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ABSTRACT: Rainfed agriculture in Ethiopia has failed to produce enough food, to achieve the increasing demand for food. Pinpointing the appropriate site for rainwater harvesting (RWH) have a substantial contribution to increasing the available water and enhancing agricultural productivity. The current study related to the identification of the potential RWH sites was conducted at the Chacha watershed central highlands of Ethiopia which is endowed with rugged topography. The Geographic Information System with Analytical Hierarchy Process was used to generate the different maps for identifying appropriate sites for RWH. In this study, 11 factors that determine the RWH locations including slope, soil texture, runoff depth, land cover type, annual average rainfall, drainage density, lineament intensity, hydrologic soil group, antecedent moisture content, and distance to the roads were considered. The overall analyzed result shows that 10.50%, 71.10%, 17.90%, and 0.50% of the areas were found under highly, moderately, marginally suitable, and unsuitable areas for RWH, respectively. The RWH site selection was found highly dependent on a slope, soil texture, and runoff depth; moderately dependent on drainage density, annual average rainfall, and land use land cover; but less dependent on the other factors. The highly suitable areas for rainwater harvesting expansion are lands having a flat topography with a soil textural class of high-water holding capacity that can produce high runoff depth. The application of this study could be a baseline for planners and decision-makers and support any strategy adoption for appropriate RWH site selection.

KEYWORDS: Runoff depth, antecedent moisture condition, AHP, weighted overlay, water resource

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Introduction

Water is crucial for all forms of life and is utilized for different purposes including agricultural services, human drinking, domestic use, industrial, hydropower, etc. Agriculture is the main driver of the Ethiopian economy with 85% of export income, and 45% of the country's GDP (Yimere & Assefa, 2022) Ethiopia's agriculture is mainly reliant on rainfed farming which is leading to the imbalance between the food demand and agricultural production of the country (Worqlul et al., 2017). In recent years, the rainfall anomaly in Ethiopia is becoming erratic and highly inconsistent in association with climate change (Wagesho et al., 2013). This rainfall anomaly results in high spatiotemporal variability of surface and groundwater availability that further affects agricultural production in Ethiopia (Melesse et al., 2013).

Now a day, the Ethiopian government gives high attention to irrigation to combat the food insecurity challenge of the country by producing more than once a year. Ethiopia has a huge water resource potential that encompasses 124 billion m^3 of annual surface runoff and a groundwater potential of over 2.6 billion m^3 (Awulachew et al., 2005). But, this water potential is accumulated in some parts of the Ethiopian highland areas with rugged topography that constrains its utilization (Melesse et al., 2013). Besides this, the surface and groundwater potential of the country is decreasing because of the changing climate, growing population, and natural resource degradation (Wassie, 2020). Thus, fresh water is becoming a scarce resource in Ethiopia not only in drought-sensitive areas but also in rainfall-plentiful regions (Woube, 1999). A huge portion of the country's people does not have access to adequate water that satisfies their needs sustainably. Thus, it should be crucial to find other better options that enable acquiring sustainable water supply to enhance agricultural production through irrigation.

RWH is one of the best and most feasible alternatives to tackle the issue of water insufficiency in such water scare areas (Ammar et al., 2016; Islam et al., 2010). It is defined as a technique of collecting and storing surplus runoff depth during the rainy period to utilize for the dry periods (Helmreich & Horn, 2009; Islam et al., 2010). RWH is tremendously imperative to conserve valuable natural resources including soil and water which are diminishing from time to time worryingly (Al Marsumi & Al Shamma, 2017). For the expansion of RWH technology, appropriate site selection is important (Hindersah et al., 2018; Kadam et al., 2012). The selection of suitable sites for rainwater collection is very challenging and costly (Oweis et al., 2001). Locating sites for water harvesting storage structures requires gathering and extracting different data, that is, hydrology, soil, climate, topography, land use land cover, agronomy, and socio-economic factors (Khudhair et al., 2020). The expected scale of rainwater harvesting will be ranged from small-scale/micro water harvesting development at each farmer's field to large-scale/macro water harvesting scale like community pond developments. The farmers can apply the water harvesting technology for home gardening by collecting the precipitation water from the rooftop of their house and can also collect the surface runoff flowing in their fields as micro-water harvesting techniques. At the same time, depending on the availability of communal lands, various macro-rainwater harvesting techniques will be developed to collect water from external catchments and can also utilize by diverting flood from natural streams. The farm ponds, water tanker, or bore-holes can be used to store the precipitation water and utilize it during the dry period.

The GIS and remote sensing (RS) tools are helpful to provide accurate, reliable, and updated land, soil, and water resources information for identifying suitable sites for water harvesting structures (Oweis & Hachum, 2006). Many studies applied the geospatial tools to identify the proper location of the RWH sites (Abdulla & Al-Shareef, 2009; Al-Ardeeni, 2015; Al Marsumi & Al Shamma, 2017; Ammar et al., 2016; Buraihi & Shariff, 2015; Concepcion et al., 2006; Ejegu & Yegizaw, 2020; Handia et al., 2003; Ibrahim et al., 2019; Kadam et al., 2012; Khudhair et al., 2020; Mugo & Odera, 2019; Oweis et al., 2001; Oweis & Hachum, 2006; Sazakli et al., 2007). Slope, runoff depth potential, soil texture, land use land cover, and drainage density were the most commonly used factors for suitable site identification of RWH. de Winnaar et al. (2007) applied the distance to crops, distance to homes, and runoff potential as selection criteria and Kadam et al. (2012) also used only the runoff potential as the selection criteria in their study. Kadam et al. (2012) added the distance to roads factor for choosing a suitable place for RWH and Ammar et al. (2016) also incorporated the size of the catchment area as selection criteria for rainwater harvesting techniques. All the above-mentioned studies confirmed that appropriate RWH site selection has the potential to increase adequacy and water efficiency for agricultural practice. But, those researchers applied a very limited number of factors to identify a suitable RWH site. For example, Khudhair et al. (2020) applied the runoff depth, slope, soil type, road proximity, and drainage density only. While, Al-Ardeeni (2015) selected only the factors of slope, LULC, soil texture, and rainfall. Slope, LULC, soil texture, soil depth, rainfall, and lineament density were also used by Ejegu and Yegizaw (2020) and Yegizaw et al. (2022). No research was conducted considering all the factors selected in the present study. Therefore, the present study tries to consider the combination of many factors that were not applied by other researchers previously and this may give a better result in the appropriate site selection. Appropriate RWH technology implementation that considers various biophysical and social factors of a watershed enhances the productivity of water and improves the income of the societies.

The geospatial technology integrated with the AHP process is used to evaluate the effect of each factor on the RWH suitable site selection (Ejegu & Yegizaw, 2020; Khudhair et al., 2020). Once the individual impact is assessed and classified into four suitable classes, the weighted overlay techniques in the GIS environment can be applied to identify the combined impact of various factors. According to Mugo and Odera (2019) and Al-Ardeeni (2015), a pairwise comparison matrix is implemented to indicate the impact level of the factors on the RWH suitable site identification. The overall weighted analysis result is therefore used to decide the suitability of the watershed for RWH implementation (Abdulla & Al-Shareef, 2009).

Currently, the government of Ethiopia encourages the use of RWH technology such as geo membranes, especially in semi-arid and arid areas. However, the adoption of the technology and its effectiveness is disappointing the farmers due to the lack of skill and knowledge of the implementing organizations and the carelessness of the users themselves (Binyam & Desale, 2015). In Ethiopia, very limited studies (Binyam & Desale, 2015; Ejegu & Yegizaw, 2020; Ketsela, 2009; Muleta et al., 2022) were conducted to recognize the potential and appropriate site for RWH technology, but no study was conducted in the Chacha watershed yet.

Due to high population density and low agricultural technology intensification, the Chacha watershed in the highlands of Ethiopia is facing food insecurity challenges. As in many parts of the country, water scarcity is a critical challenge in the watershed. One of the reasons for this is the mismatch between the location of the available water resources and the residential area of the local community. The rugged topography of the watershed also poses a problem for easily utilizing the available surface and groundwater sources. Rainwater harvesting (RWH) can be the best option to improve the water scarcity problem and improve agricultural production. Water harvesting technology is, therefore, one of the coping mechanisms to produce more food from agricultural fields in rugged topography. Furthermore, poor water management practices that can be improved through appropriate RWH practices for enhancing water availability and agricultural production is the main problem. Identifying the suitable site for RWH is therefore the first task in water harvesting technology implementation. Identifying an appropriate site that can collect more runoff and easily accessible water without extra expenditure for utilization is crucial (Glendenning et al., 2012). Therefore, the present study was intended to identify suitable RWH sites using the geospatial techniques and AHP for the Chacha watershed, central highland of Ethiopia.

Methodology

Description of the study area

The research was conducted in the Chacha watershed, North Shewa Zone, Amhara Region, Ethiopia, and covered an area of 1,131.7. The watershed flows from the upper summits area of Assagirt district into the Blue Nile Basin's Jemma sub-basin at Moretna Jirru district. The study watershed lies between latitudes 9°20′0′ and 10°0′0′ north and longitudes 39°10′0′ and 39°40′00′ east. Its altitude starches from 1,549 to 3,576 m above sea level, with slopes varying from 0% to 169%. The respective area's typical annual maximum and minimum

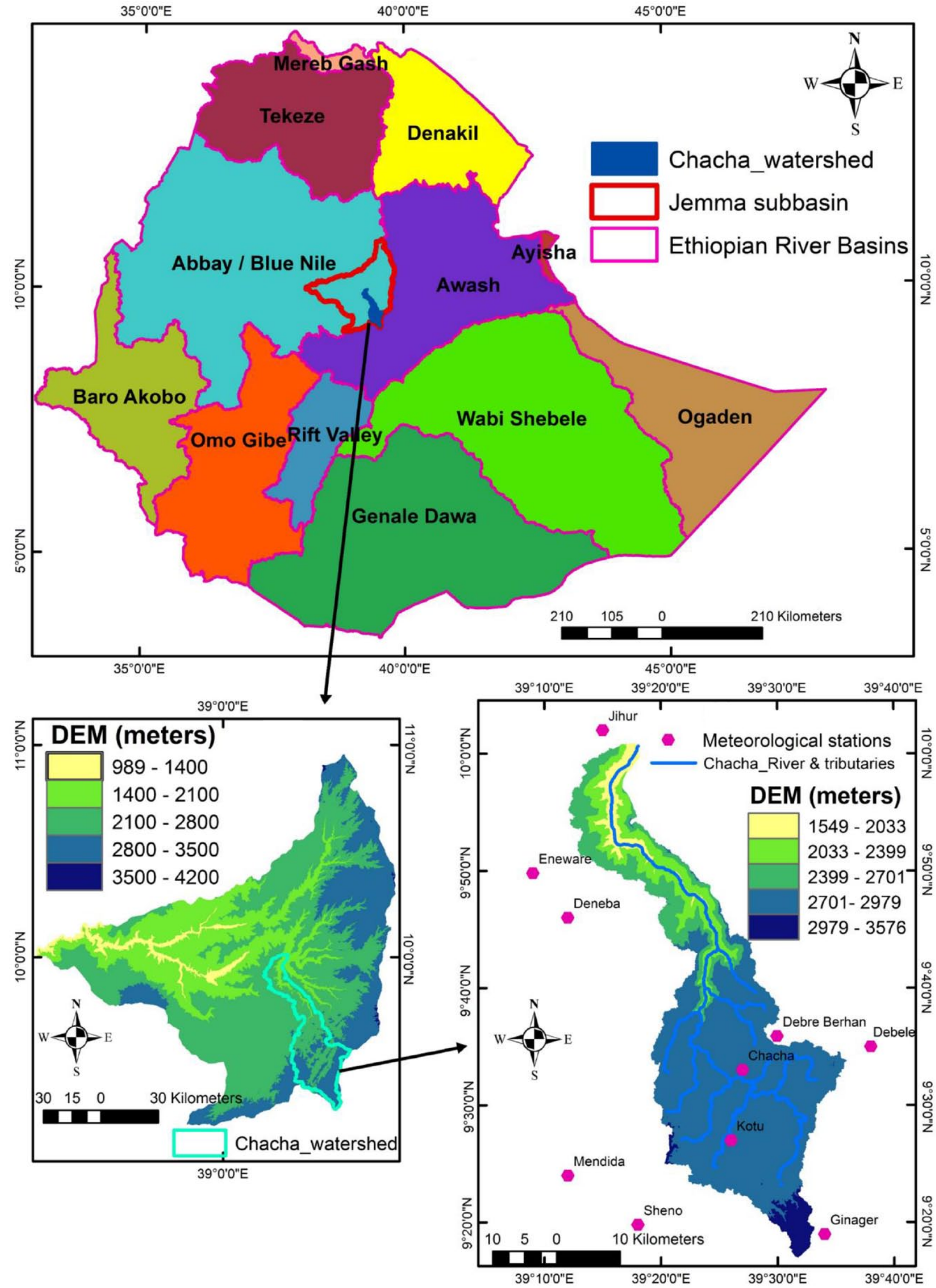

Figure 1. Study area map.

temperatures are 10.30°C and 20.10°C, with an annual rainfall fluctuation of between 900 and 1,800 mm with high seasonality of enough rainfall in the major rainy season (June, July, August, and September), but dry in the remaining months. The Chacha watershed dominant soil types include Vertisols and Cambisols and are scarcely observed with Regosols, Leptosols, and Nitisols (Hengl et al., 2017). The moist highland agro-ecological zone covers 84.8% of the research area, while the remaining 14% and 1.20% are classified as moist mid-highland and moist frost zone, respectively. The primary dominant crops in the area include barley, wheat, legumes, and potatoes. The map of the Chacha watershed is presented in Figure 1.

Data collection and data used

The 12.5 m resolution Digital Elevation Model (DEM) was downloaded from http://earthexplorer.usgs.gov/ for this study. The LULC map was adopted from a study conducted by (Tesfay et al., 2023); while drainage density, lineament delineation, and slope maps were produced using DEM. Soil data

Table 1. Rainwater Harvesting Suitability Classification Standards.

FACTOR	SUITABILITY CLASS				SOURCES
	HIGHLY SUITABLE	MODERATELY SUITABLE	MARGINALLY SUITABLE	NOT SUITABLE	
Slope (%)	0–2	2–8	8–30	>30	Maina and Raude (2016)
Soil texture	Clay and clay loam	Silty clay and loam	Sand clay loam	Sandy	Khudhair et al. (2020)
Soil depth(cm)	>100	50–100	25–50	<25	Endalkachew et al. (2022)
LULC	Bare land/water bodies	Cultivated/grazing land	Natural/plantation forests and built-up areas	–	Endalkachew et al. (2022)
Annual RF (mm)	1,357–1,681	1,102–1,356	758–1,101	0–757	–
Runoff depth	>750	600–750	250–600	<250	Getachew (1999)
Drainage density	0–21	21–40	40–80	>80	Mugo and Odera (2019)
Lineament	<0.25	0.25–0.6	0.6–1.25	>1.25	Mugo and Odera (2019)
HSG	D	C	B	A	Maina and Raude (2016)
AMC (mm)	>53	23–53	<23	–	Wayne Skaggs (1996)
Distance from the road (km)	<0.5	0.5–1.0	1.0–2.0	>2.0	Khudhair et al. (2020)

used for producing soil texture and depth were gained from the website of the Harmonized World Soil Database (Hengl et al., 2017). Long-term rainfall data (1986–2021) to detect annual rainfall and runoff depth was acquired from Ethiopia's National Meteorological Agency. The topographic sheet was used to generate information regarding road proximity.

Input database for RWH potential site selection and mapping

Potential RHW site identification and mapping using geospatial techniques and AHP is a new approach to tackling water shortage for various services, especially for improved agricultural activity. LULC, soil textural, soil depth, annual average rainfall, the intensity of lineaments, slope, runoff depth, drainage density, and road proximity are the datasets employed for RWH site identification (Getachew, 1999; Ibrahim et al., 2019; Maina & Raude, 2016; Shadeed et al., 2019). The detailed explanation of the input data is described as follows.

Slope. The slope is expressed by the degree of steepness and line direction in a specific land topography. It was employed for determining the gradient of the fields of the watershed. The slope has a direct impact on choosing the right location for RWH practice since it interferes with the design and construction of storage structures. On the other hand, it has a remarkable power on sediment accumulation and runoff generation, water flow velocity, and groundwater recharge (Al-Adamat, 2008). The extracted slope data from DEM was processed by using a GIS spatial analysis package to convert the percentage gradient of rise. The ArcGIS 10.5 toolset determines the slope value of the watershed by taking the DEM values. The slope map generated was then classified into four suitability classes, from nearly flat to very sharp sloping (Maina & Raude, 2016). The slope suitability classification standards are summarized in Table 1.

Soil texture. Soil characteristics for rainwater harvesting must be similar to those for irrigation in most cases. Soil penetrability is a key parameter that affects the rate of infiltration and soil water storage capacity (Glendenning et al., 2012). Several important soil characteristics are influenced by the soil texture in terms of infiltration rate and available water capacity. Infiltration, surface flow runoff, and the soil's storage capacity are all governed by the texture of the soil (Glendenning et al., 2012). Soils having the characteristics of rapid infiltration rates are not advisable for RWH implementation. Soil having small and medium pores are more favorable for RWH development because of its high-water retention capacity. According to (Umugwaneza et al., 2022), the soil textural class of the study watershed was classified into highly, moderately, marginally suitable, and unsuitable and summarized in Table 1.

Soil depth. The depth of soil has an impact on the water retention and good root development of crops (Shadeed et al., 2019; Wu et al., 2018). Deeper soils are more suitable for collecting rainwater (Critchley et al., 1991). The depth of soil in areas where RWH technologies are suggested is specifically important. Deep soils have a high potential to store the collected runoff, and they also provide nutrients for plant growth. It is not recommended to establish RWH systems in areas with soils of less than 1 m deep unless it is a storing system. Ideally, 2 m or more is the best, yet it is barely found in practice (Critchley et al., 1991). Areas having a soil depth of more than 100, 50–100, 25–50, and less than 25 cm are grouped as highly, moderately, marginally suitable, and unsuitable, respectively.

Land use land cover (LULC). The cover of the land is linked directly to a high proportion of infiltration and low runoff (Toosi et al., 2020). Land use land cover is an important criterion and element in selecting and implementing water harvesting processes (Shanableh et al., 2018). It can affect the hydrological response of streams in a watershed; thus, it will have a significant effect on runoff (Ibrahim et al., 2019). At a particular place, the depth of runoff produced is associated with the land cover type. Land areas covered with denser forests are linked with a high interception and maximum infiltration and thus have a low depth of runoff (Kahinda et al., 2008). Areas covered with bare land and water bodies generate high runoff depth, while low runoff is associated with vegetation areas (Kahinda et al., 2008). The LULC map of the present study was adopted from a study conducted by Tesfay et al. (2023). According to Ketsela (2009) and Maina and Raude (2016), bare land and water bodies are considered highly suitable areas, while cultivated and grazing lands are moderately suitable areas. The natural/plantation forest and built-up areas are grouped as marginally suitable areas.

Annual average rainfall. Rainfall is one of the determinant parameters in detecting suitable sites for water harvesting. It is an essential criterion for large-scale RWH development (Toosi et al., 2020). Rainfall is not only the most vital factor in water harvesting identification but also increases the recharge of the watershed (Adham et al., 2018). It has a direct and indirect impact on the majority of other criteria in planning for water harvesting in lowland areas. Rainfall in Ethiopia is expressed by high spatiotemporal variation (Melesse et al., 2013). When designing RWH systems, the watershed should receive sufficient rainfall to collect it and be consumed during a water shortage. The annual average rainfall available in a specific area is an essential criterion to decide whether a particular site is suitable for RWH establishment or not. Depending on the long-term recorded rainfall data, the Chacha watershed was categorized into highly, moderately, marginally suitable, and unsuitable areas with a rainfall amount of 1,357–1,681, 1,102–1,356, 758–1,101, and <757 mm, respectively.

Runoff depth. The depth of runoff is used to determine the amount of water that could be collected during rainfall time. RWH site identification is extremely dependent on the runoff that could be produced from the watershed. The water potential that could be obtained from a specific watershed is calculated from surface runoff data (Buraihi & Shariff, 2015). The runoff depth is determined using the Soil Conservation Service Curve Number (SCS-CN) method (Yegizaw et al., 2022). The amount of runoff varies with the antecedent moisture condition available in the watershed, hydrologic soil group, rainfall, and LULC type (Soulis et al., 2009).

The SCS-CN modeling was developed by the United States Department of Agriculture to apply in rural areas (Ramakrishnan et al., 2009; Tramblay et al., 2010; Weerasinghe et al., 2011). It is the most widely used runoff estimation method because it is multipurpose, simple, and flexible (Al-Hasan & Mattar, 2014; Soulis et al., 2009). It was used to calculate each pixel's spatial difference in runoff depth.

The CN for each pixel area was estimated based on the LULC, slope, soil texture, and antecedent moisture content. The calculation of runoff depth available in each pixel was then calculated using the annual average rainfall depth and its corresponding CN value as input. The part of the watershed having high rainfall, fine-textured soils, covered with bare land, and moist soil will have a high curve number value and thus produce more runoff depth. The model depends on the actual relationship of the direct surface runoff depth (Q) to the overall precipitation (P).

$$\mathbf{Q} = (\mathbf{P} - \mathbf{Ia})^2 / (\mathbf{P} - \mathbf{Ia}) + \mathbf{S} \tag{1}$$

According to Melesse and Shih (2003), the initial abstraction (I_a) including infiltration, evaporation, and water interception is provided by the experiential relationship as follows:

$$\mathbf{Ia} = 0.2\,\mathbf{x}\,\mathbf{S} \tag{2}$$

Where Q = depth of runoff in mm, P = annual average rainfall in mm, and S = possible maximum retention after the runoff commencement in mm. The probable maximum storage after runoff begins in mm (S) can be determined by the CN as follows:

$$\mathbf{S} = (\mathbf{25400} / \mathbf{CN}) - \mathbf{254} \tag{3}$$

By replacing I_a and S from equations (1) in equations (2) and (3), a formula with two parameters only was obtained:

$$\left(\mathrm{P} - 0.2\,\mathrm{x}\left(25400/\mathrm{CN} - 254\right)\right)^2 / \left(\mathrm{P} + 0.8\,\mathrm{x}\left(25400/\mathrm{CN} - 254\right)\right) \tag{4}$$

The estimated runoff depth was mapped in the ArcGIS tool and classified into four standardized suitability zones as per Ejegu and Yegizaw (2020), from low runoff depth to high runoff depth values. An area with a high runoff depth value was rated as highly suitable and low runoff depth-producing areas were rated as unsuitable considering the time taken to fill water in the RWH assembly.

Drainage density (Dd). Potential RWH sites should preferably be located in areas with relatively adequate drainage. The development of RWH is highly effective in the parts of the watershed with high Dd as compared to areas owning low Dd areas. High runoff potential is generated from many stream networks (Adham et al., 2018). In the current study, the stream networks and stream orders were generated from the DEM using the Arc hydro-processing tools of ArcGIS 10.5. According to Mugo and Odera (2019), the Dd standards for classifying RWH sites are explained in Table 1. The parts of the watershed with > 80, 40–80, 21–40, and <20 are categorized as highly, moderately, marginally suitable, and unsuitable areas, respectively.

Lineament intensity. Areas having a high number of cracks, joints, and faults have high water movement to the water table (Lentswe & Molwalefhe, 2020; Mallick et al., 2019; Rajasekhar et al., 2019). Lineament intensity therefore gives information on the capability of sites for rainwater collection (Prasad et al., 2014). It affects water retention, groundwater restoration, and subsurface water movement (Maina & Raude, 2016). The high lineament density indicates more loss of water and is capable of the RWH site storing less water and vice versa (Prasad et al., 2014). Locations with a minimum intensity of lineament are preferable for harvesting more water due to the absence of free cracks permitting the withdrawal of water (Mugo & Odera, 2019). Therefore, areas with low intensity of lineament were grouped as more suitable, while high lineament intensity areas were grouped as unsuitable.

Hydrologic soil group (HSG). The HSG of the Chacha watershed was determined based on the soil textural class of the soil. According to Maina and Raude (2016), the hydrologic soil group can be classified into "A," "B," "C," and "D" with characteristics of low runoff to high runoff rates, respectively. Thus, hydrologic soil group "D" was grouped as highly suitable for rainwater harvesting development, while classes "C," "B," and "A" were grouped as moderately and marginally suitable, and unsuitable, respectively. The HSG map of the Chacha watershed was therefore reclassified in ArcGIS 10.5 and grouped based on the Maina and Raude (2016) standards. The hydrologic soil classes and their detailed characteristics are summarized in Table 1. Fine textured soils with characteristics of low infiltration rate and high runoff potential were categorized in hydrologic soil group "D," while course textured soil which was described by low runoff potential and high infiltration rate is grouped in the HSG "A."

Antecedent moisture condition (AMC). The available soil moisture condition on the surface of the soil has a significant impact on rainwater storage. The soil moisture status is divided into three AMC classes using the CN method (USDA Soil Conservation Service, 1972). 1) AMC I: The soil surface of the watershed is nearly dry. 2) AMC II: Average condition. 3) AMC III: Due to previous rains, the soil in the watershed is nearly saturated. These classes are determined by the successive 5-days original precipitation records preceding the rainfall. To account for changes in evapotranspiration, the original soil conservation service approaches distinguished between the dormant and growing seasons. As the AMC increases due to the occurrence of rainfall, runoff depth that could be stored is also increased. For the present study, the average standards of the dormant and growing seasons were taken for AMC determination. As per the (USDA Soil Conservation Service, 1972), areas having an AMC above 53 mm are considered highly suitable, and between 23 and 53 mm and below 23 mm are moderately suitable and unsuitable areas, respectively.

Distance from road. Rain water harvesting sites situated near roads and residential areas are preferable over sites located far away (Al-shabeeb, 2016; Weerasinghe et al., 2011). The appropriateness of the land for RWH implementation becomes higher as the land areas became near the roads. People used these road accesses to collect their basic needs and make a more convenient life (Khudhair et al., 2020). Moreover, they can supply the construction material for the development of the RWH structures easily. Thus, road proximity was one of the measures applied to identify convenient RWH sites. The Euclidian distance of a spatial analyst tool was employed to prepare the road proximity map. A raster calculator technique of the ArcGIS 10.5 was employed to classify the study watershed into four classes based on its distance from the road (Ejegu & Yegizaw, 2020). According to Khudhair et al. (2020) water harvesting sites located at a distance below 0.5 km were categorized as highly suitable and more than 2 km from the road are rated as unsuitable.

Analytical Hierarchy Process (AHP)

Analytical hierarchy process is a statistical tool for multi-criteria decision analysis and it is considered the best feasible decision method integrated with the GIS platform to recognize suitable sites for RWH. It is the most common tool employed in several studies to identify suitable RWH locations (Krois & Schulte, 2014). The main target of AHP is to represent the level of impact of each criterion and display the interaction of each criterion. To define the prominence of each criterion on the RWH development a pairwise comparisons matrix was developed. A reciprocal matrix procedure was applied to compare the significance of the various parameters on the RWH site selection. From 1 to 9 ranks were assigned for each criterion depending on their level of significance. A consistency

Table 2. Scale Value of AHP (Saaty, 1977).

INTENSITY OF IMPORTANCE	DEGREE OF PREFERENCE	EXPLANATION
1	Equal	Two factors contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one factor over the other
5	Strongly	Experience and judgment strongly to moderately favor one factor over the other
7	Very strongly	A factor is strongly favored over another and its dominance is shown in practice
9	Extremely	The evidence of favoring one factor over another is of the highest degree possible
2, 4, 6, and 8	Intermediate	Used to represent compromises between the preferences in weights 1, 3, 5, 7, and 9
Reciprocals	Opposites	Used for inverse comparison

ratio (CR) as suggested by (Hussain et al., 2015) was calculated to confirm the uniformity of weights represented to each parameter using the following equation:

$$\mathrm{CR} = CI / RCI \quad (5)$$

Where RCI is the random consistency index and CI is the consistency index, which is given as:

$$\mathrm{CI} = (\lambda \max - n) / (n - 1) \quad (6)$$

Where λ_{max} is the principal eigenvalue computed by the eigenvector technique and n is the number of criteria (factors). Hussain et al. (2015) recommended that the value of CR should be less than 0.1% or 10%; otherwise, the weights should be re-evaluated to maintain consistency. According to Saaty (1977), the random consistency index value (RCI) of 11 parameters affecting the RWH site identification is 1.51 (Table 2).

Weighted overlay

Once the AHP was conducted for each parameter and given a rank, the percentage of influence was fixed and it was used as an input for the weighted overly analysis in the ArcGIS software. The weighted overlay tool of the ArcGIS software was applied to determine the overall impact of the parameters on the RWH-suitable site identification. This was done by adding all 11 reclassified maps and putting their corresponding percentage level of importance as computed using the AHP. Visualizing the overlying output map with individual map layers of each factor and the reality which is observed on the ground is important. The study watershed was thus categorized into four suitability classes depending on the overall influence of the parameters ranging from highly suitable to unsuitable areas. Based on the selected parameters for the present study, the highly suitable area means those areas having a combination of flat topography (<2%), low infiltration characteristics of soil, the land cover of bare land or water bodies, and more of the precipitated water converted to a runoff because of the high drainage density and a minimum number of lineaments. While part of the watershed has a combined effect of slope >30%, soil textural characteristics of high infiltration rate, a small number of drainage densities, and a higher number of faults that lost the precipitated water. Moderately suitable RWH sites are those areas covered with cultivated or grazing lands in a slope between 2% and 8% that gains a moderate amount of rainfall in comparison to the others, soil textural characteristics of moderate infiltration rate. The areas covered by natural/plantation forests and built-up areas in a slope range between 8% and 30% and with annual average rainfall between 758 and 1,101 mm are grouped in the marginally suitable areas.

Conceptual framework

For the recent study, different data were collected from multiple sources. Soil data, satellite images, hydro-climatic and DEM data were the main data required for the present study. The overall conceptual outline of the study is presented in Figure 2.

Results and Discussion

Suitability site identification criteria

The identification of appropriate sites for RWH in the Chacha watershed considers multiple criteria including slope, soil texture, runoff depth, Dd, annual average rainfall, LULC, depth of soil, lineament, HSG, AMC, and road proximity. The effect of each criterion and its integrated effect on the appropriate site identification of rainwater harvesting of the Chacha watershed is discussed as follows.

Slope. The classified slope map of the watershed was found in the range of 0%–169%. The analyzed result presented in Figure 3 and Table 3 showed that 14.3% (161.99 km^2) of the total area has a flat land ranging from 0% to 2% and it is grouped as a

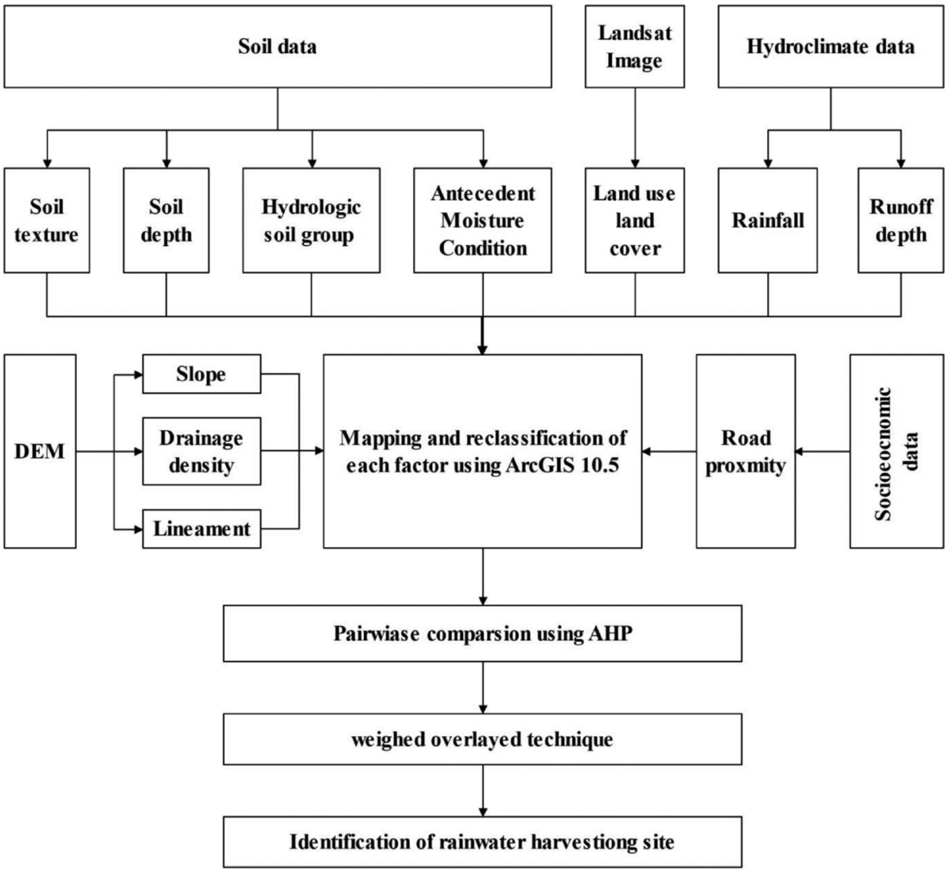

Figure 2. The general framework of the study.

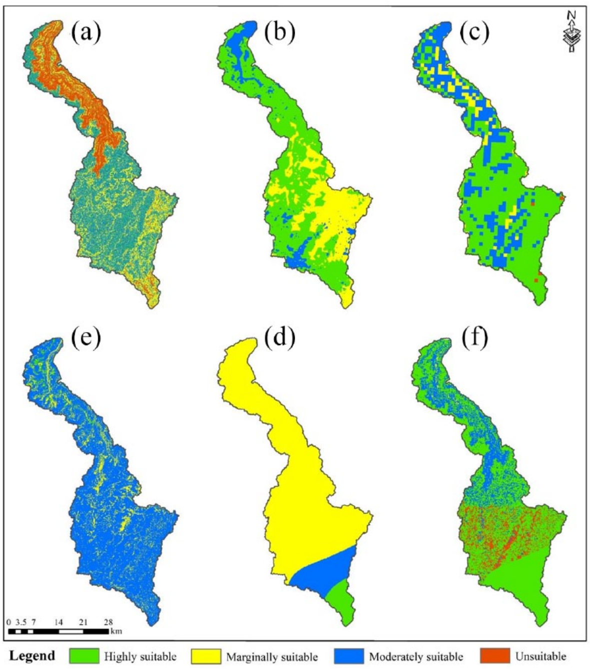

Figure 3. Reclassified maps of: (a) slope, (b) soil texture, (c) soil depth, (d), LULC, (e) rainfall, and (f) runoff depth.

highly suitable area for rainwater harvesting development. Based on the USDA Soil Conservation Service (1972) about 36.4% (412.35 km^2), 30.4% (344.51 km^2), and 18.8% (212.89 km^2) of the watershed were ranked as moderately, marginally suitable, and unsuitable areas for RWH development, respectively. The watershed found in the range of 0%–30% (highly suitable, moderately suitable, and marginally suitable) are dominantly located in the central highland and southern parts of the watershed. Whereas the northwestern lowland of the watershed is found to be unsuitable due to the steepness of the topography to collect rainwater. At the lowland parts of the watershed, there may be also an effect of surface roughness and slope direction/aspect to the unsuitability class. Steep slope areas are not suitable areas for rainwater harvesting collection because it demands high investment to construct water storage structures to harvest the rainwater. While in flat areas, the rainwater can be collected easily within the farmer's field as an in-situ water harvesting mechanism and it is also possible to collect the rainwater easily by excavating small ponds by the farmers themselves with a minimum cost. Studies conducted by Kadam et al. (2012), Ketsela (2009), and Maina and Raude (2016) also agreed with areas having gentle slopes are highly suitable while steep slope lands are unsuitable to implement rainwater harvesting technology. Therefore, in the Chacha watershed flat land areas are highly suitable to implement rainwater harvesting while steep slopes are unsuitable. The degree of slope has also an impact on the utilization of the other water sources (surface and groundwater), thus the degree of water scarcity may be minimum in the flat lands.

Table 3. Summarized Results of RWH Suitability Selection Criteria.

SUITABILITY CLASS	HIGHLY SUITABLE		MODERATELY SUITABLE		MARGINALLY SUITABLE		UNSUITABLE	
CRITERIA	AREA		AREA		AREA		AREA	
	km^2	%	km^2	%	km^2	%	km^2	%
Slope	161.99	14.30	412.35	36.40	344.51	30.40	212.89	18.80
Soil texture	671.76	59.40	116.09	10.30	343.89	30.40	–	–
Soil depth	732.1	64.70	337.63	29.80	57.51	5.10	4.50	0.40
LULC	29.52	2.60	951.75	84.10	150.46	13.30	–	–
Annual rainfall	59.12	5.20	132.10	11.70	939.8	83.00	0.03	0.0013
Runoff depth	775.20	68.50	226.3	20.00	3.40	0.30	126.75	11.20
Drainage density	472.33	41.70	289.52	25.60	177.56	15.70	192.34	17.00
Lineament density	734.68	64.90	217.19	19.20	162.45	14.40	17.43	1.50
HSG	1116.90	98.78	14.08	1.22	–	–	–	–
AMC	765.60	67.60	–	–	–	–	366.15	32.40
Distance to road	141.97	12.50	123.68	10.90	115.75	10.20	750.34	66.30

Soil texture. The soil textural classification of the Chacha watershed with clay, clay loam, silt clay, and sandy clay loam-dominated soil textural classes is presented in Figure 3. The summarized Table 3 also indicated that 59.4%, 10.3%, and 30.4% area coverage of the watershed are grouped in highly, moderately, and marginally suitable areas, respectively. The Chacha watershed is highly dominated by clay and clay loam soils in all parts of the watershed. The moderately suitable area is mainly located around the outlet of the watershed and to some extent around the Southern part of the watershed. While the marginally suitable soil texture class is found in the middle part of the watershed. The result indicated that the study area has a good opportunity to implement different rainwater harvesting technologies to enhance agricultural productivity which was constrained by water scarcity. As per the Khudhair et al. (2020) standards, clay and clay loam are highly suitable for water harvesting development due to their high water storage capacity. Land areas having sandy soil are not suitable for RWH development as a result of the high infiltration rate of the soil characteristics. But in those areas, there will be a possibility of groundwater recharging options to increase the groundwater potential. Other studies like Glendenning et al. (2012) and Maina and Raude (2016) also agreed with the idea of soils having a textural character of rapid infiltration rate are not suitable for surface RWH. Therefore, since the above half of the watershed is a clay and clay loam dominant area, it is a good opportunity to implement rainwater harvesting technology.

Soil depth. The analyzed results displayed in Figure 3 and Table 3, showed that 64.7%, 29.8%, 5.1%, and 0.4% of the watershed is highly, moderately, marginally suitable, and not suitable for RWH development, respectively. Therefore, the largest portion of the watershed has good soil depth and it enables harvesting of the required water for enhancing agricultural productivity. The moderately suitable, marginally suitable, and unsuitable soil depth classes are located in the northwestern lowland of the watershed while the most preferable soil depth class is found in the majority of the study area and is well distributed throughout the catchment. The lowland areas of the watershed located near the outlet point have rugged topography and it is exposed to soil erosion; thus, the soil depth is decreasing from time to time. Critchley et al. (1991) and Ejegu and Yegizaw (2020) suggested deeper soil is suitable for collecting high runoff.

Land use land cover (LULC). The produced result presented in Figure 3 and Table 3 showed that 84.1% (951.75 km^2) of the Chacha watershed is covered by cultivated and grazing lands. These land use land cover types are rated as moderately suitable lands for rainwater harvesting site establishment (Yegizaw et al., 2022). They are grouped as moderately suitable areas since the water harvesting technology can be implemented in such land use land cover types with less investment cost in the form of an in-situ water harvesting system. Natural and plantation forests and built-up areas cover 12.4% (138.46 km^2) of the Chacha watershed with a category of marginally suitable areas for rainwater harvesting development. These land use land cover types are not highly preferable for rainwater harvesting practice since they are preserved for forest management. The remaining 3.7% (41.52 km^2) is covered by bare land and water bodies with a suitability rating of highly suitable and preferable land use land cover types for rainwater harvesting development. Al-Ardeeni (2015) and Yegizaw et al. (2022) suggested that utilizing the bare lands and water bodies for rainwater collection purposes is favored over the other land use types in the context of wise land utilization. Moreover, this land use type can also collect more runoff from small catchments relative to the other land use types (de Winnaar et al., 2007). The water bodies are grouped in highly suitable categories because they can help to store more water during the rainy season by constructing obstruction structures like dams, diversion weirs, and other floodwater harvesting structures. Studies conducted by Ejegu and Yegizaw (2020), Jamali et al. (2014), and Mugo and Odera (2019) also employed the same suitability classification in their studies.

Annual average rainfall. The annual rainfall of the study area varied from 757 – 1681 mm. Based on the rainfall suitability classification 5.2%, 11.7%, 83.1%, and 0.01% of the Chacha watershed are rated highly, moderately, marginally suitable, and unsuitable, respectively (Table 3). This suitability classification was based on the relative comparison of the natural rainfall at different locations in the study area. The upper catchment of the study area received high rainfall values ranging from 1,101 to 1,681 mm (Figure 3). Particularly, the summit part and originating point of the watershed received a rainfall amount between 1,381 and 1,681 mm since it is located at a higher elevation. While the upper part of the watershed is endowed with annual rainfall amount between 1,101 and 1,381 mm. Although there is a high annual average rainfall amount in the upper parts of the watershed this rainfall is mainly utilized during the rainy season due to the undulating nature of topography Thus, it is possible to collect this rainfall as surface runoff within the field and utilize it during the dry period to enhance the agricultural production. The largest part of the watershed which incorporates the central, northwestern, and southwestern parts received an annual average rainfall range between 757 and 1,101 mm. A very small portion of the watershed located around the outlet point received an annual average rainfall of 757 mm and it is classified as unsuitable area for water harvesting development in comparison with the other parts of the catchment. This area has, therefore, low rainfall amounts as compared to the other areas plus the total topography is also rugged. Consequently, RHW implementation is very crucial for improving the food insecurity problem in the area. Other studies Krois and Schulte (2014), Muleta et al. (2022), and Tahvili et al. (2021) used annual average rainfall as a selection criterion for rainwater harvesting site identification, but the range of classification is different due to the differences in the natural rainfall endowment of the study areas. But, all the above studies agreed that high rainfall amount earning areas are highly suitable lands for rainwater harvesting development even though the standards varied between studies.

Runoff depth. The runoff depth of the Chacha watershed varied from 575.52 to 1,519 mm (Figure 3). According to the USDA Soil Conservation Service (1972) standards, 68.5%, 20%, 0.3%, and 11.2% of the Chacha watershed were grouped under highly, moderately, marginally suitable, and unsuitable groups, respectively. The result shows that the watershed has high annual average rainfall with hydrologic soil groups having low infiltration characteristics; this results in high runoff depth in the watershed. The surface roughness, degree of slope, slope position, and hydraulic connectivity contribute to the runoff that could be produced. Moreover, the curve number value of grazing land and water bodies is more than 90% which plays an inordinate role in the computed runoff value (Shadeed & Almasri, 2010). Lands covered with forests generate low runoff values, as the plant cover facilitates infiltration rates, intercepts a considerable amount of water, and stored it in the soil. The computed result of the runoff map showed that the annual runoff depth values of the central flat land part of the watershed have less than 250 mm, which is rated as an unsuitable area for rainwater harvesting site implementation. This is because the amount of surface runoff that could be collected from this area is minimal. The upper part of the watershed produces more runoff depth and it was grouped as a highly suitable area. This is because; the annual average rainfall value of the watershed is high and the majority of the rainwater goes as surface runoff due to the low infiltration characteristics and high slope gradient of the watershed (Ejegu & Yegizaw, 2020; USDA Soil Conservation Service, 1972).

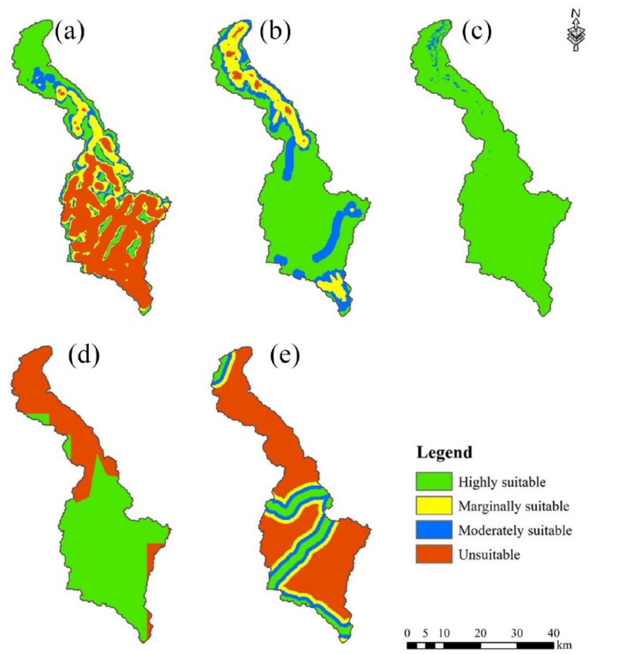

Figure 4. Reclassified maps of (a) Dd, (b) lineament intensity, (c) HSG, (d) AMC, and (e) distance from road.

Drainage density. The drainage density classified map presented in Figure 4 indicated that out of the total 1,131.75 km^2 watershed area, 472.33 km^2 (41.7%) of the catchment was rated as a highly suitable class concerning the drainage density. This means it has more than 80 drainage networks with different stream orders that will support the collection of runoff water (Mugo & Odera, 2019). Table 3 shows that 289.52 km^2 (25.6%)

of the watershed is rated as moderately suitable with the availability of drainage density range of 40–80. The remaining 177.56 km^2 (15.7%) and 192.34 km^2 (17%) area of the watershed had a drainage density between 21–40 and 0–21, respectively. The more the drainage density, the higher the suitability of the land for rainwater harvesting development. This is because; more runoff will be collected from densely populated drainage networks as compared with the watersheds having a small number of drainage networks. Therefore, as shown in Table 3, about two-thirds of the watershed area was grouped as highly and moderately preferable areas for the implementation of RWH technology. The study area has rugged topography and this able to have high number of drainage density in majority of the area. Due to the presence of small Dd to harvest runoff, 17% of the watershed was found not suitable for RWH development. When the Dd is less than 21 in number, the runoff that will be collected may not fulfill the required water demand for agricultural production. The unsuitable area is dominantly located in the upper and central parts of the watershed. Most of the highly preferable lands are located in the lowland areas of the watershed, while the moderately fit areas are found in all parts of the watershed. Similar studies were conducted by Adham et al. (2018), Muleta et al. (2022), and Yegizaw et al. (2022), and all the studies agreed more runoff can be harvested from the watersheds with high drainage densities as compared to watersheds with small drainage densities.

Lineament intensity. The lineament intensity of the watershed as it is revealed in Table 3 indicated that 64.9% (734.68 km^2) area coverage of the study area has an intensity of lineaments less than 0.25. Low lineament intensity in a region reflects the availability of a minimum number of faults and is highly suitable for the storage of adequate water due to the formation of a rock strata structure that is free of cracks (Mugo & Odera, 2019). The highly suitable sites for rainwater harvesting development are located around the central part of the watershed. Very small areas of the watershed (1.5%) had a high density of lineaments with a rating of greater than 1.25, which is not satisfactory for water storage. In such areas, a significant quantity of water drains through the faults and joins to various channels. As shown in Figure 4 the high lineament intensities are placed in the northwestern lowland areas of the watershed specifically near the outlet. The remaining parts of the study area are classified as moderately and marginally suitable classes for rainwater harvesting expansion with area coverage of 19.2% (217.19 km^2) and 14.4% (162.45 km^2), respectively. Mugo and Odera (2019) and Prasad et al. (2014) conducted similar studies and they draw a similar conclusion that aligns with the present study. Therefore, the lower the value of the lineament intensity the more suitable site for rainwater harvesting development.

Hydrologic soil group (HSG). According to the analyzed result from the ArcGIS software, the study area has only two HSGs "D" and "C." Majority of the watershed (98.78%) has a hydrologic soil group "D" with clay-dominant soil textural class Table 3. The characteristic of this hydrologic soil group is producing high runoff potential due to the low water transmission and low infiltration rate. Therefore, this hydrologic soil group is considered a highly suitable class for rainwater harvesting development. From the total area of the Chacha watershed, 1.22% has an HSG "C" which is expressed by a slow rate of infiltration when completely wetted and delays the downward flow of water. This HSG is rated as the moderately suitable type for RWH implementation. The HSG "C" is scarcely situated in the northwestern lowland parts of the watershed and the other parts are dominantly covered with hydrologic soil group "D" (Figure 4). Maina and Raude (2016) confirms that areas having HSG "D" generates high runoff depth and this is a highly suitable site to implement RWH.

Antecedent moisture condition (AMC). The analyzed result for the moisture condition of the study area has shown that 67.6% of the catchment has antecedent moisture condition above 40 mm and the reaming 32.4% of area coverage has moisture content below 23 mm (Table 3). According to the USDA Soil Conservation Service (1972) an area having a moisture content above 40 mm after 5 days of rainfall is ranked as wet soil or highly suitable, and below 23 mm is ranked as dry or not suitable areas. The analyzed result indicated that there is no antecedent moister condition range between 23 and 40 mm, which could be categorized in the antecedent moisture condition class II. Figure 4 shows that an area starting from the originating part of the catchment to the central part of the catchment is represented as a highly suitable area due to the presence of high moisture content and from the central part towards the outlet, the point is represented as not suitable because of the moisture deficiency in the area. Naturally this area has a rough surface that is not suitable for storing moisture rather it infiltrates rapidly. The dry areas required more water to fill the pores' pace of the soil and make it moist before storing water in the soil (Wayne Skaggs, 1996).

Distance from roads. Out of the total area coverage of the watershed, 66.3% is located at a distance higher than 2 kilometers from the road and this is not recommended to implement RWH (Figure 4). This is because the distance of the site from the communication networks and the main road is too far and farmers may face a challenge when supplying construction materials to link their products with market accessibility. Concerning distance from roads, 12.5%, 10.9%, and 10.2% of the watershed were grouped as highly, moderately, and marginally suitable for RWH technology practice. This is because rainwater harvesting sites located near the roads can easily supply construction materials for implementation. Areas found around the middle of the watershed are near the roads and they are grouped into highly suitable to marginally suitable areas. Because those sites are near the highway road of Debre

Berhan-Addis Ababa and Debre Berhan-Jiru and other gravel roads. But the remaining areas are categorized as unsuitable areas due to the long distance from the roads (Wayne Skaggs, 1996).

Weighted overlay of factors

The overall suitability analysis of the watershed for RWH site identification was figured based on the AHP grades of the selected 11 parameters. The pairwise comparison and normalized pairwise comparison matrix values of the AHP are presented in Tables 4 and 5, respectively. The computed consistency ratio (CR) of the present study that helps to check the uniformity of weights assigned to each parameter is 9.1% and this is an acceptable value. The color in Table 4 below shows the diagonal of each factor and the pair comparison values will be one in the diagonals.

The slope, texture of the soil, runoff depth, Dd, annual average rainfall, LULC, the intensity of lineament, HSG, AMC, soil depth, and distance from the road influence 24%, 20%, 18%, 11%, 10%, 7%, 3%, 2%, 2%, 1.7%, and 1.3%, respectively. The result indicated that slope, soil texture, and runoff depth, have the highest influence; drainage density, annual average rainfall, and LULC have a moderate influence on the suitable site selection of RWH Table 5. While the selection of a convenient site for RWH is less affected by road proximity, soil depth, AMC, HSG, and lineament intensity. According to the analyzed result of all the parameters in the ArcGIS 10.5 weighted overlay technique, 10.5%, 71.1%, 17.9%, and 0.5% of the watershed are highly, moderately, marginally suitable and unsuitable for RWH implementation. A flat land having soil texture characteristics of high water holding capacity that can produce high runoff depth is considered the preferable site for RWH. In such areas, it is possible to apply both the micro and macro water harvesting techniques. The part of the watershed having a considerable number of drainage networks situated in bare land or water bodies with high annual average rainfall has a moderate impact on the suitable RWH site identification. About 0.5% of the watershed is grouped as a not suitable area for RWH implementation. This may be because of the steep topography, a highly fractured land with minimum drainage density, and dry soil moisture conditions. As shown in the overlaid map Figure 5, the northern, northeastern, and middle watershed parts are highly suitable while the small portion of the watershed near the outlet point is not suitable for RWH development. The sensitive parameters obtained in this study were aligned with the study carried out by Ammar et al. (2016), Ejegu and Yegizaw (2020), Ibrahim et al. (2019), Maina and Raude (2016), and Yegizaw et al. (2022).

In general, RWH implementation is very important in the Chacha watershed to supplement the irrigation for those areas that receive irrigation water below the crop water demand as a result of the water scarcity problem. Moreover, it has a remarkable contribution in the areas that have no access to surface and groundwater resources and only depends on rainfed agriculture because of the topographical barrier. As compared to other areas, the average annual precipitation in the majority part of the Chacha watershed is adequate to produce crops during the rainy season, but it is very difficult to utilize it during the dry period. Therefore, collecting and storing this precipitation water to utilize it during the dry period as RWH is a good solution instead of using different lifting mechanism like pump to deliver water from the surface and groundwater sources. Although the RWH is highly suitable in flat lands, it is possible also to apply it in moderately steep topography as micro water harvesting techniques like storing runoff by excavating ponds within the farmers' field to produce crops more than once instead of keeping the rainy season only. Appropriate RWH site identification is therefore very important to manage and utilize the precipitated water efficiently. It has a great contribution to combating the food insecurity problem caused by water scarcity which is challenging the community living in the study area. The selection of the appropriate RWH techniques in each suitable spot sites will be the future task.

Conclusions

Identifying an appropriate rainwater harvesting site considering different influencing factors of rainwater harvesting suitability is very crucial. Several factors, namely slope, soil texture, LULC, annual average rainfall, runoff depth, Dd, lineament density, AMC, soil depth, HSG, and distance from the road were considered for the RWH site identification of the Chacha watershed. The land suitability analysis for RWH development of the watershed is analyzed using the geospatial tools with a multi-criteria analysis of the AHP. The result of the AHP pairwise matrix indicated that slope, soil texture, and runoff depth were the most influencing factors with weight of 24%, 20%, and 18%, respectively. Drainage density, annual average rainfall, and LULC have a moderate weighting influence with a percentage influence of 11%, 10%, and 7%, respectively. The less sensitive or influencing factors were road proximity, soil depth, AMC, HSG, and lineament intensity with a weighting influence of 1.3%, 1.7%, 2%, 2%, and 3%, respectively. The overall weighted overlay analysis result of the watershed depicted that 10.5% is highly suitable for RWH, and 71.1% of the watershed is moderately suitable. The remaining 17.9% of the watershed was rated as marginally suitable, whereas the unsuitable class was 0.5% of the watershed. The Chacha watershed has experienced water scarcity due to the rugged topography and uneven spatiotemporal distribution of water resources. Developing different water harvesting structures near the farmers' fields considering these rainwater harvesting site selection criteria is the best option to alleviate the problem. Thus, the government or NGOs should promote the RWH technology development in the watershed to enhance the agricultural productivity of each farmer and combat food insecurity. This study can serve as baseline information for the government, NGOs, and local communities to implement the appropriate technology for the development of RWH. Moreover, this study will be very

Table 4. Pair-Wise Comparison Matrix of RWH Selected Criterion.

FACTORS	SLOPE	SOIL TEXTURE	RUNOFF	DD	RAINFALL	LULC	LINEAMENT	HSG	AMC	SOIL DEPTH	DISTANCE FROM ROAD
Slope	1.00	2.00	3.00	4.00	5.00	5.00	6.00	7.00	7.00	9.00	9.00
Soil texture	0.50	1.00	2.00	4.00	4.00	5.00	6.00	7.00	7.00	9.00	9.00
Runoff	0.33	0.50	1.00	4.00	5.00	5.00	8.00	9.00	9.00	8.00	9.00
DD	0.25	0.25	0.25	1.00	2.00	4.00	6.00	7.00	8.00	8.00	9.00
Rainfall	0.20	0.25	0.20	0.50	1.00	3.00	6.00	8.00	8.00	9.00	9.00
LULC	0.20	0.20	0.20	0.25	0.33	1.00	4.00	5.00	5.00	6.00	7.00
Lineament	0.20	0.17	0.13	0.17	0.17	0.25	1.00	2.00	2.00	3.00	4.00
HSG	0.17	0.14	0.11	0.14	0.13	0.20	0.50	1.00	2.00	2.00	2.00
AMC	0.14	0.14	0.11	0.13	0.13	0.20	0.50	0.50	1.00	2.00	2.00
Soil depth	0.11	0.11	0.13	0.13	0.11	0.17	0.33	0.25	0.50	1.00	2.00
Distance from road	0.11	0.11	0.11	0.11	0.11	0.14	0.25	0.50	0.50	0.50	1.00
Sum	3.22	4.87	7.23	14.42	17.97	23.96	38.58	47.25	50.00	57.50	63.00

Table 5. Normalized Pair-Wise Comparison and Weight of Factors for RWH Site Selection.

FACTORS	SLOPE	SOIL TEXTURE	RUNOFF	DD	RAINFALL	LULC	LINEAMENT	HSG	AMC	SOIL DEPTH	DISTANCE FROM ROAD	WEIGHT (%)	λ_{MAX}	CI
Slope	0.31	0.41	0.41	0.28	0.28	0.21	0.16	0.15	0.14	0.16	0.14	24	13.60	0.26
Soil texture	0.16	0.21	0.28	0.28	0.22	0.21	0.16	0.15	0.14	0.16	0.14	20	13.32	0.23
Runoff	0.10	0.10	0.14	0.28	0.28	0.21	0.21	0.19	0.18	0.14	0.14	18	14.46	0.35
DD	0.08	0.05	0.03	0.07	0.11	0.17	0.16	0.15	0.16	0.14	0.14	11	13.37	0.24
Rainfall	0.06	0.05	0.03	0.03	0.06	0.13	0.16	0.17	0.16	0.16	0.14	10	12.73	0.17
LULC	0.06	0.04	0.03	0.02	0.02	0.04	0.10	0.11	0.10	0.10	0.11	7	12.03	0.10
Lineament	0.06	0.03	0.02	0.01	0.01	0.01	0.03	0.04	0.04	0.05	0.06	3	11.39	0.04
HSG	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0.03	2	11.43	0.04
AMC	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	2	11.46	0.05
Soil depth	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	1.7	10.51	−0.05
Distance from road	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	1.3	11.79	0.08
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	CI mean		0.14
CR												$(0.14/1.51)\times 100=9.1\%$		

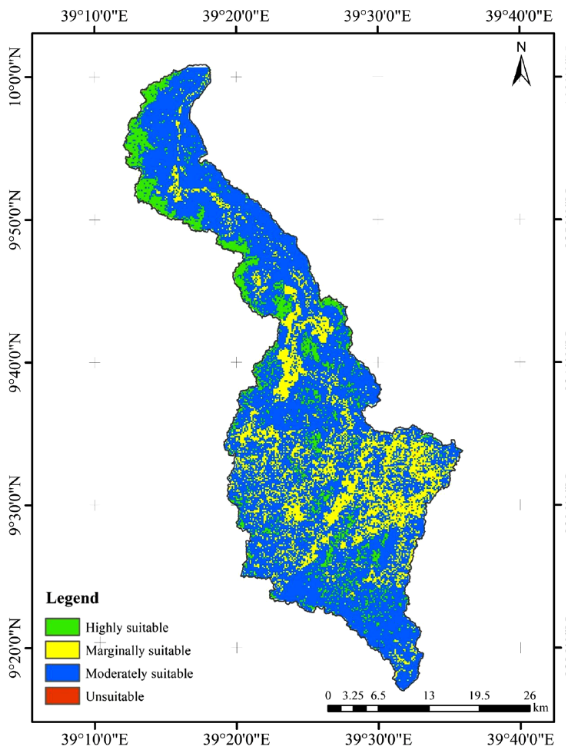

Figure 5. Overall suitability map of rainwater harvesting.

important guidance for water resources planners and decision-makers in their future tasks of suitable site identification.

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Consent for Publication

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Please contact the authors for any data requirements.

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