International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-10 Issue-3, September 2021

Estimation and Analysis of Rainfall–Runoff for Urban Hydrology using TR-55 SCS–CN and GIS Approach in Hebbal Valley of Bengaluru, South India

Ganesh V, Ajey Kumar V G, Aravindan S, Sudha Ravindranath, Vidya A

Abstract: *Urban floods are increasing frequently and severely. Climate change is usually attributed to urban floods with insufficient evidence. While in certain cases this appears to be true, the influence of landscape change in urban growth is more important. This study analyses development of an urban landscape with the complexity of established cities and combines physiographic data for the assessment of peak surface runoff in the study area, Hebbal valley. A portion of the Cauvery river basin draining into the Pinakini river in the district of Bangalore. It encompasses a 305.21 sq.km region in East Bengaluru and North Bengaluru. The land use and land cover classification was classified as 14 different categories: dark, light, roads and vegetation. The region of study has undergone unpredictable expansion and changes in the Land Use Land Cover in the last two decades. Several flood occurrences have occurred in different regions of Hebbal Valley throughout recent years. Rainfall analysis conducted between 1970 and 2018 with 1596mm of greatest precipitation. For the study, several space and non-space data were collected and thematic maps were produced. Runoff estimates for 2018 were made for 24 micro water sheds in the Hebbal Valley using SCS-CN TR55 technique for urban hydrology. The objective of this study is to determine the quantity of peak runoff produced, to develop better urban management techniques. The finding shows that rush volume has increased in recent years as land use patterns have changed and precipitation intensity has increased substantially over shorter periods. The study suggests spatial intervention efforts to provide suitable buildings and measures for flood flow.*

Keywords: *Curve Number, GIS, Hydrologic Soil Group (HSG), SCS-CN, Runoff Estimation.*

Manuscript received on September 20, 2021.
Revised Manuscript received on September 25, 2021.
Manuscript published on September 30, 2021.

* Correspondence Author

Ganesh V*, Department of Civil Engineering, Sri Venkateshwara College of Engineering, Bengaluru (Karnataka), India. Email: ganesh.v_cv@svengg.edu.in

Ajey Kumar V G, Department of Civil Engineering, Sri Venkateshwara College of Engineering, Bengaluru (Karnataka), India. Email: ajeyhosadurga@gmail.com

Aravindan S, Department of Civil Engineering, Sri Venkateshwara College of Engineering, Bengaluru (Karnataka), India. Email: Aravindan.s_cv@svcengg.edu.in

Sudha Ravindranath, Senior Scientist, Regional Remote Sensing Centre-South, Bengaluru/National Remote Sensing Centre, Hyderabad (Telangana), India. Email: ravindranath_s@nrsc.gov.in

Vidya A, Scientist Engineer 'SE', Regional Remote Sensing Centre-South, Bengaluru National Remote Sensing Centre, Hyderabad (Telangana), India. Email: vidya_a@nrsc.gov.in

I. INTRODUCTION

Flooding interferes with the environment, which causes both the natural and human conditions and the cost of the ecosystem, human costs including death and bodily harm, and sickness. The figures include the cost of medicine, economic costs, social costs and of the ecosystem costs. As socioeconomic activity, infrastructures and human beings are aggregated, the severity and cost of flood damage in cities or metropolitan areas is enhanced and increased. Increased incidence of urban flooding has been linked to urbanisation in flood plain areas [1] [2]. Urbanization increases population and building density, which increases surface screening and impenetrable areas, leading to fast increases in volume and speed of runoff [16]. Urbanization has been shown as a major contributor to the production of artificial floods that have affected the masses of ecosystems and energy dynamism. In 2050 urban development, along with global population growth, could bring 2.5 billion people to cities, with Asia and Africa accounting for almost 90% of that increase, according to the Population Division of the UN Department of Economic and Social Affairs[17][18].

Previous research of different estimation of runoff has shown that SCS-CN is good for our Indian conditions. [3][4] Therefore, this study uses the SCS-CN method, which includes techniques for remote sensing and geographic information systems (GIS), to estimate the study area.

II. STUDY AREA

Hebbal valley is a component of the Cauvery river basin draining into the Pinakini river in the district of Bangalore extending from 13˚02'48"N in latitude and 77˚35'13"E in longitude.. It encompasses a 305.21 sq.km region in East Bengaluru and North Bengaluru as shown in fig 1 and fig 2. Urbanization in Bengaluru is the leading source of conversion of former surfaces to unprecedented concrete and asphalt areas urban floods are a complex occurrence, which can be caused by poor drainage in several forms, such as high intensity rainfall. The main source of floods in Bengaluru is Rainfall. A lot of precipitation has affected a lot of human activities in Hebbal valley.

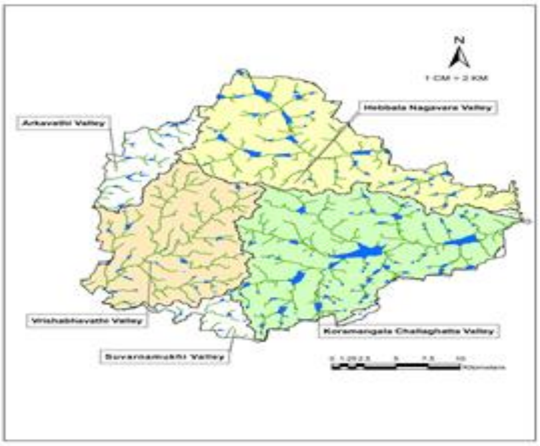


Fig 1. Map showing location of study area &different valleys of Bengaluru

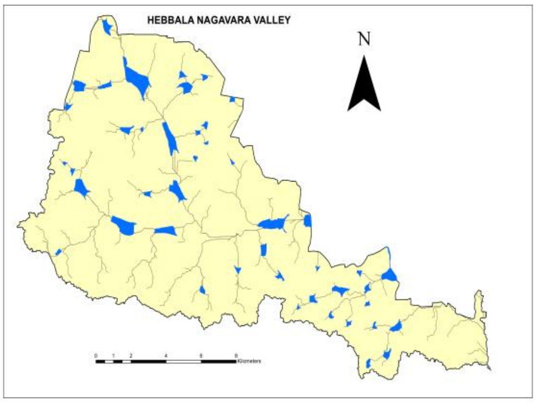
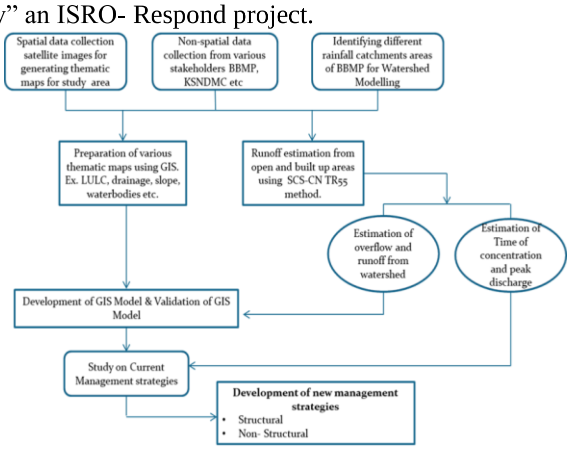


Fig 2. Map showing Hebbal Valley

III. MATERIALS AND METHODOLOGY

Topo maps have been scanned and georeferenced from Survey of India (SOI) on a scale of 1:50,000. The current research utilized multi-spectral Resources satellite data – 2A LIS S IV of 5m resolution, 2.5m resolution Cartosat-1 and 10m digital elevation model (DEM). Visual satellite-image interpolation has been performed using GIS techniques for the research region. The topo sheets were used to designate flow accumulation, drainage, LU/LC, the watershed boundary and other relevant maps necessary for predicting runoff for additional information concerning spatial data. The ground truth assessment was carried out before the thematic maps for the region of research were defined. Flowchart 1depicts methodology of the present studies on "Urban Flood Monitoring and Management using RS & GIS for Bengaluru City" an ISRO- Respond project.



Flow chart 1 Methodology adopted for present study

Runoff was calculated using Micro Watersheds- TR55 NRCS Soil Conservation Service - SCS-CN Model for Urban Hydrology [10]. The soil map was collected by the Bengaluru Karnataka State Remote Sensing and Applications Centre, for the study region, and Rainfall data collected at different locations from the Karnataka Natural Disaster Monitoring Center for Rainfall data for the 2018 study area. For estimation of run-off Land Use Land Cover it was characterised using ArcGIS-10.5 software. The values in the hydrologic soil group and the previous moisture condition in the watershed have been determined. The number of the curve value. Fig 3 shows the thematic maps prepared for study area.

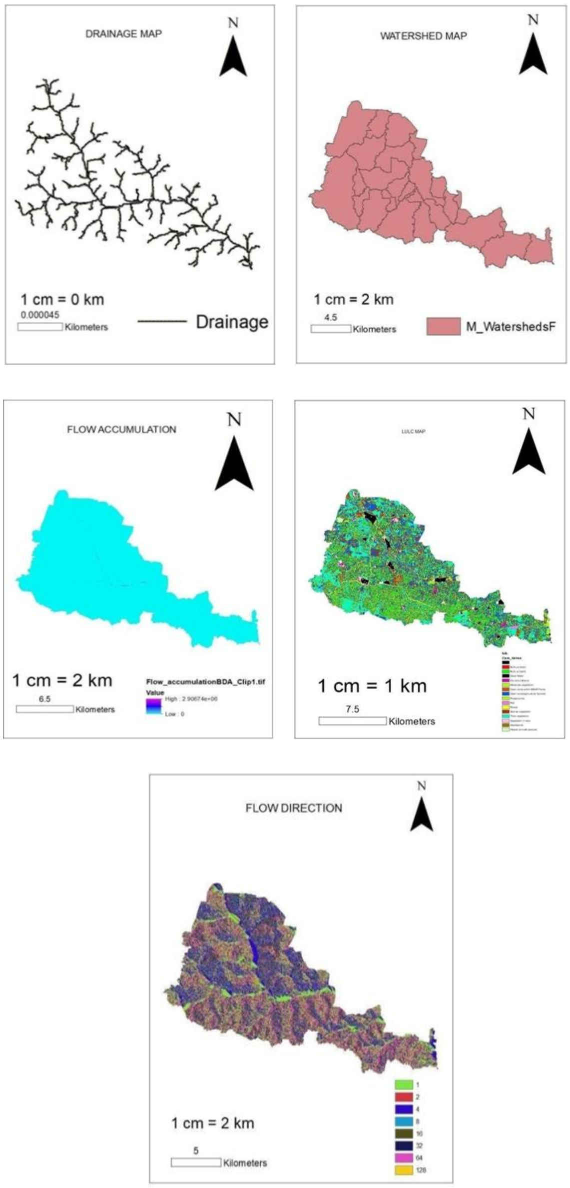
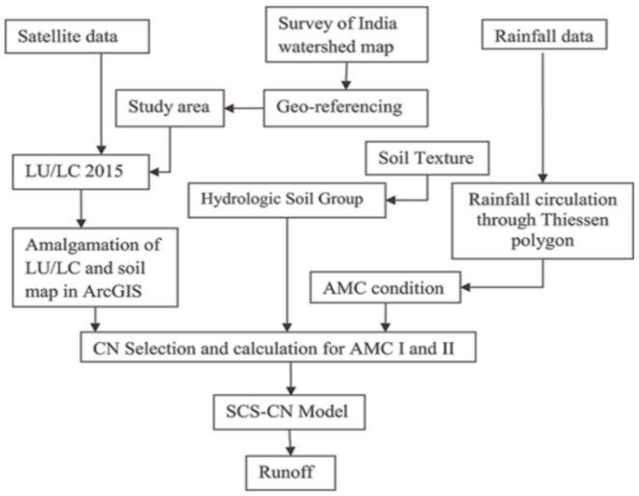


Fig 3. Thematic Maps delineated for study area

The approach for runoff calculation in the current study is presented in Flowchart 2.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)



Flowchart 2 Methodology to estimate runoff by SCS-CN

The SCS-CN approach is normally used empirical method to estimate the quantity of runoff for a catchment [11].

$$Q= (P-Ia)^2/P-Ia+S \quad (1)$$

Where Q is runoff generated in mm, P refers to precipitation in mm, Ia is the initial abstraction in mm and S is potential retention factor. Where,

$$Ia=0.2S \quad (2)$$

For Indian condition, Potential retention factor is given by,

$$S=(25400/CN)-254 \quad (3)$$

Where, CN refers to Curve Number which is taken from Mary C. Halley P.E.et al. cumulative curve number was derived from LULC classifications considering hydrologic soil group (HSG) classifications such as group A, B, C & D. [4][6] Equation rewritten as

$$Q= (P-0.2S)^2/P-0.8S \quad (4)$$

A. Antecedent Moisture Condition

AMC conditions are basically derived as AMC I, AMC II & AMC III it is considered taking care of preceding rainfall events for purpose of runoff modelling. Where AMC I refer to dry condition in past 5 days, AMC II average condition and AMC III refers to wet condition. Table 1 and 2 represents the AMC condition and multiplication factor for associated curve number.

Table 1 AMC for determining the value of CN

AMC Type	Total Rain in Previous 5days	
	Dormant season	Growing season
I	Less than 13mm	Less than 36mm
II	13 to 28mm	36 to 53mm
III	More than 28mm	More than 53mm

Table 2 Multiplication factor for converting AMC II to me and III conditions

Curve number/Weighted curve number for AMC II	Factors to convert from AMC II to III	
	AMC I	AMC II
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	100

B. Calculation of Curve Number

Runoff was calculated using Micro Watersheds- TR55 NRCS Soil Conservation Service - SCS-CN Model for Urban Hydrology. Table 3 represents calculation of weighed CN in study. Figure 4 depicts composition of LULC for one watershed.

Table 3 Calculation of weighted CN for Krishnarajapura Watershed

MICROWATERSHED-23					
RAINGAUGE STATION: KRISHNARAJAPUR					
Rowid	FEATURE_CLASS	AREA_SQKM	%AREA	CN	Product of CN X Area
1	Thick vegetation	1.4838	10.33	71	105
2	Moderate vegetation	0.7626	5.31	73	56
3	Sparse vegetation	1.6276	11.33	76	124
4	Open lands/agriculture/ fallows/	2.7102	18.86	74	201
5	Built-up (dark)	0.8647	6.02	90	78
6	Built-up (light)	4.9452	34.41	80	396
7	Open lands within BBMP Parks	0.0204	0.14	74	2
8	Roads	1.7993	12.52	98	176
9	Rail	0.0529	0.37	98	5
10	Deep water	0.0090	0.06	74	1
11	Vegetation in lake	0.0391	0.27	100	4
12	Weeds (smooth texture)	0.0042	0.03	86	0
13	Dry tank (others)	0.0356	0.25	91	3
14	Playgrounds	0.0152	0.11	91	1
	Total	14.3697			1151

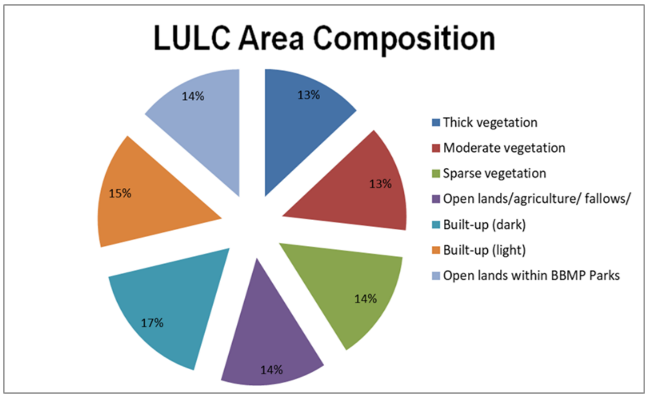


Fig 4 Land Use Land Cover Composition of Krishnarajapura Watershed

IV. RESULTS AND DISCUSSIONS

Calculations of runoff under different AMC conditions have been estimated using SCS-CN as per the TR55 in LULC compositions for 24 different Hebbal Valley micro-watersheds. Figure 5 shows the precipitation trend in the region of Bengaluru for years past and present changes in the precipitation pattern can be seen in 2005 with more than 1596 mm of precipitation [1]. Figure 6 illustrates the percentage deviation trend in rainfall for the study area. Table 4 presents the results of runoffs from watersheds adopting SCS-CN for particular 2018 precipitation events. For the study area, the figure 5 displays the trend of rainfall.

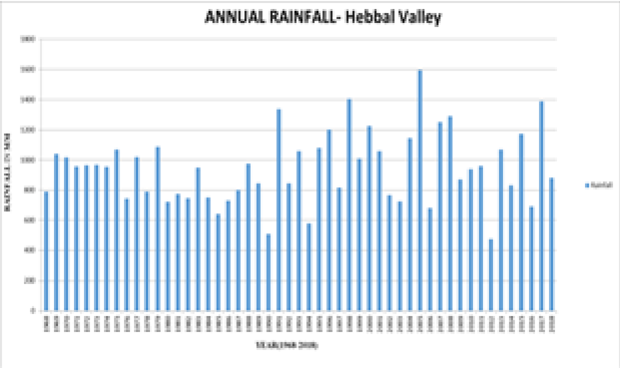


Fig 5 Rainfall analysis for Hebbal Valley

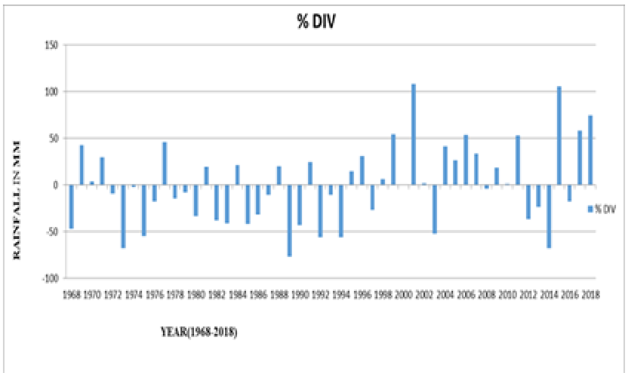


Fig 6 Rainfall deviation for Hebbal valley

Table 4 Sample calculation of amount of runoff generated

DATE	RAIN FALL (mm)	AMC (condition)	CN	S	Runoff (Q)in mm	Q in m	Area of Watershed in m²	Total Volume of runoff in m³
Sep-14	15.8	1	63.2	147.30	0.000	0	14369675	0
Sep-15	23.0	1	63.2	147.30	0.000	0	14369675	0
Sep-16	1.5	3	91.3	24.09	0.000	0	14369675	0
Sep-17	42.8	3	91.3	24.09	23.239	0.02324	14369675	333932
Sep-18	7.2	3	91.3	24.09	0.211	0.00021	14369675	3027.84
Sep-19	0.0	3	91.3	24.09	0.000	0	14369675	0
Sep-20	0.2	3	91.3	24.09	0.000	0	14369675	0
Sep-21	4.1	3	91.3	24.09	0.000	0	14369675	0

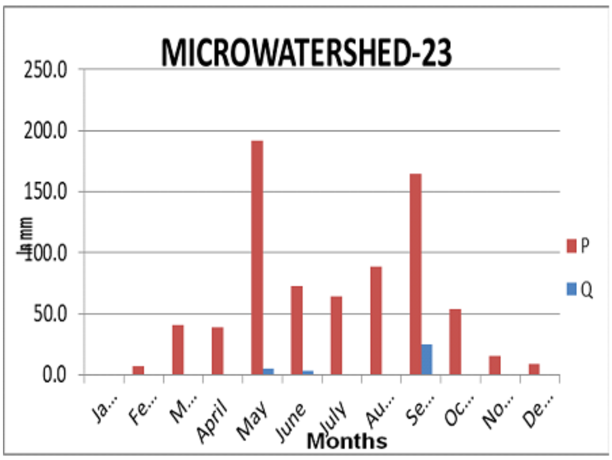


Fig. 7 Runoff variation for the year 2018

Fig 7 shows the variation in rainfall-runoff for the various months of 2018, it is seen that in the month of September highest runoff was generated in particular watershed of Krishnarajapura of Hebbal Valley.

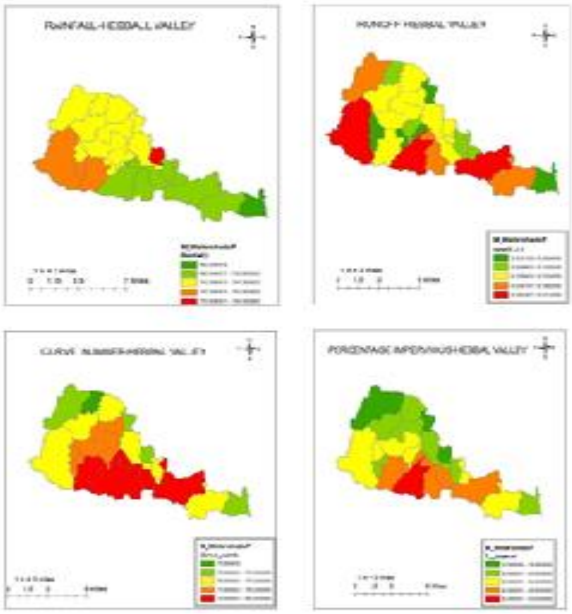
Table 6 Calculation of Peak Discharge

Peak Discharge		
Drainage Area, Am	5.55	mi²
Runoff curve number	80	
Time of Concentration, Tc	11.27	hr
Rainfall Distribution	II	
Rainfall, P (24hr)	42.80	mm/day
	1.69	in/day
Initial Abstraction, Ia	0.41	in
Ia/P	0.24	
Unit Peak Discharge (Graph), qu	500.00	csm/in
S	2.48	
Runoff Q	0.39	in
Peak Discharge, qp	1068.11	cfs
	30.25	m³/s

Table 6 Calculation of Time of Concentration

Time of Concentration (Tc)		
Flow Length	7529.67	ft
Watercourse slope, s	0.01	%
Average Velocity, V	0.19	ft/s
Time of concentration, Tc	11.27	hr

Time of Concentration and Peak discharge is calculated as per TR 55 for urban watersheds as shown in Table 5 and Table 6 for Krishnarajapura watershed and the same is conducted for other watersheds of study area. Results extracted from satellite imageries and results obtained from runoff estimation is incorporated in database of GIS using ArcGIS software and Fig 8 shows various GIS thematic maps consisting % impervious, curve number, rainfall, runoff, volume of runoff, mean daily intensity, peak discharge and time of concentration for various micro watersheds of Hebbal Valley.



Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

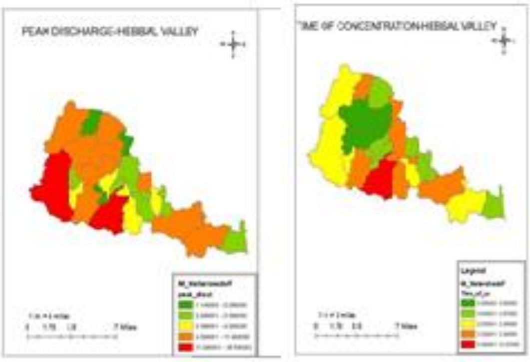


Fig 8 Results of the study incorporated in GIS

V. CONCLUSION

Rapid evolution and encroachment are a major cause of flooding in the city of Bengaluru. The area under consideration is frequently damaged by floods without rainy season constraints. Over 50 per cent of total annual precipitation is recorded in August, September and October in 2005 with maximum annual precipitation of 1596 mm. For the study the satellite image, precipitation details were obtained. The study field subject maps were generated, such as accumulation of flow, flow direction, drainage, land use, etc Runoff estimates for Hebbal Valley for the year 2018 were calculated for the 24 micro-watersheds of the research region using SCS-CN TR-55 for an urban hydrologic approach and time of concentration. The results and additional computations of the runoff estimates have been included in GIS and a map has been developed. A short assessment on management strategy for storm-water runoff has been collected in several nations and an appropriate technique has been derived to be adapted to the current urban context. The rise in concrete surfaces and the conversion into impermeable layer of former strata was a severe negative, leading to flooding in the study area. The main concerns for smooth administration of life are disasters. Uninterrupted movement of persons must be taken care of. Lakes and rajakaluve precipitations cause the incidence of flash flooding in order to properly maintain the existing structures and to recommend and design a better management strategy for the field of research. The flood results in the study region and practical data on floods have been matched in the study area. Studies have also shown that action on present management methods must be taken and storm water management approaches must be integrated for the city of Bangalore.

ACKNOWLEDGMENT

Author gratefully acknowledges the financial assistance and facilities provided by Indian Space Research Organisation (**ISRO**), under the ISRO-RESPOND scheme ISRO/RES/4/667/18-19, and special thanks to Dr. K Ganesha Raj, General Manager, Dr. K S Ramesh, Sci/Engr 'G' & Head Applications RRSC-South, NRSC/ISRO, Bengaluru, for their valuable suggestions during the project. In addition, authors acknowledge Sri Venkateshwara College of Engineering, Bengaluru, for providing necessary encouragement, manpower and technical facilities for carrying out the project.

REFERENCES

1. Rajakumara H N et al. (2019) Rainfall analysis of Vrishabhavathi Valley in Bengaluru Region, International Journal of Recent Technology and Engineering.
2. R K Somashekar et al.(2011) Runoff estimation and morphometric analysis for Hesaraghatta watershed using IRS-1D LISS III FCC Satellite data, J Indian society of Remote Sensing, March 2011.
3. Ishtiyaq Ahmad et al. (2015) Application of curve number method for estimation of runoff potential in GIS environment, 2nd International conference on Geological and Civil Engineering.
4. Pradeep Raja K.P et al. (2019) Runoff estimation using SCS-CN method for degrading lakes/tanks: a case study of Bilikere and Halebidu tanks, Karnataka (India), J. Ind. Geophys. Union (January 2019) v.23, no.1, pp: 69-84
5. Dhawale, A.W., 2013. Runoff estimation for Darewadi watershed using RS and GIS. Int. J. of Recent Technology and Engg., 1, 46–50.
6. Pandey, A., Chowdary, V.M., Mal, B.C. and Dabral, P.P., 2003. Estimation of runoff for agricultural watershed using SCS curve number and geographic information system. Map India conference proceedings, Agriculture India., 307, 1213–1229.
7. Satheeshkumar, S., Venkateswaran, S. and Kannan, R., 2017.Rainfall–runoff estimation using SCS–CN and GIS approach in the Pappiredipatti watershed of the Vaniyar sub basin, South India. Modeling Earth Systems and Environment, 3(1), 1-8.
8. USDA-NRCS., 1986.Urban hydrology for small Watersheds, TR55, United States Department of Agriculture, 210-VI-TR-55, 2nd edn, June 1986.
9. Rao, B.S.P., Amminedu, E., Rao, J., Srinivas, N. and Rao, N.B., 2011. Run-off and flood estimation in Krishna River delta using remote sensing and GIS. J. Ind. Geophys. Union, 15, 101–112.
10. TR55- for urban hydrology.
11. K. Balakrishna et al. (2019) Runoff estimation of watershed in Hemavathy basin using GIS based SCS-CN method, International Journal of Current Engineering and Technology.
12. Rajakumara H N et al. (2019) Rainfall analysis of Vrishabhavathi Valley in Bengaluru Region, International Journal of Recent Technology and Engineering.
13. Anand, B. K. (2004). Integrated approach for watershed development using remote sensing and geographic information system, M.E. Thesis Department of Civil Engineering, accepted by Bangalore University, Bangalore.
14. Tripathi, M. P. (2002). Runoff modelling of a small watershed using satellite remote data & GIS. Journal of the Indian Society of Remote Sensing, 30(1&2), 40–52.
15. Mishra SK, Jain MK Singh VP (2004) Evaluation of the SCS–CNbased model incorporating, antecedent moisture. Water ResourManag 18:567–589,2004. Kluwer Academic Publishers.Printed in the Netherland.
16. Ansah, S.O., Ahiataku, M.A., Yorke, C.K., Otu-Larbi, F., Yahaya, B., Lamptey, P.N.L., Tanu, M., 2020.Meteorological Analysis of Floods in Ghana [Research Article]. March 24. Advances in Meteorology, Hindawi. https://doi.org/10.1155/2020/4230627.
17. Aram, F., Higueras Garcia, E., Solgi, E., Mansournia, S., 2019.Urban green space cooling effect in cities.Heliyon 5, 1339. https://doi.org/10.1016/j.heliyon.2019. e01339.
18. Rafiq, F., Ahmed, S., Ahmad, S., Khan, A.A., 2016. Urban floods in India. Int. J. Sci. Eng. Res. 7 (1), 14.Ravari, A.A., Mazloomi, M., 2015.A framework for urban morphology with respect to the form. Journal: ARMANSHAHR SPRING-SUMMER 8 (14), 91–103.

AUTHORS PROFILE

Mr. Ganesh V, Assistant Professor, Civil Engineering Department, Sri Venketeshwara college of Engineering, Bengaluru. M.Tech in Geo informatics at Karnataka State Remote Sensing Application centre, Bengaluru, BE Civil Engineering at Sir M Visvesvaraya Institute of Technology, Bengaluru.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Mr. Ajey Kumar V G, Junior Research Fellow- ISRO RESPOND, Sri Venkateshwara College of Engineering, Bengaluru. Studied M.Tech in Construction Technology from BMS College of Engineering, Bengaluru. Published various research articles in national and international journals and conferences on various fields of civil and environmental engineering. Actively involved in R & D works, guided student projects on GIS and training for students on GIS.

Mr. Aravindan S, Assistant professor, SVCE, Bengaluru. Having 5yrs of experience in Water Resources Engineering, graduated from College of Engineering, Guindy and pursued B.E in Civil Engineering from Anna University, Chennai. I have published my research in SCI journals. My project on WDS design for rural area is recognized by KSCTC.

Dr. Sudha Ravindranath, Senior Scientist at RRSC-South, Regional Centre of National Remote Sensing Centre, Hyderabad, an Unit of Indian Space Research Organisation, Government of India. With a background in Physics & Geography, she has Masters from Gujarat University and Ph.D from Bangalore University. Her areas of specialization include Remote Sensing & GIS, Urban Geography and Archeology etc. She has worked on a number of national and regional level projects and published papers in national and international journals of Remote Sensing (RS) & Geographic Information System (GIS). Some of the prestigious projects she has handled using Geospatial Techniques are Cultural Resources Management planning of Hampi, a World Heritage Site of UNESCO, Inventory and Site Management Plans of Heritage Sites and Monuments of national Importance (SMARAC), Space Based Information System for De-Centralized Planning (SISDP) for South India, and many more.

Smt. Vidya A. Scientist/Engineer 'SE', Regional Remote Sensing Centre-South, Bengaluru/National Remote Sensing Centre, Hyderabad. M.tech Remote Sensing and GIS from IIRS, Dehradun. Life Member Indian Society of Remote Sensing. Given many invited talks on applications of Remote Sensing and GIS in various training programmes organized in-house and outside departments.

Retrieval Number: 100.1/ijrte.C64840910321
DOI: 10.35940/ijrte.C6484.0910321
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)