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GIS and Remote Sensing Based Assessment and Estimation of Rainwater Harvesting for Crop Production in Daro-Labu District, Oromia, Ethiopia

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Abstract

Rainwater harvesting is the process of intercepting, conveying, and storing rainfall for future use as an alternative source of water in the drought prone areas of Ethiopia especially eastern Oromia. The aim of the research was to assess and mapping potential area of water harvesting site in Daro Labu District. There are various methodologies and criteria to identify suitable sites and techniques for rainwater harvesting (RWH). GIS and remote sensing is the recent technology of spatiotemporal data used to assess the factor of influences for rainfall and runoff depth estimation for identification of potential area of RWH for crop production and mapping of the potential site. The influence factors for consideration of the assessment was climate data, soil texture and depth, land use and land cover (LULC) type, slope difference was used. The total area of the catchment was about 156064.72 ha with antecedent moisture condition (AMC) of II, I III by having the values of 82, 67, and 91 respectively. The annual average rainfall of 20 years was 925.2 mm with maximum and minimum of 1134 mm and 737.3 mm, with average annual runoff depth estimate of185.3 mm. From the estimated annual runoff the volume of water harvested was about 2.89 x 10^8 m^3. The suitability map of the study area shows that, extremely potential, highly potential, moderately potential, marginal and not potential accounts by coverage areas about (12,828.52 ha) 8.22%, (25,220.05 ha) 16.6%, (99,038.67 ha) 63.5%, (11,777.28 ha) 7.54%, and (7120.20) 4.62% respectively. In order to change the water harvested for crop production and meet the irrigation requirements of selected crop (tomato, onion, and maize) was 528 mm, 354.3 mm and 558.5 mm respectively was taken. The total cultivated area was about 58.6% and the area can be irrigated using the volume of water harvested was about 63% of the total cultivated area for single crop season of the study area. Thus, Rainwater harvesting can be considered as livelihood income generation and increases with production and productivity of the communities as well.

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ArcGIS, Remote Sensing, Water harvesting, Crop Water Requirement, Daro Lebu.

Introduction

Water is a very crucial element but finite and considered a limited natural resource. 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.

The annual average rainfall of Ethiopia ranges between 400 to 1300 mm, and rain fed agriculture is predominantly practiced agricultural system in the country. The country is endowed with ample water resources with 12 river basins, and that provide an estimated annual runoff of 125 billion m^3 and 22 natural artificial lakes. The groundwater potential varies from 2.6 to 13.5 billion m^3 per year, which makes an average of 1,575 m^3 of physically available water per person per year, a relatively large volume (Makombe *et al.,* 2011; Michael & Seleshi, 2007; MOA, 2011).

Moreover, Ethiopia has at least 5.3 million hectares (5.3 Mha) of irrigation potential; 3.7 Mha from gravity fed surface water, 1.1 Mha from groundwater and 0.5 Mha from rainwater harvesting (Awulachew & Ayana, 2011; Makombe *et al.,* 2011). 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 for crop production but not fully irrigated and involving with supplementary irrigation.

In Ethiopia, high amounts rainfall makes rainwater as a potential resource in which increases the need for private and onsite water supply management initiatives. It's also facing a high adoption rate of water harvesting technologies around 42% (Wakeyo & Gardebroek, 2015). Moreover, there has limited number of study that evaluates the relation between rainwater harvesting and crops yield (Bouna *et al.,* 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).

The incorporating demands that align with local rainfall patterns can substantially increase the efficiency of the system. In terms of both water conservation and storm water mitigation (Zhang *et al.,* 2009). When used in conjunction with infiltration based solutions, excess overflow water from RWH systems (that would otherwise generate street runoff or enter the storm sewer network) can be infiltrated (often after preliminary treatment, as determined by national regulations) for groundwater recharge (Dillon, 2005).

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). Environmental benefits concerning the reduction of emissions and the decreasing of consumed resources with RWH system implementation have been explored in recent years (Angrill *et al.,* 2012). In this regard, the scientific literature shows that the selected use of rainwater in the building and the type of implementation project (renovation or new construction) significantly affect the economic feasibility of the system and implications of RWH for energy consumption have currently contested (Pinzon *et al.,* 2015).

Different studies used different parameters for estimation and allocation of water harvesting for crop production FAO, (2003) as cited by Kahinda *et al.,* (2008) lists six key factors when identifying by consideration of RWH sites. Climate, topography, agronomy practice soils moreover, socioeconomic criteria had influences the importance of water harvesting. In addition, used physical (land use, rainfall, and soil texture and soil depth), ecological and socio-economic factors might be a problem and should be identified through research work. Rao *et al.,* (2003) identified land use, soil, slope, runoff potential, proximity, geology, and drainage as criteria to identify suitable sites for RWH.

The eastern Ethiopia especially west, Hararge Zone (WHZ), there is insufficient of scientific information and practices to properly allocate and plan RWH interventions for crop production and as well for domestic uses. The problem of water scarcity and sensitive land suitability is certainly acute and harsh, which demands special methods of control and management of water resource. 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 serious water crises in near future time. Besides, in the areas where irrigation water made available unforeseen problems like water logging, alkalinity and salinity of the soil and various water borne diseases and social problem have appeared in the absence of any scientific management of watershed.

Hence, the present research has planned to give thought to these problems of water allocation and to suggest ways and means through rainwater harvesting and proper watershed and catchment area management.

Therefore, the assessments is aimed to assess GIS and Remote sensing based potential areas of Rainwater harvesting and determine, the amount of rainwater harvesting and estimation of runoff depth using SCS-CN for crop production in the study area.

Materials and Methods

Description of the Study Area

Location of the study area advantageous

The assessment was accompanied in Western Hararghe Zone of Oromia Region, at 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"- 40º45'00"E and 08º10'00"-08º40'00"N respectively and found within Wabe Shebelle river basin catchment areas (figure 3).

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. 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.

Topography and soil type

The land feature of the district is known by undulated type and an even mountainous with altitude range from 1041-2775 m a.s.l. (Ethio-DEM, 2017). The study area was covered about 156064.72 ha with major soil type of 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).

Methods of Data collection and Analysis

The two methods of data collection; primary data collection and secondary data were used.

The secondary data include data of land use and land cover, size, physical performance and present capacity of each components of the system was collected from different respective office for estimation of Rainwater harvesting of the study area. Different shape file of soil suitability map were taken from Oromia water work design and enterprise (OWWDE).

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

Using Digital Elevation Model (DEM)

The DEM was employed 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 done by extracting from DEM in order to investigate the spatial relationship of agricultural fields and the catchment-drainage networks. Digital Elevation Model data was developed using the method described in the procedure of extraction through ASTER data (figure 4).

Slope of the study area

Slope data were generated 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 expressed in percent ranging from zero(0) to 100. Seven categories of FAO guidelines slope classification was used for the values (>3%, 3-5%, 5-8%, 8-16%, 16-30%, and greater than 30%).

Soil texture and soil depth

To derive the soil texture, depth, drainage and infiltration attributes based on the dominant soil type map was extracted from the Harmonized World Soil Database (DSMW, 2009) with a spatial resolution of 25 x 25 arc minutes. The soil class attributes was taken 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).

Rainfall data validation

The district of twenty years (1999-2018) climate data of five meteorology 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 as well yearly water has been harvested was estimated. The weather data also used to for crop water requirement using dependable method of effective rainfall from mean monthly rainfall.

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 with 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).

$$P_X = \frac{\bar{1}}{N}[\sum \frac{Px}{Pi} * Pg] \quad \textbf{...(1)}$$

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 all 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 *Mechara, Micheta, Dumuga, Chancho* and *Gelemso* stations have been also averaged into long term mean monthly values and used for evapotranspiration calculation.

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).

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 depend on the AMC of the five day rainfall depth amount which is listed as (Table2). 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,

1. 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 waters.

These dates for the growing period are important because most of the rainwater harvesting is expected to be done in the growing periods when there is plenty of rainfall. The rainfall-runoff relationship using the Curve number analysis method developed by the USDA was calibrated based on a consecutive five day total rainfall summation. This is because when it rains in the dry season or at the start of the growing season, the soil is dry and soil moisture depletion is high.

2. A column for rain in 5 days was created in the Excel data file for Daro-labu district climate (for all five-meteorology station).

3. The growing season and dry season were defined basing on results from New Loclim in another column.

4. Every five (5) day total rainfall was classified depending on its intensity using guidelines in step I, step II and step III all created as conditions in the excel datasheet columns based on the Antecedent Moisture condition of the soil as shown in Table1 below.

5. Determination of actual curve number: For each 5 day total rain depending on whether it lies in the dry or wet season, there are three possible runoff curve numbers. For each 5-day rain, the respective curve number in column excel sheet for data were obtained. Prior to this step, its good analysis to classify the data separately into class I curve number value, class II or class III respectively.

$S = \frac{25400}{CN} - 254$ (S in millimeter)…(2)

$Q = \frac{(P-Ia)}{(P-Ia+S)}^{2}$ for Ia< 0.2…(3)

$Q = \frac{(P-0.2S)^2}{(P+0.8S)}$ For P > 0.2S and Q = 0 for P<0.2S…(4)

Where:

Q = runoff depth, (mm)

P = rain fall, (mm)

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

I*a* = 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)).

$$weighted\ CN = \sum \left(\frac{Cx * Ax}{A_{tot}}\right) \quad \ldots(5)$$

Where CN =the respective land type curve number

Cx = Values of weight land type

Ax= the area of the respective land class

Land use and land cover

Land use land cover of the study area was done from spot image land from (Spot Satellite Pour observation dela Terre) using remote sensing taken from Ethiopian Mapping Agency Now called Ethiopian Geospatial Information (EGI) ofspot image data of 2016.

In order to do the image classified into land use and land cover of the study area using ArcGIS Map ver. 10.4. 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.

Mapping Potential Areas of Rain Water Harvesting

Criteria of selection and assessment of suitability level

Depend on information obtained from field survey supported by expert judgment; five criteria were selected for the identification of potential areas of rainwater harvesting i.e. (soil texture, soil depth, rainfall (precipitation and evapotranspiration), topography, and land use land cover was 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), 4 (high), 3 (medium), 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).

Mapping potential areas of water harvesting

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 was identified.

A GIS model generatingsuitability map forwater harvesting

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. 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).

$$S = \sum WiXi \quad \ldots(6)$$

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).

CROPWAT 8.0 Model Input data

After all assessment of water harvesting done, and amount of annual Runoff depth was estimated, crop water requirement of the study area was done for validating the runoff production of the study area. Therefore, that for CWR there is different input parameter used. The software requires the following input data: Climate data: Temperature, Humidity, Wind and Sunshine hours. The process of rainfall data, crop and cropping information. Crop name, planting date, crop Coefficient (Kc), Stages length (days), critical depletion fraction (p), yield response factor (Ky), crop height in m (if available), rooting depth (m) Soil data: Total available soil moisture, (FC-WP), maximum rain infiltration rate, maximum rooting depth, Initial soil moisture depletion (% TAM) and Initial available soil moisture were used as an input data.

$$CWR_i=\sum_{t=0}^{T}(Kci.ETo-Peff) \quad \ldots(7)$$

Where

CWRi= crop water requirement of a in mm per day

Kc_{i} = crop coefficient of given crop I during the growth stage in which

t = initial growth stage T is the final growth stage respectively.

P_{eff} = effective rainfall

$$NIR = ETc * Effrain \quad \ldots(8)$$

Where: NIR is net irrigation requirement, ETc is crop evapotranspiration and Effective rainfall.

Dependable rainfall

The irrigation water applied to bring the soil moisture content at the root zone to field capacity taking into account the effective root zone depth. Irrigation, soil moisture determined by Gravimetric method. Measured amount of water applied to all treatments. The effective root zone of onion is considered to vary from 30-40 cm depending on the growth stage. The depth of water was determined using the following equation (eqn...9):

$$d=\sum_{i}^{n}\frac{M_{fci}-M_{bi}}{100}BixDi \quad \ldots(9)$$

Where; d = net amount of water to be applied during an irrigation, mm

Mfci = field capacity moisture content in the i^{th} layer of the soil, percent

Mbi =moisture content before irrigation in the i^{th} layer of the soil, percent

Bi = bulk density of the soil in the i^{th} layer

Di = depth of the i^{th} soil layer, mm, within the root zone, and

n = number of soil layers in the root zone D.

Methods of Data collection

The collected data of soil 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 was collected from different respective office for estimation of Rainwater Harvesting of the study area. Meteorological data of the district was taken from national meteorological agency (NMA). The secondary data include cloud free Landsat 8 image (spatial resolution of 30 m distance) and Shuttle Radar Topography Mission (SRTM) digital elevation

Results and Discussion

Slope and Soil Physical Properties for Water Harvesting

Slope suitability class

The slope gradient was classified depend on FAO slope classification methods which means depend on percentage from 0-100 percent. The area covered by the slope classes with respective area were listed in table 1. More than 46% of the area of district slope was found at less than 3 percent as well as, 37% of the study area also found under slope 3-5%. According to FAO (1990) slope suitability classification for water Harvesting 0-3 % slope was highly suitable, 3-5 % slope was moderate suitable. In general, the steeper and longer a slope is, the faster water runoff generate, and the greater potential there is for erosion. But many other factors come into play in determining what becomes of a slope over time when exposed to storm water runoff (Table 5). Rainwater drains into a body of water by first passing over, under, or through several landmarks (Figure 8). According to previous research and the result obtained the slope value greater than.

As it shown (Table 5) the slope of the study was done and resulted with, the highest area coverage accounts 46.88% of the area were less than 3% slope which is gentle slope followed by 37.83% of the area found between 3-8%, 10.11%, 4.15%, 1.03% of the area found between 8-16%, 16-30% and greater than 30% respectively. 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 7).

Soil physical properties

Soil texture class of the study area

The study area has been 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 area coverage of soil texture of the district was, sandy clay loam (53.8%) was the highest coverage followed by clay soil (21.78%), loam soil (14.28%), clay loam (7.3%), sandy soil (1.9%), 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 (Figure7). The laboratory result from sample taken were also described in (Table 2). In order to identify suitability area of water harvesting with respect to soil texture suitability class has affected by clay content. The higher the clay contents there is higher soil moisture and water accumulation FAO soil classification (1992).

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 5) and figure 10.

Land Use and Land Cover Classification

LU/LC suitability class

The Vector data of remote sensing spot image was change into raster form using image classification from ArcGIS map toolbar and the Spot image area has already been classified into different LULC using ERDAS IMAGE classification. 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 8) and (Figure 11).

LULC accuracy assessment

One of the most important final steps at classification process is accuracy assessment. The aim of accuracy assessment to quantitative assesses how effectively the pixels were sampled into the correct land cover classes. Moreover, the key emphasis for accuracy assessment pixel selection was on areas that clearly identified on Landsat high-resolution image, Google earth and Google Map. A total of 120 points (locations) created were in the classified image of the study area. The Accuracy Assessment Cell Array Reference column filled was according to the best guess of each reference point (Appendix Figure 2).

Suitability of hydrological soil group

In this study, a logical condition for overlaying analysis was defined in ArcGIS 10.4 to develop the spatial extent of the hydrological soil group from the soil and infiltration rate raster file of the study area shape file. The spatial extent of soil hydrological group for the study area, which derived from soil texture, was as shows in (Table 8) and (Figure 14). Hydrological soil groups were based on estimates of runoff potential that affected with soil type. 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 it can be seen in the table, the hydrological soil group with class (HSG-C) has the higher area coverage with 53.79% followed by HSG-D (29.06%), HSG-B (14.38%) and HSG-A with area coverage of 2.87%, respectively.

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 HSG-D and HSG-C have high runoff potential. Therefore, the runoff potential with respect to HSG shows high runoff with D, moderately potential with C, lower potential with B, and poorly runoff potential with A respectively (figure 14).

Suitability of rainfall of the study area

The characteristics of rain fall of the study area known by erratic type with mean annual rainfall amount of 1000 mm with minimum and maximum of 700 mm to 1100mmrespectively was affected by seasonal variability. The suitability of annual rainfall amount was highly suitable with greater than 1000 mm suitable 900 mm to 1000 mm, medium suitable from annual amount of 800 mm – 900 mm and less than 700 mm was poorly suitable area (Figure 15). There was been of the highest area coverage with medium potential mean annual rainfall twenty year of Southeast to Northeast parts of the study area.

By considering the relative proportion of the hydrologic soil group, it can be concluded that most of the soils in the study area had been contributing a significant amount of runoff, and only a low to medium proportion of the precipitation is infiltrated to the soil. So that the soil texture and hydrological soil group of the area were mostly covered with moderate to poor drainage types of soil. The value of curve number as it shows in the (Table 9) below were under hydrological soil group HSG_C of 26.41% and HSG_D of 15.25% were the highest coverage area under agricultural land and under HSG_C covered about 11.40% and 10.44% under vegetation cover and wood land type respectively. Hence the HSG of C and D were known by high runoff potential soil type the area would have generate high amount of runoff per hectare of land per year.

The rainfall runoff model of the area was estimated after considering different factors of the influential such as climate (Rainfall, Temperature, Relative Humidity, Sun shine hour and, Wind speed) soil type (texture structure depth) topography (slop and contour), seasonal variation which can be affect the amount of rainfall runoff of the study area as a whole. Depend on the factors the amount of runoff estimated was shows in (Table 9).

In the GIS based SCS-CN model, the CN and yearly rainfall values were used as inputs to compute annual runoff. For various curve numbers, the runoff estimated for average antecedent moisture conservation (AMC) conditions because of average yield estimation.

The daily rainfall data for 20 years from 1999 to 2018 were taken from Ethiopian Meteorological Agency (EMA) and change into monthly average for each year. The initial abstractions (Ia) were calculated for each LULC types (explained under the Soil Conservation Services (SCS) curve method). If a storm event is less than the initial abstraction value, there is a runoff available for that rainfall event.

The result of SCS-CN method of rainfall runoff estimation of twenty years data of (1999-2018) shows with minimum records of 122.7 mm in 2011 and maximum records of 288.77 mm in 2005 with annual average of 185.25 mm (Table 9) and (Figure 12).

Accordingly, the volume of estimated water harvested has been accounted to 2.89x108 m3. This estimation obtained was in line with the work of Gatechew Haile (2018).

Curve Number (CN) classification of the study area

The SCS-CN of Daro Labu area was done from LULC type and derived from FAO CN classification. Depend on the value of CN obtained the area covered and CN suitability class also determined. The CN values for the study area was range from 40 - 100 with different suitability levels described (Table 10).

As it shows from (figure 12) the curve number of the study area has been affected by soil type and texture class of the soil of the study area. So that, the GIS based analysis of curve number CN value indicates that the North West of the District is high to extremely high potential water harvesting site of the area. However, the North and South east of the District of the area was low to medium water harvesting potential area (Figure 12).

Mapping Potential Area Using Weight Overlay method

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 due to clay and clay loam soil texture, soil depth (>100 cm), annual rainfall(>1000 mm), slope (<3%) and consolidated or Built up LULC area was water harvesting (Table 13).

The next suitability resulted with 16.6% 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. The weighted criterion (Table 13) was aggregated to produce a final suitability map according to defined regulation in ArcGIS (Figure 18).

To this effect, out of the total area of the study area which is 156064.72 ha, 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 18).

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 900-1000 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 slope (8-16%) annual rainfall amount was between 800-900 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 figure18.The largest part of unsuitable land is in the west and south west central part of the study area. The north, central part and the south west of the district were optimum potential/ suitable parts of the district.

Selected Crop Water Requirement of Daru Labu District

Gross irrigation requirement of the study area

In order to estimate irrigation water requirements of some selected crops in the potential irrigable sites, the definition of area of influence of the climatic stations using ArcGIS inside and around the study area was assessed. To obtain a spatial coverage of climate data over the study area, each station was assigned to an area of influence using the Thiessen polygons method (FAO, 1997). This method assigns an area of estimated the nearest to each climate station as presented in (Fig 8). Irrigation water requirement of each of the selected crops were calculated using CROPWAT8 soft-ware. For the calculation of ETc/cwr, data from the considered meteorological station was used.

As indicated in appendix table 13, different percentage of area coverage was adopted for each crop based on the assumed benefits the farmers will obtain from them. CROPWAT software assumes 100% efficiency and 24 hours irrigation duration, but in real world, the indicated efficiency and irrigation hours are an achievable due to different uncertainties. Gross irrigation water requirements of maize and potato at the identified potential irrigable sites under surface irrigation methods were estimated depend on ETo of the area.

Crop water requirements of in the area also depend on the weather condition as a result crop water requirement of a given crop any area was influenced by the climate condition of the area. For this reason, data of twenty years (1999-2018) of the area was used depend on the crop calendar of the study area.

The crop water requirement of the study area is that sampled to determine and estimate with the amount of water harvesting in relation to agricultural production. So that Maize, Tomato and Onion crop were taken and do its water usage depend on the weather data.

The climate data of twenty years for each five meteorological station using CROPWAT 8 Model were done. The result obtained that for each meteorology station was listed in (Table 14). It shows that the total water harvested at Mechara 35.49Mm3 and the crop water requirement of Tomato, Onion and Maize was 493.8, 371.0 and 596 mm of growth irrigation water depth respectively.

The area of irrigated by equally distributed water for the three crop was 2398 ha 3189 ha and 1986 ha respectively can irrigated (Table 14). At Micheta station the same for the three crops depend on its specific station weather condition. The water has estimated to harvest was 120.45 Mm3. The crop water requirement of Tomato, Onion and Maize was 502 mm, 355 mm and 615 mm.

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)

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

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

Table.3 Spatial distribution of soil texture in the study area

Soil Texture	Area (ha)	Area (%)	Drainage	Infiltration (mm h^{-1})
Clay	33,996	21.78	Poor	2
Clay Loam	11,354	7.28	Imperfect	10
Sandy loam	1,421	0.91	Moderate	30
Sandy Clay Loam	83,947	53.79	Well to Moderate	25
Loam	22,280	14.28	Well	15
Sand	3,063	1.96	Very well	50
Sum	156,064.72	100.00		

Source: FAO soil classification (1992)

Table.4 LULC classification area covered of Daru Labu District

S/N	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

NB*:- S/N= sequence number, LULC= Land use land cover

Table.5 Hydrological soil group by area coverage

S. No	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			

Source: Ethio Soil map (MOWEP, 2016)

Table.6 Area influenced under different SCS-CN method

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

NB*:- HSG= Hydrological Soil Group, CN= Curve number

Table.7 SCS-CN and runoff potential area coverage of the study area

CN range	Runoff Potential	Area (ha)	%	Suitability
30-40	None	23556	15.09	Not Suitable
41-50	Marginal	125.61	8.05	Marginal
51-60	Less Potential	154.05	9.87	Less Suitable
61-70	Medium	105.70	6.77	Suitable
71-80	High	485.90	31.14	High suitable
81-90	Highly Potential	151.8	16.13	Very high suitable
91-100	Extremely Potential	202	12.94	Extremely suitable

Table.8 The Estimation Runoff depth and Volume of water Harvest of Daro Labu District

Year	Rainfall (mm)	Runoff (mm)	Runoff(%)	Volume of WH (Mm^3)
1999	878.72	153.84	17.51	240.10
2000	923.09	174.66	18.92	272.59
2001	899.63	180.45	20.06	281.63
2002	950.93	185.89	23.75	352.55
2003	1016.11	235.44	18.25	289.41
2004	909.22	175.34	18.56	263.39
2005	1134.78	288.77	21.90	387.80
2006	1004.71	221.95	20.10	315.18
2007	803.91	151.49	18.84	236.43
2008	737.28	118.40	21.23	244.26
2009	981.31	250.20	15.95	390.49
2010	848.78	175.13	29.48	273.33
2011	755.82	122.70	23.17	191.50
2012	950.48	178.67	12.91	278.86
2013	1028.21	247.08	17.38	276.36
2014	910.14	169.59	19.46	264.68
2015	929.10	170.00	18.25	421.39
2016	935.21	165.95	28.87	258.99
2017	948.12	180.41	17.50	281.57
2018	957.81	167.99	18.84	262.18
An. Average	925.17	185.26	20.02	289.14

Figure.1 Location map of the study area.

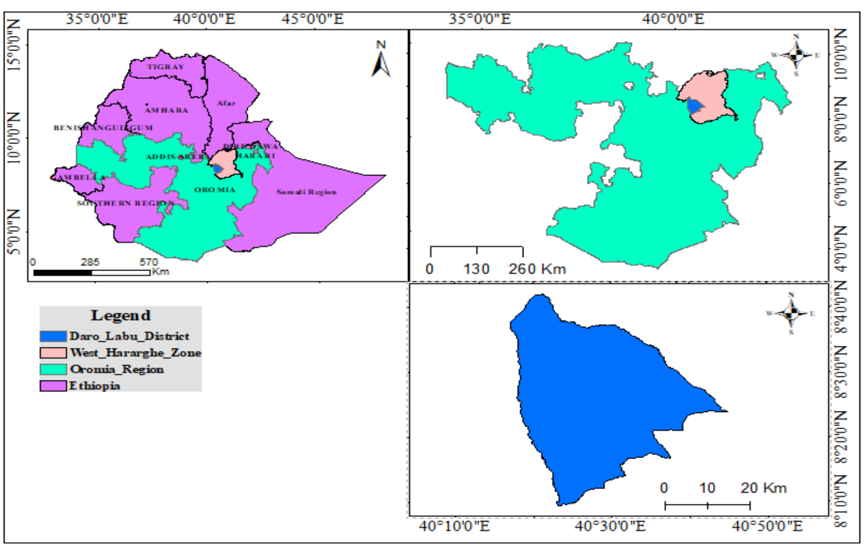


Table.9 Factors of influence of RWH potential site map of Daro Labu district

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

Figure.2 LULC map of Daro labu District

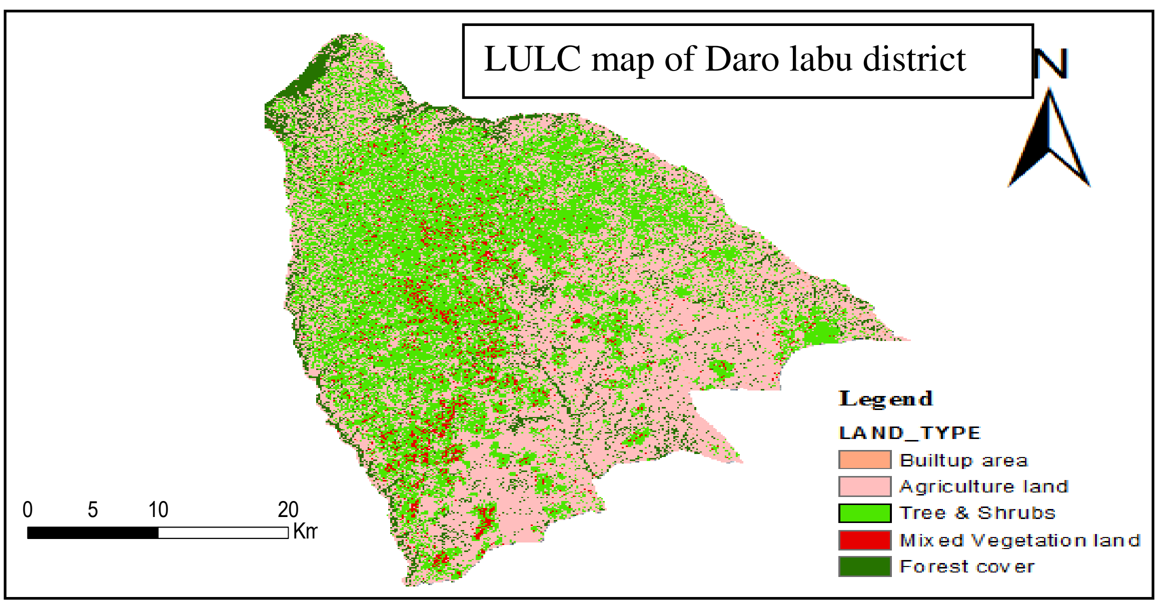


Table.10 Weightage values and rank for water harvesting potential site

S/N	Area(Km^2)	Area (%)	Rank	Suitability
1	128.30	8.22	1	Extremely
2	259.30	16.61	2	Very high
3	990.31	63.46	3	Moderate
4	117.74	7.54	4	Marginal
Sub Total	1560.72	100.0		

Table.11 Growth and Net irrigation Requirement of maize, tomato and onion at Daro Labu District

Station	Crop type	Ig (mm)	In (mm)	CWR (mm)	RWH (Mm^3)	Area (ha)
Mechara	Tomato	493.8	345.7	322.8	11.83	2396.00
	Onion	371.0	259.7	235.2	11.83	3189.07
	Maize	596.0	417.3	278.7	11.83	1985.14
Micheta	Tomato	502.0	351.0	332.5	40.15	7998.62
	Onion	355.0	249	227.0	40.15	11310.73
	Maize	615.0	430	277.7	40.15	6528.96
Dumuga	Tomato	436.8	305.7	266.6	26.61	6091.66
	Onion	320.1	224.0	206.1	26.61	8312.52
	Maize	467.7	327.4	249.7	26.61	5689.20
Chancho	Tomato	633.6	443.5	358.2	3.50	548.44
	Onion	360.0	252.0	245.5	3.50	965.25
	Maize	555.7	389.0	329.2	3.50	625.32
Gelemso	Tomato	571.8	399.8	351.6	3.10	543.02
	Onion	365.5	255.8	248.7	3.10	849.52
	Maize	558.1	390.6	296.4	3.10	556.35

NB*:- Ig=growth irrigation, In=net irrigation, CWR= crop water requirement

Figure.3 Percentage Area coverage of LULC type of Daro Labu District

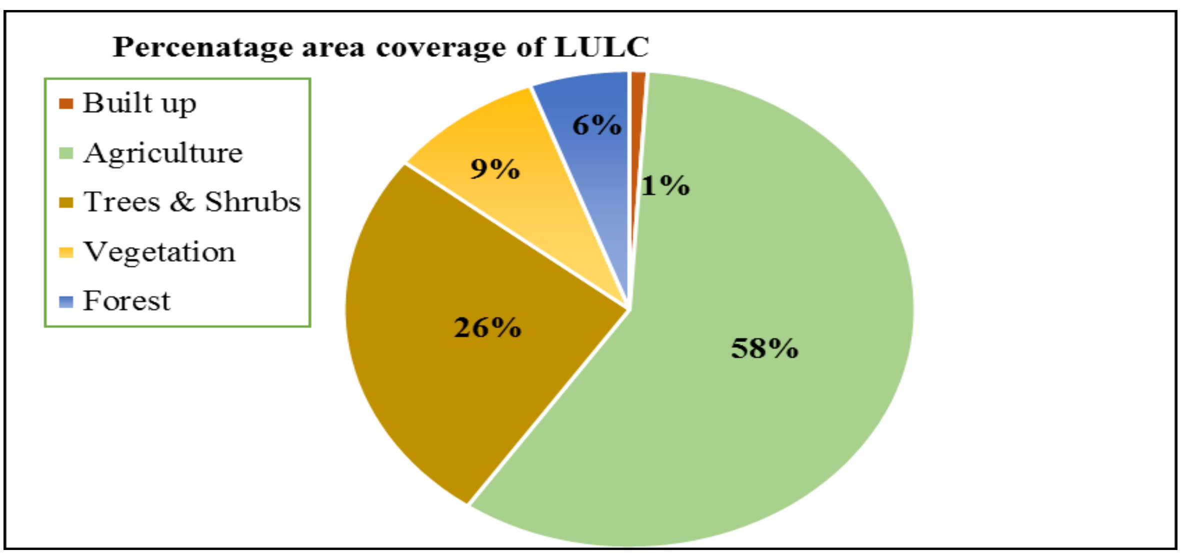


Figure.4 Graph of mean annual rainfall runoff relationship of Daro labu District

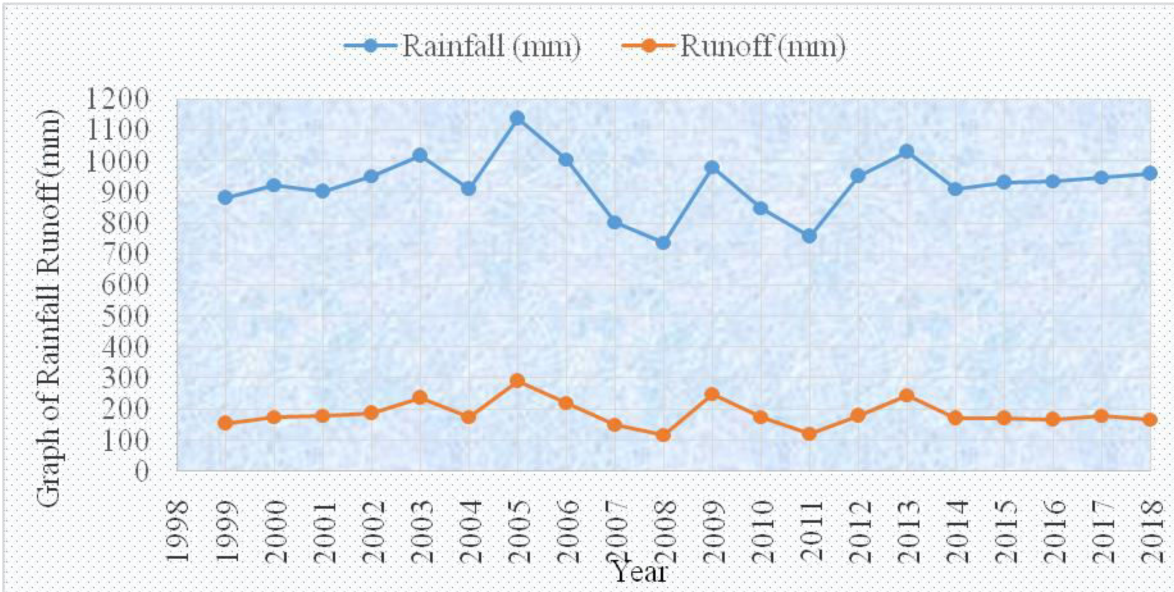


Figure.5 Weighted overlay result of RWH potential site map of Daro Labu district

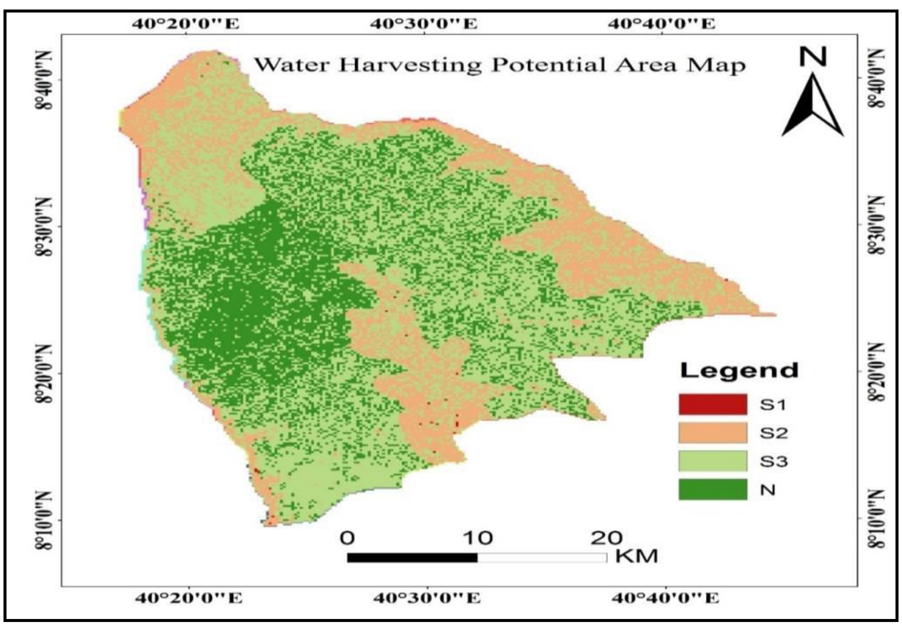
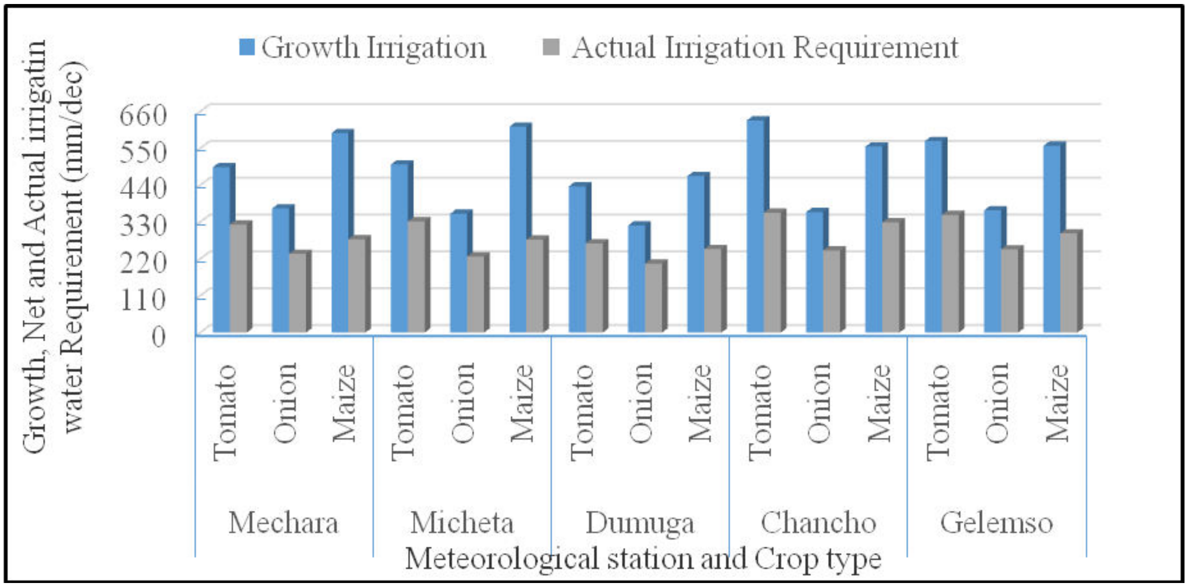


Figure.6 Growth, Net and Actual irrigation water requirement of Tomato, Onion and Maize at the study area



Depend on the information obtained area of irrigated under harvesting water estimated to account 7980 ha of Tomato, 113100 ha of Onion and 6530 ha of Maize can be irrigated at the same time (Table 10). There is also the area can be estimated under Dumuga Station, chancho station and Gelemso station for same crop that Tomato accounts 436.8 mm, Onion 320.6 mm and Maize 467.7 mm of depth of irrigation obtained from the model and the area might be irrigated has been estimated 6091.7 ha, 8312.5 ha and 5689.2 ha were estimated to irrigate under Dumuga station. The next estimated under chancho meteorological station, the growth irrigation depth of Tomato, Onion and Maize was 633.6 mm, 360 mm and 555.7 mm respectively. It could be estimated to irrigate was 548.4 ha of tomato, 965.3 ha of onion and 625.3 ha of Maize might be estimated to irrigate (Table 14).

Net irrigation requirement (NIR) of the study area

The NIR of different crops in the study area was given in Table 11. The net irrigation requirement for Tomato, Onion and Maize was 369.14, 248.1, and 390.86 mm/season. The lowest Onion water requirement was obtained (224 mm) per cropping season at Dumuga station and the highest at Mechara (259 mm) per cropping season.The result also the same with Tomato and Maize, that the lower water requirement of Tomato (367 mm) and the highest obtained at Chanch station. This is because of the occurrence of effective rainfall during rainy season (May–September) was high, whereas during the growing period of as a result, the irrigation requirement was very high. This indicates the differences in water requirement even within a single district for the same period and hence it shows the significance of requirement of scientific planning for irrigation. The difference in the NIR in Daro Labu District with station might be due to the combined effect of the changes in temperature, sunshine hour percentage, wind and the decrease in effective rainfall (Fig 19).

Actual crop water requirement

The crop actual water requirement of Maize, Tomato, and Onion at Daro Labu District has depend on Evapotranspiration, rainfall, temperature, sunshine hour and wind speed of the area was affected. So that, the crop water requirement of the selected crop under five meteorological station were almost become same with net irrigation and actual irrigation for onion at all station and there is a fluctuation for maize specially on Micheta station (figure 18). There is also obtained minimum crop water requirement under Dhumuga station and the highest under Chancho station due to the difference in Evapotranspiration at the station (figure 19).

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. Six 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 be planned and implemented in the study area.

In SCN Curve number, method, Antecedent moisture condition of the soil plays a very consequential role because the CN number varies according to the soil and that considered while estimating runoff depth. For a given study, area that Daro Labu District curve number (CN) calculated equal with 82 for AMC -I, 28.4 AMC-II and 87.5 for AMC-III. In conclusion, Soil Conversations Service; Curve Number approach do efficiently proven as a better method, which consumes less time and facility to handle extensive data set as well as larger environmental area to identify site selection of water harvesting structures.

Rainwater harvesting has a great potential to increase crop yields if only farmer capacity to harness this technology is advanced. From the Daru Labu area, the observation that rainfall alone not exceeds the crop water requirements but can be produced about half of the years 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 help 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 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.

Crop water demand that computed from Cropwats8 model results, the crop water requirement of the area has about 1440.14 mm of water. The combined potential of rainfall runoff is 8540 m^3 of water. This implies that of the available volume of water, only 40% can be utilized. The other 60% can be used for other water needs and or for expansion of the irrigated fields. Also worth noting is that only one season has been considered per year for this analysis.

Recommendation

Depend on the result obtained and the factor of influences for water harvesting and crop water requirements, the following recommendation was drown. Water harvesting has been 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 be 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.

References

Angrill, S., Farreny, R., Gasol, C.M., Gabarrell, X., Viñolas, B., Josa, A., Rieradevall, J., 2012.

Environmental analysis of rainwater harvesting infrastructures in diffuse and compact urban models of Mediterranean climate. International Journal of Life Cycle Assessment 17(1), 25-42.

Awulachew & Ayana, 2011. Performance of irrigation: An assessment at different scales in Ethiopia. Experimental Agriculture, 47(S1), 57–69.

Biazin, B., Sterk, G., Temesgen, M., Abdulkedir, A., & Stroosnijder, L. 2012. Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan AfricaA review Physics and Chemistry of the Earth, Parts A/B/C, (47-48), 139-151. http://dx.doi.org/10.1016/j.pce.2011.08.015

Bouma, J. A., Hegde, S. S., & Lasage, R. 2016. Assessing the returns to water harvesting:A meta-analysis. Agricultural Water Management, 163, 100-109. http://dx.doi.org/10.1016/j.agwat.2015.08.012

Dillon, P., 2005. Future management of aquifer recharge. Journal of Hydrogeology 13(1), 313-316.

Dingman S L. 2002. Physical Hydrology. Prentice Hall: Upper Saddle River, NJ.

FAO (2015) Available online; http://www.fao.org/ag/agp/greenercities/en/whyuph/

FAO (Food and Agricultural Organization). 2003a; http://faostat.fao.org/default.htm.Accessed on 23/10/2015.

FAO, (2003)

FAO, 2003b. Land and Water Digital Media Series. Planning of Water Harvesting Schemes, Unit 22. Nations, Rome.

Fitsum Y., Hordofa, T., & Abera, Y. 2014. Review of Water Harvesting Technologies for Food Security in Ethiopia: Challenges and Opportunities for the Research System.Journal of Natural Sciences Research, 4(18): 40-49.64

Getachew A. 1999. Water Harvesting a Water Security Strategy for Mitigating the Impact of Drought in Ethiopia. Addis Ababa, Ethiopia

Ghaffarian Hoseini, A., Tookey, J., Ghaffarian Hoseini, A., Yusoff, S. M., Hassan, N. B., 2016. State of the Art of Rainwater Harvesting Systems towards Promoting Green Built Environments: A Review, Desalination, and Water Treatment 57(1), 95-104. GDRC (Global Development Research Center), 2002. An Introduction to Rainwater Harvesting.

Hamel, P., Fletcher, T. D., Daly, E., Beringer, J. 2012. Water retention by rain gardens: implications for local-scale soil moisture and water fluxes. In: Wong, T.H.F., McCarthy, D.T. 7th edition. International Conference on Water Sensitive Urban Design, Engineers Australia, Melbourne, Australia, 2012.65

Ly S, Charles C, Degré A., 2013. Different methods for spatial interpolation of rainfall data for operational hydrology and hydrological modeling at watershed scale. A review of Biotechnology, Agronomy and Socio Environ 17 (2):392–406.

Makombe, G., Namara, R., Hagos, F., Awulachew, S. B., Ayana, M., & Bossio, D. (2011). A comparative analysis of the technical efficiency of rain-fed and smallholder irrigation in Ethiopia (Vol. 143). Addis Ababa: IWMI.

Michael, M., & Seleshi, B. 2007. Irrigation practices in Ethiopia: Characteristics of elected irrigation schemes (pp. 80). Colombo, Sri Lanka: IWMI.

MoA. 2011. Small-scale irrigation capacity building strategy for Ethiopia. Natural Resource Management Directorate, Addis Ababa, Ethiopia.

Moutaz, Al., 2001. Surface water modeling using GIS and remote sensing: A case study in Malewa catchment, Navaisha, Kenya.

Mwenge Kahinda, J., Taigbenu, A.E., Sejamoholo, B.B.P. 2009. A GIS-Based DecisionSupport System for Rainwater Harvesting (RHADESS). Journal of Physics, Chemistry and Earth Science, 34, 767–775.

Nalder, I. A. and Wein, R. W.: Spatial interpolation of climatic normals: test of a new method in the Canadian boreal forest, Agr. Forest Meteorology., 92, 211–225, 1998.

Nemec, 1973. Engineering Hydrology. Mc Graw –Hill publishing company Limited. New Delhi.

Pinzon, T., Rieradevall, J., Gasol, C. M., Gabarrell, X. 2015. Modelling for economic cost and environmental analysis of rainwater harvesting systems. Journal of Cleaner Production 87(2015), 613-626

Rejani, R., Rao, K. V., Srinivasa Rao, C. H., Osman, M., Sammi Reddy, K., George, B., Pratyusha Kranthi, G. S., Chary, G. R., Swamy, M. V. and Rao, P.J., 2017. Identification of potential rainwater-harvesting sites for the sustainable management of a semi-arid watershed. Irrigation and Drainage, 66(2), pp.227-237.

Sileshi Bekele, 2010. Irrigation Potential in Ethiopia: Constraints and Opportunities for Enhancing the System. International Water Management Institute (IWMI).

Steffen, J., Jensen, M., Pomeroy, C. A., Burian, S. J. 2012. Water Supply and Storm Water Management Benefits of Residential Rainwater Harvesting in U.S. cities. Journal of the American Water Resources Association 49(4), 810-824.

Wakeyo, M. B., & Gardebroek, C. 2015. Empty pockets, empty ponds? Adoption of water harvesting technologies in Ethiopia. Journal of Arid Environments, 120, 75-86. http://dx.doi.org/10.1016/j.jaridenv.2015.04.013.

Yarahmad, T., Khan, D., Okbagabir, S. and Handy, C. R., 2003. Moment problem quantization within a generalized scale t-Wigner (auto-scaling) transforms representation. Journal of Physics A: Mathematical and General, 36(6), p.1623.

Yemane, D., Field, J. G. and Griffiths, M. H., 2004. Effects of fishing on the size and dominance structure of line fish of the Cape region, South Africa. African Journal of Marine Science, 26(1), pp.161-177.

Zhang, Q., Li, S., Gu, and S., Tan, X. 2009. Water quality in the upper Han River basin, China: the impacts of land use/land cover in riparian buffer zone. Journal of hazardous materials, 165(1-3), pp.317-324.

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