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GIS Based Assessment of Suitability area of Rainwater Harvesting in Daro Labu District, Oromia, Ethiopia

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Abstract
Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future uses. The aim of the research was to assess and mapping suitability area of water harvesting site in Daro Labu District. Various methodologies to identify suitable sites and techniques for rainwater harvesting were use. GIS is the recent technology of spatiotemporal data used to assess the factor of influences for rainfall and runoff depth estimation. The influence factors for the assessment was climate data, soil texture and depth, land use and land cover type, slope difference were use. The SCS–CN for rainfall used to runoff depth estimation and volume from the land surface depends on the level of antecedent moisture condition (AMC.) The length of wet and dry season of the study area were known with antecedent moisture condition of II, I III by having the values of 82, 67and 91 respectively. The annual of 20 years average rainfall was 925.2 mm with maximum and minimum of 1134 mm and 737.3 mm respectively with average annual runoff depth of estimate was 185.3 mm. From the estimated annual runoff, the volume of water harvested was about 2.89 x 10^8 m^3. From the total area of (156064.72 ha), the suitability map of the study area shows very highly, highly, low and not potential accounts by coverage areas about 8.2%, 16.6%, 63.5%, and) 7.5% respectively. The runoff in the study area was affected by geomorphological factors, land use change, topography, soil texture and depth, affects the runoff rate and volume significantly.
Key words: ArcGIS, Rainwater Harvesting, SCS-Curve Number, Suitability area Daro Labu
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1. INTRODUCTION

The ever-increasing world population has threatened by the ever-continuing water shortage problem. Climate change and a growing demand for water for agricultural and urban development are increasing the pressure on water resources. Between 75 and 250 million people in Africa are projected to be exposed to increased water stress by 2025, yields from rain fed agriculture could be reduced by up to 50% in some regions, and agricultural production, including access to food, may be severely compromised (Field et al. 2014). The United Nations Environment Program estimates that more than two billion people will live under conditions of high water stress by 2050, which would be a limiting factor for development in many countries around the world (Sekar and Randhir 2007).

According to World Water Council (WWC 2010), the consumption of renewable water resources has grown six-fold in the 20 century responding to three times increase of the world population. They emphasized that the demand for water within the next fifty years will increase due to prediction of 40 to 50% population growth coupled with industrialization and urbanization, resulting in serious consequences on the environment. Fresh water resources are depleting due to over-exploitation, water quality degradation, and climate change (Sen et al. 2011). According to FAOWATER (2012), the situation will become worse due to the heavy pressure on neighboring water resources placed by the rapid growth of urban areas. These areas become the end for the urban water cycle because of the high consumption rate of blue water, being the water source a river or ground water aquifer.

Amos et al. (2016) in urban areas, RWH consists of the concentration, collection, storage and treatment of rainwater from rooftops, terraces, enclosures, and other impervious building surfaces for on-site use. Ghaffarian Hoseini et al. (2016) suggest these uses can globally account for 80-90 percent of overall household water consumption, and highlight the significant of water conservation benefits associated with RWH implementation. Consequently, installation of RWH systems increases water self-sufficiency of communities and can help delay the need to construct new centralized water infrastructures (Steffen et *al*., 2012).Water scarcity and need for water supply augmentation are not the only reasons that have motivated communities to increase RWH system installation.

Climate variability has a big effect on crop production in Ethiopia (Alemayehu and Bewket. 2016). However, Ethiopia's geographic location has provided it with relatively high rainfall rates, which make rainwater as an additional water resources supply in Ethiopia (Feki et al. 2014). Due to the high pollution rates in most surface water in Ethiopia, it does not considered a safe or an economic water supply resource. The high rainfall amounts makes rainwater as a potential resource in Ethiopia, which increases the need for private and onsite water supply management initiatives. Ethiopia also facing a high adoption rate of water harvesting technologies around 42% (Wakeyo and Gardebroek 2015). Moreover, there has limited number of study that evaluates the relation between rainwater harvesting and crops yield (Bouna, Hegde, and Lasage, 2016). Hence, good rainwater harvesting and management technologies had needed to improve rainwater use efficiency and sustain rain feed agriculture in Sub-Saharan Africa (Biazin et al. 2012).

Recent studies have shown that infiltration techniques coupled with RWH can also help in modifying the urban micro-climate by increasing moisture content and evapotranspiration (Hamel et al. 2012) so mitigating the heat island phenomenon (Furumai 2008; and Coutts et al. 2012).

According to Parkes et al. (2010) suggests that the water supplied by RWH systems typically requires greater operational energy to deliver than the mains water it displaces.

There are several benefits of rainwater harvesting, such as to control excessive runoff, flood in the downstream catchment, and to improve soil moisture and for soil conservation (Madan *et al.* 2014; Ammar et al. 2016; Li et al. 2018).

The application of GIS can be helpful for a first screening and identification of area potentially suitable for RWH (Prinz et al. 1998). However, the application of GIS for identification of RWH potential areas in Ethiopia does almost not exist and there is not so much documented work in this regard. On the other hand, Ethiopia was known as the water tower country in eastern Africa, having twelve rivers basins. Ethiopia constitutes diversified agro-ecological zones which enable the country to produce many types of agricultural products of both crops and livestock‘s.

The annual average rainfall of Ethiopia ranges between 400 to 1300 mm, and rain fed agriculture is predominantly practiced agricultural system in the country. Even though, 3.5 million hectare of land is suitable for potential irrigated agriculture practice, in terms of the water resources for water supply and agricultural purposes, only 0.2 million hectare of land is currently under irrigation in 2010 and increase to 1.2 million hector (MoA. 2020). In this case, only about 25 percent of the people have access to clean water of some kind. The present water requirement of the land to produce a one-season crop will require around 3% of the total runoff (Getachew 2009; and Fitsum et al. 2014). The most source of water resource available is rainfall as a local source, and that is why rainwater harvesting is extremely necessary.

There is insufficient of scientific information and practices to properly allocate and plan RWH interventions. The selection of potential area of rainwater harvesting affected by different problem of water and sensitive land is certainly acute and harsh, which demands special methods of control and management. Owing to increasing population and development of agriculture, water from various sources consumed at such a fast rate that it is going to pose a grave water crises in near future. Hence, the present research planned to give thought to these problems and to suggest ways and means through rainwater harvesting and proper watershed management. The aim of this work was to assess the suitability, and mapping the water-harvesting site in Daro Lebu district.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

2.1.1. Study area

The Assessment was conducted at Daro-Labu District of Oromia, Ethiopia. The area covered about 156064.72 ha with altitude 1040- 2730 m a.s.l (Ethio DEM 2016) of Daro Labu district. It is located 435 km to the east of Addis Ababa and 115 km from Chiro (Zonal Capital) to the south on a gravel road, that connects to Arsi and Bale Zones. Geographically location was found between latitudinal and longitudinal positions are lies between 40º20'00"- 40º70'00"E and 08º15'00"-08º40'00"N respectively and found within Wabe Shebelle river basin catchment areas (figure 1).

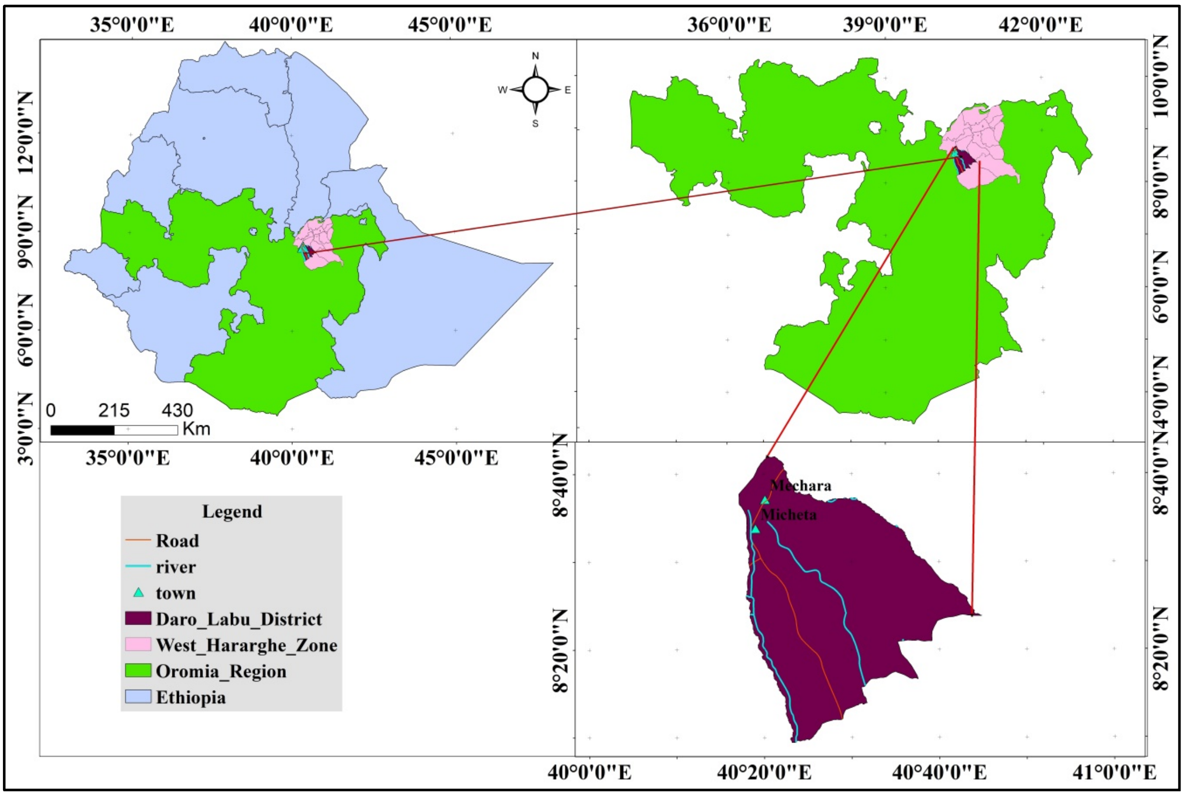

Figure 1: Location map Daro labu district

2.1.2. Climate

The area has bimodal type of rainfall distribution with annual rainfall ranging from 750-1200 mm with average annual rainfall of 1090 mm and ambient temperature of the district varies from 14 to 26^{o}C with an average of 20^{o}C summarized from Mechara Meteorology station(unpublished). The nature of rainfall is very erratic and causing marvelous erosion. The predominant production system in the district has mixed crop-livestock production with unusual sub-systems. The crops grown in the area includes cereal (maize, sorghum, and finger millet), fruit crops like banana and mango and pulse crop (soya bean, groundnut) were produced for consumption. The other production especially cash crop Hararghe specialty coffee and Chat has been produced.

2.1.3. Topography and soil type

The land feature of the district knows by undulated type and an even mountainous with altitude range from 1041-2774 m a. s. l. (Ethio-DEM 2017). The area coverage is about 156064.72 ha with major soil type of the area is covered by Chromic Cambisols (43.28%), Chromic Vertisols (21.3%), Rendzinas (20.6%) and Vertic Cambisols (9.89%) and its texture is sandy clay loam which is reddish in color (FAO Soil Classification 2015).

2.2. Methods of Data collection and Analysis

The collected data of rainfall was analyzed and organized by excel then interpretation such as homogeneity test consistency of the continuous data (rainfall data) was done depend on the result. The spatial data analyzed by ArcGIS software. Those parameters were (i.e. slope and contour interval analysis), DEM was used to identify the slope factor from the respective topo-map of the area was analyzed.

Data on land use and land cover, size, physical performance and present capacity of each components of the system collected from different respective office for estimation of Rainwater Harvesting of the study area. Different shape file of soil suitability map has taken from Oromia water work design and enterprise (OWWDE).

Meteorological data of the district was taken from Ethiopian national meteorological agency (NMA) The secondary data include cloud free Landsat 8 image (spatial resolution of 30 m distance) and Advanced Space borne thermal emission and reflection radiometer (ASTER) data (30 m x 30 m) DEM, was downloaded from United States Geological Survey (USGS) of Global Visualization Viewer Website :(https://earthexplorer.usgs.gov).

2.3. Assessment of Topography and Land feature

2.3.1. General approach of rainwater harvest (RWH) mapping

Selection of criteria; assessment of suitability level criteria for potential area of water harvesting assignments of weights overlay to these criteria were done. The spatial data for the criteria including GPS/ GCPs to supplement and generating maps for each using GIS tools; Developing a GIS-based suitability model using GIS Model builder which combines maps through MCE process; and Generate suitability maps was done.

2.3.2. Using Digital Elevation Model (DEM)

The DEM was employee to offer varieties of data that assist in produced landforms map, soil types, and hydrologic information drainage networks and sub-catchment boundary of the study area was due by extracting from DEM in order to investigate the spatial relationship of agricultural fields and the catchment-drainage networks. Digital Elevation Model data were developing using the method described in the procedure of extraction through ASTER data (figure 4).

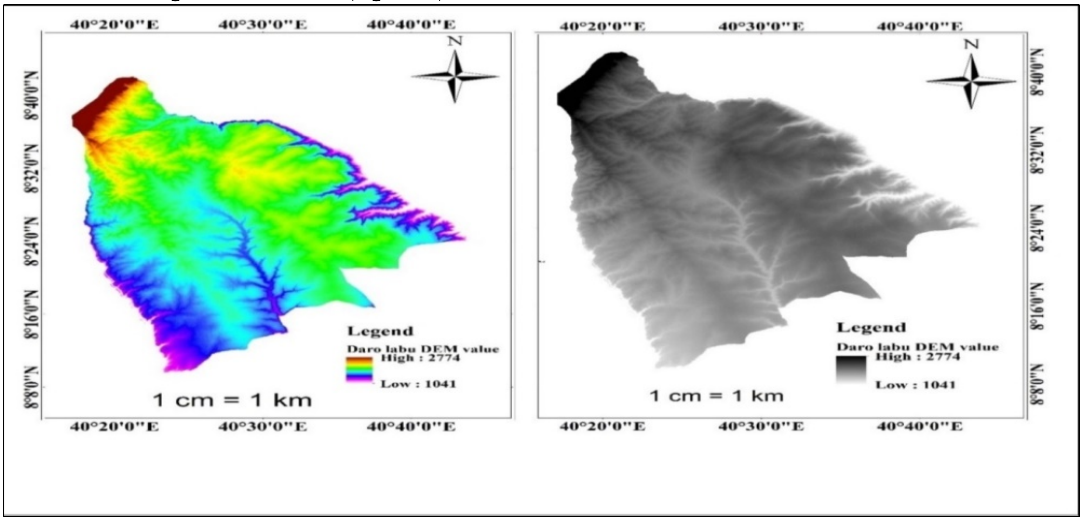

Figure 2: Digital Elevation Model Map of Daro labu District

2.3.3. Slope of the study area

Slope data were generate from the DEM grid corresponding to the boundary of the catchment. The slope assignment corresponds to the maximum change in elevation between a cell and its eight neighbors, i.e. the steepest downhill gradient for a grid cell on a raster surface. The slope was express in percent ranging from zero to 100. At the end the slope % data was classified into seven categories according to FAO guidelines which used the values (>3%, 3-5% 5-8%, 8-16%, 16-30%, and greater than 30%) was Downloaded from (http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm)

2.3.4. Soil texture and soil depth

To derive the soil texture, depth, drainage and infiltration attributes based on the dominant soil type map was extract from the Harmonized World Soil Database (DSMW, 2009) with a spatial resolution of 25 x 25 arc minutes. The soil class attributes were took from the International Soil Information Research Center (ISRIC). The soil depth map was a simplified version of the soil depth data from the FAO spatial data repository (FAO, 2007).

2.4. Rainfall data validation

The district of twenty years (1999-2018) climate data of five meteorological station (*Mechara, Micheta, Gelemso, Dumuga and Chancho*) daily rainfall, maximum and minimum temperature, Relative humidity, sunshine hours and wind speed was taken from national meteorological agency (NMA).The data were used to estimate the annual precipitation amount of the study area. Annual average rainfall of five-meteorology station was taken and runoff estimation was computed from annual rainfall amount also calculated.

2.4.1. Estimation of missing data

Missing records of the rainfall stations were estimated by using normal ratio method which is recommended to estimate missing data in regions where annual rainfall among stations differ by more than 10% (Dingman, 2002). This approach enables an estimation of missing rainfall data by weighting the observation at N gauges by their respective annual average rainfall values as expressed by equation 1 (Yemane, 2004).

$$P_X = \frac{\bar{1}}{N}[\sum \frac{Px}{Pi} * Pg]$$

(1)

Where:

P_x = missing data,

P_x = the annual average precipitation at the gauge with the missing data,

P_i =annual average values of neighboring stations

P_g =monthly rain fall data in station for the same month of missing station
N = the total number of gages under consideration
The monthly maximum and minimum temperature values at *Mechara, Micheta, Dumuga, Chancho* and *Gelemso* stations have been averaged into annual maximum and minimum long term monthly values. These values were used as input data for evapotranspiration computations. Other climatic data such as sunshine duration, relative humidity and wind speed data of the stations were averaged into long term mean monthly values and used for evapotranspiration calculation.

2.4.2. Consistency of rainfall data

Double-mass curve analysis revealed that there is good direct correlation between the cumulative rainfall of the five meteorological station (Mechara, Micheta, Dumuga, Chancho and Gelemso) with the cumulative average rainfall of the five stations (r =0.999). This indicates that the rainfall of the all station is consistent. Figure (5) the correlation coefficients of the five stations indicated that there is good direct correlation between the stations' records and their corresponding base stations. Therefore, that the rainfall data from all stations were used for further application. Sometimes the rainfall amount at certain rain gauge station for a certain days or months may be missing due to the absence of instrumental failure or some observer.
In such like cases, the nearby station technique was used to estimate the missing data.
To prepare the rainfall data for further application, their consistency checked using double mass curve analysis was used. A plot of accumulated rainfall data at site of interest against the accumulated average at the surrounding stations had been generally used to check consistency of rainfall data. To check the degree of consistency, Nemec (1973) provided the value of coefficient of correlation as follows.
r = 1: direct linear correlation
o.6 ≤r <1: good direct correlation
-0.6 < r <0: insufficient – reciprocal correlation
-1 < r <0.6: good reciprocal correlation
r = -1: reciprocal linear correlation
The stream flow and rainfall data are relatively consistent if the periodic data are proportional to an appropriate simultaneous period, and of these data, which are inconsistent, can be adjusted by proportioning, using correlation coefficient, between the stations (selesh 2000, Moutaz 2001 and Yarahmad 2003).

2.4.3. Thiessen polygon method

Rainfall distribution by the thiessen polygon method accepts that the estimated values taken on the observed values of the nearby station (Nalder et al. 1998). Nearest neighbor, methods were intensively examined by pattern recognition procedures. Despite their inherent simplicity, nearest neighbor algorithms were considered versatile and robust. Although alternative techniques have been develop, their inception, nearest neighbor methods remain very popular (Ly *et al*. 2013).
The application of rain gauge as precipitation input carries many uncertainties. The spatial and temporal distribution of rainfall at sub-basin scale, using GIS approaches found to be very effective in the study area.

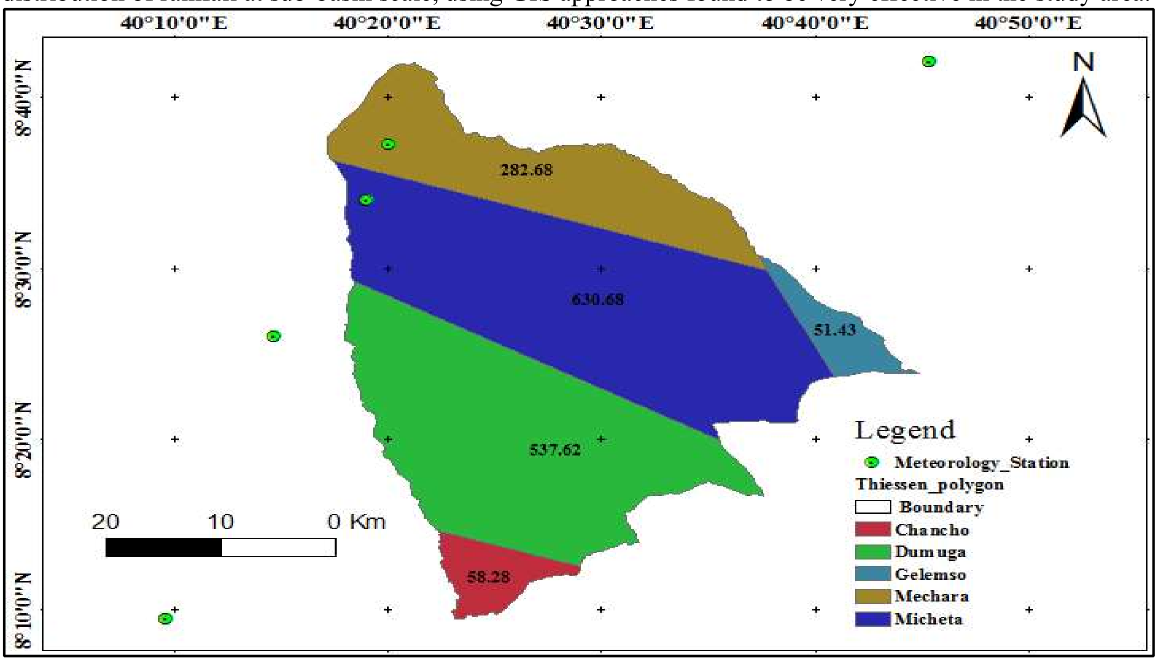

Figure 6: Area considered under thiessen polygon map of the study area

2.4.4. Runoff depth estimation

The run off depth estimation was done by calculate the runoff for each grid cell using monthly precipitation, land use land cover and soil type. Soil Conservation Service and Curve Number (SCS-CN) method were used to calculate the potential runoff in the study area. This method requires the determination of the maximum retention (S), which depend on the curve number (CN). Curve number value was computed which dependent on land-use classification and the hydrological soil group (HSG) of the land type. Land use/land-cover corresponds to the water retention capacity of the soil, were also a determinant factor for the rainfall-runoff relationship. Based on world land-use/land-cover classes, it was done from spot image using satellite extraction land sat of 2016.

Rainfall Runoff depth estimation was depends on the AMC of the five-day rainfall depth amount, which listed in (Table 2). This was done using the runoff curve number method and computing the expected runoff using the local climate time series data from Daro-labu district weather station. The data was opened up in an Excel file and the corresponding runoff curve numbers for each individual 5 day rainfall accumulation classified and assigned.

The corresponding runoff was then determined and analysis carried out to find the expected runoff. The steps followed to estimate runoff potential was,

i. Local planting season dates were obtained from New LocClim and a cumulative 5 day rainfall total column was created in the excel sheet. Single point mode search was used in New LocClim and an actual location for Daro Labu District with coordinates 40.77E, 8.57N was picked. The data obtained for the vegetative/cropping season was as shown in figure 5 below. From the data, there are two seasons a year in Daro Labu District area. One beginning on 8th March and ending on 3rd May, lasting 67 days and another one beginning on 29th March and ending on 26th October lasting 299 days. These are close estimates of the climate in this area, even when the actual dates of rain onset are determined meteorologically and sometimes delay or arrive earlier depending on the monsoon wind currents and heating in the Indian Ocean.

Table 1: Classification of Antecedent Moisture Condition (AMC)

AMC	Total 5 day Antecedent Rainfall (mm)	
	Dormant season	Growing season
I	< 13	<36
II	13- 28	36 – 54
III	> 28	>54

Source: Silveira et al (2000)

$$S = \frac{25400}{CN} - 254 \quad \text{(S in millimeter)} \qquad 1)$$

$$Q = \frac{(P-Ia)^2}{(P-Ia+S)} \qquad \text{For } Ia < 0.2 \qquad 2)$$

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \text{ For } P>0.2S \text{ and } Q=0 \text{ for } P<0.2S \quad \text{(Ebrahimian,2002)} \qquad 3)$$

Where:

Q = runoff depth, (mm)

P = rain fall, (mm)

S = maximum recharge capacity of the considered after 5 days rainfall antecedent

Ia = 0.3S (initial abstraction of rainfall by soil and vegetation, mm)

CN = Curve Number, was found out from the table (Mockus,1964 and (USDA 2004)).

$$weighted\ CN = \sum\left(\frac{C_X * A_X}{A_{tot}}\right) \qquad 4)$$

Where CN =the respective land type curve number

Cx = Values of weight land type

Ax= the area of the respective land class

2.4.5. Land use and land cover

Land use land cover of the study area was done from spot image land from (Spot Satellite Pour I' Observation de la Terre) using remote sensing taken from Ethiopian Mapping Agency Now called Ethiopian Geospatial Information of data spot image 2016. In order to do the image classified into land use and land cover of the study area using ArcGIS Map ver. 10.4. Land-use and land-cover was extracting from Landsat 8 OLI Satellite Imagery, using ERDAS Imagine version 15 image classifications. A different LU/LC classes were applied through supervised classification, and maps such as reference and topographic maps, from Google earth explorer and world land-cover images was used.

2.5. Mapping Potential Area of Rain Water Harvesting

2.5.1. Criteria of selection and assessment of suitability level

Depend on information obtained from field survey supported by expert judgment; six criteria was selected for the identification of potential areas of rainwater harvesting i.e. (soil texture, soil depth, rainfall (precipitation and evapotranspiration), topography, population density and land use land cover were used.

The different scale on which the criteria were measured, MCE requires that the values contained in the criterion map were converted into comparable units. The criteria maps were re-classed into five comparable units i.e. classes namely; 5 (very high suitability), 4 (high suitability), 3 (medium suitability), 2 (low suitability), and 1(very low suitability). The suitability classes was used as base as to generate the criteria maps (one for each criterion).

2.5.2. GIS based mapping potential areas of RWH of the study site

The GIS database of RWH potential in Daro-Labu District was developed using Arc GIS and Arc view (version 10.4) software, using both vector and raster (gridded) available databases. The major variables identified for prioritizing RWH in the GIS were rainfall, topography (slope and contour interval), soils, land suitability and drainage or hydrological soil group of the study area were identified.

2.5.3. A GIS model for generating RWH suitability map

Generating suitability map was done in a suitability model builder of ArcGIS 10.4 The model produces RWH suitability maps by incorporating various factor maps layers using a Multi-Criteria Evaluation (MCE). Several tools of ArcGIS environment were built in the model to solve various spatial challenges that included reclassifying values, projecting, and overlaying. All vector type format maps were converted into raster datasets to enable the ArcGIS weighted overlay. A weighted linear combination (WLC) of MCE is standardized to a common numeric range, and then summed by means of a weighted average. All factors were combined by using a weight to each factors followed by a summation of the results to generate a suitability map calculated using equation 6 by Malczewski (2004).

$$S = Wi * X_i \qquad (5)$$

Where

S = suitability output level per pixel i

Wi = weight of factor i

Xi = criterion score of factor i

Therefore the higher the suitability value, S of a given site (pixel) i, the more suitable the pixel is for RWH technologies. S is based on the established suitability ranking of 1-5 where 1 denotes the sites (pixels) that are not suitable and 5 indicates areas (pixels) that are very highly suitable for Rainwater harvesting (RWH) adopted from (De Winnaar et al.2007).

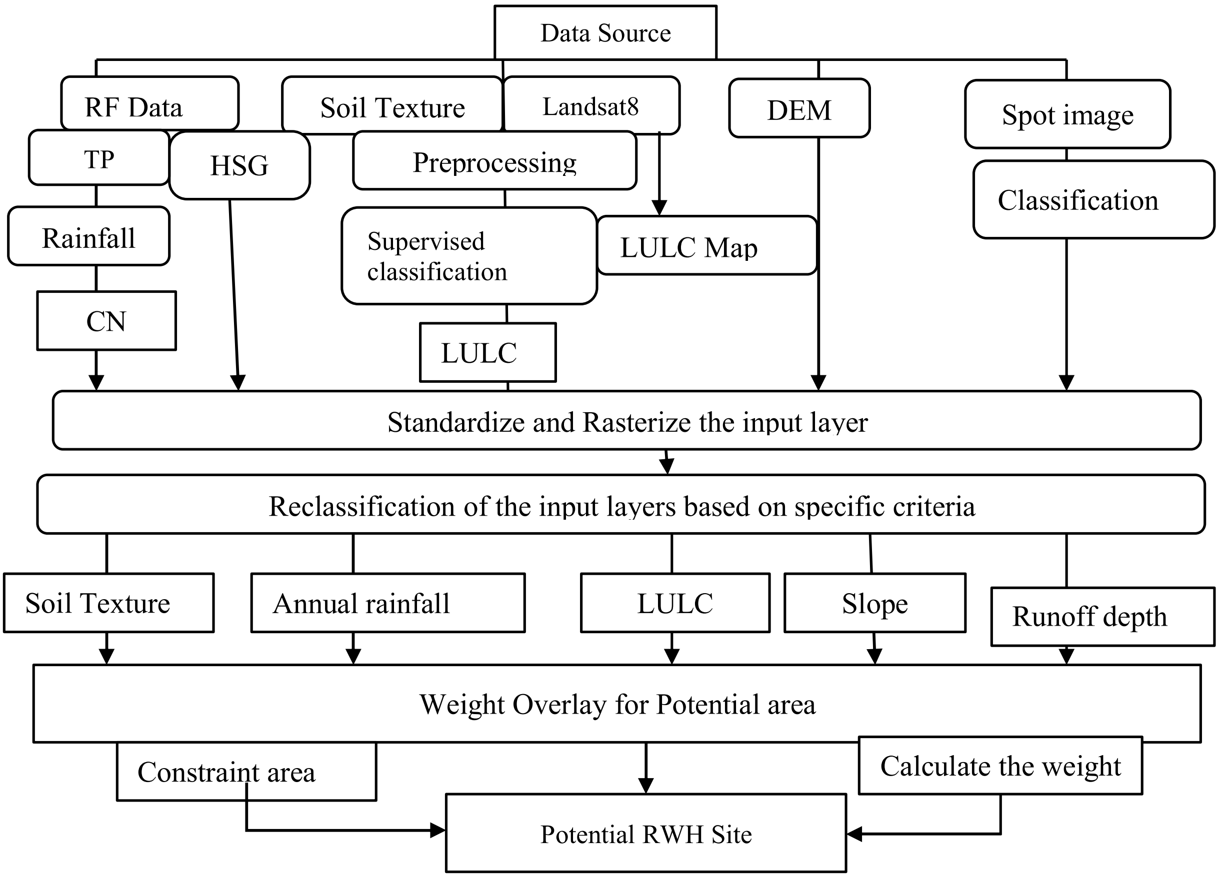

Figure 3: Flow chart methodology of water harvesting

3. RESULTS AND DISCUSSION

3.1. Slope and Soil Physical Properties for Water Harvesting

3.1.1. Slope suitability class

More than 46 percent of the area of district slope was found at less than 3 percent as well as, 37 percent of the study area also found under slope 3-5 percent. According to FAO(1990) slope suitability classification for water Harvesting 0-3 percent slope was highly suitable, 3-5 percent slope was moderate suitable. The steeper and longer a slope is, resulted with high amount of runoff generate, and the greater potential there is for erosion. Rainwater drains into a body of water by first passing over, under, or through several landmarks (Figure 4).

Table 2: Slope classification and area coverage of Daro-labu District

S/No	Value (%)	Area(ha)	Area (%)	Slope Type	Suitability level
1	<3	73161.34	46.88	Gentle	Very highly
2	3-8	59032.28	37.83	Moderate	Highly
3	8-16	15776.86	10.11	Mode Steep	Moderate
4	16-30	6479.38	4.15	Steep	Low
5	>30	1611.72	1.03	Highly Steep	Very low
Total		156064.27	100.00		

In relation to water harvesting the highest potential found with the slope less than 3% and the lowest values were found at the slope greater than 30%, which was steep, and the water runoff rather than accumulated to harvest and infiltrated into underground resource water at steep slope area (Figure 4). The slope suitability for rainwater harvesting has influenced by steepness of the land. So that, the slope increase from steep to gentle, and rather flat the water harvesting were increases for suitability. This also suggestion by (Ketsela 2009 and Tumbo *et al*., 2014).According to FAO 1990 the slope which classes zero to 5 percent were highly suitable and 5 to 8 percent were moderately suitable for water harvesting which is also agree with the work of (Kahinda *et al*., 2009 and Mbilinyi *et al*., 2014).

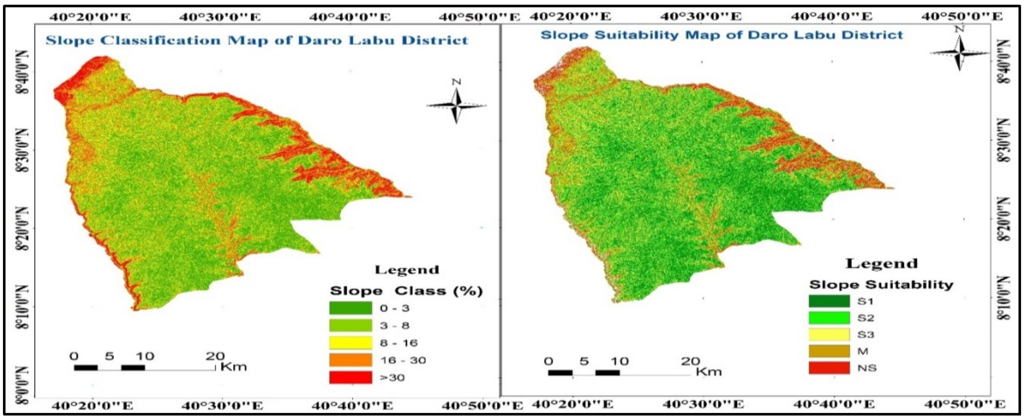

Figure 4: Slope classification and slope suitability map of Daro labu District

3.1.2. Soil physical properties

3.1.2.1. Soil texture class of the study area

The study area has characterized by diversified geomorphology and soil patterns. However, the identification of representative soil textures and their physical as well as chemical properties were based on the FAO/ UNDP's (1999) classification. The area of soil texture was classes as shown in figure7. Spatially, the study area has covered with different soil texture classes. Of the district was, sandy clay loam (53.8%) the highest coverage followed by clay soil (21.78%), loam soil (14.28%), clay loam (7.3%), sandy soil (1.9%), and sandy loam (0.9%) respectively. These textural soil classes indicates that the more in clay content there is the higher the soil moisture and at the area of high sandy content there is high run off due to the permeability of the ability of sandy soil (Figure 5). In order to identify suitability area of water harvesting with respect to soil texture sitability class has affected by clay content. The higher the clay contents there is higher soil moisture and water accumulation for harvesting which suggestion by FAO soil classification (1999 and 2003) this remedial also agree with (Tumbo *et al.,* 2014).

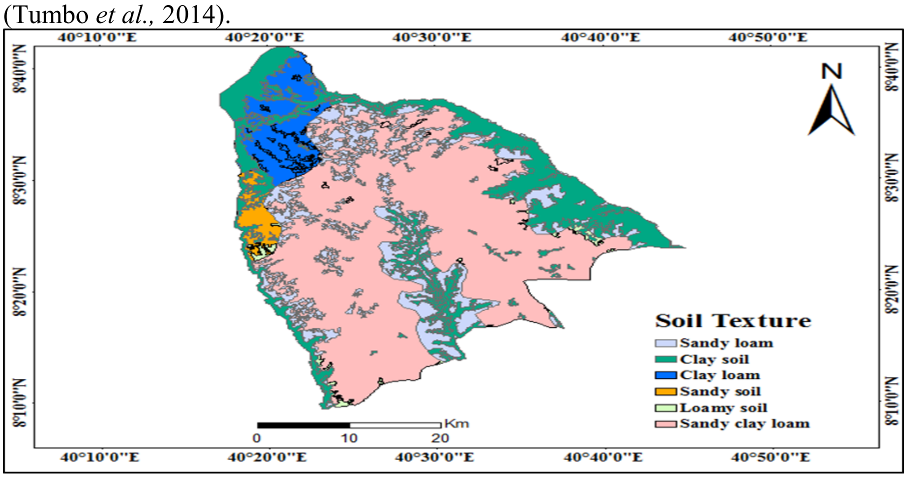

Figure 5: Soil texture map of Daru labu District

3.1.2.2. Soil depth classification and suitability of the study area

The soil depth of Daro Labu district area was characterized by shallow soil which 10cm to deep soil up to 150cm depth were found (OWWDI and HWSDB). Depend on the soil depth there is an effect on surface runoff potential area. The overall soil suitability of Daro Labu District in relation to water harvesting suitability was described in (Table 6) and figure 10.

Table 3: Major soil type suitability classification results of water harvesting

Soil Type	SMU	Depth (cm)	Texture	Drainage	Flooding	Erosion	WH Suitability	Area (ha)	% of Coverage
Luvisols haplic	IV LVha	140	SCL	Well	none	sheet	S1	1024.78	0.66
Luvisols chromic	IV LVcr	140	SCL	Well	none	sheet	S2	83534.8	53.53
Luvisols vertic	III LVvr	150	CL	Well	none	sheet	S3	10126.5	6.49
Leptosols lithic	V LPli	15	C	E/well	none	sheet/splash	S3	5252.08	2.10
Leptosols lithic rendzic	V LPli	10	L	E/well	none	sheet/splash	S1	10253.1	6.57
Leptosols lithic	IV LPli	10	L	Well	none	sheet	S2	12026.7	7.71
Vertisols haplic	IV VRha	180	C	Mode well	none	none	S3	2024.78	1.30
Vertisols calcic	V VRcc	165	C	Poor	For 1 month	none	NOT	3394.75	0.89
Vertisols eutric	III VReu	145	CL	Imperfect	15 days	rill/gulley	S3	1228.4	0.79
Vertisols chromic	IV VRcr	140	C	poor	none	none	NOT	4580.8	0.31
Cambisols dustric	III CMdu	140	SL	Well	none	sheet/splash	S2	3088.8	1.98
Cambisols chromic	IV CMcr	60	SL	Well	none	sheet/splash	S2	965.080	0.62
Nitisols eutric	III NTeu	180	S	Well	for one month	none	S2	27630.2	17.06

SMU= soil map unit, WH= water harvest, C= clay, L=loam, CL=clay loam, S= sand, SCL sandy clay loam, E=excessively, Mod=Moderate

3.2.3. Suitability of hydrological soil group

Hydrological soil group was depending on the bases on estimates of runoff potential that affected with soil type (Table 4). Soils have assigned to one of four hydrological soil groups according to the rate of water infiltration, when the soils do not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. As described in USDA-NRCS (2009), soils with hydrological group of A and B, have moderately low runoff potential; when they are saturated, whereas the soil in D and C have high runoff potential. Therefore, the runoff potential with respect to hydrological soil group shows high runoff suitability group with D, moderately suitable with C, lower with B, and poorly runoff with A respectively and (Table 4).

Table 4: Hydrological soil group by area coverage

S/N	HSG	Area (ha)	Percent	Drainage	Texture	Infiltration
1	A	83947	2.87	Well	S	High
2	B	22280	14.28	Mod well	SCL	Moderate
3	C	4484	53.79	Moderate	C	Slow
4	D	45350	29.06	Poor	CL	Poor
Sum		156064.72	100			

3.2. Land Use and Land Cover Classification

3.2.1. LU/LC suitability class

The comparison of requirements of land-use types with properties of land units brought together in a land suitability classification. Suitability was indicating separately for each land/use type, showing whether the land is suitable or not suitable, including where appropriate degrees of suitability (Table 5). The major reasons for lowering the classifications, i.e. the land limitations, should be indicated (because of erosion hazard in one area or a high water-table in another, for instance). In large or complex surveys, involving many mapping units land evaluation could assist by the use of geographic information systems (Figure 6). According to this, results of land use and land cover (LULC) shows that forest land, vegetation coverage land, cultivated land, Settlement land, and small coverage. Land-use land-cover layer map analyzed and reclassified based on the effects of land-cover classes on both the surface runoff depth and RWH structural technologies. Built up and cultivated lands was rated in high suitability class, for their suitability for most types of RWH technologies whereas settlements and forest was rated low, for their unsuitable and not economically feasible (Table 5). The results obtained were; built up, vegetation, forestry, Tree and shrubs, and agricultural areas by the Land Resources Conservation Department of Daro Labu District Agricultural Office. Remote sense satellite images were interpretation results of spot image satellite of vector formats of 2016. The result revealed that the study area was dominantly covered with cultivated land of 58% followed by tree and shrubs which account 25.97%, vegetation caver about 8.77% the rest was forest land and built up with area coverage of 5.66% and 1.02% respectively (Table 5) and (Figure 6).

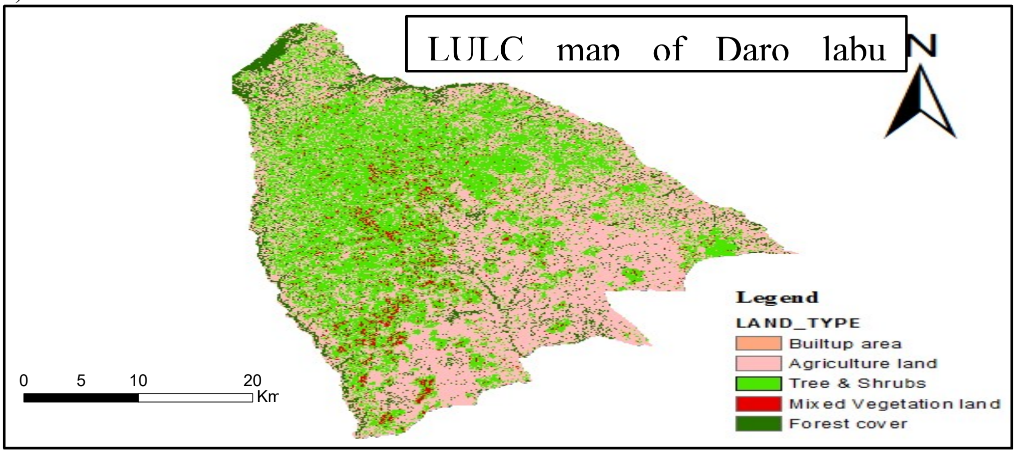

Figure 6: Land use land cover classification map of Daro Lebu district

Table 5: Slope suitability classification of Daro Lebu district

S/No	LULC	Area (ha)	Area (%)	Suitability Class
1	Vegetation	13,693.07	8.77	Less suitable
2	Tree & Shrubs	40,533.55	25.97	Suitable
3	Forest	8,829.24	5.66	Not suitable
4	Cultivated land	91,423.08	58.58	Very suitable
5	Build up area	1,585.61	1.02	Extremely suitable

Vegetation: Vegetation is an assemblage of plant species and the ground cover they provide. It is a general term, without specific reference to particular tax, life forms, structure, spatial extent, or any other specific botanical or geographic characteristics. It is broader than the term flora, which refers to species composition (Ayalew A. et al 2006).

Shrub Land: A shrub is a woody plant that is typically less than 8 meters tall. Unlike a tree, shrubs have several stems and vary widely in size; some **s**hrubs are less than 2 meters high (e.g., rose bushes), while others are around 6 to 8 meters tall.

Tree: The difference between Forest and Other land with tree cover is the land use criteria.

2. Includes groups of trees and scattered trees (e g trees outside forest) in agricultural landscapes, parks, and gardens and around buildings, if area, height, and canopy cover criteria are;

3. Includes tree stands in agricultural production systems, for example in fruit tree.

Forest: A forest is an area of land dominated by trees. Hundreds of definitions of forest are used throughout the world, incorporating factors such as tree density, tree height, land use, legal standing, and ecological function. The Food and Agriculture Organization defines a forest as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.

Agricultural Land: Agricultural land defined as the land area that is either arable, under permanent crops, or under permanent pastures**.** Arable land includes land under temporary crops such as cereals, temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. It is thus generally synonymous with farmland or cropland, as well as pasture or rangeland.

Built-up area: Built-up and related land, in land use and agriculture statistics, comprises residential land, industrial land, quarries, pits and mines, commercial land, land used by public services, land of mixed use, and used for transport and communications, for technical infrastructure, recreational and other open land.

3.2.4. Suitability of rainfall of the study area

The suitability of annual rainfall of the study area was depend on the distribution rainfall amount, which were affected by land use and land cover, soil, and slope gradient. There has been of the highest area coverage with medium potential mean annual rainfall distribution of the southeast to northeast.

Table 6: The Estimation runoff depth and volume of water harvesting of Daro Labu District

Land type	HSG	CN value	Area(ha)	Area cover (%)	Weighted CN= CN*%A
Agricultural land	A	76	2487.01	1.59	1.21
	B	86	12500.33	8.01	6.89
	C	90	48451.85	31.05	27.95
	D	93	27983.89	17.93	16.68
Vegetation cover	A	49	282.10	0.18	0.09
	B	69	2202.56	1.41	0.97
	C	79	9492.56	6.08	4.80
	D	84	1715.87	1.10	0.92
Tree and Shrubs	A	35	637.51	0.41	0.14
	B	56	5646.68	3.62	2.03
	C	70	26307.50	16.86	11.80
	D	77	7941.86	5.09	3.92
Forest	A	30	314.10	0.21	0.06
	B	50	729.16	0.79	0.39
	C	59	1445.86	3.67	2.17
	D	67	6180.54	1.11	0.74
Built up area	A	49	95.14	0.06	0.03
	B	69	276.86	0.18	0.12
	C	79	605.27	0.39	0.31
	D	84	608.34	0.39	0.33
G. Total			156064.75	100	82.00

3.3. Mapping Potential Area Using Weight Overlay method

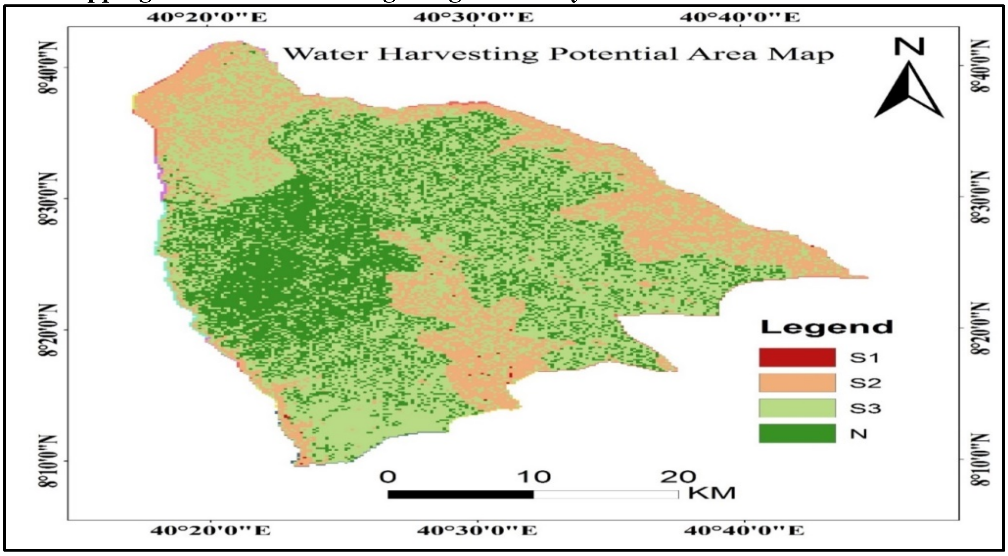

Figure 7: Weighted overlay result of RWH potential site map of Daro Labu district

Table 7: Factors of influence of RWH potential site map of Daro Labu district

S/N	Parameter	Description	Area (Km^2)	Area (%)	Suitability Rank
1	Texture	C, CL	989.00	63.37	S1
		SL, SCL	291.35	18.67	S2
		S, SC	280.25	17.96	S3
2	Soil depth (cm)	>100	1115.8	71.5	S1
		50-100	9.7	0.6	S2
		25-500	159.9	10.2	S3
		0-25	275.3	17.6	N
3	Annual RF(mm)	>1000	64.99	4.16	S1
		950-1000	117.74	7.54	S2
		900-950	990.31	63.46	S3
		850-900	259.30	16.61	Marginal
		<800	128.30	8.22	N. Suit
4	Slope (%)	<3	731.62	46.88	S1
		3-8	590.32	37.83	S2
		8-16	157.77	10.11	S3
		16-30	64.79	4.15	Marginal
		>30	16.12	1.03	N. Suit
5	LULC	Built up	15.86	1.02	S1
		Tree & Shrubs	405.34	25.97	S4
		Cultivated	914.23	58.58	S3
		Open grass	136.93	8.77	N
		Forest	88.29	5.66	S2

The overall results of weights overlay of potential area of Daro Labu District shows that, only 8.2% of the total area was extremely potential water harvesting, due to clay and clay loam soil texture, soil depth (>100 cm), annual rainfall(>1000 mm), slope (<3%) and consolidated or built up and land use/cover was considered (Table 7). The next suitability resulted with 16.6% of all was highly potential due to the factors suitability with soil texture of sandy loam and sandy clay loam, soil depth (50-100 cm), annual rainfall of (950-1000 mm). The weighted criterion (Table 7) was aggregate to produce a final suitability map according to defined regulation in ArcGIS (Figure 7). A small portion of about 12,828.5 ha (8.22%) of the district was assessed highly suitable for water harvesting due to factors such as gentle slope (0–3%), absence of impermeable layer within 150 cm soil depth, impermeable soil depth with built-up area of land cover type and annual rainfall greater than 1000 mm (Figure 7).

The second portion of 25,922.4 ha (16.61%),) of the total area of the study area was calculated as moderately suitable site for water harvesting due to moderate slope (3–8%), annual rainfall amount with 950-1000 mm. The largest part of the study which account about 99,038.7ha (63.46%) of the total area was evaluated as moderately suitable because of factors such as slope (8-16%) annual rainfall amount was between 850-900 mm with semipermeable soil depth of less than 50 cm and cultivated land cover type was verified. The fourth suitability classification of the potential was evaluated as marginal low suitability area due to annual rainfall amount less than 700 mm. The largest part of unsuitable land is in the west and south west central part of the study area. The rest which account about 7210.20 ha (4.62%) of the catchment district of land was not suitable for water harvesting because of steep slope greater than 30%, shallow soil depth of 10 cm and may be rockiness land was considered as unsuitable site (Table 8).

Table 8: Weighted values and rank for water harvesting potential area

S/N	Area(ha)	Area (%)	Rank	Suitability
1	12828.52	8.22	1	Extremely
2	25220.05	16.61	2	Very high
3	99038.67	63.46	3	Moderate
4	11777.28	7.54	4	Marginal
5	7,210.2	4.62	5	NS
Sub Total	156064.72	100.0		

4. SUMMARY, CONCLUSION AND RECOMMENDATION

4.1. Summary and Conclusion

The assessment has conducted at Daro Labu District on Rainwater harvesting factor. In this study, geographical information system (GIS) was used to employed and generate a water harvesting. Different site selection criteria affecting the water harvesting in the study area were defined based on a literature review and discussions with relevant factor of influences such as rainfall, slope, soil texture and depth, land use and land cover (LULC) drainage density was considered.

The rainfall runoff depth estimation was done by SCS-CN method that influenced by soil moisture condition (AMC). The depth of five day (5) rainfall with the lengths of dry and growing season of the study area was identified using New LocClim model accordingly, even the study area found under semi-arid there is short dry season and long wet season was considered for the reason that it's the area of bimodal rainfall.

Soil Conservation service and Curve Number model has utilized in the present work by land use map and soil map described in ArcGIS, as input. The amount of runoff represents 20% of the total annual rainfall. In the present study, the methodology for the tenacity of runoff utilizing GIS and SCS approach could do applied in other similar Catchment for arranging of various conservation measures. The good soil and water conservation measures need for planned and implemented in the study area.

Rainwater harvesting has a great potential to increase crop yields if only farmer capacity to harness this technology is advancing. From the Daro Labu area, the observation that rainfall alone not exceeds the crop water requirements but can be produced about half of the year's production and the farmer can cultivate throughout the year.

The Weighted Overlay (WO) technique used to identify the potential sites for water harvesting in the study area was done with the preprocessing of reclassifying with the aid of raster format of GIS model. This method based on the collection of all the criteria after multiplying weights in rating, thereafter determining weights and unifying rating for each criterion. The study area has classified into four classes in terms of the suitability for the water harvesting namely: very low suitability for water harvesting, moderately suitable for water harvesting, high suitability for water harvesting and very high suitability for water harvesting. The study area was do classified into no suitability, low suitability, moderate suitability, high suitability, and very high suitability in terms of water harvesting. It is recommend conducting a fieldwork to investigate the selected sites to test the suitability of soil and the sub-surface layers for water harvesting purposes.

4.2. Recommendation

Depend on the result obtained, the factor of influences for water harvesting and crop water requirements, the following recommendation was drown. Water harvesting has done not only for single purpose; it is the work of multi-purpose objective, for crop production, for soil and water conservation, for domestic or consumption. Topography and soil type as well the slope of the area was identified it simple to minimize the risk of water scarcity and soil erosion problem. Water harvesting work used to have the opportunity work for a given community and sources of income generation. Soil texture and LULC were the major influence factor for water harvesting, hence high clay content area, with flat to gentle sloppy area should considered by reducing workload and cost.

Therefore, rainfall water harvesting should be embraced to increase productivity and improve yields due to the fact that it has a great potential as observed in this assessment work. The advantage of water harvesting is that it also has another opportunity for the farmer to engage in production to increase the livelihood, and also earn from that activity as well.

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