Potential Water Harvesting Site Identification for Micro-dam Using SCS-GIS Approach: Case of Genfel River Catchment, Eastern Zone of Tigray, Ethiopia

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Abstract
Potential water harvesting area assessment in the country particularly in the Study area is essential for increasing agricultural production. This study was, therefore, very important to identify potential water harvesting areas for Micro Dam construction. In SCS CN-GIS with Analytic Hierarchy Process (AHP) method in Genfel Watershed Eastern Zone of Tigray, Northern Ethiopia to select potential water harvesting area. Digital Elevation Model, 30m resolutions to generate physiographic characteristics of the Watershed were downloaded from united states geological survey, Required data set, a remotely sensed land sat 7 image of march 2016 with a spatial resolution of 30m to classified the land cover types, and Daily rainfall data were collected from six metrological stations (2000 – 2015) from National Metrological Agency to estimate annual runoff. The causative factors for water harvesting sites for micro-Dam in the watershed are taken into account as runoff volume, Soil, slope, drainage density, Land use land cover, and Geology. Questionnaires were distributed to experts to score each, water harvesting potential site contributing factor used as criterion separately in their order of significance. SCS-CN method was used to estimate runoff volume of the watershed Multi-criteria analysis hierarchy process method was used to compute the priority weights of each criterion and map. estimation of direct run-off depth of the watershed showed that an average runoff volume of 35902.6m3/year was generated basin slope (C1) and Geology (C2) were the most water harvesting potential contributing factors of the area based on the decision-makers' preferences. The Reclassified potential water harvesting zones depicted that Small portion of the watershed 3% were found very high potential water harvesting zone for micro dam site whereas the identified very high potential water harvesting area had a direct runoff volume of 50818.5m3/year. to 47469.4m3/year. The identified potential water harvesting areas were compared with micro dam areas to verified and check the validity and reliability of the results. The result shows that SCS CN-GIS with Analytic Hierarchy Process (AHP) method integration with Analytic Hierarchy Process can be used to map potential water harvesting areas to assist decision-makers on the selection of micro dam site.
Keywords: SCS CN; Analytical Hierarchy Process; GIS; runoff volume.
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INTRODUCTION
Background Information and Justification
Water is the most vital not only to fulfil the basic human need for life and health but it is socio economic development also, (Harish et al., 2014). According to FAO, 2003 report water can be categorized as renewable and non-renewable, renewable water resources are the total amount of a country's water resources both surface water and groundwater, which is generated through the hydrological cycle and non-renewable water resources are resources made with increasing pressure on natural freshwater in parts of the world. As studies indicated Ethiopia is the water tour of Africa due to its geographical location and favourable climatic conditions provide the country with high rainfall. Ethiopia has vast water resources which are estimated in 122 billion m3 with an annual groundwater recharge of 28 Billion m3, (Ministry of Water and Energy, 2010). According to AGWATER, 2012 report the ground potential of Ethiopia is shaped by complex geological formations and the diversity of the topography, climate and soil. Recent studies indicate that groundwater reserves may be far greater than the commonly used estimate of 2.5 billion cubic meters (BCM). As the Tigray region is drought-prone inadequate recharge, resulting from small, erratic and undependable rainfall may result in going down of groundwater potential. Although groundwater resources are limited the population is increasing and towns are expanding leading to over-abstraction of the groundwater, (Gebrehaweriea, 2009), so it becomes necessary for us to harvest it effectively we can maximize the storage and minimize the runoff. Generally, countries with low available water can solve their problems of water (domestic and other) by making effective water harvesting (Worm and Hattum, 2006). Water harvesting is defined as: "the process of concentrating rainwater through flowing and storing in order to use it in a useful manner" (Hamid et al., 2009, Owais, et al., 2002). According to the document, particularly in arid and semi-arid areas, the prevailing climatic conditions make it of crucial importance to use the limited amount

of rainfall as efficiently as possible otherwise it can be lost by surface run-off or evaporation. The study area Genfel river catchment have a characteristic of dray Wayne Dega with small rainfall However water is a basic need for several purposes such as drinking, agriculture the need for water is increasing from time to time to fulfil the demand for water groundwater extraction was implemented however the area receive small rain so it is timely issue to introduce new technology that assists in setting suitable strategies for water management and development one of this is water harvesting. Many studies used AHP and GIS and remote sensing methods to identify suitable water harvesting sites for example (Ramakrishnan, 2009), SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali Watershed, Mahi River Basin, India, found that the high runoff potential of the watershed, developmental structures such as farm pond, check dam, subsurface dyke, and percolation tanks are suggested in the watershed for water resource development. (Al-shabeeb, 2016) studied The Use of AHP within GIS in Selecting Potential Sites for Water Harvesting Sites in the Azraq Basin—Jordan and fund five class of suitability for water harvesting namely very low suitability for water harvesting, low suitability for water harvesting, moderately suitable for water harvesting, high suitability for water harvesting and very high suitability for water harvesting. (Harish et al., 2014) studied site suitability analysis of water harvesting structures using remote sensing and GIS a case study of pisangan watershed. (Weerassinghe et al., 2011) studied water harvesting and storage location assessment using GIS and RS. However, the current study used the SCS-GIS-based approach to identify potential water harvesting sites. So far studies on the identification of potential water harvesting area using GIS and RS however SCS-GIS-based water harvesting area identification for micro dam purpose was not conducted in the study area. Therefore the current studies try to identify potential water harvesting areas for micro dam sites.

METHODOLOGY AND MATERIALS

Description of the study area

The study was conducted in Genfel watershed in Eastern Zone of Tigray, its environs (Northern Ethiopia) which is an intermountain plain area located at 39°18′0″ and 39°54′0″ longitude Easting and 13°30′0″ and 14°15′0″ latitude Northing (Figure. 1). It is about 50 kilo meters (km) far from Mekelle city. The topography of the study site is undulated with an altitude ranging from 1812 to 3072 meters above sea level (a. s. l.).

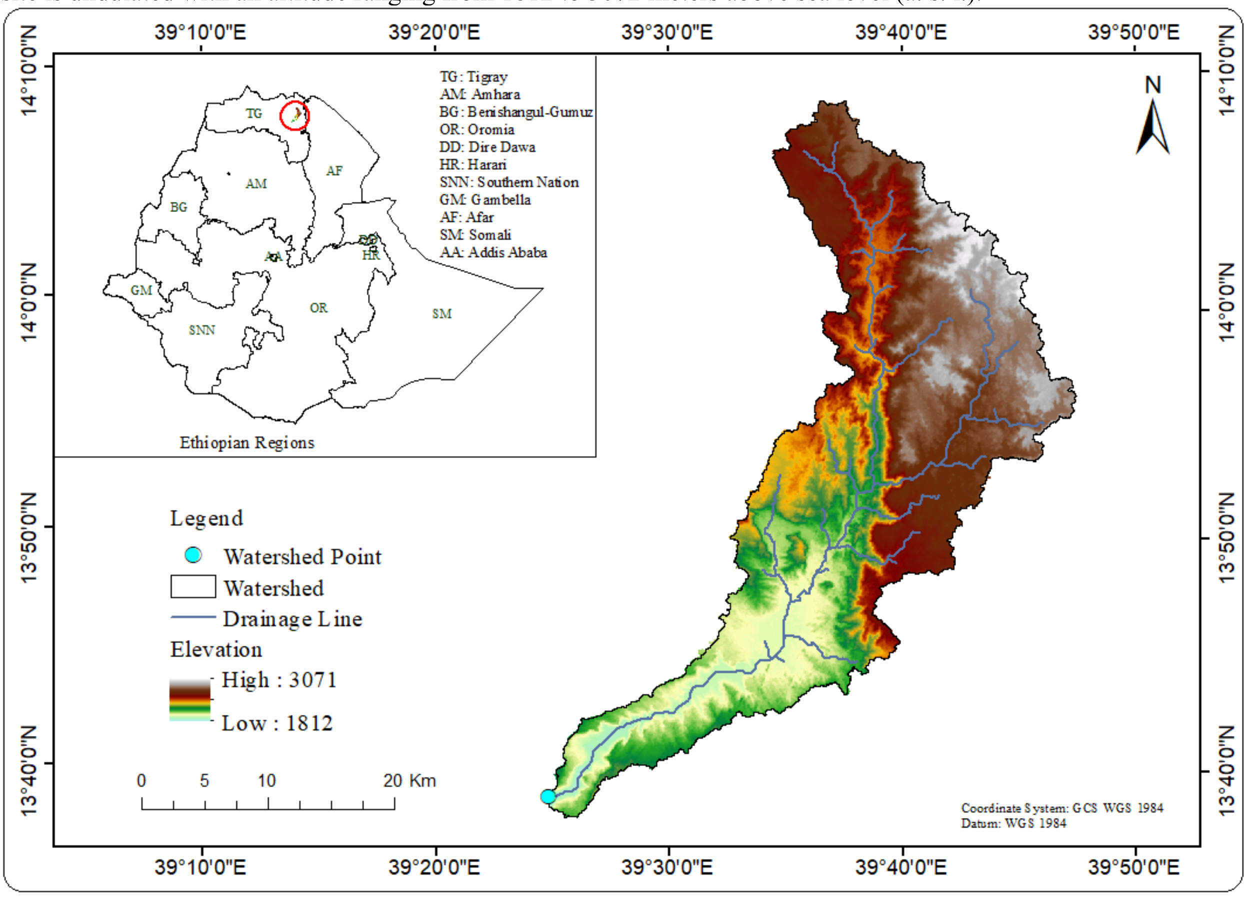

Figure 1: Location of Genfelcatchment, (Aschalew et al. 2018).

The soil types in the area are important as they control the amount of water that can infiltrate into the soil, and hence the amount of water which becomes runoff, (Teka, 2014).The major soil in Genfel river catchment according to the international soil classification method, (FAO, 1998) are sandy clay loam (26.1%),sandy clay loam (6.5%), clay loam (51.5%) and sandy clay (15.8%), (Figure 8).The major geology types in Genfelwatershedaccording (Tesfamichael, 2009) are: Intrusive, Metamorphic rock, Resent sediment, Sedimentary rock. The vast area about 65% of the area is covered by the Sedimentary rock group and metamorphic rock 34%, were as Resent sediment and Intrusive covered very small area 0.9% and 0.2% respectively. The drainage network of Genfel river catchment extracted From SRTM DEM 30m. According to (*Aschalewet al*., 2017) slope classification the vast area 48.91% (274.52 Km^2) of the study area have the topography characteristics feature of flat terrain which lies within slope ranges from 0-3% and 0.16% (0.96 Km^2) are mountainous terrain which lies within the slope range of >50 % , (Table 1).

Table 1: Slope classification

No	Slope class	Area (km2)	Percentage (%)
1	0-3	180.2	24.7
2	3-8	213.4	29.3
3	8-15	153.7	21.1
4	15-30	97.2	13.3
5	30-50	59.7	8.2
6	>50	23.9	3.3

Based on the Ethiopian agro- ecological classification, the agro-ecology of the study sites are classified as 36 % Midland ranging from 1500-2300, 67 % highland 2300- 3200. m. a. s. l. and locally called “Weynadega” and Dega respectively (*Aschalewet al*., 2017). The climatic condition of the study area is referred from the Wukuro Metrological station found within the Genfelcatchment of the period (2000-2016) with some missing value. Accordingly, monthly average temperature of the study area varies between **29^{0}c in** Mar **to 19.5^{0}c** July**.** Rainfall distribution of the study area is characterized one rain fall type, short rainy season which extends locally from July up to August (kerempt) receive 75.63 % (465.54mm).

METHODOLOGY

Data used and source

- The Soil and Terrain database for northeast Africa developed by the Food and Agricultural Organization (FAO) of the United Nations (FAO, 1998), at 1:1 000,000 was collected from ministry of agriculture (MoA).
- Land sat imageries of 2015 cloud free were downloaded from United States geological survey (USGS) Sentinel. Via FTP (http://glovis.usgs.gov) to identify the dominant land use land cover.
- Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), 30m resolutions were downloaded from United States geological survey (USGS) via FTP (http://glovis.usgs.gov) to delineate and characterize the watershed.
- The Daily rain fall of three representative’s metrological stations (wukro, Hawzen and Senkata) for the year 2000 - 2016 were collected from National Metrological Agency (NMA).
- Geological map of the areawas collected from ministry of agriculture (MoA).

Methodology

In this study integration of SCS CN model in GIS environment with Multi -criteria analysis method Analytical Hierarchy Process-(AHP), was used based on a group of criteria and constraints and HEC-Geo HMS for CN generation. Based on their importance and significance five different criteria and constrains were chosen which include C1= slope, C2= Geology, C3= Soil, C4= Drainage Density and C5= Land use land coverand weights was calculated using AHP and weighted overlay was done to generate the water harvesting site(i.e. micro dam) and the runoff potential of identified potential water harvesting sites was estimated using SCS-CN method then finally the suitability of selected potential sites was validated using ground truth. Figure 2.

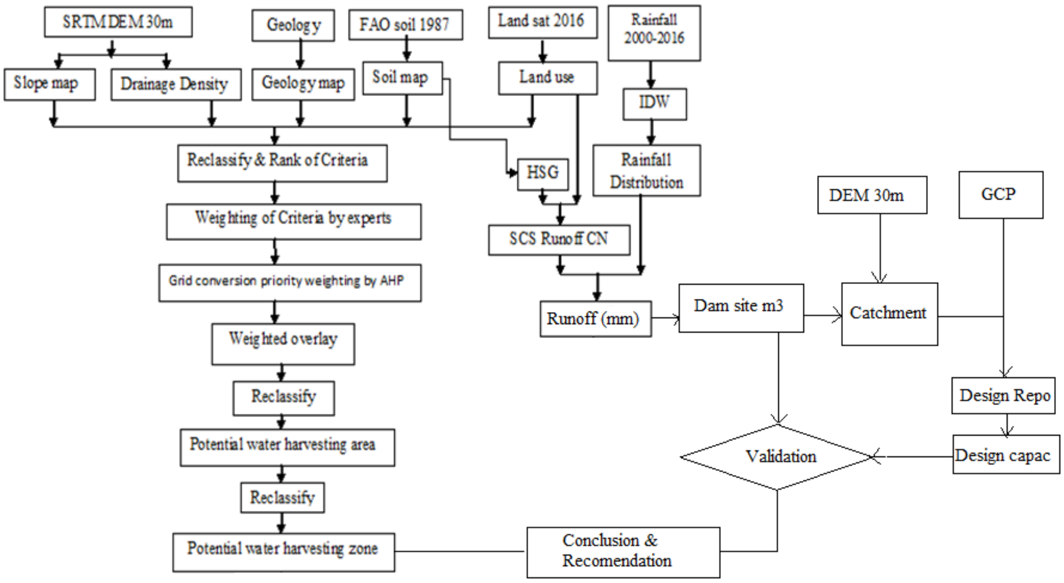

Figure 2: Flow chart for water harvesting site (i.e. micro dam)

Generation of criteria maps using GIS

Drainage density

The Drainage density map was derived from the drainage map. i.e., Drainage map is overlaid on watershed map to find out the ratio of total length of watershed to total area of watershed and it is categorized. The drainage density of the watershed is calculated as:

$$DD = L/A \qquad \text{eq 1}$$

Where, DD = drainage density of watershed, L = Total length of drainage channel in watershed (km), A = Total area of watershed (km2).

Slope map

Slope is one the major factor that affect the water harvesting the slope of the current study area was produced using the Spatial Analyst or 3D-Analysis tools of Arc-GIS from the Advanced Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), data having 30m resolutions.

Soils map

A Soil map of the Genfel watershed was extracted from the Soil and Terrain database northeast Africa developed by the Food and Agricultural Organization (FAO) of the United Nations (FAO, 1998). Missing data were filled from the Soil and Terrain Database for Eastern Africa obtained from the Data Exchange Platform for the Horn of Africa (DEPHA). Soil type classes of FAO were translated in to soil texture classes, using the percentage of the topsoil textures (coarse, medium and fine) from the universal soil texture triangle, (Tesfamichael 2009).

Geology maps

Geology map of the watershed was prepared by digitizing existing soil maps of the Tekeze River basin integrated master plan produced in 1997 (scale 1:250000) and landforms and soil maps produced by Hunting technical service in 1976 (scale 1:50,000). The soil textural classes identified in the watershed was used to prepare Hydrologic Soil Group (HSG) map considering the soil infiltration and drainage characteristics.

Land use Land cover

The land use land cover classes of the study area were prepared from Land sat 7 (ETM+) data. A supervised classification method based on maximum likelihood classifier was adopted using ERDAS Imagine 9.1 software. After classification an accuracy assessment was done and an overall accuracy of 87.2% and Overall Kappa Statistics of 0.821 is obtained from the accuracy assessment report table. Land use classes in the area include: cropland, forest, shrubs land, Bush land, grazing land, bare lands, woodland and Built-up (Table 2). Land use types were grouped into different categories, weight is assigned to each class as shown in Appendix 1. The LULC has an influence on infiltration rate. Forest and lush vegetation favour infiltration whereas urban and pasture areas support overland flow of water. Urban wetlands were assigned a score of 8 and forest a score of 2.

Table 2: land use land cover class

Number	LULC	Area	percent
1	Agriculture	590.20	81.06
2	Bare land	81.18	11.15
3	Forest	0.13	0.02
4	Settlements	30.20	4.15
5	Shrubs	26.36	3.62
6	water bodies	0.07	0.01

Determination of weights using AHP

AHP is used for a group of criteria, sub-criteria to set up the hierarchical structure by selecting the weighted individual criterion in whole decision making process. The weights reflect the relative importance of each criterion and hence to be selected carefully. AHP was applied to make pair-wise comparisons between the criteria and thus reduced the complexity (Saaty, 1980). The pair-wise comparison matrix involves pair-wise comparisons to create a ratio matrix. As input, it takes the pair-wise comparisons of the parameters and produces their relative weights as output. Pair-wise generated by using a scale of 1 – 9 in which 1 having equal importance and 9 having extreme importance of in between two criteria (Malczewski, 1999) Once the pair-wise matrix is made, Saaty's method of Eigen vectors/relative weights is calculated, AHP identifies and takes into account the inconsistencies of the decision makers which is one of the strength (Garcia et al., 2014).

Table 3: Pair wise comparison matrix Source: (Muema, 2016).

Intensity of importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extremely importance

The square pair-wise comparison matrix is presented in Table 4 (a). To generate the criterion values for each evaluation unit, each factor was weighted according to the estimated significance for surface water potential harvesting. The normalized matrix is presented in Table 4 (b). Meanwhile, the individual judgment, which never agreed perfectly with the degree of consistency achieved in the ratings, was measured by using Consistency Ratio (CR), indicating the probability that the matrix ratings were randomly generated. The Random Indices for matrices are listed in Table 5. The rule of thumb is that a CR less than or equal to 0.1 indicates an acceptable reciprocal matrix, while a ratio over 0.1 indicates that the matrix should be revised.

Table 4: Pairwise comparison matrix (a), Normalize matrix (b).

(a)

Criteria	c1	c2	c3	c4	c5
c1	1	2	3	4	5
c2	0.5	1	2	3	4
c3	0.33	0.5	1	2	3
c4	0.2	0.25	0.33	1	2
c5	0.16	0.2	0.25	0.5	1

(b)

Criteria	c1	c2	c3	c4	c5
c1	0.45	0.51	0.46	0.38	0.33
c2	0.23	0.25	0.30	0.29	0.27
c3	0.15	0.13	0.15	0.19	0.20
c4	0.09	0.06	0.05	0.10	0.13
c5	0.08	0.05	0.04	0.05	0.07
Total	1	1	1	1	1

Table 5: consistency ratio

Criteria	c1	c2	c3	c4	c5	Total	Weight	CS
c1	0.45	0.51	0.46	0.38	0.33	2.13	**43%**	5.34
c2	0.23	0.25	0.30	0.29	0.27	1.34	**27%**	4.75
c3	0.15	0.13	0.15	0.19	0.20	0.82	**16%**	4.60
c4	0.09	0.06	0.05	0.10	0.13	0.43	**9%**	4.59
c5	0.08	0.05	0.04	0.05	0.07	0.28	**6%**	5.37
	1	1	1	1	1			
							CI	0.09
							RI	1.12
							CR	0.08

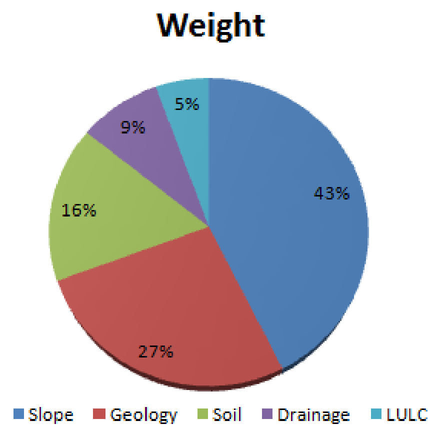

Figure 3: criteria weights

Weighing of water harvesting suitability factors to find potential water harvesting site

To find suitable site for water harvestingiw3qndividual Suitability was performed using AHP method. AHP model perform criteria weighting, Normalization, consistency ratio and water harvesting suitability factors which were considered in this study, such as slope factor, soil factor, land cover /use factor, Geology factor and Volume of factor. After criterion weights are obtained in AHP, the weights were used for spatial water harvesting suitability mapping of the study area. Then the water harvesting suitability map where reclassified into five classes as; Very low, Low, Moderate, High and Very high on the output map depicting the water harvesting potential zone of the study.

Reclassifying and Ranking

Reclassifying criteria maps of Soil, Slope, Land use /land cover (LULC), drainage density, Geology and volume of the water. The derived datasets were combined to create a suitability map that was used to identify potential areas for water harvesting site (i.e micro dam). However it was not possible to combine them in the present form. So using ranking method was weights are given accordingly higher weights are given for more suitable areas and lower weights are given for areas less suitable areas. That common measurement scale is what determines how suitable a particular location – each cell – is for water harvesting. Higher values indicate more suitability (esri, 2016).

Drainage Density

Drainage density is very essential factor that affect potential water harvesting site identification and it is preferably that potential water harvesting site be located on relatively adequate drainage density. The drainage density output was reclassified, into four class figure 4 (a). Value of 8 assigned to the adequate range of drainage density micro watershed (those micro-watershed with a drainage density of >5) and value of 2 to the poor range of drainage density (those micro watersheds having a drainage density of <1) Appendix 1.

Reclassifying Slope

It is preferable that potential water harvesting site be located on relatively flat ground. The slope output was reclassified, slicing the values into equal intervals. Value of 8 assigned to the highly suitable range of slopes (those with the lowest present of slope) and value of 2 to the least suitable range of slopes (those with the steepest present of slope), Table 4 (b) and ranked the values in between linearly.

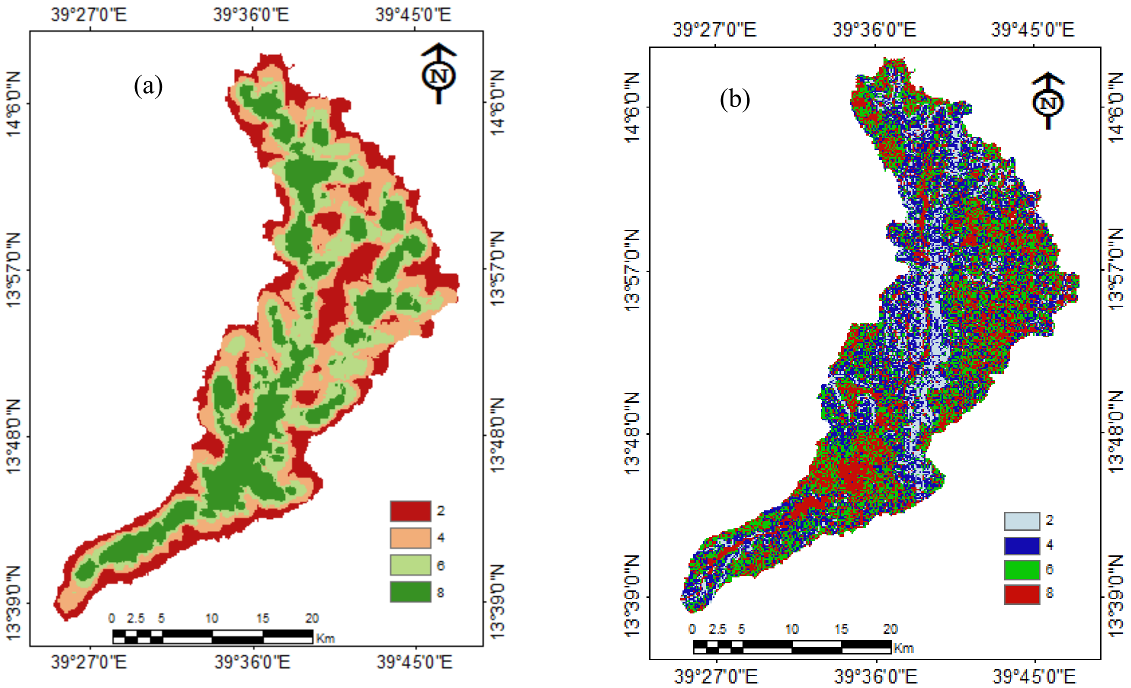

Figure 4: Weighted Drainage Density (a), weighted slope (b).

Reclassified soil
Soil map was classified on the basis of infiltration capacity. On the basis of infiltration capacity, the soil types found in the basin include; highly infiltrated, moderately infiltrated, and less infiltrated. The structure and infiltration capacity of soils will also have an important impact on the efficiency of the soil to act as a sponge and soak up water. Different types of soils have differing capacities. The chance of water harvesting potential is increases with decrease in soil infiltration capacity, which causes increase in surface runoff. Higher weight (8) assigned to the highly suitable range of soils (those soils have low infiltration capacity) and lower weight (2) assigned to the least suitable range of soils (those soils have high infiltration capacity), Appendix 1. The prepared weight soil map is shown in Figure 5 (a).

Reclassified Land use land cover
The vegetation cover of soils, whether that is permanent grassland or the cover of other crops, has an important impact on the ability of the soil to act as a water store. Runoff of rainwater is much more likely on bare fields than those with a good crop cover. The presence of thick vegetative cover slows the journey of water from sky to soil and reduces the amount of runoff. Impermeable surfaces such as concrete, absorbs almost no water at all. The land use land cover classes of the study area include: Built Up, Mixed Vegetation, Forest, Plantations, and Water Body. Land use types were grouped into different categories, weight is assigned to each class based on infiltration. Higher weight (8) assigned to land use land cover class that support overland flow of water whereas land use land cover class that favour infiltration assigned lower weight (2), Appendix 1. The prepared weighted land use map is shown in Figure 5 (b).

Reclassified Geology
Geology map of the watershed is one of the important factors that influence the potential of surface water harvesting. Geology of the watershed is classified in to four class based on their importance in potential water harvesting or potential site for micro dam construction Figure 5 (c). Higher weight (8) is given for geology class that favour infiltration and lower (2) weight was given for geology class that support infiltration, Appendix 1.

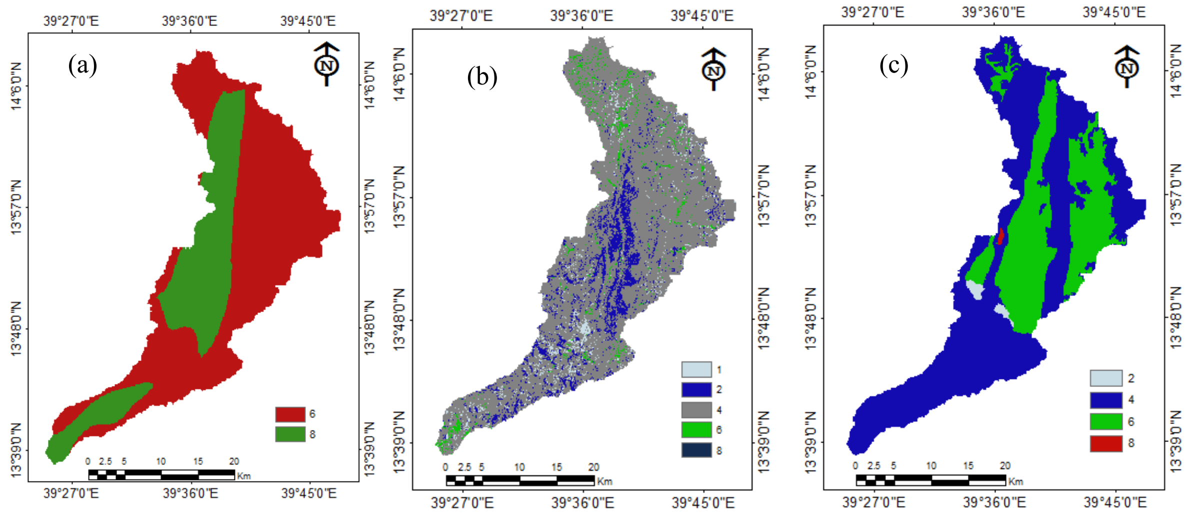

Figure 5: weighted land use land cover (a), soil (b), and Geology (c)

Surface water potential area

The reclassified datasets are then combined to find the most suitable location for surface water harvesting (micro Dam). The values of the reclassification datasets representing slope, Drainage density, soil infiltration, land use land cover, Geology and runoff volume have all been reclassified and weight has been given based on their importance to surface water harvesting to have a common measurement scale (more suitable cells have higher values). Then all inputs are weighted, assigning each a percentage of influence resulted from AHP. The higher the percentage, the more influence a particular input will have in the suitability model.

Estimation of Direct Runoff

The current study employed integration of HEC Geo-HMS with SCS CN in Arc GIS environment method to estimate the direct runoff volume of the study area. HEC Geo-HMS to generate SCS curve number grid and SCS CN to estimate direct runoff volume map.

Generating SCS curve number grid map

SCS curve number grid is used by many hydrologic models to extract the curve number for watersheds. The current study used soil map and land use map to create a curve number grid using HEC-Geo-HMS in Arc-GIS 10 environment. The land use land cover map was add to Arc GIS and the correct land use class number was defined to each land use land cover class of the watershed looking to the USGS land cover institute (LCI) http://landcover.usgs.gov/classes.php, webpage site, Table 6. Then the land use grid converted in to shape file and saved in polygon feature class which will be merged with soil data later.

Table 6: land use land cover class number (USGS)

No	Land use land cover	Class Number
1	Agriculture	84
2	Bare land	31
3	Water Body	11
4	Settlement	21
5	Shrub land	51
6	Forest	43

Similarly the soil map of the study are was added in Arc GIS and the corresponding soil code of each soil type of the area, the hydrologic classification of the soil characteristics was assigned to each polygon unit as per the HSG (USDA, 1972) the soil texture of the study area was classified into A, B and C hydrological soil groups that refers to the infiltration potential of the soil after prolonged wetting, Appendix 2. Next create four fields named PctA, PctB, PctC, and PctD all of type short integer in soil feature class. For each feature (polygon) in soil_PctA will define what percentage of area within the polygon has soil group A, PctB will define what percentage of area within the polygon will have soil group B and so on. This is critical when we have polygons with more than one soil group (for eg. A-B-A/D would mean that group A, group B and group A/D soils are found in one polygon; A/D would mean the soil behaves as A when drained and as D when not drained, and so on). If we have classifications such as these, we need to define how much area of a polygon is A/B/C/D. For Grenfell watershed area we have only one soil group assigned to each polygon so a polygon with soil group “A” will have PctA = 100, PctB = 0, PctC = 0, and PctD = 0. Similarly for a polygon with soil group D, only PctD = 100, and other three Pcts are 0. Now populate PctA, PctB, PctC and PctD based on Soil Code for each polygon. Then both soil data and land use data merged using union Overlay analysis tool to create polygons that have both soil and land use information. After the processing of spatial data for creating the curve number grid a look-up table that will have curve numbers for different combinations of land uses and soil groups was prepared from Land use categories and associated CN, source (USDA-SCS, 1986), Table 7.

Table 7: curve number values of land use land cover (USDA-SCS, 1986)

Number	LULC	Class Number	A	B	C	D
1	water bodies	11	100	100	100	100
2	Forest	43	30	58	71	78
3	Settlements	21	57	72	81	86
4	Agriculture	84	67	77	83	87
5	Shrubs	51	35	56	70	77
6	Bare land	31	77	86	91	94

Generating Curve Number (CN) map

A curve number map was generated by intersecting DEM, merged hydrological soil group map and the land use map, and look up table. Before intersecting these input layers under utility tool in HEC-Geo HMS extension tool under GIS environment, first the land use data was prepared for CN grid by converting the raster LULC map for the years of 2000 and 2014 in to polygon under conversion tool in Arc-GIS 10. The soil data was also prepared for CN grid by creating hydrological soil group code and their percentage in the attribute table of soil layer. Then, both layers were merged by using union tool in the analysis tool of Arc-GIS 10. In this map new polygon has been obtained and with each polygon the soil hydrologic group and land use was associated. Using the HEC Geo-HMS extension tool the DEM, merged (land use map and soil map), and look up table was combined together to generate the curve number (CN) map of 2016.

The surface runoff was predicted using SCS-CN equation below (SCS, 1972). The relationship between CN, storage parameter (S), and daily runoff depth and discharge is:

Q = (P-Ia) 2 /P + (1 + *Ia)**S, when P>0.2S, and Q=0 when P<0.2S

Ia *S*……………………………………………………….………equation (2)

Where Q is predicted runoff (mm), P is the measured event rainfall (mm), *Ia* is the initial abstraction (mm), initial abstraction ratio and S is the maximum water retention parameter (mm).

The runoff was estimated at two abstraction ratio levels: = 0.05 and = 0.20 that are most commonly used in different literatures. However, the use of the initial abstraction ratio at of 0.20 is a drawback of the SCS-CN method and the existing SCS-CN with of 0.05 performed well than the old version of the initial abstraction ratio (= 0.20) (Teka, 2014: Ponce and Hawkins, 1996). As a result, to have good result in estimating runoff using the above SCS-CN equation, the use of λ value of about 0.05 would be more appropriated and the reason for the use of low initial abstraction ratio can be the rainfall intensity, shallower soil depths and lesser vegetation covers (Teka, 2014). Accordingly, the former equation will be rearranged as:

Q= (P-0.05*S) 2/ (P+0.95*S) ……………………………………………..equation (3)

When p>0.05*S and Q=0 when P< 0.05*S

Where Q is predicted runoff (mm), P is the measured event rainfall (mm), *Ia* is the initial abstraction (mm), initial abstraction ratio and S is the maximum water retention parameter (mm).

The maximum water retention parameter (S) was computed using:

S= (25400/CN) - 254 ………………………………………………...…equation (4)

Therefore, having the CN map using the equation 5 and 6 under the raster calculator tool for storage and runoff depth map was generated finally the runoff volume of the watershed was estimated by multiplying the runoff depth map with the watershed area (72806 ha) under raster calculator. For run off estimation the average annual rainfall for the period 2000 to 2016 of three representative stations was used table 8.

Table 8: Average annual rainfall (2000-2016)

year	Hawzen	Senkata	Wukuro
2000	762.5	876.4	984
2001	886.4	888.2	1040.2
2002	439.3	405.2	588
2003	390.5	466.9	505.7
2004	367.7	604.6	475.3
2005	450	509.9	495.7
2006	747.2	632.8	674.3
2007	523.1	566	757.8
2008	339.3	550.1	523.4
2009	427.8	285	366.2
2010	567.7	651.6	691.1
2011	500.3	615.1	683.9
2012	644.2	549.2	646.6
2013	392.3	558.1	390
2014	187.4	421	336.5
2015	408.7	520.4	395.6
2016	531.8	212.9	755.7

RESULTS AND DISCUSSION

Result of surface water harvesting area Assess and evaluate

The multi-layer integration through five layers: - slope, geology, Drainage density and Land use land cover gave the potential water harvesting area for micro dam site in Genfel watershed factor layers were incorporated in Arc GIS spatial data analysis using weighted overly function. Finally a suitability map was developed that show the potential water harvesting area for micro dam sites in the study area as shown in Figure 6 (b). The figure depicted that high water harvesting potential area where lies more on the lower catchment area.

Then after, the potential water harvesting area for micro dam site was classified in to five zones for quick identification and comparison of potential zone level as very low, low, moderate, high and very high potential water harvesting area, figure 6 (a), Similarly (Al-shabeeb, 2016), classified suitability map of water harvesting in to five class namely very low suitability for water harvesting, low suitability for water harvesting, moderately suitable for water harvesting, high suitability for water harvesting and very high suitability for water harvesting The estimated total area shares of the potential zone for micro dam site are shown in table 9. The result evaluate that 21.7 Km^2 was found to be very highly potential zone for water harvesting this accounted for 3%, 108.7 Km^2 was found moderately potential zone which accounted 15.6% of the total area and the vast area 381.6Km^2 accounting for 54.7% was found to be very low potential zone for water harvesting this finding was agreed with the finding of (Al-shabeeb, 2016) which reported vast area of the catchment was found low suitable water harvesting area.

Table 9: water harvesting potential zones area

OBJECTID	Potential_	Area (km^2)	Percent (%)
1	Very Low potential zone	381.6	54.7
2	Low potential zone	95.3	13.7
3	Moderate potential zone	108.7	15.6
4	High potential zone	90	13
5	Very High potential zone	21.7	3

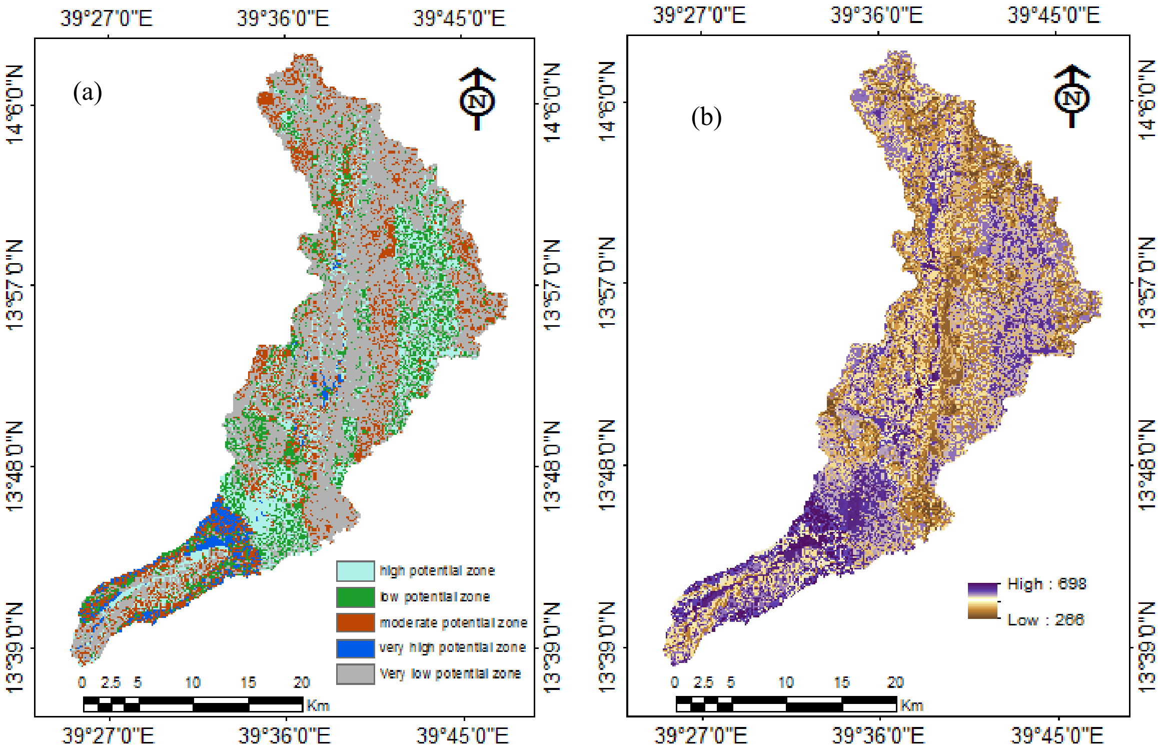

Table 6: potential Water harvesting area (a), Potential water harvesting zone (b)

Result of runoff potential of identified potential water harvesting
CN and Storage

The result of CN generation and Storage map is shown in figure 7 (a) and Figure 7 (b) respectively. The result illustrate that shrub land and forest land of the watershed has low curve number (<50) while bare land had high curve number value (>90) this represents that very pervious surface. The result implies that bare land and poorly managed Agriculture land had little or no infiltration; however Shrub land and Forest land had very pervious surface areas. This finding was agree with (Efrem, 2017) which reported bare land and untreated cultivation had low water retention capacity than shrub/bush land and plantation forest.

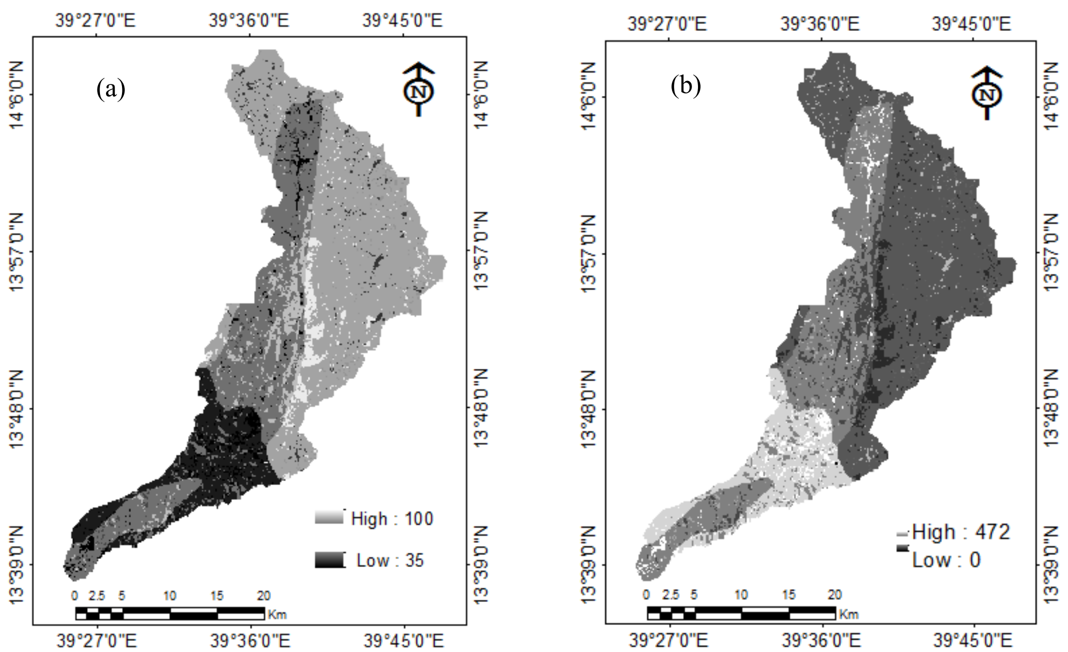

Figure 7: (a) CN, (b) Storage

The result of direct runoff estimation depth for 2016 show that the direct runoff ranges from 603mm to

294mm, Figure 9 (a). the equivalent runoff volume of the catchment in m^3/year the direct runoff volume is Multiplied by the area of the catchment (72805.9ha) the representative runoff volume ranges from 50818.5m^3/year to 1936.6m^3/year and average runoff volume generated for 2016 is 35902.6m^3/yr. The result of an overlay union between water harvesting potential zone (WHPZ) and estimated runoff volume of the watershed is present in figure 9 (b). The map illustrated that very high water harvesting area have a runoff volume within the range of 50818.5m^3/year to 47469.4m^3/year, and 47324m^3/year to 43829m^3/year, 43683.5m^3/year to 40188.8m^3/year, 39897.6m^3/year to 36696.2m^3/year and 36111.7m^3/year to 19366.4m^3/year for high, moderate low and very low potential zone respectively. This show that the very high potential water harvesting area have high direct sub surface runoff which is very essential for harvesting more water available for domestic, livestock and agricultural use by buffering and bridging drought spells and dry seasons through storage.

Validation of the suitability of selected potential sites

The current study used five Micro dams Laelay wukro, Korir, Ruwafeleg, Tegahne and Flaga from the study area to validate the suitability of the selected potential water harvesting area Table 12. The dam capacity was correlated with designed dam catchment capacity. First the each dam site catchment is generated from DEM30m then the direct runoff of each dam catchment is extracted from the watershed estimated direct runoff by masking each dam catchment then the result is multiplied by the area of each dam catchment in hectare to find the designed runoff volume of each dam site catchment. Finally, the designed runoff volume of each catchment is correlated with the capacity of the dam volume. The correlation between dam capacity and the designed dam catchment capacity is presented in figure 22. It resulted in a correlation coefficient of 0.64 which shows that there is a strong positive linear relationship between the dam capacity and designed runoff of the dam catchment thus the identified potential water harvesting map is valid.

Table 10: Micro-Dam

No	Site Name	Location			Catchment area (km^2)	Designed volume mill m^3	Estimated volume in mill m^3
		X	Y	Elevation			
1	*Laelay wukro*	566279E	1526418N	2045m	9.16	0.9	0.67
2	*Korir*	566212E	1519876N	2052m	10	1.6	0.98
3	*Ruwafeleg*	578704E	1542132N	2756m	6.8	2.7	0.9
4	*Tegahne*	578801E	1535611	2741m	8.8	1.08	0.23
5	*Flaga*	580773E	1546642N,	2872m	9	0.9	0.49

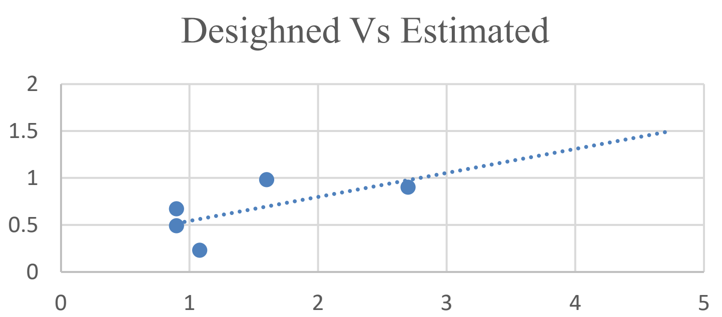

Figure 8: Correlation of designed and dam capacity volume (in mill m^3)

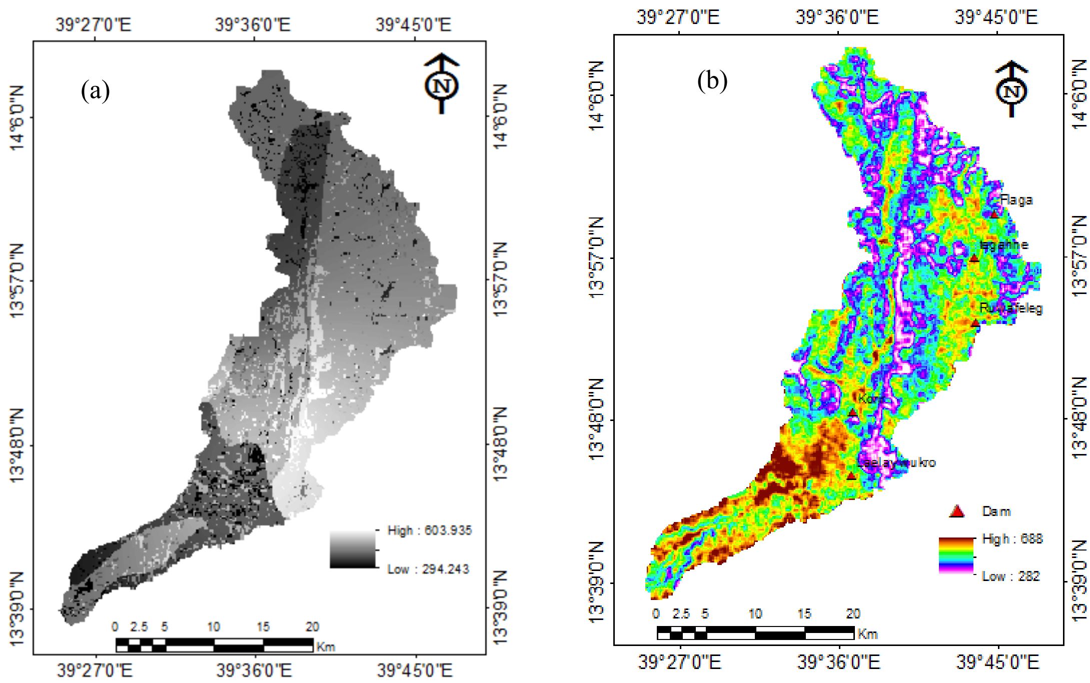

Figure 2: Runoff volume in mm (a), Overlay between Potential map and Dam point (b)

Conclusions and recommendations

Conclusions

- SCS-GIS approach to produce water harvesting potential zone map for micro-dam site identification performs satisfactorily in Genfel watershed.
- The results of this study illustrates SCS-GIS approach that used as a tool for exploration of water harvesting sites in a scientific way and hence building the decision making easier and accurate.
- Information derived from this study can be used to inform government, investors and other stakeholders on best site selection for successful construction of micro dams for different purpose.
- Estimation of runoff volume using SCS-CN methods is successful and found simple and easy to use. However, this model requires extensive input data such as land use/land cover, soil type, curve number, antecedent soil moisture, base flow type, basin area, and rainfall data etc., which were not easily available from one source.
- From the study, it was noted that to define the weights for each criteria, expert opinion in the subject of interest is paramount. In this case, experts input from regional bureau of agriculture and water, Slope (C1) and Geology (C2) were the most water harvesting potential contributing factors of the area based on the decision makers' preferences.
- A small portion (3%) of the watershed where found the best site for water harvesting for micro dam sites.
- The estimated direct runoff volume generated from the watershed for 2016 showed an average runoff volume of 35,902.6 m^3/year.
- The very high potential water harvesting zone has a direct runoff volume of 50,818.5 m^3/year to 47,469.4m^3/year.

Recommendations

The following is a set of recommendations based on the findings of this research project:-

- Genfel watershed needs to stop over reliance on ground water extraction if it is to achieve sustainability and invest in surface water harvesting because of its potential and viability.
- The regional bureau of agriculture and water with the concerned bodies and stakeholders should strengthen integrated soil and water conservation activity every year and afforest upper catchment area so as to reduce the transport of silt to the lower catchment.
- The Regional Government through Line Ministries (Ministry of Agriculture and Ministry of Irrigation and Water resource) and Federal Governments should adopt SCS-GIS approach in the identification of potential of water harvesting and exploitation of water resources.
- Validation of the result was good however, further studies should be carried out in sediment transport of the

watershed under different land use land cover change.

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Appendix

Appendix 1: Weighting and Ranking of Factors and sub-factors

Decision Factors	Relative Weight of decision factor	Decision sub-factors	Ranking decision
Slope (present)	0.43	0-3	8
		3-8	6
		8-30	4
		>30	2
Geology	0.16	Intrusive	8
		Metamorphic rock	6
		Sedimentary rock	4
		Resent sediment	2
Soil Infiltration	0.27	Low Infiltration	6
		Moderate Infiltration	4
		High Infiltration	2
Drainage density (km/km2)	0.09	<1	2
		1-3	4
		3-5	6
		>5	8
LULC	0.06	Agriculture	1
		Bare land	8
		Forest	4
		Settlements	6
		Bush land	2
		Water body	9

Appendix 2: Hydrological Soil Group (USDA-SCS1964)

HSG	Runoff potential	Infiltration	Soil Texture
A	Low	High	Sand, Sandy loam, loamy sand
B	moderate	Moderate	Silt loam, loam
C	Medium	Slow	Sandy clay loam
D	High	Very slow	Clay loam, Silty clay loam, Sandy clay, Silty clay, or Clay