Estimation of Rainfall-Runoff of Amrutha Cascade System in Visakhapatnam District, Andhra Pradesh (India) by using SCS-CN Method

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Abstract:

Water is one of the most important sources on the surface of the earth. All living organisms depend on it. Without water, we cannot sustain our lives. Many standard methods are there to bridge the gap between demand and supply. Proper water management is the only solution for future generations by using the existing methods. In many parts of our country, groundwater quantity and especially quality have severely degraded due to environmental impacts. Climate change shows the implications for a new level of uncertainty related to freshwater supplies. Rainfall runoff is one of the most the essential part to plan a management in water resources. The method Soil Conversation Service-Curve Number (SCS-CN) is a simulation model which analyses runoff volumes from the rainfall. There are several methods used to estimate surface runoff to get more accurate results at particular catchments of different areas. The present study area was carried out on the surface runoff estimation of the Amrutha tank. This tank is considered independent and is located at Rajam village of Butchayyapeta Mandal of Visakhapatnam district, Andhra Pradesh. The total area covered under this particular catchment is 9.84 Sq km. In this study area, Sentinel data, Land use/Cover, Drainage map, soil data, and 30 years of rainfall data have been carried out for the assessment of Amrutha Cascade.

Keywords: ArcGIS, Amrutha Cascade, Drainage map, Soil data, Land use/cover, Sentinel data.

1. Introduction:-

Water is one of the most precious gifts in this world which is available at free of cost given by nature. Proper management and planning are required to save water resources. All the living organisms are depending on the water. Without these natural resources, living organisms cannot sustain their lives on the surface of the earth. Water plays a very important role in the growth of the economy of a particular country. Day by day the world's population increasing, and as a result, the availability (Ponce VM; et al SCS-CN 1996) of water resources decreasing, and a lot of land in the forest was occupying by the human population. Especially in India, there are several problems facing in the urban areas due to lack of water resources and not having proper coordination between local authorities which causes greater failures of the water (Vinthra R; et al SCS-CN 2016) resources system. The availability of water in lakes, rivers, and reservoirs depends upon (Amrutha R; et al SCS-CN 2009) climatic conditions. The water helps in the construction (Bansode A; et al SCS-CN 2014)of reservoirs, dams, and their maintenance and helps in the removal of sediments, and increases the water holding capacity of reservoirs. The ground and surface water have visualized the parts of the hydrological system. Out of the world's population, India has 16% population and 4% freshwater resources (Kudol AB; et al SCS-CN 2015) available in the form of lakes, rivers, and large water bodies. The present study area discusses the Amrutha Tank using the SCS-CN model. It is one of the simplest technique (Kadam A; et al 2012) to calculate the rainfall runoff modeling. There are two methods available one is the Neitsch cliff method and another one is the Soil conservation service method (SCS) curve number (CN) method. SCS method was used to calculate the runoff in the Amrutha (Soma sekhar R.K.; et.al 2011) cascade to get more accurate results. SCS-CN (Mishra sk; et al 2004) stands for soil and water assessment tool originally developed by Arnold for the United States Department of Agriculture (USDA). It is a physically distributed (Subramanya K.; et al 2008) parameter model to predict the impact of the land management practices of the model on land, water, and agricultural chemical yields in large complexes varying with soil, water, and management over a longer period of time. In order, to set up a model (Sravanam S; et al 2015) that includes weather data, soil, topography, and land management practices of the particular tank. This model is used as a tool for the design of large river basins

2. Study Area:

The present study area mainly discusses the Amrutha tank using the SWAT model which is located near Butchayapet village located in Anakapalli revenue division of Visakhapatnam district, Andhra Pradesh. The capacity of the tank is 10.56 Mcft and also plays a very important role to provide irrigation facilities and covers under the Sarada river basin. Butchayapet contains one gauge station and it is 4.42 km away from the station. For a period of 30 years, rainfall data had been collected for calculating runoff estimation using the SCS-CN method to get accurate results. The average rainfall for a particular catchment area is about 1013.40 mm. Nearly 80% of the yield of the tank depend upon the tank is estimated at 7.62 Mcft. The files are needed to be converting from rater to vector data in the standard format. Basically the model requires different type of datasets; they are weather data, satellite data. Thematic maps like soil data, Land use/Land cover, catchment boundaries and other attribute resources for evaluation of hydrological process. The total area of the present study area was 9.84 Sq km located in Butchayapeta village in Visakhapatnam district. The main objective of the study area was to analyze the hydrological viability of tanks considering various common factors like tank storage, catchment, rainfall, land use/land cover, soil etc. The location map of Amrutha Cascade mentioned below in the Figure 2.1.

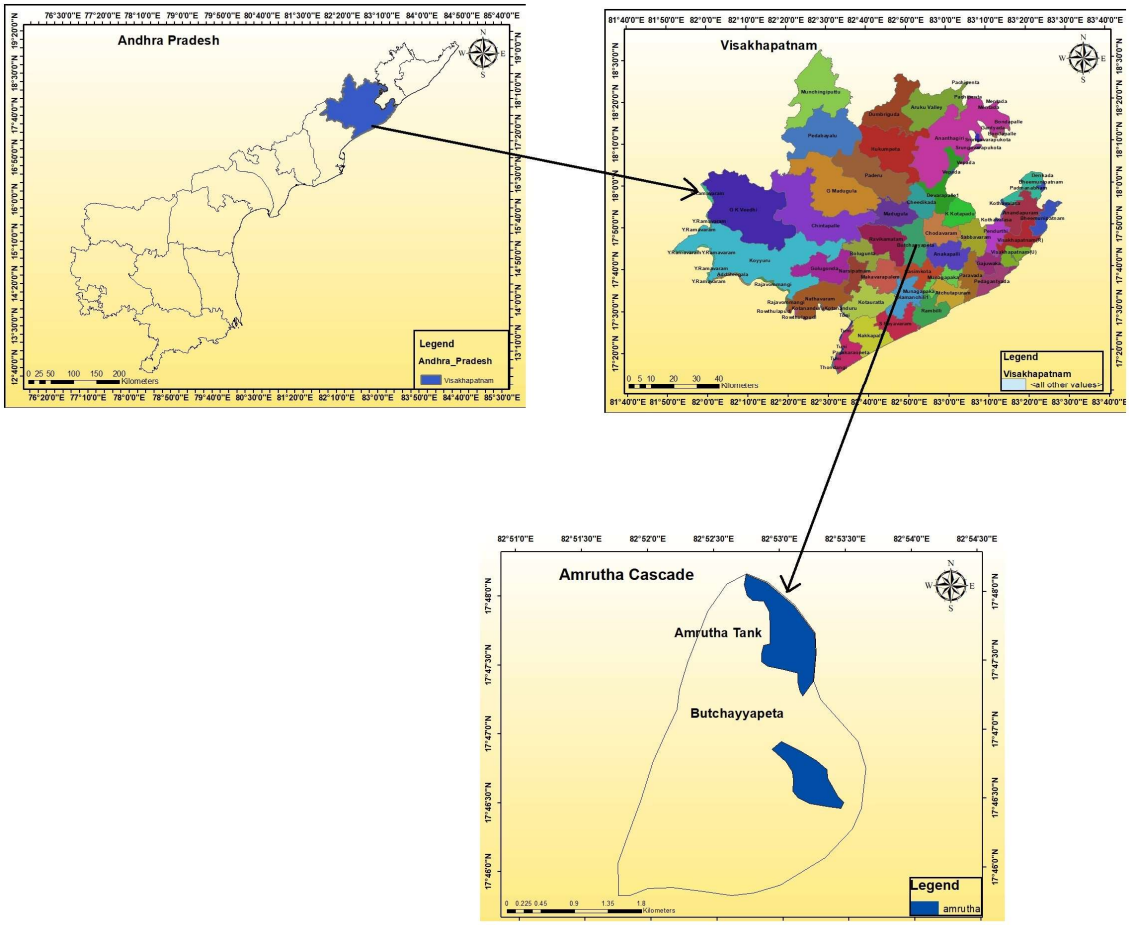


Figure 2.1: Location of map of Amrutha Cascade

3. Methodology:-

The entire work was executed with the help of different software like Arc GIS 10.4, ERDAS Imagine 2014 and Arc SWAT which is compatible to Arc GIS 10.4. For the present study area different data had been taken into consideration to get accurate results. They are Land use/cover, Soil data, drainage map, location map of Amrutha Tank and 27 years of weather data. Soil data was obtained from NBSS & LUP Nagpur Maharashtra. The soil map was prepared based on the hydrological soil group and obtained in raster data. With the help of GIS software the data has been converted into rater data to vector data. At last twenty seven years of rainfall data was collected from IMD using SCS curve number for SWAT simulation.

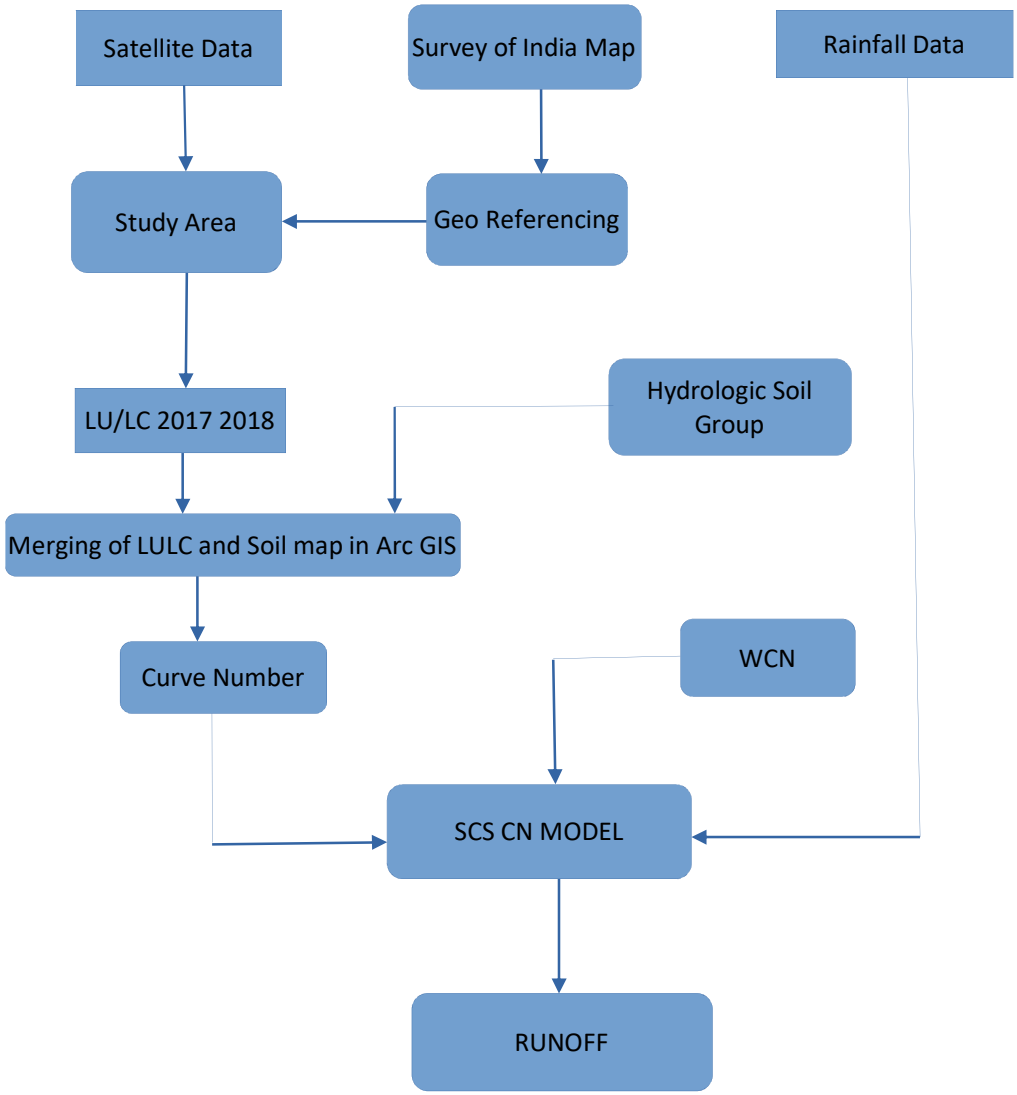


Fig: 3.1 Methodology to estimate the surface runoff by using SCS-CN model.

4. Soil Data:-

Soil data have been collected from NBSS and LUP Nagpur Maharashtra. The soil group has been done based on the properties of soil provided in the form of raster data. Soil erosion was one most predominant environmental problems which affect highly for agriculture production. It also includes sandy soils, loamy soils, clayey loamy soils, Red soils, and clayey soils. The river course is confined by alluvial deposits. In general, the alluvium is inundated by floods during monsoon. The deltaic alluvial soil is distributed along the banks of the River of Sarada River and its tributaries. Throughout the river basin red and laterite soils are distributed mostly. Red soils are derived from weathering processing of Gneissic and chondrite rocks

mostly available in hilly slopes. The soil map was mentioned below in the figure. 4.1.

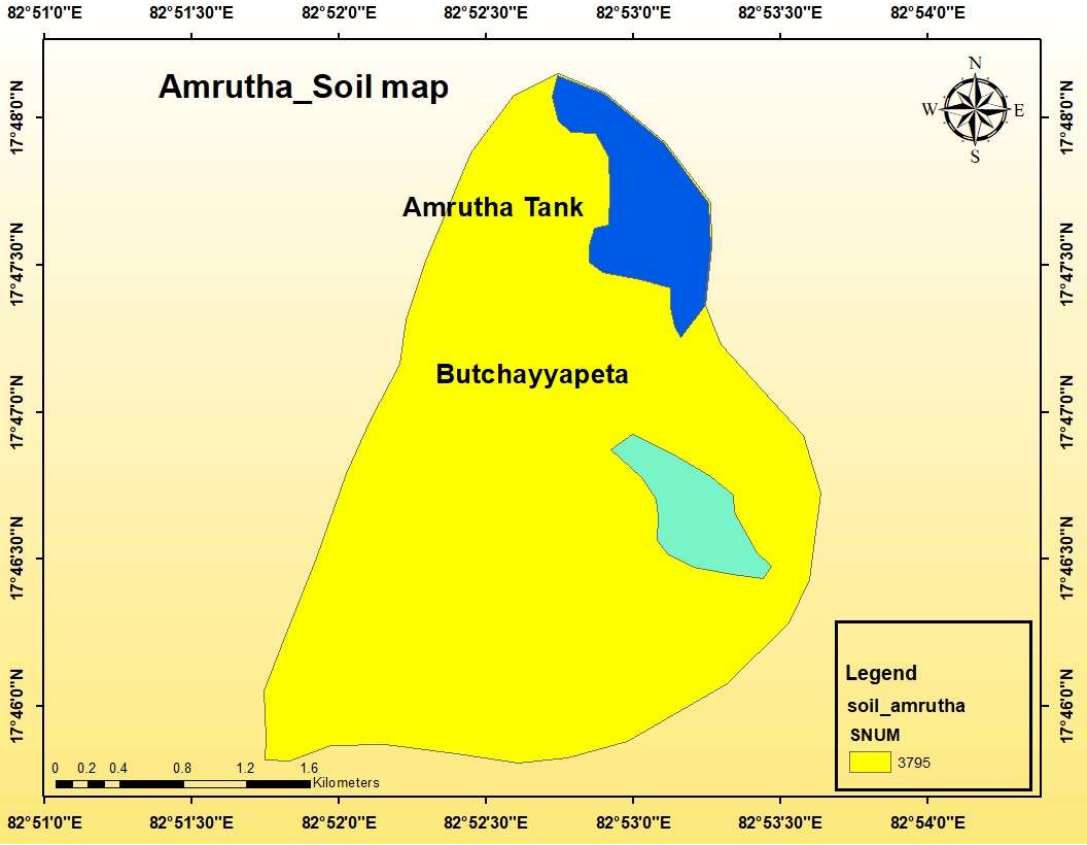


Figure.4.1: Soil map of Amrutha Cascade

5. Soil Conservation Service (SCS) Curve number:-

The SCS CN method was developed in 1954 and it is one of the best methods for calculating surface runoff for a given rainfall from small urban watersheds and forests. This method is very simple, easy to understand, and useful for ungauged watersheds. The main reason is wide acceptability and applicability lies in the fact for accountability producing runoff watershed characteristics: surface condition, soil type, and antecedent moisture condition. This study mainly discusses the existing SCS-CN method. The concepts of factors affecting curve number, the sensitivity of the parameters, advantages, and its limitations. The main objective of SCS-CN was to evaluate the design of soil and water conservation management practices. It is used set up to collect data on rainfall, runoff, and other associated factors. The curve number method was the retention of water measured by soil-water vegetation and land use takes complex values from 0 to 100. In general, the curve number depends on Hydrological soil groups, land use and antecedent

moisture condition. It is a simple model to calculate direct runoff with the help SCS-CN method and the relationship with hydrology is:

S= (24500/CN)-254

Q= ((P-0.3S) 2)/ (P+0.7S)

CN= (Σ(NCi X Ai))/A

Where,

CN= Weighted Curve Number

CNi = Curve number from 1 to any number. N.

Ai= Area with curve number CNi

A= Total Area of the watershed.

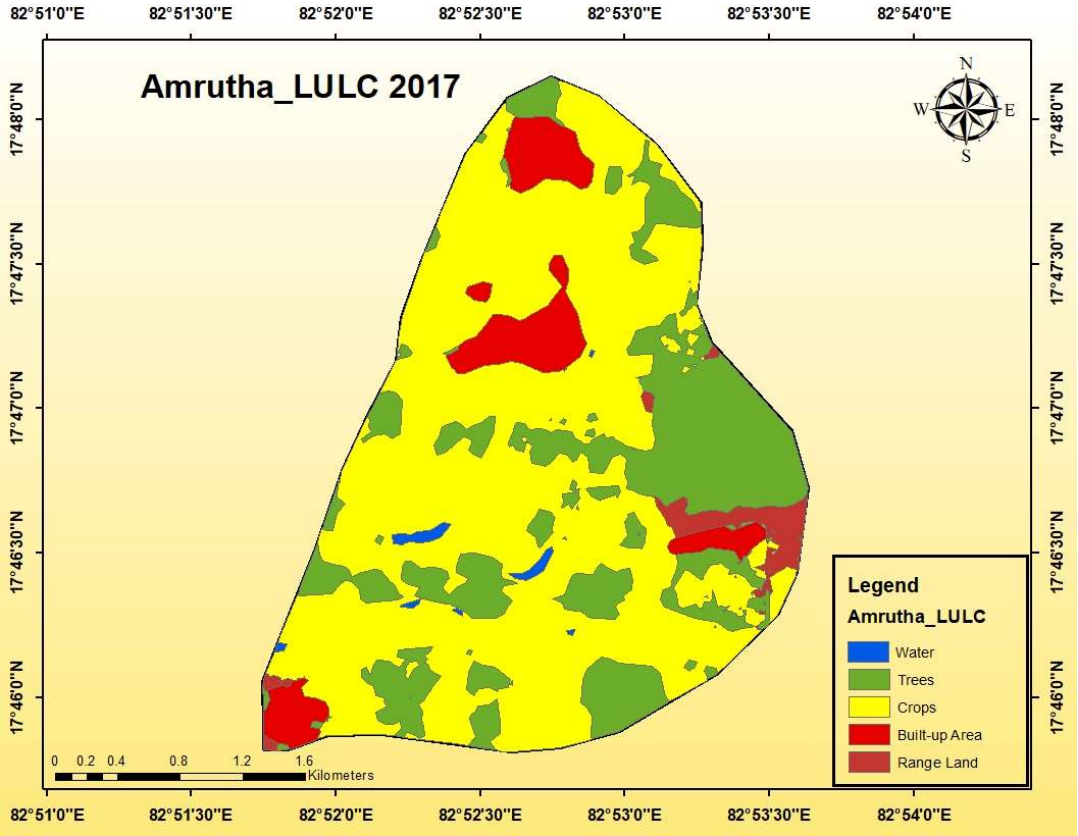
Where CN is the hydrological soil complex of the curve number denoted as CN and it is a function of soil type, Antecedent Moisture Condition (AMC), and land cover type. Q is direct runoff type, mm; P, the total storm rainfall, mm; and S, the potential maximum retention of water by the soil, mm. The runoff curve number method is a procedure to estimate hydrological procedure developed by USDA. It is a method that is developed to estimate the rainfall-runoff on 24 hours basis.

Q = ((R+2) −200)2 /(CN(P R−8)+800)

Where R=2.54, P= Rainfall (mm), Q runoff (Cm).

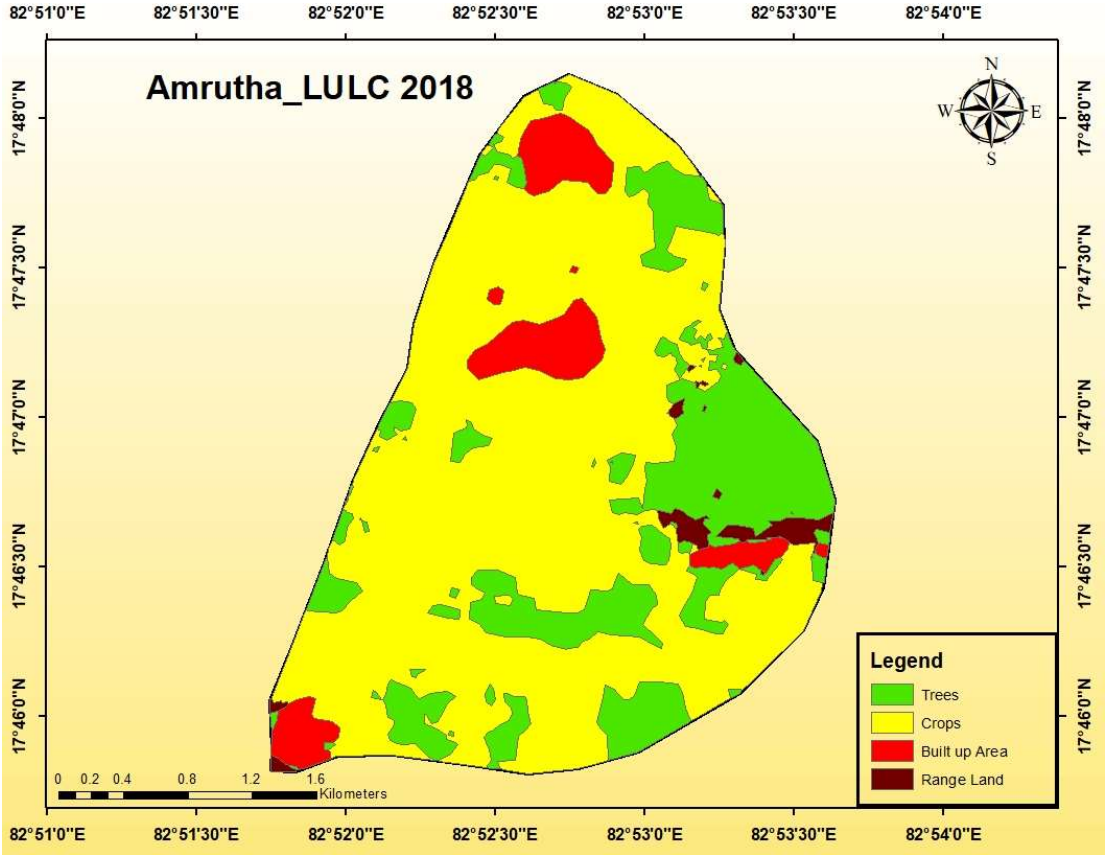
6. Land use/Land Cover:-

LU LC map was prepared by using Sentinal data using four bands having 10 meters resolution. The satellite images for the Amrutha cascade of the year 2017-2018. The obtained satellite images were Geo-referenced with the help of Arc GIS software 10.4. The supervised classification has been done using ERDAS Imagine software 2014. It provides real-time information about land use/ land cover and also plays a very important role in calculating hydrological parameters very accurately by using distributing hydrological parameters. For classification, this method is very important and useful for the study area for the past period years 2017 & 2018. In the present study area, different classes have been identified, they are build-up area, cropland, water body, and scrub lands. All classes are calculated using the attribute table. The obtained thematic map was converted from raster to vector by using ERDAS Imagine 2014 for further analysis.



TAB 1. MAJOR LULC CLASSES OF Amrutha Cascade AND ITS PERCENTAGE TO TOTAL CATCHMENT AREA (TCA) FOR THE YEAR 2017

S.No.	Major LULC Classes	Area (sq km)	Percentage to TCA
1	Trees	1.42	14.43
2	Built-up Area	1	10.16
3	Crops	3.29	33.43
4	Range Land	2.24	22.76
5	Water Body	1.84	18.69



TAB 2. MAJOR LULC CLASSES OF Amrutha Cascade AND ITS PERCENTAGE TO TOTAL CATCHMENT AREA (TCA) FOR THE YEAR 2018

S.No.	Major LULC Classes	Area (sq km)	Percentage to TCA
1	Trees	1.34	13.61
2	Crops	0.51	5.18
3	Built-up Area	4.79	48.67
4	Range Land	3.2	32.52

7. Drainage System:-

The stream order is very important for doing an analysis of any drainage basin present on the earth's surface. Based on the Strahler system of stream ordering method, seven stream orders have been identified. Usually, the first order has been available over the hilly region of the basin. According to the system, the Sarada River of the upper part is found to be a drainage basin of seventh order. Among the seven orders, the first order has a maximum frequency. To increase the order, the stream values are decreased gradually and stream values are matched with Strahler (1964). It shows small variation among the streams from any given order of the streams to the next higher order of the streams in different types regions and environment. The present study area of Amrutha cascade consists of dendritic drainage type.

8. Results and Conclusion

8.1 Drainage and Administration of Amrutha Cascade:-

The present study area of the Amrutha cascade consists of dendritic drainage patterns and mostly develops on the rocks having uniform rock structure and depends on the slope of the Sarada River basin. The first order segments are proportional to the next highest order and the variation will be small and shows the fine texture of the basin and steep slopes. The upper part of the Sarada River basin was found to be the seventh order of the drainage basin. The drainage map of Amrutha Tank has been shown in the figure. 8.1.

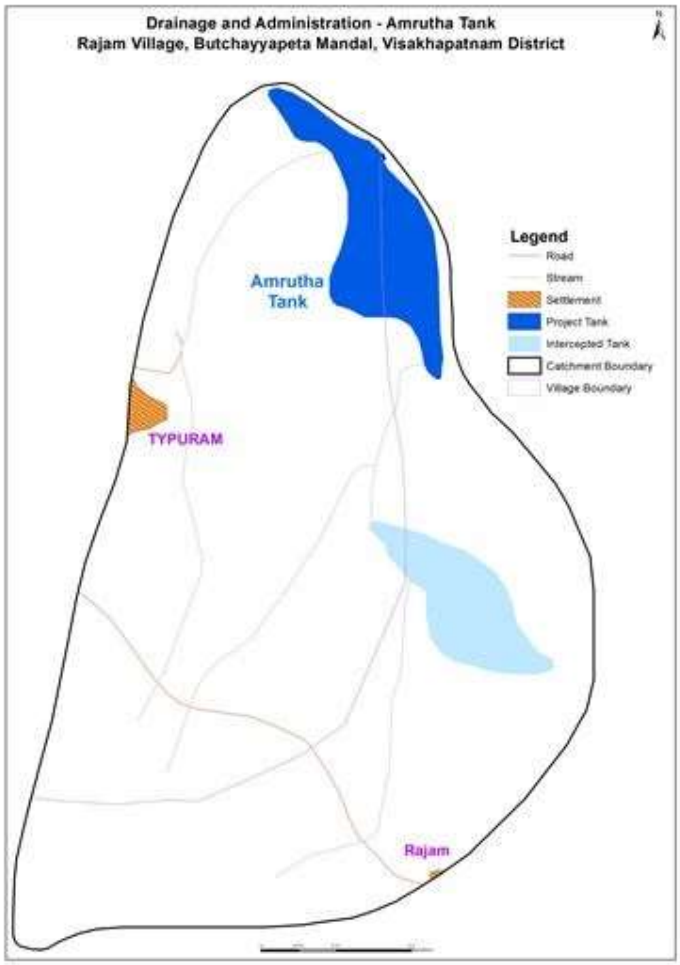


Figure.8.1: Drainage Map

8.2 Hydrological Soil Groups (HSG) of Amrutha Cascade:-

The soil data was collected from NBSS and LUP Nagpur, Maharashtra. On the basis of soil properties were categorized in four types like A, B, C, D. The soil map was digitized and created database by using Arc GIS Software. For each polygon, a number and color was assigned using the software. Unique curve number was assigned to land use and hydrological soil group. The corresponding areas give weighted curve number for Amrutha Cascade. Basically, the weighted curve number is the factor is used for runoff estimation. 82% of yield was calculated for each tank using SCS-CN method in the cascade. Vedurla gadda was source canal for Amrutha Cascade. In the below figure 4.1 Hydrological Soil Group was

mentioned and in the figure 8.2 HSG'S and its distribution of percentage of Amrutha Cascade.

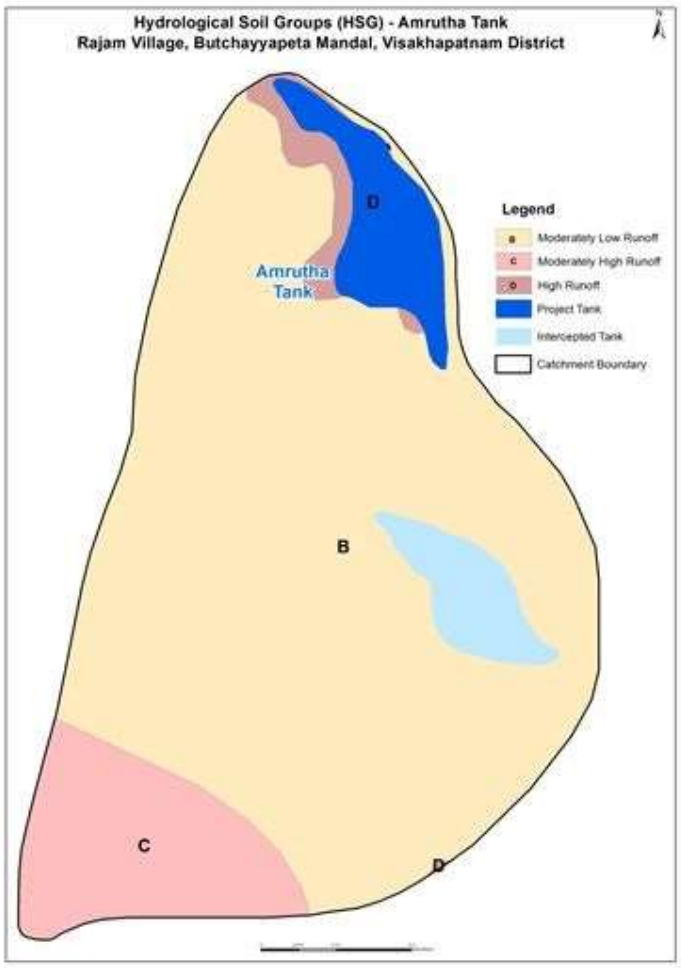


Figure.8.2: Hydrological Soil Group map

Table 1: **HSG'S OF AMRUTHA CASCADE STUDY AREA**

S.No	HSGs of study area	Area in acres	Area in %
1	Low runoff	0.99	40.74
2	Moderately Low runoff	0.44	18.10
3	Moderately High runoff	0.46	18.93
4	High runoff	0.54	22.22

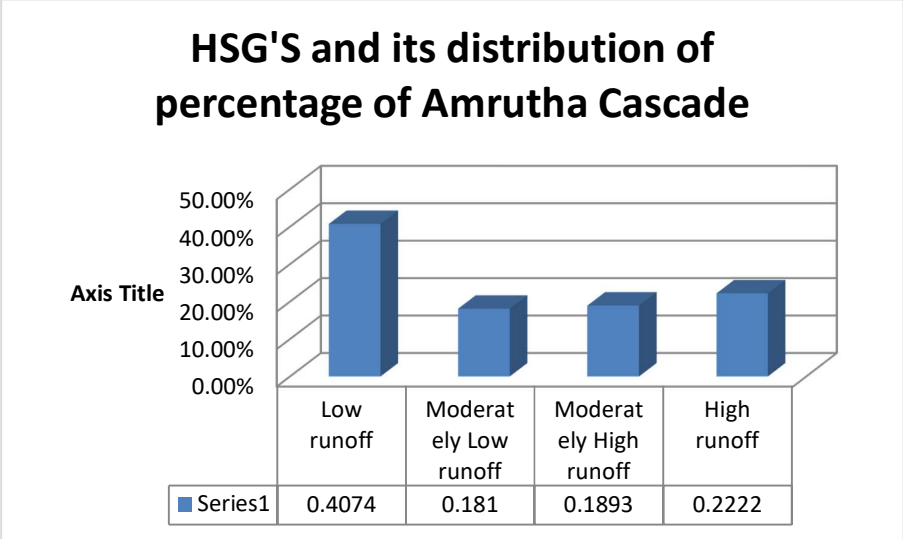


Figure.8.3 HSG'S and its distribution of percentage of Amrutha Cascade.

8.3 Land use/Land Cover:-

The Land use/Land Cover map was prepared by using ERDAS 2014 software. The satellite image was taken into an account to classify the number of classes. For each class 20 samples were collected and all the samples were merged into one class, likewise all the class were done. The supervised classification was run with help of the software and need to reclassify all the classes once again to get accurate results. In this present study area seven classes were identified. They are Agriculture land (20.64%), Agriculture land plantation (25.21%), Built-up area (Rural) (22.89%), Built-up industrial (2.74%), Scrub lands (2.42%), open tanks (13.81%) and normal tanks (12.44%). The LULC map was mentioned below in the figure.8.4.

Table 2: Major LULC classes of Amrutha Tank and its percentage to Total Catchment Area

S.No	Major LULC Classes	Area (sq km)	Percentage of TCA
1	Agriculture land	1.94	20.46%
2	Agriculture land plantation	2.39	25.21%
3	Built-up area (Rural)	2.17	22.89%
4	Built-up industrial	0.26	2.74%
5	Scrub lands	0.23	2.42%
6	Open tanks	1.31	13.81%
7	Normal tanks	1.18	12.44%
Total Catchment Area		**9.48**	**100%**

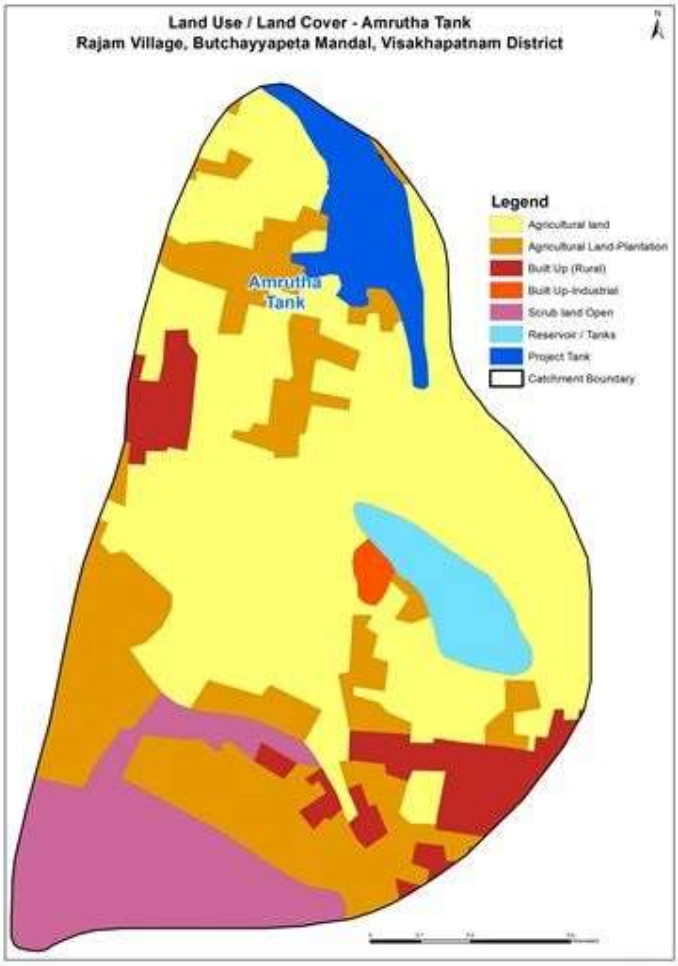


Figure.8.4: LULC map

8.5 Rainfall runoff for Amrutha Tank (mm):-

For sustainable water management, to estimate the quantity of water and development of water resources in urban areas which is available in different resources in urban areas including distant water resources. The availability of water from any source depends upon the watershed and meteorological parameters. The two main factors which effects runoffs in urbanized watersheds are impervious are impervious area and rainfall. There are several models ranging from empirical to physically distributed parameter model which are available for quantifying to generate from watersheds for surface runoff. The present study area carried out the assessment of Amrutha tank to estimate rainfall runoff by using SCS-CN method. The tank has comes under Sarada river basin and one rain gauge station is located near Butchayyapeta. To calculate rainfall runoff, 30 years of rainfall data was collected from IMD

(Indian Meteorological Department). The data was collected and used for analysis and the average rainfall for the particular catchment area was 1062.53 mm. In the Figure 8.5 Average Rainfall and Runoff of catchment area.

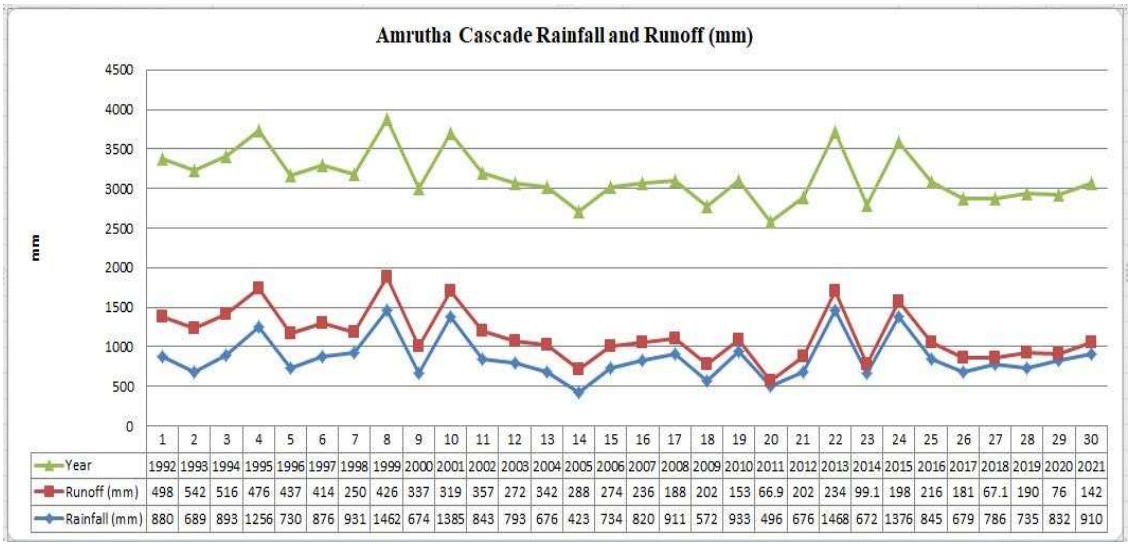


Figure.8.5 Average Rainfall and Runoff of catchment area

Table-3: Amrutha Tank – 82% Dependable yield estimation (Monsoon)

Year	Rainfall (mm)	Runoff (mm)
1992	879.64	498.12
1993	689.36	542.18
1994	893.12	516.1
1995	1256.34	476.18
1996	729.54	437.14
1997	876.23	414.38
1998	931.14	249.58
1999	1462.18	426.12
2000	673.54	337.38
2001	1384.71	319.47
2002	842.74	356.81
2003	793.27	272.16
2004	676.23	342.19
2005	423.19	287.64
2006	734.32	274.13
2007	820.27	236.24
2008	911.13	187.93
2009	571.85	202.14
2010	933.47	153.16
2011	496.39	66.9

2012	676.17	201.68
2013	1468.33	234.18
2014	672.37	99.14
2015	1376.17	198.16
2016	845.14	216.17
2017	678.64	181.14
2018	786.16	67.12
2019	734.87	189.54
2020	832.43	76.04
2021	909.63	142.48

9. Summary and conclusion:-

The present study area used ArcGIS and ERDAS software for assessment of SCS-CN method. It is a simple, easy method to understand and also plays great role to estimate rainfall runoff to get the results easily. The runoff can be estimated by using GIS based curve number used in Hydrological model effectively by using different methods. There are some inputs have taken into account. They are Land use/Land Cover, Hydrological Soil Group, Drainage Map, Satellite data of particular location of Cascade and meteorological data of 30 years. The present Cascade comes under Sarada River basin and the average rainfall of the particular sub-basin is 1062.53 mm. The total area of the catchment is 9.84 Sq km. The data is incorporated into Arc GIS to get accurate results to estimate the runoff by using SCS-CN method. GIS is an efficient tool to prepare most of the data for SCS-CN model. The improvement of the model can be validating by using CN values. Initially the abstraction depends on the catchment characteristics of the season. To calibrate the model properly long measuring is required. In this model daily discharge not giving the good result and observed at many points there is a large deviation for the daily runoff by using LU/LC and different soil conditions. The digital database have been created by using conservation techniques such as percolation ponds, dams etc., for better management of land and water resources can be used for sustainable development of the watershed.

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