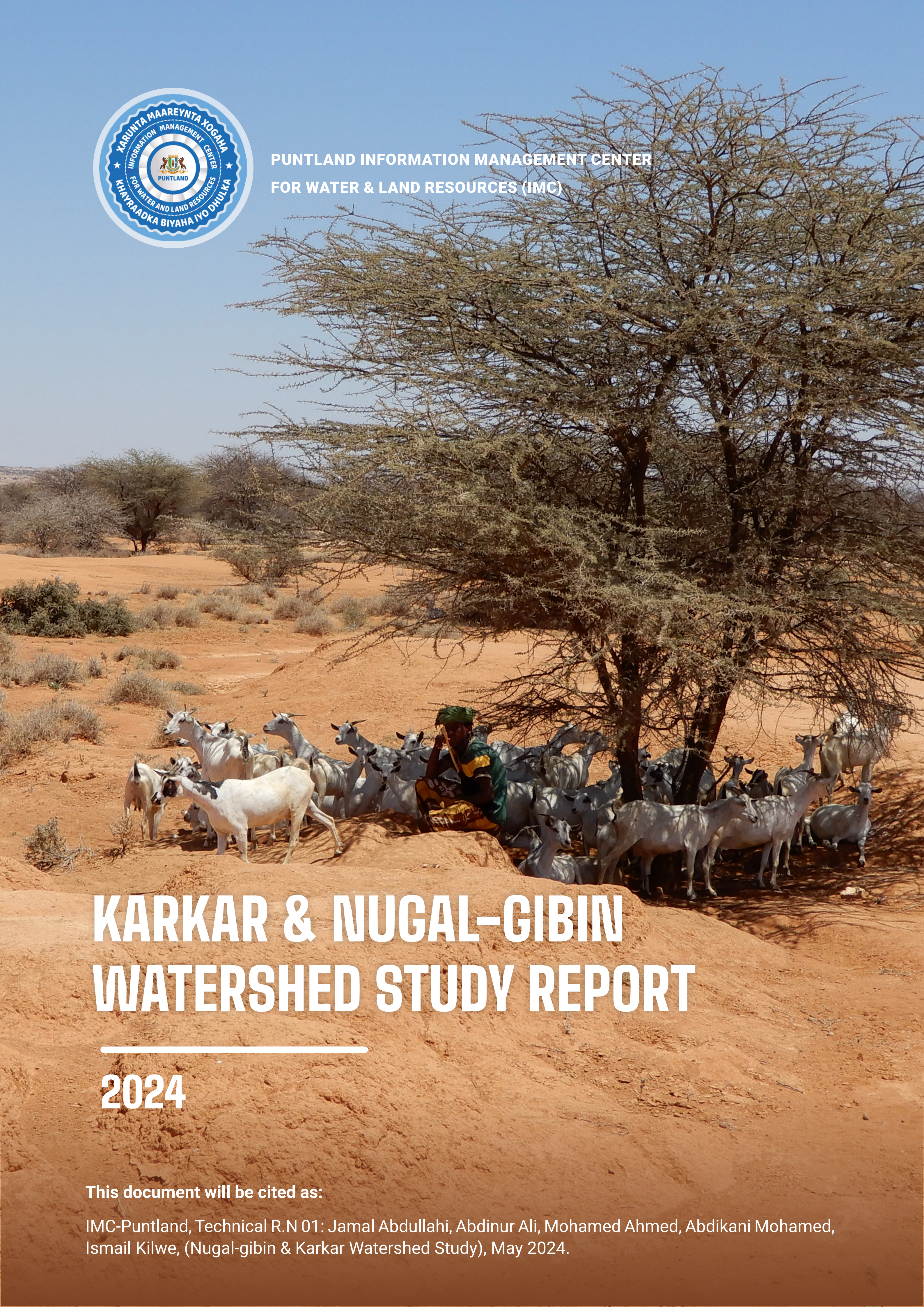

PUNTLAND INFORMATION MANAGEMENT CENTER
FOR WATER & LAND RESOURCES (IMC)

KARKAR & NUGAL-GIBIN WATERSHED STUDY REPORT

2024

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List of Abbreviations

DEM	Digital Elevation Model
ET	Evapotranspiration
FAO	Food and Agriculture Organization
SWALIM	Somalia Water and Land Information Management
GI	Galvanized Iron
GIS	Geographic Information System
GPS	Global Positioning System
IDPs	Internal Displaced People
ILWRM	Integrated Land and Water Resource Management
IMC	Information Management Center for Water & Land Resources
ITCZ	Inter-Tropical Convergence Zone
LCCS	Land Cover Classification System
LCCS3	Land Cover Classification System Version 3
LTA	long-term average
LULC	land use and land cover
MoAI	Ministry of Agriculture and Irrigation
MoEMW	Ministry of Energy Mineral and Water
MOERCC	Ministry of Environment Range and Climate Change
MoHADM	Ministry of Humanitarian Affairs and Disaster Management
MoLAH	Ministry of Livestock and Animal Husbandry
MoPEDIC	Ministry of Planning Economic Development and International Cooperation
M.S.L.	Mean Sea Level
NPK	Nitrogen Phosphorous and Potassium
ODK	Open Data Kits
QGIS	Quantum Geographic Information System
RS	Remote Sensing
SLM	Sustainable Land Management
TV	Television
WAL	Water and Land

Forward

The “Karkar & Nugal-Gibin Watershed Study Report” represents a pivotal step in advancing the sustainable management Puntland’s water and land resources. This study is a reflection of our collective commitment to addressing critical environmental challenges, fostering resilience among local communities, and enhancing decision-making for sustainable development. By analyzing the unique characteristics and vulnerabilities of the Karkar and Nugal-Gibin watersheds, this report contributes invaluable insights into land use, land cover, water resource management, and the impacts of climate variability.

The Puntland Information Management Center for Water and Land Resources (IMC), in collaboration with the Food and Agriculture Organization (FAO-SWALIM), undertook this study with support from WAL line ministries and community members. We are deeply grateful for the unwavering commitment and dedication of the field teams, including female interns and technical staff, who actively contributed to data collection, analysis, and interpretation. Their hard work has not only enriched the quality of this report but also demonstrated the importance of empowering women in environmental research and governance.

This report also underscores the critical role of partnerships. The involvement of district mayors, community respondents, and technical advisors from FAO-SWALIM exemplifies the power of collective action in tackling complex environmental issues.

The findings of this study bring to light pressing challenges such as land degradation, water scarcity, and the adverse effects of climate change. These issues threaten the livelihoods of the local population, predominantly reliant on pastoralism and agriculture. The study provides actionable recommendations, including sustainable land and water management practices, rehabilitation of degraded areas, and capacity building of government staff. These interventions are essential for safeguarding the watersheds and ensuring long-term resilience and prosperity for the people of Puntland.

We trust that this report will serve as a cornerstone for informed decision-making, policy formulation, and resource allocation. It is our hope that the insights and recommendations presented herein will inspire stakeholders at all levels to take decisive action toward sustainable watershed management in Puntland.

Together, let us work towards a future where Puntland’s natural resources are preserved and its communities thrive in harmony with the environment.

Abdinur Ali Jama
Director General

Puntland Information Management Center for Water and Land Resources

Acknowledgement

The Puntland Information Management Center for Water and Land Resources (IMC) and Food and Agriculture Organization, Somali Water and Land Information Management (FAO SWALIM) worked tirelessly to implement watershed mapping in Nugal-gibin (Dangoroyo), Karkar (Qardho), and Hayland (Dhahar). IMC would like to thank all institutions and individuals who contributed to the project, including village respondents and farmers for their warm welcome and support. Grateful to the district mayors of Qardho - Abdikadir Said Qaal, Dhahar – Bashir Mohamed Isse, and Dangorayo – Mohamed Farah Muse (Jooge) for the welcome and support to the survey teams throughout data collection.

We would like to convey our heartfelt gratitude to FAO SWALIM for funding, technical support, and supervision throughout field data collecting, ensuring the team has the ability and skills needed to meet the target objectives.

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The successful completion of the watershed study project was greatly facilitated by the guidance and aid of Ugo Leonardi-Technical Advisor SWALIM along with the oversight and backing of Flavian Muthusi (Hydrologist), Okumu Nakitari(ILWRM Project Coordinator) , Stephen Waswa(Information Management) , Japhet Kimeu(Land Resources Officer), Michael Makokha(GIS Specialist), Bernad Onyango(GIS Developer), Osman Abdule(SWALIM Liason-Puntland), Mohamed Gees (Information Management), and Bakhita (Operations) of SWALIM. Their leadership and support were instrumental in ensuring the smooth execution of this project.

Executive Summary

The aim of the study was to analyze and map the Nugal-gibin and Karkar watersheds by identifying existing land use and land cover (LULC), assessing land degradation and mapping water sources distribution with an aim of enhancing decision-making to guide sustainable interventions, as well as to bolster the capacity of government staff in understanding pre-watershed management activities.

Purposive sampling was employed to select 64 sample sites which represented various forms of gully erosion, land cover and water sources in the study area. The methodology involved desk reviews, field data collection through interviews, direct observations, and measurements. Data analysis utilized both qualitative and quantitative methods, employing tools of Google Earth Engine, ArcGIS, and QGIS.

The study uncovered several environmental challenges induced by climate change including inadequate rainfall, Increased temperatures, and decline in livestock and crop production due to diseases, poor management of land and scarcity of water resources. Other issues identified included unsustainable land management methods (overgrazing, over cultivation, and unplanned urbanization) gully erosion threatening rangeland ecosystems, and loss of biodiversity.

The study identified 24 gully formations, the majority of which are continually growing as a result of poor interventions such as poorly designed rockpile structures, increasing runoff intensity, and top soil loss.

The effectiveness of the intervention (rock piles, gabion, and soil bunds) techniques appears unsustainable due to the fact that gullies continue to expand and the stock-rockpiles have been impacted by the high intensity water flow, despite the fact nine of the twenty-nine erosion features have had interventions.

The study confirmed the most predominated land cover types in the both watersheds is natural and semi-natural vegetation, characterized open to sparse shrubs, sparse trees, and open to closed herbaceous. Additionally, there are small portions of irrigated crop fields within the Karkar watershed. the major land use practices of the both watersheds are nomadic pastoralism, irrigated crops, urban and rural settlements.

The study revealed that the primary water sources for the two watersheds are Berkeds, which fall significantly short of meeting the communities' water needs, especially during prolonged dry seasons. Berkeds often deplete within the first month following the rainy season due to overwhelming demand, leaving communities highly vulnerable to water scarcity. During these dry periods, boreholes become the main water source; however, access to these boreholes is limited for many communities, further exacerbating the challenge. Additionally, most agricultural activities in the watersheds depend on dug wells for irrigation. These wells are particularly susceptible to drought as water table levels drop significantly during extended dry spells, further threatening the sustainability of agricultural livelihoods.

This critical water scarcity underscores the urgent need for strategic interventions to improve water accessibility, diversify sources, and enhance the resilience of both communities and agricultural systems in the watersheds.

The study suggests for urgent interventions for the two watersheds by implementing sustainable land management practices such as soil and water conservation to address gully formations and prevent further degradation of the land resources. Water resources interventions such as rehabilitation of existing water sources such as Berkeds, Hafır dams and boreholes, as well developing natural springs. In terms of food security, good agricultural practices, adoption of drought tolerance crops, sustainable crop management practices such as crop rotations, disease surveillance and prevention and livestock treatment are urgently required.

Key words: Watershed Management, Land Use and Land Cover (LULC), Water sources, GIS and Remote sensing, Gully erosion, Climate Change, Food Security.

1. Background and Purpose of the study

A watershed is “that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course” Geographer John Wesley Powell. While there isn’t a single, universally accepted definition for the phrase “watershed,” it can be simply defined as an area of land where water flows to a common location, forming a hydrological basin”. For the purpose of this study, the term “watershed” is used to refer above of 50,000 hectares, encompassing the specific scale of the two watersheds under investigation (Singh, N., 1994).

The Karkar and nugal-gibin watersheds are crucial to the livelihoods of the Puntland population. These areas are known for their extensive grazing lands, believed to sustain the majority of the district’s livestock. They supply essential water resources to downstream communities, attract a wide range of biodiversity, support thousands of livestock species, and play a key role in the local economy.

Watersheds are important to the life cycle, but they also face many obstacles to sustainability, such as the depletion of natural resources, the deforestation and scarcity of water, ineffective farming and grazing methods, and extreme weather conditions like erratic rainfall and high temperatures. Several challenges have been raised that pose a threat to the success of watershed management. Among these are inadequate mapping and information gaps that make it difficult to decide on the best course of action for successfully tackling the problems. Furthermore, the watershed’s land use and cover have changed significantly due to population growth. The two watersheds’ food security deteriorated as a result of climate change variability, such as a reduce in rainfall.

Thus, the purpose of the study is to provide information on LULC, existing water sources, status of land degradation, and the watersheds’ climate variability and change, and investigate how communities adapt to the shocks from floods and droughts.

IMC Puntland collaborated with FAO SWALIM and WAL line ministries to undertake a two-week watershed mapping in Nugal-gibin and Karkar watersheds. The information provided is intended to be acquired to contribute better in terms of decision making and improve adequately planning watershed ecosystems intervention in the future. This data will contribute to informed decision-making and improved planning for interventions in the watershed ecosystems.

2. Objectives of the study

2.1. Primary objectives

The primary objective of this study is to collect data on LULC, land degradation and water resources Additionally, the study aims to examine the impact of land degradation on land cover, land use, and community livelihoods within these watersheds, as well as the influence of climate variability on community well-being.

2.1.1 Specific objectives

The specific objectives of watersheds study are:To determine the types of land use and land cover in the two watersheds.

- To assess the types and extents of land degradation, interventions and evaluating the effects on rangeland and community's livelihoods
- To identify the existing water sources within the watersheds.
- To analyze the impact of climatic variability and change on the watersheds.
- To strengthen and enhance the capacity of government officials working in the field of land and water resources, notably considering gender equality by promoting gender inclusion.

3. Materials and Methodology

Quantitative and qualitative data were collected with the aid of open data collection platform Kobo toolbox assisted by field notes such as a field survey manual which was prepared by a collaborative effort of FAO-SWALIM, IMC and the line ministries to provide detailed instructions and guidelines for the survey team including Land cover photo keys. This manual served as a reference document during the data collection process, ensuring consistency and accuracy in the field data collected.

Desk Review

The IMC and line ministries team conducted review on existing and the available literature including IMC and SWALIM databases.

Remote sensing data (Satellite data)

A supervised land cover classification system using medium resolution satellite-driven data from Sentinel 2 was used for the mapping of the land cover in the watershed study.

Topographic data was applied using Digital Elevation Model (DEM) of 30 m resolution to produce slope and Elevation Maps of the watershed. Additionally, interpreting satellite images was undertaken to get a preliminary understanding of the area's features and characteristics.

Geographic Information System (GIS):

which is a computer system used to capture, store, analyze, and display geographic data. It's used to integrate data from remote sensing, field surveys, and other supplementary sources to create meaningful maps.

FAO Land Cover Classification System Version 3 (LCCS3), has been used to guide a methodology for Land cover classification.

Field data collection:

Two weeks field survey was conducted to collect data on land cover, Land use, existing water sources and Climate variability and that was aimed to validate the results obtained from remote sensing analysis. This survey involved the assessment and ground truthing of 64 preselected sample sites. Before the field data commenced preliminary land cover maps of the two-watersheds, as well as selected field sample sites, and study area was printed in color of A3 laminated paper, and distributed to the field teams to assist them in field data collection. For the data collection forms were developed and built into the Kobo Collect tool. This tool was utilized by field team on their mobile phones to collect information.

Direct Observations:

Direct observations were employed to facilitate the timely and effective collection of data that supports decision-making and response validation. In particular, gullies, interventions, and other natural resource management mechanisms were verified through direct observation.

Sampling Techniques:

This study employed purposive sampling techniques. The number of samples selected were 64 sample areas, of which 38 sample locations were in Karkar and 26 sample locations were in Nugal-gibin.

The sample site selection criteria included accessibility, land cover representativeness, existing water sources, land use systems of the watershed, climate susceptibility and relevance to the study purposes.

Data Analysis:

Quantitative data was gathered through on-site interviews using the open-source platform Kobo Toolbox which allowed for offline data collection through a structured survey form. This method of data collection enabled the minimization of data inconsistencies and data loss thanks to the channeling of data through programmed answer sets. After field data collection, the data was validated daily. Hence, the field team cleaned the data and proceeded to the analysis of the datasets through Microsoft excel, qualitative analysis and GIS&RS using desktop GIS tools; ARC and QGIS and cloud computing platform; google earth engine.

3.1. Selection Criteria of the two watersheds

The below criteria was used to select the watershed study area:

Criteria	Description
Accessibility (Distance from Major paved roads, towns etc.):	• The proposed watersheds (Nugal-gibin & Karkar) are located with and around 30 km far from the main road connection between the Major towns of Bossaso, Qardho and Garowe.
Vulnerability of climate shocks (History of flooding, drought, locust infestation):	• It has dry streams namely Sinujiif and Kalyaxeed, Bilcil and Bixin in Nugal-gibin watershed and consider flood plain called Baarwayn. • In Karkar, most of the watershed has flood plains with limited dry streams Like Kubo. • Qardho as part of Karkar watershed is the most affected site for devastating flash floods due to the Kubo stream cross the town with poorly management of water flow path when it passes to inside of the town. • The flood of this stream carries huge sediment, it deposited around Sinujiif village which has several hand-dug wells utilized for domestic and Livestock drinking. • The floods destroy the dug wells during raining season of the year. • The present flood plains reflect a dense grazing activities. • Frequent droughts (3 to 4 consecutive seasons of rainfall deficit in every 5 years) occur in both watersheds.

Livestock population:	• Pastoralism, the practice of extensive livestock herding, is the major economic activity and livelihood for many of the communities living in both watersheds. • Rural livelihoods are largely dependent on products from rangelands. Camels and goats browse the thick thorny bushes **(Shrubland),** sheep and cattle prefer the lush pastures of grasslands **(Herbaceous vegetation).** • Trees and shrubs provide wood for energy, livestock feed, medicines and to some extent timber, food, and shelter.
The extent and types of land degradation (including soil erosion – rill and gully)	• During selection, a preliminary mapping of gully erosion was conducted for both watersheds as part of key objective to address this phenomenon with watershed management and information production activity of IWLRM II Project. • Gully and rill erosions as a major threat to livestock herding and then watersheds communities' livelihoods. • Erosion results in the loss of ecosystem services, and thereby in the loss of natural resources (**Soil fertility and plant growth**) that are vital to local communities. • As watershed resource maps (Land & Water) depicts the main factors driving soil erosion were Wind and water erosion factors which led rill and gully erosion acceleration that increasing gradually in the area.
Limited Data availability (hydro-met, soils, land use/cover, etc.):	• Information gap for water and land resources
Population density (reasonable size of the population – in the sub watershed:	• Both watersheds have medium population with three Major towns/city districts (Dangorayo, Qardho and Dhahar).

Table 1: Selection criteria of the two watershed

3.2. Study Limitations

The study limitations includes:

- The time allocated for data collection was inadequate for gathering thorough and detailed information on water sources, including the total number of Berkads and dug wells. However, the visited water sources are representative sample of other water sources.
- The study also coincided with a dry period whereby communities occupied with other priorities such as migration in search of pasture and water.

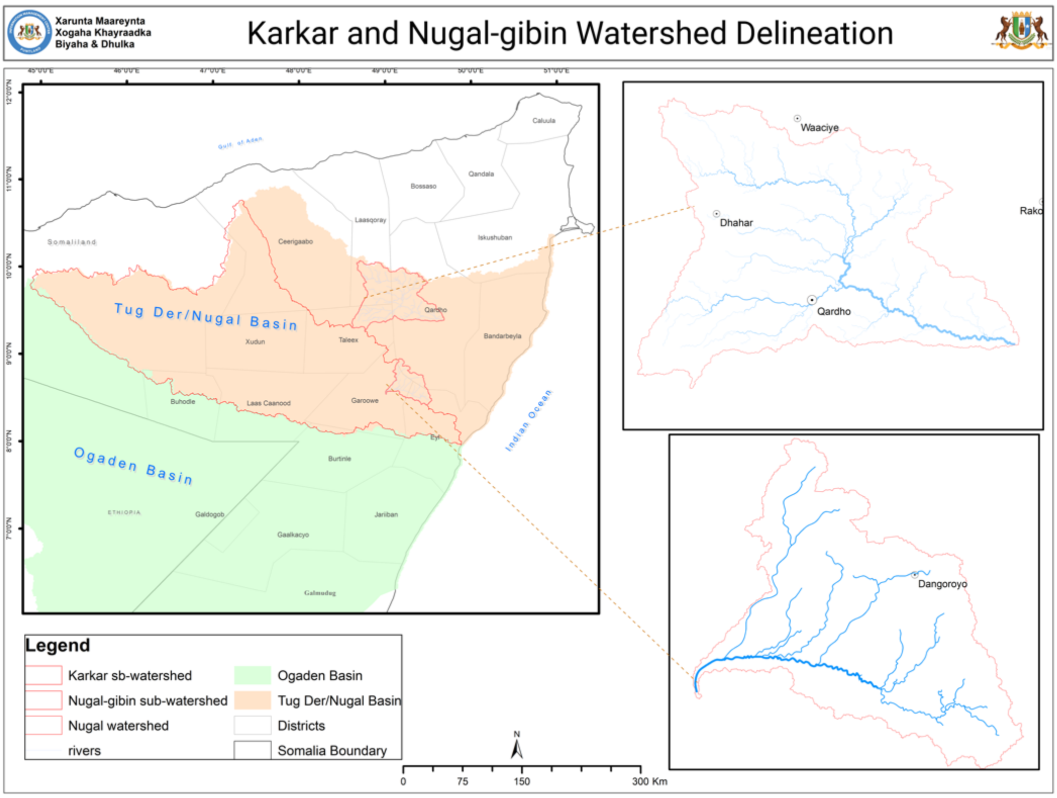
4. Watershed Characterization

4.1. Study area description

The study covered two watersheds: Karkar, which is located between latitudes 9°20 and 10°0N and longitudes 48°40 to 49°40E, and the Nugal-gibin watershed, which is located between latitudes 8°20 and 8°50 N and longitudes 49°0 to 49°30 E.

The Karkar watershed has an elevation that varies from 560 m to 1069 m m.s.l. (mean sea level), while the Nugal-gibin has an elevation that varies from 348 m to 792 m m.s.l.

The total area of Karkaar watershed boundary is 590,191.1 Ha (hector) and Nugal-gibin is 158,401.19 Ha (hector), and both watersheds lies on Nugal basin.



Map 1: Karkar and Nugal-gibin Watershed Delineation

4.2. Population

People live in the two watersheds, comprises of both rural and urban settlements. Most of the residents are pastoral community, and their livelihood depend on livestock whereas the residents in the major cities (Qardho, Dangoroyo, Dhahar) mainly depends on small business, remittance, and humanitarian aid - *(Puntland Population estimation survey, 2014)*.

4.3. Climate of the Watersheds

The rainfall distribution of Nugal-gibin and Karkar is bimodal, with two distinct rainy seasons (Gu and Deyr). Between March and June is the first main rainy season (Gu), and September to December is the second main rainy season (Deyr). The months from April to June and October to November often have the most rainfall throughout these seasons. The two watersheds receive variable annual rainfall, typically ranging from 133mm to 202mm in Nugal-gibin and Karkar, respectively. *(Puntland Climate Time Series Database 2008-2024)*.

The four seasons and the variation of climate related to the watersheds are:

- Jilaal is the northeast monsoon, which is a dry and hot season that lasts from December to March.
- Gu is a transition period that lasts from April to May, an important rainy season
- Xagaa is the southwest monsoon, which lasts from June to September. Lastly,
- Deyr is a second transition period that lasts from October to November, which is also second most important rainy season of the year.

About every two to three years, the sub- watersheds experience a drought that causes livestock losses. Devastating flash floods are becoming more frequent because of improper urbanization, deforestation, and inadequate drainage infrastructure.

4.4. Geology

The intricate geological formations of Taleex and Karkar inside the two watersheds have an impact on the recharge and flow characteristics of their respective water sources. The availability and flow of water within the watershed are also governed by the geological formation.

4.4.1. Taleex Formation

This structure, which extends for 250 meters, is called after the town of Taleex in the Sool region. It is an example of a typical evaporitic formation that originated in a shallow sea with an arid climate and deposition environment. It is made up of a series of thick, massive the anhydrite strata with gypsum and limestone intercalations. Locally, this sequence also contains layers of gravel, sand, and clay that seasonal rivers have deposited in the shallow lagoonal environment. Certain locations have documented lateral facies shifts from gypsum and anhydrite to limestone. Transitions between anhydrite, gypsiferous limestone, and thick limestone are common and easily traceable over a relatively short distance. A larger anhydrite series succession can be found in the Nugal Valley, which encompasses a significant portion of the Sool and Nugal districts. *(FAO-SWALIM (2012)*.

4.4.2. Karkar Formation

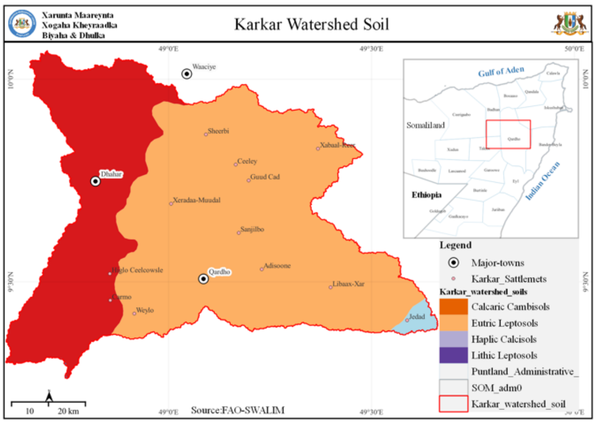
White marls, marly limestone, and fossiliferous limestone in bedded form make up the Karkar Formation. Limestone frequently has a well-developed cavernous system and is karstified. The hues vary from brown to yellow to white. In certain places, there are also sporadic thin shale layers and thin gypsum layers. The thickness of the sequence varies from 200 to 400 meters, and it is normally conformable on the Taleex Formation. Weathered boulders and 2-3 meters of lateritic sand typically indicate the contact between Karkar and the underlying Taleex Formation. *(FAO-SWALIM (2012)*.

4.5. Soil Characteristics

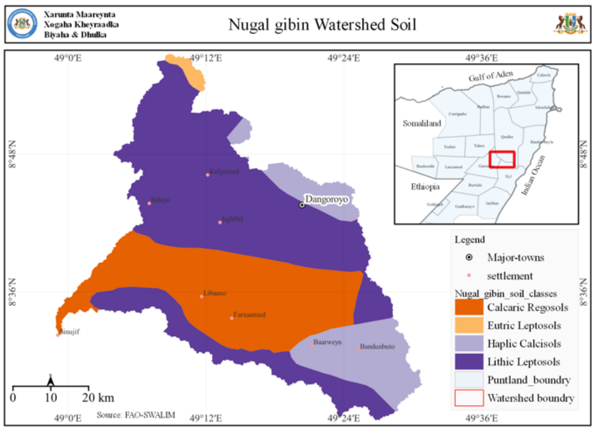
The soil within the two watersheds is generally characterized by well-developed and deeply weathered material, except in areas affected by erosion, and recent alluvial deposits.

In the Nugal-gibin watershed, common soil types include Eutric and Lithic Leptosols, Calcaric Regosols, and Haplic Calcisols, while the Karkar Watershed features Calcaric Cambisols, Eutric Leptosols, Haplic Calcisols, and Lithic Leptosols. These diverse soil types support the growth of crops and other ecosystems within the sub watersheds *(FAO-SWALIM, 2012)*.

The soil in Qardho district is confirmed to be loam by land resources assessments conducted in 2022. The gathered soil nutritional analysis shows deficiencies in both micro and macronutrients, necessitating the application of a basal fertilizer for most crops that is NPK 17:17:17 with trace nutrients iron, manganese, copper, boron, zinc, and molybdenum. Sugarcane, cotton, beans, cowpeas, fruit trees, sesame, and vegetables are suitable crops. (IMC-Puntland,2022)



Map 2: Soil Map of Karkar watershed



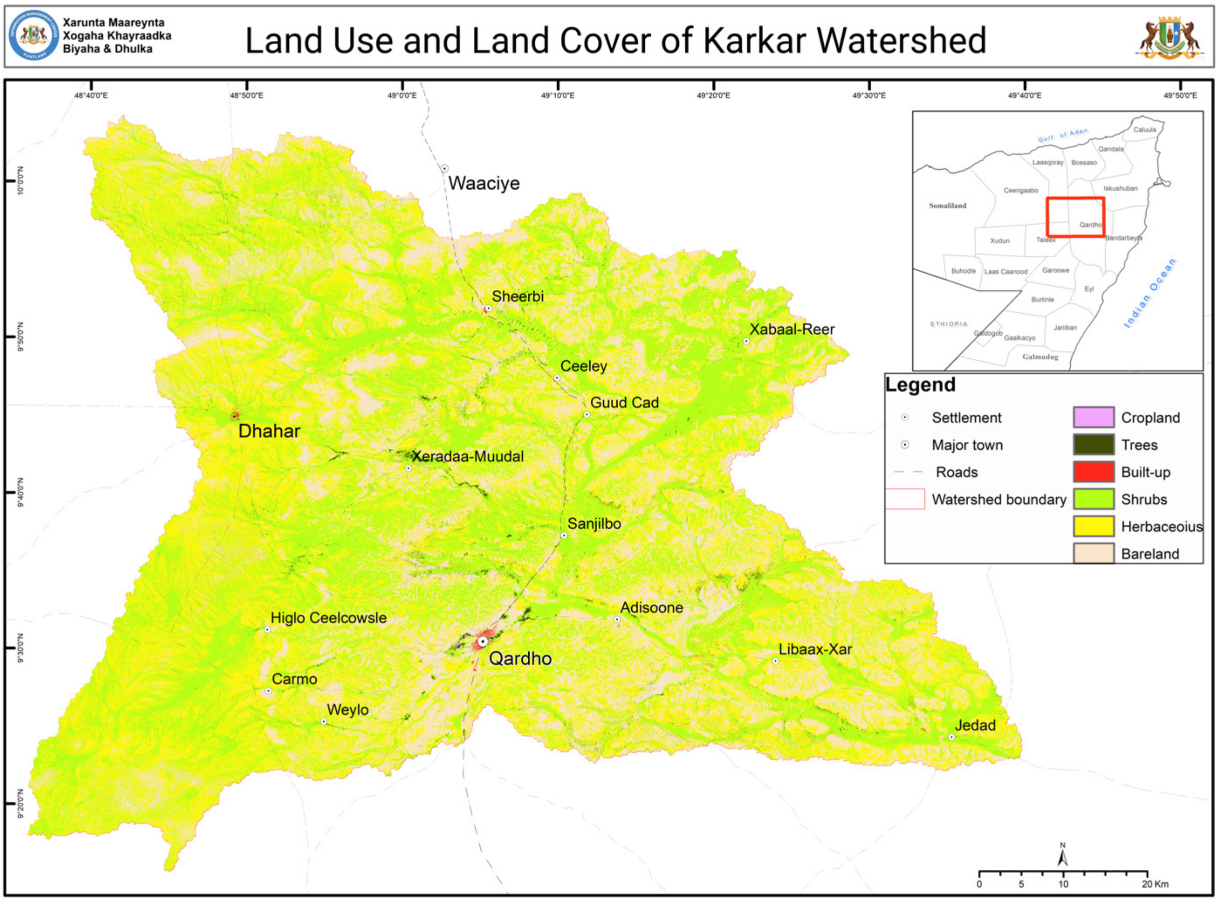
Map 3: Soil Map of Nugal-gibin Watershed

5. Results and Discussions

5.1. Karkar Watershed

5.1.1. Land cover

Six distinct land cover classes, primarily consisting of natural and semi-natural vegetation, make up the Karkar watershed. Most of the land cover species were found to have deciduous leaf phenology. Sparse trees, sparse shrubs, and open to closed herbaceous are the dominant land cover classes. The closed trees are not common in the watershed. Built-up non-linear of (roads), non-vegetated terrestrial areas with bare surfaces (Badland, bare rocks, and bare soil), natural water bodies of seasonal rivers and artificial water bodies of (Hafir dams and Berkads) are some of the other cover types in the watershed. These classes were developed based on the FAO Land Cover Classification System (LCCS 3).



Map 4: Land Cover of Karkar watershed

The primary woody plant species identified in the Karkar Watershed includes; Acacia tortilis (**Qurac**), Acacia Bussei (**Galool**), Ziziphus Mauritiana (**Gob**), Ziziphus Hamur (**Xamur**), Boscia minimifolia (**Maygaag**) , Cadaba farinosaforsk (**Qalaanqal**), and Salvadora persica (**Caday**) and other commonly grown herbaceous species includes Andropogon kelleri (**Duur**), Eragrostis haraensis (**Gubungub**), Chrysopogon aucheri (**Dureemo**), duosperma eromoophilum (**Sarin**), Sporobolus Spicatus (**Sifaar**), Rako, Madooyaa, Pulicaria Somalensis (**Adaar**), and Aerva persica (**Geedcad**).

The following descriptions were utilized during land cover classification analysis to help end users comprehend for separate classes, as shown in the ***Table 2*** below:

LCC	Land Cover Classification Description
Trees	Woody plants with a single, well-defined stem carrying a defined crown and 5 m and above tall.
Shrubs	Area covered by woody plant species with height expressed in meters ranging from 2 and less than 5 meters' height.
Herbaceous	Plants without persistent above-ground stems or shoots and lacking definite firm structure. There are two categories, depending on physiognomy: Graminoids and Forbs. There is no upper height limit; the only condition is plant physiognomy.
Bareland	An area of land with no visible vegetation or majorly covered by bare rocks, bare soil or gully and rill channels present with varying depth.
Built-up	Area of urban settlement including buildings, and other constructions, rural villages of built up, herbaceous growth forms and bare area and Internal Displaced People (IDPs) and Airports.
Cropland	Area covered by single or mixed cultivated plantation or crop types of tree orchards, shrubs or irrigated herbaceous. .

Table 2: Land Cover Classification considered in the Image classification (LCC).

#	Cover Area (Ha)
Trees	5,016.01
Built up	7,113.52
Shrubs	198,307.34
Herbaceous	244,446.72
Bareland	135,268.51
Irrigated cropland	39.00

Table 3: Karkar Land cover area by hectares

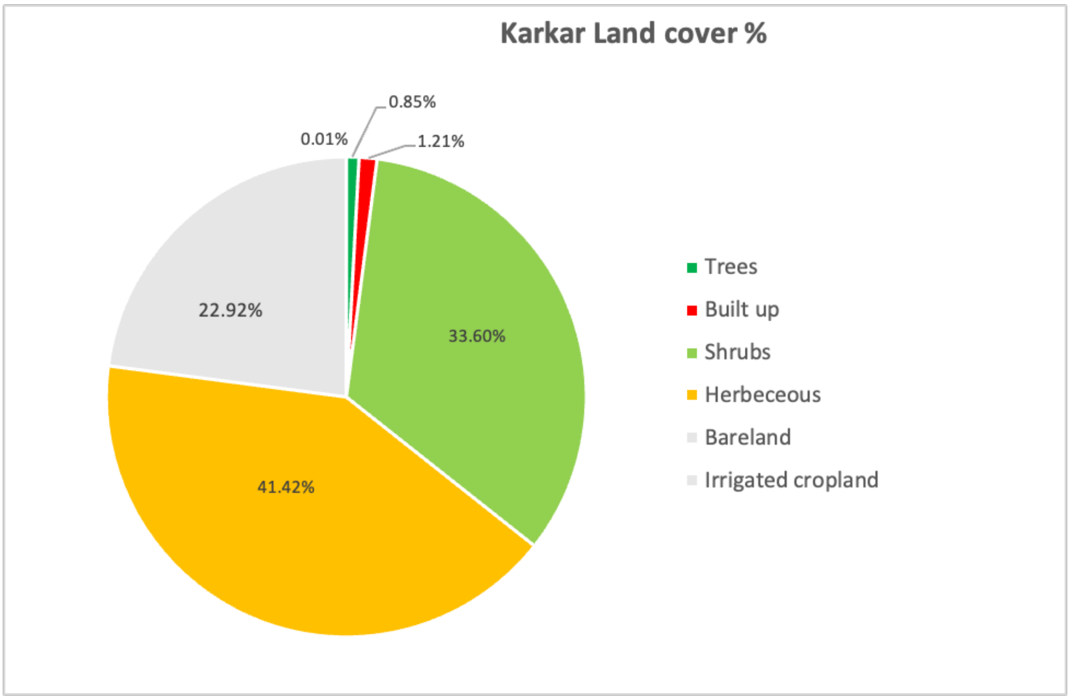


Figure 1: Karkar Land cover in percentage

This pie chart displays the percentage distribution of various land cover types in the Karkar Watershed. The dominant land cover is Herbaceous, which accounts for 41.42%, Shrubs are the second most common occupying 33.60% of the land. Bareland, indicated comprises 22.92% of the area, Built-up area make up 1.21%, while the least represented covers are Irrigated Cropland at 0.85% and Trees at 0.01%.

5.1.2. Land Use

The primary land use in the watershed is nomadic pastoralism (*Transhumance*), goats, sheep, camels, and cattle are the four main types of livestock herds raised by both urban and rural inhabitants in the watershed. Another land use in the Karkar watershed is irrigated agriculture, which is practiced along seasonal rivers and alluvial plains. Crop production predominantly depends on shallow wells or boreholes for irrigation. In the Qardho district, agro-pastoralism is widely practiced in Kubo, Carmooyin, and Ceelmur. Other land uses in this watershed include stone quarrying for construction purposes and wood collection for firewood. The farmers receive hard currency from the sale of their harvested farm products and collected firewood, which they export to the main cities to support their families.

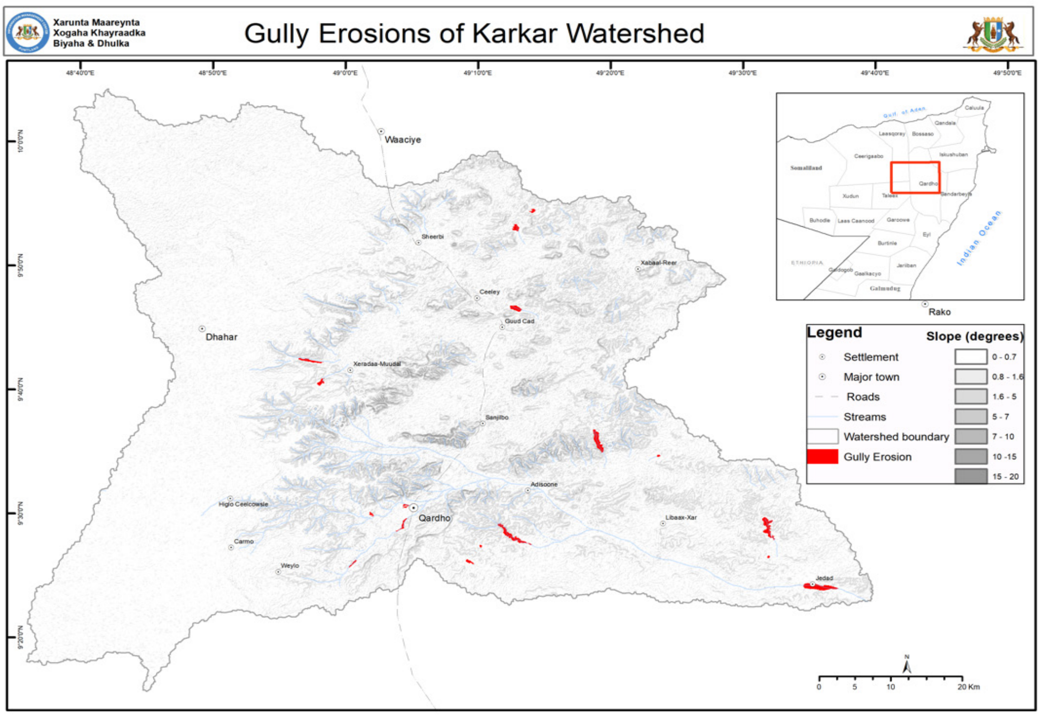
The various land use systems found in the Karkar Watershed throughout the study are briefly explained in the table below.

Land use systems of Karkar (LU)	Description of the Land Use
Agro-pastoralism (*semi-sedentary grazing*)	Community practices both crop cultivation and raring different types of livestock species in areas of Kubo, Carmooyin and Ceelmur.
Settlement	Major towns, villages, Airport buildings and IDP.
Badlands	No currently in use or areas with visible gully erosion
Nomadic pastoralism	Pastoral community of Karkar watershed uses a transhumance pastoralism system while migrating from one place to another looking for good pasture and water for their livestock as they rely on seasonal fluctuations.

Table 4: Land use systems of Karkar (LU)

5.1.3. Land degradation

Land degradation, resulting from a combination of natural and human-induced factors, leads to a decline in the quality and productivity of the physical environment. This is a significant global concern characterized by the deterioration of land quality and its capacity to sustain agriculture, and ecosystems. In the watershed's, gully erosion, and the decline in agricultural productivity are the primary types of land degradation leading to a reduction in available grazing land.



Map 5: Gully erosion of Karkar Watershed

5.1.3.1. Gully erosion of Karkar

There are notable indicators of land degradation, namely gully erosion, in the Karkar watershed, the extent of erosion processes was demonstrated by the field investigation, which revealed 16 gullies and 3 developing rill erosions from diverse areas inside the Karkar watershed. Beyond just reducing topsoil, the effects of this erosion are felt throughout the ecosystem, upsetting essential services like grazing areas. Furthermore, local communities have alerted attention to a concerning trend of gullies that are gradually growing, underscoring the critical need for intervention. The Karkar Watershed's gully erosion is becoming more severe, which puts the surrounding ecosystem and communities at serious risk. If sustainable land management methods (SLM) and prompt intervention are not used, the ongoing growth of gullies will cause irrevocable harm to the grazing land.

Degradation type	No. of Visited gullies/rills	Type of Intervention	Sites without intervention
Gully erosion	16	Stone-rock-pile/ Soil band	5
Rill erosion	3	Stone-rock-pile	1

Table 5: Karkar land degradation number and types

The data collected during the field study shows that gully erosion is a significant concern for the rangeland's long-term sustainability. Significantly reduced of grazing has occurred because of gully expansion, which is also influencing the watershed's agricultural areas, such Kubo. Moreover, there is a noticeable decline in biodiversity because of the growth of these erosive features, which also destroys habitat and flora.

The community in the watershed faces additional issues due to frequent flooding occurrences caused by gully erosion, which has resulted in the loss of land and biodiversity. Due to the loss of topsoil and land cover, which slows down water flow and causes sediment deposition downstream, gully formation exacerbates flooding caused by high intensity runoff.

Gully erosion is still a major problem despite efforts to alleviate it, such as the construction of soil and water conservation structures like stockpiles and hafir dams for conservation purposes. The study confirmed that despite these commendable efforts, the rangeland's degradation has not been halted. Massive areas of valuable pastureland are at risk from gully erosion if more comprehensive conservation measures are not implemented.

Despite the prevalence of gully erosion, efforts to mitigate soil erosion in the Karkar Watershed are limited. only 6 out of 19 gully erosion sites had a soil conservation measure; the remaining gullies doesn't have any interventions in place worsening the status of the watershed.

Degradation type	Selected hotspot gully Images	Main drivers identified	Proposed and Recommended Interventions
Degradation type: **gully erosion** Location: **Hodobohol** Coordinates: 9.619217056, 49.31371458 Site: **19**	 *Figure 2: Hodobohol Gully*	Reduced vegetation cover as result of unsustainable land practices, combined with the steep sloping and elevated terrain resulting in the initiation and enlargement of this gully in Hodobohol	Comprehensive initiatives of sustainable soil and water conservation strategy is recommended. Implementation of proper Gabions rather than stone/rock piles, afforestation of degraded land is pivotal to restore the land resources.
Degradation type: **gully erosion** Location: **Gelis iyo Cudud** Coordinates: 9.435646305, 49.15544301 Site: **21**	 *Figure 3: Gelis & Cudud Gully*	This area lies high elevation associated with steep sloping and the soil's limited capacity for rapid absorption, generate surface runoff that catalyzes the gully erosion process through removal of topsoil. The loss in vegetation cover because of overgrazing, tree cutting.	Implementation of sustainable Water and soil conservation structure, sustainable grassing practices of (seasonal grazing and proper livestock herd size management), Afforestation of endogenous tree and herbaceous species is recommended including Andropogon kelleri to reduce runoffs and restore ecosystem.
Degradation type: **gully erosion** Location: **Baqafuul** Coordinates: 9.908295, 49.238099 Site: **11**	 *Figure 3: Baqafuul Gully*	Poor soil quality associated with limited capacity to absorb high rainfall amounts and moderate sloping and increased elevation of the sites caused gully erosion of the site. Additionally, un sustainable land use system of overgrazing is also prominent in the area.	Soil quality improvement through sustainable soil and water conservation structures, such as gabions and afforestation is important. To address the issue of overgrazing rotational grassing practices is suggested.

Table 6: Selected gully erosion hotspot in Karkar watershed

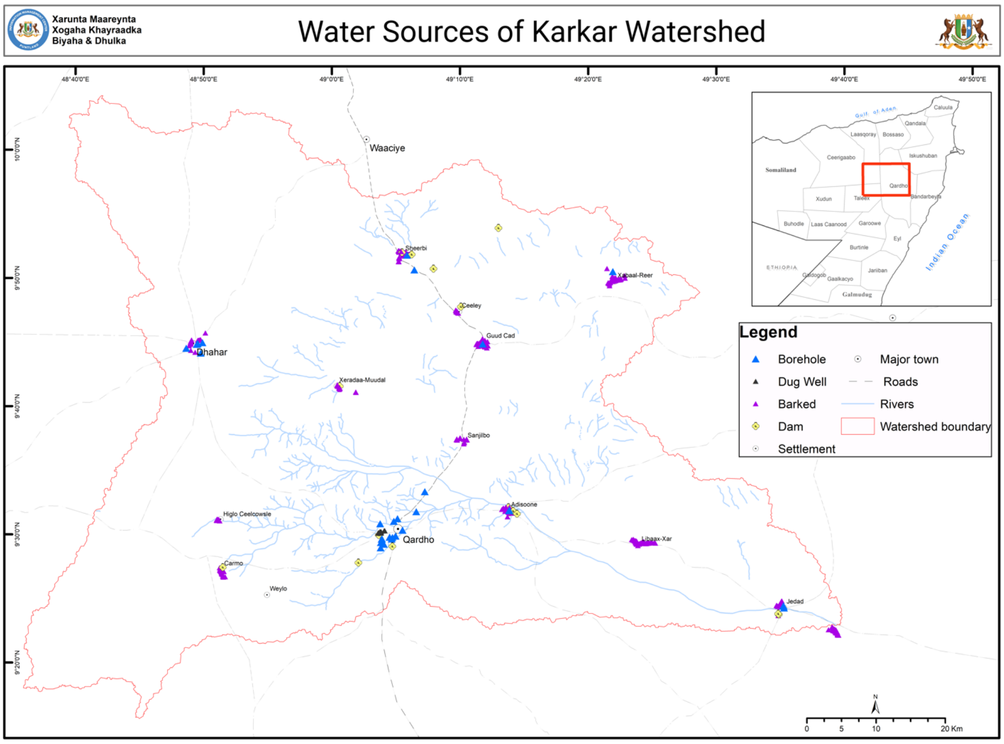
5.1.4. Hydrology

Karkar watershed has an arid climate often accompanied by erratic rainfall conditions. The annual rains have a bimodal distribution with peak amounts during the *Gu* (March-June) and the *Deyr* (September–December).*(Puntland Climate Time Series Database 2008-2024).*

Annual variations in the rainfall amount and distribution can have a substantial effect such as ground water depleting, dry out of surface water, reduced pasture, weakening on animal. Body condition, and decrease of crop production.

5.1.4.1. Water Sources

According to table 7, the Karkar Watershed has 501 total water sources, including both surface and groundwater, based on data compiled from the SWALIM/IMC datasets collected in various years (2008, 2012, 2013, 2017, 2019, and 2022), supplemented by satellite-based mapping of surface water (Berkads and Hafir Dams).



Map 6: Water sources of Karkar watershed

a) Surface Water Resources:

The surface water sources are Berkads, Hafir dams, and seasonal rivers. These sources are necessary for domestic, livestock and irrigation use. There are 409 Berkads and 16 Hafir dams in the Karkar Watershed. Seasonal variations, high rates of evaporation, and sedimentation can all lessen the effectiveness of these sources. Moreover, during dry spells, the areas that rely on these sources experience increased shortage of water, forcing both people and livestock to relocate to neighboring groundwater-dependent areas.

Source type	Quantity	Visited sources	Functioning of visited water sources	Non-functioning of visited water sources
Boreholes	48	5	5	none
Dug wells	28	0	0	none
Berkads	409	6	6	none
Dams	16	2	2	none
Totals	501	13	13	0

Table 7: Water sources information of Karkar watershed.

There are 501 water sources identified in Karkar watershed, 15 of which were visited during data collection and were all marked as operational. Surface water is susceptible to several factors, including pollution, evaporation, sedimentation, and improper management. The surface water sources need maintenance and rehabilitation such as desilting, sealing, and appropriate management of both solid and liquid wastes.

b) Groundwater Sources:

Since ground water sources like boreholes are strategically important to the Karkar watershed's water supply, face low risk of contamination compared to the surface water sources. The watershed contains a total of 48 boreholes and 28 dug wells. Nevertheless, the depletion of groundwater sources is a result of prolonged dry spells and overexploitation.

The ground water requires complete rehabilitation of the pumps, power supply, GI pipes, kiosks, animal troughs, and elevated tanks

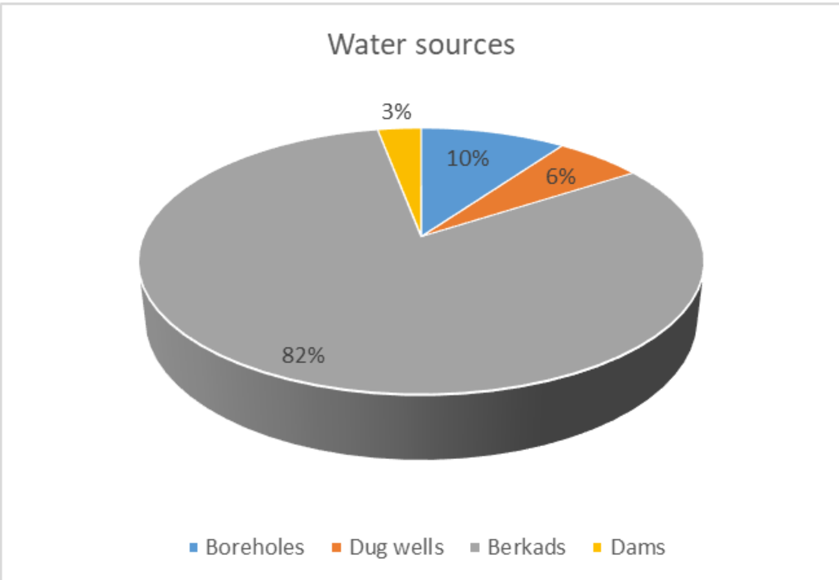


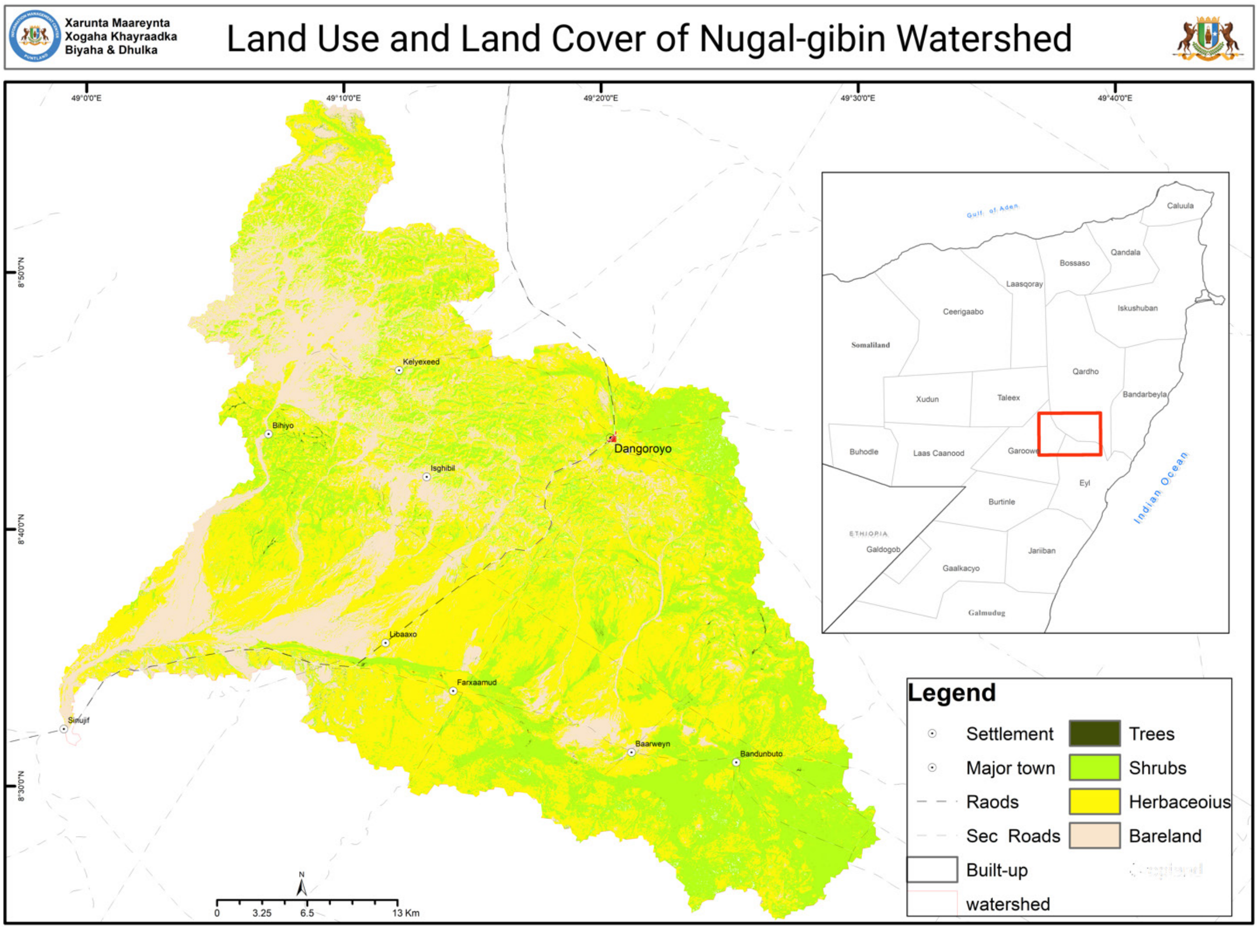
Figure 5: Water sources of Karkar Watershed

82% of the consumption of Karkar watershed depends on surface water such as Berkeds, which shows the significance contribution of the surface water in the livelihoods of the communities. While 10% of the consumption depends on groundwater such as boreholes.

5.2. Nugal-gibin Watershed

5.2.1. Land cover

There are five distinct land cover classifications in the Nugal-gibin Watershed, with natural and semi-natural vegetation accounting for the bulk of each classification. The classifications identify open to closed herbaceous areas, sparse trees, and shrubs. Roads, built-up linear spaces, non-vegetated terrestrial regions with bare surfaces (gully erosions, bare rocks, and bare soil), and artificial and natural water features (Hafir dams and Berkads) are examples of additional types of cover. The FAO Land Cover Classification System (LCCS 3) was used while creating these classifications.



Map 7: Land Cover of Nugal-gibin watershed

The main woody types of plant species found in the Nugal-gibin Watershed includes, Acacia tortilis (**Qurac**) Boscia minimifolia (***Meygaag***), Ziziphus Hamur (**Xamur**), Cadaba farinosaforsk (***Qalaanqal***), Commiphora Spp(**Qaroon**), Euphorbia cuneata vahl (**Dhirindhir**), Commiphira Horida (**Kabraro**) and Caesalpinia erianthera (**Jirme**).Other herbaceous species that are frequently grown include; Leptinemia Pyrotechnica (**Niriq**), duosperma eromoophilum (***Sarin***), Indigofera spinosa (**Xajiin**) and rako.

The following descriptions were utilized during land cover classification analysis to help end users comprehend for separate classes, as shown in the ***table 8*** below:

LCC	Land Cover Classification Description
Trees	Woody plants with a single, well-defined stem carrying a defined crown and 5 m and above tall.
Shrubs	Area covered by woody plant species with height expressed in meters ranging from 2 and less than 5 meters' height.
Herbaceous	Plants without persistent above-ground stems or shoots and lack definite firm structure. There are two categories, depending on physiognomy: Graminoids and Forbs. There is no upper height limit; the only condition is plant physiognomy.
Bareland	An area of land with no visible vegetation or majorly covered by bare rocks, bare soil or gully and rill channels present with varying depth.
Built-up	Area of Urban settlement including buildings, and other constructions

Table 8: Land Cover Classification considered in the Image classification (LCC).

#	Cover Area by Ha
Trees	349.78
shrubs	49,121.14
Herbaceous	75,607.22
Bareland	33,213.05
Built-up	20.00

Table 9: Nugal-gibin land cover in hector

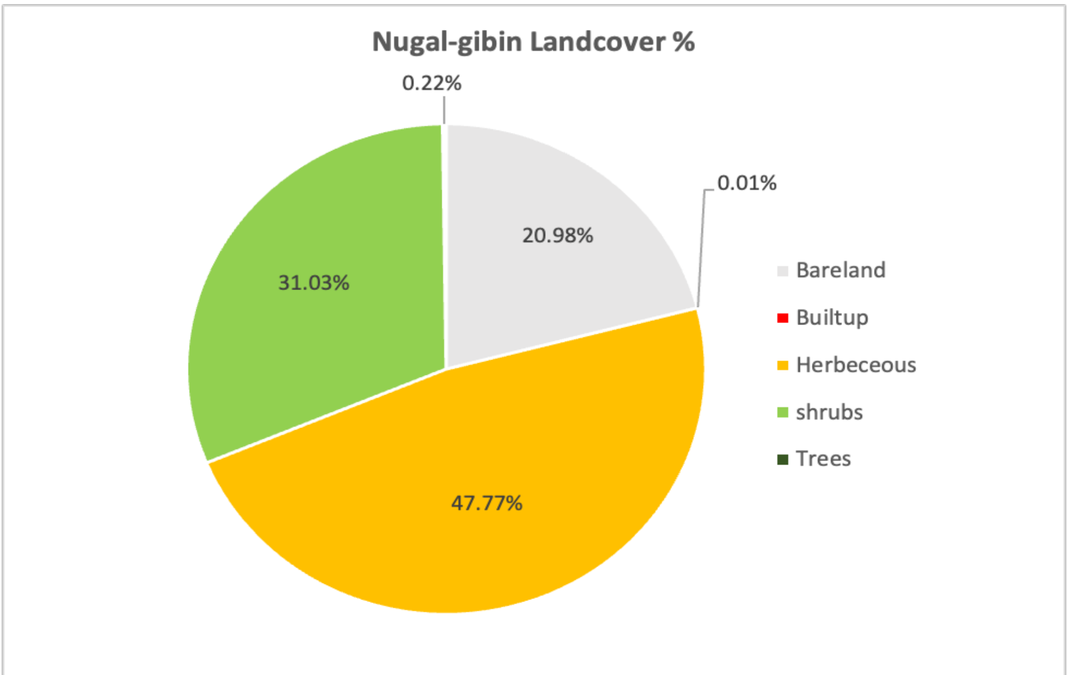


Figure 6: Nugal-gibin Land cover in percentage

This pie chart illustrates the percentage distribution of different land cover types in the Nugal-gibin Watershed. Herbaceous cover is the most prevalent covering 47.77% of the area. Shrubs are the second most common, occupying 31.03% of the land. Bare land makes up 20.98% of their cover. Trees constitute 1.21% and the least represented land cover is Built up at 0.01%.

5.2.2. Land Use

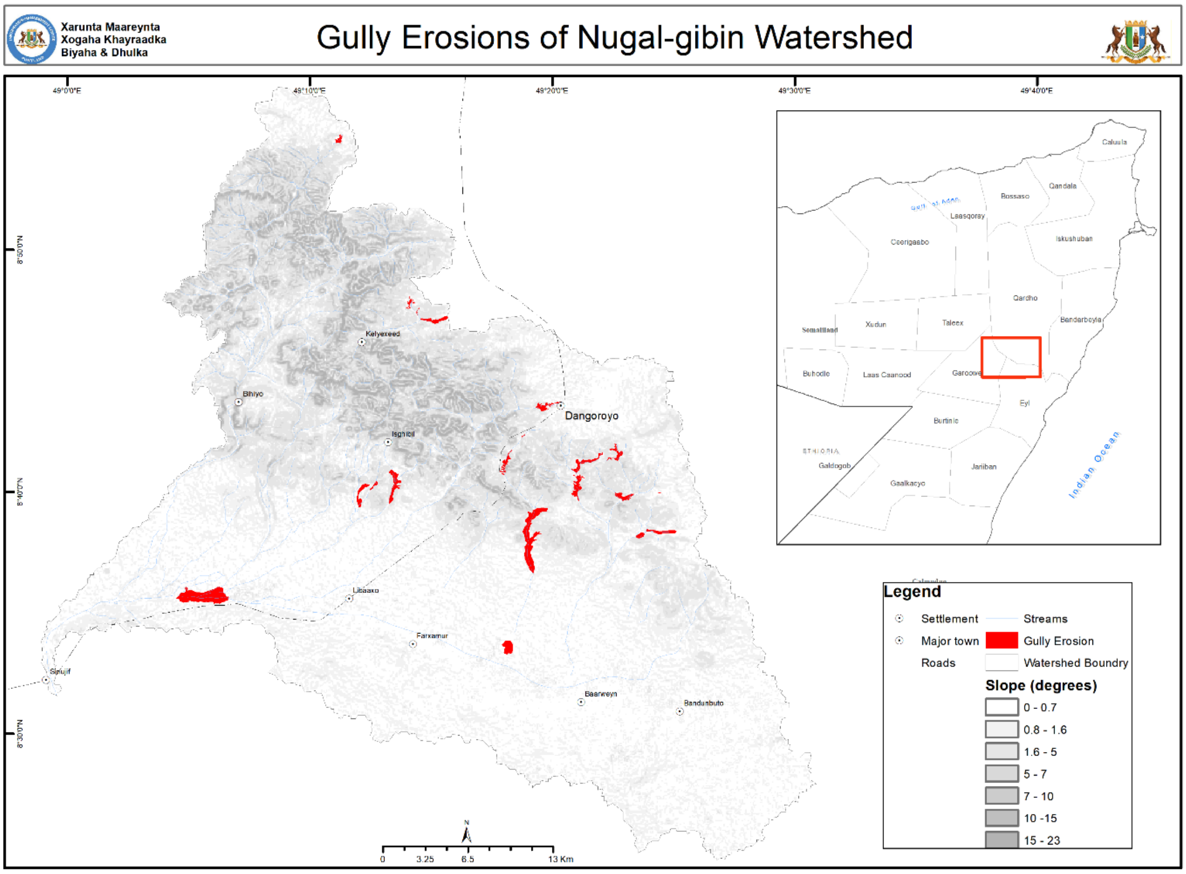
In the Nugal-gibin watershed, nomadic pastoralism is the predominant land use type. The local people mostly raise three different kinds of livestock: camels, sheep, and goats. Goats and camels favor mountainous lands, while sheep usually graze on savanna grasses in lower-lying locations. The watershed encompasses both urban and rural areas, with a focus on small business operations, including stone quarries for construction, soil extraction for building, and firewood collection for both domestic and commercial use.

Land use systems of Nugal-gibin (LU)	Description of the Land Use
Settlement	Major towns, villages, buildings and IDP.
Badlands	No currently in use or areas with visible gully erosion
Nomadic pastoralism	Pastoral community of Nugal-gibin watershed uses a transhumance pastoralism system while migrating from one place to another looking for good pasture and water for their livestock as they rely on seasonal fluctuations.

Table 10: Land use systems of Nugal-gibin (LU)

5.2.3. Land degradation

Degradation of land resources in Nugal-gibin is caused by urbanization, unsustainable farming practices, deforestation, and climate change impacts. These practices lead to reduced rangeland, biodiversity loss, water scarcity, soil erosion, and diminished soil fertility all of which jeopardize the decline in land production.



Map 8: Gully erosion of Nugal-gibin Watershed

5.2.3.1. Gully erosion

Significant land degradation is also a problem in the Nugal-gibin Watershed, with gully erosion being the main cause. The watershed study confirmed 9 fully developed gullies and 1 rill erosion, highlighting the magnitude of erosion-induced land cover modification. Moreover, local observations support the gullies' continued expansion, emphasizing the urgent need for intervention.

Degradation type	No. of Visited Gullies/Rills	Soil conservation	Sites without intervention
Gully erosion	9	Stone-rock-pile	7
Rill erosion	1	Stone-rock-pile	0

Table 11: Nugal-gibin land degradation number and types

Insufficient efforts are being made to conserve soil in the Nugal-gibin Watershed, notwithstanding the severity of gully erosion. To address erosion-induced land degradation, interventions such as soil conservation measures (Gabions, soil bunds, and half-moon) are present in only 3 out of 10 gully erosion locations. Additionally, some of the gullies are larger because they enclose a sizable area of degraded ground, which squeezes out rangeland.

The lack of conservation activities in most sites underscores the need for comprehensive intervention strategies to mitigate erosion processes and restore the degraded landscape.

The limited success of current conservation initiatives highlights the pressing need for a coordinated and holistic approach to combat gully erosion in the Nugal-gibin Watershed. Without swift and decisive action, the continued degradation of the landscape could have far-reaching environmental and socio-economic consequences.

The study reveals various elements contribute to the occurrence of gully erosion in Nugal-gibin, arising from a blend of natural phenomena of human interventions, insufficient vegetation covers from unsustainable land use, which cannot effectively shield against soil erosion. Intermittent heavy rainfall occurrences associated with devastating floods, combined with the watersheds rugged terrain, intensify the erosive effects, resulting in the initiation and enlargement of gullies.

The main drivers of Nugal-gibin degradation is substantial rainfall, coupled with the soil's limited capacity for rapid absorption, generate surface runoff that catalyzes the gully erosion process through removal of top soil.

Additional contributors to gully erosion in Nugal-gibin include deforestation for a purpose of farm and livestock fencing, slope and elevation of the land and concentrated water flow in one area, along with narrowing of seasonal river banks making soil soft and unable to withstand the force of strong water flow.

Degradation type	Selected hotspot gully Images	Main drivers identified	Proposed Interventions
Degradation type: **gully erosion** Location: **Wamaaley** Coordinates: 8.69170376 ,49.30329467 Site: **7**	 *Figure 7: Wamaaley Gully*	The main drivers of this gully erosion are loss of vegetation cover (deforestation and overgrazing), weak soil structure, steep slope, high elevation and high intensity of rainfall, and frequent droughts.	Afforestation and reforestation of degraded sites associated with sustainable soil and water conservation techniques are advised. Stone/rock pile Interventions seems in effective for gully erosion control so sustainable way for ecosystem restoration is necessary through comprehensive study for suitable soil conservation in the sub watershed. Construction of Gabions, Proper water and harvesting techniques could play a significant role in reducing water runoffs.

Degradation type: **gully erosion** Location: **Salaama** Coordinates: 8.59216316,49.10116893 Site: **2**	 *Figure 8: Salaama Gully*	This area lies high elevation associated with steep sloping and the soil's limited capacity for rapid absorption, generates surface runoff that catalyzes the gully erosion process through removal of topsoil. The loss in vegetation cover as a result of overgrazing is also another main driver for this gully expansion.	Soil conservation and restoration of degraded gully sites to reduce topsoil loss is indispensable. Sustainable land use practices are recommended to reduce overgrazing and deforestation from human activities.
Degradation type: **gully erosion** Location: **Durdurista** Coordinates: 8.798695, 49.23543 Site: **24**	 *Figure 9: Durdurista Gully*	Poor soil quality associated with limited capacity to absorb high rainfall amounts and moderate sloping and increased elevation of the sites caused gully erosion of the site. Additionally, Un sustainable land use system of overgrazing is also prominent in the area.	To prevent the loss of topsoil, soil conservation and restoration of degraded gully sites are essential. It is advised to utilize sustainable land use techniques to lessen overgrazing and human-caused deforestation.

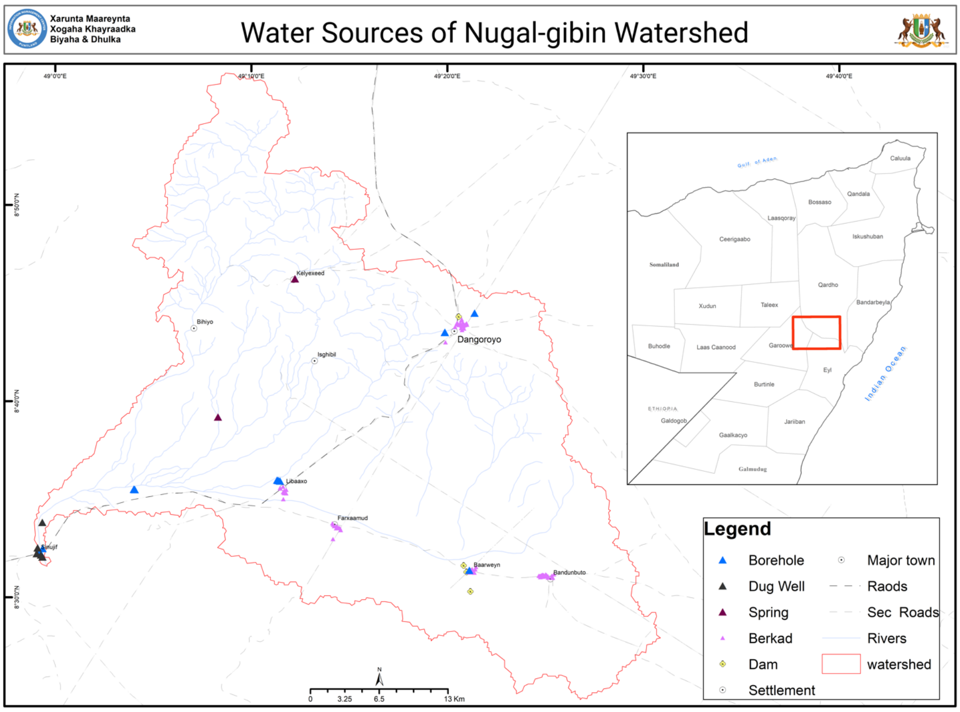
Table 12: Land Degradation hotspots in Nugal-gibin Watershed

5.3.3. Hydrology

The intensity and distribution of rainfall have a significant impact on the hydrological dynamics of the Nugal-gibin watershed, which is in the arid climate zone of the Nugal region. Rainfall patterns in this area are erratic and frequently unpredictable. Two distinct seasons typically see rainfall: the Gu season, which lasts from March to June, and the Deyr season, which lasts from September to December. *(Puntland Climate Time Series Database 2008-2024).*

5.3.3.1. Water Sources

According to the data gathered from the SWALIM/IMC datasets collected in various years (2008, 2012, 2013, 2017, 2019, and 2022), along with satellite-based mapping of surface water, the Nugal-gibin watershed contains a combined total of 108 water sources, inclusive of both surface water and groundwater as shown in the table 13, and figure 10.



Map 9: Water sources of Nugal-gibin watershed

a) Surface Water:

In the Nugal-gibin watershed, surface water sources—such as Berkads, hafir dams, and seasonal rivers—play essential lifelines that provide a variety of needs, including consumption for the households and livestock. According to an extensive analysis that combined satellite data with field verification, the Nugal-gibin watershed has 82 Berkads and a network of 4 hafir dams. Nevertheless, despite their importance, a number of variables, including seasonal fluctuations, evaporation, and sedimentation, can impair these sources' effectiveness. These issues make water scarcity worse, especially during lengthy dry spells, and posing serious obstacles to the viability of nearby settlements.

Source type	Quantity	Visited sources	Functioning of visited water sources	Non-functioning of visited water sources
Boreholes	17	7	6	1
Dug wells	2	0	0	none
Berkads	82	2	2	none
Dams	4	1	0	none
Springs	3	1	0	none
Totals	108	11	8	1

Table 13: Nugal-gibin surface water sources

As part of the data collection process, only 11 out of the 108 water sources indicated in the table underwent assessments; of those, 9 were functional and 2 non-functional. Due to high evaporation, pollution, sedimentation, and poor management, had an impact on these surface water. Rehabilitative methods such as sealing, desilting, and effective waste management are needed to keep them intact. Groundwater supplies necessitate significant upkeep in the interim for elevated tanks, kiosks, GI pipes, power supply systems, pumps, and animal troughs.

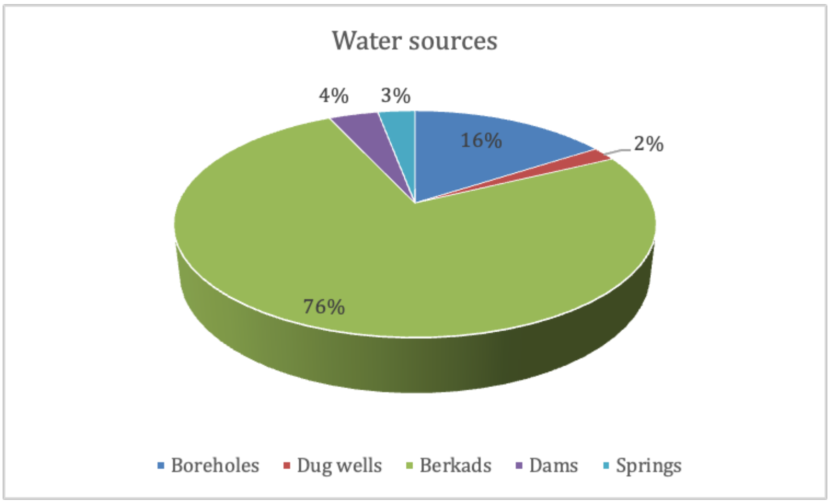


Figure 10: Water sources of Nugal-gibin watershed

b) Ground Water

A strategically significant role is played by groundwater sources, especially boreholes, in providing the Nugal-gibin watershed community with the water requires. The watershed depends on 2 dug wells, 3 natural springs, and 17 boreholes. But the persistent strain brought on by protracted dry spells and over-exploitation has resulted in a notable depletion of groundwater reserves. The watershed's ability to sustain its water sources is severely threatened by this decline, underscoring the critical need for prudent management and conservation measures to prevent future shortages.

5.3. Climate Variability and Change

According to the study, the 42 visited sites, 52% of the communities have access to climate information, while 48% do not. This indicates that the people who live in the two watersheds have limited access to climate information.

39 visited sites responded, 46% rely on radios, 26% on local elders, 18% on government officials, 8% on TVs, and 3% on other sources.

Out of 41 visited sites, 10% being very confident, 36% confident, 20% not confident, and 34% unsure.

According to field respondents the frequency of flash floods and droughts rose dramatically, which exacerbated the living circumstances in the two watersheds by causing food insecurity, a decrease in fodder, crop diseases, and a reduction in rainfall in some locations. Of the 41 areas that were visited, 95% had severe droughts, while 5% had the least severe. Moreover, 83% of floods were severe, 8% were moderately severe, and 7% were the least severe.

Over the past ten years, the two watersheds' combined annual rainfall has steadily decreased, and the length of the crop growing season has decreased, and temperatures has also increased indicating an imbalance between the amount of rainfall received and the length of the growing season. This has made life more difficult without using modern irrigation techniques, developing new water sources, and adopting crops that require less water.

Farmers and animal herders in the two watersheds stated spike in crop and livestock disease incidents. Migration and immunization deficiencies have been identified as contributing factors to the rise in livestock diseases, while a specific vegetable disease is affecting the production of highly desired vegetables such as tomatoes.

Karkar and Nugal-gibin watershed's face a high number of food security incidents due to low production of livestock which is the main sources of livelihoods in the watersheds and also poor yield of the crops which is the result of the challenges mentioned includes, lack of fodder, crop and livestock diseases, drought and below normal rains.

The drought incidents in the past 10-20 years have been increasing due to the poor rainfalls, furthermore, the severity of the droughts has been increased due to lack of proper coping mechanisms in place which resulted a high influx of population from rural to urban areas, huge loss of livestock and formation unfavorable living conditions in the rural areas.

The study reveals that there's very minimal measures to minimize the risks associated with the shocks while very minor number of the communities in the two-watershed stated they tend to rely on the forecasts, early warnings, livestock supplementary feedings, livestock migration, and use of pesticides and fertilizers.

The coping mechanism to the shocks that are in place in the two-watersheds include, reduction of household food consumption, sale of livestock and assets, cash for work, food sharing, migration and reliance of saving from the sales of livestock and cash for work.

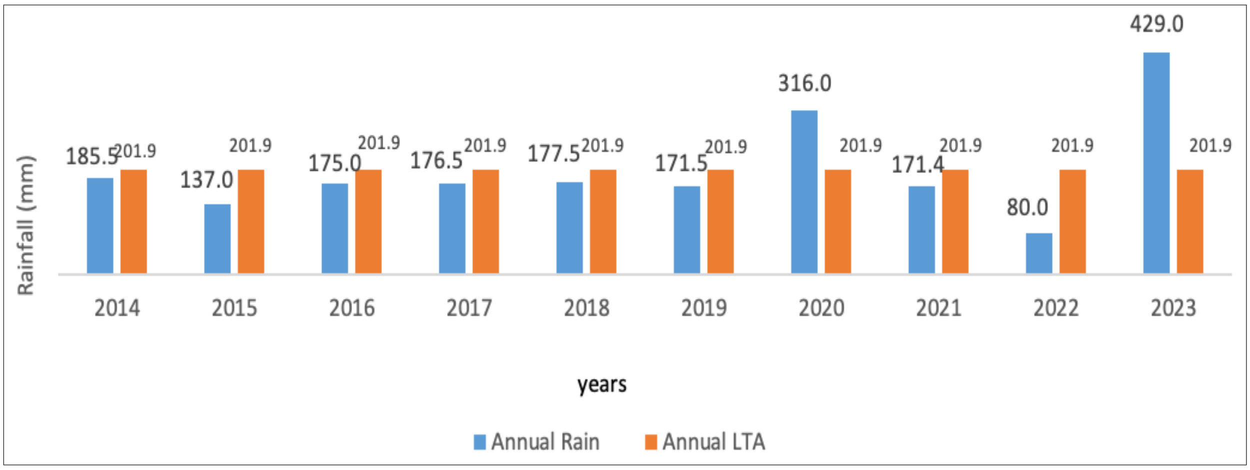


Figure 11: Qardho observed rains

The recorded rainfall data from the Qardho rain gauge station in Karkaar watershed over the past decade suggests that, the rainfall has been lower than the long-term average. However, there were two years, 2020 and 2023, when the amount of rainfall reported was more than usual. The highest amount of rainfall was 429 mm was recorded in 2023; while the lowest amount was 80 mm recorded in 2022. The rainfall chart provides an illustration of this data.

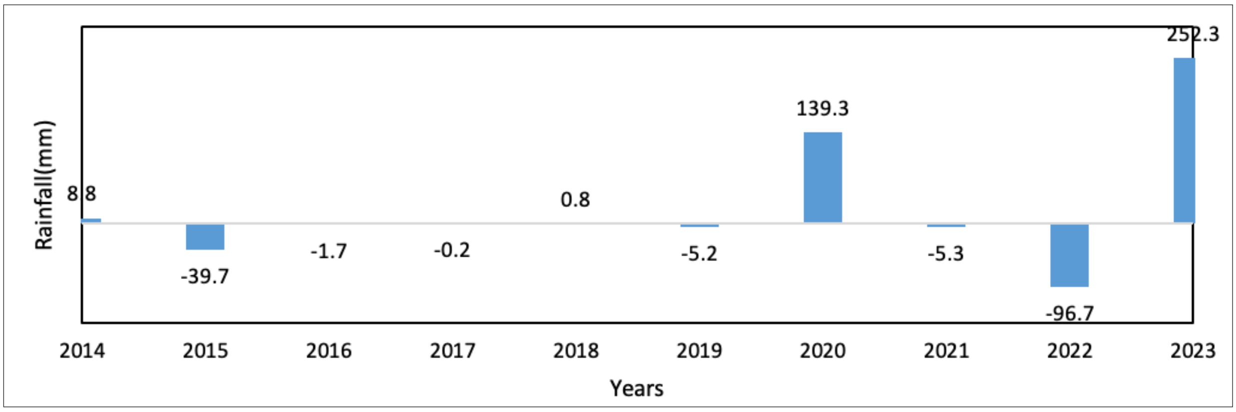


Figure 12: Qardho Anomaly

The observed anomaly in rainfall stations over the last ten years indicates that the Karkaar watershed has experienced less rainfall. Rainfall above the long-term average (LTA) is shown by positive numbers, while rainfall below the LTA is indicated by a negative value. These discrepancies are thought to have a fundamental basis in climate change.

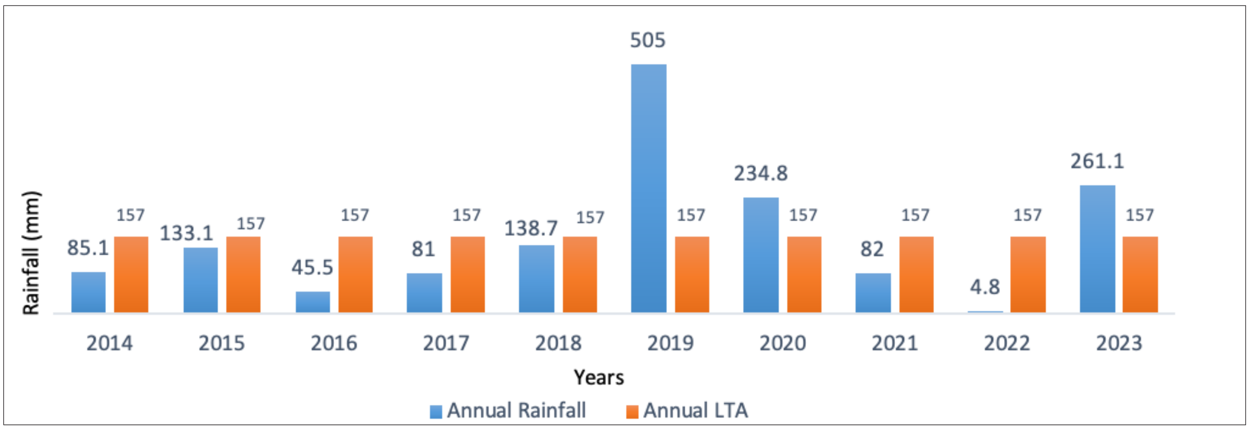


Figure 13: Dangoroyo observed rains

The observed rainfall data at the Dangoroyo rain gauge station from 2014 to 2023 indicates that the rainfall has been below the long-term average. However, there were exceptions in 2019, 2020, and 2023 when the recorded rainfall exceeded the average. In 2019 the highest amount of rainfall was recorded and reached 505mm, while the lowest amount, just 4.8mm, was recorded in 2022. This information is depicted in the rainfall chart.

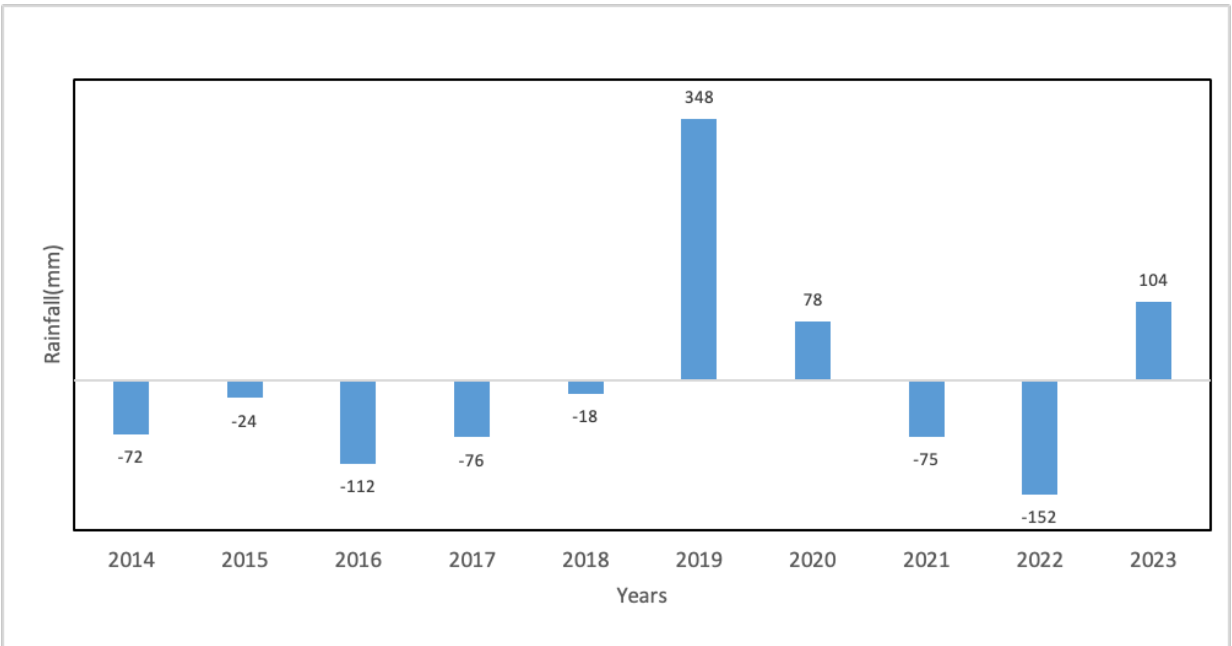


Figure 14: Dangoroyo Anomaly

There has been less rainfall over the last ten years in Nugal-gibin watershed, according to the recorded and observed anomaly in rainfall patterns. Positive values indicate rainfall above the long-term average (LTA), while negative values indicate less rainfall than the LTA. The cause of these variations is thought to be climate change.

5.4. Capacity building of Female Interns and Government Staff

Building the capacity of government employees, including WAL ministries and IMC interns, was one of the main goals of this watershed study. To highlight this, four female interns from IMC and seconded staff from IMC line ministries participated in all phases of the project, from planning to data collection and analysis. The ministries participated the study are the ministries of, planning, disaster management; environment, agriculture, water and livestock.

The primary focus of the capacity building includes practical training and mentoring. i.e. female interns have actively participated in data collection throughout the fieldwork within the Nugal-gibin and Karkar watersheds. Their participation not only made it quicker to collect important data, but it also gave them the ability to make significant contributions to the understanding of the conditions pertaining to land cover, land use, and environmental deterioration.

They have acquired different skills in data management such as use of ODK, GPS, GIS technologies, data collecting procedures, and data analysis methods.

The capacity building of female interns was made possible with the support of IMC senior officers, who ensured the interns could confidently apply their training in real-world scenarios. Under the guidance of the IMC technical team, interns gained knowledge and expertise in land cover, land use, climate, and water sources in particular watersheds. This will significantly contribute to the empowerment of women in the Puntland government's water and land resource sectors.

Conclusion and Recommendation

6.1. Conclusion

The study objectives were to collect data on LULC, land degradation and water resources Additionally community livelihoods within these watersheds, as well as the influence of climate variability on community well-being.

According to the study, the two watersheds' community majorly depend on a total of 511 surface water sources for their livelihood activities. Of these, Nugal-gibin has 82 Berkads and 4 Hafir dams, while Karkar has 409 Berkads and 16 Hafir dams. resulting in an increasing demand for water during dry periods. Disease outbreaks in communities are experienced during the rainy season due to contaminated water.

The major land cover in the Karkar watershed are herbaceous (244,446.72 Ha), while the shrubs making up the second largest cover type (198,307.34 Ha). And Nugal-gibin watershed are primarily covered by herbaceous species (75,607.22 Ha), while the shrubs make up (49,121.14 Ha).

The study revealed that there is land degradation in both watersheds as a result of un sustainable land management practices, limited soil capacity to absorb heavy rainfall, reduced vegetation cover and slope steepness.

The primary land use systems for both watersheds are nomadic pastoralism and livestock herders moves from one place to another in search of pasture and water. However, land degradation, including gully formation and soil erosion, has negatively affected the grazing lands., in some areas of the watershed's livestock feed is in danger of going extinction. Similar to this, soil erosion modifies the natural flow of water and creates gullies, which in consequently affects the runoff patterns.

Based on the findings of the study conducted across 42 visited sites, it is evident that access to climate and weather-related information remains limited within the communities residing in the two watersheds. With 52% having access and 48% lacking it, there exists a significant gap in the dissemination of crucial climate-related knowledge. Furthermore, analysis of the respondents across 39 sites reveals a varied reliance on different sources for such information, with radios being the most utilized at 46%, followed by local elders at 26%. Government officials, TVs, and other sources contribute to a smaller portion of information access. Delving deeper into the certainty levels regarding climate information across 41 surveyed sites, it is notable that only 10% of the communities are absolutely certain, while a majority exhibit varying degrees of confidence, uncertainty, or lack of assurance.

6.2. Recommendation

The study's findings indicate that the following interventions are essential to ensure the long-term sustainability of the watersheds.

- It is crucial to implement sustainable land management techniques to prevent the development of rill erosions and the expansion of watershed gully features. These techniques include terracing for the high elevation ends of both watersheds, installing gabions correctly, reforesting degraded areas, and building check dams.
- The study has revealed that most gully interventions have been ineffective in mitigating intended impact. therefore, it is recommended to explore and adopt more appropriate methods for gully conservation
- Improving the management of water resources by innovative methods such as building dams and strategically placing boreholes could greatly increase the supply for the most vulnerable villages, pastoral settlements, and the IDPS.
- Promoting and assisting agro-pastoralists in planting drought-tolerant crops, enhancing their access to markets and value chains, and addressing issues with soil and water quality to increase crop productivity as this will enhance their livelihoods.
- Use sustainable livestock management techniques to boost animal productivity. These techniques include rotating grazing systems, giving grazing areas rest times, and managing herds sensibly to prevent land degradation. Additionally, by enhancing disease detection and animal treatments.
- Promoting community stewardship in watershed management and encouraging community-based participatory natural resources management.
- Large-scale watershed mapping, which aims to gather comprehensive data on land and water resources, would enhance the execution of effective planning and interventions.
- The study's conclusions emphasize the significance of adopting sustainable land and water management strategies into practice for the purpose to resolve watershed shortcomings including the quickly developing gully erosions, changes in land cover and use, and insufficient water supplies for infrastructure.

Annex 1: Field photos


GPS Map Camera
--,Sanaag,Somalia
Sanaag, Somalia
Lat 9.746748, Long 48.822708
03/02/2024 06:09 PM GMT+03:00
Note : Captured by GPS Map Camera

Annex 2: Sample sites

SAMPLE SITE LOCATIONS

NUGAL WATERSHED

District	Sample Location	Sample Number	Longitude (X)	Latitude (Y)	Sample Representation
Dangoroyo	Dhiday	1	49.14605027	8.941607779	Land cover and Land use
Dangoroyo	Dhiday	2	49.1920689	8.914069745	Land degradation
Dangorayo	Kalyaxed	3	49.20230477	8.769877898	Water sources and Socio-economic
Dangoroyo	Dangorayo	4	49.33946453	8.724143717	Water sources and Socio-economic
Dangorayo	Dangorayo	5	49.33097813	8.726470634	Land degradation
Dangoroyo	Tabxade	6	49.36523172	8.74713913	Land cover and Land use
Dangorayo	Wamaalay	7	49.30329467	8.69170376	Land degradation
Dangoroyo	kalcad	8	49.34798516	8.682464531	Land degradation
Dangorayo	Bugux ujeedo	9	49.37901357	8.69894971	Land degradation
Dangoroyo	Qurac majooge	10	49.42662126	8.638278777	Land cover and Land use
Dangoroyo	Qurac majoge	11	49.40608964	8.639100041	Land degradation
Dangorayo	Budunbuto	12	49.4208724	8.515636574	Water and socio-economic
Dangorayo	Baarweyn	13	49.35311806	8.51748442	Water and socio-economic
Dangorayo	Dooxada Budunbuto	14	49.39370223	8.517073788	Land cover and Land use
Dangoroyo	Xananka baarwayn	15	49.29638235	8.531240604	Land cover and Land use
Dangoroyo	Farxamur	16	49.23394912	8.562534213	Water and socio-economic
Dangoroyo	Farxamur	17	49.23278567	8.571807661	Land cover and Land use
Nugal	Libaaxo	18	49.19417339	8.59366528	Water and socio-economic
Dangoroyo	Salaama	19	49.07012819	8.583844323	Water and socio-economic
Dangoroyo	Sinujif	20	48.98675271	8.538803084	Water and socio-economic
Dangoroyo	Bilcil	21	49.22239153	8.658369821	Land degradation
Garowe	Goolada libaaxo	22	49.17697754	8.578659386	Water
Dangoroyo	Bohosha salaama	23	49.10116893	8.59216316	Land Degradation
Dangoroyo	Durdurista	24	49.23543	8.798695	Land Degradation
Dangoroyo	Beeraha salaama	25	49.0679033	8.5886774	Land cover and Land use
Dangoroyo	Beeraha salaama	26	49.0703375	8.5878608	Land cover and Land use

KARKAR WATERSHED

District	Sample Location	Sample Number	Longitude (X)	Latitude (Y)	Sample Representation
Dhahar	Dhahar	1	48.82485299	9.746251413	Water & Socio-economic
Dhahar	Booxaaro	2	48.8095036	9.860977445	Land cover
Dhahar	Booxaaro	3	48.96597025	9.832584117	Land cover
Dhahar	Muudal	4	49.00275872	9.698678939	Water & Socio-economic
Dhahar	Higlo ceelcawsle	5	48.85047827	9.521523987	Water & Socio-economic
Dhahar	Carmooyin	6	48.85411844	9.455636906	Water & Socio-economic
Dhahar	Waylo	7	48.91626676	9.420075097	Water & Socio-economic
Dhahar	Dhufaaco	8	48.74009011	9.32448271	Land cover
Qardho	Ceeley	9	49.16723375	9.78799772	Water & Socio-economic
Qardho	Ceeley	10	49.19949476	9.777524647	Gully erosion
Qardho	Baqafuul	11	49.238099	9.908295	Water source
Qardho	Wadeeba	12	48.971294	9.59176221	Land cover and Land use
Qardho	Kurtumo	13	49.08322924	9.594613676	landcover and use
Qardho	Xabaal reer	14	49.36722319	9.828433944	Water & Socio-economic
Qardho	Aaga baqafuul	15	49.23969589	9.831770767	Landcover and use
Qardho	Kur jaleelo	16	49.30517914	9.749402436	landcover and use
Qardho	Guudcad	17	49.19615983	9.749792996	Water & Socio-economic
Qardho	Sanjilbo	18	49.17317367	9.622030604	Water & Socio-economic
Qardho	Hodobohol	19	49.31371458	9.619217056	Degradation
Qardho	Cad	20	49.3953909	9.5731234	Degradation
Qardho	Gelis iyo cudud	21	49.15544301	9.435646305	Degradation
Qardho	Gelis iyo cudud	22	49.1701857	9.456334605	Degradation
Qardho	Gelis iyo cudud	23	49.20258322	9.472048007	Degradation
Qardho	Dhaxanciid	24	49.00643871	9.429852367	Degradation
Qardho	Adisoone	25	49.23042025	9.530715526	Water and soc-economic
Qardho	Kurtumo	26	49.12943891	9.581548392	Landcover and use
Qardho	Dooxada adisoone	27	49.27860967	9.506218739	Landcover and land use
Qardho	Gelis iyo cudud	28	49.24918102	9.431004575	Landcover and use
Qardho	Dooxada libaaxar	29	49.39906184	9.429071181	Landcover and use
Qardho	Libaaxar	30	49.40001998	9.486936127	Water and soc-economic
Qardho	Qalaanqalo	31	49.46979326	9.46900518	Landcover and use
Qardho	jedad	32	49.53248314	9.481118835	Degradation
Qardho	Jedad	33	49.58518096	9.400566451	Degradation
Qardho	Qormo burcad	34	49.64440612	9.380625116	Water band socio-economic
Qardho	Dooxada Jedad	35	49.52155861	9.386536511	Landcover and use
Qardho	Kubo	36	49.06386703	9.510328113	Land cover and land use
Qardho	Kubo	37	49.06265432	9.503535235	Land cover and land use
Qardho	Sheerbi	38	49.08896583	9.861200302	Socio-economic

Annex 3: List of Karkar Gully erosions

Karkar gully erosion							
#	Sample Number	Longitude(X)	latitude(Y)	Name	Area in M^2	Area in HA	Area SqKM
1	32	49.53248314	9.481118835	Jedad	2182825.907	218.282591	2.182826
2	21	49.15544301	9.435646305	Gelis iyo Cudud	329670.361	32.967036	0.32967
3	22	49.1701857	9.456334605	Gelis iyo Cudud	103555.885	10.355589	0.103556
4	24	49.00643871	9.429852367	Dhaxanciid	247264.481	24.726448	0.247264
5	12	48.971294	9.59176221	Wadeba	838092.886	83.809289	0.838093
6	13	49.08322924	9.594613676	Kurtumo	510750.676	51.075068	0.510751
7	39	49.53248314	9.481118835	Jedad	96060.368	9.606037	0.09606
8	36	49.06386703	9.510328113	Kubo	464317.389	46.431739	0.464317
9	37	49.06265432	9.503535235	Kubo	191946.129	19.194613	0.191946
10	23	49.20258322	9.472048007	Gelis iyo Cudud	2212649.757	221.264976	2.21265
11	33	49.58518096	9.400566451	Dooxada Jedad	3066136.948	306.613695	3.066137
12	19	49.31371458	9.619217056	Hodobohol	2063238.344	206.323834	2.063238
13	11	49.236305°	9.906267°	Baqaful	272688.987	27.268899	0.272689
14	15	49.214450°	9.883118°	Baqaful	630739.414	63.073941	0.630739
15	10	49.214324°	9.774803°	Ceeley	910195.6	91.01956	0.910196
16	20	49.3953909	9.5731234	Cad	106850.097	10.68501	0.10685
17	25	49.227232°	9.538386°	Adisoone	81605.998	8.1605998	0.081605998

Annex 4: List of Nugal-gibin Gully erosions

Nugal-gibin gully erosion							
#	**Sample Number**	**Longitude(X)**	**latitude(Y)**	**Name**	**Area in M²**	**Area in HA**	**Area SqKM**
1	2	49.1920689	8.914069745	Dhiday	179731.724	17.973172	0.179732
2	5	49.33097813	8.726470634	Dangorayo	430142.938	43.014294	0.430143
3	7	49.30329467	8.69170376	Wamaalay	399890.271	39989028	0.39989
4	8	49.34798516	8.682464531	kalcad	1301831.288	130.183129	1.301831
5	9	49.37901357	8.69894971	Bugux ujeedo	415397.65	41.539765	0.415398
6	11	49.40608964	8.639100041	Qurac majoge	663738.923	66.373693	0.663739
7	21	49.22239153	8.658369821	Bilcil	1401342.36	140.134235	1.401342
8	23	49.10116893	8.59216316	Bohosha salaama/ Qolqol	3181719.267	318.171927	3.181719
9	24	49.23543	8.798695	Durdurista	632873.697	63.28737	0.632874

Annex 5: Questionnaires

WATERSHED DATA COLLECTION FORM

Questionnaire ID

____

Record your current location

This question collects a single GPS coordinate that denotes a single point

latitude (x.y °)

____

longitude (x.y °)

____

altitude (m)

____

accuracy (m)

Observer name

____

District

Area Name

Watershed

Choose watershed

◯ Nugal ◯ Karkar

LAND COVER

General landcover

☐ Vegetated
☐ Non-Vegetated

Specific land cover type (Vegetated)

◯ Natural-seminatural Vegetation ◯ Cultivated-Managed Lands

Specific land cover type (Non-Vegetated)

◯ Non-Vegetated terrestrial ◯ Water

Vegetation type

◯ Tree
◯ Shrub
◯ Herbaceous

Plantation type

◯ Orchard (single fruit crop) ◯ Orchard (mixed fruit crop)

Cover percentage

- ◯ 70 - 100%
- ◯ 30 - 70%
- ◯ Less than 30%

Vegetation height (m/cm)

- ◯ 10 and above
- ◯ 3 to 5
- ◯ 2 and below

Vegetation leaf phenology

◯ Evergreen ◯ Deciduous

Vegetation leaf type

◯ Broad ◯ Needle ◯ Aphyllous

Surface type

◯ Natural ◯ Artificial

Natural surfaces

- ◯ Baresoil
- ◯ Badland (Gully)

Artificial surfaces

- ◯ Built-up linear
- ◯ Built-up non-linear

Waterbody type

- ◯ Spring
- ◯ Seasonal river ◯ Dam
- ◯ Berkad ◯ Borehole

Take image

Prompts user to take photograph

Remarks

LAND USE

Land use type

- ☐ Nomadic pastoralism
- ☐ Agro-pastoralism
- ☐ Settlement
- ☐ Irrigated agriculture
- ☐ Rainfed agriculture

Water supply

- ☐ Rainfall
- ☐ Irrigation
- ☐ Post-flooded/Flooded
- ☐ Groundwater

Irrigation type

- ☐ Surface
- ☐ Sprinkler
- ☐ Drip
- ☐ Other

Field size

- ☐ Less than 1 Ha
- ☐ More than 1 Ha

Crop rotation period (months)

- ○ 3
- ○ 6
- ○ 9
- ○ 12

Crop management practices

◯ Greenhouse

◯ No management practice ◯ Other

Crops

- ☐ Maize
- ☐ Beans
- ☐ Sorghum
- ☐ Millet
- ☐ Groundnuts
- ☐ Cabbages
- ☐ Spinach
- ☐ Date
- ☐ palm
- ☐ Sunflower
- ☐ Sesame
- ☐ Tamarind
- ☐ Tomatoes
- ☐ Guava
- ☐ Lemon
- ☐ Citrus
- ☐ Grape
- ☐ fruit
- ☐ Mango
- ☐ Grapes
- ☐ Banana
- ☐ Papaya
- ☐ Egg plant
- ☐ Cucumber Watermelon

Is there any water source?

◯ Yes ◯ No

Water source type

- ☐ Borehole
- ☐ Dug well
- ☐ Dam.
- ☐ Berkad

What is the depth of the water source?

State the condition of the water source

○ Functional ○ Abandoned ○ Not functional

Is there a supply and distribution system?

○ Yes ○ No

If yes, state the nature and condition of the system

Do they keep livestock?

○ Yes ○ No

Select animals kept

☐ Cattle. ☐ Goat. ☐ Sheep. ☐ Camel

Is there evidence for land degradation?

○ Yes ○ No

Land degradation type

☐ Gully ☐ Rill. ☐ Sheet

Enter width of the erosion feature

Enter depth of the erosion feature

How has land degradation affected the surrounding area?

- ☐ Loss of arable land
- ☐ Sedimentation and water pollution
- ☐ Flooding
- ☐ Loss of biodiversity
- ☐ Increased carbon dioxide emission

Are there soil conservation measures?

- ○ Yes
- ○ No

Soil conservation measures

- ☐ Stock/rock piles
- ☐ Contours
- ☐ Terracing
- ☐ Gabions
- ☐ Afforestation
- ☐ Soil bunds
- ☐ Controlled grazing

Take image

Prompts user to take photograph

Remarks

CLIMATE VARIABILITY AND CHANGE

Did you access any forecast information for the past (current) rainy season?

- ○ Yes
- ○ No

If yes, what sources of information did you access? Select all appropriate

- ☐ Radio
- ☐ Newspaper
- ☐ TV
- ☐ Local elders/leaders
- ☐ Government extension officers
- ☐ NGO extension officers
- ☐ Other

Level of confidence in the forecast

- ◯ Very confident
- ◯ Confident
- ◯ Not confident
- ◯ Not sure

Did you have access to early warning before the last drought or floods?

- ◯ Yes
- ◯ No

If yes, what did you do with the information in preparation for drought or floods?

____

How frequent are droughts and their severity (1=severe 2=moderately severe 3=least severe)

____

How frequent are floods and their severity (1=severe 2=moderately severe 3=least severe)

____

How do you feel the following climate related factors have changed in the past 10 years?

____

The total amount of rainfall per year

◯ Increased a lot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Length of growing period per year

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Temperature

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Incidents of livestock diseases

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Incidents of crop diseases

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Incidents of food insecurity

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Fodder availability

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Incidents of drought

◯ Increased alot

◯ Increased

◯ Stayed the same

◯ Decreased alot

◯ Decreased

Severity of drought

◯ Increased alot

◯ Increased
◯ Stayed the same
◯ Decreased alot
◯ Decreased

Incidents of floods

◯ Increased alot
◯ Increased
◯ Stayed the same
◯ Decreased alot
◯ Decreased

Select the risks with potential negative impact to livelihood

☐ Droughts
☐ Floods
☐ Crop Disease
☐ Human Disease
☐ Livestock Disease
☐ Livestock Death
☐ Land Dispute
☐ Loss/theft of key asset
☐ Food Insecurity
☐ Death of bread earner
☐ Crop failure or poor harvest
☐ Shortage of water for domestic use
☐ Shortage of water for livestock
☐ Low prices for animals
☐ Insufficient pastures for animals
☐ Shortage of land for cultivation
☐ Other?

Do you take any measures to reduce exposure to the above risks?

- ◯ Yes
- ◯ No

If yes, what measures? Select all appropriate

- ☐ Paying attention to forecasts and early warning systems
- ☐ Accumulate livestock
- ☐ Invest in social capital
- ☐ Seek alternative income sources
- ☐ Using pestcide and fertilizers in agriculture
- ☐ Acquisition of drought tolerant species
- ☐ Migration
- ☐ Supplementary feeding
- ☐ Expanding cultivated land for agro-pastoralists
- ☐ Other

When negatively affected by adverse climatic conditions, what coping mechanisms do you pursue to reduce impact? Select all appropriate

- ☐ Relying on savings
- ☐ Food aid from government
- ☐ Cash for work from NGO
- ☐ Food sharing with relatives friends
- ☐ Reduction in household food consumption
- ☐ Credit from banks microfinance
- ☐ Sale of livestock and other assets
- ☐ Migration
- ☐ Other

Name of respondent?

____

Annex 6: Land Cover Key photos

Class name	Class definition	Field photos	Watershed
Open shrubs with herbaceous			Karkar watershed
Irrigated crops			Nugal-gibin watershed
Open Herbaceous			Nugal-gibin watershed
Herbaceous with shrubs			Karkar watershed

Gully erosion			Nugal-gibin watershed
Built-up			Karkar watershed
Open Trees of Acacia Tortilis with Bareland			Karkar watershed

Annex 7: List of field mission participants

SN	Name	Organization	Title	Email
1	Mohamed Ahmed Omar	IMC - Puntland	Water Resource Expert	mohamed.ahmed@imcpuntland.so
2	Jamal Abdullahi Mohamed	IMC - Puntland	Land Resource Expert	jamal.abdullahi@imcpuntland.so
3	Abdikani Mohamed Ali	IMC - Puntland	IM Expert	Abdikani.mohamed@imcpuntland.so
4	Ismail Khalif Kilwe	IMC - Puntland	GIS/RS Expert	ismaciilkilwe@imcpuntland.so
5	Suad Ahmed Osman	IMC - Puntland	Water Resource Intern	suadosmanahmed@gmail.com
6	Hafso Ahmed Mohamed	IMC - Puntland	Land Resource Intern	hafsawaraabe@gmail.com
7	Fatimo Ali Yusuf	IMC - Puntland	GIS/RS Intern	faatimaali6@gmail.com
8	Furqan Said Hassan	IMC - Puntland	IM Intern	furqansaid98@gmail.com
9	Faruq Dahir Salad	MoERCC	Head of Planning	faruq.egag2020@gmail.com
10	Amino Muse Guled	MoHADM	M&E Officer	xajiin.ym@gmail.com
11	Abdifatah Abdulahi Ali	MoPEDIC	Advisor	a3.ibrahim10@gmail.com
12	Hassan Mohamed Abdi	MoLAH	Assistant Director of Planning	cabdicade781@gmail.com
13	Mohamud Ali Osman	MoAI	Head of Value chain	samatar.0002@gmail.com
14	Mohamed Abdullahi Ali	MoEWM	Director of Geological survey and Data Management	gacaloos999@gmail.com

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PUNTLAND INFORMATION MANAGEMENT CENTER FOR WATER & LAND RESOURCES (IMC)

imcpuntland info@imcpuntland.so www.imcpuntland.so