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# Identifying Suitable Sites for Rainwater Harvesting Using Gis and Multi - Criteria Decision Making Techniques in Liban Zone of Somali Region, Ethiopia

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## ABSTRACT

Ethiopia possesses ample potential water resources but does not have the infrastructure needed to harness them. Severe weather conditions and significant fluctuations from year to year and season to season of this whether element could adversely influence efficiency. Collecting rainwater can alleviate scarcity of potable water and farming productivity in locations lacking alternative water resources (Mohanty et al., 2020). The Somali region of Ethiopia is among the provinces that exemplify the most water-scarce areas (ESR, 2016). The area relies on groundwater withdrawal as a part of its drinking water source, yet the water supply has decreased due to falling water levels (MoWR, 2013).The objective of study is to pinpoint and find appropriate locations for rainwater harvesting through the application of GIS and MCDM methods in the Liban zone of the Somali region based on the Food and Agriculture Organization (FAO) catalogs of parameters including areal climate, water systems, landscape, agricultural practices, soils, and socioeconomic factors. Based on the land suitability map created through this research, the areas deemed most appropriate (highly suitable and suitable) are mountainous regions featuring large earthen hills with significant elevation potential. The valleys within the examined locations exhibit various slopes, causing some (particularly those with steep inclines) to be unsuitable for reservoir construction. The southwestern part of the target area displayed greater degrees of suitability due to its gentle slope, and these locations are suggested as reservoir sites because of their closeness to the river. Although the current study facilitates the direct identification of suitable sites for RWH from the map, it is ultimately advised to conduct onsite visits to guarantee a more thorough investigation. In light of recent climate shifts and as a strategy for managing water resources in the Liban zone of the Somali regional state, the establishment of RWH reservoirs ought to be viewed as a feasible solution for areas that lack alternative potable water supply options or do not have enough water to fulfill both public and private requirements.

**Key Words:** Rainwater Harvesting, $GIS^1$, $MCDMI^2$

## 1. Introduction

Ethiopia possesses ample potential water resources but lacks the infrastructure necessary for their effective utilization. This situation is referred to as economic water scarcity, resulting from insufficient economic capability to address gaps for the efficient usage of existing resources (Seckler and Barker, 2010). Rain-fed agriculture has been extensively practiced for centuries in Ethiopia, and this industry has relied heavily on rainfall (Biniyam and Desalegn, 2015). Consequently, rainfall is a vital element in weather conditions that influences agricultural productivity. Severe climatic conditions, along with significant inter-annual and seasonal fluctuations in this weather component, could negatively impact productivity. Collecting rainwater can alleviate the lack of drinkable water and enhance agricultural yield in regions where no alternative water sources are present (Mohanty et al., 2020).

Ethiopian Somali region is one of the areas that illustrate the majority of water-scarce regions (ESR, 2016). The area depends on groundwater withdrawal as part of its drinking water source; however, the availability of water has decreased due to falling water levels (MoWR, 2013). Identifying appropriate locations, especially larger ones, for establishing RWH systems poses a difficulty for water resource managers and planners (Toosi et al., 2020). This is due to the fact that the application of RWH technology relies on the physiographic, environmental, technical, and socio-economic characteristics of a particular region of focus, and a model that is effective in one area may not be applicable in another (Jasrotia et al., 2009).

Multi-Criteria Decision-Making (MCDM) and Geographic Information Systems (GIS) can be employed to pinpoint appropriate sites for RWH (Toosi et al., 2020), followed by the implementation of the Analytical Hierarchy Process (AHP) and Pairwise Comparison (PWC) method as

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the foundation for the structured technique of MCDM analysis (Adham et al., 2017; Perez et al., 2005). The data needed for the analysis can be gathered via a structured online survey designed to ensure that experts rate and weigh each criterion. Additionally, GIS utilized the Weighted Linear Combination (WLC) and hydrology tools, which includes decision rules as an analytical approach for addressing MCDM in the final scoring of the combined map (Malczewski, 2000). In general, the application of GIS for site selection relies more on deterministic rules that guide the integration of various parameter maps, allowing different locations to be organized based on multiple evaluation criteria (Malczewski, 2004).

Multiple investigations (Adham et al., 2017; Toosi et al., 2020) pinpointed RWH locations using GIS & MCDM methods by applying both quantitative and qualitative elements such as landscape, resource accessibility, soil durability, land utilization, etc. (Dugan et al., 2013). During the 1990s, most research concentrated mainly on biophysical factors; however, studies carried out post-2000 began to incorporate socioeconomic aspects (Toosi et al., 2020). This process can be achieved by identifying locations on topographical charts and through field assessments. Recent research employs remote sensing to enhance the understanding of hydrological and morphological factors (Saleh Alatawi, 2015). Hydrological, numerical, and decision support models are also accessible for RWH development (Franz et al., 2008). Despite its significant interest, studies on the subject are quite scarce in the Liban zone of the Somali regional state of Ethiopia, that's the reason this paper is fundamentally conducted. To achieve this goal, the present research seeks to recognize and find appropriate locations for rainwater collection by employing GIS and MCDM methods in the Liban area of the Somali region, with the following specific objectives;

- • To identify potentially fitting site coordinates from different alternatives during comparative evaluation.
- To generate suitability map founded on both qualitative and quantitative criteria.
- To evaluate and contrast the significance of various decision-making factors

## 2. Materials and Methods

### 2.1. Description of the Area

#### *2.1.1. Geographical Location*

Liban zone of the Somali regional state of Ethiopia is situated along a boundary line that divides the historical lands of the Somali and Oromo communities inhabiting the southwestern region of Ethiopia (Ahmed Y., 2020). The geographical position of Liban zone is found between $10^{0}10'0''$-$8^{0}40'0''$North latitude and $42^{0}32'0''$ - $44^{0}0'0''$East longitude has an approximate total population of 339,821, consisting of 197,315 males and 142,506 females. While 46,892, or 8.69%, are residents of urban areas, an additional 258,214, or 47.83%, were engaged in pastoral activities. This region is situated between the Ogaden and Wabi Shebele river basins. It is bordered to the south by Kenya, to the northwest by

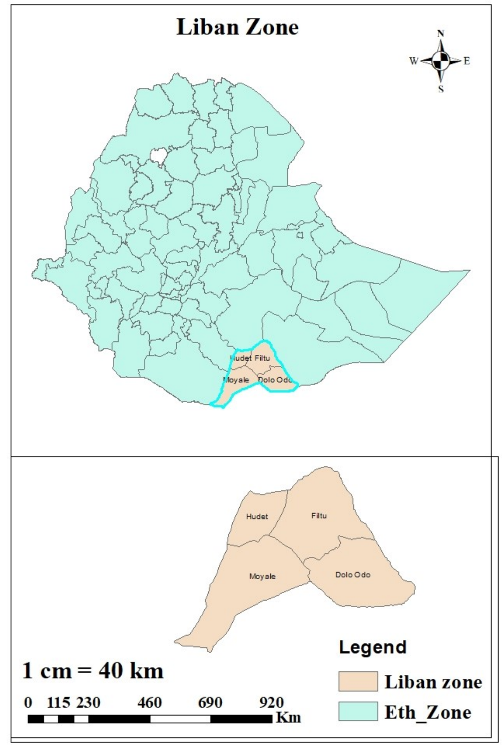



**Figure 1:** Location of Liban zone with respect to Somali Regional Map and Ethiopian boundary

Source. CSA,2007

the Oromia region, to the northeast by the Afder, and to the southeast by the Somali federal state of Jubaland. As per the existing administrative framework, the zone is divided into six weredas: Awbare, Jigjiga, Kebri Beyah, Harshin, Tuli Guled, and Gursum. The towns within the Liban zone include Filtu, Gof, Bokolmayo, Deka Suftu, and Dolo.

### 2.2. Topography and Rainfall

The climate in the Liban region is dry. There is significant variability in annual rainfall. The most notable difference in rainfall patterns underscores the necessity of collecting water for utilization during droughts. On average, every 5 years, there is a rainfall occurrence of 60 mm/day, and every 7.5 years, the area experiences a rainfall event exceeding 100 mm/day. The area has an elevation between 1,141 and 2,157 meters above sea level, with the majority of the central-west regions being hilly, while the northern, southern, and eastern areas are situated at lower altitudes. Besides the distinction between High and Lowlands, the Ethiopian terrain is noted for the Great Rift Valley that traverses the nation. This rift system is a geological formation that emerged from the separation of tectonic plates. The Liban zone lies at the southern edge of the Great Rift Valley, close to the waibishebele basin. Due to the interplay between topography and climate, the likelihood of water shortages and flooding is greatest in the southern section of the landscape (Reinier et al., 2006).

**Table 1:** Compilation of information utilized throughout the research

| S.no | Title | Type | FAO parameter | Source |
|---|---|---|---|---|
| 1 | Rainfall | Data | Climate | Climate Engine |
| 2 | DEM | Rater | Topography and hydrology | USGS/Earth explorer-30 m resolution |
| 3 | Soil texture | Shape file | Soil | Ministry of Agriculture |
| 4 | Land cover | Img. File | Agronomy | Ministry of agriculture |

## 2.3. Data Collection and Analysis

Selecting an appropriate site for a water reservoir for Rainwater Harvesting (RWH) is difficult due to the intricate factors involving hydrological, geological, and economic aspects of a specific area (Shahabi et al., 2016). The Food and Agriculture Organization (FAO) outlines four essential factors for assessing soil water conservation locations vital for RWH (Kahinda et al., 2008). These factors encompass a region's climate, hydrology, topography, agronomy, soils, and socioeconomic conditions. The five criteria were employed to identify potential locations for small dams through a review of literature, insights from local experts, and existing data. In this research, the FAO factors were utilized as a framework for criteria: precipitation for climate; adjacent stream systems for hydrology; land gradient for topography; land use for agronomy; and soil composition and drainage for soils. Four biophysical criteria chosen for this study, as illustrated in Table 1.

Criteria weights were established based on the assessments of experts gathered through a structured questionnaire following the MCDM (AHP, pairwise comparison) analysis. This structured questionnaire included four inquiries concerning four chosen criteria, with each criterion assigned specific levels of significance to evaluate the importance level of a criterion according to expert perspectives. They evaluated the significance of each criterion by scoring them from one to a specific number, with a minimum grading of and highest degree of significance.

## 2.4. Methodological Framework

AHP signifies a multi-criteria decision-making approach that offers a systematic methodology for arranging and evaluating factors in intricate decision-making scenarios, grounded in mathematics and expert knowledge (Adham et al., 2017). This technique was first introduced by Thomas Saaty in the 1970s (Saaty, 1977). Since its inception, it has been widely utilized across a range of fields (Toosi et al., 2020). A key characteristic of AHP is its hierarchical depiction (Fig. 2.) of a problem's components, demonstrating the connections among the tiers of information. The top tier in the hierarchy is the primary goal (objective), with the subordinate tiers consisting of criteria and sub-criteria (indicators) contributing to that primary goal (Saaty, 2015). The needed AHP outcomes are the chosen criteria weights determined through the pairwise comparison approach (Perez et al., 2005).

The procedure initiates with four 4 biophysical criteria assessed qualitatively through MCDM analysis and quantitatively through GIS analysis. The qualitative assessment employs the Saaty AHP Model (Saaty, 1977) to create a structured questionnaire aimed at consulting local experts in the Liban Area regarding the criteria. Results from the survey were utilized to apply a set of scores to the AHP pairwise comparison model, resulting in the final qualitative weights. The quantitative GIS analysis facilitated the classification of the previously mentioned four criteria into sub-criteria, taking into account RWH reservoir needs within the ArcGIS framework. Data sourced from USGS in the form of Digital Elevation Model (DEM) and most data from the target area was adjusted to align with the GCS_WGS_1984 Projection, a geographical coordinate system that uses degrees as the angular unit, which was then reprojected to the WGS 1984 UTM coordinate system (which uses meters as the linear unit) to ensure consistency in the datasets. All datasets were transformed from global and/or national scales to the study area and standardized to a uniform resolution of the original DEM. The final GIS outputs were subsequently reclassified and resampled for use in the WLC model, which is a widely used GIS-based decision-making algorithm for addressing Multi-Attribute Decision-Making (MADM). The drainage network and related drainage points were created from the DEM to identify suitable reservoir sites.

Based on the chosen criteria, the greatest weight emerged as the most significant factor in choosing sites appropriate for RWH. After categorizing the selected criteria according to the requirements of the study area, relevant maps were produced using a GIS environment. Subsequently, the WLC model was employed to merge the four created criteria maps in accordance with their weights. In the WLC model, each criterion map, modified by cell size and geographical coordinates within the GIS environment, was initially multiplied by its respective weight and then added to the other criteria using the same method. Ultimately, the result of the WLC model was the land suitability map. Figure 2 below summarizes the overarching principles and choices utilized within the scope of this methodology.

## 2.5. Reclassification of Criteria

Decisions regarding the inclusion or exclusion of features in an analysis necessitate quantifiable field expertise and modeling knowledge (Forkuo, 2011). The values must be ranked even within a single layer, as some may be more favorable than others (Gorsevski et al., 2013). Each dataset presented distinct value ranges and numbering systems, which emphasizes the need for a unified classification prior to their analysis. For this reason, the FAO land suitability classification was applied. Due to the varying scales of criteria measurement, the multi-layer process mandates that the values in the criterion map be converted to consistent units. Consequently, the criteria maps were reclassified into five (5) comparable units (Mahmoud and Alazba, 2015)

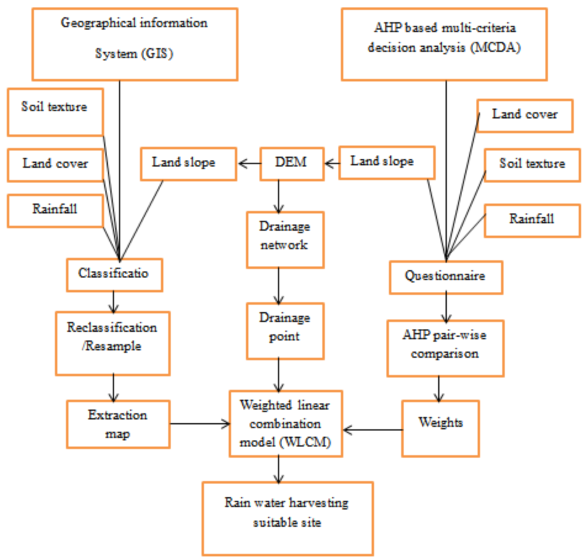



**Figure 2:** Framework of Methodology

aligned with suitability categories: highly suitable, suitable, moderately suitable, marginally suitable, and not suitable, with each criterion map containing these classifications.

### 2.6. Drainage Network/Point Extraction

To achieve optimal objectives, in addition to generating the land suitability map utilizing the WLC model, it is essential to extract and illustrate drainage points in order to identify locations suitable for RWH, as the map alone does not reveal elevations or ideal RWH sites. Therefore, following the research methodology (Fig. 2), the drainage points were extracted by delineating the drainage network based on the DEM using the Flow Accumulation tool (within the GIS hydrology tools). By applying a threshold value to the outcomes of the Flow Accumulation tool, a stream network can be defined. The situation where all water exits a catchment through a drainage point is indicative of the perfect location for an RWH facility. The ArcGIS Spatial Analyst tools were employed to generate streams and drainage points from the DEM.

## 3. Results and Discussion

### 3.1. Slope Classification

DEM is necessary not just for delineating the watershed and sub-catchments with Arc SWAT using watershed delineation tools, but also for the creation of stream networks and the calculation of density. The slopes, elevation, and stream networks of the Liban zone were obtained from the DEM data. The DEM data, with a resolution of 30m, was sourced from SRTM from https://earthexplorer.usgs.gov/. The DEM for the research area was produced as illustrated in figure 3. The altitude of Liban zone varies between 151 and 1555 m.a.s.l.

**Table 2:** Classification of criteria for AHP and methodology for evaluating RWH locations (arid and semiarid areas).

| S.no | Criteria | Classes (description) | Values | Suitability | Suitability rank |
|---|---|---|---|---|---|
| 1 | Soil texture (clay content %) | Clay | >20% | Highly suitable | 5 |
| | | Clay loam | 15-20% | Suitable | 4 |
| | | Loam | 11-15% | Moderately suitable | 3 |
| | | Sandy loam | 5-11% | Marginally suitable | 2 |
| | | Sandy | 1-5% | Not suitable | 1 |
| 2 | Land slope | Flat | <1.5% | Highly suitable | 5 |
| | | Undulating | 1.5-2.5% | Suitable | 4 |
| | | Rolling | 2.5-4.5% | Moderately suitable | 3 |
| | | Hilly | 4.5-7.5% | Marginally suitable | 2 |
| | | Mountainous | >7.5% | Not suitable | 1 |
| 3 | Land cover | Rangeland | - | Highly suitable | 5 |
| | | Rain fed farmland, Barren land | - | Suitable | 4 |
| | | Irrigated farmland | - | Moderately suitable | 3 |
| | | Fruit orchard, forests and shrubs | - | Marginally suitable | 2 |
| | | Water, build-up | - | Not suitable | 1 |
| 4 | Rainfall (mm/year) | Very high | >325 | Highly suitable | 5 |
| | | High | 250-325 | Suitable | 4 |
| | | Medium | 175-250 | Moderately suitable | 3 |
| | | Low | 150-175 | Marginally suitable | 2 |
| | | Very low | <150 | Not suitable | 1 |

Source: (Adham et al., 2016: Adham et al., 2017: Adham et al., 2018)

The incline of Liban zone was created in the ArcGIS environment using the spatial analysis tool within surface navigation. The transformation was take place from stratified to categorized rage units. Five slope categories was produced for convenience of calculation. The slope categorization of Liban zone is created as depicted in figure 6 utilizing natural breaks. Consequently, slope classes ranging from 0-3.02 are the most prevalent in the area. The manual interval categorization was conducted in Arc GIS by inputting specified threshold values according to the classification established by Adham et al. 2010. The slope map of Liban zone is created as shown in the figure.4. DEM served as an entry for the raster categorization of the slope map layer.

Finally the suitability map was created as illustrated in the figure below. Consequently, the southwestern and eastern areas were identified as appropriate for rainwater harvesting

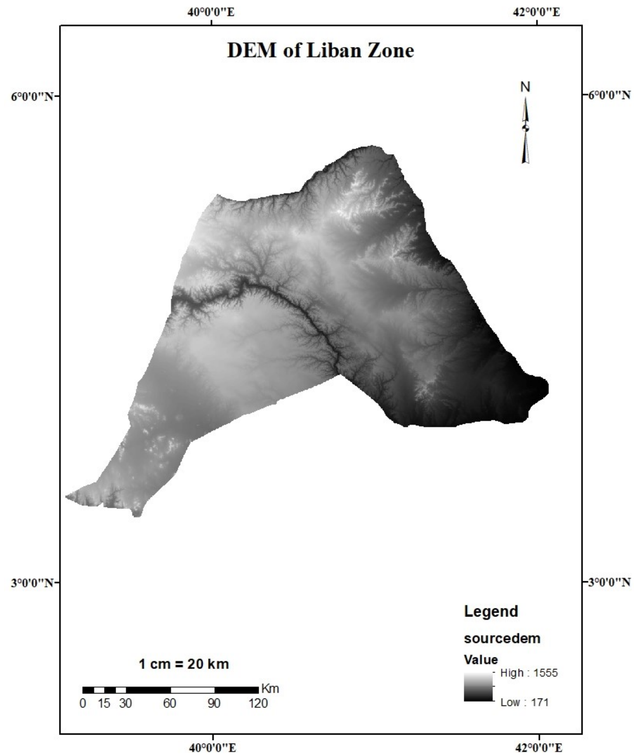



**Figure 3:** DEM of Liban Zone.

Source. https://earthexplorer.usgs.gov/.

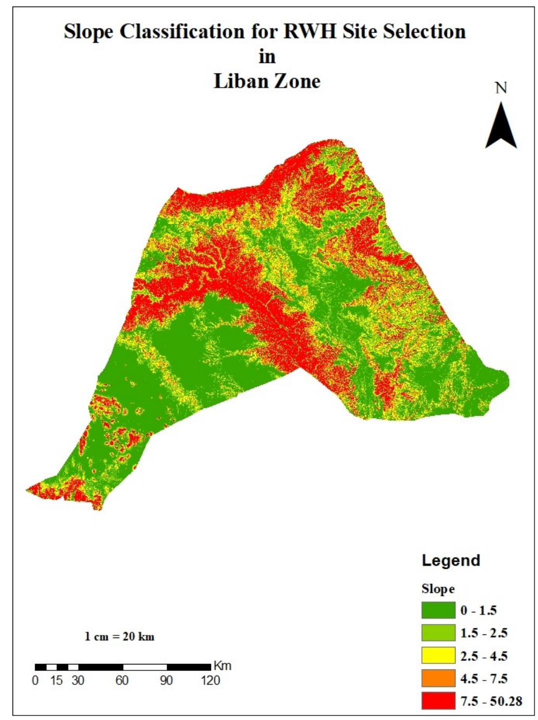



**Figure 4:** Slope map of Liban Area

Source. https://earthexplorer.usgs.gov/.

sites based on the slope requirements. In contrast, the central and far northern regions are classified as unsuitable.

### 3.2. Stream Network and Drainage Outlets

Arc SWAT 2012 interacting with Arc GIS 10.5 was utilized for creating the stream network and computing its density. This is a component of the delineation process in SWAT. DEM is an essential component for the delineation procedure. Several steps are involved, including DEM configuration and stream characterization. These are outlined in detail below:

- SWAT project configuration was established to initiate automatic delineation.
- Using the watershed delineation tool, the DEM configuration was completed. The masking of the watershed then follows using the “delineate manually” tool. This permits manual selection by outlining a polygon over the whole area of the watershed.
- DEM-based stream identification was carried out, using flow direction and flow accumulation tools applied to separate DEM cells to establish streams based on threshold area.
- Monitoring locations are regarded as drainage exits.

The final layer of the stream network and drainage outlet points map is illustrated as depicted in the figure 6. The central area of the zone has seen an increased collection of outlet points.

### 3.3. Classification of land use and land cover

The land cover map for the Liban zone was obtained from the Ministry of Agriculture as a shape file with the correct grid. The land use and land cover data was produced as in figure 7 by categorizing broadly as Wood land, wet land, forest, settlement, shrub land, grassland, and bare land. For the simplicity of computation, the map was categorized into just five classes.

Shape file of land cover information was obtained from the Ministry of Agriculture as an img. file. The layer was subsequently transformed into raster data by tailoring the image classification tool through maximum likelihood classification under the supervised classification tool. The raster layer map was then changed into tiff format using the conversion tool j.e features to others under the spatial analysis tool. Consequently, all classes were organized into predefined categories based on the threshold class provided by **Adham et al., 2010**. At this stage, all class attributes were supplemented with additional fields to incorporate the new classes and suitability classes. This was followed by the creation of the shape file using the catalog and initiating, editing, and finalizing the editing tool.

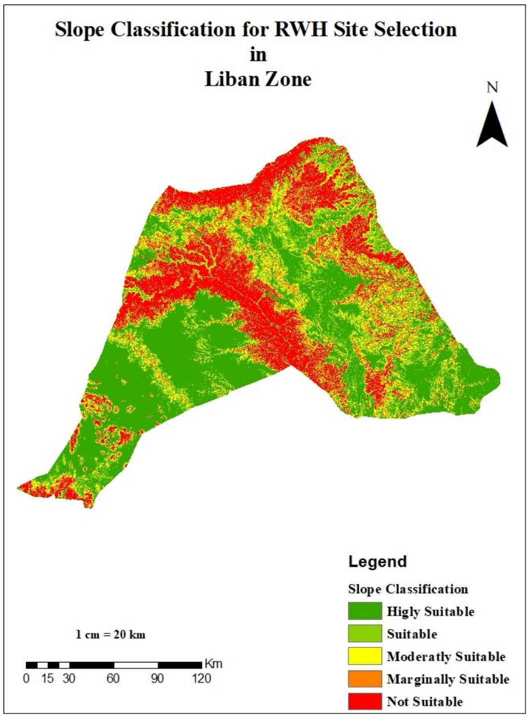



**Figure 5:** Slope appropriateness map of Liban zone

Source. https://earthexplorer.usgs.gov/.

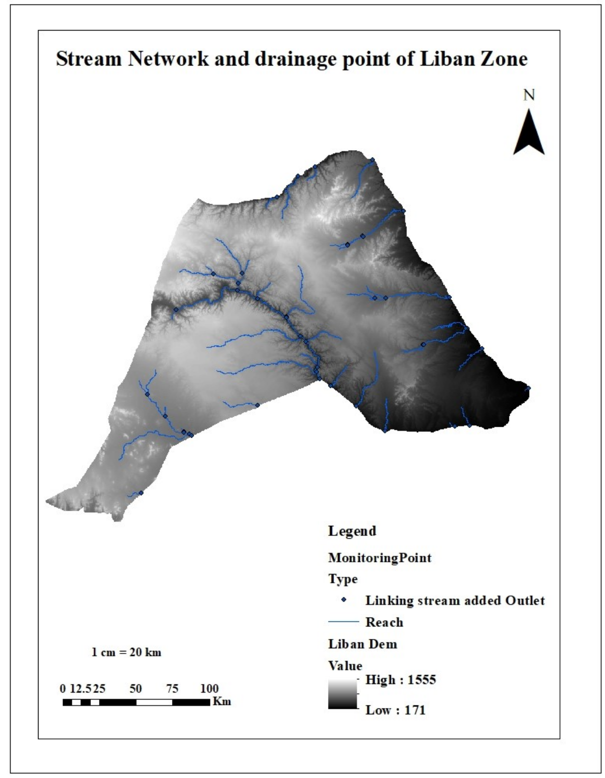



**Figure 6:** Stream Network and Drainage Outlet Points in Liban Zone

Source. https://earthexplorer.usgs.gov/.

**Table 3:** Updated Consolidated Categories of Land Cover Map of MoA

| Land cover | General class |
|---|---|
| Dense forest | Forest |
| Moderate forest | Forest |
| Sparse forest | Forest |
| Wood land | Barren land |
| Closed grassland | Range land |
| Open grassland | Range land |
| Closed shrub land | Shrub land |
| Open shrub land | Shrub land |
| Perennial cropland | Irrigation farm land |
| Annual cropland | Rain-fed farm land |
| Wet land | water body |
| Water body | water body |
| Settlement | Built-up |
| Bare soil | Barren land |
| Rock outcrop | Others |
| Lava flow | Others |
| Salt van | Others |

The Reclassify tool was utilized to change the interval classification into the manual classification. The classification choices are transformed into the newly defined added categories, namely General merged classes. The newly created general class (merged class) is presented in table 3. The related Suitability map is produced according to the classification **Adham et al.. 2010** as depicted in figures 8 and 9.

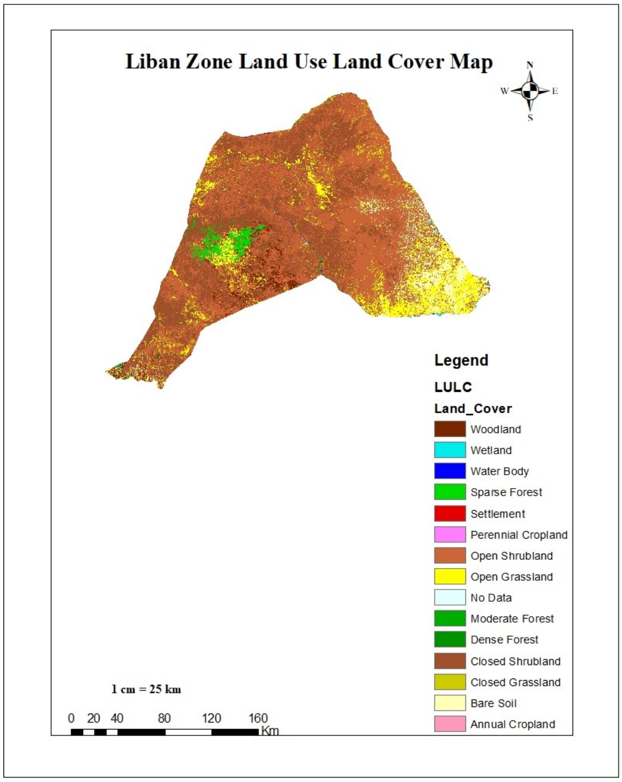
Relatively, East lower portion is grouped as suitable land scape with the requirement of land cover. Middle portions near to the main river section are categorized as unsuitable. Most of areas Liban zone is categorized under marginally suitable for rainwater harvesting site with point of view of land cover.

### 3.4. Soil Classification

The soil categorization by MoA for the Liban area has been produced in Arc GIS according to figure 10. Initially, the national map layer was cropped to fit the demand area, specifically the Liban zone, using the clip feature within the Geo-processing tool of Arc GIS. Each type of soil is subsequently categorized according to the clay content criteria. The proportions of clay found were gathered from various sources and are shown in the table below.

The evaluation of the appropriateness for rainwater harvesting locations from **Adham et al., 2010** for various clay content soils is presented in table 5 and produced spatial map is shown in figure 11.

Finally the suitability map is produced as shown in figure 12. Accordingly, north-west portion of Liban the area is adequately appropriate for rainwater collection locations. The next appropriate category is positioned in the central part of the area. The southern section of the area is not



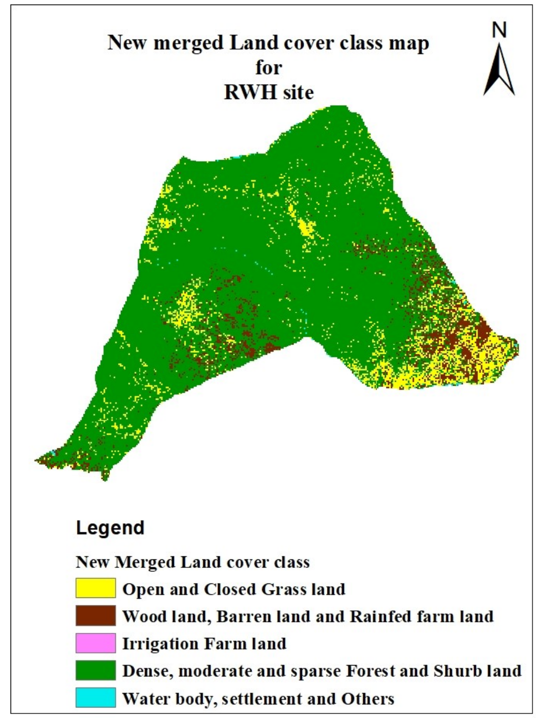




**Figure 7:** Land Use Map of Liban Zone.

Source. https://earthexplorer.usgs.gov/.

**Figure 8:** General Category of Land Cover in Liban Zone

Source. https://earthexplorer.usgs.gov/.

**Table 4:** Content of clay in various soil types

| Soil Type | Clay presence percentage | Suitability Class |
|---|---|---|
| Eutric cambisols | 0.08 | Marginally Suitable |
| Leptosols | 0.098 | |
| Calcic Xerosols | 0.015 | Not Suitable |
| Helpic Xerosols | 0.015 | |
| Gypsic Yermosols | 0.025 | |
| Othic solonochanks | 0.03 | |
| Calacaric Fluvisols | 0.14 | Suitable |
| Calcic flubisols | 0.11 | Moderately Suitable |
| Chromic vertisosl | 0.35 | Highly Suitable |
| Eutric vertisols | 0.35 | |
| Orthic luvisols | 0.35 | |
| Eutric nitisols | 0.3 | |
| Dystric nitisols | 0.3 | |

**Table 5:** General Category of soil with clay content Specifications

| Classes (description) | Values | Suitability | Suitability rank |
|---|---|---|---|
| Clay | >20% | Highly suitable | 5 |
| Clay loam | 15-20% | Suitable | 4 |
| Loam | 11-15% | Moderately suitable | 3 |
| Sandy loam | 5-11% | Marginally suitable | 2 |
| Sandy | 1-5% | Not suitable | 1 |

Source: (Adham et al. 2010)

suitable for rainwater collection sites, the majority of Moyale and Dolo Odo districts.

## 3.5. Rainfall Data

The selected stations for rainfall Information is shown in figure 13. The precipitation data utilized in this research is gathered on a monthly schedule, from which yearly rainfall statistics are produced. The average monthly rainfall data set and the position of each gauge at each corners and central section of the region and surrounding areas was gathered from satellite information of climate engine with https://app.climateengine.org/ link from 1990/01/01 to 2019/01/01. For the rainfall data CHIRPS (4.8 X 4.8 km) high-quality satellite datas were employed.

Each station was chosen according to the geographical input from each woredas in Liban zone and surrounding towns. This guarantees oversight of the impact from adjacent stations on each woredas within the zone. The stations involved are Filtu, Baraghalo, Dolo Odo, Elmadera, Hudet, Gebeto, Moyale, Quulay, Ueb, Baan-Deheer, Bare, Sogiya, Bur, Hargele and Ara.Further the mean annual rainfall of each station is computed and shows in the table 6.

The average yearly precipitation across Liban and nearby stations varies from 818mm at Moyale to 236mm at Bur station. The mean for all stations was calculated to be 459.622 mm.

The theission, a polygon was created in Arc GIS utilizing the analysis tool under the proximity feature. This navigation

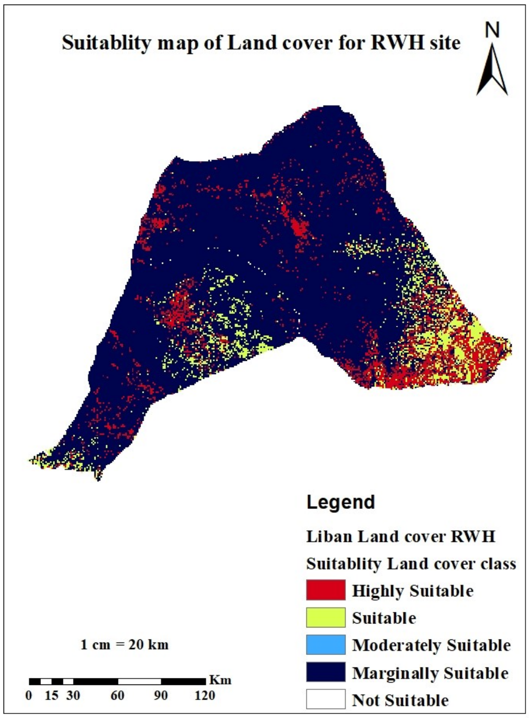



**Figure 9:** Land cover appropriateness map of Liban area

Source. https://earthexplorer.usgs.gov/.

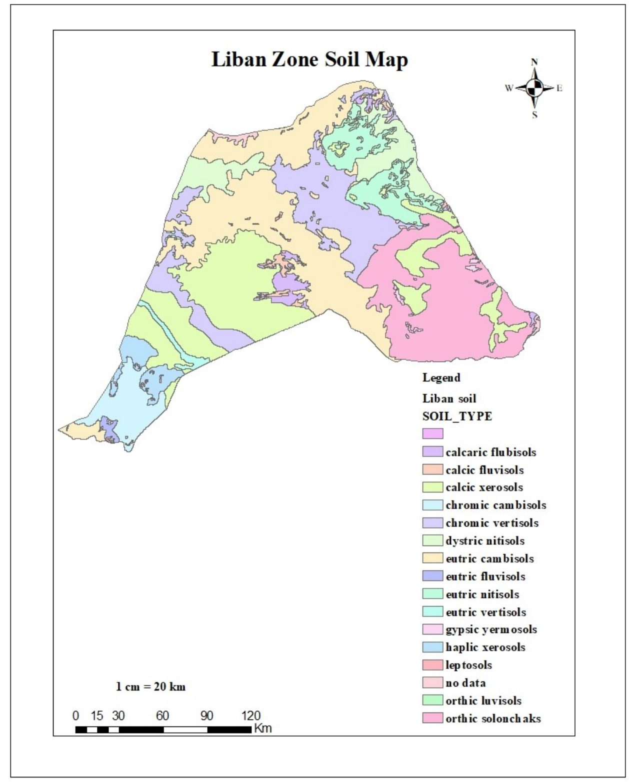



**Figure 10:** Soil Map of Liban Zone

Source. https://earthexplorer.usgs.gov/.

**Table 6:** Mean yearly rainfall of each chosen station in Liban zone

| S.no | Station Name | Longitude | Latitude | Mean annual rainfall(mm) |
|---|---|---|---|---|
| 1 | Filtu | 40.6656 E | 5.1022 N | 561.71 |
| 2 | Baraghalo | 40.5338 E | 4.7273 N | 451.22 |
| 3 | Dolo Odo | 42.0718 E | 4.1824 N | 248.01 |
| 4 | Elmadera | 40.1245 E | 4.6479 N | 562.40 |
| 5 | Hudet | 39.2374 E | 4.7601 N | 574.27 |
| 6 | Gebeto | 40.6162 E | 4.3851 N | 386.21 |
| 7 | Moyale | 39.1110 E | 3.5357 N | 818.48 |
| 8 | Quulay | 40.9677 E | 4.6342 N | 439.32 |
| 9 | Ueb | 41.0693 E | 4.9462 N | 442.27 |
| 10 | Ara | 40.3333 E | 4.5850 N | 528.30 |
| 11 | Baan-Deheer | 41.4291 E | 4.9955 N | 308.01 |
| 12 | Barrey | 42.6157 E | 4.6342 N | 279.77 |
| 13 | Sogiya | 38.7238 E | 4.2153 N | 721.09 |
| 14 | Bur | 42.2064 E | 4.1947 N | 236.24 |
| 15 | Hargele | 42.0609 E | 5.2964 N | 337.03 |

is straight forward draw each rainfall category in adjacent regions is organized into one group while the following category belongs to another group, utilizing the local station data set. The polygon map is then trimmed to fit the demand area using a geo-processing tool j.e Liban area as illustrated in figure 14.

The categorization additionally assisted with groups of five manual interpolation classes as illustrated in the figure. The ultimately obtained map serves as input for the criteria for selecting rain harvesting locations. Consequently, the central and western areas of the zone experience significant annual rainfall, while the northeastern sections of the zone have a lower average annual rainfall.

## 3.6. Qualitative Data

Analytical hierarchical process was utilized to assess the final significance of the judgment from experts. The presenters needed to complete the weight for each of the four criteria j.e. Soil composition, vegetation, gradient, and precipitation were evaluated by juxtaposing each contributing element against the others on a scale from 1 to 9 (refer to Table 6 for specifics). The ultimate score was derived from the average of all categories compared, as provided by 25 participants. The rank sum approach was utilized to determine the overall shared weight of each criterion factors (Malczewski, 2000).

Utilizing the rank sum approach (Eq. 2.1), the calculation of the conclusive weights for each indicator was conducted. The rationale for selecting the rank sum method stems from its ability to provide insights when a suitable number of indicators are employed. Given that all criteria factors possess five categories, each distinct weight is sufficiently differentiated.

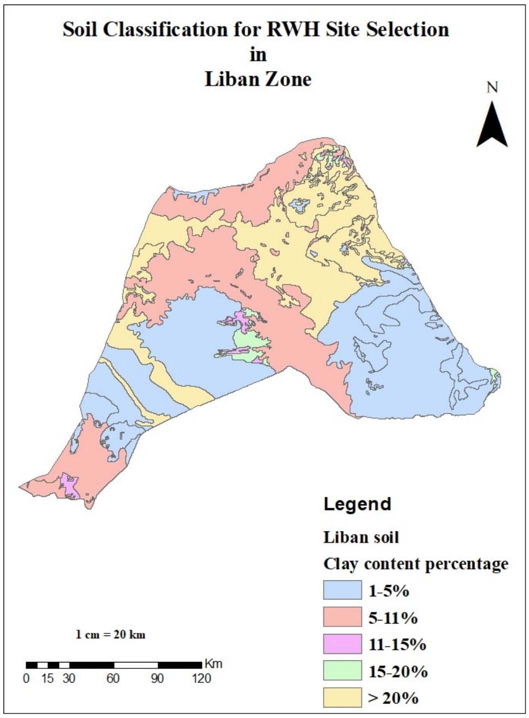



**Figure 11:** Soil map of Liban Zone According to the Classification Clay Content

Source. https://earthexplorer.usgs.gov/.

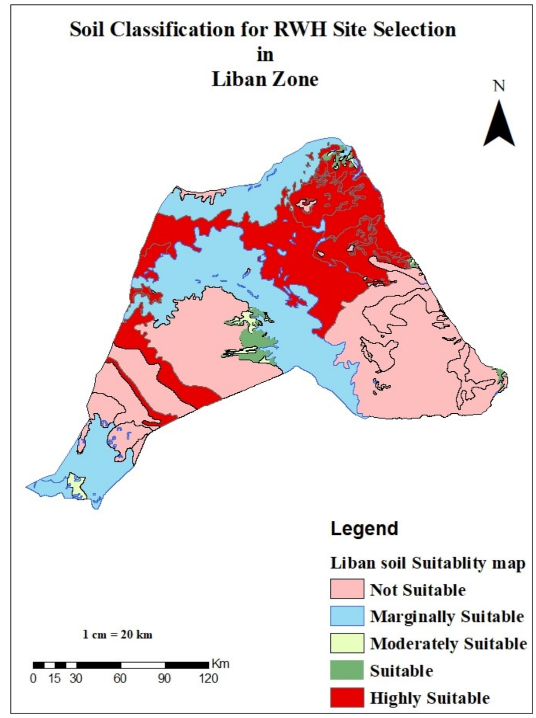



**Figure 12:** Soil Applicability Map of LIban Area designated for rainwater collection site

Source. https://earthexplorer.usgs.gov/.

**Table 7:** Ranking the significance of each element relative to one another for RWH site selection utilizing AHP

| S.No | Class of Importance | Value |
|---|---|---|
| 1 | Equal Importance | 1 |
| 2 | Moderate importance | 3 |
| 3 | Strong Importance | 5 |
| 4 | Very strong importance | 7 |
| 5 | Extreme importance | 9 |
| 6 | Intermediate values | 2,4,6,8 |
| 7 | Values for inverse comparison | 1/3,1/5,1/7,1/9 |

$$w_j = \frac{n - r_j + 1}{\sum_{k=1}^{n} n - r_k + 1} \tag{1}$$

Where $w_j$ is the normalized weight for the j-th indicator category; n represents the quantity of indicator categories being examined; and rj is the rank position of the $j^{th}$ indicator class.

The average ranking from 25 participants for each criterion was utilized to calculate the final weight of all factors provided. (Table 8). The descriptive matrix were generated by accounting each attendant srank assigned and the reciprocal rank were produced by inverting each similar class ranks. The totals of each class were utilized to estimate the final weight by dividing each class rank by its respective sum.

**Table 8:** AHP evaluation of significant elements for choosing a RWH location

| | Rainfall | Slope | Soil | Land cover |
|---|---|---|---|---|
| Rainfall | 1 | 5 | 7 | 6 |
| Slope | 1/5 | 1 | 9 | 8 |
| Soil | 1/7 | 1/9 | 1 | 4 |
| Land cover | 1/6 | 1/8 | ¼ | 1 |
| **Sum** | **1.509524** | **6.2361111** | **17.25** | **19** |

**Table 9:** Standardized weight of various criteria factors

| | Rainfall | Slope | Soil | Land cover | Criteria weight |
|---|---|---|---|---|---|
| **Rainfall** | 0.66246 | 0.801782 | 0.4058 | 0.3157895 | **0.874332** |
| **Slope** | 0.13249 | 0.160356 | 0.52174 | 0.4210526 | **0.494256** |
| **Soil** | 0.09464 | 0.017817 | 0.05797 | 0.2105263 | **0.152381** |
| **Land cover** | 0.11041 | 0.020045 | 0.01449 | 0.0526316 | **0.079031** |

Where, Black shaded area are average of choices provided by stakeholders and, White regions are a reversal of those.

The overall total of the weight for each class was adjusted, which is regarded as the final weight for each factor. The results identified rainfall as the most significant factor. Following that were slope, soil, and land cover in that order. The lowest average value was deemed to hold the highest rank. Table 9 shows the detail of computation.

**Table 10:** Verification of the criteria weight for consistency

| | Rainfall | Slope | Soil | Land cover |
|---|---|---|---|---|
| Rainfall | 1*0.874332 | 5*0.494256 | 7*0.152381 | 6*0.079031 |
| Slope | 0.2*0.874332 | 1*0.494256 | 9*0.152381 | 8*0.079031 |
| Soil | 0.143*0.874332 | 0.111111*0.494256 | 1*0.152381 | 4*0.079031 |
| Land cover | 0.16666*0.874332 | 0.125*0.494256 | 0.25*0.152381 | 1*0.079031 |

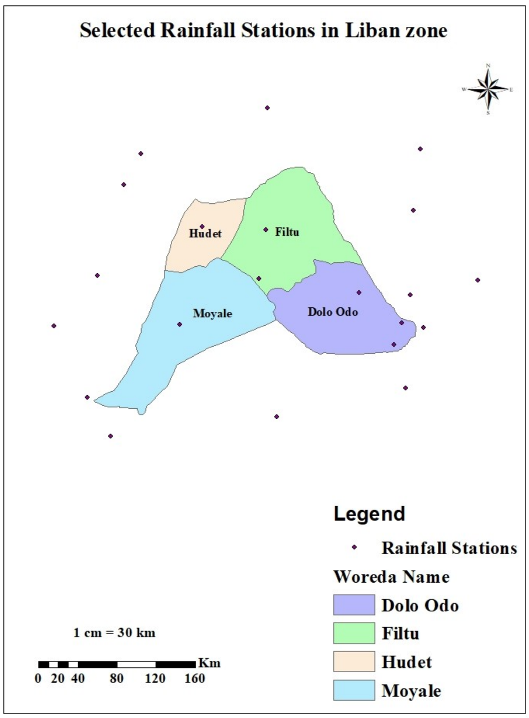



**Figure 13:** Selected Rainfall Stations in Liban Zone

Source.https://app.climateengine.org/

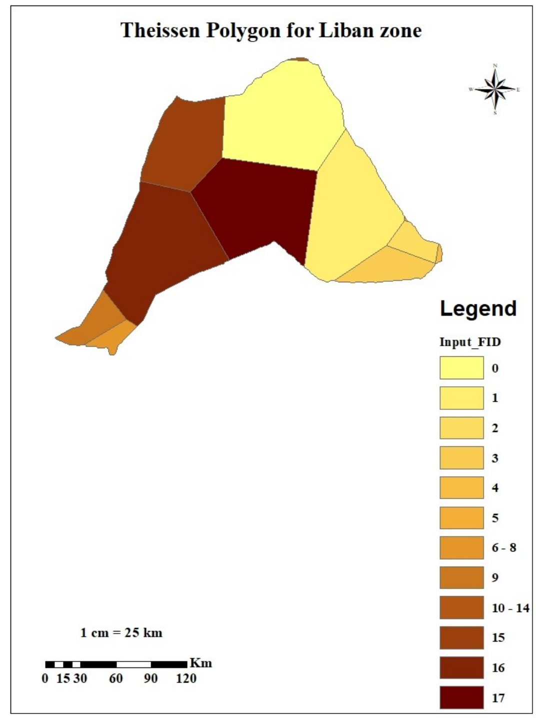



**Figure 14:** Theissen Polygon for Liban Zone

Source.https://app.climateengine.org/.

The reliability was verified as a result of non-normalized column weights alongside the normalized values. Table 10 shows the detail of it.

The ratio was calculated using the weighted sum value and the weights of the criteria, which were utilized for the computation of hmax, CI and CR values. According to the proposed random index measurement, the final CR values were calculated using the equation provided below.

$$CR = \frac{hmax}{RI} \quad (2)$$

Where, CR represents the consistency ratio, and RI is the random index calculated as 0.9. The CR value falls within an acceptable range as it is below 0.1.

### 3.7. Weighted Overlay Analysis

The development of new layers for soil, land use/land cover, slope, and rainfall was calculated based on the weighted computed values. This was accomplished by inputting new cells using the editing tool with the catalog option. The layers were subsequently transformed into raster format by utilizing the conversion tool found in the Arc Toolbox, changing from polygon to raster format j.e. rainfall polygon and soil.

The navigation of the arc toolbox offers a specialized tool for analyzing hydrological data, as well as a spatial analysis tool. The weighted overlay analysis tool was chosen for the development of the final suitability map, taking into account the qualitative assessments of experts and quantitative spatial data.

As depicted in the figure below, the appropriate locations in the Liban zone for implementing rainwater harvesting were identified in the southwestern areas, while the north-eastern and southeastern regions were deemed unsuitable.

Finally, to create the precisely recommended site for rainwater collection, both the stream flow and outlet point

**Table 11:** Evaluating the consistency ratio for criteria importance

| | Rainfall | Slope | Soil | Land cover | Weighted sum value | Criteria weight | Ratio |
|---|---|---|---|---|---|---|---|
| Rainfall | 0.874332 | 2.47128 | 1.066667 | 0.474186 | 4.886465 | 0.874332 | 5.588798 |
| Slope | 0.174866 | 0.494256 | 1.371429 | 0.632248 | 2.6727994 | 0.494256 | 5.407723 |
| Soil | 0.124905 | 0.054917 | 0.152381 | 0.316124 | 0.6483269 | 0.152381 | 4.254644 |
| Land cover | 0.145722 | 0.061782 | 0.038093 | 0.079031 | 0.3246275 | 0.079031 | 4.107597 |
| hmax | | | | | | | 4.83969 |
| CI((hmax-n))/(n-1)) | | | | | | | 0.279897 |
| CR | | | | | | | 0.0911 |

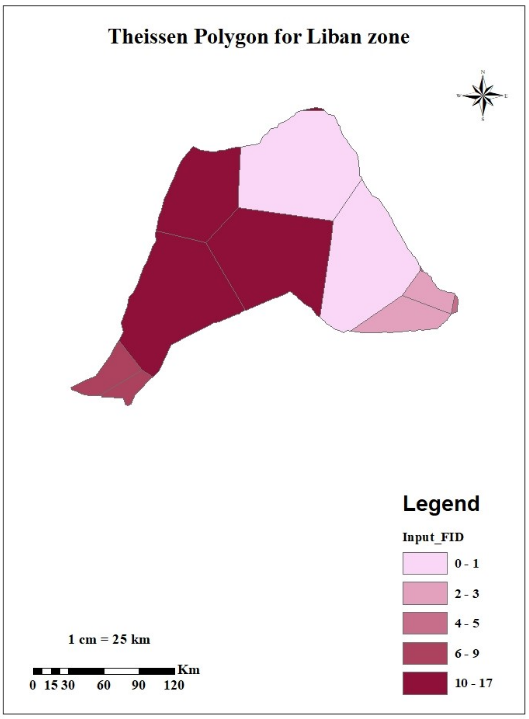



**Figure 15:** Rainfall Categorization in Liban Zone

Source. https://app.climateengine.org/

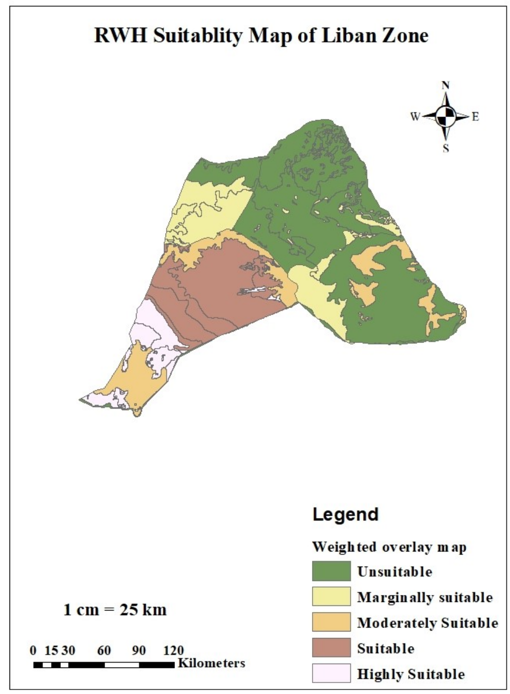



**Figure 16:** Rainwater collection site suitability map for Liban zone

**Table 12:** Coordinate of appropriate outlet locations for rainwater harvesting area

| Suitability class | Priority | Latitude | Longitude |
|---|---|---|---|
| Highly Suitable | 2 | $4^{0}$01’25”N | $39^{0}$45’05”E |
| | 2 | $3^{0}$58’3”N | $39^{0}$51’33”E |
| | 1 | $3^{0}$50’22”N | $39^{0}$45’15”E |
| Suitable | 1 | $4^{0}$30’5”N | $40^{0}$25’18”E |
| | 1 | $4^{0}$28’10”N | $40^{0}$29’33”E |
| | 2 | $4^{0}$11’03”N | $40^{0}$15’09”E |

factors were combined simultaneously, and the resulting map is displayed below.

As the map shows, three ideal outlet locations and three acceptable points were chosen as the most appropriate sites for implementing rainwater harvesting.

## 4. Conclusion and Recommendations

In light of recent climate shifts and as a strategy for managing water resources in the Liban zone of the Somali regional state, the establishment of RWH reservoirs should be regarded as a practical solution for areas that lack alternative potable water sources or adequate supply to fulfill both public and private demands. This research aimed to pinpoint appropriate sites for RWH. The same technique can be utilized in comparable regions (arid and semiarid) while taking into account their specific conditions. As previously noted, this strategy can be extended more broadly to assess potential locations for new RWH initiatives, thereby enhancing the chances of effective long-term outcomes. Furthermore, because of the tool’s adaptability and simplicity in applying various criteria and RWH performance metrics, it can be employed in diverse environments. The tool’s advantages

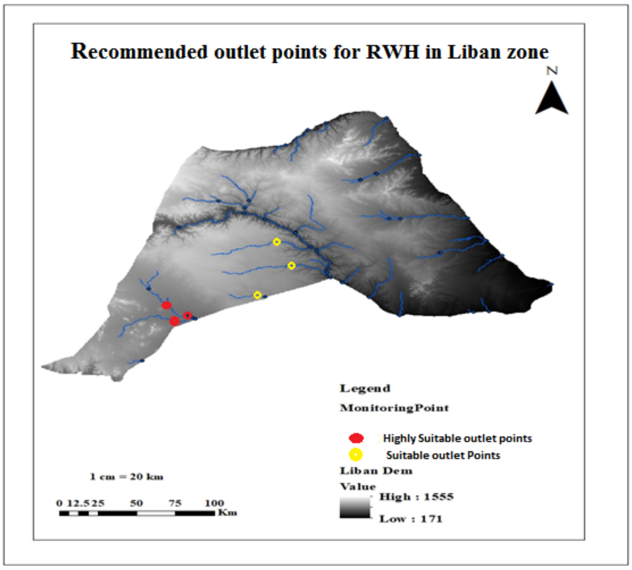



**Figure 17:** Suggested rainwater collection discharge location for Liban zone

likewise involve minimal time and expense necessary for these assessments, rendering the approach a feasible choice and important strategy for local RWH administrators and communities in their attempts to alleviate drinking water scarcity in regions lacking alternative water supplies.

The suggested locations are deemed very appropriate owing to their favorable valley formations and extensive catchment zones. The reservoir outlines were created following the positions of their drainage points as GIS-driven choices using a 30 m resolution DEM raster. This generated numerous possibilities, thus facilitating the selection of reservoir sites.

Based on the land suitability map produced in this research, the most appropriate regions (highly suitable and suitable) are mountainous and comprise substantial earthen hills with favorable elevation prospects. The valleys in the investigated sites have various inclines, which renders some of them (with abrupt slopes) inappropriate for reservoir development. The southwestern part of the target region demonstrated greater levels of suitability due to its gentle slope, and they are suggested as reservoir locations because of their closeness to the River.

Further onsite surveying is necessary for the final selection of reservoir sites because of limitations in data and information systems. To broaden the range of these studies, it is advisable to improve the resolution of all datasets to enhance the precision of the land suitability map. Furthermore, acquiring more specific and precise meteorological data gathered through denser network of meteorological stations is essential for enhanced analysis. Taking socio-economic aspects into account can also elevate the quality of results in upcoming studies. Although this study allows for the selection of appropriate locations for RWH directly from this map, it is advisable to conduct onsite visits to guarantee a more thorough examination.

**Conflict of Interest**

Authors declare that there is no conflict of interest is involved in publishing this research paper.

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