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Estimation of Runoff with respect toTemporal and Spatial Land use changes in Cochin Urban Agglomerate, India: A case-study of 2018 flood.

Aneesh T.D, Reji Srinivas, Archana.M.Nair, Krishna.R.prasad, Arun T.J and Bhuvaneswari Ande

Abstract— Urban flash flooding is a common scenario in the recent years. As a fast growing Tier-II metro, Greater Cochin,Kerala experiences rapid increase of impervious surfaces since last five decades. During the S-W monsoon of 2018 Kerala state witnessed intense flooding and landslides. Cochin urban area undergone severe urban pluvial flooding during the same event. This study focused on change in direct surface runoff volume due to the improper planning of land cover changes. Land use/Land cover (LU/LC) changes for the years 1968, 1990, 2000, 2017 was prepared.. Kerala flood-2018 event has assigned as a base rainfall event for calculating the runoff volume for these periods by using Soil Conservation Service- Curve number (SCS-CN) method. The runoff volume amplified from 61-78% since 1968 to 2017 respectively.

Index Terms— Greater Cochin, Kerala Flood-2018, Five decades, LU/LC, SCS-CN, S-W monsoon, Urban flash flood.

1 Introduction

The changes in land use land cover (LU/LC) occurs more than tenfold during the last few decades and will move on in the future [1]. Imperviousness has a major impact on change in runoff volume, intensity, duration etc. Distribution of a rainfall event physiography, soil type and catchment also have a direct influence on runoff [2]. Urbanization cause reducing infiltration and increase the chances of flood as a result of improper planning, occupation of low lying area and poor maintains of storm water drains. Runoff yield gradually increased from forest area, grass land, farm land, barren land and urban-built up region [3].

The rapid rate of urbanization of the study area was reported in many studies [4], [5]. The observed land use changes are mostly noticed with industrial, commercial and residential areas, which in turn resulted increase in the impervious surfaces. Advent of satellite Remote Sensing (RS) techniques are recognized as an effective tool for detecting the land cover changes. The composite usage of RS and GIS were provides a flexible environment for analyze the multispectral data for identifying change detection.

- *Author: Aneesh T.D, currently pursuing PhD program in Hydrology in NCESS, Kerala, India, PH-+919496393730. E-mail: tdaneesh@gmail.com*
- *Co-Author: Dr. Reji Srinivas, currently working as a Scientist in NCESS, Kerala, India, PH-+919846223737. E-mail: Srinivasreji@gmail.com*
- *Co-Author: Krishna.R.Prasad and Arun T.J*, currently pursuing PhD program in Sedimentology in NCESS, Kerala, India, PH-+918921862050,+917594862237*. E-mail: krishnarprasad@gmail.com, aruntj.sagar@gmail.com **
- *Co-Author: Dr.Archana.M.Nair, Currently working as a Asst.professsor in IIT-Guwahati, Assam, India. PH:+917086073663.E-mail: nair.archana@iitg.ernet.in*
- *Co-Author: Bhuvaneswari Ande, Currently pursuing PhD program in IIT-Guwahati, Assam, Ph. +919126873067.E-mail: bhuvi27@iitg.ernet.in*

Kerala state experienced prolonged rainfall from 1st of June to 19th of August 2018 due to a low pressure zone above the southern peninsula. This intense rainfall resulted severe flooding and landslides in the state and reported causality of more than 375 peoples and an estimated 1.2 million people were temporarily sheltered. This flood has been reported as worst with notable comparison to the 1924 catastrophic Flood. As per the IMD India[12], the state received 2346.6 mm of rainfall during this S-W monsoon in contrast to a normal expected rainfall of 1649.5mm. This was about 42% above the normal precipitation.

2 Profile of the Study Area

Ernakulam district is situated in the central part of Kerala state with Lakshadweep Sea on the west. The study area (fig.1)within the district is a fast growing Tier II metro termed as Greater Cochin, also known as Queen of Arabian Sea with a population of 2,232,564 [6]. The Cochin urban agglomerate lies between 9^0 47′ and $10^0$16′ N latitude and $76^0$12′ and $76^0$28′ E longitude with an area of 910 km^2. The district is drained by the Periyar River and its tributaries on the north and Muvattupuzha River on the south. The study region is geographically sub-divided into low land and midland area. The urban region starts from the coastal region itself and extends up to the midland region having a maximum elevation of 5 to 20 m. amsl. The average annual rainfall received in the study region is about 298 cm. with total average rainy days of 132, of which ~ 67% is contributed by the South-West monsoon during June to September and ~ 18% by North-East monsoon during October to December remaining 15% precipitation happens during January to May (Pre monsoon). Study region experiences high rainfall on its

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eastern part along the slopes of Western Ghatt.

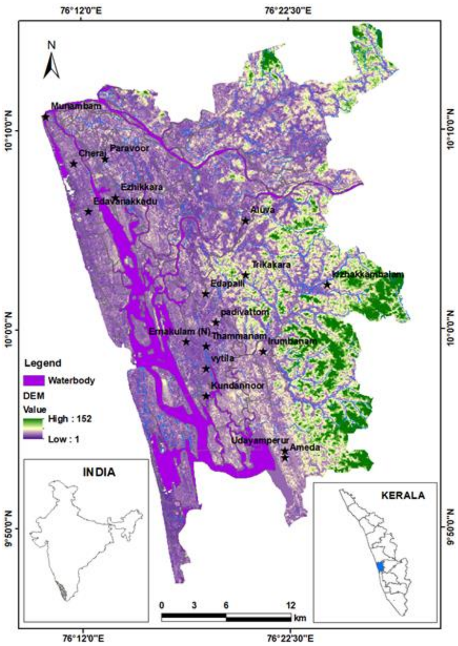

Fig. 1. Study Area

Cochin witnessed a high rate of population growth and fast developing trends in the past 30 years. Cochin is rapidly growing towards north ward on both sides of National Highway-47 (NH 47). Expansion of urban areas significantly impacts the environment in terms of LU/LC changes, runoff, ground water recharge, water pollution and storm water drainage.

3 Materials and Methods

Survey of India topographic sheet of scale 1:50000, Landsat 5, Landsat 7 and Sentinel 2A multi spectral images are used as the base map and further analysis, LU/LC classification maps for 1990,2000 and 2017 respectively. Supervised classification in ERDAS imagine is applied to satellite images for done LU/LC changes. The rain fall event during flood inundated period of August 2018 was obtained from IMD [12].

Runoff was calculated based on change in land use pattern using Soil conservation Service –Curve Number (SCS-CN) method developed by the USDA soil conservation service. In the present study, a modified version for Indian scenario [7], [8], [9], [10] was used. Which is based on the moisture absorption potential of the soil. The potential storage 'S' (mm/inches) is related to a curve number. The curve number (CN) of a specified area is based on the characteristics of the soil type, land use, hydrological soil group, hydrological condition and antecedent moisture condition (AMC). The SCS model computes direct runoff for a storm event with the following equation by Handbook of Hydrology, 1972.

$$Q=\frac{(P-I_a)^2}{(P-I_a+S)} \quad \text{for } P>I_a \qquad (1)$$

$$Q=0\text{ , for } P\leq I_a \qquad (2)$$

Here P is the precipitation in mm, I_a is the initial abstraction- for Indian condition the value is considered as 0.3S. Q is the direct runoff volume and S is the potential maximum retention.

S is expressed in terms of CN

$$\text{ie:- } S=\frac{25400}{CN}-254 \qquad (3)$$

Here S is in the SI units (S in mm.)

As stated, CN is a function of soil type, land cover and antecedent moisture condition, and it has a range from 30-100.

$$CN=\left(\sum(C_i\times A_i)\right)/A \qquad (4)$$

CN is weighted curve number for AMC II [11]
CNi is the curve number of N
Ai is the area of curve number CNi
A is the total area of study.

AMC refers to the soil moisture content at the beginning of a storm event under consideration, which is determined as the amount of rainfall precipitated 5 days prior to the day under consideration. AMC I and III are computed by the following equation:

$$\text{AMC I}=\frac{(4.2\times CN)}{(10-(0.058\times CN))} \qquad (5)$$

$$\text{AMC III}=\frac{(23\times CN)}{10+(0.13\times CN)} \qquad (6)$$

AMC I – Lowest runoff potential
AMC II – Average runoff potential
AMC III – Highest runoff potential.
The study area is considered under Hydrological Soil Group (HSG) –C and AMC III.

4 Result and Discussion

Land use land cover changes clearly evidences the growth of impervious area and abridge of vegetation from 1968 (fig2) to present, although Non-cultivated land and built up with vegetation was negligible. Supervised classification of satellite images into seven categories, which shows that large fraction of impervious surface are mainly concentrated in the central part, such as build up, Industries and commercial platforms etc. The recent maps are reframed with site specified changes (fig3 (a), (b), (c)). Kappa accuracy assessment evidences strong agreement between ground references with classified results. An increase of 2.6 to 14% in built up land was noticed during the last 5 decades (I), (fig4). The rainfall data of Kerala state during a period of 1901-2015 in the month of August shows that the first half of monthly spell has exceeded, a maximum of 1199mm during 1931, 982mm in 1907 and 943mm in 1923 [12] (fig5). In contrary a 47% of excess rainfall during 2018 August has caused flash flood in most of the study area reveals the unplanned developments and change of LU/LC. Ernakulam district has received 2477.8mm rain during S-W monsoon, which is more than an expected normal rainfall of 1680.4mm.

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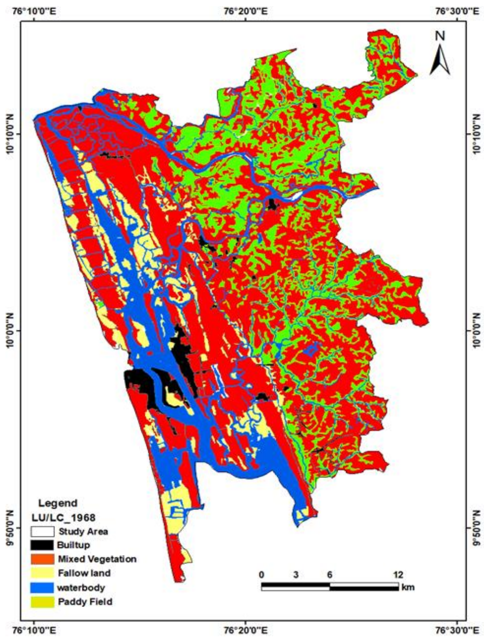

Fig. 2. LU/LC of 1968.

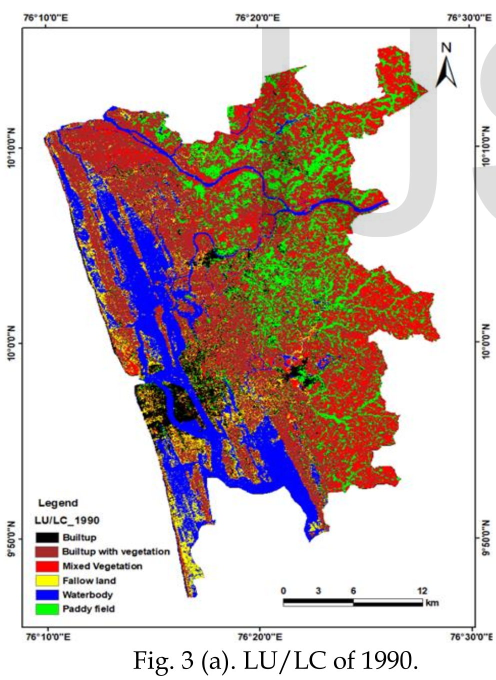

Fig. 3 (a). LU/LC of 1990.

From the published data of the National Remote Sensing Centre (NRSC) [13] and field observations the Flood inundation map of the study area was generated (fig6).

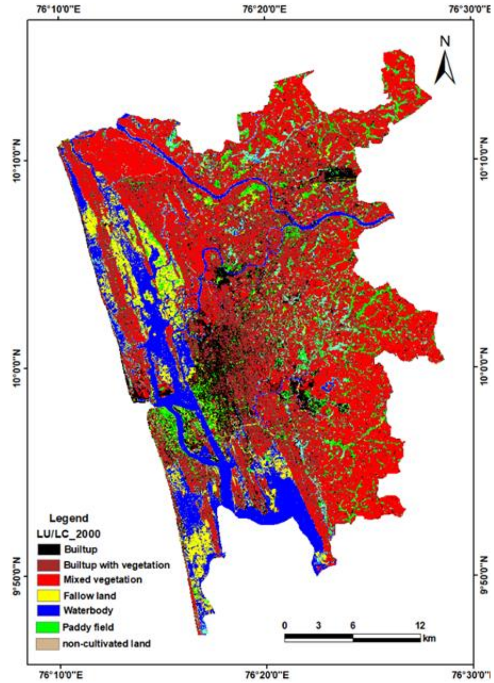

Fig. 3 (b).LU/LC of 2000.

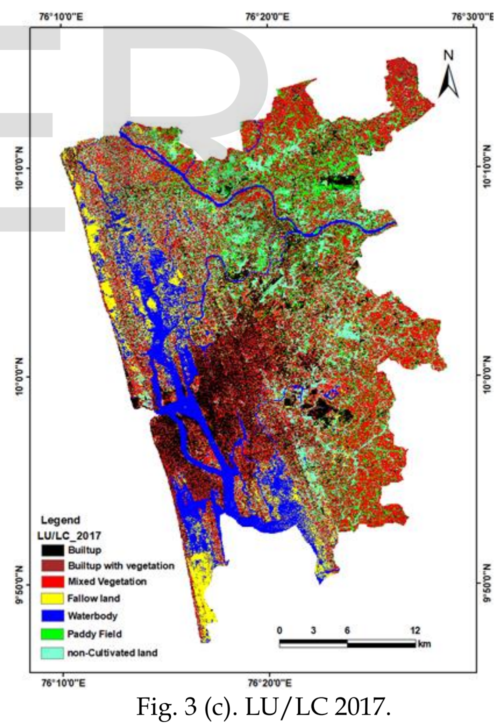

Fig. 3 (c). LU/LC 2017.

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Table. I. LU/LC changes of study area.

Classes	1968	1990	2000	2017
	(%)			
Builtup	2.64	5.95	7.57	13.96
Builtup with Vegitation		40.79	31.17	15.27
Mixed Vegitation	57.58	19.63	30.41	23.85
Fallow Land	7.71	5.95	5.82	7.25
Water body	13.19	13.12	12.84	12.86
Paddy Field	18.88	14.55	6.48	10.00
Non-Cultivated land			5.71	16.81

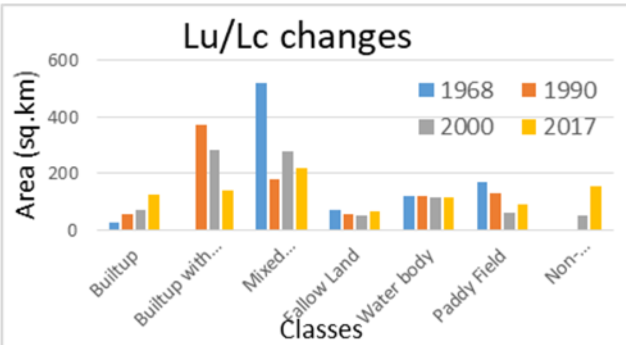

Fig. 4. Land cover changes since 1968.

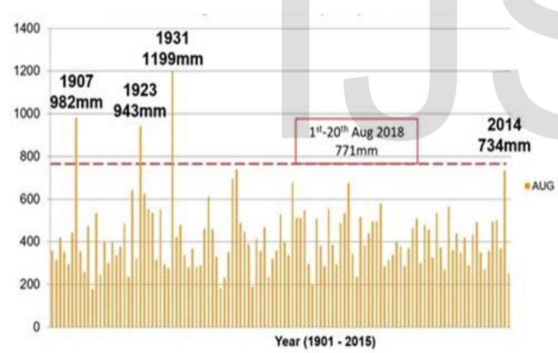

Fig. 5. The rainfall event for a period of 1901-2015 August with recent flood event [12].

From the fig.6, it is clearly evidences that Periyar River in spate and overflowed, many areas close proximity to the river are hit by the flood. More over the urban region away from the drainage basin of river also witnessed huge surface runoff and flash flood, which specifies the after effect of interconnected impervious area. Based on the SCS-CN method the estimated curve numbers of the study area is ranging from 45 to 90. AMC conditions of the flood event is considered as AMC III and HSG-C. While comparing the same rainfall event with the prepared maps of 1968,1990,2000 and 2017 was clearly evidences that the direct runoff volume has changed from 90mm to 114 mm (61-78%) during the reported highest storm event on 16 August 2018 (II) , (fig7).

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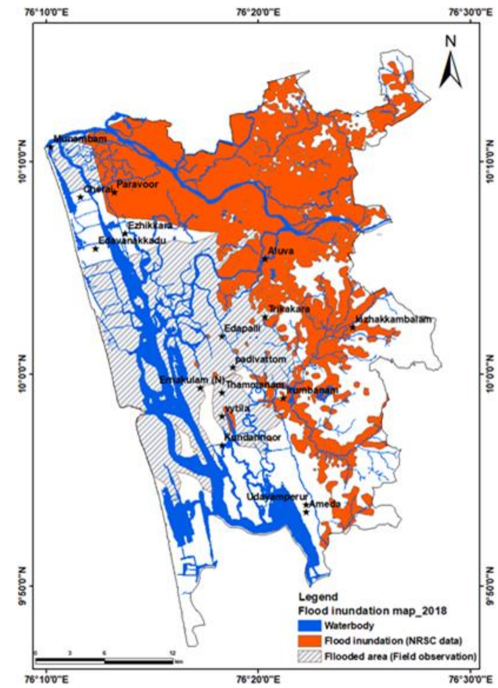

Fig. 6. flood inundation map during August-2018

Table. II. Runoff volume since 1968.

Date	Rainfall	Q_1968	Q_1990	Q_2000	Q_2017
2018	(mm)	Runoff Volume (mm)			
08-Aug	43.72	9.36	2.30	0.76	0.06
09-Aug	19.82	0.16	1.53	2.02	3.26
10-Aug	19.85	0.17	1.54	2.03	3.27
11-Aug	12.57	0.34	0.04	0.13	0.52
12-Aug	7.17	1.98	0.53	0.33	0.06
13-Aug	13.53	0.19	0.11	0.26	0.77
14-Aug	10.90	0.68	0.01	0.01	0.19
15-Aug	**136.62**	**81.83**	**96.10**	**99.05**	**105.02**
16-Aug	**145.88**	**90.21**	**104.89**	**107.90**	**114.00**
17-Aug	62.08	20.34	28.99	30.95	35.12
18-Aug	32.08	3.31	7.30	8.35	10.76
19-Aug	29.28	2.31	5.73	6.67	8.83
20-Aug	6.64	2.23	0.68	0.46	0.13
21-Aug	9.52	1.07	0.10	0.02	0.04
22-Aug	11.24	0.60	0.00	0.02	0.25

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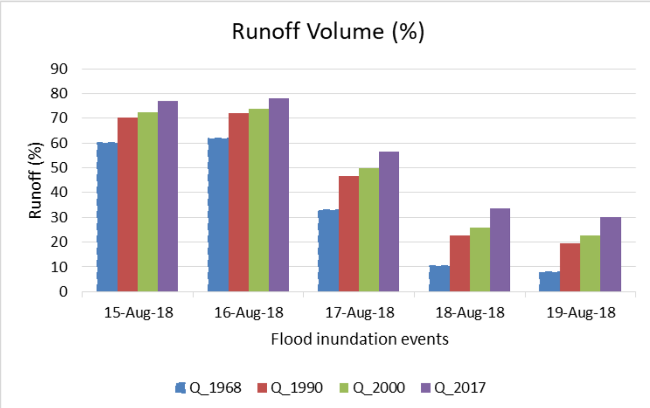

Fig. 7. Runoff volume since 1968 -2017.

Conclusion

The land use pattern of the study area has considerable changes since 1968 to 2017, which influences direct runoff volume. The most significant changes were observed with built-up, non-cultivated land and built up with vegetation class. The core of the urban sprawl is gathered with thick settlement. The effective impervious built up area has a growth of 23 km^2 in 1968 becomes 127 km^2 in 2017, simultaneously built up with vegetation reduced from 370 km^2 to 139 km^2 respectively. A comparative estimation of runoff volume during the flood event with past decades seems to an increase from 61-78%. Present scenario has disturbed the prevailing of urban flood, because the developed areas cannot taken back to its natural condition. The effect can minimize by a better planning, society would be rather benefited if NGO's and stakeholders took up public awareness among people, even though the implementation is a big challenge. Developers and city planners should improve new strategies for new developments and existing constructions, such as the steps for protecting natural open spaces, retain of existing sewer lines, replacing impervious pavements and parking yards will condense impact from flash flood hazards.

7.2 Acknowledgments

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