CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

This chapter briefly shows the research papers studied for the objectives of my study. The literature review carried out under the study is categorised as follows:

- Literature related to Rainfall Analysis
- Literature related to Land Use/ Land Cover Analysis
- Literature related to Urban Sprawl
- Literature related to Runoff Computations
- Literature related to Rainfall Analysis

2.2 LITERATURE REVIEW RELATED TO RAINFALL ANALYSIS

Kothiyari and Garde (1992) showed rainfall intensity-duration-frequency relationship for planning and design of water resources projects. Different 80 rain-gage stations in India were analysed. Making use of the assumption that general properties of the convective cells that are associated with short-period (i.e., less than 24 hr) rainfalls are similar in different hydrologic regions, a general relationship for rainfall intensity, duration, and frequency was developed. The correctness of form of the developed relationship was ascertained through its comparison with existing equations and the use of data from different hydrological regions. The relationship proposed herein is found to produce more realistic results for Indian conditions than the ones in vogue. The applicability of this relationship to the data from other countries was checked with the limited data available. The proposed relationship may be used in India for design practices.

In India studies showed that there is no trend of increase or decrease in average rainfall over the country (**(Lal (2001).** The freshwater availability in river basins is also likely to decrease due to the changing climate **(Gosain et al. (2006)).** Guhathakurta and Rajeevan (2006) constructed monthly, seasonal and annual rainfall time series of 36 meteorological sub-divisions of India using a fixed but a large network of about 1476 rain-gauge stations. These rainfall series were thus temporally as well as spatially homogenous. Trend analysis was carried out to examine the long-term trends in rainfall over different subdivisions. Also, monthly contributions of each of the monsoon months to annual rainfall in each year were computed and the trend analysis was performed. It had been found that the contribution of June, July and September rainfall to annual rainfall is decreasing for few sub-divisions while contribution of August rainfall is increasing in few other subdivisions.

On an annual scale and for the entire country, most of studies have come up with more or less similar results indicating no change over the country but when it comes to the seasons and regional level, the changes are certain. **Gadgil (2007)** stated that it is important to have a thorough understanding of the fundamental systems causing the monsoon and the variables influencing its variation. However, significant changes in long-term rainfall on regional scale have been identified (Guhathakurta and Rajeevan 2007). An increasing trend was observed in annual rainfall in nine river basins of northwest and central India (Singh et al. 2008).

An increasing trend was also reported in most of the south India, except Kerala whereas decreasing trend in central India and northern Indian plain (Kumar et al. 2010). Due to the instrumental limitation, short duration rainfall data are not available in Sylhet. According to **Rathod and Aruchami (2010)** rainfall variability is defined as the coefficient of variation variability, the standard deviation to mean ratio, or the deviation of rainfall from the mean. Rainfall variability has been examined and debated at the local, regional, and global levels in relation to climate change. Before creating any predictability models.

The study of precipitation trends is critically important for a country like India whose food security and economy are dependent on the timely availability of water. In the study by **Vijay Kumar et al. (2010),** monthly, seasonal and annual trends of rainfall were studied using monthly data series of 135 years (1871 – 2005) for 30 sub-divisions (sub-regions) in India. Half of the sub-divisions showed an increasing trend in annual rainfall, but for only three (Haryana, Punjab and Coastal Karnataka), this trend was statistically significant. Similarly, only one sub-division (Chhattisgarh) indicated a significant decreasing trend out of the 15 sub-divisions showing decreasing trend in annual rainfall. In India, the monsoon months of June to September account for more than 80% of the annual rainfall. During June and July, the number of sub-divisions showing increasing rainfall is almost equal to those showing decreasing rainfall. In August, the number of sub-divisions showing an increasing trend exceeds those showing a decreasing trend, whereas in September, the situation is the opposite. The majority of sub-divisions showed very little change in rainfall in non-monsoon months. The five main regions of India showed no significant trend in annual, seasonal and monthly rainfall in most of the months. For the whole of India, no significant trend was detected for annual, seasonal, or monthly rainfall. Annual and monsoon rainfall decreased, while pre-monsoon, post-monsoon and winter rainfall increased at the national scale. Rainfall in June, July and September decreased, whereas in August it increased, at the national scale.

The article by **Jain and Kumar (2012)** aimed to review studies pertaining to trends in rainfall, rainy days and temperature over India. Sen's non-parametric estimator of slope has been frequently used to estimate the magnitude of trend, whose statistical significance was assessed by the Mann-Kendall test. There are differences in the results of the various studies, and a clear and consistent picture of rainfall trend has not emerged. Although the different units (sub-basins or sub-divisions) may have a non-zero slope value, few values are statistically significant. In a study on basin-wise trend analysis, 15 basins had a decreasing trend in annual rainfall; only one basin showed significant decreasing trend at 95% confidence level. Among six basins showing increasing trend, one basin showed significant positive trend. Most of the basins had the same direction of trend in rainfall and rainy days at the annual and seasonal scale. Regarding trends in temperature, the mean maxi mum temperature series showed a rising trend at most of the stations; it showed a falling trend at some stations. The mean minimum temperature showed a rising as well as a falling trend. At most of the stations in the south, central and western parts of India a rising trend was found. Some stations located in the north and northeastern India showed a falling trend in annual mean temperature. Most of the data used in trend analysis pertained to the stations located in urban areas and these areas are sort of heat islands. This article also highlighted the need of a network of baseline stations for climatic studies.

Appiah et al. (2015) studied satellite Remote Sensing and Geographic Information System and analysed the land use and land cover change dynamics in the Bosomtwe District of Ghana, for 1986, 2010 thematic mapper and enhanced thematic Mapper+ (TM/ETM+) images, and 2014 Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI/TIS) image. Their findings showed some of the important changes in the land use and land cover patterns in the district.

Mohan and Kandya (2015) investigated the effect of urbanization on the land surface temperature (LST) based DTR. Study presented spatial and temporal variations of satellite-based estimates of annually averaged DTR over megacity Delhi, the capital of India, which are shown for a period of 11 years during 2001–2011 and analyzed this about its land-use/land-cover (LULC) changes and population growth.

In a study carried out by **Priyan (2015)** has stated that Rainfall Variability is one of the key factors that affect agricultural production in any region. Hence the proper understanding of rainfall pattern and its trends may help water resources development and to take decisions for the developmental activities of that place. The study was an attempt to evaluate the spatial and temporal rainfall variability of Anand district of Gujarat State in Western India. In the study the spatial and temporal rainfall characteristics of this district were studied. Long-term annual and monthly rainfall data (Monsoon months) were considered from 1901 to 2014. The daily rainfalls of monsoon months of all the eight Talukas were analysed for the five years from 2010 to 2014. It was found out that spatial and temporal variability was high in the district.

The change in rainfall pattern and intensity is becoming a great concern for hydrologic engineers and planners. Many parts of the world are experiencing extreme rainfall events such as experienced on 26th July 2005 in Mumbai, India. For the appropriate design and planning of urban drainage system in an area, Intensity Duration Frequency (IDF) curves for given rainfall conditions are required was discovered by **Zope et al. (2016).** The aim of the study was to derive the IDF curves for the rainfall in the Mumbai city, Maharashtra, India. Observed rainfall data from 1901 pertaining to Colaba and from 1951 of the Santacruz rain gauge stations in Mumbai were used in the study to derive the IDF curves. Initially, the proposed IDF curves are derived using an empirical equation (Kothyari and Garde), by using probability distribution for annual maximum rainfall and then IDF curves are derived by modifying the equation. IDF curves developed by the modified equation gave good results in the changing hydrologic conditions and were compatible even with the extreme rainfall of 26th July 2005 in Mumbai.

Arvind et al. (2017) shared his views describing that rainfall is a prime input for various engineering design such as hydraulic structures, bridges and culverts, canals, storm water sewer and road drainage system. The detailed statistical analysis of each region is essential to estimate the relevant input value for design and analysis of engineering structures and also for crop planning. A rain gauge station located closely in Trichy district is selected for statistical analysis where agriculture is the prime occupation. The daily rainfall data for a period of 30 years is used to understand normal rainfall, deficit rainfall, Excess rainfall and Seasonal rainfall of the selected circle headquarters. Further various plotting position formulae available is used to evaluate return period of monthly, seasonally and annual rainfall. This analysis will provide useful information for water resources planner, farmers and urban engineers to assess the availability of water and create the storage accordingly. The mean, standard deviation and coefficient of variation of monthly and annual rainfall was calculated to check the rainfall variability. From the calculated results, the rainfall pattern is found to be erratic. The best fit probability distribution was identified based on the minimum deviation between actual and estimated values. The scientific results and the analysis paved the way to determine the proper onset and withdrawal of monsoon results which were used for land preparation and sowing.

Shortage of water in the river in relation to rainfall change plays a pivotal role in water sharing like Ganga was stated by **Bera (2017)**. In attempt to understand the rainfall changes, Mann-Kendall test and Sen’s slope estimation on hundred years’ (1901-2000) rainfall data of 236 districts in entire Ganga basin were run. The results claimed that half of the districts showed a decreasing trend in annual rainfall in which 39 districts were statistically significant. During pre-monsoon (Jan.-May), 78% of the total districts showed the decreasing trend with the significance of 54 districts. A majority of the districts under the Kosi, Gandak and Sone sub-basins showed the significant negative trend in annual, pre-monsoon and post-monsoon season.

Prasad et al. (2018) stated that spatial and temporal distribution of rainfall is a key factor which affects the availability of water for human use including agriculture and ultimately crop productivity. Climate change is likely to have adverse effects on crop production due to abiotic stresses in which water is an important variable. Intergovernmental Panel on Climate Change (IPCC, 2007) has projected that future climate change especially in temperature and rainfall are likely to affect agriculture, increasing the risk of hunger, water scarcity and rapid melting of glaciers.

Panda and Sahu (2019) emphasized examining the spatiotemporal dynamics of meteorological variables in the context of changing climate, particularly in countries where rainfed agriculture is predominant, is vital to assess climate-induced changes and suggest feasible adaptation strategies. To that end, their study examined long-term changes and short-term fluctuations in monsoonal rainfall and temperature over Kalahandi, Bolangir and Koraput districts in the state of Odisha. Both rainfall and temperature data for period of 1980–2017 were analysed in their study. Statistical trend analysis techniques namely Mann–Kendall test and Sen's slope estimator were used to examine and analyse the problems. Statistically significant trends were detected for rainfall and also the result was found statistically significant at 99% confidence limit during the period of 1980–2017. Rainfall showed a quite good increasing trend (Sen's slope = 4.034) for June, July August and September season.

Praveen et al. (2020) analysed the increasing rainfall trend during the period 1901–1950, while a significant decline rainfall was detected after 1951, for India.

Nath et al. (2023) focussed on examining changes in summer temperature and monsoon rainfall in four Indian states in response to global warming or a global climate scenario. The results of the trend analysis using the MK test and Sen's slope estimator indicated both increasing and decreasing trends in precipitation characteristics across urban cities in all four states namely Gujarat, Maharashtra, Rajasthan and Karnataka. However, when considering the average mean monsoon rainfall for the four states, a statistically significant decrease was observed at a 5% significance level. Change points or shifts in precipitation trends were identified as 1964 for Karnataka, Gujarat, and Maharashtra, and 1978 for Rajasthan. Regarding temperature data, a significant upward trend was observed in most urban centers in the four states. The linear trend line analysis indicated an increasing trend for Karnataka, Gujarat, and Rajasthan, while

Maharashtra showed a slightly negative trend for summer temperatures at a 5% significance level. The change points for temperature trends differed among the four states, occurring in 1981 for Karnataka, 1976 for Gujarat, 1968 for Maharashtra, and 1983 for Rajasthan.

2.3 LITERATURE REVIEW RELATED TO LAND USE/ LAND COVER ANALYSIS

Additionally, RS and GIS technology make detection of LULC changes easier and quicker than it is with traditional surveying and mapping methods **Da Costa & Cintra (1999)**. Furthermore, remote sensing data is the only reliable technique to observe the variations of LULC swiftly, affordably, and correctly. To detect the change using remotely sensed data, various techniques have been developed recently, such as supervised classification, clustering or unsupervised classification. For instance, modifications to land usage may result in climate change, which may raise temperatures and cause water bodies to dry up. The stability of the ecosystem may be threatened as a result of a decline in vegetation or an uneven pattern of it **(Mas (1999)).**

Mohan (2005) conducted urban LULC change detection as part of planning for rural and urban populations in the National Capital Region (NCR) in Delhi, where a related study was conducted.

Using an unsupervised classification method, **(Rao & Narendra (2006); Boakye et al. (2008))** mapped changes in land use and land cover. ERDAS imagine software was used to categorise the data and create the final maps. The ERDAS Imagine programme has been used by scientists and researchers in a variety of projects for classification purposes.

Using imagery from the Landsat MSS Image from 1976, the Landsat TM Image from 1990, and the IRS ID LISS III from 2005, **Yu et al. (2007)** carried out additional analysis in ERDAS IMAGINE in the Birahi Ganga Sub-Watershed of the Garhwal Himalaya, India.

Several researchers, including **Rao and Narendra (2006); Remi et al. (2007); Chaudhary et al. (2008);** and **Kim et al. (2008),** have used supervised classification in their investigations as opposed to unsupervised classification. The highest level of classification accuracy was achieved, they claimed, using the Maximum Likelihood Classification (MLC) decision rule to identify land use and land cover. Studies have been on watershed management have been carried out where resources can be most effectively applied to improving the welfare of the inhabitants and the regional economy. Studies were conducted to decide on different land use alternatives in a watershed by visual interpretation techniques utilizing GIS in order to obtain the best possible resource utilization.

The Indian Municipal Corporation of Hyderabad provided integrated Indian Remote Sensing - ID PAN and Linear Imaging Self Scanning Sensor - III satellite data, which was used by **Asadi et al. (2010)** to create a spatial digital database of Land Use/ Land Cover (LULC). ERDAS, an image processing programme, was utilised for data conversion and input. Database creation and analysis were carried out using Arc/Info and ArcView GIS software.

An increasing number of people are using up the limited availability of water, as well as agricultural land, forest, land for urban uses, and industry. More land needs to be cultivated in order to support the needs of a growing population. Changes in land use and land cover, are measurable fluctuations in the spatial extent (an increase or decreases) of some kinds of LULC. Changes in land use and vegetation cover (LULC) have an impact on both the local and regional climate of a region, and they are a major factor in the reduction of biodiversity. The shifting landscape may have a profound impact on both the local and global ecosystem **Rudel (2009).** Changes in land use and land cover, or LULC, are measurable variations in the spatial extent (increases or decreases) of a certain form of LULC.

Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. To maintain the present natural resources and to understand the causes and consequences of over exploitation of soil and water resources the land use, a land cover mapping and monitoring was done in the study area i.e. Jalgaon District by **Kaul and Ingle (2012).**

Aghil and Rajashekhar (2013) analysed that the Loss of wetland and vegetation due to urbanization is the reason behind frequent floods during heavy rainfall in Bengaluru. Their work focused on estimating direct runoff using Soil Conservation Service Curve Number (SCS-CN) method, one of the popular and widely used method to estimate the direct runoff from a watershed. SCS–CN method based on all the three antecedent moisture conditions (AMC I, AMC II and AMC III) were used for their study. Rainfall data for 17 years (2000-2017) was collected from the meteorological department. In addition, Land use and Land cover maps were used. This study is useful for watershed development and planning of water resources effectively. The results revealed that SCS – CN method is a promising potential and reliable method to estimate the runoff of the Yelahanka watershed area.

Mallupattu and Reddy (2013) studied land use/land cover (LULC) changes in an urban area, Tirupati, from 1976 to 2003 by using Geographical Information

Systems (GISs) and remote sensing technology. The study area was classified into eight categories on the basis of field study, geographical conditions, and remote sensing data. The comparison of LULC in 1976 and 2003 derived from toposheet and satellite imagery interpretation indicates that there is a significant increase in built-up area, open forest, plantation, and other lands. It is also noted that substantial amount of agriculture land, water spread area, and dense forest area vanished during the period of study which may be due to rapid urbanization of the study area.

The selection, planning, and management of natural resources can be used by public or private organisations to meet the growing demands for basic human needs and welfare while also achieving sustainable development goals with a more thorough analysis of LULC change **(Usman et al. (2015)).** For the monitoring and study of LULC changes since the 1970s, satellite Remote Sensing (RS) data has been the main and most reliable source of data. It makes it possible for researchers to more quickly, efficiently, and thoroughly examine changes in land cover.

Yangchen et al. (2015) attempted to analyse land use land cover (LULC) changes in Bhutan over a period of thirteen years from 2000 to 2013. The images of Landsat 5, 7 and 8 were used for LULC classification and change detection. There was a significant increase in the built-up area which accounted for 6% in 2006 and 14% in 2013. Also, the snow cover increased from 4% in 2000 to 6% in 2006 and 9% in 2013. The overall accuracy of about 66% for 2000 and 2006 was fairly good. A low accuracy of 52% for 2013 may be partially because the spectral quality of the images was not good enough and partially due to the fact that the wavelengths of the bands of Landsat 8 satellite are little different than the corresponding bands of Landsat 5 and 7 satellites.

Water's ability to erode surfaces also gets stronger as runoff up slopes rises. The bare slopes thus serve as triggers for natural disasters like flood and widespread migration **(Bibi et al. 2019).**

Geographic information system (GIS) methods are frequently utilised with RS to enhance the effectiveness of land cover change detection **Chaikaew (2019).**

The rapidly changing human activities, such as population growth, industrialization, and urbanisation, are causing significant changes in LULC patterns was portrayed by **Mishra et al. (2019).**

Rapid modifications in LULC patterns are especially detrimental to developing countries and are depleting vital resources like vegetative cover, body of water, and types of soil **Twisa & Buchroithner (2019).**

By boosting water flow and heightening gradients towards flooding, these artificial interruptions also have a substantial impact on changing the climate and triggering disasters **Haindongo et al. (2020).**

Blantyre City had experienced a wide range of changes in land use and land cover (LULC) was observed by **Gondwe et al. (2021)** used Remote Sensing (RS) to detect and quantify LULC changes that occurred in the city throughout a twenty-year study period, using Landsat 7 Enhanced Thematic Mapper (ETM+) images from 1999 and 2010 and Landsat 8 Operational Land Imager (OLI) images from 2019. A supervised classification method using an Artificial Neural Network (ANN) was used to classify and map LULC types.

Abebe et al. (2022) analysed the status of LULC changes and key drivers of change for 30 years through a combination of remote sensing and GIS with the surveying of the local community understanding of LULC patterns and drivers in the Gubalafto district, North-eastern Ethiopia. Five major LULC types (cultivated and settlement, forest cover, grazing land, bush land and bare land) from Landsat images of 1986, 2000, and 2016 were mapped.

Land use land cover (LULC) changes act as global environmental drivers, and therefore, LULC change analysis has become the primary concern for the monitoring agencies. The study by **Ande et al. (2022)** aimed to project the land use and land cover (LULC) by analysing the change rate in the past, forecasting the near, middle, and far future scenarios of Cochin, a highly urbanised coastal city of Kerala, India. Their model simulated LULC was validated by comparing the observed LULC 2020 with the simulated one. The model demonstrated acceptable LULC dynamics with an overall accuracy of 87.5%.

Land use land cover (LULC) changes act as global environmental drivers, and therefore, LULC change analysis has become the primary concern for the monitoring agencies. **Bhuvaneswari et al. (2022)** aimed to project the land use and land cover (LULC) by analysing the change rate in the past, forecasting the near, middle, and far future scenarios of Cochin, a highly urbanised coastal city of Kerala, India. They performed the maximum likelihood classification technique on a series of Landsat imageries at five different times. The simulated future LULC scenarios illustrated a sweeping increase in the built-up lands and shrinkage of natural land covers such as agricultural lands, forests, fallow lands, and water bodies.

According to **Seyam et al. (2023)**, carried out LULC analysis for examining land use trends and assisting in the prediction of future sustainable land management. The research area was a recently developed, rapidly industrialized region in Mymensingh, Bangladesh, where the process of urbanization has also encouraged and altered the uses of the surrounding landscape. The build-up area experienced the greatest changes due to the process of urbanization and industrialization, which increased it by 217.1% (6.56 km^2) and had a major impact. Thus, it concluded that a major LULC change is identified, and the rapid urbanization and industrial activities are the driving factors to trigger the transformation in the study area during the two decades.

2.4 LITERATURE REVIEW RELATED TO URBAN SPRAWL

Srivastava and Gupta (2003) presented that rapid growth in population coupled with expansion of urban fringe and encroachment in the prime land is a matter of great concern for the authorities associated with the urban planning. The expansion of sub-urban territory in Allahabad city of Uttar Pradesh State was a matter of concern for Planning Departments. Keeping this in view, it is planned to develop a remote sensing-based methodology for the preparation of land use/ land cover map using digital image processing techniques for Allahabad city and to monitor the changes in various classes. Changes in area under major land use/ land cover types have been determined through the comparison of their spatial extent in 1994 and 2000. It is observed that there has been an increase of nearly 8.0 km^2 in built up area, coupled with decrease of about 20 km^2 and 2.5 km^2 in agriculture and scrub respectively in 6 years.

Angel et al.(2007) defined and presented a comprehensive set of metrics for five dynamic attributes of urban spatial structure commonly associated with 'sprawl': (a) the extension of the area of cities beyond the walkable range and the emergence of 'endless' cities; (b) the persistent decline in urban densities and the increasing consumption of land resources by urban dwellers; (c) ongoing suburbanization and the decreasing share of the population living and working in metropolitan centers; (d) the diminished contiguity of the built-up areas of cities and the increased fragmentation of open space in and around them; and (e) the increased compactness of cities as the areas between their finger like extensions are filled in. They also introduce several metrics for key manifestations of sprawl. They present these metrics as well as actual calculations of these metrics for two cities: Bangkok and Minneapolis.

Abbas et al. (2010) studied urbanization in Katsina, Nigeria, indicated that urban sprawl and its concomitant effects of soil and land degradation resulting from increasing built environments, continues to characterize the peri-urban landscape.

Sreenivasulu and Bhaskar (2010) have once again supported this assertion by explaining that changes in land use can be due to urban expansion and the loss of agriculture land, changes in river regimes, and the effects of shifting cultivation.

Urban sprawl is mainly driven by unorganized growth, increased immigration, rapidly increasing population was stated by **Sankhala and**

Singh (2014). Urban expansion and pattern could be depicted by spatial and temporal remote sensing satellite data. In this study, an attempt had been made to investigate the effect of Urban Sprawl on Land use / Land cover change of the year 1995, 2000, 2006 and 2010 for Jaipur city, one of the planned cities in India. The pattern of urban sprawl was identified using Remote Sensing technique. The investigation resembles noteworthy change in the spatio-temporal urban sprawl pattern, direction, magnitude and effects on Land use/ Land cover.

Bajracharya et al. (2015) analysed that in urban and suburban areas, much of the land surface is covered by buildings and pavements, which do not allow precipitation and snowmelt to soak into the ground. Hard surfaces such as streets, parking lots and built-up areas are impervious surfaces through which, water cannot pass through. As more and more landscapes are covered with hard impervious surfaces, the amount of water that infiltrates, decreases and the amount that runs off, and increases. This research is focused on studying run-off conditions in context of urban areas. The study area was Kathmandu Metropolitan City (KMC). The city was in the stage of rapid urbanization and with it, a rapid increase in built-up spaces. Parameters for determining run-off coefficients were mainly land cover and land use data, soil type and slope of surface. Results showed that runoff was alarmingly high, indicated by the difference between the run-off values of pre- development and post-development scenarios. Urban development pattern had caused a major impact, in the prevailing run-off and it is very crucial that these issues were addressed in urban planning to promote effective solutions for maintaining water cycle and water resources in urban areas.

Mridha et al. (2016) represented the Land use and Land cover change in Ramganjmandi tehsil of Kota district in Rajasthan, for a period of 30 years, 1990 to 2020. Supervised classification in ERDAS imagine software, opting maximum likelihood classifier is used for the classification of the region into 7 classes. LANDSAT 1-5, 7, 8 Level 1 collection were used for the years 1990, 2000, 2011, 2018 and 2020. The region showed a rapid change in the classes of Mining, Agriculture, Vegetation, and waterbody. The vegetation cover of the region has also declined from the year 1990 to 2020.

Steurer and Bayr (2020) discussed measuring urban sprawl using land use data. He stated that Land Use Policy, 97, 104799. Traditional density measures can be improved by making use of the classifications of land use data. Rather than just using population density per area, land use data can be used to fine-tune the area definition by "cutting out" areas that are (for legal or other reasons) not used for housing. The resulting density measure is a more meaningful indicator of urban sprawl and also allows for comparisons across cities. The most popular methods to measure urban sprawl focus on population density. Low population density numbers are suggestive of high degrees of urban sprawl.

2.5 LITERATURE REVIEW RELATED TO RUNOFF COMPUTATIONS

The use of remote sensing and GIS technology can be useful to overcome the problem in conventional methods for estimating runoff. **Ara and Zakwan (2018)** analysed modified Soil Conservation System (SCS) CN method is used for runoff estimation that considers parameter like slope, vegetation cover, area of watershed. The land cover map developed for the study region were used in analysing the runoff generated over the command area. Rainfall data and soil map for the region was acquired to calculate the antecedent moisture condition (AMC) and hydrological soil group (HSG) map respectively. SCS curve number model was employed to determine the runoff. The computation was carried out on a GIS platform to accommodate the spatial variability. Total runoff generated over the study region during the year 2007 was computed as 17.98 mm.

Muthusi et al. (2020) stated that Mavoko Municipality which borders Nairobi city in Kenya had experienced widespread land use \ land cover change which has altered the hydrological patterns of this watershed leading to occurrence of widespread flooding after rainfall events. This study used the Soil Conservation Service Curve Number (SCS-CN) method integrated with remote sensing and Geographic Information Systems (GIS) techniques to estimate urban runoff and to study the impact of the land use\land cover changes on surface runoff rates between 1989 and 2018. Built-up areas that were largely impervious increased from 24.6% in 1989 to 37.0% in 2018 while the more pervious land under grasslands, open spaces and barren land decreased from 65.5% in 1989 to 44.5% in 2018. 69% of the annual precipitation in 1989 was converted into runoff while in 2018 76% of the annual precipitation was converted in runoff. The result was consistent with the land use/land cover changes and modelling results which showed that 68% of the area experienced increased runoff, 23% no change and 9% a decrease in runoff. Correlation between potential maximum storage and the runoff volumes increased from 0.56 in 1989 to 0.59 in 2004 and 0.77 in 2018. The observed correlation between potential maximum storage and the runoff volumes indicates that the SCS-CN Method, Remote Sensing and Geographic Information Systems Approach can be a useful tool for runoff estimation.

2.6 LITERATURE REVIEW RELATED TO LAND USE/LAND COVER CHANGES ON RUNOFF

Tang et al. (2005) analysed that one of the goals of smart growth was water resources protection, in particular minimizing the runoff impact of urbanization.

To investigate the magnitude of the potential benefits of land use planning for water resources protection, possible runoff impacts of historical and projected urbanization were estimated for two watersheds in Indiana and Michigan using a long-term hydrological impact analysis model. An optimization component allowed selection of land use change placements that minimize runoff increase. Optimizing land use change placement would have reduced runoff increase by as much as 4.9 percent from 1973 to 1997 in the Indiana study watershed. The results of this study had significant implications for urban planning.

Bhat et al. (2017) observed that the fast rate of increase in urban population is mainly due to large scale migration of people from rural and smaller towns to bigger cities in search of better employment opportunities and better quality of life. Urban sprawl resulted in loss of productive agricultural lands, open green spaces and loss of surface water bodies. In their study, an attempt had been made to monitor land use/land cover of part of Dehradun city over two periods of time i.e., from 2004 to 2014 for change detection analysis and to assess urban sprawl using IRS P-6 data and topographic sheets, in GIS environment for better decision making and sustainable urban growth.

Thankachan et al., (2020) stated that a thorough understanding of hydrology is essential for the effective planning and administration of a region's water resources. Rainfall and runoff are key factors in assessing an area's hydrology and developing appropriate water management plans. The SCS-CN method is a popular technique for calculating surface runoff that takes into account the type of soil, antecedent moisture condition, and pattern of land use. The SCS-CN method was used in their study to calculate the runoff of the Palar watershed in the state of Karnataka, South India. The entire area of the watershed is 2872.357 km^2. Rainfall levels ranged from a minimum of 418.7 mm in 2003 to a maximum of 1231.67 mm in 2005. The average yearly runoff is determined to be 626.91MCM and 218.26 mm. The correlation between runoff and rainfall is 0.8253. The study's findings can be efficiently coordinated with the management of watersheds.