GIS Based On Identification of Potential Runoff Sites in Maroodijeeh Catchment, Somaliland

A DISSERTATION

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

MASTER OF TECHNOLOGY

IN

GEOTECHNICAL ENGINEERING

Submitted by:

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CANDIDATE'S DECLARATION

I, MOHAMED OMAR ABDULAHI, Roll No – 2K19/GTE/22, student of M.Tech. (Geotechnical Engineering), hereby declare that the project Dissertation titled "GIS Based on Identification of Potential Runoff Sites In Maroodijeeh Catchment, Somaliland" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi

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Date: 28.06.2021

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CERTIFICATE

I hereby certify that the Project Dissertation titled "GIS Based on Identification of Potential Runoff Sites In Maroodijeeh Catchment, Somaliland" which is submitted by MOHAMED OMER ABDULAHI; Roll No – 2K19/GTE/22; Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge, this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi

Date: 28.06.2021

PROF. RAJU SARKAR

SUPERVISOR

ACKNOWLEDGEMENTS

I like to thank the almighty ALLAH for his blessing throughout my period of study.

I would like to express my very great appreciation to my supervisor Prof Raju Sarkar**,** for his valuable and constructive suggestions during the planning of my project work. In addition, give me immerse support to ensure that my work conforms to the set standards. I am sure that this project would not have been possible without his support. His willingness to give his time so generously has been very much appreciated.

I owe sincere and thankfulness to Eng. Mohamoud Qawdhan**,** who made me believe in myself and guided me in the GIS part of my project. Through the whole process of writing my project.

Finally, I wish to thank my parents for their support and encouragement throughout my study.

Mohamed Omar

Abstract

Somaliland is a pastoral community with minimal water resources relying on rainwater and groundwater. The recurrent drought effects on Somaliland, specifically on the Maroodijeeh region, are rising due to climate change. Thus, surface water management's necessity becomes essential to resolve the frequent food crisis, increase the required production, and contribute to food and nutrition security and build local communities resilience.

This study's main objective is to estimate surface runoff and find proper regions for runoff collection based on the physical properties like watershed through practicing GIS besides MultiCriteria Evaluation (MCE) as the mechanism for result support.

The curve number (CN) procedure of soil conservation service (SCS) was employed. GIS was applied to generate a hydrologic soil map and the land use/land cover map, which were then intersected to create the CN value map. Runoff was then evaluated for the whole area using rainfall data according to the SCS-CN method.

Different layers used for the multi-criteria evaluation are land use/cover, soil, slope, rainfall data, and drainage network. The soil conservation service model evaluates the study area's runoff depth. Analytical Hierarchy Processes (AHP) applied to determine proper runoff harvesting sites based on rainfall. The weighted linear combination (WLC) method integrates these physical models in this paper.

Implementing the WLC covers the following of the propriety maps:

- Setting.
- Selecting the weights of relative significance.
- Combining the importance and standardization.

The results show that suitable sites with maximum runoff depth values are encountered in the upstream catchment. From the comparison study result, most surveyed points described as suitable (53.8%) were followed by highly suitable (38.4%), and only 7.7 % are in unsuitable areas. The area results explain that the database and methodology worked for improving the suitability model, including the propriety levels of the models and the models' relevant importance weights, provided good results.

Table of Contents

List of Tables

List of Figures

ABBREVIATIONS AND ACRONYMS

AHP	Analytic Hierarchy Process
CN	Curve Number
DEM	Digital Elevation Model
FAO	Food and Agricultural Organization of the United States
GIS	Geographic Information Systems
RS	Remote Sensing
SCS	Soil Conservation Services
SWALIM	Somalia Water and land Information Management
UNFCCC	United Nations Framework Convention on Climate Change
GPS	Geographic Positioning System
Jilal,	The northeast monsoon, a dry and hot season from December to March
Gu,	Transition period, an important rainy season from April to May
Hagaa,	The southwest monsoon, a dry and hot season from June to September
Deyr,	the second transition period, an important rainy season from October to November.

CHAPTER 1
INTRODUCTION

Water, a fundamental human necessity, a pressure aid in jeopardy, is a crucial maximum critical herbal aid for all elements of human existence, environmental survival, monetary improvement and the right fine of existence. As water is one of the Earth's most significant precious, indispensable and threatened assets, it turned into diagnosed loss of freshwater as one of the five foremost issues going through humanity because it ranked sparkling water 2nd after populace.

A look at an international map gives the misguided response that there is seldom a water problem: water is the most common substance on Earth and covers 71% of the location of the international parquet, but now not all water is sparkling. The enormous majority of floor water on the planet is neither clean nor toxic. This still valid while seawater in the oceans (which contains too much salt to drink) is not included. Another trendy belief insufficient water is that of simple assets. Whether or not the water is polluted, sufficient water is a complicated issue because water is a complicated medium inextricably linked to the Earth's ecology. Industrial and commercial sports is a major cause of water pollutants and runoff from agricultural land, urban runoff, and the discharge of untreated and treated wastewater (Water fine, 2016).

Globally, freshwater represents the most practical 2.5% of all water on Earth (Shiklomanov, 1997), of which 2.5%, less than 1%, are easy to use for humans. It is also restricted via way of means of its choppy distributions in international's areas and nations because of climatic condition and populace size. Most of the effortlessly to be had freshwater assets exist in rivers and lakes shared via means of or more powerful nations. This makes already finite and scarce water assets in addition restricted. When the aid is scarce and shared, the opposition over it will increase mechanically, and struggle may want to be the result. Most of the African nations are water-scarce. In addition, major river basins in Africa are across the world shared among or greater nations.

The entire problem of world meals safety is intently related to water availability. This precious existence and monetary aid are wasted and misused worldwide, and significant water pollution makes the water unusable. Unlike resource, which includes oil, which coal, wind, hydroelectric or nuclear strength may be another, water has no relief and prefers faith and beliefs. It has the strength to transport hundreds of thousands of human beings due to its shortage or abundance. Lack of finances and investments for water improvement is one foremost cause and hazard for a looming international water disaster. Other boundaries are political, social and environmental. Water troubles have been internationalized in the course of the Nineteen Nineties for various motives, including shortage, droughts, floods, pollutants, sharing, and conflicts.

Suffering from all kinds of water scarcities, Somaliland, being water-scarce united states, is never extraordinary from the above situation. On the one hand, Somaliland is placed in an intense waterscarce location. On the alternative hand, Somaliland is lacking, and now no longer handiest effortlessly to be had water assets, each additionally the human and economic assets to installation companies and water infrastructures, which are urgently required. Furthermore, facilities that must formerly be installed for water delivery and irrigation have been destroyed in the local war. Limited water assets negatively affected socio-monetary sports within the United States, offering to expanded poverty, social mobility, and political struggle.

Somaliland is predominantly pastoral groups depending on rainwater and groundwater; this necessitates floor and floor water aid control. The sample of the wet seasons is but converting with time, proscribing the possibility for rainfed agriculture and locations the existence of based populace completely in jeopardy.

Thus, the need for floor water control becomes essential to clear up the common meals disaster and to grow the required manufacturing and contribute to meals and vitamins safety and construct the resilience of nearby groups.

Using runoff water for Agriculture and farm animals may enhance family livelihoods and assist construct resilience in opposition to weather alternate for small maintain farmers.

Rainfall in many elements of Somaliland is erratic. However, it's miles pretty not unusual place to have heavy storms happening in a localised location and ensuing to large runoff volumes inside a rapid duration of time. If no longer checked, the generated runoff can end result in considerable damage, as witnessed in Hargeisa metropolis in 2005. A bridge turned into washed and lives misplaced from flash floods. The flashy waters, in the end, locate manner to the ocean via togas.

1.1 Problem Statement and Justification

The agropastoral communities of the Maroodi-Jeex Catchment experience multiple livelihood challenges, including recurrent droughts, erratic and unreliable rains, soil erosion of serious rate and magnitude, serious reduction of crop yields, and food security. Livestock remains the principal source of livelihood, followed by crop production. The lower part of the catchment also faces other essential resources, which increases Hargeisa's development.

Practical usage of water sources has been at once or in a roundabout way identified in numerous regulations as critical elements in improving and conserving the environment. An estimate of the amount of runoff expected in the catchment area is vital for effective water resource management. Without an impressive assessment of the runoff that can be captured or conserved, it is challenging to think about rainwater utilization plans. Harvesting rainwater for crop production is a hopeful and generally correct way to improve rainfed management in the semiarid tropics.

1.2 General objective

The main objective is to quantify runoff water passing the Maroodi-Jeex catchment and identify the potential runoff water harvesting sites in the catchment using GIS-based on the SCS-CN method.

The specific objectives of the study are:

- To review the existing and current literature and data related to the surface runoff of the Maroodi-Jeex catchment.
- To describe the study area considering the soil, land cover, land use/cover, slope and drainage network of the catchment to define the possible factors that may influence rainfall-run catchment process.

- To identify and recommend appropriate sites for runoff storage using the SCS Curve Number method through GIS.
- To validate the recommended points through field visit.

1.3 Study Area

The Republic of Somaliland is located in the Horn of Africa. The Gulf of Aden outlines its borders in north Somalia, east in Ethiopia. It is located between the parallel 08 00 '- 11 30' north of the equator and between the 42'30 '- 49'00' meridian east of Greenwich. The capital of the Republic of Somaliland is the city of Hargeisa. In 1991, after the fall of the Siyad Barre regime, it declared its dependence on the rest of Somalia. The total area of Somaliland is 137,600 km2, with a predictable population of 3.5 million. 60% of the population are shepherds and agropastoralists who live in rural areas. The remaining 40% reside in urban areas, and the villages were founded on previous traditional water sources similar to natural depressions, shallow wells, earth dams and berkads.

The Marodijeex catchment located in the region of Somaliland, in Farawaye district lying in the Western part of Hargeisa, encompasses all areas of the upper catchments that drain and pass through Dabolaq village way to Hargeisa City. The catchment is located at about 25km from

Hargeisa City. The catchment is partially shared by four villages (namely: Aburin, Dabolaq, Gadiogal, and Har Adad). The outlet point of the catchment is at Hargeisa.

The four villages are further divided into 22 clusters. Hydrologically, the watershed comprises two bifurcating critical watersheds: Usbally and Sharief, with a total catchment area of (400 km^2). These critical branching watersheds originated at the upper reaches of Har-Adad. This naming sequence is from left to right as one sees from top to down along the watercourses to Hargeisa. MUC is bounded by Faraweyne district in the Eastern and Southern part, while in the North and West is bordered by Arab Siyo Valley that drains to the Red Sea and Alay Bede District.

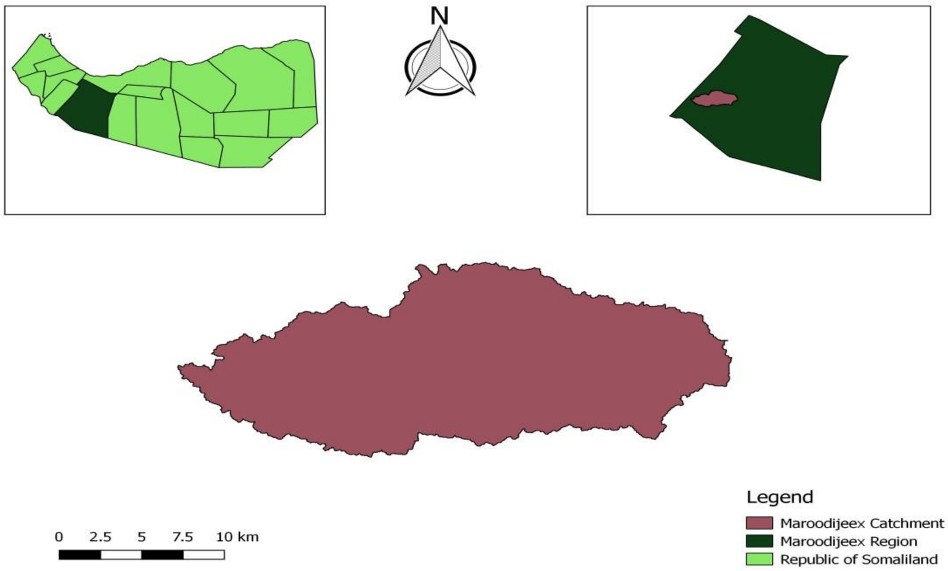

Figure1 Study Area Map

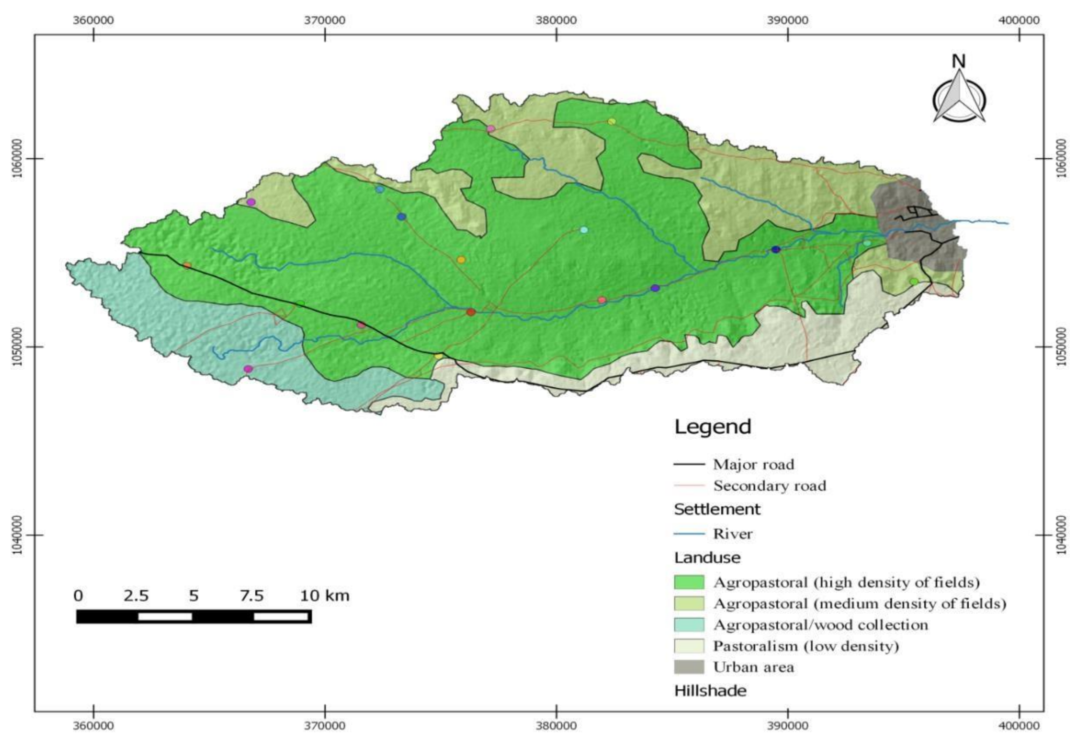

Figure 2 Sketch Map of Maroodijeex Catchment

1.4 Landscape

The Maroodijex Catchment is located in Maroodijex region of Somaliland. Major villages include *Haraf, Hagal, Hareed* and *Dhaboolaq*. The whole Maroodijex Catchment, west of Hargeisa city, is approximately 400 km^2. It is characterized by hills and ridges of landscape with a seasonal watercourse that flows west of Dhaboolaq through Hargeisa city.

1.5 Climate

Based on the climate data that was collected from representative weather stations of *Hargeisa, Malowle* and *Aburin*, The study area is located in a semi-arid zone.

The daily average of most temperatures across the country ranges from 30 ° C to 40 ° C, except at the highest elevations and along the ocean coast. The average daily minimum temperatures range from 20 ° C to over 30 ° C in the afternoon to 85 per cent at night and vary somewhat with the season. In the colder months of December to February, visibility at higher altitudes is commonly restricted by fog.

Temperatures across the catchment are high for most months of the year. The temperatures, however, increase from the highlands towards the sea. In Hargeisa, the mean monthly temperature varies between 17 – 24 ^{0}C.

Most of the country holds under 500 millimeters of rain per year, and a large area that includes the northeast and distant Somaliland receives only 50 to 150 millimeters. However, some higher elevation areas in Somaliland record more than 500 millimeters per year, such as coastal areas. In general, rain occurs in the form of showers or localized torrential rains and is very changeable. The rainfall is higher in the Maroodijex catchments, with *Aburin* and *Hargeisa* stations recording over 260 mm and 400 mm of annual rainfall, respectively (SWALIM, Surface Runoff Estimation, Tog waheen River Basin Pilot study, 2013).

The distribution of rainfall is linked to four seasons:

1. *Jilal (*winter) from December to March.
2. *Gu (Spring)* from April to May.
3. *Hagaa (Summer)* from June to September.
4. *Deyr (Autumn)* from October to November.

1.6 Land cover

The land cover of the areas consisted of savannah and general open shrubs (crown of 65-15%). The dominant tree species are *Acacia etbaica, A. nilotica and A. bussei and A. tortilis, A. Segenal. A. tortilis and Zizyphusmauritiana* are found along the seasonal river. In river valleys, there are also two appropriate land cover types: Irrigated Agriculture (fruit trees and cash crops), General Open Trees, and Shrubs. Natural herbaceous species are *Cenchrus ciliaris, Cynodon dactylon, Sporobolus marginatus, Tragus racemosus* and *Aristida adscensionis*.

1.7 Geology and hydrogeology

The main geological formations that have been described in this selected study area is as per below:

Lower Eocene E1–Auradu Formation. White, grey massive, limestone max. Thickness 380m.Quaternary –recent deposits: *Togga's* alluvium, etc.

According to a geological map of the study, areas is consisted of mostly Yesomma sandstone of

Cretaceous (ky), Maastrichtian to Early Eocene (Ea) and followed by Pleistocene to present (Q).

(SWALIM, Hydrogeological Survey and Assessment of Seletced Areas in Somaliland and Technical Report No. W-20, FAO-SWALIM (GCP/SOM/049/EC), 2012).

1.7.1 Soils

Soil types closely follow the land form of the terrain. The dominant soils of the selected landscape under study areas are *Vertic Calcisol (Aridic, clayic)* locates in the rainfed farms and followed by *Haplic Calcisols (Aridic, clayic)* , *Haplic Fluvisols (Calcaric, Aridic)* in the valleys, *Lithic Leptosol (Calcaric)* , *Hyperskeletic Leptosol and Haplic Regosol* (skeletic) in the ridges and hills.

The soil on the gentle to the moderate slope is classified as Calcic Grumic Vertisols and Lithic

Leptosols. At the same time, that of the hilly areas is Haplic Phaeozems and Eutric Cambisols. The soil on the escarpment or hilly areas is very shallow to shallow and grey in color. Soil on the gently sloping ground receives sediment flow from up hills. This sediment is sometimes sandy and it overburdens fertile cropping fields. Had it not been for the silt coming up hill the fertility of the soil is generally poor.

The 'Calcic Grumic Vertisols' are those tending to be black cotton soils and are located on farmlands. 'Lithic leptosols' are located on the hilly or ridges, and they are very shallow soils as the top soil has been washed away. 'Haplic Fluvisols' are located around the watercourses, and they are said to be 'Fluvisol' because the flood forms them. Even though they are recently transported and deposited, they are structurally unstable prone to erosion, particularly gully. These are the most sensitive soils to gully formations. These soils are, however, small in the catchment.

1.7.2 Water Resources

Due to the lack of reliable surface water resources in the catchment and other areas of Somaliland, the population relies more on groundwater sources for domestic, livestock and other agricultural objectives. The most common groundwater sources in the catchment are shallow wells and boreholes. Several springs also exist in the catchment (Muthusi, 2007).

The distribution of the water sources is essentially decided by the type and depth underlying the water aquifer. In many areas along the river channels, dug wells are established, either at the river bed or riverbank, to tap on the shallow waters mainly for small scale irrigation for fruits and vegetable production where the surface water is not available, deep boreholes are established as the primary source of water for the communities. The main advantages of the boreholes are that they mostly have water throughout the year, unlike some shallow wells which dry out during drought periods.

The main advantage of the boreholes is that they mostly have water throughout the year, unlike some shallow wells which dry out during drought periods. The boreholes are also well protected, which improves sanitation. (SWALIM, Hydrogeological Survey and Assessment of Seletced Areas in Somaliland and Technical Report No. W-20, FAO-SWALIM (GCP/SOM/049/EC), 2012).

Table 1 Description of Land Use with Hydrological soil group

Description of Land Use	Hydrologic Soil Group			
	A	B	C	D
Paved parking lots, roofs, driveways	98	98	98	98
Streets and Roads:				
Paved with curbs and storm sewers	98	98	98	98
Gravel	76	85	89	91
Dirt	72	82	87	89
Cultivated (Agricultural Crop) Land*:				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contours)	62	71	78	81
Pasture or Range Land:				
Poor (<50% ground cover or heavily grazed)	68	79	86	89
Good (50-75% ground cover; not heavily grazed)	39	61	74	80
Meadow (grass, no grazing, mowed for hay)	30	58	71	78
Brush (good, >75% ground cover)	30	48	65	73
Woods and Forests:				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83

Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77
Open Spaces (lawns, parks, golf courses, cemeteries, etc.):				
Fair (grass covers 50-75% of area)	49	69	79	84
Good (grass covers >75% of area)	39	61	74	80
Commercial and Business Districts (85% impervious)	89	92	94	95
Industrial Districts (72% impervious)	81	88	91	93
Residential Areas:				
1/8 Acre lots, about 65% impervious	77	85	90	92
1/4 Acre lots, about 38% impervious	61	75	83	87
1/2 Acre lots, about 25% impervious	54	70	80	85
1 Acre lots, about 20% impervious	51	68	79	84

CHAPTER 2
LITERATURE REVIEW

2.1 Water scarcity in Somaliland

The scarcity of water assets is generic trouble in Somaliland with respective efforts to enhance the circumstances. To date, the valuable resource base regarding groundwater, its recharge, and streamflow are simplest understood to a restrained extent due to shortage of monitoring though the condition is improving. The location faces a growing drop in step with capita water availability because of population increase and a deterioration of the situation. Based on the above case, water assets control is critical in Somaliland (Peterson & Gadian, 2012).

2.1 Groundwater situational analysis

Common hydrogeological situations in Somaliland may be defined as difficult on water availability and water quality. Climatic conditions vary from semi-arid to arid, and floor water availability and shallow groundwater ranges vary with the rainfall intensities withinside the particular seasons. High salt concentrations withinside the groundwater of several wells render them marginally appropriate or fallacious for people and/or animals. Groundwater, being the initial supply of water supply, is typically acquired from boreholes, dams, dug wells and springs (Peterson & Gadian, 2012).

The water sources in Somaliland is described through water shortage and rare water quality, affecting animals and the human populace through restrained water availability.

Water resource used in Somaliland includes Berkads and small dams for floor water catchments. As springs, shallow wells and boreholes are utilized for draining the groundwater sources. They are organized in keeping with suitability on terrain, water resource availability and aquifer traits. Groundwater yields range widely. While floor catchments depend on the quantity, depth and frequency of rains, groundwater yields depend upon the aquifer traits inclusive of work, recharge and water quality (Peterson & Gadian, 2012).

2.2 Groundwater quality

Milanovic studied groundwater quality (2011), who describes groundwater quality as associated with the chemical composition from geological formations through which the water has reached and the stability among recharge and discharge. Concentrations of chemical parts in groundwater range extensively in Somaliland areas, relying on hydrogeological things (spring, dug well, drilled well).

Generally, only a few groundwater references in Somaliland agree to worldwide models. The salt content material of the water exceeds typically 1 g/l, which below everyday occasions, is the higher restriction for human consumption. However, in Somaliland and Puntland, water's reputation with pretty excessive ion concentrations is essential, while there is usually no option (Peterson & Gadian, 2012).

2.3 Water demand and availability

The demand and availability of water were analyzed by Stevanovic (2012) based on field research and earlier studies by various authors. With the absence of perennial streams and the primarily dry climate with little rainfall in Somaliland, groundwater remains the only reliable water supply in most study areas. However, the aquifers are limited, essentially deep and often very salty or poor in yield compared to the growing demand driven by population growth.

The population is heavily dependent on shallow and deep groundwater resources. Problems arise when the groundwater is brackish or salty. Aquifers have been studied by various organizations using mainly geoelectric resistance tests (vertical electrical sounding), although there are problems with analyzing the results and precision, as pointed out by Melchioly (2011), leading to results and recommendations that are in part questionable and each drilled to dry wells. (Peterson & Gadian, 2012).

Hargeisa, the capital of Somaliland, is an example of this excessive growth. It is on the edge of the Hawd Plateau. The population has increased significantly, especially in the last half-century. From a small village of 2,000 in 1930, Hargeysa now has almost a million people or about a quarter of the total population of Somaliland. This is evident from the 2009 water census.

Hargeisa is presently powered by an external water source from the alluvial sediment Geed Deeble.

2.4 Surface water

The Surface water resources are short. The majority of the population depends primarily on the extraction of rainwater. However, the rainy season pattern changes over time, including persistent rainfall and droughts that are common. The rain can last several hours and sometimes generate flash floods to produce months of water for months when harvested. Springs, berkads and dams are the main sources of surface water in Somaliland. (Muthusi, 2007).

Limited areas in Somaliland taken various measures to address water scarcity. Few agro-pastoral households collect rainwater in underground trenches with a capacity of approx. 6 m3, which are reminiscent of Berkads. The trench is marked with a plastic sheet to restrict water from entering (Muthusi F., 2007).

Soil water is done for household purposes also, in some cases, for irrigation. Twenty-litre jerrycans are also widely applied in rural areas to save water instead of the large plastic barrels common in cities.

2.5 Climate Change

Climate change is a statistically significant change in average climatic conditions or variability over a longer period (normally decades or more). Climate variation may be caused by physical processes or manufactured changes in the atmosphere or land use composition. United Nations Framework Convention on Climate Change (UNFCCC, 1992) describes climate change

as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (Muthusi, 2007)

Climate change on water resources is driven by various mechanisms: dry and wet seasons and increased flood risk, and more frequent and extreme droughts. Climate change will also significantly impact water availability and the quality and quantity of available and accessible water. The potential evapotranspiration increases with temperature. The rates can lead to a decrease in runoff, resulting in reducing renewable water supply. The effects of climate change will further increase a region's vulnerability to a variety of factors, including:

- Floods
- Droughts
- Soil erosion rate
- Soil mass movement
- Availability of soil moisture

In areas that are already vulnerable due to their short availability of aquifers, climate change is expected to affect the runoff pattern-infiltration-evaporation. This leads to less infiltration and more drainage. Rising temperatures lead to greater evaporation (Peterson & Gadian, 2012).

2.6 Surface and groundwater vulnerability and sustainability limits in Somaliland

Surface and groundwater resources in Somaliland and Puntland are exposed to both anthropogenic impacts and climate change. Anthropogenic impacts are driven by population growth and manifest themselves mainly in the over-reclamation of groundwater resources and the deterioration of the watershed, resulting in the increased runoff. The influence is expected primarily from the rise in temperature and the respective rise in evaporation and partly through the intensification of precipitation events. Groundwater table decreases somewhat in shallow and deep wells. As population pressure and climate change increase, this trend is supposed to continue and may increase in the future (Muthusi, 2007).

CHAPTER 3
METHODOLOGY AND DATA

The outcome of this study will depend on the various types of data collected from other sources. The data collected to estimate the water runoff are the digital elevation model (DEM), climate data, soil map and use of the mapped soil. The research methodology consists of a desk study and an actual validation fieldwork survey for data collection and investigating.

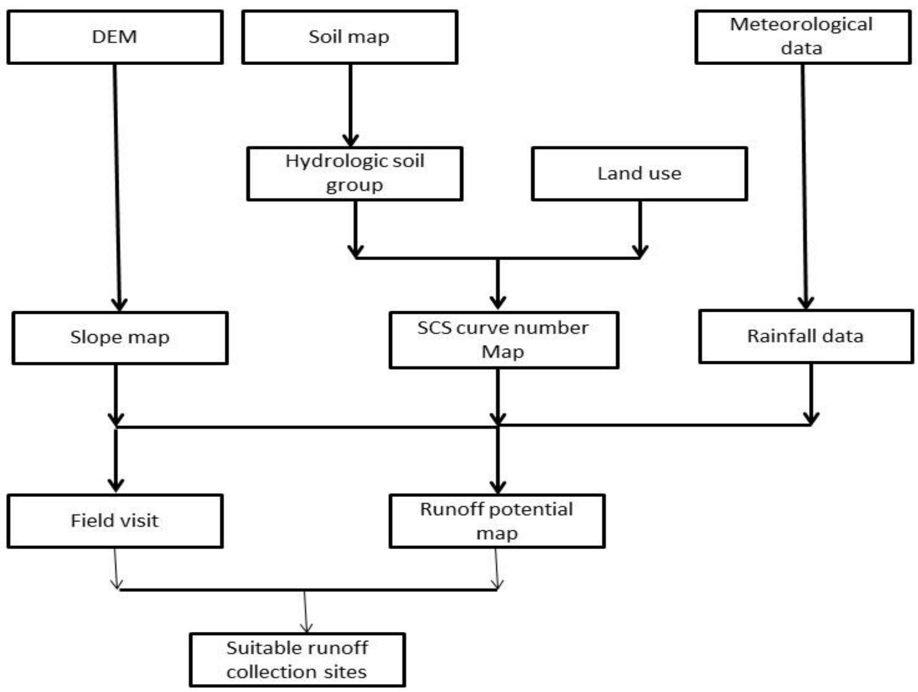

Figure 3. Conceptual framework

Data

1. Raster DEMs with 30 m resolution obtained and downloaded from (http://www.gdem.aster.ersdac.or.jp/.) It is used in this study to capture important hydrological parameters.
2. Climate data were provided by FAO- SWALIM.

3. The soil map was derived from (Soil Survey of Selected Area in Somaliland) generated by FAO-SWALIM. Scale 1:600,000

4. Land use data were extracted from land-use systems generated by SWALIM in Somalia.

3.1 Preparing data and modelling

A digital elevation model obtains the hydrological flow accumulation parameters of the stream network, including a slope with a resolution of 30 m. ArcGIS is used to derive hydrological parameters and then use DEM to estimate all long-distance flow parameters until the continuity of flow is maintained at the drainage basin outlet.

3.2 Slope

The slope is one of the critical factors in controlling soil and base flows. In addition, the slope also determines the separation capacity of the soil and thus the capacity of the land. The slope is made based on the terrain relationship, which is the elevation difference between two points divided by the horizontal straight-line distance between the two points (Winnaar, 2007). The slope is determined by the Digital Elevation Model (DEM) and is divided into five gradient percentages according to the FAO Gradient Classification.

Runoff and its properties, such as the statistical analysis of the observed records used to make probabilistic statements about the flows (annual outflow and frequency of occurrence of certain size runoff events) and the rational equation used to determine the maximum derivative of drainage from the catchment area was used.

In this study, Soil Conservation Service Curve Number (SCS-CN) method evaluated the depths and maintained their spatial location. Arc GIS10.3 were used for processing; they were a subset from the Study area soil map and land use map.

3.3 Modelling runoff

The runoff is a dynamic process that depends on spatially and temporally varying factors to assess the speed at which a modelling design is created in a GIS gives an ideal environment. Such an approach enables the storage, integration, analysis and support of large environments and provides an efficient and inexpensive method for studying factors that influence the runoff rate over a large area. This method was also chosen because of its simplicity in the data requirements and because it estimates the influence of land use/cover changes on the derivation of the parameters (CN) for calculating the excess precipitation. The following parts provide a brief description of the methods used.

3.4 SCS method of estimating runoff volume

The main objective of using the SCS-CN method for the Maroodijeex drainage basin is to determine the amounts of runoff resulting from selected rainfall events to manage these amounts and store water for future needs. The Soil Conservation Service (SCS) runoff curve number is a conceptual guide, and its main purpose is to consider the runoff depth during the rainfall based on the curve number parameter. This method has many benefits in its simplicity, predictability, stability, relationship on parameters, and sensitivity to runoff generated by the watershed. The disadvantages connected with this are: Sensitive to CN, unclear description of changes under the above conditions, variable accuracy due to biomass changes, absence of provisions to consider spatial scale, and an initial extraction ratio set at 0.2 (Victor & H).

The hydrographic watershed is mainly due to both surface and subsurface; the keys belong to; Horton land runoff, land runoff, constant flow process, direct runoff through partial surface runoff channel. The curve number method considers direct runoff, which combines channel runoff, surface runoff , and groundwater runoff (United States Department of Agriculture, 2004).

The Runoff curve number equation evaluates whole storm runoff from total storm rainfall; This relationship does not include time and precipitation rate as variables. In this case, the water flow depth (Q) is limited between 0 and the maximum rain depth (P), and the actual hold (PQ) at the corner is increased by a constant value to ensure its stability; the maximum possible deductible (U.S. agricultural Ministry, 2004).

The runoff equation describes the runoff (Q) as precipitation (P) and the number of curves (CN), which is related to storage(S). Among the following parameters: hydrological soil group, land use and, hydrological surface characteristics and moisture conditions.

Equation 1 - known as the runoff curve number, presents the relation among the parameters described above

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

Where:

Q = runoff depth (mm)

P = rainfall (mm)

S = maximum potential retention after the start of the runoff

(mm) Ia = initial abstraction (mm)

$$Q = \frac{1000}{CN)} - 10 \quad (2)$$

The initial sampling mainly included an interception, infiltration of the first part of the storm, and storage of the surface depression. Due to the variability of infiltration during the first storm, this is difficult to determine because it depends on watershed conditions. Land cover, surface texture, and rainfall rate are considered functions of maximum potential retention, and they are described in Equations 1-3 (USDA, 2004).

$$Ia = 0.2S \quad (3)$$

3.5 Soils

The identification of CN uses the hydro classification. Soils are divided according to penetration and other properties in four classes: A, B, C and D. Important soil properties that hydrologically affect soil classification is adequate soil depth, medium clay content, infiltration properties and permeability. The following is a summary of four hydrological groups (K. Subramanya, 2013): Group (low potential runoff): Soils with high infiltration also flows, if carefully wetted, consist mainly of sand or gravel deep, well-drained too much. Certain soils produce a high level of water permeability.

- Group B (moderately-low potential runoff): Soils with an average infiltration rate with complete wetting mainly consist of relatively deep to deep, moderately well to welldrained soils with rather fine to relatively coarse textures. These soils are average water permeability.
- Group C (moderately-high potential runoff): Soils with average infiltration flows and complete moistening mainly consist of deep to deep, well to well-drained moderately soils with moderately fine to relatively coarse textures. These soils are moderate water permeability.
- Group D (high runoff potential): Soils with low infiltration rates and complete soaking, which essentially consist of clayey soils with high swelling potential, soils with permanently high groundwater levels, soils with a clay layer or layer of clay, near-surface and flat soils on almost impermeable material.

Table 2 Soil group and corresponding soil textures

Soil Group	Runoff Description	Soil Texture
A.	Due to the high infiltration rate, low runoff potential.	Sand, loamy sand, and sandy loam
B.	Medium penetration rate leads to medium runoff potential	Silty loam and loam
C.	Due to low infiltration rates, high/medium runoff potential	Sandy clay loam
D.	High runoff potential and very low infiltration rates	Clay loam, silty clay loam, sandy clay, silty clay and clay

3.6 Antecedent Moisture Condition (AMC)

The SCS-CN method is susceptible to the value of the curve number, and this parameter needs to be accurately determined. The curve number is a function of hydrological soil group, land use and previous moisture. The humidity mentioned five days before the storm. Due to the increase in soil moisture due to early rainfall, runoff increases during heavy rains.

AMC describes the moisture content of the soil at the beginning of the observed rainfall-runoff.

For possible reasons, SCS distinguishes the three stages of AMC as follows:

AMC-1: The soil remains dry but does not wilt. The culture was performed satisfactorily.

AMC-2: Average conditions.

AMC-3: It has rained enough in the last five immediate days and saturated soil conditions control. This study will collect precipitation data from the nearby available Hargeisa and Aburin stations.

It is considered for the whole watershed of the provided storm.

Table 3 Antecedent moisture conditions (AMC) for determining the values of CN

AMC Category	Total rain in 5 days Dormant season	Growing season
1	Less than 13 mm	Less than 36 mm
2	13 to 28 mm	36 to 53 mm
3	More than 28 mm	More than 53 mm

3.7 Analytical Hierarchy Process (AHP)

Many factors need to be considered in urban land-use decision-making. Most of the available methods are qualitative. All aspects are considered descriptive and cannot be quantified. Therefore, it is difficult to analyze the cumulative effect of all these factors. AHP is regarded as a practical approach to quantifying qualitative factors to quantify the integrated effects of these factors.

(Bamshad Senavr).Saaty developed this hierarchical process method (AHP) in 1980.

This method is compared with that of the two standards. The pair-wise comparison methods used to compare the relative influence of requirements on the continuum are classified into nine classes. Using this method must be weighed can be determined the relative importance of each standard against the identification criteria. The Analytic Hierarchy Process is a mathematical method that prioritizes processes, evaluation criteria, and decisions making. The nature of AHP analyzes transparent and clear reasons for choosing different option plans.

Other methods, ease of thinking, reasoning and efficiency, and multilateral collaboration to change group decision-making.

3.8 Field visit

Field visit was conducted for ground verification of the GPS points that has been selected remotely. Field studies introduce visits to the study area to take GPS points and pictures to identify the natural features, vegetation status,

The fieldwork phase of the study comprised the collection of primary and secondary data and was carried out from mid-May to mid-August 2019. The primary data collection required the collection of soil, land use and land cover data. Visits to various offices, including the Hargeisa Metrological Station, FAO-SWALIM office, collect climate data and map land-use practices and land cover features of the watershed.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Rainfall

There is a strong dependence on rainfall; however, in sub-Saharan Africa, it is considered one of the lowest precipitation measurement stations in the world, especially in agricultural production. The reliability of the information gathered a primary problem because even in which rainfall information is available, weeks can elapse among series and accessibility to customers is poor (F.H.M.Semazzi, 2007). Rainfall is a direct assuming pressure with inside the runoff era in each watershed. The main reason for this research is to find out how to use first-class methods to obtain runoff data in low-data areas where the spatial distribution of rainwater communities is insufficient or nonexistent.

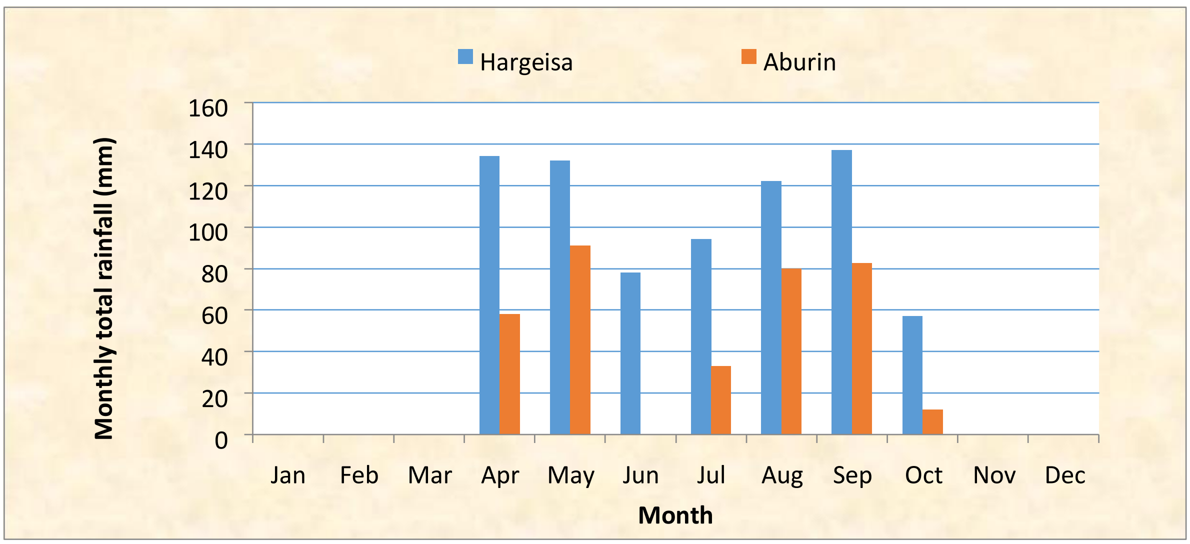

Figure 4 Total monthly rainfall data for the year 2019

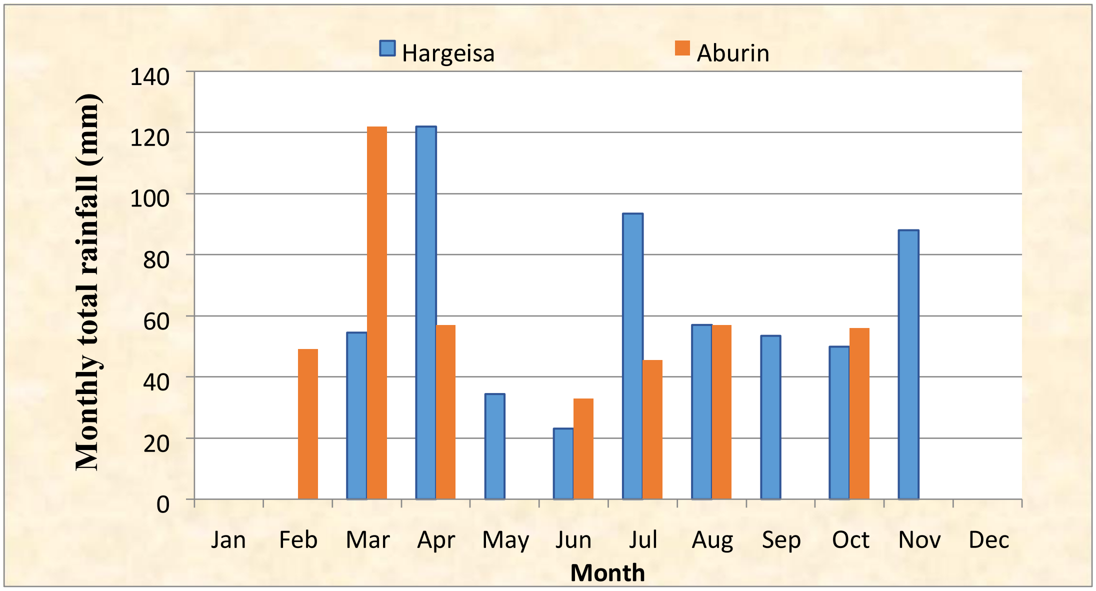

Figure 5 Total monthly rainfall data for the year 2020

The above records are overall annual rainfall measured from rainfall stations that records turned into to be had for 2019 and 2020. The found rainfall shows that the catchment has one extended wet season between March and November. Two distinct peaks in rainfall occur in April / May and August / September as shown in Figures 5 and 6. The adjusted rainfall quantities display spatial-temporal rainfall distribution of the two stations and maybe competently carried out to derive the runoff depth.

4.2 Hydrologic Soil Group

The map towards hydrologic soil groups including the spatial; variation of these groups in the study area is presented in figure 8 and table 2. Three hydrologic groups A, B, and D were observed under this study area. It is evident that this region predominant comprises of HSG D (67.7%), B (24.9%) and A (7.4%).

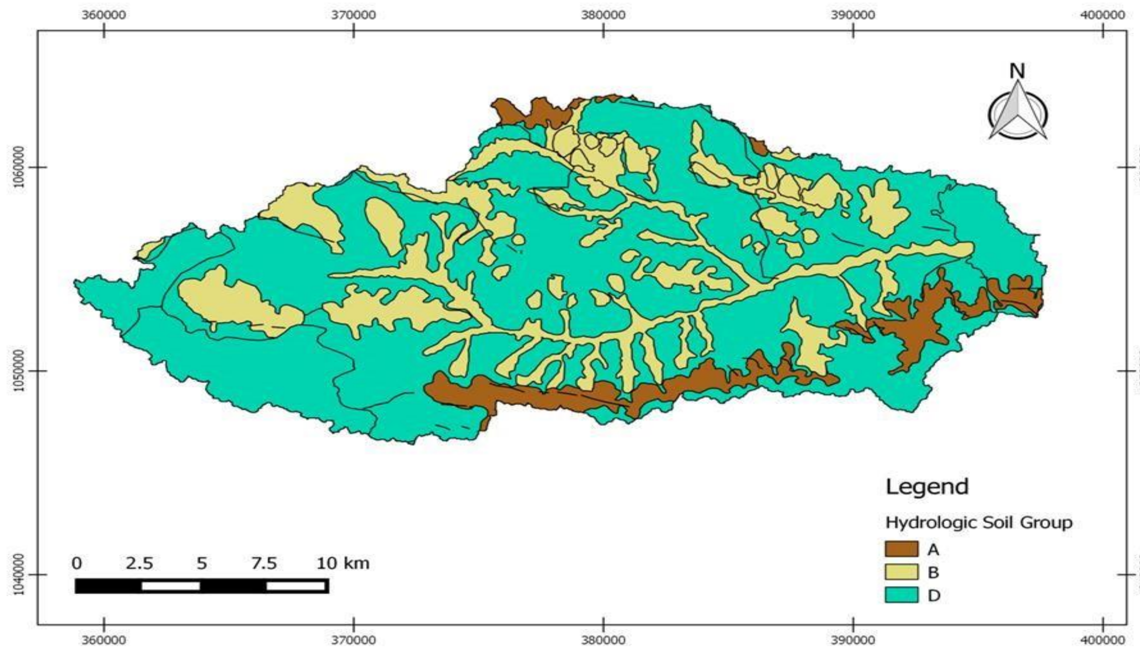

Figure 6 Hydrologic Soil Group

Table 4 Hydrologic Soil Group

Hydrologic Soil Group	Area(Ha)	Percentage of Area (%)
A	3124.1	7.4
B	10446.8	24.9
D	28402.6	67.7
Total	41973.5	100.0

4.3 Curve Number

The first step was to create the curve number map, which is prepared by intersecting the soil hydrologic group map with the land use map. A new map will be obtained by intersecting these maps, including the hydrologic soil group (Hydro group) and land use (Subclass). The curve number (CN) value according to the curve numbers from Urban Hydrology for Small Watersheds (Soil Conservation Service, 1986) was then entered, referring to the land cover type and hydrologic soil group (HSG). Once the CN values have been provided for all records, the CN map for the study area was created (Babikar). The second step is calculating runoff, which is based on the SCS curve number-runoff method. In this method, runoff is calculated using the equation below equation:

$$S = \frac{254000}{CN)} - 254 \qquad (4) \text{ in (mm)}$$

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad (5)$$

The current study equation number (4) was applied to calculate S in mm using the long-term mean monthly rainfall depth in mm and equation number (3) to calculate the runoff depth. Figure (7) reveals the diagram, which explains the steps of the curve number generation and Runoff calculation

Figure (7) displays the curve number map of the study area, which was classified into five classes according to the CN values, described as follow (0-30, 31-46, 47-62, 63-78 and 79-94). A map of curve numbers was generated based on the hydrological soil groups and land cover grid surfaces

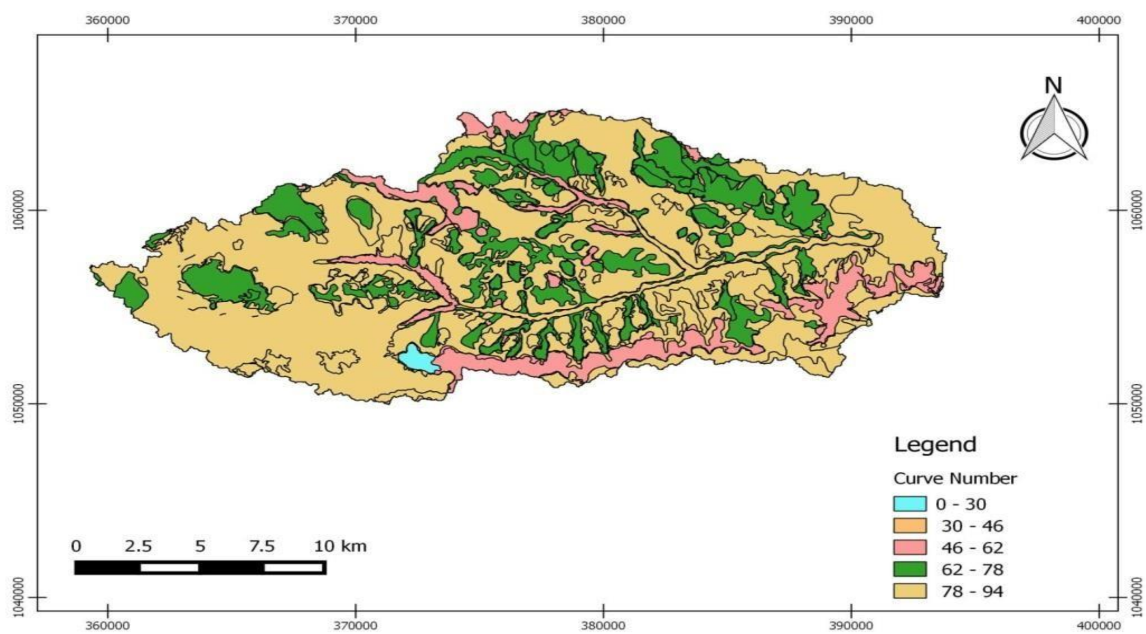

Figure 7 Curve number Map

Table 5 Combination of Curve Number, HSG and land use/cover

Land use/cover	Hydrologic Soil Group	CN
Agricultural Area	A	70
Agricultural Area	D	88
Agricultural Area	B	79
Bare Soil with Scattered Vegetation	B	79
Bare Soil with Scattered Vegetation	D	89
Bare Soil with Scattered Vegetation	A	68
General Open Shrubs (15-65%)	A	48
General Open Shrubs (15-65%)	B	67
General Open Shrubs (15-65%)	D	83
General Open Shrubs (15-65%) with Open Herbaceous	D	73
General Open Shrubs (15-65%) with Sparse Trees	D	77
Herbaceous (1-100%) with Sparse Shrubs	D	89
Herbaceous (1-100%) with Sparse Shrubs	B	71

Herbaceous (15-100%)	D	85
Herbaceous (15-100%)	B	62
Sparse Herbaceous (1-15%)	B	80
Sparse Herbaceous (1-15%)	D	93
Sparse Shrubs (1-15%)	B	72
Sparse Shrubs (1-15%)	D	86
Sparse Shrubs (1-15%) with Sparse Herbaceous	D	84
Sparse Shrubs (1-15%) with Sparse Herbaceous	B	68
Urban Areas/Settlements	B	80
Urban Areas/Settlements	A	68
Urban Areas/Settlements	D	94

4.4 Slope

The area's slope concerns the runoff, recharge, and flow of surface water and is a significant site selection parameter. According to the FAO slope analysis, the derived slope map figure (8) is divided into five slope percentage categories.

Table 6 Slope classification

No	Slope class	Slope %
1.	Flat	<2
2.	Undulating	2-8
3.	Rolling	8-15
4.	Hilly	15-30
5.	Mountains	>30

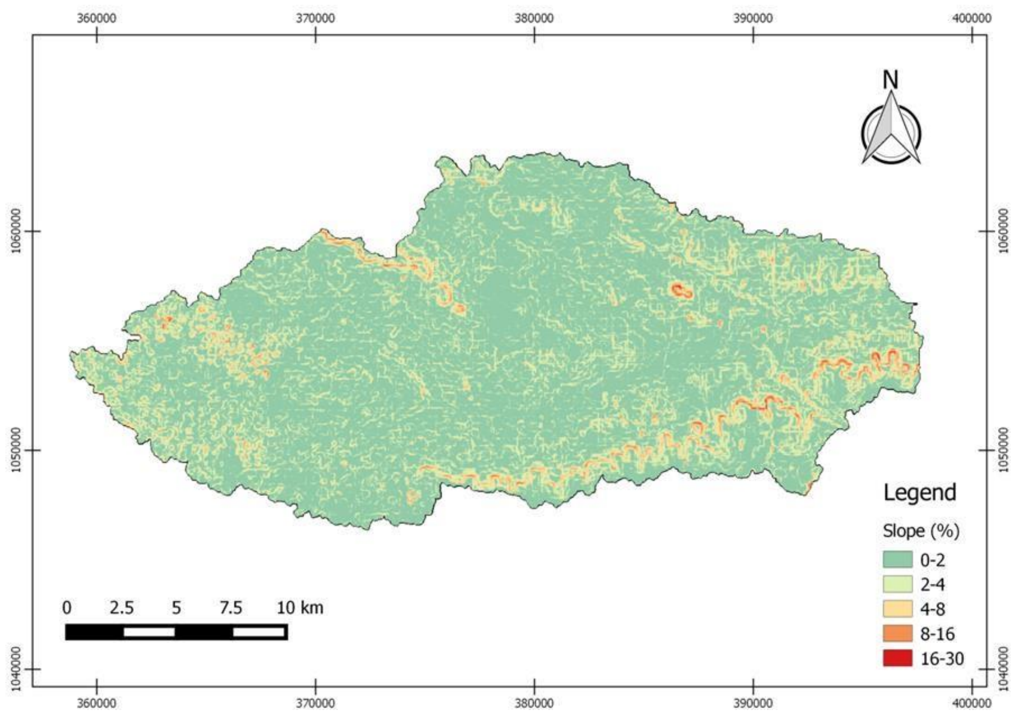

Figure 8 Slope Map of Maroodijeex Catchment

4.5 Runoff Potential

The curve number for every polygon became decided from the soil and land use information. This runoff was determined based on the SCS method. Figure (7) reveals a runoff depth map of the study area, where the area was divided into five groups that can be illustrated as follows (04.4, 4.4-8.8, 8.8- 13.2, 13.2-17.6 and 17.6-22 mm). The results showed that not all of the study area contributes to runoff equally; while there was a significant variation in the normal flow and runoff throughout the watershed. The excessive curve number indicates excessive runoff and low infiltration (city regions with high urbanisation levels), while a low curve number indicates low runoff and excessive infiltration (dry soil, rural areas, including the low level of urbanization).

The estimated runoff depth shows that the watershed has an excellent surface runoff potential.

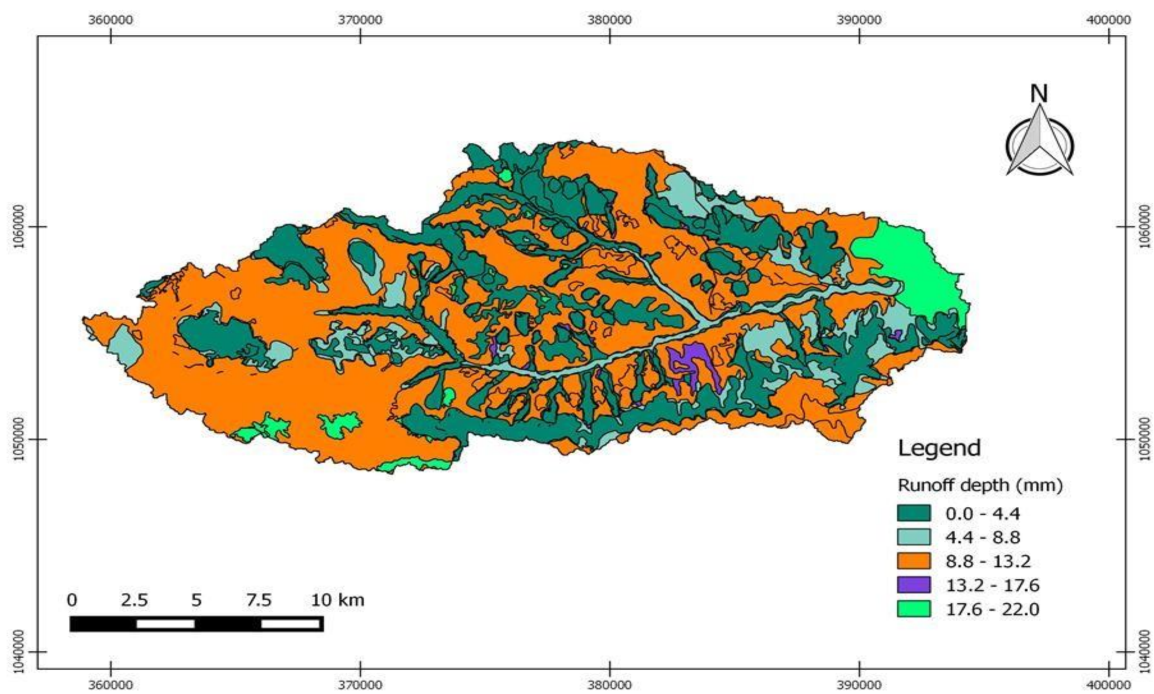

Figure 9 Runoff depth map

4.6 Analytical Hierarchy Process (AHP)

In this examine, Analytic Hierarchy Process (AHP) became used hired to generate a runoff harvesting suitability map of a examine area. This approach was produced by Saaty (1977). The pairwise evaluation approach consists of evaluating every component towards each different part in pairs (Ronad 2006). The weights of criteria in the Saaty process are measured using the principle Eigen vector of the rectangular reciprocal matrix of pairwise correlations among the two parts.

The rate of three physical standards became decided on primarily based totally on an evaluation of the literature. Practising the WLC approach, some rate became appointed to every criterion withinside the scale of 1 to 4. Three physical standards had been used withinside these studies for choosing the proper sites for the runoff harvesting are Rainfall, Curve Number (combined Land use and Soil) and slope.

Weights and ratios are assigned to all the specific criteria, as shown in Table 7. The WLC method is related to combine these physical standards. The implementation of the WLC method includes standardizing suitability maps.

It is defining the weights that are relatively important to suitability maps.

- Bundling weights and standardized.
- Obtaining map charts

Table 7 Different weight assign to Layers through AHP

	Curve Number (CN)	Rain	Slope
Curve Number (CN)	1	2	3
Rain	1/2	1	2
Slope	1/3	1/2	1

All the generated thematic layers are integrated into ArcGIS to map suitable regions to collect runoff from the surveyed area. The overall weight of each final included layer calculated using the formula Si= (Rw.Rr) + (SLw.SLr) + (CNw.CNr). Among them, "w" describes the weight of each standard, and "r" describes the rate of any standard, specifically: Rainfall(R), slope (SL) and curve number (CN). Represents a water harvesting index, which implies a dimensionless range that can determine the appropriate collection site in the area (AlShabeel, 2016).

Lastly, the concluding suitability map becomes advanced to display the capacity sites for excessive runoff Harvesting Sites in the observed area. The runoff harvesting suitability map is classified into three classes: Highly suitable, moderately suitable, and unsuitable.

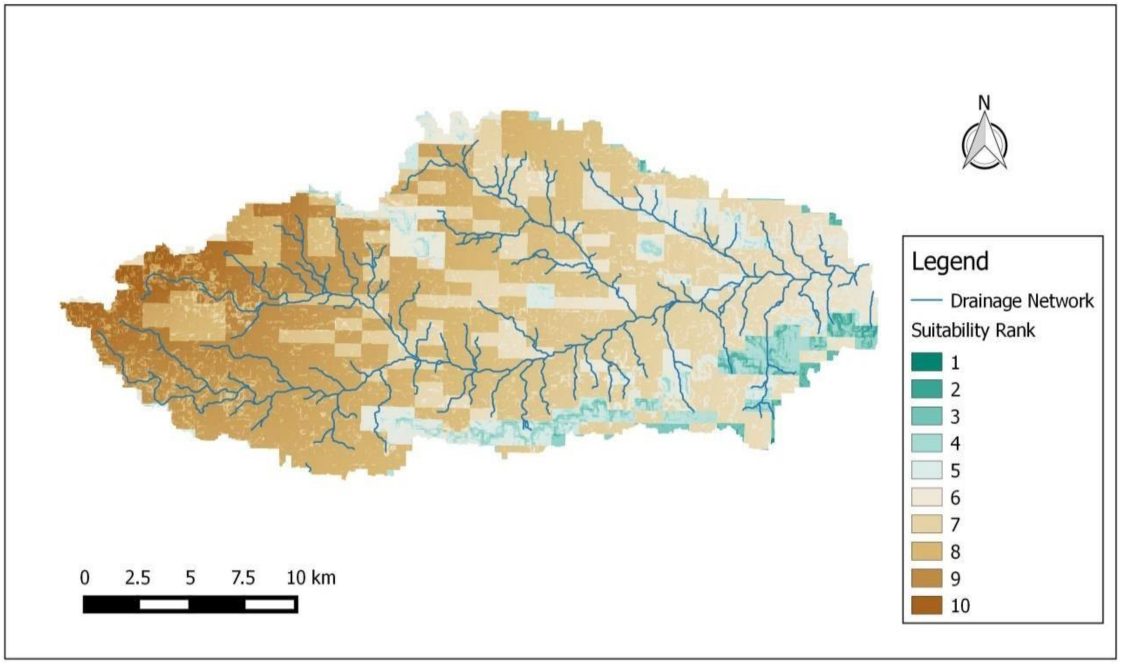

Figure 10 Suitability Map

Table 8 Suitability Table

No	Legend	Range
1	1-4	Low suitable
2	4-7	Moderate Suitable
3	7-10	Highly Suitable

4.7 Field Visit

An on-site verification was conducted to assess the suitability of the selected location for runoff harvesting. To investigate the authenticity of the soil, 13 points were selected. A series of digital images were taken during the field visit. The photos were captioned and used in analyzing the current view on the ground. The images were also included in this report to highlight important observations. The validation consisted of evaluating the produced suitability map, ranked from Rank (1 to 10) and the surveyed runoff harvesting sites. From this result of the field study, the maximum of the studied sites was determined as having various characteristics, as shown in table (6). From the comparison study result, most of the surveyed points classified as suitable (53.8%) were followed by highly suitable (38.4%). Only 7.7 % are with unsuitable regions. The validation consequences confirmed that the database and method used for improving the suitability standard, including the suitability stages of the standards and the standards' relative significance weights, have given good outcomes.

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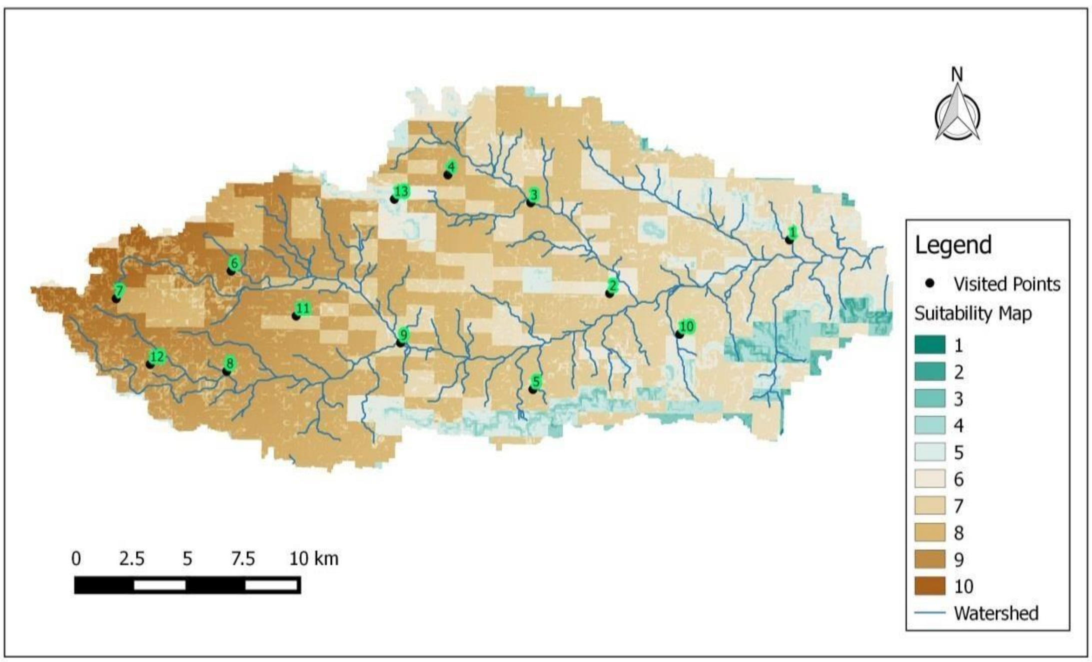

Figure 11 Visited Points

Table 9 Description of the Validation Points

Visited Points	Slope (%)	Soil Group	Land Use/ cover	CN	Runoff Depth(M)	Suitability Rank	Photo No
1	(2-4)	D	Savannah	84	0.37	6	6
2	(4-8)	B	Savannah	68	0.04	5	5
3	(8-16)	B	General Open Shrubs	56	0.1	7	7
4	(2-4)	B	Savannah	73	0.11	6	6
5	(8-16)	A	General Open Shrubs	48	0.44	6	6
6	(2-4)	D	Agricultural Area	88	0.52	8	8
7	(0-2)	D	Agricultural Area	88	0.52	10	10
8	(0-2)	D	Transhumance	88	0.52	9	9
9	(2-4)	B	General Open Shrubs	79	0.22	5	5
10	(4-8)	D	Savannah	83	0.33	6	6
11	(2-4)	B	Bare Areas	79	0.22	6	6
12	(2-4)	D	Agricultural Areas	88	0.52	10	10
13	(8-16)	B	General Open Shrubs	48	0.1	2	2

CONCLUSION AND RECOMMENDATIONS

Marodijeh Catchment is an area lying in the upper part of Hargeisa City with a potential source of runoff. If the catchment degradation continues unabated, nothing can stop the flood from intensive rains and its concentration as runoff. Presently, many settlements close and within its river are at risk. Many places along the water course downstream to Hargeisa city houses are constructed very close or within the wadi.

Accordingly, it should be remarked that people who live in the catchment area, downstream areas such as Hargeisa must take the right approach, and that their timely intervention in the collection of runoff is crucial.

The efficient and sustainable use of runoff is essential to enhance the appearance of rainfed farming management within the study area. Runoff collection is an option to better use the drainage by collecting and storing it during heavy rainfall and using it during periods of water scarcity—an essential step before planning and actual implementation.

It identifies possible areas for runoff harvesting requiring a spatial understanding of some essential physical parts such as soil, climate, topography, and land use.

This study identifies potentials using GIS suitability model based on the Model Builder ArcGIS 10.6. The suitability model practised an MCE method connected many biophysical parts: soil texture, soil depth, climate, slope, land cover and groundwater depth.

Although, socio-economic circumstances (e.g. market access, infrastructure, population density) that are most important for a full assessment of soil suitability for RWH were not considered due to the lack of data for this area. Therefore it is advised to include socio-economic factors in future studies to develop the assessment of competencies.

The suitability model produced a suitability map to the study area. The determination of the suitability model verified doing information from the study area. Demonstrated that the database and methodology applied to generate the propriety model, including suitability levels, models and materiality weights of the standards, were successful.

While this study, the GIS discovered a successful suitability map tool giving an easy-to-knowing source of information to quickly classify more assuring fields than other fields for

RWH interventions. This data is helpful for planners and decision-makers, but care should be taken when interpreting the data generated. A field study should always precede the actual selection and implementation of runoff collection and control sites.

Apart from that, fieldwork is required to get the socio-institutional context of the field to finish the work as mentioned above. Slightly modified to include different information with different spatial resolutions.

The Geographical Information System (GIS), a management system for spatial and non-spatial databases, permits us to handle many data from multiple sources. GIS stores, Retrieves, manipulates, analyzes, also presents data to custom specifications, making it a model tool for site selection RWH with coverage maps of the slope, soil, land use/cover and order of the buffered streams. This study area has full scope for storage basins, infiltration, dams and control barriers. The created map helps select the suitable location of the collection structures and consider the site's suitability for the management of water resources, thematic layers such as soil, drainage, land use/land cover properties.

Essentially, the physical features of each catchment area were produced from remote sensing data and combined with drainage, soil and slope maps in a GIS environment. In addition, a multi-criteria analysis carried out to delimit these zones of proper surface and groundwater use structures, including artificial enrichment structures, using an equally weighted approach. Therefore, combined remote sensing and GIS can give the right platform for multidisciplinary data reports and sustainable land and water resources.

The SCS model used the long-term mean monthly rainfall at the Hargeisa and Aburing Rainfall stations to estimate the depth of the runoff.

As the actual amount of the annual runoff, these databases can be converted into land use/land cover maps with the help of GIS techniques and can be effectively carried out change detection, runoff estimation, soil erosion study, site suitability analysis for rainwater harvesting, prioritization of watershed, etc. by using GIS techniques.

For effective implementation of runoff collection activities following the watershed logic and working ridge-to-valley should be respected. For this, all components of a watershed should be considered in entirety, and tools such as GIS are critical.

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