G- Journal of Environmental Science and Technology

(An International Peer Reviewed Research Journal)

Available online at http://www.gjestenv.com

Identification of suitable sites for artificial water tanks in Adigrat town through GIS and remote sensing technique

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ARTICLE INFO

Received: **24Jun 2015**
Revised: **15July2015**
Accepted: **06Aug 2015**

***Key words*:**
GIS, Artificial watertanks, Hydrology

ABSTRACT

The Adigrat town sometimes faces a severe shortage of water; this is primarily due to maximum runoff of rain water and lack of water conservation practices. In this study, an attempt is made to identify suitable sites for artificial water tanks for water conservation and augmentation of groundwater through a combination of GPS surveying and GIS based hydro-geomorphic approach in Adigrat town. GPS survey was done to know the magnitude of the problem. Hydro-geomorphological characteristics of Adigrat drainage basin were studied using ASTER data. As a result fourteen sites were identified suitable for artificial water tanks in Adigrat town. These sites were identified on the basis of water accumulation, stream channels order, water need assessment, underground water, rock types. The study will helps in designing a suitable water management plan and flood control for Adigrat town.

1) INTRODUCTION

Ethiopia has ample water resources that could be developed, for example, by developing storage facilities. Even though it has uneven spatial and temporal distribution, resulting in droughts in some parts of the country, it is estimated that Ethiopia has more than 122 billion cubic meters (BCM) of surface runoff from 12 river basins, not considering ground water [1]. This amounts to a per capita water availability of about 1,644 cubic meters (m^3), which makes Ethiopia a water abundant country [2]. The United States stores 6,000 m^3 of water per person, Australia 5,000 m^3. While Ethiopia stores only 43 m^3 per person. While water use in Ethiopia is estimated to be about 30 liters per person per day, it is more than 150 liters/per person/day in UK and Brazil and stands at more than 550 liters/per person/per day in USA [2]. This means that in Ethiopia there is potential for developing water facilities, for instance, storages that could be used for multi purposes.

The present study is an attempt to find suitable location for construction of Artificial water tanks to store rain water. It is estimated water use/ per person is low to 5 to 20 liters/ per day. The world average use about 650 cubic meters (171,712 gallons) of water per person per year [3]. So compare to world average water use Adigrat city has very low water use.

2) MATERIALS AND METHODS

Study Area: Adigrat town is located at 14^0 20' north latitude and 39^0 29' east longitudes at a distance of about 898 kilometres North of Addis Ababa and 125 kilometres north of Mekelle, the regional capital. The total area of the town is 1877.24 hectares. The town is an administrative capital of Eastern Tigray Zone and the capital of Gant Afeshum wereda [4].

The population of Adigrat citybased on 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA) is 57,588.

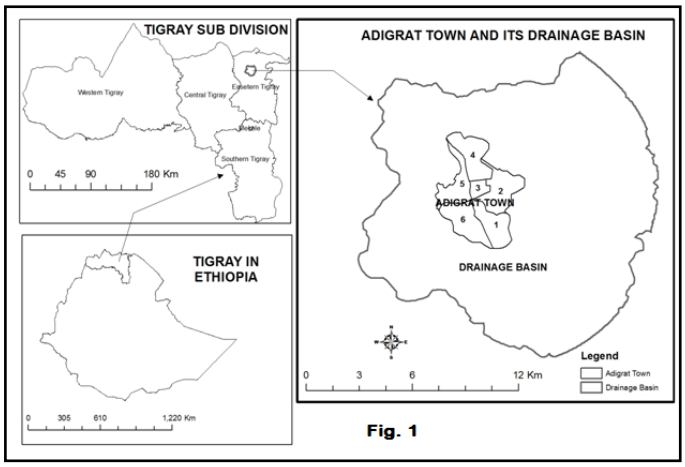

Fig. 1

Methodology: The present work is based on hydrology analysis of Adigrat Drainage Basin. The locations of artificial tanks were proposed based on water accumulation, stream order and local water use. To calculate hydrology of the basin direction of flow, flow accumulation, stream order and stream length was calculated as following:

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Slope: The Slope is the maximum rate of change in value from that cell to its neighbours. Basically, the maximum change in elevation over the distance between the cell and its eight neighbours identifies the steepest downhill descent from the cell. Equation 1 explains the function.

Tan θ = rise/run **Eq. 1**

Direction of flow: The direction of flow is determined by the direction of steepest descent from each cell [5].This was calculated as:

Change in z-value / distance * 100 **Eq. 2**

The distance was calculated between cell centres. If the descent to all adjacent cells is the same, the neighbourhood is enlarged until a steepest descent is found.

Water Flow accumulation: Cells with a high flow accumulation are areas of concentrated flow and were used to identify stream channels. Cells with a flow accumulation of zero are local topographic highs and were used to identify ridges.

Weighted raster in the Flow Accumulation function was determining how much rain has fallen within a given watershed. In such a case, the weight raster was continuous raster representing average rainfall during a given storm.

The output from the Flow Accumulation function represent the amount of rain that flow into each cell, assuming that all rain became runoff and there was no interception, evapo-transpiration, or loss to groundwater. This could also be viewed as the amount of rain that fell on the surface, upslope from each cell.

This method of deriving accumulated flow from a DEM is presented in Jenson and Domingue [6]. An analytical method for determining an appropriate threshold value for stream network delineation is presented in Tarboton et al. [7].

Stream order: In this study Strahler method was adopted to create stream order of Adigrat drainage Basin. In the Strahler method, stream order increases when streams of the same order intersect. Therefore, the intersection of two first-order links will create a second-order link, and the intersection of two second-order links will create a third-order link. The intersection of two links of different orders, however, will not result in an increase in order. For example, the intersection of a first-order and second-order link will not create a third-order link, but will retain the order of the highest ordered link. The Strahler method is the most common stream ordering method. However, because this method only increases in order at intersections of the same order, it does not account for all links and can be sensitive to the addition or removal of links.

Conditions for locations of artificial tanks: Proposed Artificial tanks were classified into three categories, large size, Medium size and small size. These were classified giving following conditions.

Conditions for large size tanks –

1. Water accumulation…….41.04 to 15.45 sq km of Area
2. Stream Order……Not less than 5th Order
3. Slope……Not more than 10 Degree
4. Elevation……Not more than 2400m
5. Distance from Settlement……Not more than 100m

Conditions for Medium size tanks –

1. Water accumulation…….15.46 to 4.93 sq km of Area
2. Stream Order……Not less than 4th Order
3. Slope……Not more than 10 Degree
4. Elevation……Not more than 2500m
5. Distance from Settlement……Not more than 100m

Conditions for small size tanks –

1. Water accumulation…….4.92 to 1.68 sq km of Area
2. Stream Order…….. Not less than 3rd Order
3. Slope……..…Not more than 10 Degree
4. Elevation……Not more than 2600m
5. Distance from Settlement……Not more than 100m

3) RESULTS AND DISCUSSION

Slope in Adigrat Drainage Basin: Slope of Adigrat drainage basin ranges from 0 degrees to 75 degrees in the total area of 204.62 km^2.**Table 1** shows the slope categories, area and percentage of total area.

Table 1: Slope in Adigrat Drainage Basin

Sloe	Area km^2	Percent of Total Area
0-5	60.79	29.79
5.1 - 10	46.28	22.67
10.1-15	34.40	16.85
15.1 - 20	26.38	12.93
20.1 - 25	17.32	8.49
25.1 - 30	10.00	4.90
>30	8.92	4.37

Source: Study

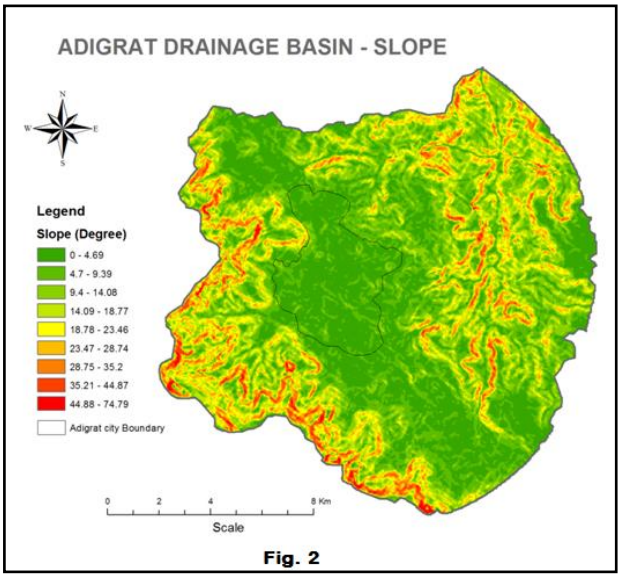


Fig. 2

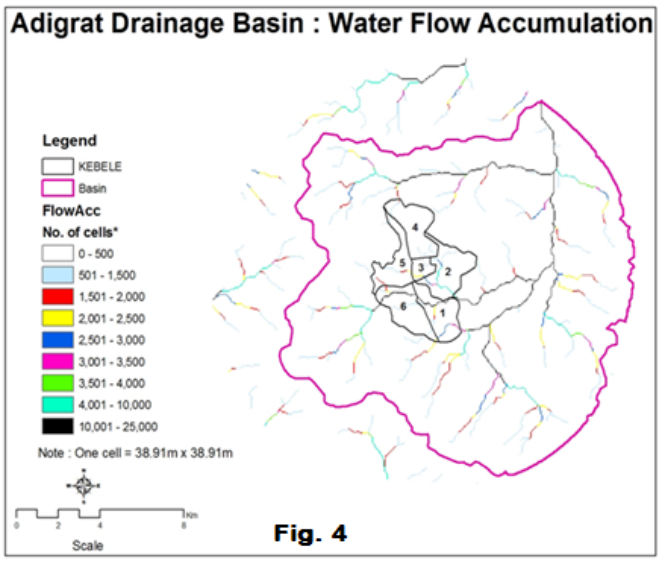
Flow direction in Adigrat Drainage Basin: Water Flow direction of Adigrat Drainage Basin is shown in **Table 1 and fig 3.**

Table 2 - Water Flow direction of Adigrat Drainage Basin

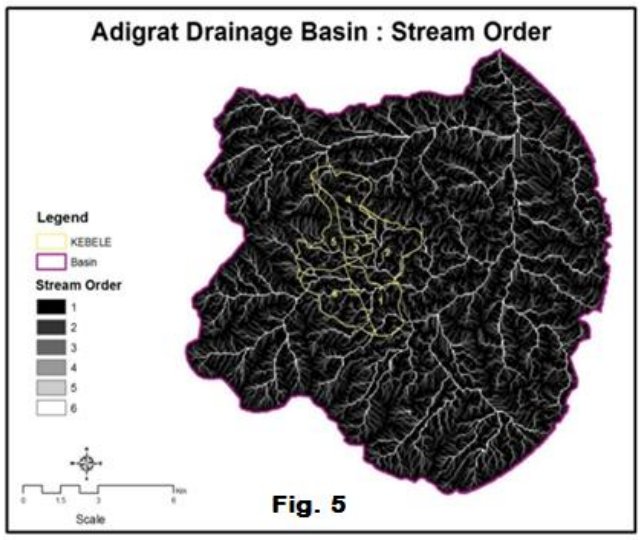
SN	Direction of Flow	Area (km^2)	Area (%)
1	E	44.823	14.12
2	SE	32.984	10.39
3	S	37.123	11.69
4	SW	33.202	10.46
5	W	38.127	12.01
6	NW	36.074	11.36
7	N	52.622	16.57
8	NE	42.546	13.40
Total		317.500	100.00

Source : Study

Water Flow Accumulation in Adigrat Drainage Basin: Water accumulation in Adigrat drainage Basin is up to 25 sq km. as a stream channel.Largest water accumulation is in Kebele No. 1 and 5. **(Figure 4)**



Stream order in Adigrat Drainage Basin: Adigrat drainage basin has 6 stream orders. Stream order increases from west to east because of its general slope to east direction. **(Figure 5)**



Artificial Water Collection tanks: Water accumulation, Stream Order, Slope, Elevation, Distance from water need fourteen artificial water tanks were identified in different locations.**Table 3** and **Figure 6**.

Figure 6 shows the locations of proposed water tanks. Out of total fourteen water tanks 5 belong to large category, 4 belong to medium category and rest 5 tanks belong to smaller category. The size of each category of water tank and their water holding capacity is given in **table 4.**

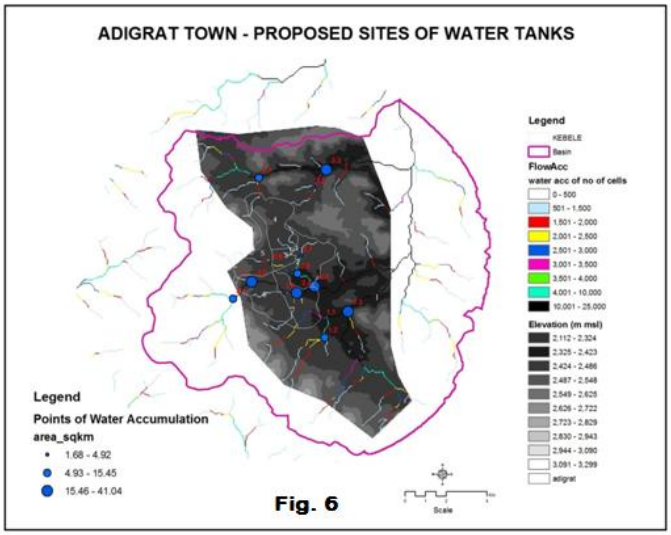


Table 3: Water accumulation and Location of Artificial Water Tanks in Adigrat Basin

Tanks UID	Water Accumulation of Area in sq km	Latitude	Longitude
1.1	4.924	14.257206	39.475909
1.2	9.070	14.249754	39.474802
1.3	41.040	14.258287	39.485293
2.1	8.272	14.269523	39.441226
2.2	26.492	14.274849	39.449545
2.3	1.679	14.269261	39.461490
2.4	33.328	14.268283	39.466334
2.5	33.975	14.269685	39.473628
2.6	11.396	14.275383	39.467703
2.7	4.437	14.282076	39.470322
2.8	3.137	14.281096	39.458136
3.1	15.448	14.313887	39.458096
3.2	4.861	14.307231	39.479068
3.3	31.810	14.313126	39.484886

Source: Study

Table 4 Category of proposed water tank and their water holding capacity

Type of Tanks	No	Size LWH	Volume of water		Total Volume of Water	
			Cubic m	Gallon(US)	Cubic m	Gallon(US)
Large	5	20*10*10	2000 m^3	528344.10	10000 m^3	2641720.52
Medium	4	10*10*10	1000 m^3	264172.05	4000 m^3	1056688.20
Small	5	10*05*10	500 m^3	132086.02	2500 m^3	660430.13
Total	14				16500 m^3	4358838.85

Source: Study

4) CONCLUSION

Adigrat city lie in semi arid climatic zone of North Ethiopia. Water scarcity is a frequent problem. Per capita water use is very low; it is estimated to range from 5to 20 litres per day. The availability of water is also not equally distributed spatially as well as temporally. In this paper fourteen sites were identified where construction of water tanks is possible to store rain water. These fourteen tanks may store 16500 m^3rainwater. The tanks are proposed near the areas where water may be used for various purposes as Agriculture, Schools, residential and commercial settlements.

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