

A Study on Impact of Urbanisation on Surface Runoff in Muvattupuzha Municipality

Beenu Cherian¹, D Praveen Das², Liya John³, M Devadathan⁴, Ginu S Malakeel⁵

U.G. Student, Department of Civil Engineering, Muthoot Institute of Technology and Science, Kochi, Kerala, India¹

U.G. Student, Department of Civil Engineering, Muthoot Institute of Technology and Science, Kochi, Kerala, India²

U.G. Student, Department of Civil Engineering, Muthoot Institute of Technology and Science, Kochi, Kerala, India³

U.G. Student, Department of Civil Engineering, Muthoot Institute of Technology and Science, Kochi, Kerala, India⁴

Asst. Professor, Department of Civil Engineering, Muthoot Institute of Technology and Science, Kochi, Kerala, India⁵

ABSTRACT: Runoff is an important component contributing significantly to the hydrological cycle, design of hydrological structures and morphology of drainage system. There are different methods for estimating runoff. The SCS-CN method is the simple, predictable and stable conceptual method for estimation of direct runoff depth based on storm rainfall depth. The method combines the watershed parameters and climatic factor in one entity called the curve number. Remote Sensing and Geographical Information (GIS) techniques are being widely used, as all the factors of SCS model are geographic in character. The study was carried out in Muvattupuzha located in Ernakulam district of Kerala. The hydrologic soil group map, landuse map and slope maps were generated with GIS tools. The curve number values from NRCS Standard tables were assigned to each HRUs to generate CN values map. In this study an attempt has been made to find the impact of urbanization on runoff in Muvattupuzha Municipality.

KEYWORDS: Runoff, SCS- CN Method, GIS, Landuse map.

I. INTRODUCTION

Hydrology plays a vital role in the protection and management of water and other environment resources associated with the occurrence and distribution of water above and below the land surface. The runoff of a catchment area in any specified period is the total quantity of water draining into a reservoir. Surface runoff is the water flow that occurs when soil is fully saturated and excess water from rain over the land. The runoff mainly depends upon the intensity of rainfall, its duration and distribution. Basically there are two types of concepts which are responsible for runoff generation. These are the infiltration-excess runoff and the saturation excess runoff. In the infiltration-excess runoff concept, it is assumed that the overland flow occurs only when the rainfall intensity is greater than the infiltration rate at the soil surface. The second type of runoff generation also occurs where the soil surface is saturated and any further rainfall, even at low intensities, generates runoff that contributes to stream-flow. The more prevailing one is the saturation-excess runoff generation. Curve Number method (SCS-CN) is one of the most widely used approaches for accurate runoff calculation of the catchment area. SCS-CN provides an empirical relationship for estimating initial abstraction and runoff as a function of soil type and landuse. In India the availability of accurate information on runoff is scarce. A good runoff model includes spatially variable parameters such as rainfall, soil types and land use /land cover.

ArcGIS 10.1 is the software used for the digitizing the area. The software is developed by Esri. It is an important tool in analysis of parameters such as land use/ land cover, soils, topographical and hydrological conditions. Due to geographic nature of these factors of SCS runoff model can easily be model into GIS.

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II. RELATED WORK

Estimation of runoff have important role in the water resource management. Several studies were going on about the methods for runoff modelling and its estimation. Sarita Gajbhiye [2015] conducted a study on runoff estimation using remote sensing and GIS. The curve number method was used as a distributed model. L. Yeshodha et.al [2013] conducted a study to estimate the surface runoff for Krishnagiri district, Tamil Nadu using SCS- CN method. In this runoff was computed for different areas barren land, agriculture, industrial, forest. In this analysis, it was concluded that the runoff mainly depends upon rainfall and soil texture. SCS model has been used to estimate runoff and this model gives quick estimate of generated runoff. SKhaleghi b et.al [2014] conducted study in Zilberchai basin. This work used a methodology of determining surface runoff by Geographic Information System model and applied SCS- CN method that needs the necessary parameters such as land use map, hydrologic soil groups, rainfall data, DEM, physiographic characteristic of the basin. The results show that the high average weighted of curve number which indicate that permeability of the basin is low and therefore the flooding is high. So, the fundamental works was essential in order to increase water infiltration in Zilberchai basin and to avoid wasting surface water resources.

III. OBJECTIVES

The objective of the study is to develop the landuse map of the Muvattupuzha municipality and to determine the effect of urbanization on runoff. For this we developed the hydrologic soil map and landuse map of the area and then intersected together to develop the curve map. From this we calculated the parameters like curve number (CN), potential maximum retention (S) and runoff by the SCS-CN method.

IV. AREA OF STUDY

We selected the study area as Muvattupuzha which lies between longitude $76^{\circ} 20'$ and $77^{\circ} 00'$ E and latitude of $9^{\circ} 40'$ and $10^{\circ} 10'$ N with an elevation range of 20m above Mean Sea Level (MSL). Muvattupuzha is situated in Ernakulam District of Kerala with an area of 13.18km^2 . The average summer temperature is 32.5°C and average winter temperature is 20°C . The area mainly has laterite soil.



Fig 1. Study Area

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VI. MATERIALS AND METHODOLGY

(A) . Materials Collected

Topographic map of scale 1:50000 prepared by Survey of India (SOI) were used for creating landuse map of 1968. The watershed atlas at the scale of 1: 250,000 were used to digitize the area. The soil map of the Kerala was collected from Kerala Forest Research Department, Peechi. Arc GIS 10.1 software was used for creating, managing and generation of different layer and maps. The Microsoft excel was used for mathematical calculation. The landuse map of 2016 created from the google earth image.

(B) Methodology

- Preparation of Land use map of the study area using the toposheet and google earth image.
- Preparation of Hydrologic soil group (HSG) map from Kerala soil map.
- Creation of curve number map from HSG map and landuse map.
- Estimation of runoff using SCS-CN method.

VII. ESTIMATION OF RUNOFF

(A) SCS Method

SCS-CN is the mostly used method for runoff modelling. SCS model was developed by U.S. Soil Conservation Service in 1972, and known as the Hydrologic Soil Cover Complex Model. It has been widely used internationally for water resources management, urban storm water modelling and runoff estimation. It is also called as Natural Resources Conservation Service Curve Number method (NRCS – CN). The Curve Number (CN) is an index developed by the Natural Resource Conservation Service (NRCS), to represent the potential for storm water runoff within a drainage area. In general, a good correlation has been found between observed and computed runoff by using SCS- CN method. SCS-CN provides an empirical relationship for estimating initial abstraction and runoff as a function of soil type and landuse. Rainfall runoff relationship can be visualized by the factors such as initial abstraction (Ia), direct runoff (Q), and actual retention (F).

The SCS model can be expressed as:

$$Q = \frac{(P - Ia)^2}{(P - Ia + S)} \dots \dots \dots (1)$$

Q is runoff depth (mm), P is storm rainfall (mm), and S is potential maximum retention or infiltration (mm). According to the Indian condition initial abstraction is equal to 0.2 times the infiltration. Therefore the runoff model can be expressed as:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.7S)} \dots \dots \dots (2)$$

For convenience and standard application of equation, S is expressed in the form of a dimensionless runoff curve number (CN).

$$S = \frac{2540}{CN} - 25.4 \dots \dots \dots (3)$$

The CN represents the runoff potential of the land cover-soil complex characteristics governed by soil antecedent moisture condition (AMC), soil type, and land use and treatment. CN values range from 0 to 100.

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(B) Curve Number

The runoff curve number is an empirical parameter used in hydrology for predicting direct runoff from rainfall excess. All the factors responsible for generation of runoff from rainfall in the watershed actually govern the curve number including hydro meteorological and watershed characteristics. Composite (or area weighted) CN is estimated by compositing the area weighted average CN calculated for the entire watershed. Satellite data of land use and soil maps obtained from various sources are overlaid to delineate polygons with unique land use and hydrologic soil group (HSG) combinations for determination of CN for each grid and then computation of the area weighted average CN is as follows,

$$CN = \frac{(CN_1 * A_1) + (CN_2 * A_2) + \dots + (CN_n * A_n)}{A}$$

where A_1, A_2, \dots, A_n represent areas of polygons having CN value CN_1, CN_2, \dots, CN_n and A is the area of each grid = $A_1 + A_2 + \dots + A_n$.

(C) Hydrologic Soil Group

There are four hydrologic soil groups ranging from A to D.

HSG A: Soils with high infiltration rates, consisting mainly deep sands and gravels with high rate of water transmission (final infiltration rate greater than 0.3 in/hr).

HSG B: Soils moderately fine to coarse soils having a moderate rate of water transmission (final infiltration rate of 0.15 in/hr to 0.30 in/hr).

HSG C: Moderately fine textured soils that may have a layer that impedes downward movement of water, with slow infiltration and water transmission rates (final infiltration rate of 0.05 to 0.15 in/hr).

HSG D: Clayey soils with permanent high water table or shallow soil over impervious material having very slow infiltration and water transmission rates (final infiltration rate less than 0.05 in/hr).

(C) Antecedent Moisture Content

There are three AMC groups which were defined as dry, moderate and wet, and denoted as AMC I, AMC II, and AMC III, respectively.

Table 5.1. AMC Group

AMC Group	Soil characteristics	Total 5-day antecedent rainfall (mm)	
		Dormant season	Growing season
I	Soils are dry but not to wilting point; satisfactory cultivation has taken place	Less than 13	Less than 36
II	Average condition	13-28	36-53
III	Heavy rainfall or light rainfall and low temperatures have occurred within the last 5 days; saturated soil	Over 28	Over 53

The soil characteristics for the classification of AMC group is given in the above table. Based upon the five day antecedent rainfall we found out the AMC group.

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VIII. RESULTS AND DISCUSSIONS

(A) Creation of landuse map

We have created the landuse map of year 1968 of Muvattupuzha municipality from toposheet and that of year 2016 from the google earth image. Here we classified the area as agricultural land, built up area, and open area and river. Area of each cover typewas calculated.

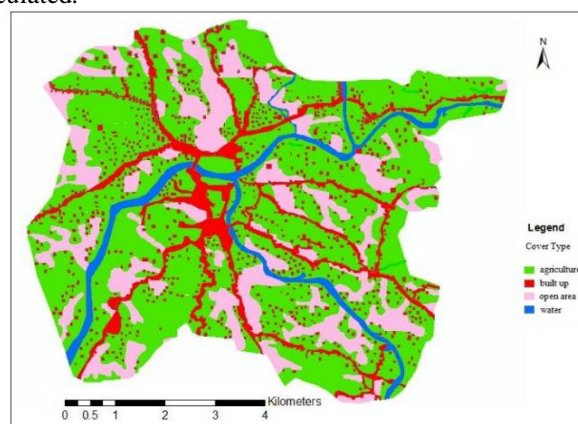


Fig 5.1 Landuse Map – 1968

The landuse map of the year 1968 is given in the figure 5.1 and landuse map of 2016 is given in the figure 5.2. From the landuse maps, it is evident that the landuse pattern has changed drastically over a period of 48 years.

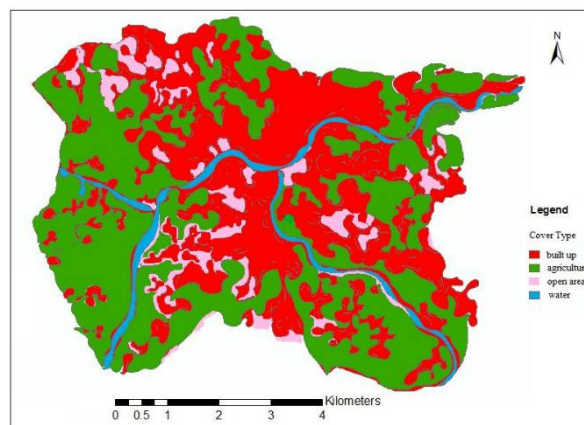


Fig 5.2 Landuse Map - 2016

(B) Creation of hydrologic soil group

From the Kerala soil map, the hydrologic soil map of Muvattupuzha municipality was created which includes the soil groups C only.

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(C) Creation of Curve Number Map

Curve number map was created by intersecting the hydrologic soil group and landuse map. The hydrologic response unit (HRU) was obtained from curve number map. Obtained hydrologic soil groups are agriculturalC , built up C , open area C.

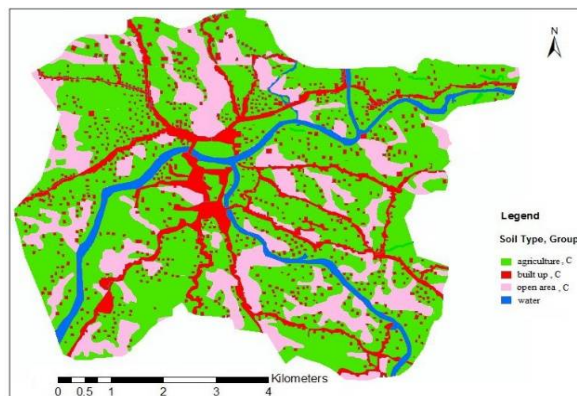


Fig 5.3 Curve Number Map – 1968

The curve number map of year 1968 in given figure 5.3 and the curve number map of 2016 in given figure 5.4

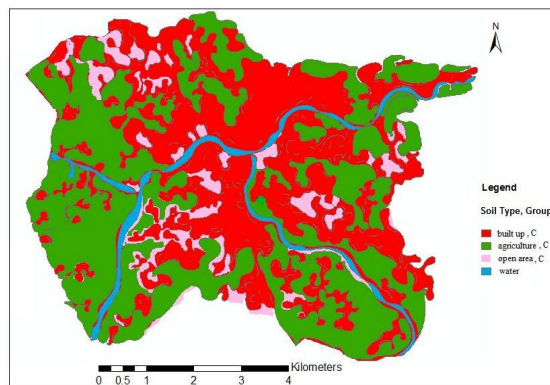


Fig 5.4 Curve Number Map - 2016

Table 5. Area of each cover type in Muvattupuzha municipality

Cover type	Area (m ²)	
	1968	2016
Agricultural land	22410243.6	13425849.1
Built up area	3477135.35	15638188.51
Open area	4831707.01	2009310.22

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The area of each land covertype obtained from the software is given the table above. The land use map of 1968 consists of agricultural land with an area of 22410243.6 m², built up land with an area of 3477135.35 m², open area with an area of 4831707.01 m², and river have an area of 1470083.35 m². The land use map of 2016 consists of agriculture land with an area of 13425849.10 m², built up land with an area of 15638188.51 m², open land with an area of 2009310.22 m² and river with an area of 115821.48 m².

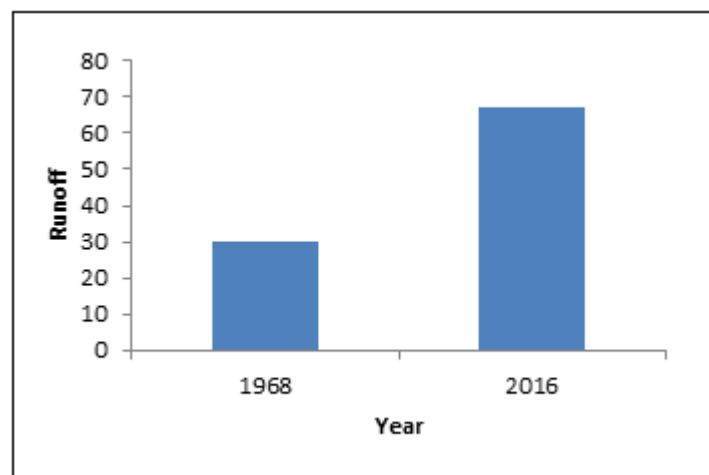


Fig 5.5 Bar chart showing temporal variation of runoff

In 1968, out of the total area 69% of the area is agricultural land, 10.8% of the land is builtup area, 15% of the area is open area and 5.2% of the area is river. In 2016, out of the total area 41.7% of the area is agricultural land, 48.58% of the area is builtup, 6.2% of the area is open area and 3.52% of the area is river. This results shows that there is a decrease in area of agricultural land by 21.3%, builtup area increased by 37.78%, the open area decreased by 8.8% and the area of river also reduced by 1.68%. As the result of urbanisation, there is gradual increase in the built-up area and decrease in agricultural area. Increase in the impervious surface leads to decrease in the infiltration rate and thus the runoff will increase. The annual rainfall in the catchment area in the year 1968 is 4866.63 mm and in the year 2016 is 2813.82 mm. The runoff of the catchment in the year 1968 is 1471.006 mm and in the year 2016 is 1887.20 mm. That is the runoff of the area in 1968 is 30.2% and in 2016 is 67%. The variation in the runoff is given in the figure 5.5. There is also variation in the annual rainfall. As a result, the amount of water available for different purposes also reduced. The water which overflow through the surface can be collected in and utilized for different purposes in effective manner. The results from the estimation of surface runoff helps us to take necessary measure to conserve the water.

XI. CONCLUSION

It can be concluded that the runoff mainly depends upon rainfall, soil texture and the type of land cover. The SCS-CN model, which has been used in this study, to estimate runoff is simple and effective. Geographical information system is also an efficient tool for the preparation of most of the input data required by the SCS curve number model. In this study, it was found that the builtup area having higher curve number contributes higher runoff and the agricultural land with lower curve number contributes lesser runoff. Due to urbanisation the infiltration rate has been reduced and thus the runoff has been increased. In the present study, it can be seen that runoff was increased by 36.8% over a period of 48 years. Thus it is very evident that as a result of urbanisation the runoff increases at the cost of decreased infiltration.

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