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An Assessment of Environmental Issues in Drainage Pattern Analysis Using GIS

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Abstract

Urbanization accompanies the introduction of vast impervious areas and efficient hydraulic conveyance systems resulting changes to an urban setting to dramatically alter the surface hydrology. Remote sensing techniques have been used for monitor the land use changes of Bangalore city over the past five decades (1965-2014) and their impact on natural drainage system. Satellite derived Digital Elevation Model (DEM) and topographic sheets are used to delineate natural drainage pattern of the study area. In this study, corona and LISS-IV data is used along with other ancillary data like rainfall and flow data. Using visual interpretation and field knowledge of the area the surface water bodies/Tanks/Lakes and drainage network was delineated using GIS tool. The results revealed that water bodies were reduced in number and surface area, shape, and some portions of crop lands were converted into built-up areas. SRTM DEM is used for evaluation of morphological parameters like density, slope, stream length etc. Based on pour point and drainage pattern, the entire study area was demarcated as three watersheds. The surface runoff has been generated using Strom Water Management Model (SWMM), which operates on a basis of sub catchment areas precipitation. The runoff volumes obtained from SWMM tool and manual method are compared.

Keywords: *Storm Water Management Model, Geographical Information System, Digital Elevation Model, LISS -IV*

INTRODUCTION

Urbanization represents a modification of the natural conditions of a watershed. The main features of natural areas modified by urbanization and directly related to the quantity and rate of storm water runoff. Currently, the characterization of urban drains and its pattern and their differences with respect to natural basins is based on the description of the infiltration and storage capacity and how these processes are modified once urbanization takes place. This characterization can be improved by also considering morphological and topological features of urban catchments and how they differ from the ones observed in natural watersheds. This study discusses the morphologic and topologic characterization of urban drains (potential and actual), and exemplifies the changes caused to natural catchments by urban development using remote sensing and GIS approach.

Water is part of a larger ecological system, a prime natural resource, a basic human need. The civilizations have grown on the banks of perennial rivers all over the world. As we know a major river is a third or fourth order drain fed by many first and second order tributaries. Population is increasing at exponential rate almost all over the world with urban areas growing even faster than the rural areas. Even though the rate of urbanization in India is among the lowest in the world, growth of urban population in India has been extremely rapid during the course of this century. While the total population of India has grown by 3.5 times from 1901 to 1991, its urban population has increased by approximately 9 times over the same period. The urban areas are very important, as they contribute to nearly 55% of the GDP of India and this share is expected to rise further in the coming years. Water is a scarce and precious national resource to be planned, developed, conserved and managed on an integrated and environmentally sound basis, keeping the socio-economic aspects and needs of the area.

The technique for drainage pattern techniques used for assessment of rainfall drainage pattern includes Stream flow Generating Processes (SGP) [2], DHI MOUSE simulations [1], Geographical information system (GIS) [6],[12], for assessing the drainage pattern are some of them.

In this paper, geospatial techniques are used to analyze land use/land-cover changes of Bangalore district over the past five decades (1965 -2014) and their impact on natural drainage system. Satellite derived Digital Elevation Model (DEM) and topographic sheets (1972) are used to delineate natural drainage pattern of the district. The urban land use map developed in this study is further overlaid on drainage line layer to identify the critical areas where the natural floodwater flows are being inhibited by urbanization.

Rainfall and flow data are utilized to identify areas of heavy flow, whereas, satellite data including (corona-1965 and LISS-IV2014) and land use/cover of the study area. Alternatives to natural drainage systems are also suggested wherever possible. Results may be major alterations to the morphology of drainage systems. It should be very much useful for understanding the hydrologic response of anthropogenic basins, and to improve the modelling, planning and design of sub-urban and urban areas.

MODELLING TOOL USED

- Arc GIS 9.3
- SWMM 5.1

The Storm Water Management Model (SWMM) is a computer program that computes dynamic rainfall-runoff for single event and long-term (continuous or period-of-record) runoff quantity and quality from developed urban and undeveloped or rural areas. The runoff component of SWMM operates on a collection of sub catchment areas that receive precipitation and generate runoff and pollutant loads.

The routing portion of SWMM transports this runoff overland and underground through a system of pipes, channels, storage and treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each sub catchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

STUDY AREA

Bangalore, capital city of Karnataka it is the sixth largest metropolis in the country. Bangalore urban with a population of about five million consists of three taluks namely Anekal, Bangalore North and South. It is situated in the heart of the South-Deccan plateau in peninsular India to the South-Eastern corner of Karnataka State between the latitudinal parallels of 12° 39' N & 13°18' N and longitudinal meridians of 77°22' E & 77° 52'E at an average elevation of about 900 meters covering an area of about 2,191 sq.km. The Bangalore district supports tanks serving the irrigation needs to various capacities.

The main features of the climate of Bangalore are the agreeable range of temperatures, from the highest maximum of 33o C in April to the lowest minimum of 14oC in January. The two rainy seasons, June to September and October to November, come one after the other but with opposite wind regimes, corresponding to the southwest and northeast monsoons. The mean monthly relative humidity is the lowest during the month of March at 44% and records highest between the months of June and October at 80 to 85%. The mean annual rainfall is 859.6 mm, with three different rainy periods covering eight months of the year. June to September being rainy season receives 54% of the total annual rainfall in the S-W monsoon period and 241-mm during the N-E monsoons (Oct - Nov). The built-up area in the metropolitan area was 16 % of total in 2000 and is currently estimated to be around 23-24 %. The rest of the area is occupied by either agriculture lands, quarries or other vacant land.

In recent times, the increase in vehicular traffic has increased suspended particulate matter and other oxides of carbon, nitrogen and sculpture in the environment.

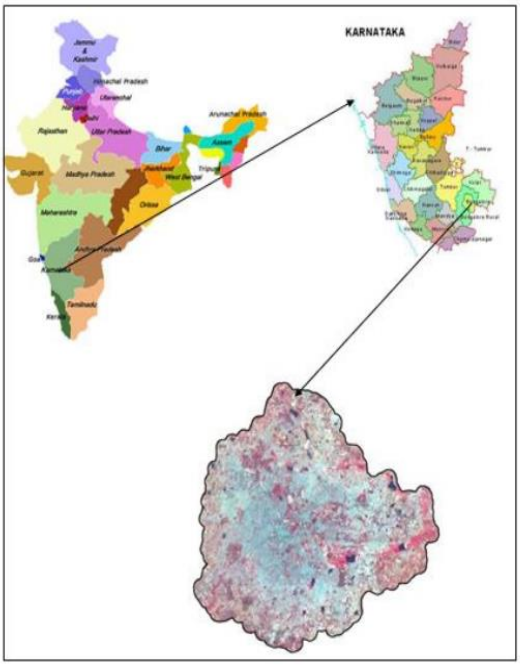

Fig1. Study area

Natural Resources

Bangalore has four major natural valleys located within the water shed of two principal river basins, the Arkavathy to the west and South Pennar to the East. The Bangalore plateau is made up of the four valleys which take off from north and fall gradually towards the south. Of the four valleys, the three main are Vrishabhavathi, Koramangala and Chellaghatta and all of them run in a north to the south direction and divide Bangalore into three distinct and separate drainage zones. The fourth valley is Hebbal and this runs from north of the ridge and continues in the north easterly direction. These are the four

Journal of Water Resource Engineering & Pollution Studies
Volume 4, Issue 2, May-August, 2019

valleys but what is not all that well-known is that there are five other valleys and they too play a vital role in the natural drainage system of Bangalore.

Climate

The climate of Bangalore is classified as the tropical wet and seasonally dries. Dry season - December to February summer season - March to May South-West monsoon - June to September. The mean annual rainfall is 1200 mm Bangalore receives about 970 mm of rain annually, the wettest months being August September, October and in that order.

Drainage

The growing geographic spread of Bangalore and accompanying construction activity has interrupted the natural valley system of the region. Construction has also resulted in tilling up small Water bodies and low-lying areas.

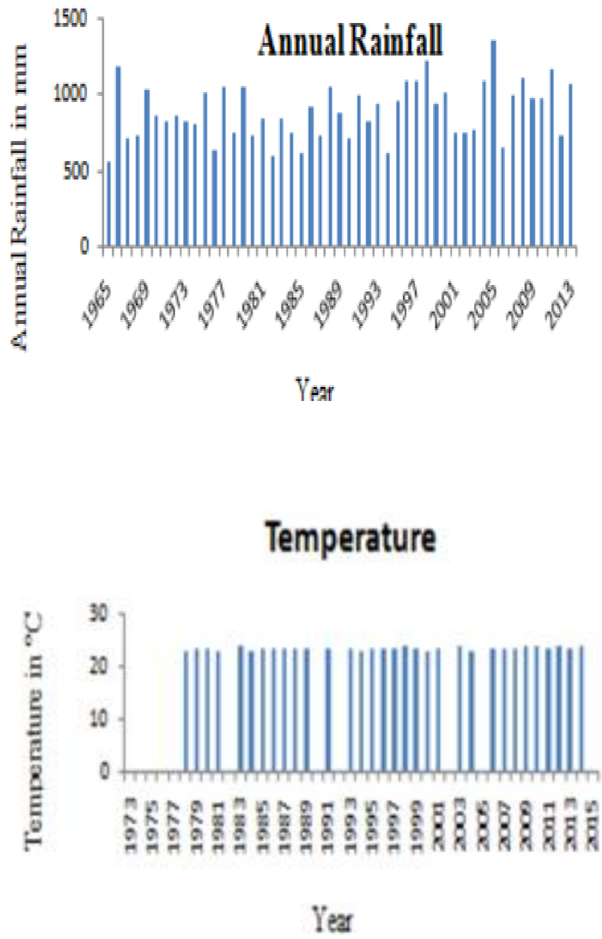

Fig2. Annual Rainfalls and Temperature

The flooding of drains during each monsoon exposes its poor state and their inadequate capacity, and impacts the City's overall infrastructure. With the growth of the City, the number of lakes has reduced to 64 from 400, and small lakes and tank beds have vanished because of encroachment and construction activities. This has resulted in storm-Water drains reducing to jitters of insufficient capacity, leading to flooding during monsoon. Dumping of municipal solid Waste (MSW) in the drains compounds the problem and leads to blockages. To control floods, it is important to remove silt and Widen these storm Water drains to maintain the chain flow and avoid Water from stagnating at one point.

METHODOLOGY

The study will be carried out by collecting both primary(satellite data) and secondary data(Ancillary data), then the primary data collected from various satellites censors are LISS III,LISS IV and Corona were undergone geometric correction, the digital topographic data are collected using DEM, SRTM DEM and CARTOSAT. Geographical information system is used to assess the drainage pattern of the study area. The drainage pattern for the area is simulated using SWMM. At last change detection is done using GIS.

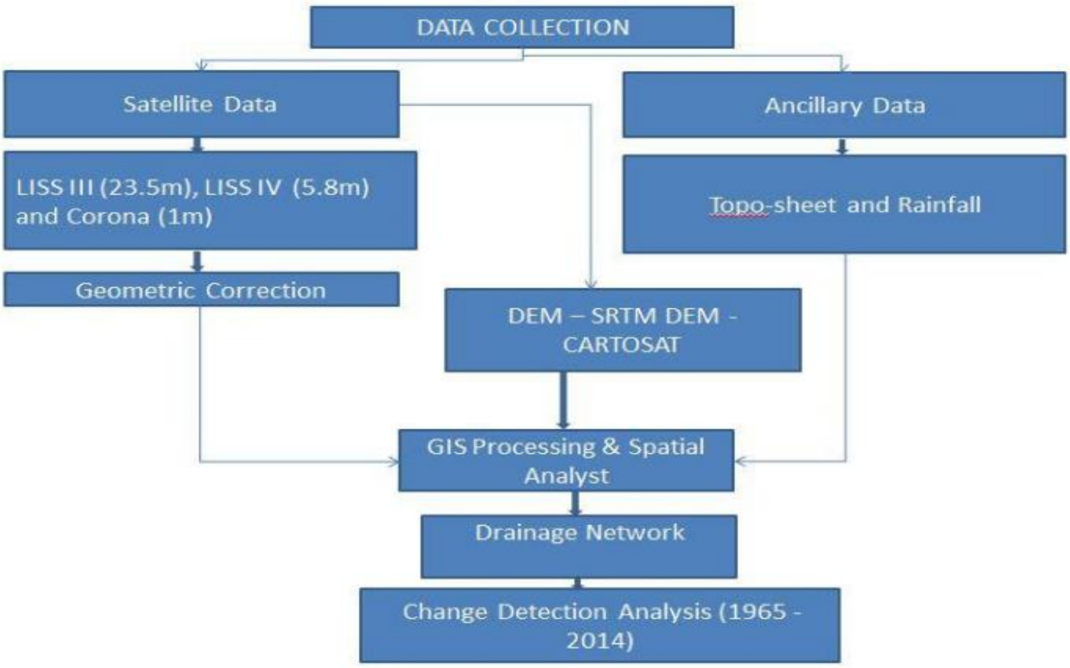

Fig.3: Methodology

Journal of Water Resource Engineering & Pollution Studies
Volume 4, Issue 2, May-August, 2019

RESULT AND DISCUSSIONS

Visual interpretation of water bodies was done using top sheet of 1972 --- as reference. And the change was found out based on reduction or increase in water bodies; it was found that water bodies was reduced in its surface area in terms of shape, size, few were converted into croplands and few into urban area. For 1972 was 271 water bodies, Initial number of water bodies present in 1965 was 265 and further reduced to 240 in 2014.

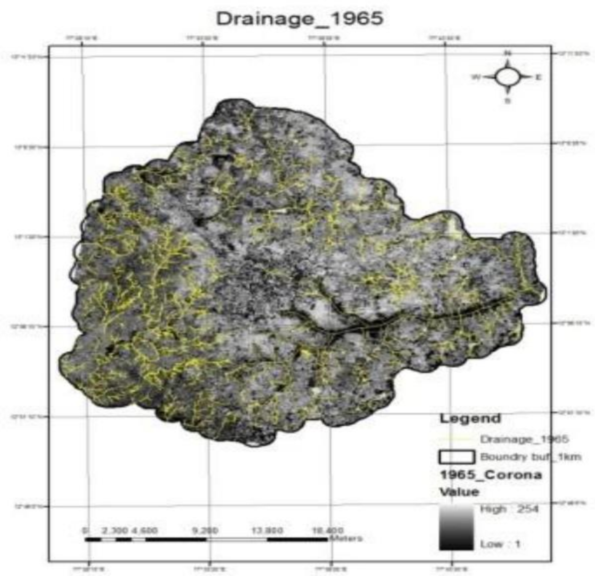

Fig 4. Drainage Network -1965

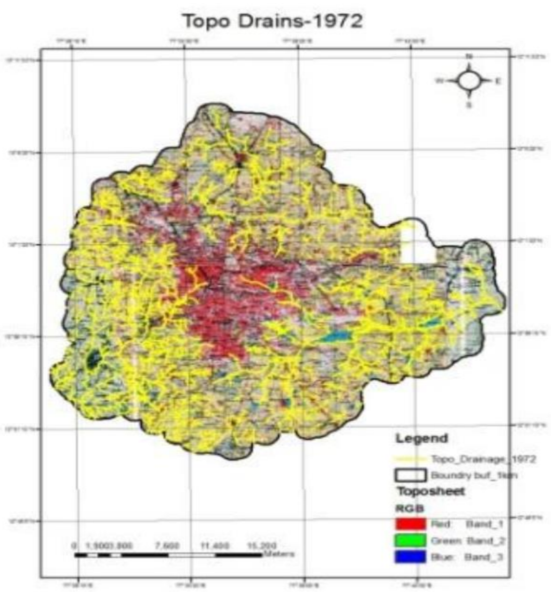

Fig 5. Drainage Network -1972

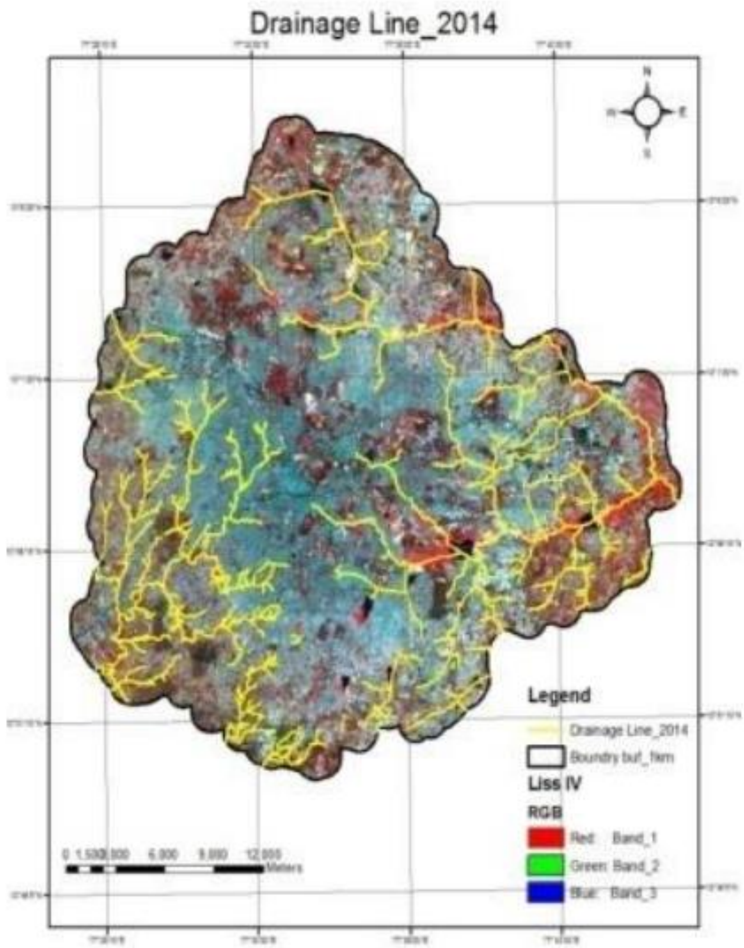

Fig 6. Drainage Network -2014

Visual interpretation of Drainage line was done using top sheet of 1972 as reference. And the change was found out based on reduction or increase in Drainage line; it was found that Drainage line was reduced in its surface area in terms of shape, size; few were converted into croplands and few into urban area. Drainage density it is a measure of the total length of the stream segment of all orders per unit area and controlled by the Slope gradient and relative relief of the basin.

Change Deduction

The streams/rivers, canals, ponds etc. is considered under this category. The prominent ponds/lakes are easily detected on satellite imagery by their black and dark blue tones. The changing rate of water bodies of this area is also showing decreasing trend.

Journal of Water Resource Engineering & Pollution Studies
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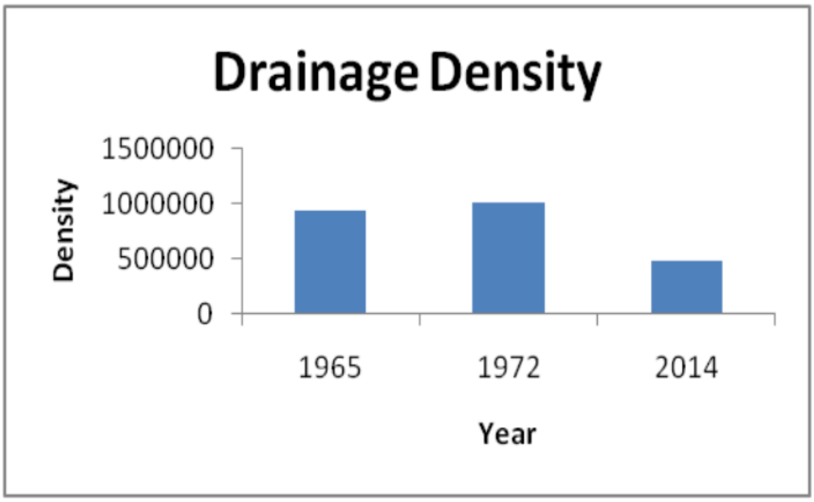

Fig 6. Drainage Density Statistics

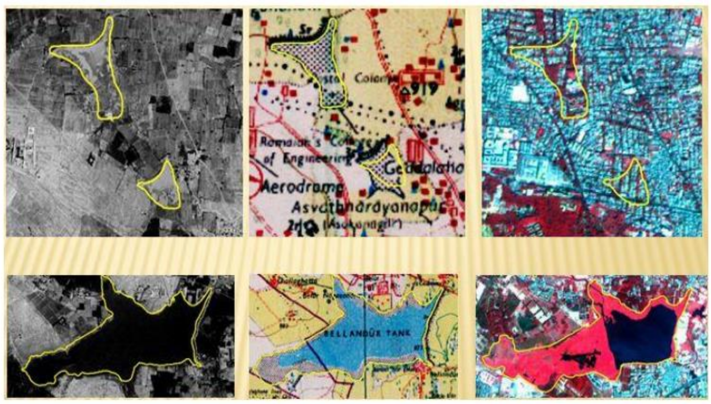

Fig 7.Change Deduction

Visual image interpretation of water bodies

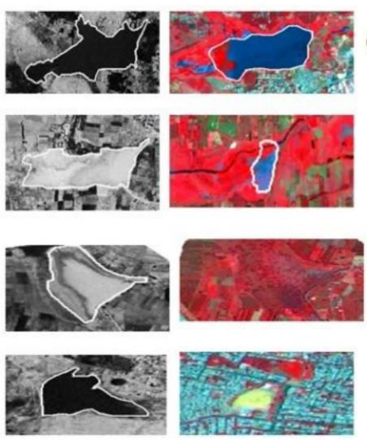

Fig 8.Visual image interpretations of water bodies

STORM WATER MANAGEMENT MODELING RUNOFF ESTIMATION

The SWMM (Storm water management model) main window is pictured below. It consists of the following user interface elements: a Main Menu, several Toolbars, Status Bar .The Study Area Map window, a Browser panel, and a Property Editor window. A description of each of these elements is provided in the sections that follow.

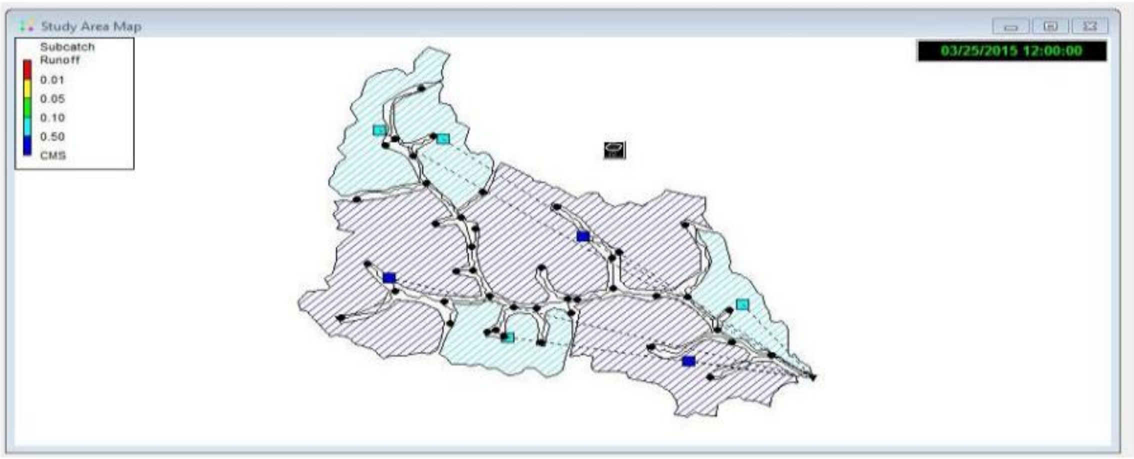

Fig 9.Study Area Map Swm

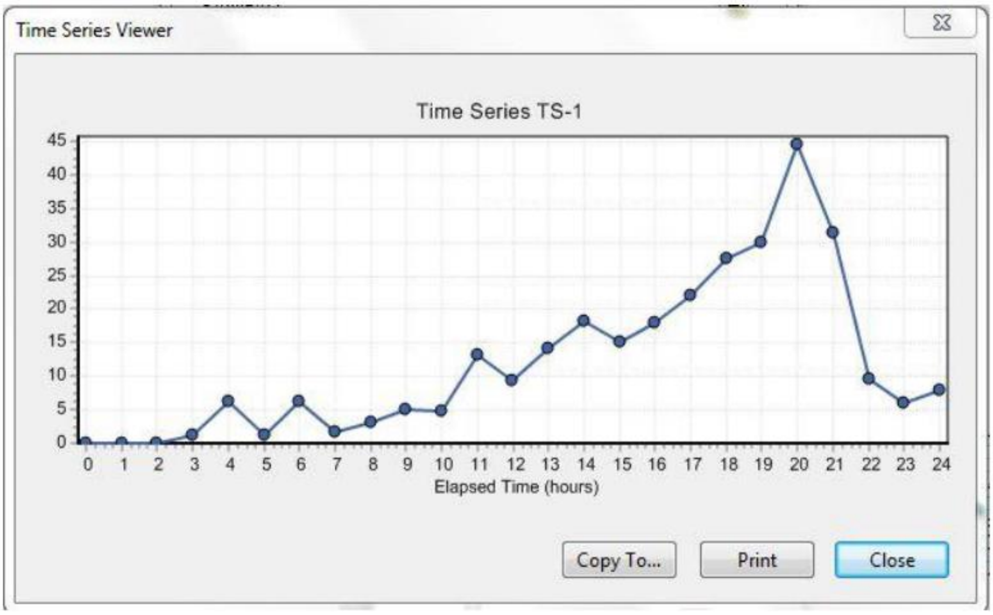

Fig 10.Time Series Rainfall

SUMMARY RESULT

Sub catchment	Total Precipitation mm	Total Run on mm	Total Evaporation mm	Total Infiltration mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coefficient
3	296.10	0.00	0.27	1.22	294.88	95.27	4.72	0.994
5	296.10	0.00	0.27	1.67	294.43	100.23	6.80	0.993
6	296.10	0.00	0.28	1.38	294.72	101.33	5.74	0.912
7	296.10	0.00	0.28	2.17	293.93	100.71	11.85	0.971
8	296.10	0.00	0.27	2.65	293.45	101.52	8.71	0.948
9	296.10	0.00	0.27	1.87	294.23	107.88	7.09	0.950
10	296.10	0.00	0.28	1.96	294.14	102.76	9.77	0.922

CONCLUSION

Results of analysis and interpretation of time series satellite data were compared indicating spatial changes of drainage. Analysis of satellite images show overflowing water bodies of the Bangalore city, nearby areas and stagnation of water in the urban outskirts of the city. Visual interpretation of water bodies was done using top sheet of 1972 --- as reference. And the change was found out based on reduction or increase in water bodies; it was found that water bodies was reduced in its surface area in terms of shape, size, few were converted into croplands and few into urban area. For 1972 was 271 water bodies, Initial number of water bodies present in 1965 was 265 and further reduced to 240 in 2014. This work analyzed the parameters of SWMM model in Hebbal basins, obtaining determination coefficients from 0.994 to 0.997, runoff peak errors from 0% to 30%and runoff volume errors from 0.3% to 71.1%. In the validation phase, average determination coefficients from 0.90 to 0.94 were obtained.

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