annual streamflow 1960 – 2015 in Genale River, just before joining the Dawa river. Source: FLO1K (Barbarossa, V et al., 2018.)

Figure 27. Above: Situation before (Imagery data 12 February 2013) - Below: Situation before (Imagery data 22 September 2016.)

Near Dolo Bay, the Genale river was diverted a few years ago in order to create new good farmland in the original river meander[2]. The people living at the newly created course of the river were compensated and relocated. The bridge at the original river course now crosses some remaining puddles of stagnant water with many water birds. On the newly created farm land, maize is being grown. This area was also inundated during the severe flood of Oct-Nov 2019. Figure 27 shows the original (above; satellite image of 2013) and the new course of the river (below; satellite image of 2016).

Another diversion of the course of Genale river happened in a natural way several generations ago. This old meander is still visible in the landscape by its more lush and extensive vegetation, as was observed on the ground and on satellite imagery (Figure 28).

Naturally, slightly elevated and stretched river banks develop along meandering rivers. These elongated banks are still visible nowadays, for example at the old river meander near Sigalow village. The area within these river banks (where originally the Genale river was flowing) is much greener than the surrounding areas, because the coarse-grained river sediments in the old meander are hydraulically connected to the river. Vegetation in this old meander is abundant and the soils are known to be fertile. Hence, crops are being grown seasonally and the area is used for grazing year round. The old meander is clearly visible on google earth satellite imagery, the vegetation is greener than the surrounding area. One of the elders remembered a story that this was once the flow path of the Genale river, but this was before the time of his grandparents. This piece of land is used as communal grazing grounds. The microclimate feels a bit cooler than the surrounding land. The locals once dug a shallow well in this old meander and found very fresh water, which confirms the hydraulic connection to the Genale River.

[2] A meander is a curvy bend of a river swinging from side to side as it flows across the landscape, within a valley or across a floodplain.

Figure 28. Left: A Panorama of the difference between the normal grazing grounds (left) and the green grazing area located in an old river bed of the Genale river (right). The former elevated Genale river bank is still visible in the landscape in the middle of the picture. Right: At the location of the old meander (marked in green) the vegetation is greener than the surrounding area, as can be seen on Google Earth satellite imagery.

Dawa River

The Dawa river is a seasonal river which is an important source of water for the communities and towns along the southern border of Dolo Ado Woreda, such as Suftu and Holmoge village as well as Dolo Ado town. The water is used for domestic consumption, as well as livestock watering and small scale irrigation (Figure 29).

According to the Dolo Ado Woreda Water Office, there are no monitoring stations in the Dawa River within the woreda. The Dawa river is reported to flow in its lower reaches, from Dolo bridge up to Melka Miri, only between May and November somewhat over six months (GDMP 2007).

The FLO1K global maps of mean, maximum and minimum annual streamflow at 1 km resolution from 1960 through 2015 (Barbarossa, V et al., 2018), was used to get an indication of annual flow in Dawa river at Dolo Ado town, just before merging with the Genale river (Figure 30). FLO1K comprises mean, maximum and minimum annual flow for each year in the period 1960–2015, which represent the lowest and highest mean monthly flows for a given year. The data shows that minimum monthly flow in Dawa river is approaching no flow (0 m^3/s), while the maximum monthly flow can be as high as 320 m^3/s. This shows the very strong seasonality in river flow.

During the rainy season, the Dawa river floods the surrounding plains, where it increases soil moisture content and improves the fertility of the soils. As the riverbed is filled-up with medium to coarse sediments, the Dawa river serves as valuable safe (ground)water reservoir to the communities settled close to the river even during the dry season when there is no river flow. Water availability is especially high where natural barrier (rock outcrops), bridges and drifts block the subsurface water flow.

Figure 29. Above: the Dawa river near Holmoge village, where the water is used for livestock watering, domestic use as well as irrigation. Below: The Dawa river is seasonal and most of the river bed fell dry already during field visit in January 2020.

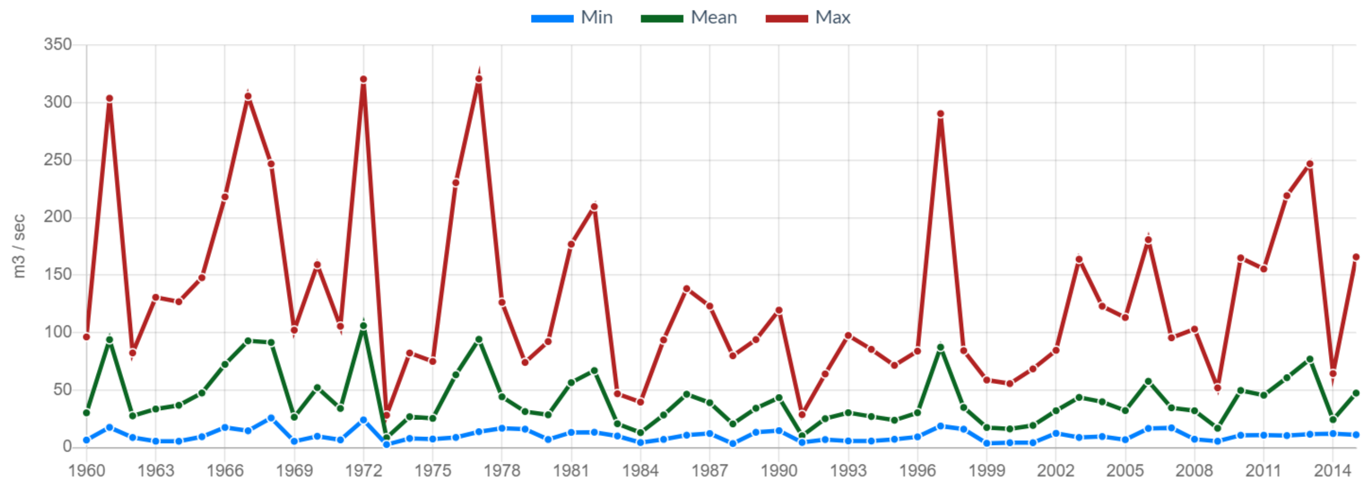


Figure 30. Mean annual streamflow 1960 – 2015 in Dawa River, just before joining the Genale river. Source: FLO1K.

4.2 Wadis

There are many wadis (dry riverbeds) in the area, containing flowing water only during a few days a year after a heavy rainfall event. New wadis are being formed due to active erosion forming new gullies that get wider and deeper going further downstream, such as observed near Biyoley town (Figure 22). As groundwater concentrates in low lying areas, dry wadis often form a source of water that can be accessed by scoop holes or hand dug wells. In other wadis, puddles of stagnant water can be found, such as in Wadi Sagola at Washakbar, next to the left overs of a surface dam. Due to subsurface layers of evaporites, this stagnant water is often found to have high amount of salts and dissolved solids. For example at Washakbar, the water in the wadi is too saline (EC of 3300 µS/cm was measured during the field visit) for domestic consumption, but livestock is drinking the water. Further downstream, the same Wadi Sarole along the road between Kobe refugee settlement and Kole village, contains more water due to groundwater seepage, and flowing water (around 2 l/s) was observed during the field visit. Due to the high rate of evaporation and high mineral content of the seeping groundwater, outcrops of 'calcrete' (hardened and compact calcite cemented rock fragments) can often be found in those wadis (Figure 31).

4.3 Access to water

Limited reliable data is available on water demand and supply in the project area. Besides Genale River, there are no permanent natural surface water sources in the project area. Communities mainly use water from hand dug wells, scoop holes in dry river beds, birkads, boreholes and artificial ponds. Nearby Dawa and Genale river hand dug wells, at times equipped with pumps, are common. Also boreholes connected to piped water schemes are present, but the piped water systems visited in January 2020 were dysfunctional or not yet operational. In the central rangelands, far away from the Dawa and Genale river, birkads predominate.
Water is mostly used for domestic purposes and watering livestock. Only in communities nearby the Genale and Dawa river use water for irrigation purposes. In general, women and children are responsible for fetching water. Water access, also in comparison with national averages, is poor. Few sources are available, and many are non-functional. During the wet season most communities can collect water from nearby wadis, ponds, birkads and shallow wells. During the dry season long trips have to be undertaken to collect water because water levels drop. Pastoral communities often migrate to areas near Genale or Dawa river for watering of their livestock.

When it is available, people in the central rangeland use rain water harvested in local ponds, hafir dams, and communal birkads. In a normal year, the rain water harvested in those storage facilities is generally sufficient in quantity to cover the community's need for the whole year. However, according to variations in geographical rainfall patterns, the rain water harvested during the rainy season in storage facilities (birkads, ponds, dams) may become depleted towards the end of the dry season in parts of Dolo Ado Woreda.

In times of emergency, when the stored water in birkads finishes, the Water Office of Dolo Ado Woreda is supporting communities in the central rangeland with water trucking. The Woreda has two trucks available (20,000 liter or 20 m^3 volume per truck) in Dolo Ado town, but the great distance to some of the communities is a major challenge.

Figure 31 Above: Dry wadi near Biyoley town. Second: Herd of goats in a dry wadi near Hilaweyn Refugee Settlement. Third: Wadi Sagola at Washakbar, with the left overs of a surface dam. Below: Flowing water in Wadi Sarole along the road between Kobe refugee settlement and Kole village.

4.4 Water infrastructure

The Water Office of Dolo Ado Woreda has a database containing the water points and water infrastructure in the woreda, but according to the Head of Water Office this data is not available.

An assessment team found a variety of water sources across visited areas in Somali Region, including Liben Zone (Gu Assessment Report 2019 for Somali Region). A total of 36 Boreholes (31 Functional and 5 non-functional) were found in Liben Zone, as well as 96 hand dug wells (80 Functional; 16 Non-Functional), 8 Hafir Dams (4 Functional; 4 Non-Functional), 198 Birkads (161 Functional; 37 Non-Functional), 8 River Intakes (6 Functional; 2 Non-Functional) and 74 Ponds (61 Functional; 13 Non-Functional). It is not clear how many of these water sources are located in Dolo Ado Woreda.

Field observation and focus group discussions indicate that a large number of water structures are non-functional, often broken-down due to poor maintenance or abandoned due to water being too saline. Focus group discussions and interviews suggest that boiling the water before consumption is not a common practice, and chlorine for disinfection is often not available. As many water sources are poorly protected they are vulnerable for (faecal) contamination.

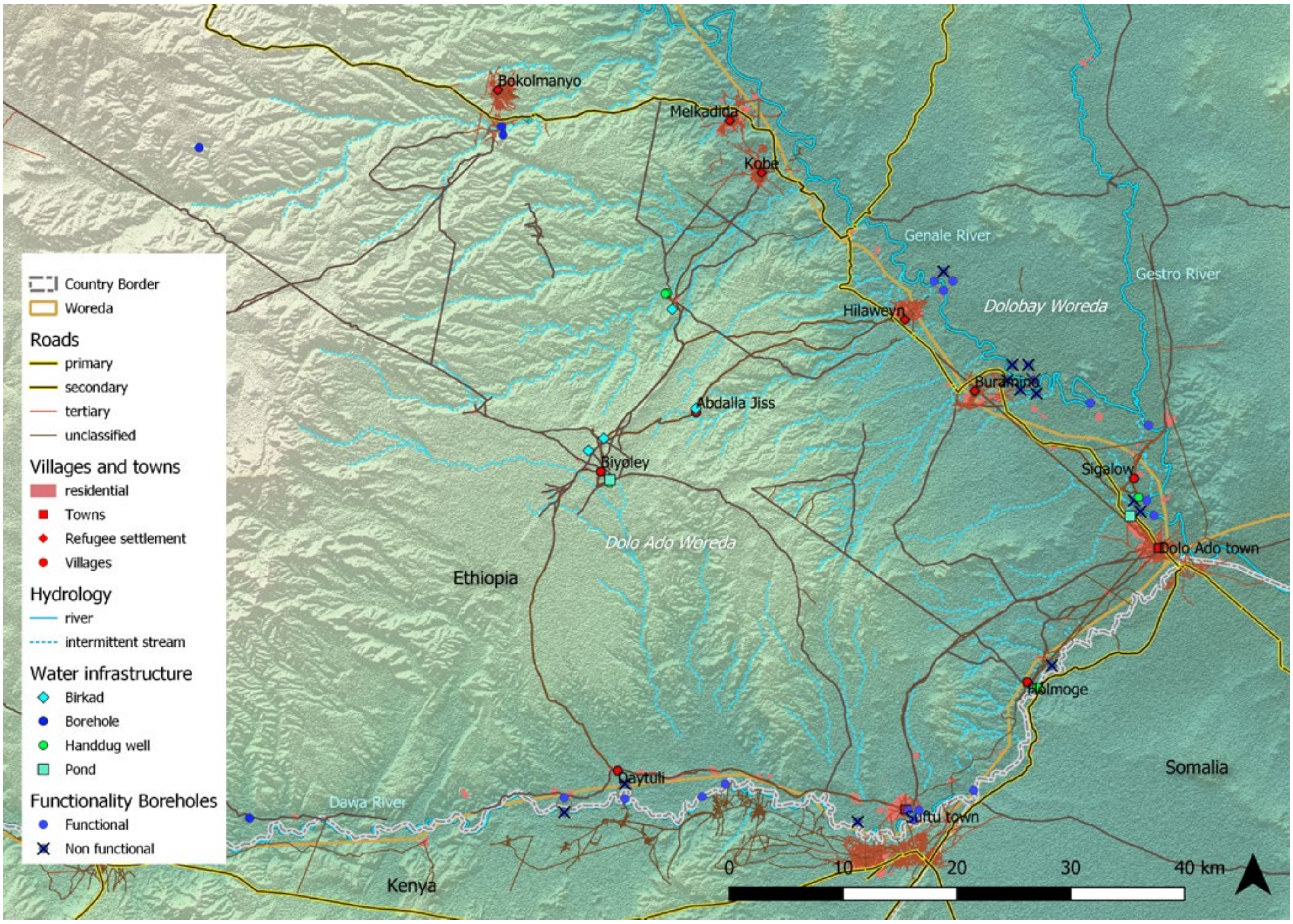


Figure 32. Known water infrastructure in the project area. In the central rangelands, birkads and (artificial) ponds are the main sources of water. These sources are often unable to provide a reliable water supply in both quantity and quality. Along the Genale and Dawa river shallow wells and a few piped water schemes provide water to the rural communities. Many of the improved water sources are non-functional. (Source borehole data: the GW4E project, Groundwater Mapping for Resilient WASH, 2019).

4.4.1 Piped water systems

The major parts of Dolo Ado town are connected with pipe extension from the water supply system in town. In the rest of the woreda, such bigger water supply systems don't exist. A few small piped water systems were visited during the field visit in January, but all were found to by dysfunctional or still under construction. For example in Washakbar town, a borehole was drilled 60 m deep and connected to a piped water system with an elevated tank of 20,000 liter (Figure 33), and from there distributed to a cattle trough and domestic water yard. Unfortunately, the system is not working now, according to the local community because parts of the distribution pipes, cables and wires were washed away by a flood three years ago and as a result the submersible pump fell into the borehole. During the field visit it was observed that the casing is also obstructed with a big stone. The system was operating/functional for just 6 months, but with a constant yield. The water quality could not be tested, but according to the community it was not completely fresh but good enough for domestic use. Prior to the construction, a geophysical assessment and test drilling was done by the national and regional government. In Holmoge, a borehole was drilled close to Dawa river with the plan to connect this borehole with a piped system to a water tank in town for water distribution. However, works are on hold and the community does not know when the project will be finished.

4.4.2 Boreholes

The Water Office of Dolo Ado Woreda is currently making a shift from putting focus on constructing new boreholes instead of birkad . According to the Water Officer, "birkads break, rely on rainwater and are not sustainable". Hence, the focus of the woreda is on boreholes. The procedure for siting and drilling boreholes is as follows:

- For sites along Genale and Dawa river, the woreda has information on potential sites. When they plan to drill a borehole they analyze the depth and salinity of alluvial deposits. In some places, especially along Genale river, they won't drill too deep ("We should not drill between 19 to 25 m"), to avoid reaching saline groundwater. At most sites wells are shallow, if you go deeper, it will be saline.
- Drilling boreholes in the centre of the woreda, away from the main rivers, is much more challenging. According to the Water Office, they still do not understand enough the geohydrological information. Currently there is a Godbokel study site, where the government program DRIB is undertaking a study for the Somali Regional government to check if they can drill up to 500 m depth. This is a geophysical study, with specialist from Somali region. This is still ongoing, so no results yet available.

Figure 33. Above: Elevated tank of 20.000 liter, part of the non-functioning piped water system of Washakbar village. Second: An elevated water storage tank is under construction in Holmoge village, to supply water from the COOPI-ECHO borehole once this is finished.

Figure 34. Third: The non-functional borehole at the Genale river bank, near Sigalow village. Below: the unfinished borehole near Holomoge village, at ~100 m from the Dawa river.

Figure 35. Above: Hand dug well on the edge of the pond near Biyoley village, protected from livestock with thorny bushes. Second: Hand dug well, lined with concrete, along the Genale River near Sigalow village.

Figure 36. Third: Artificial pond north of Dolo Ado town, used for watering livestock (goats and camels). Below: The earth dam on the northwest-side of the artificial pond of Biyoley town.

Proper maintenance and repair of the boreholes is also an issue. According to the Water Office small issues of boreholes can be solved by the woreda, but during the field visit, most boreholes outside Dolo Ado town were found to be dysfunctional.

Two examples of boreholes are shown in Figure 34. On the river bank, at ~5 m from the Genale river, a borehole was drilled (~26m deep) and constructed by the NGO OWDA one year ago. A piped water system (on solar energy) was installed but the water was reported to be too salty for domestic use. The submersible pump has been removed, but the solar panels are still in place and currently not used.

At ~20 m from the Dawa high water riverbank (120 m from the current river) borehole was drilled and the plan is to connect this borehole with a piped system to a water tank in town. The well is drilled by the NGO COOPI, funded by IRC and the ECHO project. The project started 2 years ago but is not yet finished. A donor sign already provides information on the project ("Emergency WASH response for drought affected communities living in Dollo Addo woreda of Liben Zone. Funded by ECHO, through IRC, implemented by COOPI"). The community does not know when the project will be finished. Water is reported to be 'fresh'. No field measurement could be taken. The well is said to be approximately 13 m deep.

4.4.3 Hand dug wells and scoop holes

Shallow hand dug wells are used all over Dolo Ado Woreda as effective water sources. These are holes dug by hand, sometimes protected with a lining, a concrete cover and/or thorny bushes to keep animals away from the well (Figure 35). During the dry season, when ponds and rivers or wadis dry, scoop holes are used to fetch shallow groundwater.

4.4.4 Ponds

No natural ponds are present in the area, but several human-made ponds were observed, which are used for water supply. Near Dolo Ado town, a pond was formed as a result of excavation works for road construction. This pond is used for livestock watering (not for human consumption) and was found to be heavily contaminated with excrements (Figure 36). In Biyoley town, a pond was created in a natural depression by blocking the outflow of a wadi with an earth dam (Figure 36).

Hafir dams are traditional surface water storage reservoirs, which may be either water holes in natural depressions, or where the capacity has been increased by excavation. Within Dolo Ado woreda, there is only one hafir dam, located at Makinajab village, which was not visited.

Water quality - Animal waste can pose several water quality concerns. Due to livestock watering and many water birds in the lake, the lake water is full with animal waste which is a source of microorganisms (e.g. bacteria, faecal coliforms, Cryptosporidium, Giardia). As such, human consumption of the lake water is a serious health concern and might result in waterborne diseases such as diarrhea. It is strongly advisable to provide chlorination systems combined with chlorination training and awareness to the community. A short term solution can be to boil the water before consumption. A safer source of water would be the use of the shallow hand dug wells on the edge of the lake. This shallow groundwater is less prone to contamination than the water in the lake. As these wells are recharged by groundwater, the fear of the community to finish the available water is unfounded. The groundwater table will drop during the dry season, as will the water level in the lake.

Water quantity - Most of the water in the lake is lost to evaporation. Construction of several birkads on the edge of the lake could be an option to prevent this. This would also improve the water quality. According to the community, there are no plans to install a birkad here, even though it is within 1 km from the village, which is the WHO standard.

Box 4. The Biyoley pond

South-east of Biyoley town, a sickle shaped earth dam of ca 300m long and 25-40 m wide was constructed by the community in 2008, as part of a 'Food for Work' program. The earth dam blocks the water and creates a lake that is connected through a channel with the nearby wadi. The lake is filled each rainy season with rain and in the event of heavy rainfall also with flood water from the wadi. The maximum extend of the lake is around 500 m long and 300 m wide, storing an estimated 75.000 m3 of water.

After the rains have stopped, the size of the lake reduces quickly until all water is evaporated. The water in this lake is used for domestic and livestock consumption as long as water is available. On the edge of the lake, several hand dug wells are constructed by the community, as well as some protected hand dug wells funded by COOPI. When questioned, the villagers say they don't use the water in the wells as long as the lake contains enough water, as "they want to preserve the water in the wells for periods of drought". Instead, villagers use donkey carts to fill jerrycans with lake water for human consumption. The villagers do not have the habit to boil the water before drinking, nor is chlorine available for purification.

No issues with salty water are reported in this area. At time of field visit, the hand dug well contains plenty of water with a measured Electrical Conductivity (EC) of 511 µS/cm, and the EC of the lake was measured at 314 µS/cm.

The lake itself is home to hundreds of water birds (including glossy ibis and white storks) and is also extensively used for watering of livestock (camels, donkeys). Due to the gully erosion, the recharging channel was cut off and the lake is no longer being recharged by the flood waters of the wadi, only by rain. As a result, the lake is drying quickly (evaporation is high).

4.4.5 Birkads

Birkads are traditional water harvesting ponds or cisterns which collect run-off water when it rains. Birkads are cement-lined underground water tanks, usually rectangular in shape and about 15m x 12m x 3m in size, that store rainwater which is captured in a water catchment. Depending on the size of the catchment area and the amount of surface runoff (excessive rain water that does not infiltrate), a birkad can be filled in only a few or even a single rainstorm(s). The birkads encountered in the project area were all communal, and covered to minimize the evaporation of the water. Meshed grids are used at the inlet to keep animals and materials out. Sediment traps at the inflow avoid siltation of the birkad. Only in Dolo Ado town some organizations or households from better-off income have a privately owned birkads, which are filled mostly with water from the piped water system or by truck.

Peak dependency occurs during the dry season between the Deyr rains (Oct-Dec) and Gu rains (Mar-June). In the end of dry seasons or when rains fail, birkads dry up and need to be filled with water collected elsewhere through water trucking (often done by the government or NGO's). Several of the birkads visited have problems with leaking water due to cracks in the cement-lined floor or walls. At some sites,

Figure 37. Left page above: Birkad in Washakbar with a volume of 600 m^3, constructed by Oxfam for the ECHO project. Left page below: Intake area of the the birkad in Washakbar collecting runoff from a hilly and rocky catchment. Right page above: The community of Abdalla Jiss uses two birkads as main sources of water, which were constructed by ZOA and COOPI. However, the water level in the first birkad is going down quickly as result of a big crack. Right page below: the water inside a birkad.

Figure 38. Rain Water Harvesting tank at the DRR centre of Daytuli community.

for example in Abdalla Jiss village, the presences of sedimentary rocks at shallow depth makes the construction of birkads a challenge.
Water quality in birkads is generally good. As the birkads are filled with the surface runoff of excessive rainwater, the EC of the water in birkad is often much lower (100-300 µS/cm) than the water in nearby wells and wadis (sometimes up to 3000 µS/cm). Compared to other (open) water sources, water temperature is relatively low, which is generally favourable for water quality. However, birkads can be susceptible to contamination if not well maintained. For example due to faecal contamination by livestock or humans in the catchment area, or if animals are able to enter the birkad. Thus, the use of water treatment mechanisms, such as adding chlorine or boiling the water, before domestic use is advised.

4.4.6 Water trucking

At the end of dry seasons and/or when rains continue to fail, most water sources (like birkads, ponds and shallow hand dug wells) dry, and non-riverine-communities have to access water via trucking operations, sometimes for several months. Over the years, water trucking in Dolo Ado Woreda has been carried out for free, either by the Government or humanitarian agencies.

The Water Office of Dolo Ado Woreda has two 20.000 liter trucks available in Dolo Ado town, but the great distance to some of the communities is a major challenge. These water trucks fetch water from a water source nearby the community in need, and use the water to refill birkads (or other water reservoirs). During a drought, pastoralists move from the central rangelands to the riverine communities, taking their herds with them. The elderly, young and lactating mothers stay behind in the village and depend on water trucking.

The distribution of water by water trucking can be unfair, as water is usually delivered to a central point, which means that access to it is on a first-come-first-served basis. This undermines any attempt to target the most vulnerable households, amounting to a situation of 'survival of the fittest'.

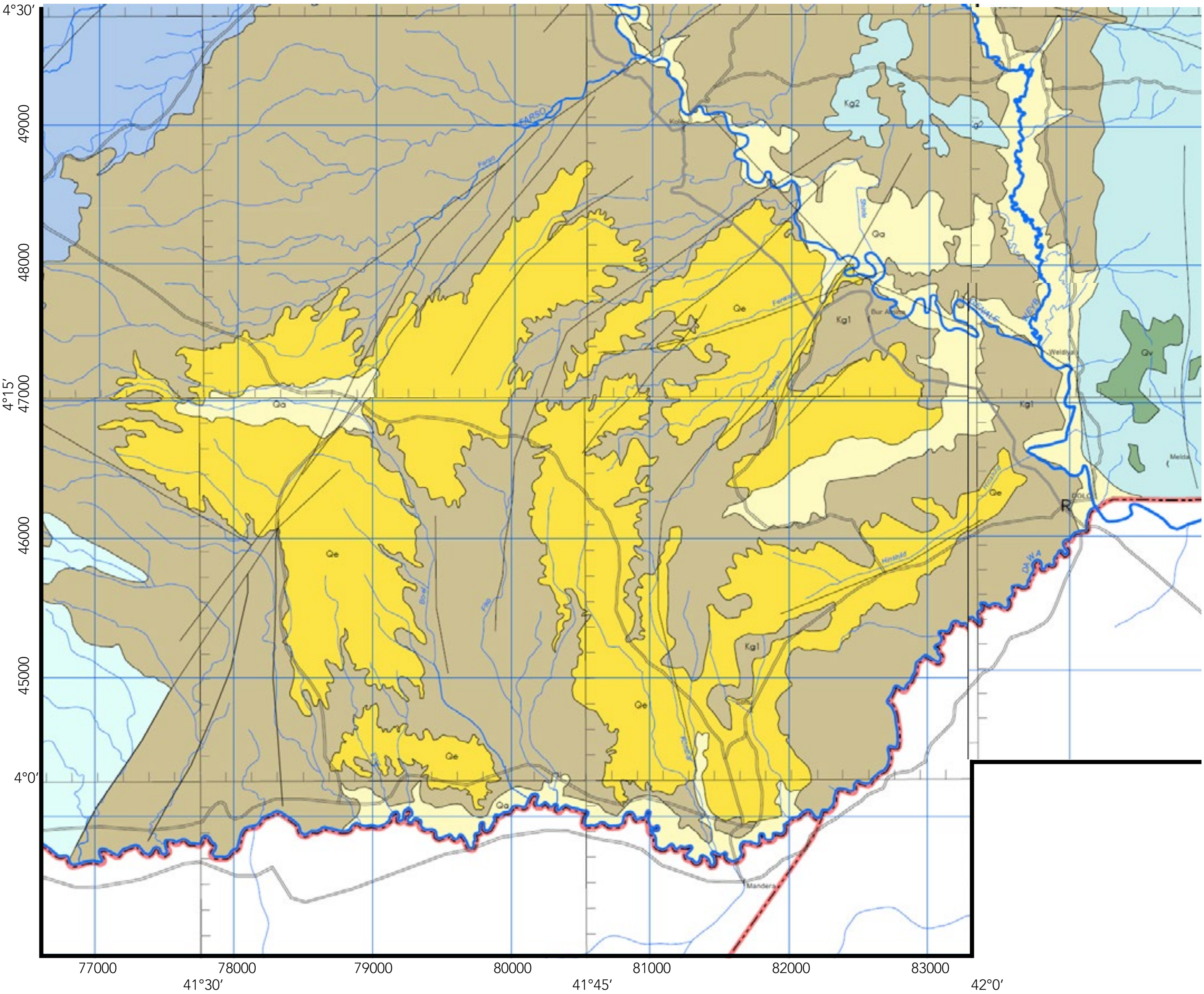
4.4.7 Rain Water Harvesting tanks

In Biyoley town (part of Biyoley kebele), a Disaster Risk Reduction (DRR) center has been constructed by RACIDA in partnership with the Biyoley community with funding from the European Union through Cordaid in the year 2018 under the RESET II program. Under the same program, a Rain Water Harvesting (RWH) tank was constructed at the nearby school.

4.5 Geology and groundwater potential

Figure 39 shows the Geological Map for the project area, which is reworked from the Genale-Dawa River Basin Integrated Resources Development Master Plan Study Project (2007), series GDMP-Geol250, part of Sheets GD-06 and GD-07.

Figure 39. Geological map of the project area (source: GDMP 2007)



Quaternary Volcanics and Sediments

Qa	Alluvial deposits: gravel, sand, silt and clay
Qe	Eluvium: Red to reddish brown sandy soil, black cotton soil, calcrite, minor ferricrite, silt and clay
Qv	Scoraceous-vesicular-olivine-phyric basalt

Mesozoic Sedimentary Successions

Jg	Gabredarre Formation: micritic to microcrystalline and oolitic limestones
Jh2 / Jh1	Hamanlei Formation: Lower unit (Jh1) less fossiliferous limestones with beds of calcareous sandstone and silt-stone, upper unit (Jh2) micritic, locally oolitic (grainstone), peletic limestones
Kg2 / Kg1	Korahe Formation: Lower unit (Kg1) dominantly sandstones with beds of dolomites, limestones, marl, shale, gypsum and anhydrites; Upper unit (Kg2) dominantly gypsum and anhydrites with beds of limestones, shales, marl and iron carbonate rock (siderite)

The distribution, movement and quality of groundwater in the soil and rocks is strongly linked to landscape's geological characterization. Groundwater follows pressure gradients often through fractures and conduits (i.e. natural 'pipes' in rock). Water quality is the result of the chemical, physical, biological and, at times, human interactions between water, soil, rocks and vegetation.

Shallow groundwater can be found near-surface, mainly in alluvial aquifers, reaching to a depth of 25-50 meter below ground level (m bgl). Deep groundwater can be found in sandstone and karstified (locally dissolved) limestones aquifers, and in conductive fractures in otherwise impervious rocks.

Unconsolidated sediments

Recent unconsolidated surficial deposits (loose sediment of both fluvial and eluvial origin) up to 10 meters thickness widely occur throughout the area. The lower reaches of the Dawa and Genale river valleys are filled with brown-grey sand, silt, clay and gravel deposits (alluvium of Quaternary age; Qa on the geological map), deposited on lowland plains and river banks or as recent channel deposits along small river/wadi channels. Material left on location as a result of dominantly chemical weathering of the underlying bed rocks (eluvium of Quaternary age; Qe on the geological map), cover most of the middle and high parts of the area. These residual deposits are of sandy (arenaceous from sandstones), silt (argillaceous from siltstones) and calcareous (from limestones) origin and are grey to brownish grey and reddish brown in colour.

The area is underlain by Mesozoic sedimentary sequences, but bedrock exposures are scarce, as the bedrock is for the most part covered by the Quaternary deposits. These recent surficial deposits cover most of the area, but only the more extensive and continuous developed surficial deposits are shown as Qa or Qe on the geological map.

Thin cover of calcrete, consisting of strongly calcite (sometimes iron) cemented rock fragments, occur commonly over the entire area. These calcrete occurrences form small patchy areas in the lowlands as hardened and compact carbonate concretions that locally reach 5 to 10 meters thickness (Figure 40).

The alluvial sediments that are found along the Genale and Dawa river form shallow but extensive aquifers. The permeability of the fine to medium grained sands is generally high and can form moderate to high productive aquifers. These aquifers are mainly recharged during periods of high river discharge, but in areas with many fractures, water may also originate from deeper aquifers. The sandy alluvium in Genale Valley and Dawa Valley has a high potential for shallow groundwater and can be exploited using shallow wells. However, aquifer productivity is often limited in the more isolated patches of alluvial sediments due to its shallow depths and limited lateral occurrence. At places where the alluvium consists of finer sediments like silt and clay, groundwater potential is much lower because of the lower permeability of silts and clays.

Also the eluvial deposits can form extensive aquifers, but due to high heterogeneity and a high content of clays and silts, the aquifer productivity is overall low. The local occurring calcrete is nearly impermeable and locally restrict the flow of groundwater and limit groundwater recharge through infiltration.

Figure 40. Occurrences of conglomeratic horizons of calcrete form small patchy areas in the lowlands as hardened and compact carbonate concretions that locally reach several meters thickness, as found in Wadi Sarole crossing the road between Kobe refugee settlement and Kole village (photo above) and on the wadi floor south of Biyoley village (photo below).

The alluvial sediments that are found along the Genale and Dawa river form shallow but extensive aquifers. The permeability of the fine to medium grained sands is generally high and can form moderate to high productive aquifers. These aquifers are mainly recharged during periods of high river discharge, but in areas with many fractures, water may also originate from deeper aquifers. The sandy alluvium in Genale Valley and Dawa Valley has a high potential for shallow groundwater and can be exploited using shallow wells. However, aquifer productivity is often limited in the more isolated patches of alluvial sediments due to its shallow depths and limited lateral occurrence. At places where the alluvium consists of finer sediments like silt and clay, groundwater potential is much lower because of the lower permeability of silts and clays. Also the eluvial deposits can form extensive aquifers, but due to high heterogeneity and a high content of clays and silts, the aquifer productivity is overall low. The local occurring calcrete is nearly impermeable and locally restrict the flow of groundwater and limit groundwater recharge through infiltration.

Shallow sedimentary rocks

The Quaternary alluvial and eluvial deposits (loose sediments) cover a sequence of sedimentary rocks of Cretaceous and Jurassic age. The upper unit of Cretaceous sedimentary rocks, known as Korahe Formation (Kg1 on the geological map), comprises of inter-bedding of sandstones (both calcareous and non-calcareous) with beds of dolomites, limestones, marls, mudstones, shales and evaporites (gypsum/anhydrite). Beds of evaporites are abundant in the upper section of the sequence (Figure 41), which makes groundwater locally brackish with high TDS, meaning it has a high content of total dissolved minerals (TDS).

Figure 41. Rock fragments of evaporites like gypsum/anhydrite can be found throughout Dolo Ado Woreda, recognizable by its crystal structure ranging in colour from white-grey to pink-red.

Figure 42. Beds of calcareous sandstones outcrop in Wadi Sagola at Washakbar, interbedded with shales (photo above). White salt crusts on the surface of the rocks in the riverbed originate from evaporation of the standing water (photo below).

These shallow sedimentary rocks are generally sub-horizontal to horizontal, forming cliffs at places where the bedrock is exposed. For example the hills near Kole village are remnants of erosion, consisting of inter-bedding of sandstones and mudstones with beds of evaporites and shales, which are slightly tilted towards the southwest. On the sides of Wadi Sagola at Washakbar, sandstones interbedded with shales outcrop. The saline conditions can be recognized by the presence of white salt crusts on the surface of the rocks in the riverbed (Figure 42).
The sedimentary rocks of this formation form extensive and thick aquifers, but due to the low occurrence of fractures and/or karstic features, overall aquifer productivity of this formation is low. In addition, the occurrence of evaporites results in high salinity of the shallow groundwater (GDMP, 2007).

Deeper sedimentary rocks

At depths of 50 m and below, sedimentary rocks of Upper Jurassic age can be found, known as the Gebredare formation (Jg on the geological map). This formation has a thickness of 350m to 430m (GDMP, 2007) and consists of thinly bedded limestones with intercalations of shales, marls and evaporites in the upper section. Because of most of the cracks and open spaces in these rocks are not connected with each other, this formation has generally low permeability and aquifer productivity. Due to the occurrence of evaporites, groundwater is generally brackish. The potential of the aquifer is highest in areas where the formation is fractured.

The underlying unit of Middle Jurassic age are marine sedimentary rocks, known as Hamanlei formation (Jh on the geological map). The permeability of this formation is moderate to high and the thickness of the unit reaches up to 720 m with deep water table and water quality is generally good.

Basement is a metamorphic rock that underlays sedimentary formations. Basement rock is generally impervious resulting in a very low groundwater potential. In the area, the basement can be found at several hundreds of meters depth.

4.6 Groundwater occurrence

Overall groundwater recharge is low with 26 – 50 mm of rainfall per year and in the eastern part of Dolo Ado Woreda where the four micro-catchments are located groundwater recharge is even < 25 mm/yr (source: GW4E project). Limited groundwater recharge does not allow major groundwater occurrence in the area, particularly at higher grounds. A groundwater recharge of 25-50 mm/year could sustainably support a limited number of 1 to 2 m3/hour-boreholes for small settlements in rural areas. Close to Genale River and Dawa River, where sandy alluvium predominates, shallow groundwater concentrates due to high permeability and the low elevation. It is well possible that abstractions of up to 10 m3/hour are possible in these areas. All numbers are indicative. Before investing in groundwater abstraction infrastructure additional in-depth studies are needed, such as hydrogeological assessments and geophysical investigation.

In the lower areas, groundwater occurs in the alluvial sediments along the Dawa and Genala rivers. These alluvial sediments have moderate to high suitability for shallow groundwater abstraction. The alluvial sediments get major recharge from flood waters overflowing it's river banks and from lateral seepage from the rivers. The unconsolidated sediments along the major wadi's in the area contain smaller patches of groundwater, which might be suitable for domestic use if fresh.

Overall groundwater occurrence is low in the sandstones of the upper 50 m due to the relative low occurrence of fractures and/or karstic features. In addition, the occurrence of evaporites results locally in high salinity. In the deeper sedimentary rocks, at depths of 50 m and below, groundwater occurs principally in the fractures and karst features of limestone formations. As there are no deep boreholes in this area, not much is known about the occurrence of deep groundwater and the actual aquifer productivity. The thick formation of several hundreds of meters of limestones with intercalations of shales, marls and evaporites generally has a low permeability and aquifer productivity. The underlying marine sedimentary rocks could be moderate to high productive but are beyond the reachable depth for economic drilling within the context of rural water supply. An additional uncertainty is the salinity of the groundwater; often fresh groundwater in these type of aquifers exists 'pockets' of fresh water within the overall saline groundwater.

4.7 Water quality

Low water quality has multiple and severe impacts on livelihoods. The time spent on fetching water is high, water-borne and water related diseases such as diarrhea and malaria are prevalent, and the recurrence of losses of crops and livestock is high. In Dolo Ado Woreda, water quality is a major problem. Boreholes provide generally safe water, but there are few and often dysfunctional or abandoned (Figure 34). Water quality in the river beds declines during the dry season, and is prone to contamination (e.g. due to free roaming cattle). As the water level lowers in the bed, less and less water is available, and the taste and smell deteriorate. In turn, water from ponds is very susceptible to contamination, especially because of livestock entering the facilities (Figure 36). Shallow wells are generally safer, if protection measures to keep livestock out are in place (Figure 35). Most of the birkads in the project area are covered, and have a silt trap, which both lowers the risk of contamination as well as the loss of water through evaporation. However, the use of other water treatment mechanisms, such as adding chlorine or boiling water before safe domestic use of the water is advised.
The quality of the water fetched from birkads can also be improved by installing a locally manufactured low cost and easy to maintain horizontal filter, inlet hose with a float, and rope and washer pump system to lift the water (Oxfam).

No wastewater treatment or sewage system is in place in the urban areas in for example Dolo Ado town (Woreda Water Office), so water sources are at risk of contamination. Due to a lack of sanitary facilities and activities, waterborne diseases can be spread via groundwater when contaminated with faecal pathogens from pit latrines (Figure 43).

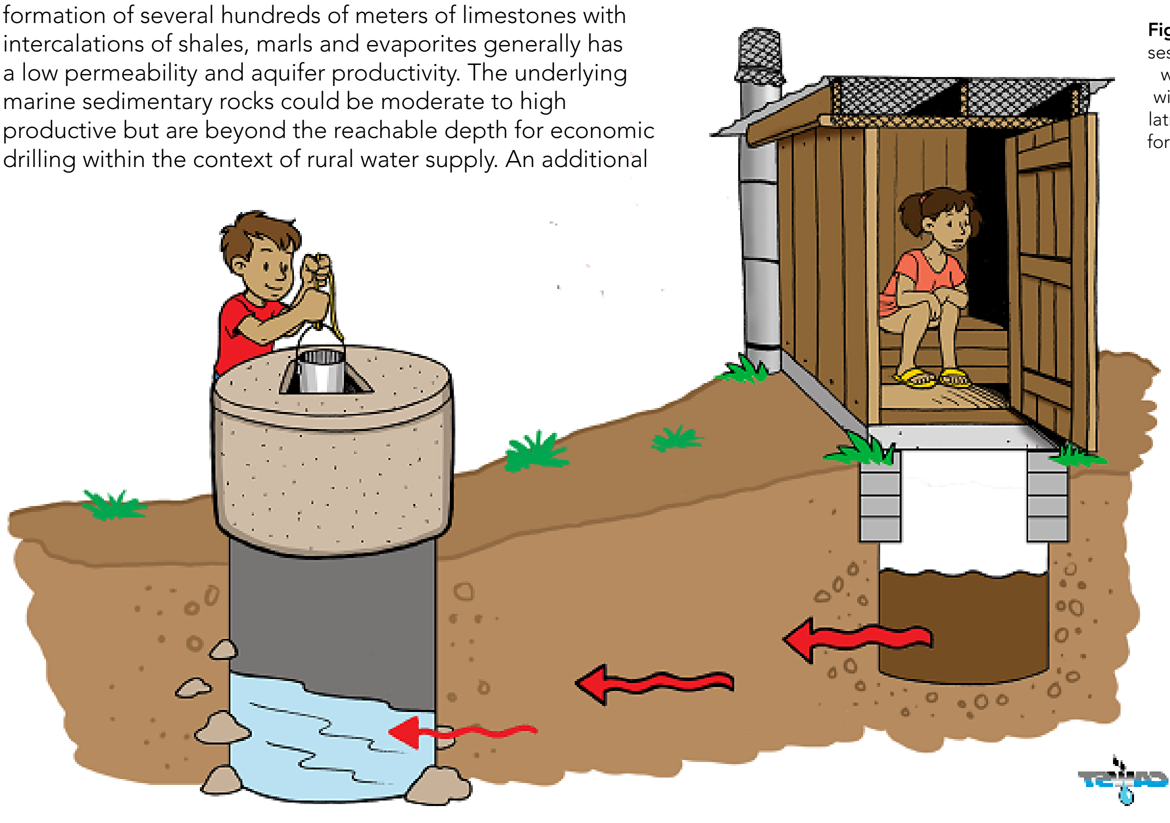


Figure 43. Waterborne diseases can be spread via groundwater which is contaminated with fecal pathogens from pit latrines (source: Centre for Affordable Water and Sanitation Technology).

4.8 Towards a more robust water supply

Access to safe and clean water is limited in Dolo Ado Woreda. Boreholes and piped water systems are the predominant source of domestic water in towns; in the rural area villagers collect potable water from wadis (as long as fresh water is available), birkads, ponds and scoop holes. Field observations indicate that large percentages of the water infrastructure are non-functional due to either design, construction or maintenance problems. Despite efforts of the Woreda Water Office on rehabilitation of water points, a continuous and safe water supply cannot be ensured in many places.

A high percentage of water sources are not working and will require urgent rehabilitation works to reduce imminent pressure to those other water schemes that are currently functioning as well as minimizing needs for water trucking. Functionality of improved water schemes in Dolo Ado Woreda is also low due to lack of effective operations and management capabilities, lack of proper organizational structures and incentives, and/or poor borehole siting and design in the first place. Many communities therefore resort to water collection from unsafe sources such as traditional birkads and open shallow wells, or fetch the water directly from surface water sources as (artificial) ponds and rivers, by means of scoop holes when dry.

One of the main priorities of the Woreda Water Office for the coming years is to work on a more 'sustainable water solution' by shifting from traditional birkads construction to borehole drilling (interview Water office). This is in itself a good idea, but requires a better understanding of the local hydrogeological characteristics, combined with proper borehole siting and -construction. There is some potential for deep groundwater, but borehole depth and yields are highly dependent on the degree of weathering and fractures in the sedimentary rocks. An additional challenge is that in many places groundwater is brackish due to intercalations of evaporites (anhydrite/gypsum) within the sedimentary rocks. A better hydrogeological understand and proper borehole siting is thus a must. Locally, for example in the alluvial deposits along the Genale and Dawa river, the potential for shallow groundwater is high.

Water availability could also be improved through the large scale implementation of small scale water recharge and retention measures tailored to the local conditions and geography (e.g. sand and subsurface dams, water harvesting from roads, gabions, infiltration galleries in sandy ephemeral streams and wadis), strengthening of water use associations and improved siting and construction of boreholes. Further, when implementing infrastructure, in-depth understanding and full-consideration of pastoral livelihoods is needed.

Irrigation is one means by which agricultural production can be increased to meet the growing demands in Ethiopia. The government of Ethiopia is interested in the development of irrigation sites along the Genale river. About 85 irrigation potential sites are identified in the basin by a study of IWMI in 2007. Most of the potential sites are upstream of Buramino. The construction of large-scale reservoirs and dams for irrigation would affect water availability downstream. It is recommended that possible effects of large-scale reservoirs are researched well before implementation.

Recommendations

There is a need to further develop and promote low cost water technology such as shallow wells, sand and subsurface dams, solar and hand pumps. Nevertheless, the functionality, safety and accessibility of the water sources and its infrastructure should receive as much attention.

Improving the water availability is more than just drilling another borehole. It is possible to produce potable drinking-water at community-level with the right mix of techniques for protecting and improving water quality along the chain. Community-level technologies for conserving and treating rainwater can work in extremely different environments. A range of options are needed to mix and match to suit different contexts. Besides good engineering skills, strong community involvement is needed to enhance the design and construction, and to provide feedback on technology which is essential for innovation success.

To improve the sustainability of water infrastructure it is recommended to pay more attention to participatory planning, design and construction, and consider protection and maintenance of the infrastructure from the very start of programs and projects onwards. It is also recommended to improve the protection of sources through a combination of improved hardware and soft measures (regulations, by-laws), pay more attention to siting, and hire technical expertise so that the sustainability of structures is increased.

5. Landscape restoration

5.1 Rationale of landscape restoration for DRR

The degradation of ecosystems – such as forests, wetlands and drylands – is a major driver of disaster risk and a key component of disaster vulnerability. Disaster Risk Reduction (DRR) is a framework to ensure that disaster is avoided and resilience is achieved. Ecosystems such as forests provide a range of ecosystem services that help not only to secure livelihoods and well-being of communities, but also reduce disaster risk. Hence, Eco-DRR is the sustainable management, conservation and restoration of ecosystems to reduce disaster risks, with the aim to achieve sustainable and resilient development.

Well-managed ecosystems, such as wetlands, forests and coastal systems, act as natural infrastructure, reducing physical exposure to many hazards and increasing socio-economic resilience of people and communities by sustaining local livelihoods and providing essential natural resources such as food, water and building materials. Ecosystem management not only offers an opportunity to strengthen natural infrastructure and human resilience against hazard impacts, but also generates a range of other social, economic and environmental benefits for multiple stakeholders, which in turn feed back into reduced risk.

The effectiveness of ecosystem restoration interventions is strongly dependent on landscape characteristics. Selection, siting and design of these interventions is not straightforward. In this chapter, the functioning and benefits of ecosystem restoration are clarified, the suitability for implementing different types of measures is per landscape zone is shown and discussed.

Figure 44. Four main categories of ecosystem restoration interventions.

5.2 Types of interventions

Four main categories of ecosystem restoration interventions can be distinguished based on their functioning, location in the landscape and main purpose. See also Figure 44 above and Table 8 on the next page.

- **Protection and management** refers to the active protection of ecologically sensitive and valuable areas, so that these can recover and achieve their full-potential in terms of ecosystem system services provided. Experience shows that control or even exclusion of agricultural activities, grazing of livestock and collection of natural products from degraded areas stimulates the germination of seeds, promotes seedling survival and allows vegetation to grow faster. These developments can be supported by implementing erosion control structures, planting trees and disposing urban waste(water) in a safe manner. Protection and restoration are best implemented by communities, as implementation and enforcement are to a large extent dependent on communal efforts. Examples of interventions include riverbank protection, area closures and forest management.

- **Soil and water conservation (SWC)** targets the conservation of soil, water and related natural resources on agricultural land, the land used to produce food, forage, fiber and other products. Soil and water conservation measures are often directed primarily to either soil or water conservation, but most contain an element of both. Water conservation mostly entails the implementation of land use changes, farming practices or physical structures, which often also counteract erosion. Similarly, soil conservation usually involves improving soil properties, reducing erosion, crust formation or breakdown of soil structure, all of which also increase infiltration and hence contribute to water conservation. Examples of SWC-techniques include mulching, contour bunds, trenches and permanent crops.

- **Off-stream water storage** includes many typical water recharge, retention and reuse (3R) interventions. Off-stream water storage includes all on-land interventions that collect water from surface run-off for storage in either open or closed reservoirs or in the ground. Rock catchments, birkads and ponds are examples of off-stream water storage interventions.

- **In-stream water storage** aims at water storage in riverbed sediments of seasonal rivers (shallow groundwater) or in open water reservoirs build across flow accumulation areas (surface water). As with off-stream water storage interventions, these are typical water recharge, retention and reuse interventions aimed at collecting runoff during the rainy season to make it available in dry periods. An additional advantage of water storage in riverbed sediments is that water quality is improved, so that it is relatively safe for domestic use. Examples of in-stream water interventions include sand dams and subsurface dams, gabions and valley dams.

Table 8. Categories of ecosystem restoration with a specification into types of interventions belonging to each category.

Types of interventions	Categories of interventions	Explanation and examples	Benefits	
			To local users	**To the catchment**
Protection and management	**Riverbank protection**	Protection of riverbanks and flooding areas against overgrazing, arable farming, tree cutting and water erosion. In the case of artificial reservoirs also protect the inflow area.	Erosion control, increased production of forage and other natural products.	Improved groundwater recharge, flow regulation, biodiversity, (micro) climate regulation.
	Area closure	Protection of an area against degrading activities, such as grazing, agriculture and/or tree cut-and-carry systems and fruit harvesting are allowed. Sometimes closures function as back-up grazing area for emergencies. The closure can be realized by fencing or by (community) agreements.		
	Forest management	Agreements on sustainable use or forest areas, including controlled harvesting of wood and other natural products. Increasing the ecological and socio-economic value through tree planting, wildlife management, control of invasive species, etc.		
	Rangeland management	Agreements on grazing patterns, assignment of wet/dry season and emergency grazing areas, sustainable wood harvesting, wildlife management.		
	Urban water and waste management	Collection and safe disposal of waste(water).		
	Discourage agriculture	Limit agricultural practices in these areas. Ensure that in crop production areas due measures are taken to control erosion.		
Soil and water conservation	**Basic SWC**	Mulching, grass strips, soil bunds.	Higher yields, more reliable yields. Possibility to produce crops with a higher market-value.	Improved groundwater recharge, water flow regulation and soil formation increased biodiversity.
	SWC to control wind erosion	Tree planting, tree strips (wind breaks), life fencing, agroforestry.		
	SWC for slopes	Terracing, contour bunds, contour ploughing, tied ridges, grass-strips, contour trenching.		
	SWC for very steep slopes	Stone structures above ground such as stone bunds, trenches, hillside terracing, check dams, tree strips.		
	SWC for weak soils	Soil moisture managment, mulching.		
	Conservation agriculture (CA)	The three main CA principles are: minimal soil disturbance, permanent soil cover and crop rotations.		
	Permanent agriculture	Production of permanent crops such as fruit trees, nut trees, tea and coffee.		
	Flood-adapted agriculture	Produce crops outside the flooding period, or flood resistant crops. Apply flood control interventions, such as soil bunds and diversion ditches. Apply spate irrigation or floodwater spreading.		
	Biological interventions	Revegetation, afforestation, reforestation and protection of trees. Planting of species that promote soil stability. Controlled grazing.		
	Erosion control structures	Small and larger scale structures constructed with manual labour to control erosion, such as gabions.		

Types of inter-ventions	Categories of interventions	Explanation and examples	Benefits	
			To local users	To the catchment
Off-stream water sto-rage	Hafir dams	Also known as valley tanks. Larger excavatoins for water storage on flat to gently sloping lands.	Improved wa-ter availability	Groundwater recharge, flow regulation
	Ponds	Small natural depressions in which runoff concentrates (sometimes made impervious to prevent leaking.)		
	Hill-side dams	Small hill-side half-moon shaped embankments on medium-steep slopes used to promote infiltration and store water.		
	Rock catchments	Open water reservoirs build to trap water coming of bare rock areas.		
	Birkads	Underground cisterns dug out and lined to store water, keep it cool and (when covered) prevent evaporation.		
	Managed aquifer recharge	Infiltration of surface water intro an aquifer via infiltration wells to store water and improve its quality		
	Roof rainwater harvesting	Use of suitable roof surface - tiles, metal sheets or plastics - to intercept rainfall, and conduct it to a storage tank.		
In-stream water storage	Check dams	Small dams accross a waterway that counteract erosion by reducing flow velocity.	Improved water availability and water quality	Groundwater recharge, flow regulation
	Micro-dams	Very small open water reservoirs consisting of a wall (earth or concrete) in a narrow valley aimed at storing water.		
	Valley dams	Small open water reservoirs consisting of an earthen or concrete wall on a concave location to store water.		
	Sand dams	Reinforced concrete walls across seasonal rivers capturing coarse sediments, thereby storing shallow groundwater.		
	Subsurface dams	Reinforced concrete walls across seasonal rivers that store shallow groundwater.		

Each category of interventions has its own purposes, strengths and weaknesses. Whether interventions aim at improving vegetation cover and biodiversity, promoting soil formation, storing water or any other purposes, the rate at which this happens differs per category and even per specific intervention. For example, where small water tanks store small volumes to bridge a short dry period, large surface storage and particularly groundwater storage can help to bridge an unusual dry year or a series thereof.

Landscape characteristics dictate which ecosystem restoration interventions are most suitable for a certain location. Contour bunds and terraces, for example, can be best applied on cultivated slopes, whereas sand dams can best be applied in areas where sandy seasonal streams with shallow hard rock are available.

Figure 45. Stones (flat and/or rounded) are naturally present in the landscape of Dolo Ado Woreda. These can be used for construction of landscape interventions such as stone bunds or gabion weirs.

5.3 Landscape restoration opportunity

At a different level, land use and cover are strongly linked to landscape characteristics and as such provide a useful system to analyse the ecosystem restoration suitability map.

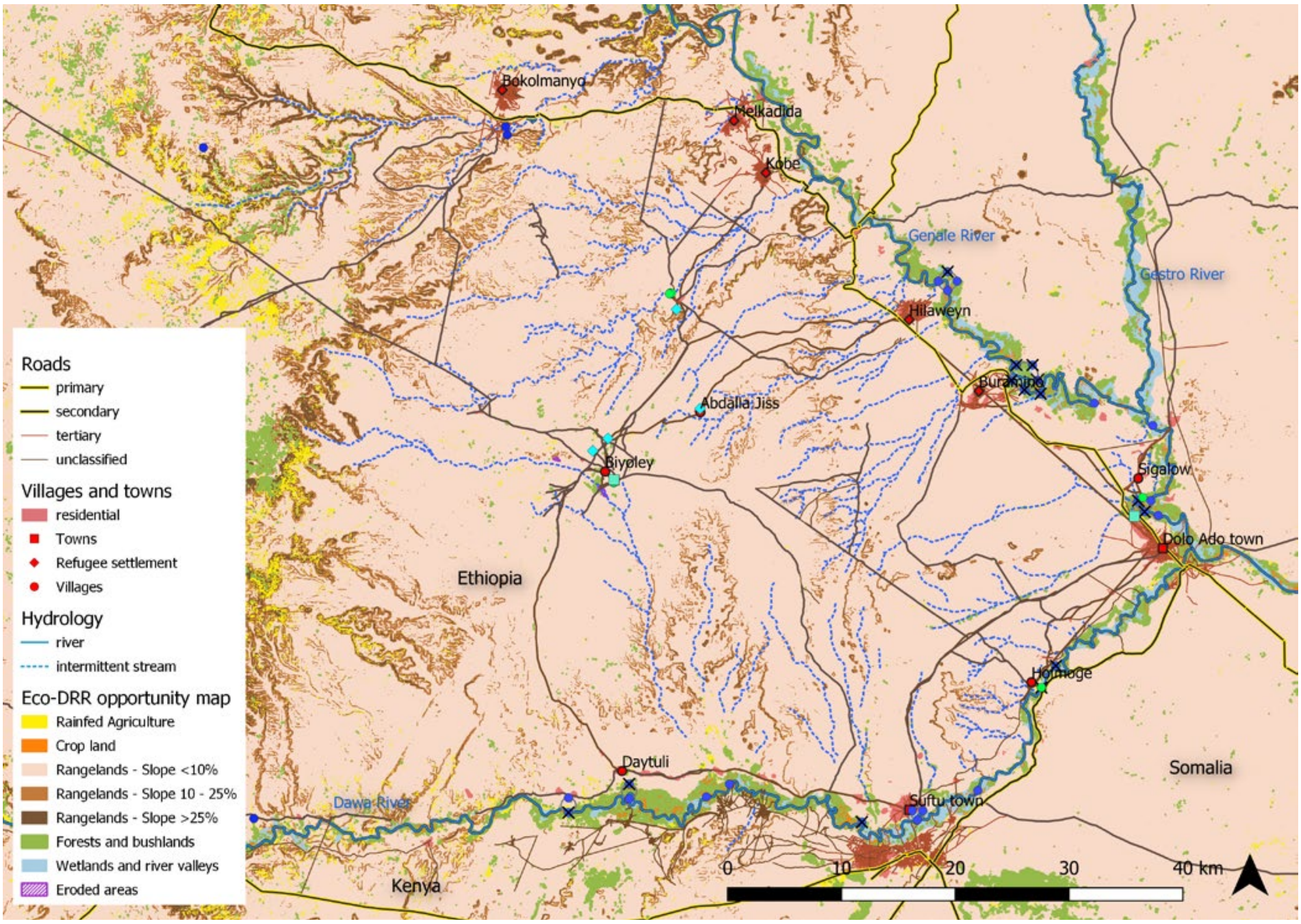


Figure 46. The Eco-DRR opportunity map for implementation of interventions. The colors on the map correspond to **table 9.**

Rainfed agricultural lands

These lands are mostly located in the central rangelands where runoff water is collected. Soils are limited suitable for agriculture due to low soil moisture holding capacities. Crop production is feasible if suitable soil and water conservation (SWC) measures are implemented. Mulching, tree and grass strips, life fencing (Figure 47) and agroforestry are recommended. The SWC measures will prevent erosion of top soil and increase water availability in the soil. Covering the soil after the rainy season with dry grass or leaves will reduce evapotranspiration from the soil and improve water availability in the root zone. Hence, implementation of these measures will lead to higher crop-yields and lower vulnerability to short-term droughts.

Crop lands

The crop lands along the Dawa and Genale river provide good soils for agriculture. Flood adapted agriculture and SWC measures as well as overland storage (e.g. flood water spreading or spate irrigation) are recommended. Flood adapted agriculture could be switching more to flood resistant crops, such as mango trees. The difficulty for the farmers is coping with different types of flooding and the unexpected timing. Crops with a shorter growing season (early maturing varieties) could be selected to ensure harvest before the flooding season. As a strong flood is likely to occur once every few years, a community flood-proof seed storage facility could make re-sowing after a flood event more easily. Agroforestry and area enclosures should be promoted for highly flood-prone areas. Agroforestry is an approach to improve soil moisture conditions and reduce runoff on agricultural land. Area enclosures should be used for severely degraded (eroded) areas to ensure recovery of vegetation, so grazing activities can be allowed after several years.

Low levels of excess water on cropland can be drained if there is somewhere for it to go, or a storage pond could be dug at the lowest part of the garden/farm to store surplus water and allow it to soak into the subsoil slowly. The pond should be filled with stones or gravel to prevent mosquitoes breeding. SWC measures are recommended as well as more water-efficient irrigation practices than furrow irrigation. Currently many pumps on generators are collecting water from the rivers, contributing to the overexploitation of water resources.

Rangelands

As with arable lands the recommended interventions in rangelands are strongly related to slope steepness and soil texture. Except for the very steep slopes where a replacement with forestry is recommended, rangelands could be kept as grazing lands as long as measures against overgrazing are implemented. To combat erosion and more importantly, slow down surface runoff to reduce flooding downstream, the focus for physical structures such as contour bunds (e.g. soil or stone/ rock bunds) and contour trenches should be on the upstream areas of villages, agricultural and communal lands troubled by gully formation and flash floods. These physical structures will buffer rainwater and promote vegetation growth. In the gully itself permeable dams, such as gabions weirs or check dams, could be installed to prevent further wearing of the gully and to reduce surface runoff as flash floods, but to slow down the runoff water and let it infiltrate into the soil. To sustainably manage the widespread rangelands, mostly governance interventions are required, such as agreements on grazing patterns (not on eroded sites), rotations and migration routes, assignment of dry season and emergency grazing areas, and protection of trees. In this regard area enclosures, harvesting of branches with protection of the main tree as well as cut-and-carry systems could be promoted. With proper protection and management vegetation cover will probably quickly recover, resulting in an improved availability of fodder for livestock and lower erosion rates.

Forests

Existing forest and bushland should be conserved, if needed by (guarded) protection and/or (life) fencing. On gentle slopes, forest and bushland can be used for fodder collection and grazing. Also, agroforestry could be considered. In all instances, preservation of the natural ecosystem functions should prevail. Forest management and a ban on tree-cutting (in specific areas) are essential to this end. Existing vegetation should be kept in place as much as possible so as to keep its soil and water conservation services. Non-degrading activities, such as grass cutting, fruit harvesting and bee keeping are recommended.

Wetlands and river valleys

The riverbanks of the Dawa and Genale river should be kept stable to reduce the chance of riverbank erosion during flooding or fast river flow. These riverbanks provide fertile soil for agriculture, but crop production on the riverbank itself loosens the soil. After harvest, the soil is bare and unprotected from fast flowing water. It is better to close the riverbanks (a ~20m buffer zone from the river itself) for agriculture and keep under natural vegetation or crop production with permanent vegetation cover (e.g. mango trees). Community tree nurseries for seedlings such as mango could be set up to provide easy access to seedlings and employment (of youth).

Built-up areas

In built-up areas, particularly around towns and refugee settlements, solid waste and wastewater pollution could become a problem, especially with the expected increase in population and economic development. Concentrated settlements also put pressure on the functioning of ecosystems in close-by areas, as they lead to overexploitation of resources (for example though firewood collection). In the towns and large settlements, it is recommended to focus on urban water management, including recycling where possible, and waste management to prevent further pollution of the landscape. In smaller settlements, woodlots and life fencing could help wood and charcoal requirements.

Eroded areas

Eroded areas should be fenced and protected so that vegetation gets time to recover. Gullies often originate in areas where water, silt and organic matter accumulate. As such, conditions for plant growth are relatively good. If left undisturbed, natural vegetation will in most cases easily recover. Attention should be paid that also the upstream part of the erosion gully is included for vegetation recovery. To speed up the process biological interventions, such as tree planting, and physical interventions, such as gully plugs, could give natural vegetation a head start. After recovery, gullies should be managed in a way comparable to forest areas.

Zone	CHARACTERIZATION		RECOMMENDED TYPES OF INTERVENTIONS			
	Current land use	Slope and stream specifications	Protection and restoration	Soil and water conservation (SWC)	Off-stream water storage	In-stream water storage
A1	Rainfed agriculture	All slopes	-	SWC measures	Hafirs, ponds, hillside dams	
C1	Crop land	All slopes	Forest management	SWC for flat soils and slopes, permanent agriculture, flood- adapted agriculture	Hafirs, ponds, Micro-dams	
R1		Slopes <10%	Rangeland management	Biological interventions	Hafirs, ponds, birkads	
R2	Rangelands	Steep slopes (10-25%)	Rangeland management	Biological interventions	Hill-side dams, birkads	
R3		Very steep slopes (>25%)	Area closures	Biological interventions	Rock catchments	
F1	Forests / bushlands	All slopes	Forest management, area closures	-		
W1a	Wetlands/ River valleys	River valleys, occasionaly flooding	Riverbank protection	Basic SWC, flood-adapted agriculture	Managed aquifer recharge, hafirs	
B1	Built-up areas	Towns	Urban water and waste management	Biological interventions	Roof rainwater harvesting	
B2		Settlements	Forest management	Life fenching	Roof rainwater harvesting, birkads	
E1	Eroded areas	Severe gully erosion	Area closures	Biological intrventions, erosion control structures	-	
	Streams	Wadis	Riverbank protection	Biological interventions, erosion control structures		Check-dams, (small) valley dams, (leaky) sand dams
		Rivers	Riverbank protection	Biological interventions		Check-dams, (leaky) sand dams, valley dams

Table 9. Interventions recommended in the different ecosystem restoration suitability zones.

5.4 Beyond the project horizon: institutionalization

The results that are presented in this baseline assessment should be institutionalized by all relevant target groups. This is recommended at three different scales: (1) at plot level, for example by farmer field schools, (2) at community level, for example by community training, and (3) at the local government level, for example by including these results in the catchment planning of the River Basin Authorities or Woreda offices action plans. In this it is especially important to institutionalize the conservation of areas with all different stakeholders, and community activities should focus on awareness, training and mobilisation.

Currently there is no Dawa-Genale River Basin Development Office (Basin Authority) or Catchment Committee established. To implement the proposed action plan on a wide scale, it is recommended that the Ethiopian government establishes a Basin Development Office and local branch office to support the activities. In the action plan it is important to:

- Ensure government support, policy development, institutionalisation
- Establish critical catchments and micro-watersheds
- Delineate intervention areas and prioritize
- Carry out activities for community mobilisation
- Adapt existing technical watershed management guidelines and ecosystem intervention guidelines to the local context

Figure 47. Life fencing (green hedges) supports SWC by reducing wind erosion.

6. Conclusions

Dolo Ado Woreda, Somali Regional State in Southern Ethiopia, is a disaster prone area where the rural communities heavily depend on natural resources. Communities are troubled by frequent droughts and floods, and these hazards result in food and water insecurity, disease and conflict. Hazards lead to disasters when the vulnerability of a system is high and its coping capacity low. Strategic ecosystem restoration and implementing landscape interventions targeting water security, food security and disaster risk reduction is key to building community resilience. To select the most effective interventions a good understanding of the landscape is essential. Based on an integrated assessment of the biophysical and socio-economic background, climate data, land cover and landuse, ecosystems and water resources, the major challenges and opportunities are explained. The assessment was based on a literature study, satellite imagery and GIS analyses, field surveys, focus groups discussion and interviews with key informants. This mapbook supports implementation by presenting a biophysical and socio-economic background and showing the potential for ecosystem based disaster risk reduction (Eco-DRR).

6.1 Challenges

The findings show that the core problem is at the level of natural resources management. Livelihoods and lifestyles are changing due to outside influences: from pastoralism to agropastoralism, with increased sedentarisation and dependency on humanitarian aid, while still being heavily dependent on natural resources. Increasing pressure from rapid population growth (influx of refugees and high birth rates) has resulted in higher food and water demand in Dolo Ado Woreda, further increasing pressure on all natural resources. The weakening of traditional resources management in absence of good alternative systems results in environmental degradation and, therewith, in the loss of resilience of the landscape. This resilience is further under pressure of a changing climate. Models of future climate projections show that Dolo Ado Woreda will remain highly susceptible to flood events. More rainfall is expected in the catchment, which creates higher river water levels during the two rainy seasons, making the area more susceptible to flooding from the river breaking its banks. Additionally, increased local rainfall will create more and stronger flash floods.
Dolo Ado Woreda should face the challenge to capture this rain water in the landscape before it reaches the rivers, to improve water availability and vegetation cover in the dry season. Disasters are becoming more frequent and intense essentially because the natural system is not optimally functioning to provide DRR.

There are several clear overarching challenges that are compounding to environmental degradation:

- Increased pressure on all natural resources, due to a rapid increasing demand for food, pasture, water and materials. The water buffering function is decreasing, soil qualities being lost, rangeland production decreasing, and the availability of natural products (such as wood) are dropping. Ecosystem services relate on a one-to-one basis with the resilience of the system. The loss of these services directly results in a higher risk of disasters.

- The impact of periods of low rainfall has increased, as the capacity of the landscape to buffer water has been lost to degradation. Overgrazing, deforestation and expansion of agriculture all contribute to the challenge.

- Water availability is low and access to safe and clean water is limited. This is partly due to the natural occurrence of saline groundwater which troubles siting new water sources and large abstraction rates. Also a lack of spare parts and incorrect operation and maintenance creates non-functioning water infrastructure.

- High climate variability in combination with a heavy dependency on rainfall forms a fragile balance. Prolongation of the Jilaal (long) dry season results in water shortages for domestic use and watering of livestock. A slight delay, or unexpected intermittency, of the Gu or Deyr (short) rains can result in total crop failure. Climate change projections indicate an increase in rainfall, more intensive rainfall events and more erratic rainfall patterns in the future. In light of these changes it will become even more important to restore the water regulation capacity of the landscape.

- Natural resources management (NRM) systems are not functioning optimally. Traditional NRM systems are weakening, while alternatives are not fully functional. There is a lack of technical capacity and shortage of monitoring data to base decision making upon. The linkages between policies, plans and frameworks, and stakeholders' needs and demands could be stronger; and the coordination and dialogue between government agencies, implementing organizations and communities could be strengthened. Awareness is just starting in communities. The larger part of the people still need information to understand the urgency for Eco-DRR. Therefore they need access to appropriate extension services in a timely manner.

6.2 Opportunities

Challenges and opportunities are often linked. Stressing the linkages between the multiple challenges and opportunities, the long and short term benefits, and the impacts at landscape and community levels is important to ensure ownership and stewardship, and thus to achieve impact at scale. For example:

- Disaster risk reduction can best be achieved through integrated resilience building. Hazards are a given, but do not necessarily lead to disasters. Flooding from the Genale or Dawa river breaking its banks, for example, is difficult to challenge but its effects can be mitigated with an improved early warning system. And erratic rainfall cannot be avoided, but its effects can be mitigated, for example by income diversification. By implementing ecosystem restoration and management, stakeholders take better control over the landscape and degradation can be slowed down or even reversed. Restoration of ecosystems is possible through improved land use, conservation of key-ecosystems and recharge, retention and reuse measures, in its turn increasing ecosystem services such as water regulation and food provision. The Eco-DRR opportunity map for implementation of interventions (Figure 47) shows that there are multiple opportunities.

- The potential to improve access, availability and quality of water is high. Because water access is rather a problem of seasonality and lack of water harvesting and infrastructure than insufficient rainfall and water resources, increased water storage could provide an enormous increase of water availability during the dry period.

- There are many possibilities to protect nature and to implement landscape interventions to reduce flood risk and improve water availability. Early Warning Committees and DRR Committees are already active in communities. Current adaptation strategies are also already practiced in Dolo Ado Woreda on small scales (such as trenches and area closures), though in general the focus is still too much on disaster response instead of disaster prevention. This mapbook shows that it is important to prioritize rainwater buffering in the landscape to reduce flood risk and improve water availability on the long term.

- Current adaptation strategies already practiced in Dolo Ado Woreda include trenches, area closures for pasture conservation, reforestation and roof water harvesting. The regional government is supporting and promoting reforestation. The institutional setting could be further strengthened to uphold planning, use and management of natural resources.

6.3 Recommendations

Impact at scale can only be achieved through the implementation of coherent and widespread interventions. It is recommended to start working towards integrated natural resources management, based on the Ecosystem based disaster risk reduction approach. This approach should be based on factual knowledge, mobilize all stakeholders and be institutionalized as early as possible.
The project team urges all stakeholders to invest more in strengthening natural resources management, at all spatial and temporal scales. This mapbook makes a case for communities, governments and NGOs to invest in small-scale measures, rangeland and forest management, sustainable farming practices, and soil and water conservation measures.
To effectively reduce disaster risks, the overarching challenges have to be tackled in an integrated manner. Improved natural resources management is crucial and should be at the core of any approach. High value ecosystems such as forests and wetlands should be protected, and ecosystem services of rangelands and agricultural lands should be expanded and managed, so that resilience is build and hazards can be prevented from turning into disasters.

Upscaling Eco-DRR through integration in existing planning and risk management processes can prevent drought, diseases and conflict over water sources. This involves critical short-term and long-term adaptation measures. For Dolo Ado Woreda, prioritization should be at buffering rainwater in the landscape.

- **Capacity building.** To efficiently deploy the available resources, it is recommended to start with knowledge and capacity building on systems thinking, integrated NRM and Ecosystem based Adaptation. Strengthening governmental and non-government extension services and effectiveness of front-line staff is an important step. Trainings and workshops should be designed for field-staff, policy makers and decision makers.

- **Visioning.** To improve planning and coordination visioning will be important. Through multi-stakeholder participatory planning, community engagement and fact-based decision-making, goals and objectives should be defined, and priorities set. The involvement of local institutions and stakeholders, embedding in the existing institutional setting, consideration of traditional practices and alignment with ongoing plans and initiatives will be crucial at this stage. Visioning will support the development of sustainable and effective land and water management strategies and support the selection of technically feasible and socially supported interventions.

- **Multiplication and expansion.** To create impact, widespread implementation of measures is needed and this can only be achieved if measures are implemented, maintained and replicated by the users of the landscape, i.e. through self-motivation. To enable this, direct incentives other than cash or food for work are required. This can be achieved through the identification of direct benefits to communities (e.g. higher water availability, improved access to fodder, food and wood during emergency situations, additional sources of income), combined with awareness raising, coordination, mass mobilization and capacity building. Ecosystem restoration provides a great opportunity to reduce disasters on the long term, but requires a joint effort, especially where it concerns the adjustment and enforcement of policies and regulations.

- **Strengthening the enabling environment.** There is a dire need for policy adjustments, regulatory measures, coordination and dialogue, and the integration of traditional management practices into governmental guidelines. In this sense the advice is to invest in catchment management plans, and a simple monitoring network. Also, it is recommended to improve the access to data and information, for example, through the establishment of a knowledge centre, in which all relevant databases, reports and guidelines are gathered.

- **Selection and design of measures and expert involvement.** Measures are most effective when hard and soft measures are combined. On farmlands, physical structures such as soil bunds, trenches and terraces can be effective, but only if ownership of the intervention is with the farmer. In rangelands the focus should be on awareness raising and management, including agreements on controlled grazing and special conservation areas. In severely eroded areas the focus should be on biological conservation measures, such as closure areas that allow the regeneration of trees and vegetation and the plantation of seedlings. Priority should be given to the protection of high-value ecosystems, such as riverine areas, wetlands and forests. Water storage for domestic and livestock watering purposes should be designed to bridge a period of approximately five months, the duration of the Jilaal (long) Dry season. Soil moisture conservation and measures enabling complementary irrigation are especially important during the Hagaa (short) dry season. More in general, all measures toward regulation of water flows and recharge of groundwater resources will have a positive impact on water availability.

- It is recommended to hire expert knowledge to supervise siting, design and construction tasks. In addition, it is important to make clear arrangements for operation and maintenance to keep infrastructure functioning.

The way forward

This Regional Baseline assessment Mapbook of Dolo Ado Woreda informs strategic planning and decision making. Building resilient livelihoods in Dolo Ado Woreda is feasible. The refugee-host community relations within the woreda are exceptionally positive, the communities are willing to work on Eco-DRR and are already familiar with the concept, and the government and NGOs are very willing to contribute. Multiple small but practical ecosystem based interventions, in parallel with improved coordination, capacity building and monitoring, good steps can be set towards more sustainable and effective natural resources management and, therewith, towards a more resilient system with increased water and food security and disaster risk reduction.

An integrated approach that addresses underlying causes is recommended. A main focus should be on capacity building to self-motivate users to manage the landscape in a sustainable manner and reach scale. Efforts can best be a combination of soft ecosystem restoration measures (regulations, capacity building, coordination etc.) and hard measures (e.g. bunds, trenches etc.). Hard measures are less effective in the long term if not combined with soft measures. Community mobilization, participatory decision-making and involvement of experts is crucial towards developing sustainable strategies at community level to reverse the degradation trend.

Four target kebeles within Dolo Ado Woreda have been selected for this project's implementation phase. In close consultation with Cordaid and RACIDA, a selection was made of the hydrological micro-catchments linked to the kebeles, for which a detailed intervention plan will be developed. The detailed implementation plans will showcase landscape restoration in the four target kebeles (Biyoley, Abdalla Jiis, Sigalow and Holmoge), which will be implemented by Cordaid and RACIDA.

Capacity building. To efficiently deploy the available resources, it is recommended to start with knowledge and capacity building on systems thinking, integrated NRM and Ecosystem based Adaptation. Strengthening governmental and non-government extension services and effectiveness of front-line staff is an important step. Trainings and workshops should be designed for field-staff, policy makers and decision makers.

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