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Research Article

Potential rainwater harvesting suitable land selection and management by using GIS with MCDA in Ebenat District, Northwestern Ethiopia

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Abstract: Rainwater harvesting (RWH) is the way to reduce the effects of mid-season dry spells and drought, which often reduce crop yields. Geographic information system (GIS) with multi-criteria decision making (MCDA) is a powerful tool to identify and solve spatial problems like the identification of the suitable site of RWH. Sentinel image, soil, metrological row data, geological data, and digital elevation model (DEM) data were the source of a dataset to undertake the preprocessing, manipulation, and analysis the suitable site identification by using GIS and remote sensing spatial analysis. More than seven parameters where identified based on an extensive literature review which is land use/land-cover, soil textural, rainfall, lineament, slope, runoff density and curve number, distance from settlement and road. The multi-criteria decision-making method was used for weight value estimation of each criterion and finally, the rainwater harvesting suitability map was generated. The potentially suitable site was grouped into four levels of suitability, which accounts in hectare 3,620, 16,0618, 69,867, and 14,010 ha of highly suitable, moderately suitable, less suitable, and restricted respectively from the total area coverage of 248,115 ha respectively.

***Keywords**: GIS, rainwater harvesting, suitable site, weighted linear combination*

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Introduction

Water is the basic means of human life for domestic purposes, but it is the main challenge for millions of people worldwide is the lack of access to safe and clean water (Worm and Hattum, 2016), particularly in developing countries (Singh et al., 2009). A large percentage of the earth's people do not have access to an adequate and constant supply of water (Alshabeeb, 2016; Haile, 2017). Water-poor areas should look for a new way of acquiring, safe, sustainable, sources of water. For instance, rainwater harvesting is another option and a viable alternative to secure water (Abdulrazzak, 2003; Sameer et al., 2019).

Rain Water Harvesting (RWH) is the way of collecting and storing water for future activity use, which means Rainwater is collected when rainfalls on the earth, deposited and utilized at any activity for different purposes (Gashaw, 2018). The database of the World Overview of Conservation Approaches and Technologies defined RWH as: "The collection and management of floodwater or rainwater runoff to increase water availability for domestic and agricultural use as well as ecosystem sustenance". Adequate water supply is a serious issue for the development of drinking water supplies and related activities (Maina and Raude, 2019). Rainwater harvesting is consequently necessary to guarantee storage while avoiding wastage (Mekdaschi and Liniger, 2013; Asala, 2017; Ammar et al., 2018)

Ethiopia is the part of Horn of Africa with a population of approximately 80 million. Agriculture is the backbone of the Ethiopian economy, it provides 60% of the Gross Domestic

Product (Ketsela, 2009). Ethiopia has suffered from great climatic variability, both yearly and over decades, and spatially and temporally. Improving the performance and use of rainwater harvesting for rainfed agriculture is key to improve the livelihoods of rural people of Ethiopia by making water available during the time of dry spells (Devereux, 2000). In most Ethiopia and particularly Amhara region the landholding size is 0.5 hectare (Amhara Rural Land Proclamations of 255/96) which is insufficient for surviving the life of the household in good condition of production. If climate variability and shift in the onset and secession of rainfall time have happened, the family will suffer from a shortage of food and related social and economic problems (OXFAM, 2010). Ebenat Districts are the most pretentious by weather and insufficiency of water and often have uncertain livelihoods. So, rainwater harvesting with efficiently utilize is the only means to continue supportable development of the District (MoFED, 2006; Alamerew, 2006: Hussein and Shariff, 2015). The implementation of RWH potential site selection depends heavily on their technical design and the identification of suitable land (Al-Adamat et al., 2012; Adham et al., 2017; Ammar et al., 2018). GIS with the integration of MCDA plays an important role in maintaining data; combine layers of spatial data site selection (Saaty, 1980; Saaty, 2000; Shadeed, 2011; Van der Vyver and Jordaan, 2011; Alshabeeb, 2016; Thakur et al., 2017; Sameer et al., 2019) So, potential land identification and selection for Rainwater harvesting suitable site in Ebenat district by using an integration of GIS, remotely sensed data and MCDA are the main objectives of the study.

Materials and Methods

Study area

Ebenat is one of the woredas in South Gonder Zone, the Amhara Region of Ethiopia. The town is located from 11°53'N to 12°5'N latitude and 37° 42'E to 38° 30'E longitude (Figure 1). Ebenat is relatively located, bordered on the south by Farta, on the southwest by Fogera, on the west by Libo Kemekem, on the north by the Semien Gondar and the topographical structure of the woreda ranges from 1,229 m.s.l up to 3,226 m.s.l and it is part of the South Gondar Zone.

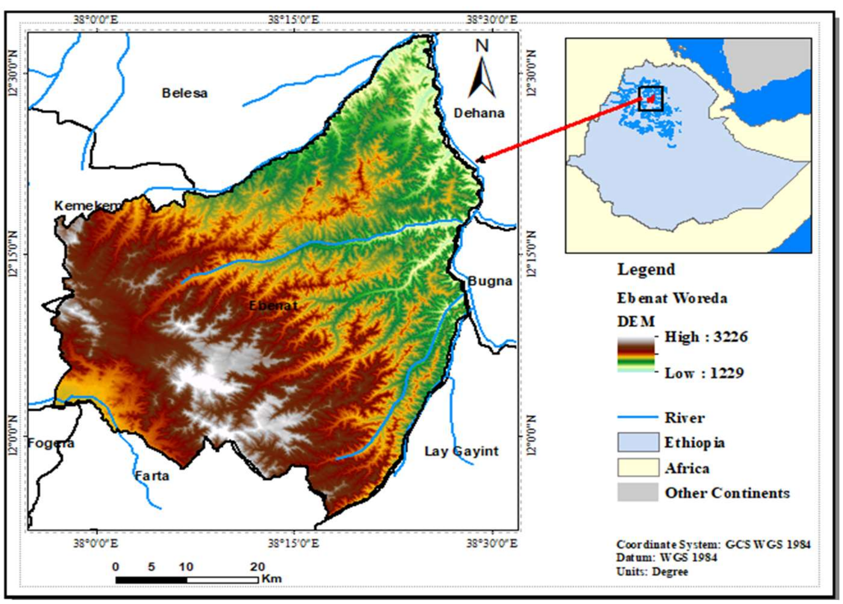

Figure 1. Map of the study area (source; Ethi-GIS).

Dataset

RWH potential site selection and mapping by using Geospatial technology and multi-criteria analysis is a new approach to tackle drought and water scarcity for domestic use, especially, for a better agricultural activity. According to Alem (1999), Sharma and Smakhtin (2006), Prasad et al. (2014), Maina and Raude (2016), Ibrahim et al. (2019), and Shadeed et al. (2019), land-use/land-cover, textural suitability, rainfall, lineament proximity, slope, curve number (CN), and runoff density and distance from settlement and road are the parameters for rainwater harvesting suitability site area identification.

Land-use/land-cover dataset

Sentinel-2A Satellite image data was used for land use/land cover classification, which was acquired in January 17/2020, which is downloaded from www.earth explorer.us, with a spatial resolution of 10 meters. After the image was layer stacked and subset to the study area, a supervised classification method was applied by taking a ground control point (GCP) for signature identification and accuracy assessment. The final result of land use land cover was 87% overall accuracy that is acceptable for different spatial analysis.

Soil texture dataset

Soils are mineral particles in a different size, that means inorganic material in the soil. These elements are named sand, silty, or clay, based on their proportional proportions. These soil particles are commonly known as soil texture (Prasad et al., 2014; Adham et al., 2018). The property of soil was alike or different and they dried influence Rainwater harvesting potential site selection. The soil texture dataset of the study area was extracted from the Ethiopian Ministry of Mines in January 2020. The soil texture types in the study area are clay, clay loam, silty clay, sand, sandy clay, loamy sand, and water body and rock which cover 49.98%, 27.34%, 22.29%, 0.07%, 0.17%, 0.10% and 0.05% of the area, respectively (Table 1).

Table 1. Soil texture type variability in the area.

Soil Texture Type	Area (ha)	Area (%)
Clay	124011.92	49.98
Clay Loam	67831.44	27.34
Silt Clay	55305.44	22.29
Sand	165.85	0.07
Sandy Clay	428.85	0.17
Loamy Sand	256.51	0.10
Water Body and Rock	114.91	0.05
Total	**248114.92**	**100**

Rainfall dataset

The rainfall data of the study area was analyzed by taking 30 years of rainfall distribution of Amhara regional metrological centre from the year interval 1989 -2019. The rainfall row data was converted into spatial distribution data by taking ArcGIS 10.3 conversation interpolation method to estimate unknown value into a point spatial data and applying the Inverse Distance Weight (IDW).

Lineament proximity dataset

Lineament is a map-able, linear feature of a surface, that is aligned in a straight-line or to some extent curved relationship and which differ from the pattern of adjacent features and presumably reflect some subsurface phenomenon (Prasad et al., 2014). The lineament data was extracted from the Sentinel satellite image of January 17, 2020 by using Geomatica geospatial software. The lineaments are highly suitable when groundwater recharge is to be conducted and the smallest suitable for surface water harvesting since it would encourage outflow (Mamat et al., 2018).

Slope dataset

The slope data was extracted from ASTER–DEM with a resolution of 10m. the DEM value of the data was analyzed by using a GIS package to convert a gradient of the percentage of rising, which shows the land surface amount of inclination on a given recharge, runoff and the movement of surface water depends on the gradient of the surface. The GIS platform spatial analysis toolset calculates the slope value of the area by taking the DEM value of the region.

Curve Number (CN)

The curve number also or a runoff curve number. it is an empirical approach used in hydrology to estimate or predict the direct runoff or infiltration from the relationship between rainfall, landcover types, Hydrologic Soil Groups (HSG) and antecedent moisture condition (Adham et al., 2018). its main objective is to estimate runoff depth from a rainfall storm based on the curve number parameter.

CN was driven from the reclassified soil group categories based on the soil texture units and land cover categories of the study area as well as since the study area has a slope >5% slope calculation was incorporated (Senay et al., 2013). Curve number is a dimensionless number ranging from 0 to 100 that represents the ability of the land surfaces to capture water. A low curve number means that water easily infiltrates into the soil, leaving less for a runoff. A high curve number means that water is not captured by the land surface (Chaudhary et al., 2013; Senay et al., 2013; Rajbanshi, 2016; Satheeshkumar et al., 2017). In this study to calculate CN corresponding to land-use/land-cover, hydrologic soil groups and DEM data was used by using the extension HEC-GeoHMS in the ArcGIS environment, by combining the attributes of each layers using spatial join or union tools and assigning a number based on their standard weight value (Table 2).

Table 2. Curve Number distribution based on HSG (USDA, 1986).

Land Use Type	Hydrologic Soil Groups			
	A	B	C	D
Urban	61	85	90	92
Water Bodies	100	100	100	100
Shrub Land	49	65	75	80
Agriculture	72	78	85	89
Grass Land	49	61	74	80
Forest	43	63	75	82
Bare Land	77	79	86	89

Runoff depth

The Soil Conservation Service Curve Number (SCS-CN) method uses curve numbers that were determined based on several factors including land-cover type, HSG, and hydrologic condition. Runoff depth estimation was used to estimate the available annual water supply according to mean annual rainfall data. The mean annual rainfall of the study area was used as a rainfall factor for this model. Curve Number (CN) is expectable from the effects of soil and land use/ land cover rainfall/runoff. According to Maidment et al. (1996), CN was estimated for each pixel for the study area using the land-cover and soil-texture maps. Runoff depth can be expressed as;

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad \ldots\ldots \text{eq. 1}$$

$$Q = \frac{(P - 0.2S)^2}{(P - 0.8S)} \quad \ldots\ldots \text{eq. 2}$$

$$S = \frac{25400}{CN} - 254 \ldots\ldots \text{eq. 3}$$

where Q is runoff depth (mm), P is precipitation (mm), S is potential maximum retention after the onset of runoff (mm), and I_a is an initial abstraction (mm) that includes all losses before the onset of runoff, infiltration, evaporation, and water interception by vegetation. I_a = 0.2, S determined by analyzing the rainfall data for many small agricultural basins and can be calculated using CN.

Data processing and analysis

Data was collected in three pauses, firstly, the selected study area was observed to collect and analyze the status and failure of rainwater harvesting one-time observation of the current status and its implementation and the selection of different standards for RWH suitable site selection. All the selected and identified criteria were pre-processed starting from Spectral Extraction, Projection and Transformation, Format Conversion, Rescaling, and Quality Control, and Extracting Area of interest. Different noise correction and missing data preparation were done. After onward the suitable site selection and criteria evaluation was processed and Re-classification and Suitable class generation were applied (Figure 2); finally, the applicability and the future possibility was drawn, on all of this way all the remotely sensed data and the ground truth points were pre-processed and analyzed by using all the applicable models and algorithms of Geo-information Technology while secondary data was collected from reviewing documents, books, internet and other related written materials obtained from governmental and non-governmental institutions.

Multi-Criteria Decision Analysis (MCDA)

It is used to combine layers of spatial data representing the criteria and to specify how the layers are combined. GIS-based MCDA includes two vital parts: constraint criteria and factor criteria. Each of the standards looks like a map layer. Factor maps are epitomized as spatial distributions to show the opportunity criteria and the value of realizing an objective. Constraint maps are restrictions that exclude certain elements to be taken into account for the election of most important or significance in the analysis (Malczewski, 1999).

AHP is a system of MCDA that is instigated within GIS, that defines weights for criteria based on a given condition. AHP was firstly developed by Saaty (1980). The AHP is an inclusive, reasonable, and operational framework, which allows the decision-maker to fix the trade-offs among objectives. Several studies have been used for the determination of areas most suitable for rainwater harvesting by using AHP. The AHP allows decision-makers to represent a complex problem in a hierarchical structure presenting the relationship of the goal, objectives, sub-objectives, and changes. The Pairwise Comparison Matrices (PCMs) contains associating all the possible pairs of criteria to determine which of all the criteria has higher importance based on the comparison of all the criteria to one another, the erection of a series of PCMs. Saaty (1980) recommends a scale from 1 to 9 (Table 3), where the rate of 1 indicates that the criteria are equally important and a rate of 9 indicates that the criterion under consideration is extremely important (Table 4) compared to the each other of all the variables. PCM includes a reliability check where a decision or election errors are identified and a consistency ratio is calculated.

Analytical framework

After selecting and defining the criteria, a structured interview was applied with professional and regional experts to categorize the scale value of 1 - 9 to evaluate the relative importance of all the selected each criterion. The experts were selected for structural interviews based on their knowledge of the study area and the rainwater harvesting issue of the study area. In addition to that, a literature review was made to cross-check the relative importance selection and levelling. According to AHP determination of relative importance result, the value of the weight of computed priority vector (Table 5), 31%, 23%, 16%, 13%, 11%, and 6% of the weight is computed for rainfall, slope, soil texture, LULC, lineament density, and runoff depth criteria of the rainwater harvesting site identification, that was used under ArcGIS weight spatial analysis to identify the potential suitable site. The weight value that computed from the AHP considers all the criteria, the environmental, and other related biological and activity of the people. All the experts that determine the relative importance value of all the criteria are the community of the woreda and all they are living in the town more than 20 years and they all know the impact of the rainwater harvesting for domestic purpose.

Table 3. A scale value of AHP.

Intensity of Importance	Definition	Explanation
1	Equal importance in a pair	Two criteria contribute equally to the objective
3	Moderate importance	Judgment and experience slightly favour one criterion over another
5	Strong importance	Judgment and experience strongly favour one criterion over another
7	Very strong importance	Judgment and experience very strongly favour one criterion over another
9	Extreme importance	The evidence favouring one criterion over another is of highest possible validity
2,4,6,8	Intermediate values	When compromise is needed
Reciprocals	Values for inverse comparison	If criterion I had one of the above numbers assigned to it when compared with criterion j, then j has the reciprocal value when compared with i

Table 4. The scale of relative importance.

Criteria	More Importance				Equal Importance	Less Importance				Criteria
	9	7	5	3	1	3	5	7	9	
Rainfall										Rainfall
Slope										Slope
Texture										Soil Texture
LULC										LULC
Lineament										Lineament
Runoff Depth										Runoff Depth

Table 5. Pairwise matrix.

Criteria	Rainfall	Slope	Soil Texture	LULC	Lineament Density	Runoff Depth	Weights (priority vector)
Rainfall	1.00	3.00	3.00	3.00	3.00	5.00	31
Slope	0.33	1.00	3.00	3.00	5.00	5.00	23
Soil Texture	0.33	0.33	1.00	1.00	3.00	5.00	16
LULC	0.33	0.33	1.00	1.00	1.00	5.00	13
Lineament Density	0.33	0.20	0.33	1.00	1.00	3.00	11
Runoff Depth	0.20	0.20	0.20	0.20	0.33	1.00	6

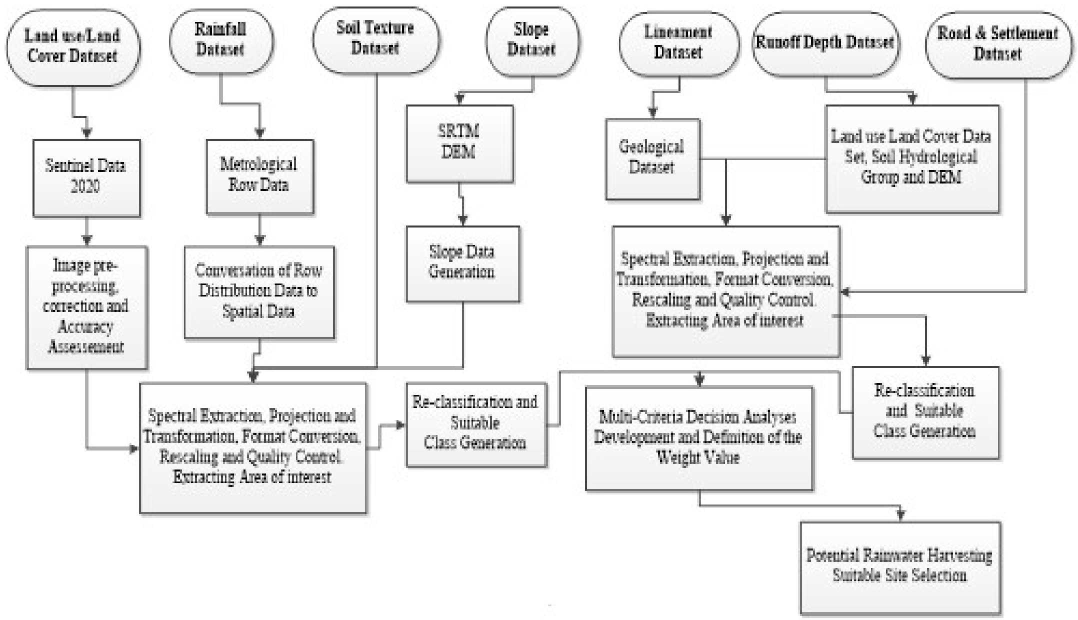

Figure 2. Flow chart for the identification of potential RWH sites.

Table 6. Criteria, Class value, suitability levels rate, weight for each criterion for identifying suitable sites of RWH, and data source.

Criteria	Class Value	Rating	Weight	Data Source
Rainfall (mm)	> 1,064 1,064 > R > 1,022 < 1,022	4 3 2	31	Ethiopian Metrology Agency
Slope (degree)	Flat Undulating Rolling to hilly Mountainous	4 3 2 1	23	USGS ASTER DEM
Soil Texture Type	Clay Silt Clay Clay Loam Others	4 3 2 1	16	Ethiopian Ministry of Agriculture and ARARI Research Center 2020
Land Use Land Cover	Bare Land Agriculture and Grass Land Shrub Land and orest Urban and Water Bodies	4 3 2 Restricted	13	Sentinel-2A dataset from USGS that acquired in 17/1/2020
Lineament Density	< 0.14 0.14 >L> 0.45 0.45 >L> 0.75 >0.75	4 3 2 1	11	Extracted by using Geomatica software
Runoff Depth	> 70 60 - 70 60 -50 <50	4 3 2 1	6	
Road and Settlement	<250m >250m	Restricted Suitable		Ethiopian Mapping Agency

Results and Discussion

The potential RWH Site selection requires consideration of multiple criteria to identify the best possible location. In this study, both factors and constraint criteria were used to identify the location of a potential suitable site.

Land-use/land-cover factor

As shown from land use the land cover (LULC) result (Figure 3) from a total of 248,114.92 hectares 0.01%, 80.72 %, 17.77%, and 1.50% of the area coverage is ranked from Highly Suitable, Moderately Suitable, Less Suitable and Not Suitable respectively intended for potential rainwater harvesting site selection. The highest suitable LULC class is bare land that only covers 0.01% of the area, next to that agriculture and grass land together which is categorized under Moderately Suitable accounts 200,267.67 ha of the study area and it is the highest area coverage that covers more than 80% of the area. This result also shows that the area is less covered by vegetation (forest and shrubland) that accounts for only 17.77%, which is categorized under less suitable. The last one that is unsuitable for the rainwater harvesting site is urban area and water bodies, which is accounts for 1.50%.

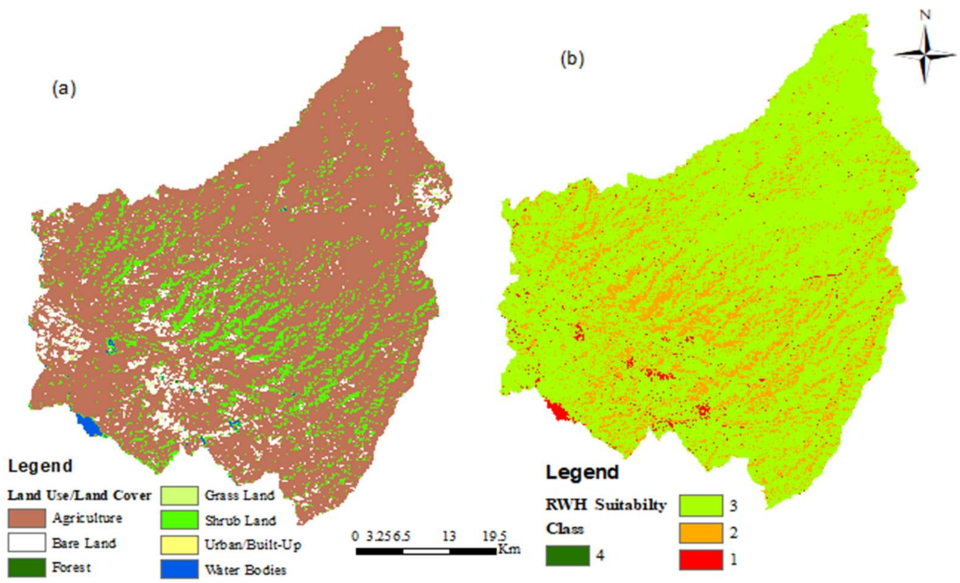

Figure 3. Land use/land cover dataset, (a) represents the classified land use/land cover data, (b) represents rainwater suitability class.

Soil texture factor

The soil texture variability of the area is extracted and grouped into four classes of rainwater harvesting suitability level (Table 8a and Figure 4), based on the soil texture analysis result, 49.98% of area coverage is highly suitable clay soil texture type and the remain 22.29%, 27.34% and 0.39% of the area coverage are ranked from Moderately Suitable, Less Suitable and Not Suitable for rainwater respectively and also according to the soil texture analysis results, clay, silty clay, clay loam, and other soil texture type are covered in an area of 124,011.92 ha, 55,305.44 ha, 67,831.44 ha, and 966.12 ha respectively. Clay soil texture type coverers all most 50% of the area and this type of soil texture is a highly suitable type for rainwater harvesting site.

Rainfall factor

The rainwater harvesting site selection depends on the availability of rainfall that was collected in a specific area (Moges et al., 2011). The rainfall variability of the area ranges from 1004mm up to 1,138.19 mm of the annual average value. According to Alshabeeb (2016), The value of the rainfall was categorized under three levels of suitability Highly Suitable, Moderately Suitable, and Less Suitable class and it accounts 8.50%, 60.55%, 30.95% respectively that shown in Table 8b and Figure 5a and 5b.

Lineament factor

The lineament distribution density ranges from 0.133 - 1.313 km^2. The lineament distribution of the area shows that in the eastern and all the round part of the area is not suitable and highly suitable respectively. As shown from Figure 5c and 5d, and Table 8c, 39.98%, and 38.30% of the area are categorized under Moderately Suitable and Less Suitable respectively, the remain lineament distribution of the area is covered by 8.59% and 13.14% under Highly Suitable and Not Suitable. The topographical ups and downs of the area are highly affected by the lineament distribution, the border part of the study area is categorized under highly suitable but is a small area coverage.

Slope factor

The landscape raise value of the area ranges from 1,229 up to 3,226 m.s.l. This value was changed into the slope in percent of raise and ranges from 0% of inclination up to 425.07% of raise. The area is highly under in the categories of rolling to hilly (Table 9a, Figure 6a and 6b), that is less suitable to control the runoff of the rainwater which accounts 72% of the area is covered and the remain 1.45%, 14.97% and 11.96% of the area highly Suitable, moderately Suitable and not Suitable, respectively.

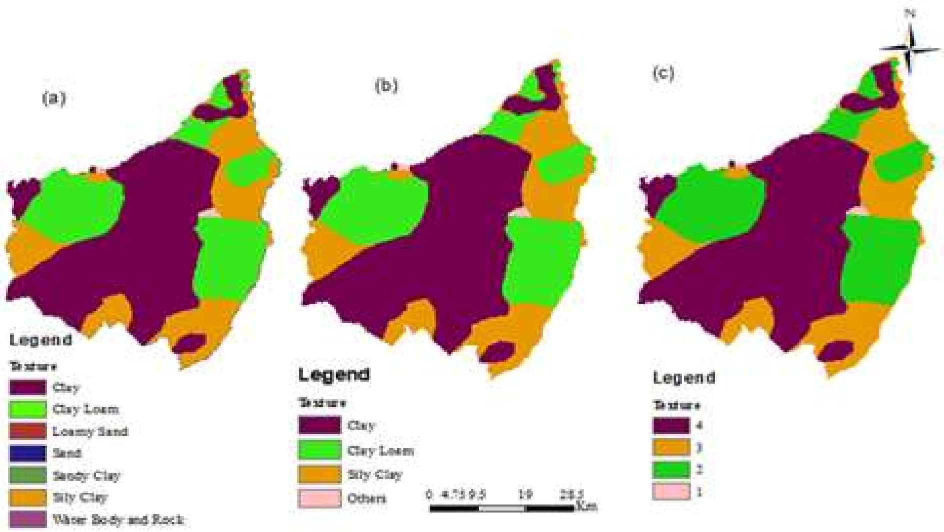

Figure 4. Soil texture type, (a) soil texture dataset, (b) suitable soil texture class, (c) classified soil texture based on the level of sustainability.

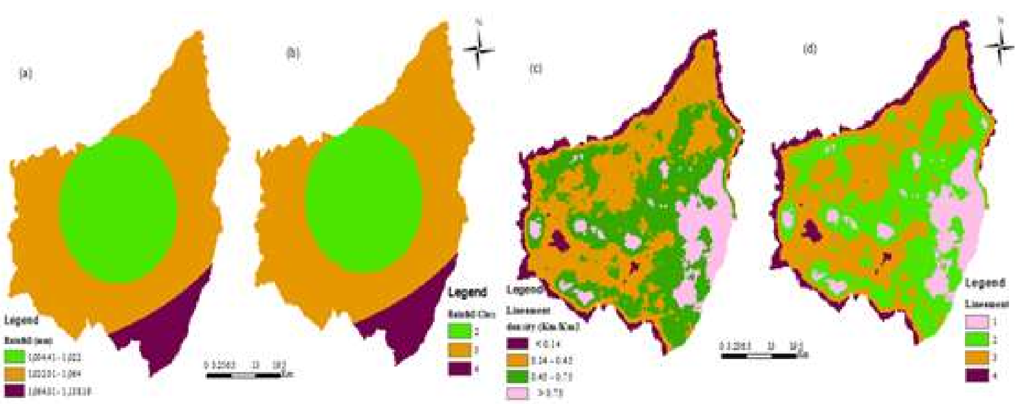

Figure 5. Rainwater harvesting distribution map, (a) rainfall distribution, (b) rainfall suitability, (c) lineament density distribution, (d) lineament density suitability level.

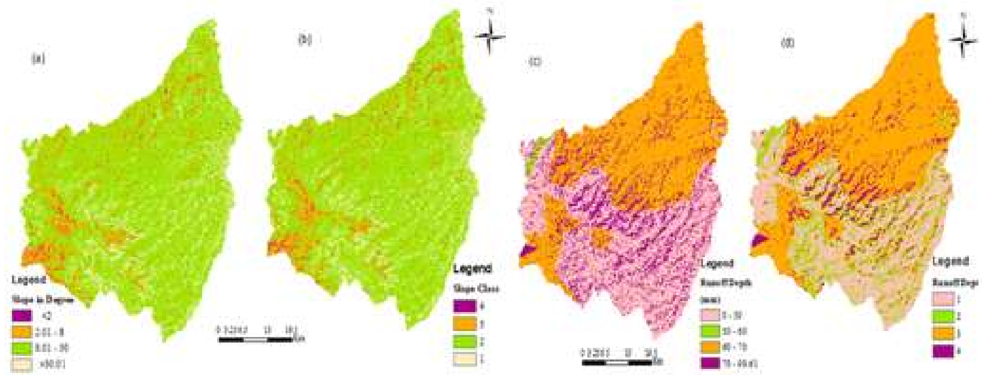

Figure 6. Rainwater harvesting distribution map, (a) slope dataset, (b) slope suitability class, (c) runoff depth distribution, (d) depth suitability level.

Table 7. Land use/land cover suitability level.

Suitability Level	RWH Suitability Class	Land Use Type	Area (ha)	Area (%)
Highly Suitable	4	Bare Land	34.86	0.01
Moderately Suitable	3	Agriculture and Grass Land	200,267.67	80.72
Less Suitable	2	Shrub Land and Forest	44,090.19	17.77
Not Suitable	1	Urban and Water Bodies	3,722.2	1.50
	Total		**248,114.92**	**100**

Table 8. Rainwater harvesting suitability distribution of (a) soil texture, (b) rainfall, (c), lineament density.

Suitability Level	(a)			(b)			(c)		
	Type	**Area (ha)**	**Area (%)**	**Rainfall (mm)**	**Area (ha)**	**Area (%)**	**Lineament Density**	**Area (ha)**	**Area (%)**
Highly Suitable	Clay	124011.92	49.98	1122.5 - 1064	21098.80	8.50	<0.14	21309.05	8.59
Moderately Suitable	Sily Clay	55305.44	22.29	1064 - 1022	150235.08	60.55	0.14 - 0.45	99184.25	39.98
Less Suitable	Clay Loam	67831.44	27.34	1022 - 1004	76781.04	30.95	0.45 - 0.75	95020.1	38.30
Not Suitable	Others	966.12	0.39				>0.75	32601.52	13.14
Total		**248114.9**	**100**		**248114.9**	**100**		**248115**	**100**

Table 9. Rainwater harvesting suitability distribution of (a) slop, (b) runoff density.

Suitability Level	Suitability Class	(a)			(b)		
		Description	**Area (ha)**	**Area (%)**	**Runoff Depth**	**Area (ha)**	**Area (%)**
Highly Suitable	4	Flat	3589.84	1.4468457	> 70	44815.06	18.06
Moderately Suitable	3	Undulating	37130.76	14.965146	70 - 60	107673.14	43.40
Less Suitable	2	Rolling to hilly	177712.58	71.625108	60 - 50	1502.81	0.61
Not Suitable	1	Mountainous	29681.74	11.9629	< 50	94123.91	37.94
	Total		**248114.9**	**100**		**248114.92**	**100**

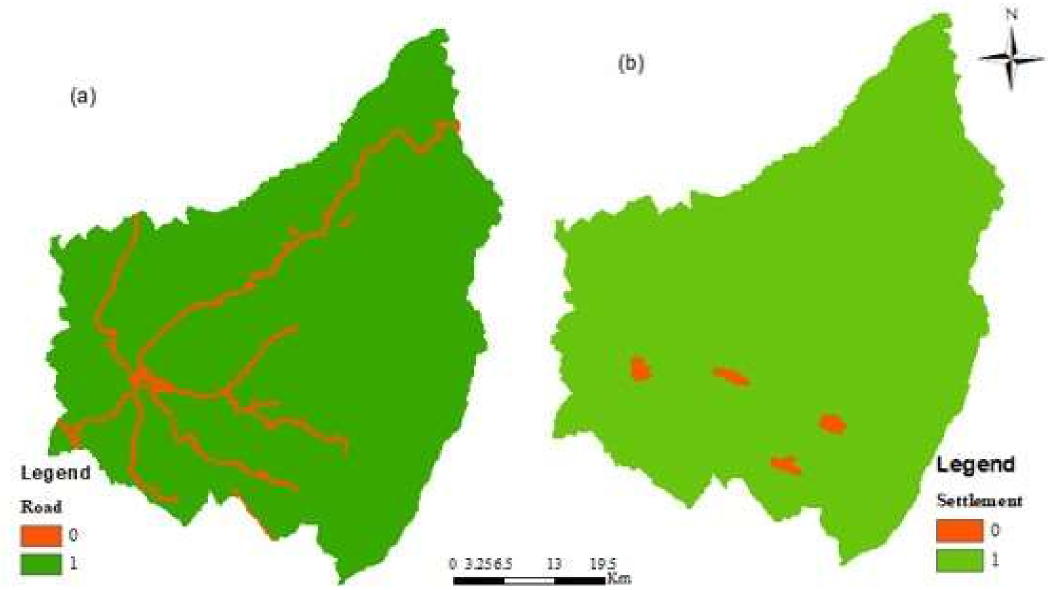

Figure 7. Road data (a), settlement data (b).

Table 10. RWH Suitable site area coverage.

Suitability Level	Rainwater harvesting site	Area (ha)	Area (%)
Highly Suitable	4	3,620.18	1.46
Moderately Suitable	3	160,617.56	64.74
Less Suitable	2	69,867.09	28.16
Not Suitable	1	14,010.08	5.65
	Total	**248,114.92**	**100**

Runoff depth factor

The runoff depth was generated from CN and it varies across LULC type and soil. The result of runoff depth data (Table 9b, Figure 6c and 6d) ranges up to 99.1 mm. the range starting from 39 mm up to 50 mm and 60 mm up to 70 mm covers an area of 38% that categorized a class of very less suitable covers and 43% that categorizes under moderate suitable indicates that runoff potential was evenly distributed. The remaining percentage of the land coverage is under in the class of highly suitable and less suitable that accounts for 18.06% and 0.61% respectively. In the forested area, the vegetation increases infiltration rates, interception losses, and retention which consequently decrease the volume of runoff.

Distance from settlement and road

RWH Suitable site should be away from the settlement and the road facility, Road and settlement are a constraint factor that is restricted in the selection and identification of Rainwater harvesting site, So the settlement and road facility was 250 m away from the suitable area that was given "0" and "1" value in ArcGIS weighted analysis in which is restricted and suitable for rainwater harvesting respectively (Sharma and Smakhtin, 2006). As shown from the distance from settlement and road result (Figure 7), the red colour represents the restricted area that is buffered by 250m to the settlement area and rod of the area, the remain green colour represents the area that is suitable for the RWH site selection.

The suitable site and land management

The overall criteria of the data were computed and weighted are LULC, soil textural, rainfall, lineament proximity, slope, runoff depth, and distance from settlement and road parameters are applied with the AHP computed weighted of 31%, 23%, 16%,13%11%, and 6% respectively out of 100% for identifying RWH suitability site. According to the final map of RWH suitable site (Table 10 and Figure 8), only 1.46 % of the area is highly suitable for potential rainwater harvesting site. that means, does not need any adjustment and technological advancement for RWH ponds land management.

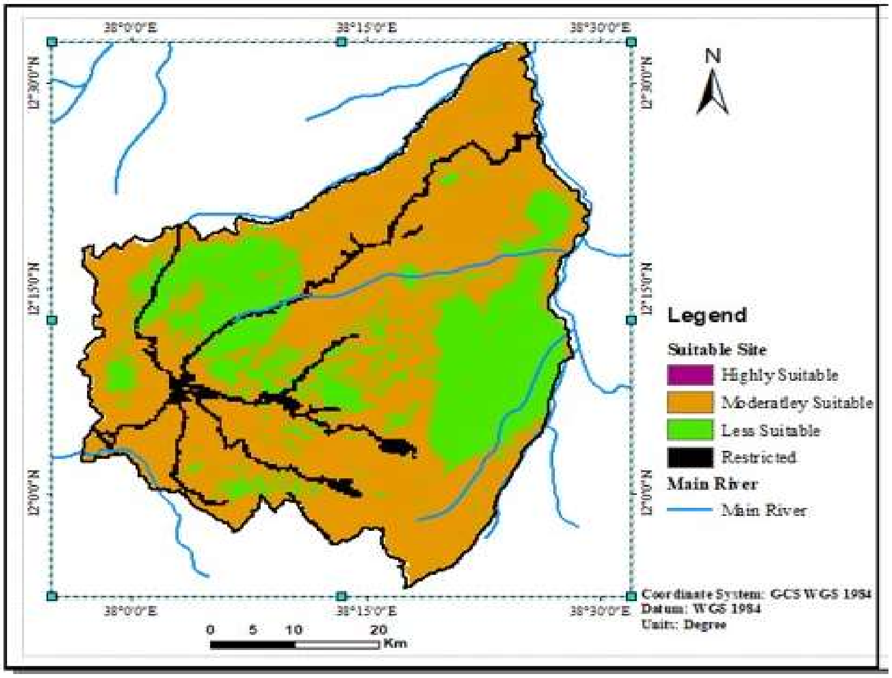

Figure 8. Rainwater harvesting suitable site map.

The remain 64.74%, of the area, were levelled under Moderately Suitable, that is also the second option to use for potential RWH Suitable site but it needs technological advancement of land management in the time of construction RWH ponds and related activates because the area is moderately suitable that means some of the criteria is not suitable and needs land management in terms of water availability, slope, LULC type, texture or lineament. The remaining area coverage of 28.16% and 5.65% of the area coverage is under the category of, Less Suitable and Not Suitable or restricted.

Conclusion

The potential RWH site selection was identified by using a GIS-based MCDA technology by taking LULC, soil textural density, rainfall, lineament proximity; slope, runoff, distance from settlement, and road variables. The finding proves that only 1.46% of area coverage is highly suitable for RWH pond construction and 64 % of the area is moderately suitable, remain 35% of the area coverage less suitable and restricted for RWH. The finding indicated that the accessibility of rainwater ponds could be improved if any technological advancement of land management is taken and the way of RWH was improved. Further studies can be conducted to narrow down different of how to put on and implementation of pond RWH. Besides, the study can further be used by incorporating the socio-economic activities of the area, where public needs and favourites are assessed. The Geospatial packages was a very powerful tool for integrating complex information to find suitable land for RWH and solving the spatial problem. The suitability site map will be useful to hydrologists, decision-makers, and planners for quickly determining areas that show RWH potential area.

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References

Abdulrazzak, M. 2003. Water harvesting practices in selected countries of the Arabian Penisula, in Khartoum, Sudan: *Proceeding of the Conference on Water Harvesting and the Future Development*.

Adham, A., Riksen, M., Ouessar, M., Abed, R. and Ritsema, C. 2017. Development of methodology for existing rainwater harvesting assessment in (semi-) arid regions. In: *Water and Land Security in Drylands*. Springer International Publishing, 171–184.

Adham, A., Sayl, K.N., Abed, R., Abdeladhim, M. A., Wesseling, J. G., Riksen, M., Fleskens, L., Karim, U.

and Ritsema, C.J. 2018. A GIS-based approach for identifying potential sites for harvesting rainwater in the Western Desert of Iraq. *International Soil and Water Conservation Research* 6(4): 297–304, doi: 10.1016/j.iswcr.2018.07.003.

Al-Adamat, R., AlAyyash, S., Al-Amoush, H., Al-Meshan, O., Rawajfih, Z., Shdeifat, A. and Al-Farajat, M. 2012. The combination of indigenous knowledge and geoinformatics for water harvesting siting in the Jordanian Badia. *Journal of Geographic Information System* 4(4): 366-376, doi: 10.4236/jgis.2012.44042

Alamerew, E. 2006. Towards widespread rainwater harvesting in Ethiopia: ERHA's experience as a successful Rainwater Harvesting Capacity Centre (RHCC). In *10th Southern and Eastern Africa Rainwater Network* (SearNet) International, Mombasa, Kenya.

Alem, G. 1999. Rainwater harvesting in Ethiopia: An overview. Integrated Development for Water Supply and Sanitation: *Proceedings of the 25th WEDC Conference*, 387–390.

Alshabeeb, A.R.R. 2016. The Use of AHP within GIS in selecting potential sites for water harvesting sites in the Azraq Basin - Jordan. *Journal of Geographic Information System* 8(1): 73–88, doi: 10.4236/jgis.2016.81008.

Ammar, A., Khamis, N.S., Rasha, A., Abdeladhim, M.A., Wesseling, J.G., Riksen, M., Fleskens, L., Karim, U. and Ritsema, C.J. 2018. A GIS-based approach for identifying potential sites for harvesting rainwater in the Western Desert of Iraq. *International Soil and Water Conservation Research* 6(4): 297-304.

Asala, L. 2017. Site Suitability Mapping of Water Harvesting Structures Using GIS and Remote Sensing. Case Study: Machakos County. University of Nairobi, 12-71.

Chaudhary, A., Mishra, S.K. and Pandey, A. 2013. Experimental verification of effect of slope on runoff and curve numbers. *Journal of Indian Water Resources Society* 33: 40 - 46.

Devereux, S. 2000. Food security in Ethiopia. A Discussion Paper for DFID. IDS Sussex.

Gashaw, D.Y. 2018. GIS-based Integrated Fuzzy Logic and Analytic Hierarchy Process model for Assessing Rainwater Harvesting Zones in Modjo Watershed, Central Ethiopia. Addis Ababa University, 14-109.

Haile, G. 2017. Modeling Approach for Identification of Potential Rainwater Harvesting Sites in Arsi Zone, Eastern Ethiopia. Addis Ababa University, 16-117.

Hussein, F. and Shariff, R. 2015. Selecion of rainwater harvesting sites by using remote sensig and GIS techniques: A case study of Kirkuk, raq. *Jurnal Teknologi* 76(15): 75-81, doi: 10.11113/jt.v76.5955.

Ibrahim, G.R.F., Rasul, A., Hamid, A.A., Ai, Z.F. and Dewana, A.A. 2019. Suitable site seection for rainwater harvesting and storage case tudy using Dohuk governorate. *Water (Switzerland)* 11(4), doi: h10.3390/w11040864.

Ketsela, G.M. 2009. Identification of potential rainwater harvesting areas in the Central Rift Valley of Ethiopia using a GISbased approach. Wageningen University, Netherlands, 13-87.

Maidment, D.R., Olivera, F., Calver, A., Eatherall, A., Fraczek, W. 1996. Unit Hydrograph Derived from A Spatially Distributed Velocity Field. In Tetzlaff, D. (ed), *Hydrological Processes*. John Wiley & Sons Ltd.,

Maina C.W. and Raude, J.M. 2019. Assessing land suitability for rainwater harvesting using geospatial techniques: a case study of Njoro Catchment, Kenya. *Applied and Environmental Soil Science* 2016(2):1-9, doi: 10.1155/2016/4676435.

Maina, C. W. and Raude, J.M. 2016. Assessing land suitability for rainwater harvesting using geospatial techniques: A case study of Njoro catchment, Kenya. *Applied and Environmental Soil Science* 2016, doi: 10.1155/2016/4676435.

Malczewski, J. 1999. *GIS and Multicriteria Decision Analysis*. John Wiley and Sons, New York.

Mamat, A., Halik, Ü. And Rouzi, A. 2018. Variations of ecosystem service value in response to land-use change in the Kashgar Region, Northwest China. *Sustainability (Switzerland)* 10(1), doi: 10.3390/su10010200.

Mekdaschi Studer, R., and Liniger, H. 2013. Water Harvesting: Guidelines for good practice. Bern: Centre for Development and Environment (CDE).

MoFED. 2006. Ethiopia: Building on progress a plan for accelerated and sustained development to end poverty (PASDEP). Addis Ababa.: Main Text. Ministry of Finance and Economic Development Volume I.

Moges, G., Hengsdijk, H. and Jansen, H.C. 2011. Review and quantitative assessment of ex situ household rainwater harvesting systems in Ethiopia. *Agricultural Water Management* 98(8): 1215–1227, doi: 10.1016/j.agwat.2011.03.009.

OXFAM, 2010. Climate Change Increasing Poverty and Vulnerability in Ethiopia. Oxfam International.

Prasad, H.C., Bhalla, P. and Palria, S. 2014. Site suitability analysis of water harvesting structures using remote sensing and GIS - A case study of Pisangan watershed, Ajmer district, Rajasthan. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives* 40(8): 1471–1482, doi: 10.5194/isprsarchives-XL-8-1471-2014.

Rajbanshi, J. 2016. Estimation of runoff depth and volume using NRCS-CN method in Konar Catchment (Jharkhand, India). *Journal of Civil & Environmental Engineering* 6: 236, doi: 10.4172/2165-784X.1000236.

Saaty, T.L. 1980. *The Analytic Hierarchy Process: Planning, Priority Setting, Resources Allocation*. McGraw-Hill, New York.

Saaty, T.L. 2000. Fundamentals of decision making with the analytic hierarchy process. In: Schmoldt, D.L., Kangas, J., Mendoza, G.A. and Pesonen, M. (eds), *The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making*. Springer, Dordrecht, 15–35, doi: 10.1007/978-94-015-9799-9_2.

Sameer, S., Judeh, T.G. and Mohammad N. Almasri, M.N. 2019. Developing GIS-based water poverty and rainwater harvesting suitability maps for domestic use in the Dead Sea region (West Bank, Palestine*). Hydrology and Earth System Sciences Discussions*, June 2018, doi: 10.5194/hess-2018-344.

Satheeshkumar, S., Venkateswaran, S. and R. Kannan, R. 2017. Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India. *Modeling Earth System and Environment* 3:24, doi: 10.1007/s40808-017-0301-4.

Senay, G.B., Bohms, S., Singh, R.K., Gowda, P.H., Vewipuri, N.M., Alemu, H. and Verdin, J.P. 2013. Operational evapotranspiration mapping using remote sensing and weather datasets: a new parameterization for the SSEB approach. *Journal of the American Water Resources Association* 49(3): 577-591, doi: 10.1111/jawr.12057.

Shadeed, S. 2011. Developing a GIS-based suitability map for rainwater harvesting in the West Bank, Palestine. *The International Conference on Environmental Education for Sustainable Development*. Plugging the Hole, Birzeit University, Palestine, 16–17 November 2011, 13.

Shadeed, S.M., Judeh, T.G. and Almasri, M.N. 2019. Developing GIS-based water poverty and rainwater harvesting suitability maps for domestic use in the Dead Sea region (West Bank, Palestine*). Hydrology and Earth System Sciences* 23(3): 1581–1592, doi: 10.5194/hess-23-1581-2019.

Sharma, B.R. and Smakhtin, V.U. 2006. Potential of water harvesting as a strategic tool for drought mitigation. International Water Management Institute, https://www.watercache.com/main/wp-content/uploads/potential_of_water_harvesting_as_a_strategic_tool_.pdf .

Singh, J.P., Singh, D. and Litoria, P.K. 2009. Selection of suitable sites for water harvesting structures in Soankhad watershed, Punjab using remote sensing and geographical information system (RS&GIS) approach- a case study. *Journal of the Indian Society of Remote Sensing* 37: 21-35.

Thakur, J., Mahesh, N. and Mohanan, A. 2017. Water poverty in upper Bagmati River Basin in Nepal. *Water Science* 2017: 93-108, doi: 10.1016/j.wsj.2016.12.001.

USDA. 1986. Urban Hydrology for Small Watersheds. Technical Release 55.

Van der Vyver, C. and Jordaan, D. 2011. Water poverty mapping and its role in assisting water management. *Communications of the IBIMA* 2011, 941217, doi: 10.5171/2011.941217.

Worm, J. and Hattum, V. 2016. Rainwater harvesting for domestic use, Agromisa Foundation and CTA. Wageningen, Open File Rep., 85.