PalArch's Journal of Archaeology of Egypt / Egyptology

A Study On Land Use Changes In Southern Part Of Visakhapatnam City Due To Urbanization-A Case Study

[1]P. Shiva Kumar, [2]Dr. G. Venkata Rao, [3]S. S. S. Nitish

[1,3]Assistant Professor, Department of Civil Engineering, Vignan's Institute of Information Technology, Andhra Pradesh, India

[2]Professor, Department of Civil Engineering, Vignan's Institute of Information Technology, Andhra Pradesh, India

Email: [1]sivaplvls@gmail.com, [2]venkataraocbit@gmail.com, [3]nitish210795@gmail.com

P. Shiva Kumar, Dr. G. Venkata Rao, S. S. S. Nitish: A Study On Land Use Changes In Southern Part Of Visakhapatnam City Due To Urbanization-A Case Study -- Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(7). ISSN 1567-214x

Keywords: Urbanization, Forest, GIS, Land use, Land cover, Runoff

ABSTRACT

With the increasing population the need of employment for few people and desire of few others to live in urban areas is increasing day by day. With this drastic increase in urbanization the use of land for various purposes is also changing since the last few years. Few parameters like vegetation cover, quantity of surface water body, forest area, the remaining barren land are major things affected by Urbanization. In this paper a study is made on changes occurred in these parameters in the southern part of Visakhapatnam city covering an area of 54.41sq.km using RS & GIS software by analyzing the satellite images of the years2005, 2010 and 2015. Vegetative cover & Forest cover are found to be varying hugely from 2005 to 2015 due to rapid Urbanization in the city. The study is also focused on to estimation of the runoff depth by using the runoff coefficient method. The runoff depths are estimated for top three highest peak rainfall depths of the rain fall years from 1997 to 2019.It is found that the Surface run off in 2030 will be increased to 25 % of the discharge in 2015 indirectly affecting the ground water recharge.

1. Introduction

Out of 1.383 x10^9km^{3}water on earth, only 3 % is available as fresh water &out of which only 30.1% is present in the soil stratum as ground water as shown in Fig:1. But with the increasing demand, extraction of ground water is increasing day by day and infiltration rate is depleting by effecting ground water table's balance.

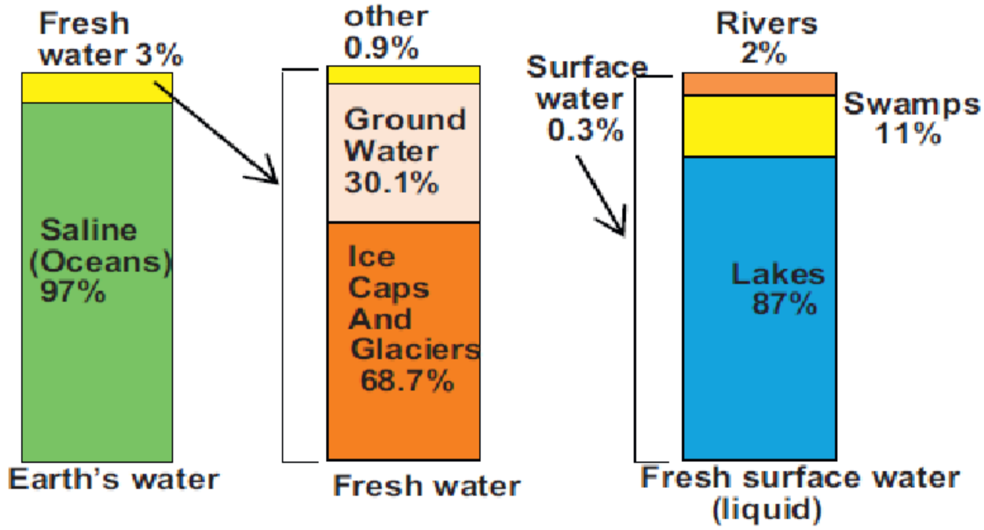


Fig: 1- Earth's water distribution scenario.

In India there is an irregular relationship between its economic growth and urbanization (Sridhar K. S., & Wan, G. H. 2016). Over construction leads to decrease in the permeable strata due to laying of roads and pavements which adversely affect infiltration (Sharp, J. M. 2010). Land use changes has become a global issue with the changes of environmental aspects (Foley J. A. 2005). With the increasing population, the no. of constructions & usage of resources have been increasing. Because of which there is considerable effect on many factors like buildup area, forest cover, vegetative cover, ground water recharge etc., In India the built-up area has changed from 12.02 sq. mts per capita in 1975 to 25.02 sq. mts per capita in 2014. There were also fluctuations in the forest area since the last few decades due to both deforestation and afforestation in various parts of India. So, estimation in the changes of such quantities helps in taking necessary steps towards achieving a better environment, adequate resources and fortunate life.

Land use changes are generally estimated using Remote sensing (RS) and Geo-Informatics system (GIS) by collecting the digital elevation models and analyzing them over years. (Karakus, Cerit, &Kavak, 2015). Along with estimating the land use/cover changes, in this paper we have also estimated the runoff depth changes by runoff coefficient method. It is one the simplest method for runoff depth estimation. Runoff coefficient method can be done with the help of remote sensing (RS) and GIS data. Satellite images, Land use and Land cover, precipitation data are into consideration in this method.

$$runoff = C * P$$

Where C= Runoff coefficient

P= precipitation in mm

Few of the standard values for C is(Singh, Singh, &Haritashya, 2011)

Type of area	**Runoff coefficient**
Urban	0.30–0.50
Forest	0.05–0.20
Parks and pastures	0.05–0.35
Pavements and roads	0.70–0.95
Water body	1

Considering these coefficient values for various land parameter changes like vegetative land, forest area, built up area, barren land from the obtained results using GIS, runoff is estimated (Goel M.K. 2011). The methodology applied in this study is as shown in Chart:1.

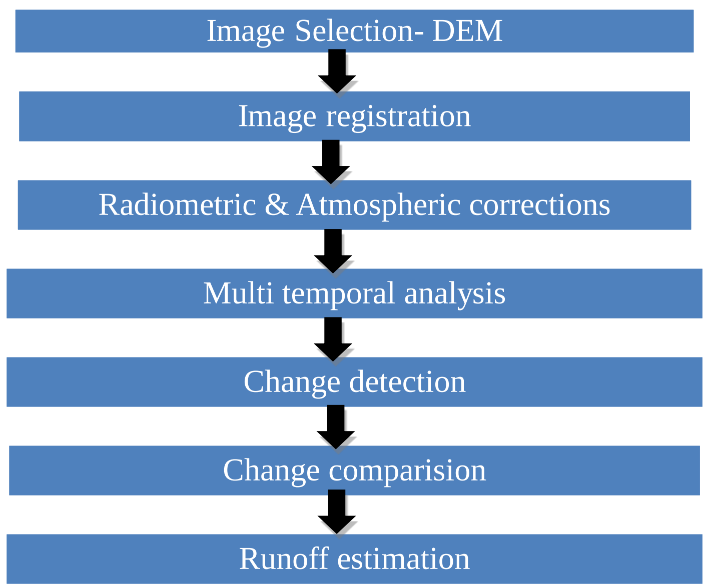


Chart:1- Flow chart of methodology

2. Study Area:

The study area Gajuwaka, NarvaGedda, Narva reserved forest is located between 17°77.71´ to 17°66.91´ Northern latitude and 83°16.142´to 83°23.213´ Eastern longitudes with area of 54.41 km^2. It lies in the southern part of Visakhapatnam City and is loosely bordered by Pedagantyada tothe South and Anakapalle to the East, Sabbavaram to the Northwest, Gopalapatnam to the North, Mulagada to the East. VSD industry, Coramandal fertilizer, Hindustan Petroleum Corporation are few major industries located in the study area. Gajuwaka a sub-urban area located on the southern part of the

Visakhapatnam city is topographically not in the bowl area. However, it is also emerging as a major industrial hub with a cocktail mix of major and minor industries including a minor port posing significant threat to the environment, quality of life and health of the residents. The shape file of the study area is selected from the toposheet of Visakhapatnam. The shape file is created with the help of Arc GIS software using polygon. The shape includes the study area of NarvaGedda, Narva reserved forest, Yerada Konda as show in Fig-2.

Fig:2-Shape file of the study area

3. Runoff Coefficient

Each sub catchment uses a runoff coefficient to characterize the runoff properties for a particular slope and ground cover. The runoff coefficient value is primary an input parameter for the runoff coefficient method, as used by hydro CAD. High coefficient values (such as for built up land= 0.9) is because most of the rainfall will appear as runoff, with minimal losses(infiltration). Lower values (such as 0.05 for lawn areas), correspond to an increased ability of the soil to retain rainfall, and will produce much less runoff. The rain fall data from 1997 to2019 is presented in table 1a& 1b.the raw data is provided in ANNEXURE-1.

Month	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
January	0	19	0	0	8.4	5.0	0	17.0	5.0	0	0	0
February	0	0	0	12.5	0	0	0	0	2\5.6	0	17.0	113.0
March	5.2	0	0	0	0	0	14.8	0	0	9.5	6.0	43.0
April	0	0	0	9.5	20	71.0	0	16.5	17.0	18.4	0	17.5
May	2.0	50.0	11.8	21.0	47.0	0	13.2	18.5	13.0	23.0	17.0	0
June	2.0	58.0	47.0	127.8	16.5	30.5	23.5	60.0	44.5	90.0	59.8	41.0
July	12.0	165.5	11.0	19.5	21.0	31.0	42.0	36.0	22.0	20.0	43.0	30.0
August	22.2	50	29.0	78.5	17.5	33.0	28.0	47.0	70.0	122	22.0	37.0
September	34.4	40.0	15.0	52.0	72.5	16.0	47.0	30.0	132.0	57.0	59.0	53.0
October	4.2	70.0	22.0	87.4	31.0	36.0	100	79.0	191.8	69.0	180.0	45.5
November	40.0	36.0	0	0	104.0	3.9	0	0	36.0	69.0	2.0	9.2
December	23.0	23.0	0	0	7.3	0	46.5	0	0	0	0	0

Table:1a- Monthly Peak rainfall from 1997 -2019

Month	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
January	0	0	0	12.4	4.0	1.2	0	0	0	0	0
February	0	0	44.0	0	8.4	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	34.2	0	33.2
April	0	0	24.2	4.0	8.4	0	26.4	0	0	37.2	30
May	4	107.5	97.2	10.2	16.0	60.4	4.2	170.2	39.2	45.2	12.2
June	70.0	53.0	34.0	18.2	10.2	30.0	97.4	38.2	45.4	15.2	16.2
July	16.4	64.6	143.0	30.0	9.2	24.2	54.2	41	17.6	28.4	13.4
August	19.6	49.0	29.4	36.0	58.4	78.2	5.4	28.2	22.6	46.4	39
September	89.0	76.0	34.0	72.0	0	83.4	46.2	49.8	35.2	276.2	47
October	43.0	119.0	42.0	62.0	148.6	208.2	11.2	24.4	39.2	0	111.2
November	38.0	225	0	184.0	109.0	11.2	132.2	1	2	0	0
December	0	93.3	6.8	0	0	13.0	26.4	0	0	0	0

Table:1b- Monthly Peak rainfall from 1997 -2019

Land Use /Land Cover:

Once the satellite images are extracted from USGS earth explorer, a masked layered image are developed in GIS(Stuebe& Johnston, 1990). This masked image is then delineated using supervised classification in order to get the quantities of required land change features like vegetation, built up area, forest cover, barren land & water body over the years 2005, 2010, 2015 as shown in

Table:2. The detailed DEMs are provided in ANNEXURE-1.

Description	**2005**		**2010**		**2015**	
Features	**Area (Sq.km)**	**Percentage Area**	**Area (Sq.km)**	**Percentage Area**	**Area (Sq.km)**	**Percentage Area**
Forest cover	15.4377	28.3%	13.8537	25.4%	12.7224	23.3%
Water body	03.9926	7.3%	1.8144	3.3%	1.339	2.4%
Barren land	06.5196	11.9%	8.4437	15.5%	6.0887	11.1%
Vegetation	20.3146	37.3%	17.523	32.2%	17.2952	31.7%
Built-up land	08.1459	14.9%	12.7836	23.4%	16.9651	31.1%
Cumulative Area	**54.4104**	**100%**	**54.4104**	**100%**	**54.4104**	**100%**

Table:2- Change in Surface features of the study area over the years 2005, 2010 and 2015.

The supervised classified images of the study area over the years showing the change of various features of land use/ land cover are obtained as shown in Fig:3, Fig:4, Fig:5.

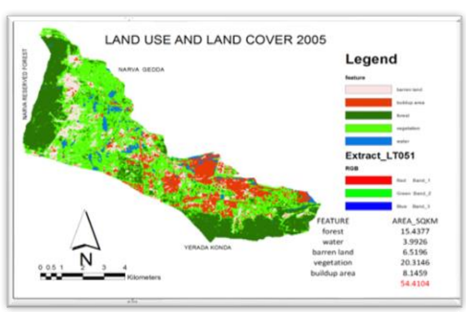
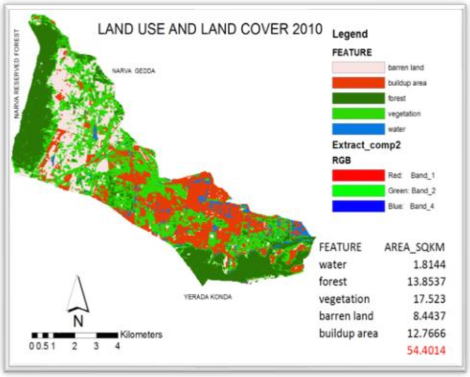


Fig:3-Land use /land cover map of 2005



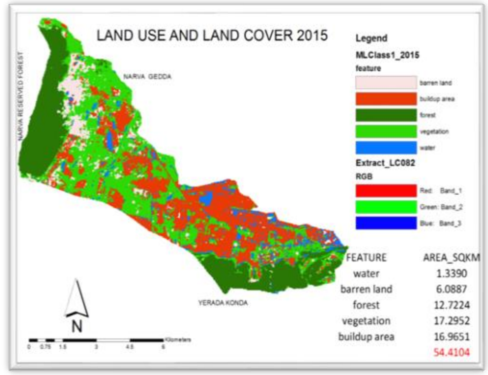


Fig:4-Land use /land cover map of 2010Fig:5-Land use /land cover map of 2015

Land use /land cover Changes from 2005 to 2010 to2015:

A comparision is made between each year to identify the change in land use/ land change features as shown in Table:3.

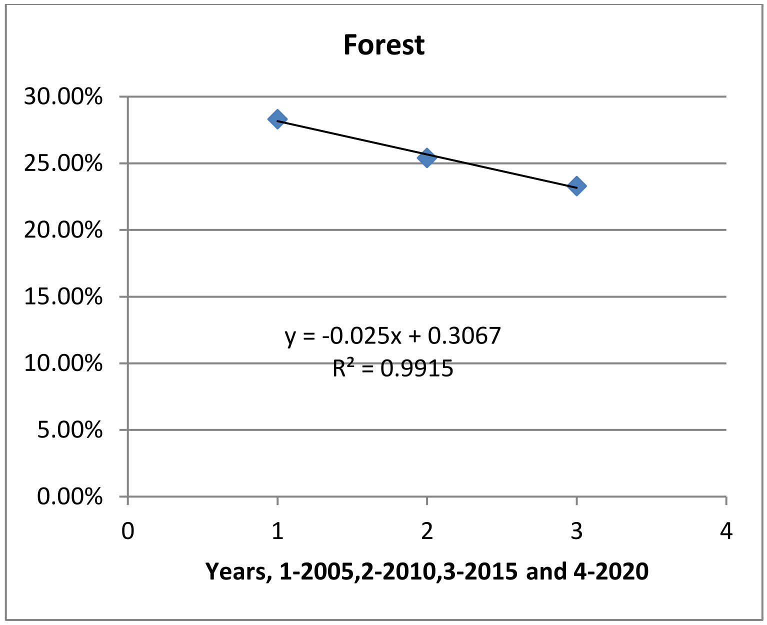
Features	2005 to 2010	Increased by	Decreased by	2010 to 2015	Increased by	Decreased by
Forest cover	28.3% to 25.4%	**-**	**2.9%**	25.4% to 23.3%	**-**	**2.1%**
Water body	7.3% to 3.3%	**-**	**4.0%**	3.3% to 2.4%	**-**	**0.9%**
Vegetation	37.3% to 32.2%	**-**	**4.9%**	32.2% to 31.7%	**-**	**0.5%**
Barren land	11.9% to 15.5%	**3.6%**	-	15.5% to 11.1%	**-**	**4.4%**
Built-up land	14.9%-23.4%	**8.5%**	-	23.4%-31.1%	**7.7%**	**-**

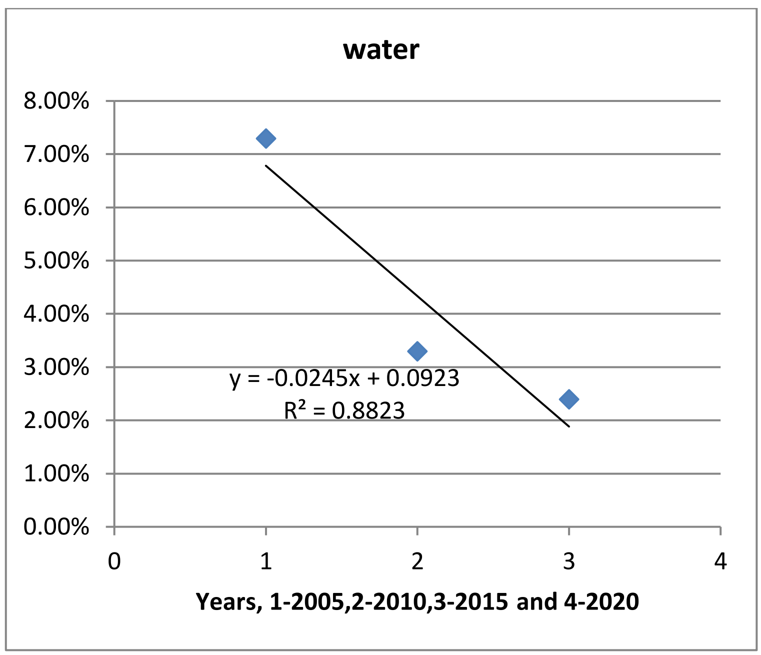
Table:3- Change analysis of Land use/change features between 2005 to 2010 &2010 to 2015

Equations for estimating changes in use of surface area:

Graphs are plotted between the quantity with respect to its corresponding year and an equation is developed for each of the features as shown in Plot:1 for Forest area vs year, Plot:2 for water body vs year, Plot:3 for vegetation vs year, Plot:4 for built up area vs year.

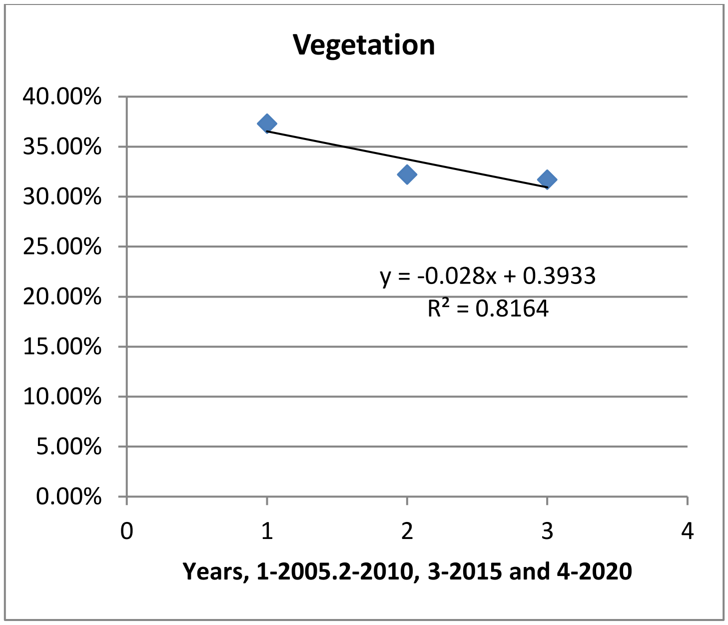
Features	Percentage area 2005	Percentage area 2010	Percentage area 2015
Forest	28.30%	25.40%	23.30%
water	7.30%	3.30%	2.40%
Vegetation	37.30%	32.20%	31.70%
Build-up land	14.90%	23.40%	31.10%

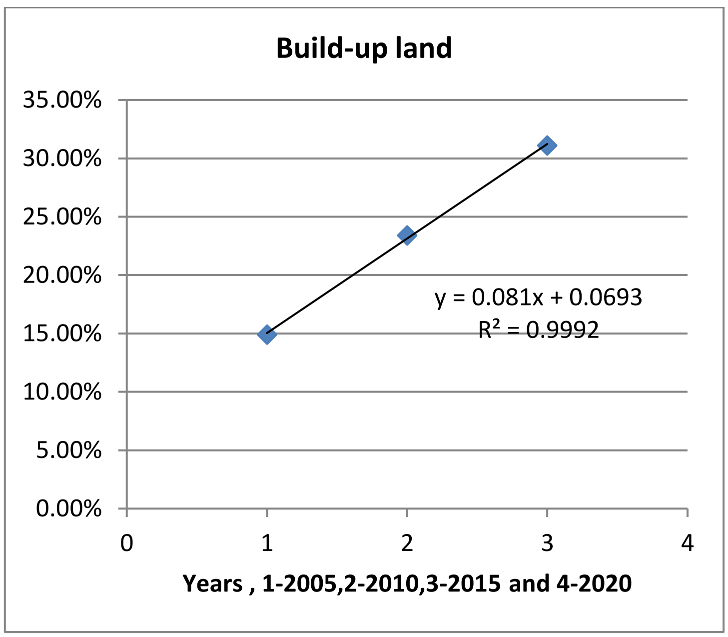




Plot:1- Graph b/t decreased forest area & years Plot:2- Graph b/t decreased water body & years

Using the equations of each feature, the trend in future changes can be estimated by which a clear understanding about the land resources are drawn.





Plot:3- Graph b/t decreased vegetation & years Plot:4- Graph b/t increased builtup land & years

Runoff Estimation for first peak rain fall (1997 -2019)(Zeleňáková, Vranayová, Repel, &Kaposztasová, 2018)[10]:

a) Run off depth

Runoff coefficient is determined as the ratio of runoff to the rainfall; it is dimensionless coefficient. The runoff coefficient values are obtained from the land use/ land cover. The runoff coefficient values taken for Forest (0.2), Vegetation(0.35), Barren land (0.45), Buildup area(0.9) and Water body(1.0)

The peak rainfall data and also the weighted coefficient values in the present study area have been taken into the consideration for estimation the runoff using runoff coefficient method. It requires rainfall data , land use /land cover data for every land use / land cover feature the runoff coefficient will vary. Estimation of Run off depth using peak rain first fall value is 208.2mm in 2014is presented in Table 4.

R=C*P

Where,R =Runoff C = Runoff coefficientP =Precipitation (peak value)

Feature	Runoff Coefficient(C)	Precipitation (P) mm	Runoff (R) R=C*P mm	R = C*P (m)
Forest	0.2	208.2	41.64	0.04164
Vegetation	0.35	208.2	72.87	0.07287
Barren land	0.45	208.2	93.69	0.09369
Buildup area	0.9	208.2	187.38	0.18738
Water body	1.0	208.2	208.2	0.2082

Table:4 - Calculation of runoff depth using second peak value 208.2mm in the year 2004

b)Run off volume

i) The run off volume is estimated with the help of runoff depth and the corresponding surface area of each feature with first highest precipitation value. The calculations of the run off volume for the years 2005, 2010, 2015 land use/land cover surface features are presented in table 5.

Feature	Runoff (R)	Area(Sq.Km) (A) 2005	Area (Sq m) (A) 2005	Volume of Runoff Cu.m= R*A (m3)
Forest	0.04164	15.4377	15437700	642825.8
Vegetation	0.07287	20.3146	20314600	1480324.9
Barren land	0.09369	6.5196	6519600	610821.32
Buildup area	0.18738	8.1459	8145900	831259.3
Water body	0.2082	3.9926	3992600	1526378.7
Total volume of run off				**5091610.02**
Feature (2010)	Runoff (R)	Area(Sq.Km) (A) 2010	Area (Sq m) (A) 2010	Volume of Runoff Cu.m= R*A (m3)
Forest	0.04164	13.8537	13853700	576868.06
Vegetation	0.07287	17.5230	17523000	1276901.01
Barren land	0.09369	8.4437	8443700	791090.253
Buildup area	0.18738	1.8144	1814400	377758.08
Water body	0.2082	12.7836	12783600	2395390.96
Total volume of run off				**5418008.36**
Feature (2015)	Runoff (R)	Area(Sq.Km) (A) 2015	Area (Sq m) (A) 2015	Volume of Runoff Cu.m= R*A (m3)
Forest	0.04164	12.7224	12722400	529760.736
Vegetation	0.07287	17.2952	17295200	1260301.22
Barren land	0.09369	6.0887	6088700	570450.303
Buildup area	0.18738	1.3390	1339000	278779.8
Water body	0.2082	16.9651	16965100	3178920.43
Total volume of run off				**5818212.48**

Table: 5- Runoff volume estimated using first highest rainfall peak

Runoff Estimation for second peak rain fall(1997 -2019)

a)Run off depth

The second peak rainfall data and also the weighted coefficient values in the present study area have been taken into the consideration for estimation the runoff using runoff coefficient method. The data required is rainfall data, Runoff coefficient Values for different surface layers. The Estimations of Run off depth using second peak rain fall value i.e 191.8mm in 2004 year are shown in table:6.

Feature	Runoff Coefficient(C)	Precipitation (P) mm	Runoff (R) R=C*P mm	R = C*P (m)
Forest	0.2	191.8	38.36	0.03836
Vegetation	0.35	191.8	67.13	0.06713
Barren land	0.45	191.8	86.31	0.08631
Buildup area	0.9	191.8	172.6	0.1726
Water body	1.0	191.8	191.8	0.1918

Table:6- Calculation of runoff depth using second peak value 191.8mm in the year 2004

b)Run off volume

i) The run off volume is estimated with the help of runoff depth and the corresponding surface area of each feature. The calculations of the run off volume for the years 2005, 2010, 2015 land use/land cover surface features are presented in table:7.

Feature	Runoff (R)	Area(Sq.Km) (A) 2005	Area (Sq m) (A) 2005	Volume of Runoff Cu.m= R*A (m3)
Forest	0.03836	15.4377	15437700	591418.28
Vegetation	0.06713	20.3146	20314600	1363719.10
Barren land	0.08631	6.5196	6519600	562706.67
Buildup area	0.1726	8.1459	8145900	1405982.30
Water body	0.1918	3.9926	3992600	765780.68
Total volume of run off				4689607.03
Feature	Runoff (R)	Area(Sq.Km) (A) 2010	Area (Sq m) (A) 2010	Volume of Runoff Cu.m= R*A (m3)
Forest	0.03836	13.8537	13853700	530735.247
Vegetation	0.06713	17.5230	17523000	1176318.9
Barren land	0.08631	8.4437	8443700	728775.747
Buildup area	0.1726	12.7836	1814400	2206449.36
Water body	0.1918	1.8144	12783600	348001.92
Total volume of run off				4990281.17
Feature	Runoff (R)	Area(Sq.Km) (A) 2015	Area (Sq m) (A) 2015	Volume of Runoff Cu.m= R*A (m3)
Forest	0.03836	12.7224	12722400	487395.14
Vegetation	0.06713	17.2952	17295200	1161026.78
Barren land	0.08631	6.0887	6088700	525515.697
Buildup area	0.1726	1.3390	1339000	2928176.26
Water body	0.1918	16.9651	16965100	256820.2
Total volume of run off				5358934.07

Table:7 - Runoff volume estimated using second highest rainfall peak

Runoff Estimation for third peak rain fall (1997 -2019)

a)Run off depth

The second peak rainfall data and also the weighted coefficient values in the present study area have been taken into the consideration for estimation the runoff using runoff coefficient method. The data required is rainfall data, Runoff coefficient Values for different surface layers. The Estimations of Run off depth using second peak rain fall value i.e **184mm** in2010 year are shown in table:8.

Feature	Runoff Coefficient(C)	Precipitation (P) mm	Runoff (R) R=C*P mm	R = C*P (m)
Forest	0.2	184	36.8	0.0368
Vegetation	0.35	184	64.4	0.0644
Barren land	0.45	184	82.8	0.0828
Buildup area	0.9	184	165.6	0.1656
Water body	1.0	184	184	0.184

Table:6- Calculation of runoff depth using second peak value 184mm in the year 2004

b)Run off volume

i) The run off volume is estimated with the help of runoff depth and the corresponding surface area of each feature. The calculations of the run off volume for the years 2005, 2010, 2015 land use/land cover surface features are presented in table:9.

Feature	Runoff(R)	Area(Sq.Km) A) 2005	Area (Sq m) (A) 2005	Volume of Runoff Cu.m= R*A (m3)
Forest	0.0368	15.4377	15437700	56808.16
Vegetation	0.0644	20.3146	20314600	1308260.2
Barren land	0.0828	6.5196	6519600	539822.88
Buildup area	0.1656	8.1459	8145900	1348961.0
Water body	0.184	3.9926	3992600	734638.4
Total volume of run off				3988490.64
Feature	Runoff(R)	Area(Sq.Km) A) 2010	Area (Sq m) (A) 2010	Volume of Runoff Cu.m= R*A (m3)
Forest	0.0368	13.8537	13853700	509816.16
Vegetation	0.0644	17.5230	17523000	1128481.2
Barren land	0.0828	8.4437	8443700	699138.36
Buildup area	0.1656	12.7836	1814400	2116964.16
Water body	0.184	1.8144	12783600	333849.6
Total volume of run off				4788249.48
Feature	Runoff(R)	Area(Sq.Km) A) 2015	Area (Sq m) (A) 2015	Volume of Runoff Cu.m= R*A (m3)
Forest	0.0368	12.7224	12722400	468184.32
Vegetation	0.0644	17.2952	17295200	1113810.88
Barren land	0.0828	6.0887	6088700	504144.36
Buildup area	0.1656	1.3390	1339000	2809420.56
Water body	0.184	16.9651	16965100	24637.6
Total volume of run off				4920197.72

Table:9- Runoff volume estimated using third highest rainfall peak

Surface runs off Estimation in coming years:

The Equation for Surface runs off estimation is generated with the help of runoff volumes of the years 2005, 2010 and 2015 presented in Table:10. A Linear Regression equation is developed using a graphical plot as shown in Plot: 5i.e. is y = 3.633x + 47.16 for future run off estimation. In this equation 'y 'is discharge and 'x' is years (increment of five years).

Description	Year-2005	Year- 2010	Year- 2015
Runoff Volume for 1st Peak (105m3)	50.9161002	54.1800836	58.1821248
Volume of Runoff for 2nd peak(105m3)	46.8960703	49.9028117	53.5893407
Volume of Runoff for 3rd peak(105m3)	39.8849064	47.8824948	49.2019772

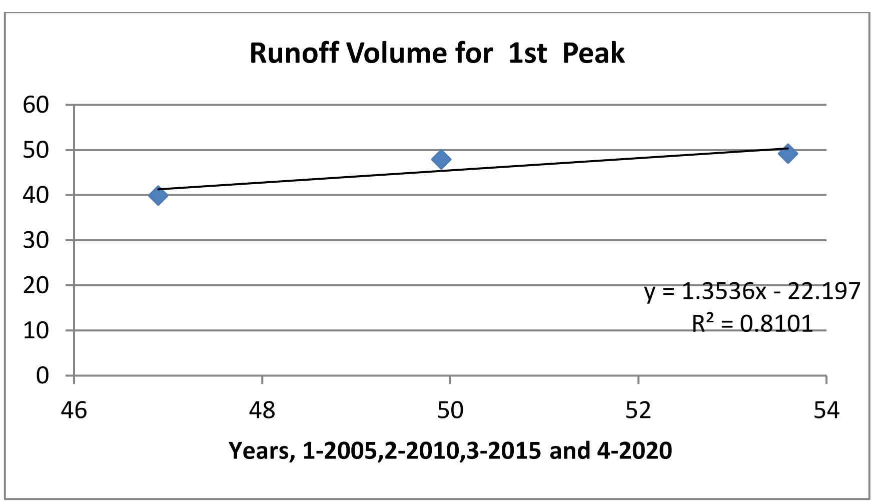
Table:10- Runoff volumes obtained

Direct Runoff volume increament from 2015 to 2030:

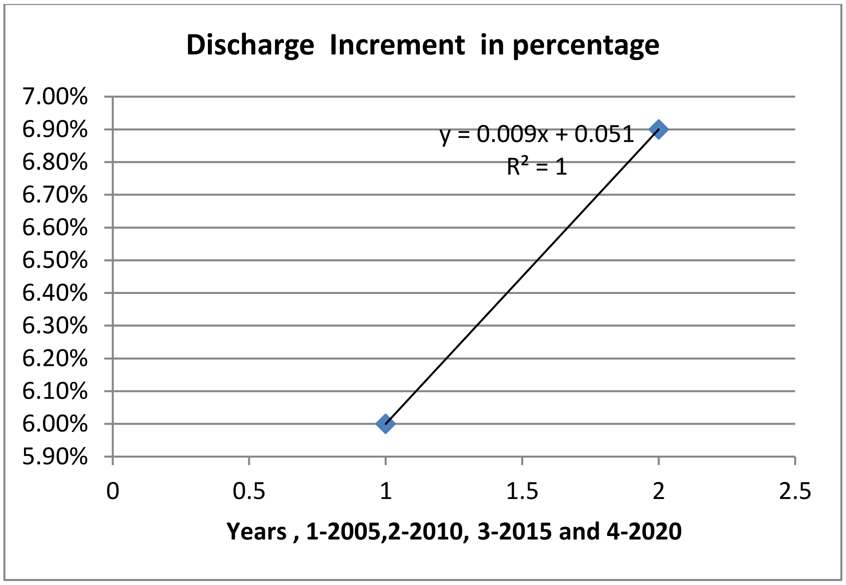
A graph is plotted between the discharge increaments from the 2005to 2010 and 2010 to 2015 As show in plot:6 and develop an equation y = 0.009x + 0.051 where ,'y 'is discharge in percentage and 'x' years(every increment five years) for estimation of percentage increment in the runoff volumes. From the graph the Increment discharge for ever five years are calculated and presented in table 11.It is observed that the discharge /surface run off at 2030 will be increasedby25 % to that ofthe 2015 discharge.

Description	2005 to 2010	2010 to 2015	2015 to 2020	2020 to 2025	2025 to 2030
Discharge Increment in %	6.0 %	6.9%	7.8%	8.7%	9.6%

Table:11- Estimated Increment in runoff %



Plot:5 Graph between run off volume & years



Plot:6- Graph between discharge (%) with years

4. Conclusion:

With the increasing urbanization the usage of land for various purposes like construction, laying of pavements, etc., is increasing day by day in order to meet the needs of people. Even though the infrastructure is developing, the land use changes will have an indirect impact on human and nature in coming future due to reduction in various resources like forest area, water bodies.
As observed from this analysis done and results obtained, few features like built up area have increased and other parameters like forest area, vegetation, & water bodies decreased in the southern part of Visakhapatnam City. Decrease of forest area leads to increased global warming and also increased erosion. Decrease in the amount of water body also leads to scarcity of water resources which will impact human, animal and irrigation in near future. Decrease in the vegetative cover will impact on amount of water getting infiltrated which directly effects the Ground water levels.
So, it is important to manage all the resources to reduce the danger in future. The runoff volume is also increasing as discussed which may lead to minor flooding and blockage of road ways and drainages.

Acknowledgment: The work done is original and few of the data is taken from a third party which is referred an samples are provided in annexure-1.

References

Sridhar, K. S., and Wan, G. H. (2016). *Urbanization in Asia: governance, infrastructure and the environment*. Springer, New Delhi.

Sharp, John M. 2010. *"The Impacts of Urbanization on Groundwater Systems and Recharge."Aquamundi*. https://doi.org/10.4409/Am-004-10-0008.

Foley, Jonathan A., Ruth DeFries, Gregory P. Asner, Carol Barford, Gordon Bonan, Stephen R. Carpenter, F. Stuart Chapin, et al. 2005. *"Global Consequences of Land Use."Science*. https://doi.org/10.1126/science.1111772.

OCED. (1975). *OECD Statistics*, <http://stats.oecd.org/>

Karakus, C. B., Cerit, O., and Kavak, K. S. (2015). "Determination of Land Use/Cover Changes and Land Use Potentials of Sivas City and its Surroundings Using Geographical Information Systems (GIS) and Remote Sensing (RS)." *Procedia Earth and Planetary Science*, 15, 454–461.

Singh, V. P., Singh, P., and Haritashya, U. K. (2011). *Encyclopedia of snow, ice and glaciers*. Springer, Dordrecht.

Goel M.K. (2011) Runoff Coefficient. In: Singh V.P., Singh P., Haritashya U.K. (eds) *Encyclopedia of Snow, Ice and Glaciers. Encyclopedia of Earth Sciences Series. Springer, Dordrecht*

Survey, U. S. G. S.- U. S. G. (n.d.). *EarthExplorer*, https://earthexplorer.usgs.gov/

Stuebe, M. M., & Johnston, D. M. (1990). Runoff Volume Estimation Using Gis Techniques. *Journal of the American Water Resources Association*,*26*(4), 611-620. doi:10.1111/j.1752-1688.1990.tb01398.x

Zeleňáková, M., Vranayová, Z., Repel, A., &Kaposztasová, D. (2018). Surface Runoff in Urban Area – Case Study. *New Trends in Urban Drainage Modelling Green Energy and Technology*, 152-156. doi:10.1007/978-3-319-99867-1_27

ANNEXURE-1

- The software used is ARC-GIS, ARC-MAP version; 10.2.
- The toposheets of the study area are collected from Survey of India-http://www.soinakshe.uk.gov.in/ (E44R1, E44R2&3, E44R4, E44R6)
- The Digital elevation models are extracted from earth Explorer- USGS-https://earthexplorer.usgs.gov/
- Topo sheet of the study area as shown in Fig:1A.

Fig:1.A- Toposheet of Visakhapatnam City

- DEM with study area Delineated as shown in Fig:2.A

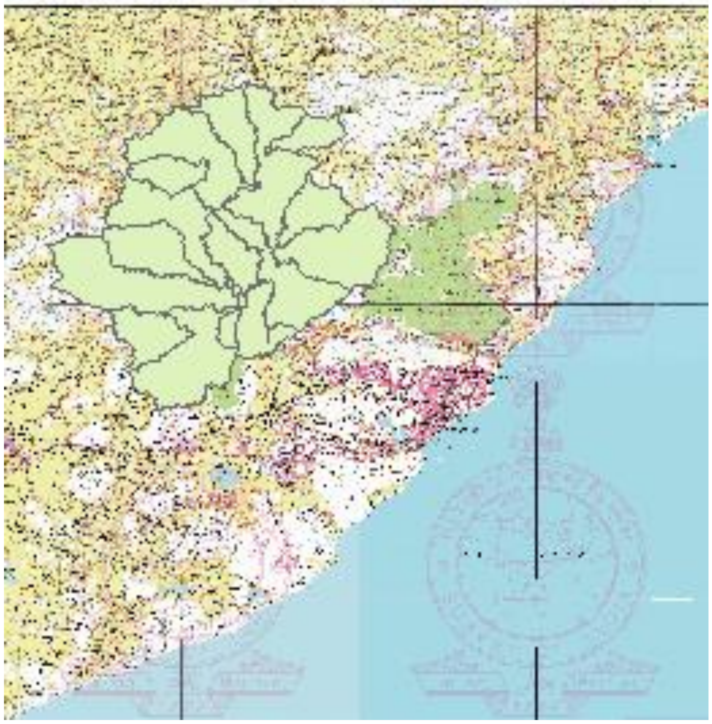


Fig:2.A- DEM after treating in ARCMAP 10.2

- Slope map of the study area generated in the software as shown in Fig:3.A

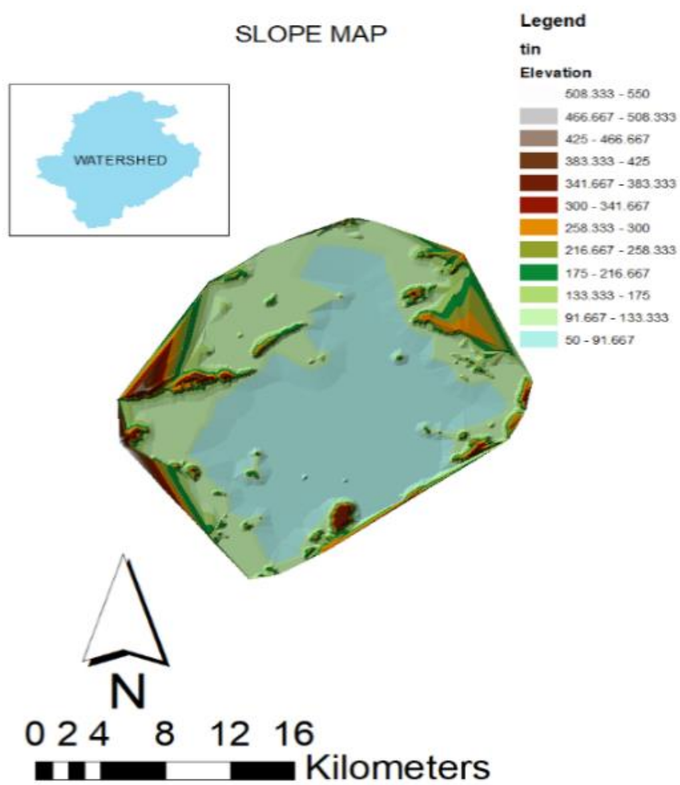


Fig:3.A- Slope map of the study area after delineation

- Supervised image of the study area with legend as shown in Fig:4.A

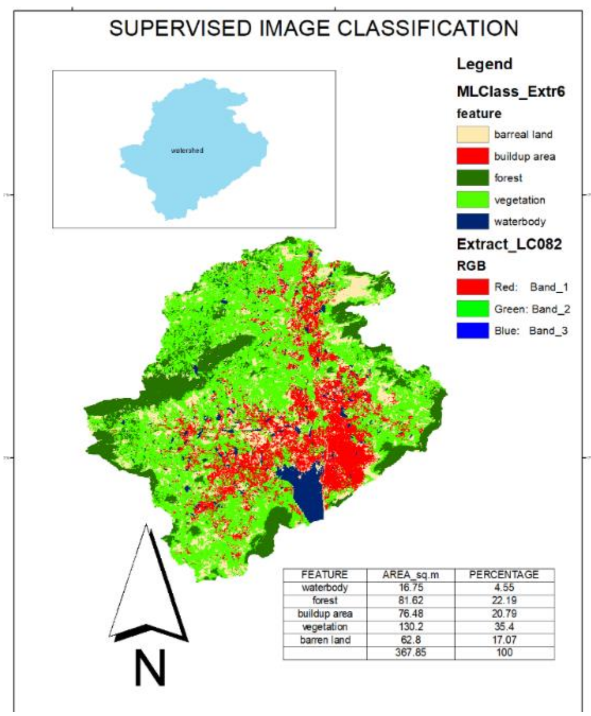


Fig:4.A- Supervised image with land use features

- The raw data collected from GVMC is shown in Fig:5.A

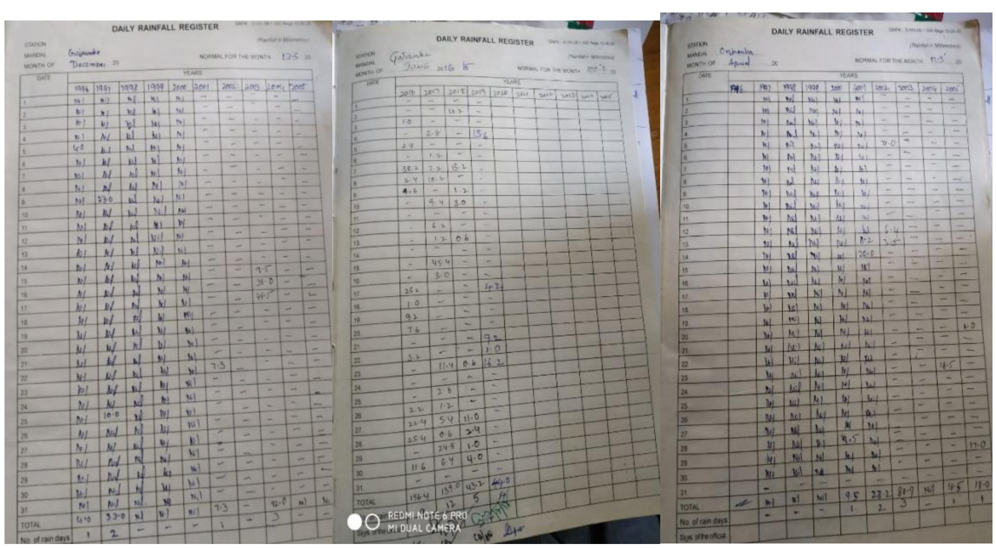


Fig:5A- Samples of Raw data collected from GVMC