Analyzing the Land Use Impact on Flood Regime of Soan River Basin.

By

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(MS WRE&M 2019, 00000320902)

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DEDICATION

Dedicated to my beloved Country, my Teachers, my Family, and the Engineers, who are working day and night for the better future of Pakistan.

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Unending glory to Allah, The Exalted, who granted me the primary inspiration and stamina all along to complete this humble work. This small contribution, if just and correct, is only a drop of appreciation for His Ocean of munificence.

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ABSTRACT

Rapid urbanization is a result of population growth, and as a result imperviousness increases, whereas infiltration, runoff discharge, and flood peak decrease. Researchers are paying close attention to various urbanization patterns and how they affect flood responses. Using HEC-HMS v. 4.9, this study focuses on the shifting effects of urbanization on the flood peak of the Soan River Basin (SRB) (Hydrologic Engineering Center - Hydrologic Modeling System). The Digital Elevation Model, maps of land use and land cover, soil and rainfall data, and other sources were used to estimate the input variables for the HEC HMS model. Urbanization has been on the rise during the 20th century, and this has grown from 3% to 17% of the total basin area between 1997 and 2020 in Soan River Basin (SRB). In response to a change in land use and land cover (LULC) on the calibrated event of 1997, the HEC-HMS model resulted in simulated peak discharge for 1997, 2010, and 2020 LULC as 2383 m3/sec, 2442 m3/sec, and 2462 m3/sec respectively. A higher rise in predicted peak discharges (flood flow) was seen in HEC-HMS modeling as a result of an increase in LULC change in the Soan River Basin (SRB) between 1997 and 2020. The study found that changing the LULC influenced flood peaks.

Keywords Flood intensity, Flooding, HEC-HMS, and HEC Geo-HMS

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The sophisticated hydrological processes in a watershed are often regulated by precipitation, evapotranspiration, temperature, humidity, topography, soils, and LULC, as well as by socioeconomic development. LULC alterations are typically brought about by social-economic development factors including population growth and fast urbanization. In most cases, "land-use transition" is characterized as a shift from agricultural land use to urban/suburban development in terms of the land cover and pertinent features.

LULC fluctuations regularly alter hydrologic processes such as interception, infiltration, evaporation, and transpiration as part of the hydrological cycle. A typical result of LULC modifications is a reduction in natural open areas and an increase in impermeable surfaces such building roofs, roadways, parking lots, and sidewalks. Increased pavements raise peak flow, runoff, and storm volume, all of which have an impact on the hydrology of watersheds (Hu & Shrestha, 2020), (Garoon et al., 2022).

More than half of all people on the planet now live in urbanized regions. By 2050, 68 percent of this percentage is anticipated to have been reached. Rapid urbanization strains our living environment in general and our river basins' hydrologic systems, raising concerns about flooding and water scarcity. These watershed management issues are getting harder to deal with because of recent and upcoming changes in the climate (de Niel et al., 2020).

Water distribution within a watershed is controlled by complex spatiotemporal hydrological processes that are influenced by several climatic, surface, and groundwater factors. The main determinants of the hydrologic balance's many components, such as evaporation, surface runoff, infiltration, and groundwater recharge, are land use and its numerous properties (Ali et al., 2011). Land use is a key factor in much research, including soil degradation and nutrient loss, flood prediction, soil degradation, and biodiversity protection. The use of land may alter as a result of several natural processes. These elements include seasonal fluctuations in land cover patterns, long-term habitat changes brought on by climate change, and the organic expansion of forest stands. Urbanization, deforestation, land conversion to agricultural uses, and forestry management practises are a few examples of land-use changes brought on by humans. Several scientists have recently been interested in the connection between land use and hydrological processes. All these studies agree that compared to other land uses including agricultural, grassland, and urban areas, forest cover decreases streamflow and increases evapotranspiration. The plant's ability to produce flow is influenced by its species and kind. Due to the intricate relationship between evapotranspiration and land use, it can be challenging to predict how changing land use will affect groundwater. The development of hydrological models that take into consideration the spatiotemporal catchment characteristics and their influence on water movement is typically required for the accurate projection of a watershed's dynamic water balance (Öztürk et al., 2013).

The worst natural calamity are floods because of their size and regularity. They frequently flourish next to hills, rivers, and canals. The majority of freshwater is sourced from streams. Because of this, stream beaches are the places on Earth where human social groupings evolve and change the fastest. Because so many people live close to rivers, flooding causes a great deal of suffering and financial harm. More than 178 million people were directly impacted by floods in 2010, and as a result, more than 33% of all economic losses took place. The likelihood of floods is influenced by a few variables, but the two most significant ones are poor management and inappropriate human encroachment along stream banks. People prefer a larger area to live in, especially in developing nations like Pakistan where population growth is rapid. As a result, increasing levels of urbanization and deforestation are the primary causes of an increase in the intensity and frequency of flood tragedies (Younis & Ammar, 2018).

In a tropical catchment, it has been demonstrated that deforestation of about 30% of the watershed increased annual mean flow by 24%. The type of flood event being studied affects how land-use changes affect peak flow. It has been observed that the impact of urbanisation on peak discharge lessens as the event's return time increases. This conclusion is supported by the fact that big flood occurrences are often caused by storms that generate soil saturation; as a result, decreased soil storability has less of an impact on surface discharge. Only during disruptive storms with higher rainfall intensities do land use factors have a substantial impact on the formation of storm runoff during long-lasting advective storms with low precipitation intensities (Shahid et al., 2020).

Using a made-up rainfall-runoff model, the effect of land use on the hydrological cycle of the near-surface soil layer in a Belgian river basin was investigated. The findings show that vegetation has a greater impact on river flows in arid locations, where plant cover results in a notable reduction in river discharge (Brath et al., 2006).

According to simulation studies performed, low flows are more vulnerable to land-use change. By referring to a German river basin, Naef et al. (2002) (Naef et al., n.d.) recently came at a similar conclusion. In the event of rapid surface water runoff, researchers discovered that land-use adjustment may dramatically lower flood runoff. The effects of forest loss, pasture conversion in forested areas, road construction in forested areas, soil compaction brought on by heavy agricultural vehicles, and urbanization in bottom valley areas have all been studied extensively in the past 20 years to quantify the effects of changes in natural vegetation on hydrological processes. According to the study's findings, river flows' susceptibility to changes in land use appeared to be significantly influenced by the geomorphologic and climatic features of the river basin. It's vital to remember that most studies found that human activity frequently had less of an impact on peak flows than was anticipated. Since their size is entirely dependent on the unique behavior of the watershed, climate, and human interventions, they can only be evaluated on-site using a modelling technique that can account for the hydrological consequences of land-use change (Brath et al., 2006).

On the other hand, recent research on the effects of changes in land use and land cover on hydrological processes in several common watersheds have shown that these consequences differ significantly from place to location due to zonal differences and site-specific factors (Wang et al., 2007). Several case studies in typical contexts are required to integrate our experiences and develop a theoretical framework to solve those large difficulties (Wang et al., 2006).

All mountain-originating rivers in northwest China's dry region flow into intermountain basins, where they form centripetal inland drainage systems or inland lakes in the lower depressions. Every one of these inland drainage systems has a network of rivers that parallels its own distinct environment and socioeconomic structure. China's arid interior river basins experience a significantly greater strain on water and land resources due to population expansion and development than other parts of the world. A steady drop in surface runoff in the lower reaches over the past 50 years has led to significant changes in land-use patterns, creating a few ecoenvironmental problems. Traditional agriculture dominates the economy in China's desert regions, with 87 percent of it concentrated in artificially irrigated oasis regions. A close relationship between water resources and land usage is necessary for this type of economic structure. It is vital to investigate how hydrological processes and land-use patterns interact to create programs for the sustainable use of water and land resources in northern China. There are many studies on the extent of unsustainable water use and the resulting environmental degradation in China's arid interior river basins, but there is little trustworthy data on changes in river flow patterns because of changing land use and land cover (Wang et al., 2006).

Higher surface runoff worsens a watershed's flooding issues (*SCS2000*, n.d.). The consequences of LULC change on flow conditions in a watershed must be carefully examined by decision- and policymakers to develop long-term strategies for managing water and land resources. Because of this, many experts have been stressing how LU/LC changes affect hydrological processes, particularly hydrologists, environmental scientists, and geologists.

It is still difficult to come up with reliable methodologies to assess how prospective changes in land use would affect the production of rainfall and runoff. Evaluation of prospective outcomes has been more common recently. Using past and present land-use patterns as well as extraordinary occurrences, event-scale hydrological models have been employed in certain studies to assess the watershed's hydrological response to real or expected rainstorms. These techniques have allowed for an evaluation of the likelihood or potential severity of impending hydrologic responses. Despite this, there aren't many statistical techniques available to predict peak flows from different scenarios of land use expansion.

The rainfall-runoff model explains how precipitation and runoff interact in a catchment area. The model will calculate the amount of surface runoff that will enter the channel or river system in response to input data on rainfall for the target catchment. There are several software programs available for modelling rainfall-runoff, and each one has benefits and drawbacks of its own. One of the most popular software programs for developing rainfall-runoff models is the HEC Hydrologic Modelling System (HEC-HMS).

Calculating the amount of runoff produced inside a certain watershed requires a thorough understanding of rainfall-runoff dynamics. Understanding the direct runoff in a particular watershed is crucial when creating a scheme for sustainable water resources. By dividing the rainfall and examining the primary causes of runoff, modelling techniques may make estimating stream flow and flood peaks considerably simpler. The sort of modelling approach used is frequently determined by the aim, the accessibility of data, and the convenience of usage. Rainfall-runoff models are a common tool for flood modelling, river level monitoring under varied flow conditions, and flood prediction. Deterministic and stochastic hydrological models fall into separate types. In contrast to stochastic models, which give outputs that are somewhat unpredictable, deterministic models do not produce randomness (Al-Mukhtar & Al-Yaseen, 2019).

The HEC-HMS model was developed to mimic every hydrologic activity in a dendritic catchment. In a real or simulated watershed, the model will replicate the processes of rainfall-runoff and routing. It will forecast how much rain will fall, at what stage, and when. The application's hydrographs can be used for a number of purposes, such as reservoir development, planning urban drainage systems, predicting floods, and determining water availability. A combination of HEC-HMS and GIS may be used to assess the effects of land-use change in the watershed based on the rise in stream flow in the river system (Hu & Shrestha, 2020).

The lumped model excludes various sub reactions when evaluating the watershed response at the outflow. The semi-distributed model, which divides the watershed into a number of sub-basins, permits geographic variation. The third kind of model is a distributed model, which permits temporal parameter changes at a client-specified resolution. The Modular Modeling System (MMS) and the European Hydrological System Model, respectively, are distributed and semi-distributed hydrological models (MIKE-SHE). Other semi-distributed hydrological models include the Hydrological Engineering Center Hydrological Modeling System, the Soil and Water Assessment Tool (SWAT), the Topography Based Hydrological Model (TOPMODEL), and the Hydrological Simulation Program-Fortran (HSPF). It is now possible to estimate rainfall "radar-based" thanks to geographic information systems, next-generation radar, and high-resolution digital elevation models (NEXRAD) (Al-Mukhtar & Al-Yaseen, 2019).

Watershed modelling system HEC-HMS is an all-inclusive modelling tool for dendritic watershed systems' hydrologic processes. Most of it is made up of various components for routing, direct runoff, and precipitation losses. HEC-HMS is widely used in hydrological research due to its accessibility, usability, and capacity to simulate runoff in both short- and long-term events while applying conventional methods (Zelelew & Melesse, 2018). HEC-HMS hydrographs are used in studies of urban drainage, water availability, future urbanization, flow projections, flood damage reduction, floodplain control, and system operation, either alone or in combination with other techniques. HEC-HMS has been shown to simulate and predict river discharge using a variety of datasets and catchment types in the past. The majority of these trials revealed that the model simulation's outcomes were site-specific, with distinct model set configurations that included loss strategies, runoff transform methods, and baseflow separation approaches reacting in varied ways (Al-Mukhtar & Al-Yaseen, 2019).

This study examined the land-use and land cover impact on the flood regime in the Soan River Basin. To explore the effect of imperviousness density on flood regime, this study is primarily focused on the 6896 km^2 (approximately) semi-mountainous Soan River Basin (SRB) in the sub-Himalayan Pothowar region of Pakistan.

1.2 PROBLEM STATEMENT

Utilizing event-scale hydrological models, several studies have evaluated the watershed's hydrological response to actual or anticipated rainstorms using past and present land use trends as well as severe occurrences (Ozdemir & Elbaşi, 2015).

These methods have provided an assessment of the propensity or severity of upcoming hydrologic responses. Few statistical methods exist, nevertheless, to forecast peak flows from potential land use growth scenarios.

In-depth research has been done on the impacts of various land uses on the hydrological cycles. Less research has been done on how changes in urban land use have affected floods.

In comparison to nonurban, wooded watersheds, urbanized watersheds often lose 90% of their storm precipitation to runoff.

Due to varying degrees of urbanization within a basin, there are few papers that discuss the various hydrological responses to urbanization across river basins. But in order to prepare and mitigate flood threats at the basin level, it is crucial to have a complete understanding of these reactions.

1.3 OBJECTIVES

a. To analyze the flood process and identify the significant land use changes and their spatial distribution during 1980-2020.

b. To analyze or investigate the effects of land-use pattern changes on flood regime of Soan River Basin.

c. To identify the possible adaptation strategies to reduce the urban flood events in the study area.

1.4 BENEFITS OF RESEARCH WORK

Analyzing the impact on flood processes in Soan catchment will minimize the land use impact on the flood processes.

a. Flood risk assessment and managing the resources to assess floods.

b. Land use, land cover, urbanization trends and their controlling and planning.

c. Policy makers should develop policies that have best reshaping strategies.

1.5 THESIS LAYOUT:

Chapter 1 **Introduction**	Briefly discuss about background of the study, objectives, and problem statement
Chapter 2 **Literature review**	Past studies review about hydrologic modeling, and land use/ land cover change
Chapter 3 **Methodology**	Detailed discussion about methodology, location of study area, and tools adapted during the research
Chapter 4 **Results**	The result of analysis, graphs and tables.
Chapter 5 **Conclusion and recommendations**	Conclusions and recommendation

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

In this chapter we will briefly discuss, methods, tools, and techniques by keeping in view past studies.

One of the biggest risks to property and people is flooding, which has increased in frequency and severity as local economies have risen. The watershed changes in terms of flood volume, runoff components, and source of stream flow as it matures and becomes more hydrologically active. Floods have increased in severity and frequency since the watershed's conversion from rural to urban land uses, although they were formerly rare during the pre-development era. Therefore, it is essential to forecast and simulate floods for planning and running civil protection operations as well as providing early flood warning. Hydrologic resources are being impacted both locally and globally as the world's population continues to grow and more pressure is placed on the land to support it (Liu et al., 2004). The evaluation of how changes in land use and land cover influence water resources is one of the most current developments in hydrologic modelling, and the impact on storm runoff production has been one of the key study issues over the past 10 years. Since soil cover and land use both affect interception, surface retention, evapotranspiration, and resistance to overland flow, the impact of land use on storm runoff production is complicated. The accumulation of organic matter on the surface lengthens the period that overland flow is held back, the plant canopy catches precipitation, the thick network of roots increases infiltration capacity and soil porosity, and other effects. Additionally, evapotranspiration is increased by thick vegetation, which has an impact on long-term energy and water equilibrium. Evidently, compared to areas with a high concentration of agricultural or urban land use, grassland or forest regions with identical soils and terrain produce less storm runoff. (Du et al., 2019a).

In Pakistan's rain-fed regions, rainfall is the primary agroclimatic conditions component that influences the cropping system and total agricultural production. Numerous climate changes are closely tied to variations in rainfall patterns. The rise in the global temperature on average demonstrated that more locations are rising than cooling. The hydrometeorological process has been affected by the linearly increasing trend of the global mean surface temperature, which is currently about 1.0°C above preindustrial levels and is expected to reach 1.5°C between 2030 and 2052 if current trends continue. Furthermore, it has been calculated that by the middle of the twenty-first century, the amount of water that is accessible and the average annual runoff will have decreased by up to 10%–30% because of climate change. A reduction in precipitation and an increase in evapotranspiration are said to cause droughts in the Intergovernmental Panel on Climate Change's Fifth Assessment Report. As a result of climate change, rainfall, a dynamic component of the hydrological cycle, changes in both regional and temporal patterns. For managing water resources sustainably and preventing floods and droughts, hydrologists, agriculturalists, meteorologists, and industrialists must understand the temporal and geographical variability of rainfall. For effective modelling of flood control using detention basins or surface water storage using rainwater harvesting systems, a full understanding of the spatiotemporal distribution of rainfall is required. (Hussain et al., 2021a).

Recent studies have shown that the growing urbanization of coastal China and other parts of the world has affected the hydrological responses within river catchments. The complex fluvial topography and spatially varied underlying surface characteristics in inland river basins are predicted to make the hydrological consequences of urbanization more difficult to understand. Despite several case studies documenting urbanization-related floods, most studies concentrated on models and/or analytical methods. (Du et al., 2019b).

Given that it is an agricultural country with a diversified, uneven, and dry to semi-arid climate, Pakistan is one of the most vulnerable to the effects of climate change. As a result of unfavorable environmental activities, the country's temperature variance is increasing over its customary limits due to unstable and unpredictable rainfall patterns. Positive effects are seen on agricultural production as a result. Water planning and use are significantly influenced by monsoonal rainfall, but because of its unpredictable nature and uneven distribution across time and space, some areas experience floods while others experience drought. Pakistan's annual mean temperature has risen by around 0.5°C during the previous 50 years, according to climatologists, and is expected to climb by another 3° to 6°C by the end of the century. The Northern Areas, central and southern Punjab, and southern Khyber Pakhtunkhwa (KP) will experience the greatest temperature rise by 2050, while precipitation will increase in some places while decreasing in others, according to forecasts from the Pakistan Meteorological Department (PMD) and the Global Change Impact Studies Centre (GCISC) (Forsythe et al., 2017). Future climate change scenarios suggest that greater precipitation uncertainty and glacier melting will make river flows more erratic. For this reason, it is accurate to claim that researching rainfall is a critical precondition for agricultural water planning and that it is an essential agro-climatological component, especially in dry and semiarid Northern areas (Hussain et al., 2021a).

This study is being conducted on the Soan River Basin (SRB) as a whole, which have drainage areas of 6896 km^2, respectively. Soan River containing tertiary-aged rocks is 272 kilometers, with elevation range of 262 to 2274 meters. A "Subtropical Triple Season Moderate Climate Zone" is the description given to the climate in this region. In the lowlands, the average annual rainfall is 400 millimeters, whereas in hilly areas, it is around 1710 millimeters, with roughly two-thirds of the rainfall falling during the monsoon season (June–September) (Hussain et al., 2021b). Rainfall is the primary source of water for both sub-catchments. Snowmelt, on the other hand, affects streamflow in Chirah. Whereas the Chirah sub catchment parallels the Himalayan subtropical pine forest and western Himalayan subalpine conifer forest, the Dhoke Pathan sub catchment parallels the xeric shrubland ecoregion of Pakistan (the principal terrestrial ecoregions of the western Himalayas). On the one hand, the Chirah sub-catchment is located upstream of the river and includes topography that is characteristic of the lower Himalayan foothills, including rugged terrain with several valleys and a steep gradient. The Dhoke Pathan sub catchment, in contrast, is a region of low-elevation hills and plateaus that is situated downstream of the river. In addition to rain-fed agriculture, deep canyons and gullies play a key role in the region's wasteland ecosystem. The Soan River, which supplies water to Islamabad and Rawalpindi's 4.5 million residents, is Pakistan's principal water source. Agriculture needs both perennial rivers and precipitation. The SRB's most important crops include wheat, groundnuts, millets, oilseeds, fodders, and other plants. Loess and non-calciferous alluvial plains make up most of the basin. A little more than half of the area is covered by flat to moderate slopes, more than a quarter by medium slopes, and the final quarter by steep or extremely steep slopes. While dry and semiarid climates predominate in the southern half of the SRB, humid and subhumid climates are characteristic of the northern half (Umukiza et al., 2021)

All living things require water to survive. It is a finite resource required for the industrial, agricultural, and economic growth of a country. The primary supply of water for home, industrial, and agricultural applications is runoff. An earlier study found that runoff has significantly changed in many different parts of the planet. It is believed that both climate change and human activity have significantly contributed to this shift. Among the environmental effects caused by humans are changes in land use, urbanization, deforestation, and water consumption for industry and agriculture. The impact of anthropogenic activity and climate change on streamflow, however, is quite complex at the regional level. Therefore, it is crucial for the evaluation and management of regional water resources to look into local climate change and land use change scenarios. Also, it is crucial for water resource planners to assess the relative contributions of climate change and land use change to observed annual streamflow changes. Investigations on how changes in runoff are impacted by hydrological parameters have taken a variety of forms. Modeling techniques based on paired catchment, statistics, and hydrology are the three categories of these strategies. The challenge and cost of locating two catchments with the similar properties is one disadvantage of the paired catchment technique. Statistics have limitations when it comes to physical interpretation, and it might be difficult to determine how directly land use change has an impact (Brath et al., 2006).

One of the key topics of the International Association of Hydrological Sciences' (IAHS) new scientific decade from 2013 to 2022 was the relationship between hydrological cycles and evolving human systems. Due to the development of civilization and the economy, many human activities have had a significant influence on the hydrological cycle and the availability of water. The peculiarity of land use/land cover (LULC) change is a blatant sign of these effects. The biodiversity of the watershed, economic activity, and hydrological processes are all significantly impacted by changes in LULC. LULC alterations, in addition to biological system fragility, are important drivers of global natural change with potentially drastic implications on human prosperity and occupations. Under agricultural regions and regular plant cover, significant changes in physical and pressure-driven soil characteristics were observed, raising the possibility that rural activity may affect the dirt water balance (Umukiza et al., 2021). The natural environment has been altered by urbanization and population growth, leading to a considerable increase in impermeable regions This mechanism, which reduces precipitation interception, delays infiltration water, and creates overland flow, has a profound impact on watershed hydrologic cycles. There is a higher danger of flooding as a result of the increasing frequency of strong rainfall events brought on by climate change, and metropolitan areas are now more vulnerable to environmental changes. To forecast and manage the flood risks brought on by these changes, we must identify the causal relationships between patterns of impervious area change and flood regimes. Impermeability, which is commonly determined as the area-weighted mean of the land-use classes, is a crucial indication of the environment and hydrology. The hydrological effects of urbanization are typically explained by mean imperviousness, also known as total imperviousness area (Oudin et al., 2018) at the basin size (TIA). Numerous researchers have looked at the connection between hydrological indicators and an increase in impervious land.

The severity and risk of future flood catastrophes are predicted to increase from those of the present. Yet other human-made activities have also increased the risk of floods, in addition to climate change. Examples of such actions include clearing wetlands known to reduce flooding, expanding agricultural operations, destroying forest ranges, and unchecked expansion. These elements all work together to raise surface runoff, which causes high flood peaks. The threat of floods is expected to increase because of climate change. Water resources, on the other hand, are extremely susceptible to changes in land use and the intensification of human activity. Because land use and floods are so intimately linked, changes in land use, such as urbanization, across the catchment region may set off a series of floods (Ekeu-wei & Blackburn, 2018). The hydrological cycle is directly impacted by changes in land use and land cover; nevertheless, the hydrological cycle is indirectly impacted by climate change, as are the consequences of the changing climate on water. Urbanization and agriculture are the main drivers of widespread land use change. Agricultural, natural, and wetland environments are transformed into densely populated built-up areas because of urbanization.

Even while food security and social and economic development are only a few of the many benefits of urban growth and agricultural output, the negative effects are much more pervasive. Flash floods, however, are more destructive than normal floods. Additionally, flash floods come suddenly, preventing accurate forecasting and early warning, leading to the destruction of both life and property. Water levels in drainage networks rise to their highest levels in a couple of minutes during this sort of flooding, which suggests a link between urbanization and hydrological features. Among these include sharp drops in infiltration, as well as rises in runoff, frequency, and flood height.

Using a hydrological model is another method for analyzing the effects of urban landscape patterns. Less hydrological information is needed since it can simulate the change in flows using scenario modelling. To evaluate the effects of the impermeable patterns, the researchers employed an event-based model and scenarios that reflected extreme instances of clustered development and sprawl type. The CLUE-S and SWAT models were used to examine the hydrological response of the Yangtze River Delta region to urbanization. It was demonstrated that changes in hydrological fluxes were more apparent in rural sub-basins than in suburban basins with higher urban growth. Distributed hydrological models have been used to estimate the impacts of urbanization on flood regimes based on physical parameters and land use conditions. To simulate the hydrologic process, distributed models including SWMM, SWAT, VIC, MIKE SHE, and HEC-HMS were commonly utilized. Large areas and basins can be simulated using the HEC-HMS (Hydrologic Engineering Center's Modeling System) from the US Army Corps of Engineers. A GIS, a hydrological model (HEC-HMS/RAS), and a framework for NEXRAD level III rainfall were created by the researchers. The HEC-HMS model's capabilities and applicability for flood forecasting in catchments have been studied scientifically.

2.2 URBAN FLOODING

Urban expansion frequently has negative repercussions like increased flood frequency and peak discharge. Urbanization frequently results in an increase in the maximum annual flow of a stream, however this increase is occasionally hidden by high year-to-year storm variability, as is the case with the annual maximum discharge for Mercer Creek from 1960 to 2000. Rural Newaukum Creek's annual maximum flow varied during the same time without showing any clear trends. After mild storms that follow dry intervals, the effects of urban expansion become most obvious. Stronger storms during prolonged rainy spells cause the soil in rural basins to become saturated, and subsequent rain or snowmelt washes off like how it does in an urban basin. (*Fs07603*, n.d.)

The metropolitan area has grown dramatically around the world during the last few decades. Between 2000 and 2030, the urban land cover will treble, and the urban population will rise from 2.8 billion to 5 billion. In Asia, where a large population is concentrated in places that are very vulnerable to flooding, around half of the urban development will take place there. A significant hydro-climatic calamity that is impacting the entire planet and is intensifying is urban floods. Flooding influences sustainable growth in the socioeconomic, social, health, and cultural spheres. Flood risk, which is defined as the severity of floods exposed to vulnerable persons and property, has been rising internationally. According to studies, flood risk is rising in many regions due to susceptibility to flooding, and flooding risk may decrease with a reduction in vulnerability.

Flood danger is anticipated to keep rising over the following several decades because of climate and LULC change. 40% of all metropolitan land would be submerged in high-flooding areas, and rising sea levels might lead to more catastrophic coastal flooding. According to (Stocker n.d. et.al) (Stocker, n.d.) between .26 to .82 m by 2100 relative to 1986 to 2005.

Worldwide losses are rising, necessitating integrated risk management solutions, the application of which should be predicated on a thorough comprehension of danger sources. This implies that both anthropogenic and climate-related factors must be considered. Future risk evaluations are highly unclear, and this uncertainty is frequently controlled by employing a variety of scenarios. Even while it is valuable for analyzing the impacts of climate change, scenario-based techniques do not provide more fundamental data on the variability to evaluate the relative risk of various adaptation measures than a stochastic method provides. Several research have concentrated on determining the likelihood of (the impacts of) climate change in response to the argument about the necessity of probabilistic climate change scenarios.

Because of this, it is uncommon to find stochastic projections of present and future risk that consider the dynamics of hazard, exposure, and vulnerability. This is especially true for developing nations, where it may be difficult to find the data needed to conduct these assessments. Many models for determining flood hazard at the global scale have recently been developed because of the development of flood models and the increased accessibility of hydrological information with regional to worldwide coverage. Thanks to this discovery, it is now feasible to analyze floods on a large scale even in nations with a shortage of data and to anticipate land change events on a large scale while taking into consideration the ambiguity of the underlying causes. However, there are restrictions because of the data's often low spatial resolution, especially when compared to the general elevation datasets that are readily available.

(|Muis et.al 2015) (Muis et al., 2015) carried out the study in Indonesia which is facing rapid urbanization and faces high flood risk and they found out that the effective way to reduce urban flooding is by spatial planning. Numerous causes are causing the number of urban flooding hazards to increase, with urban growth serving as the primary driver of future flood risk. A trend that is accelerating is rapid urbanization. More than two-thirds of the worldwide people will reside in urban areas until 2050, up from the current 54 percent. Urban areas are expanding and usually becoming denser as a result [3]. To deal with expanding urbanization and avoid enlarging on agricultural land, several towns are working to decrease their negative environmental effects. As a result, densifying already-existing metropolitan areas is the most often used urban planning strategy. It floods more frequently than the surrounding area because built-up terrain has so many impervious surfaces.

Moreover, due to river flow or sea level rise, 15% of the global population is at danger of flooding. In addition to recently afflicted areas like Queensland (2010), South-western England (2013), and the French Riviera, catastrophic floods recently hit highly developed cities like Prague, Dresden, and several other cities (2002), Bern, and several other cities (2005), New Orleans, and Copenhagen (2010, 2011, and 2014). (2015). There are significant societal ramifications. Between 2000 and 2012, it was projected that flood damage in Europe cost an average of 4.9 billion euros yearly. By the year 2050, this amount is projected to rise by almost $23.5 billion, or more than 400%.

Historically, sewage and rainwater have been transported in the same pipe to regulate urban drainage. Dams, levees, and other storage and detention structures may be used in semi-urban catchments in addition to urban drainage systems to prevent flooding. However, conventional flood control techniques usually damage riverine ecosystems in both urban and rural locations, raising the long-term danger of flooding. As a result, alternative methods of managing floods have arisen in recent decades. Other approaches are based on resilience theory and consider the city's ability to control flooding in certain places, prevent flooding in urban areas that are vulnerable to it, and reassemble itself in the event of damage.

So, along with public health protection, access to and security of the water supply, and other factors, flood protection must be considered in densely populated urban areas with major urban infrastructure. The arguments demonstrate that urban water management systems are essential components of a multifunctional urban environment. The city has to develop strategies for managing the water sector in close collaboration with regional and local planning organizations in order to address more pressing and complex issues.

According to recent findings, resilient civilizations recover to their pre-devastating status after horrific events. This may not be the case, as lessons from Hurricane Katrina in 2005 and other catastrophes indicate. Long-term population reduction and poor economic development are still visible ten years after the crisis.

Urban resilience should be viewed as an adaptive process that helps society adjust to changing socioeconomic situations, urban land use, and change climatic conditions. Floods and the complexity of the urban environment need the adoption of a systems-analytical methodology. The three systems that are involved in concerns about urban floods are the hydrology system, the impact system, and the management system.

Authorities, stakeholders, and sustainability standards must work together to implement a new adaptive approach for managing urban water resources. Enhancing metropolitan areas' social participation and appeal while ensuring increased resilience to climate change and water services. Planning must consider how tightly these urban regions operate. The study's goal is to promote the idea of urban flood resilience within a framework of sustainability and risk management considering the aforementioned. We expand on these concepts in accordance with the concept graph in and present instances of how updated tactics might assist mitigate the risk of flooding and prepare for new dangers.

In 2007, in response to the terrible floods that struck much of Europe, the EU established the Flood Directive. The "worst case scenario" and the 100-year event are the two design levels that are specified by the Flood Directive. Riverine floods are specifically addressed in the Flood Directive. Localized flooding, also known as pluvial flooding, poses a significant hazard to cities all over the world. It is brought on by torrential rainfall that overwhelms the municipal drainage system. Traditional urban drainage systems are typically designed to withstand rainfall with a recurrence period of no longer than 10 years since they rely on underground pipes. Roadways, buildings' basements, and other structures are all designed to be vulnerable to floods from more catastrophic disasters.

Even with a design level of a 100-year recurrence time, there is a 40% probability of exceeding critical conditions within a 50-year time frame. The degree of uncertainty surrounding recurrence durations is likewise rather significant given the sparse, accessible data. Regardless of the recurrence time chosen, the EU Flood Regulation highlights that there is always a non-negligible risk of system failure. Unfortunately, more work has to be done to make sure that everyone, especially the general public, recognizes this as a universal truth and takes it into account when formulating their strategic plans.

Concerns about coastal flooding are growing because of rising sea levels and continued climate change. Retreating (slowly raising buildings), defending (securing regions using tools like floodgates and dikes), or attacking—are the three basic tactics that have been proposed (building on the water, with buildings and infrastructures that can endure the water). The greatest options from an environmental standpoint are to withdraw or attack, whereas defending is seen as less prudent. If there are many resources nearby, it is economically better to defend than to attack since it will be less expensive to construct and maintain. From a social standpoint, retreating could be a wise decision.

Floods and sea level rise were explored in recent studies on Mumbai, India, and it was advised that the water be viewed as a friend rather than an adversary that needed to be defended against. The Mithi River should be referred to as a river rather than as a part of the city's sewage system, and Mumbai's islands should be called estuaries. They argued that our perceptions of the natural world and urban surroundings must alter because of the shift in vocabulary and conceptualization. They also claimed that this has an impact on how we construct cities and deal with flooding.

In terms of physical design, coastal flooding differs from floods generated by rivers and pluvial floods (caused by heavy rain). Fluvial and riverine floods frequently interact in urban areas. Localized pluvial floods happen when the capacity of the urban drainage system and natural infiltration and drainage processes are both surpassed. On the other hand, a considerably bigger rural watershed commonly causes riverine floods. As a result, in riverine towns, the size and upstream rainfall-runoff processes may frequently be to blame for the flood problem.

Thus, upstream flood control will likewise have an impact on the water level and discharge downstream. To manage both direct storm water runoff from impermeable regions and broader, often rural catchments that discharge close to or inside urban neighborhoods, urban communities must manage both types of storm water runoff. It may be argued that this is a scale-related issue where it is crucial to consider both the quantitative and qualitative components of runoff. When it comes to organizational strategy and the comprehension of risk and resilience, the issue is identical.

2.2.1 FLOOD RISK MANAGEMENT:

Although risk has numerous definitions and is a debatable subject, most descriptions have the following three characteristics:

a) The idea that the future is unpredictable and that every event that occurs in the future might be influenced.

b) The idea that people may be impacted by an uncertain future, or at least that they may view it that way.

c) The idea that risk is measured in proportion to the desired result.

Risk is hence the possibility that a desired anticipated development may not materialize as expected. When contrasted to more conventional techniques of measuring risk, such as a combination of probability and consequence or of occurrences, consequences, and the ambiguity surrounding them, it initially appears as though this assertion is solely intended to be confused (Barbaro et al., 2021).

A system's ability to "bounce back" to a single equilibrium, its resilience or buffering capacity before a disturbance forces it to migrate to another stable equilibrium, or its capacity to adapt in response to a disturbance are all examples of systems that are considered to be resilient. Several theories suggest that people may be able to adapt to disturbances, predict them, and learn from them. Resilience can be seen as a normative notion that connects results to human goals and aspirations or as a descriptive phrase that describes system behavior. Although both approaches have advantages, resilience must also become a norm if it is to be significant in relation to risk and sustainable development, which are ultimately normative concepts (Muis et al., 2015).

2.2.2 ADAPTIVE FLOOD MANAGEMENT APPROACHES

A new kind of interaction between green and blue assets is required for developing open water management solutions for the urban environment. Combining scientific and artistic approaches is necessary to solve this multidisciplinary problem (Tayyab et al., 2021). Infiltration, storage, transportation, evapotranspiration, and treatment can all be done in a variety of ways. Blue-green infrastructure incorporates urban vegetation and water management to protect the urban landscape and its ecological and hydrological components. Through enhanced heat mitigation, higher biodiversity, and improved air quality, blue-green infrastructure can sometimes improve the standard of living in metropolitan settings. Additionally, it lessens the consequences of flooding and promotes adaptability to climate change. Even better, it may boost the local economy, aid in the production of food and energy, and enhance interpersonal relationships.

Flood disasters pose significant risks to mankind because of the damage they do to infrastructure. Large amounts of water might flood structures and hinder highway access. Flooded buildings that contain delicate machinery like electrical and IT systems might have catastrophic social implications. Additionally, damage may spread to other systems across a much wider region than the one that was first injured since sensitive infrastructure systems are typically linked to and dependent upon one another. It is challenging to predict the potential effects of a flood catastrophe on society since they may manifest right away or take decades to do so. This is a problem since society typically needs infrastructure to run smoothly and provide for its citizens' fundamental requirements, such as access to clean water and power.

This is particularly true in urban settings when there are few, if any, alternatives to inadequate infrastructure. It's also likely that critical social services like hospitals won't be able to withstand disruptions in the transportation, electricity, or water networks. As a result, it is crucial to create and put into practice practical planning approaches for preserving the infrastructure. Given the devastation that flooding causes throughout the world, more has to be done to safeguard the fragile infrastructure from harm or flooding (Owusu & Obour, 2021).

Planning is necessary for the preservation of critical infrastructure when dealing with catastrophe risk management, as the information above demonstrates. While designing and constructing infrastructure, other possible risks to a functioning society, besides floods, must be considered. Water, transportation, and energy systems must be safeguarded in the event of exceptional events like floods. Simulating various scenarios and including unpleasant elements is one method of preparing the society. The integration of several social challenges and the maximization of solutions are made feasible by contemporary technology, including cutting-edge spatial planning techniques. Cost-benefit analysis, time constraints, or environmental concerns may all be used to inform solutions.

To ensure the accuracy of simulations, sufficient and high-quality data are needed for this purpose because even little inaccuracies in these datasets would have a substantial influence on the results. Site-specific design is required due to size and accuracy issues, which also limit the use of spatial generalizations. The need for an appropriate policy framework is emphasized, one that considers choices about asset replacement or renewal, urban renewal, and design processes at spatial scales ranging from local to regional. The inertia of current systems, however, may significantly limit the creative features of solutions, and combining portions may result in challenges of conflicting magnitudes (Sörensen et al., 2016).

2.3 LU/LC CHANGE IMPACT ON STREAMFLOW

Since people have significantly affected natural settings, land use change has the potential to have a significant impact on floods. Large tracts of land have been drained or stripped of trees, which has increased or decreased the soil's preexisting moisture and caused erosion. For agricultural purposes, hillslopes have been altered, which has altered flow connectivity, concentration times, flow velocity, and water storage. The intensification of agricultural practices has led to the development of platy thick soil horizons with favored lateral flow; these horizons may delay or prohibit vertical infiltration in the soils while enhancing lateral mass flow and reducing filter and buffer activities in deeper layers. Over the coming decades, it is projected that the loss of forests and agricultural land would cause significant hydrological changes. However, it is still uncertain how precisely any of these processes—land use change, for example—affect river floods (Umukiza et al., 2021).

For the same sort of change, studies on how land use changes affect streamflow and floods might provide conflicting results. Despite the veracity of the individual research findings, as each study has a very limited and study-specific perspective, it is difficult to make general generalizations about the consequences. A number of scholars have criticized the conclusions of recent publications, including studies on the relative impacts of climate and land use changes on streamflow and the effects of forest management on floods. These discussions blatantly demonstrate the need for fresh ideas in this area as well as for more in-depth quantitative insights into how changes in land use impact flood generation at the watershed scale. (Umukiza et al., 2021).

Because it occurs more frequently everywhere in the globe, flooding is a problem that must be better understood. It is obvious that a cogent research focus must be developed by fully utilizing the information attained in a variety of domains, including hydrology, soil and agricultural sciences, forest science, and geomorphology (Rogger et al., 2017).

Since the start of the 20th century, academic periodicals have published research articles on the possible impacts of substantial deforestation and urbanization on river regimes in several drainage basins in the United States. The impact of significant land use changes, such as the construction of highways in mountainous areas, on river flow was examined using similar approaches. The findings demonstrated that, as predicted, the extent of the area impacted by the intervention has a significant impact on the hydrological impacts of human activity (Brath et al., 2006).

A watershed's hydrological processes may change because of increased impermeable surfaces brought on by urbanization and industrial expansion. To better understand how changes in land use and land cover (LULC) impact hydrological processes, researchers utilize hydrologic models to simulate the physical behavior of the watershed from rainfall to runoff. Low water quality has mostly been caused by changes in land use (Jamali et al., 2015).

Rapid economic growth has accelerated land cover changes that are harmful to water supplies (Samal & Gedam, 2021). The significant increase in land use cover has resulted in increased runoff and decreased groundwater (Uddin et al., 2015). According to the data, agricultural land and settlements have expanded while grassland has considerably reduced (Getu Engida et al., 2021). Due to changes in LU and LC (land use and land cover), including an increase in peak discharges and the frequency of floods, the streamflow regimes have been altering. Peak yearly flows decrease with increasing forest cover, and vice versa (Guzha et al., 2018). Due to the many variables involved, including meteorological (the quality of the precipitation data is difficult to determine), spatial change within the watershed, and many more, the hydrological process of a watershed is frequently highly complicated. As opposed to woods, open terrain, such as a field or developed land, often allows less penetration and is more prone to run-off and overland streams, which may surely displace exposed soil from cultivated fields. Rooftops, parking lots, and other impermeable surfaces do not allow for invasion, so any water that falls on them must run off. These land-use types' of varying extents inside a bowl can have an impact on storm response and release, either increasing all-out yield in a flashier manner or decreasing and smoothing the hydrograph (Brath et al., 2006). The increase or decrease in the peak flow is directly proportional to the percent of the built-up area (Younis & Ammar, 2018)

Hydrological models are routinely built to perform runoff-rainfall simulations, and this may be accomplished by using a GIS arc map and HEC HMS. It is vital to evaluate the impact of LULC change on the hydrological processes. Through simulating discharges in HEC HMS (Hu & Shrestha, 2020) found out that there was an increase in peak discharge at the gauging station. Thus, impervious area increases in the watershed and, peak discharge increases at the outlet of the watershed.

Using the HEC HMS model, meteorological data, peak flow, and evaporation were utilized to simulate rainfall-runoff for twenty-one years. Utilized were the SCS curve number technique, SCS unit hydrograph method, and the specified hydrograph in the precipitation model.

The researchers examined the impact of LULC changes on river peak discharge in Kenya's Sosiani River basin and discovered that peak discharge increased in lockstep with the expansion of agriculture and urban areas and decreased in lockstep with the shrinkage of wooded regions. In the Narok Town Watershed, where agricultural and built-up areas rose by 55.4 percent and 10.6 percent, respectively, between 1985 and 2019, while woodland and pastureland fell by 39.7 percent and 25.7 percent, respectively, the same is anticipated to happen (Umukiza et al., 2021).

The physical properties of soil are impacted by LULC changes, especially those that take place when forests are converted to grasslands or croplands. Despite the well-documented effects of LULC changes on watershed hydrology, generalizations are challenging due to the variability of local conditions and their impact on the hydrograph. Also, the form of the hydrograph may be influenced by the LULC features' geographic distribution. Using the Curve Number (CN) technique, the link between LULC and significant hydrograph properties is frequently explored (i.e., peak discharge, flood volume, and flood duration) (Halwatura & Najim, 2013). The Soil Conservation Service (SCS) created the CN approach in the 1950s, and the National Resources Conservation Service later refined it (NRCS) (Umukiza et al., 2021). The CN technique is a lumped (in space and time) strategy for determining total surface runoff after a rainfall event, and it is explained in greater depth below (Walega et al., 2015). It is often used in research articles due of its widespread popularity, clarity, and authoritative roots. Runoff was predicted using a modified SCS-CN approach that took slope, plant cover, and watershed size into account. Owing to wide CN ranges, low CN values, and shallow precipitation depths, the largest discharge is understated due to CN composition. By encouraging native plant cover loss, increasing imperviousness, canalizing river reaches, and encouraging settlement in floodplains, LULC changes to a watershed tend to make floods worse (Umukiza et al., 2021).

The potential effects of LULC variations on streamflow have been widely studied using a variety of rainfall-runoff models in hydrological and statistical modelling. When observed flow is unknown, estimating the design hydrograph and related peak discharge for small and ungauged basins is a common difficulty in practical hydrology. The use of straightforward and well-designed rainfall-runoff models is advocated due to the challenges associated with calibrating the occasionally enormous number of parameters available in complicated and dispersed rainfall-runoff models in such circumstances (Umukiza et al., 2021).

2.4 GIS (GEOGRAPHIC INFORMATION SYSTEM) AND REMOTE SENSING (RS)

The frequent instability of watersheds, the difficulty of controlling LULC change, the availability of controlled catchment-based examinations, and the difficulty of integrating data from prior research to diverse frameworks all complicate LULC and water resources (Chen et al., 2009). LULC modification, which modifies the surface cover, eventually disrupts the hydrological response. Because changes in these parameters affect the hydrological and biological processes that occur in a watershed, a reliable evaluation of historical and current land cover/land use characteristics is required for the appraisal of a watershed and the creation of a management strategy (Garoon et al., 2022).

One of the key factors that alters a river's flow regime is a change in LU/LC. Numerous scholars from all around the world have examined how LU/LC affects a river's flow regime. It is possible to manage a watershed sustainably by being aware of how LULCC affects river regimes. Flood frequency, base flow, and mean annual discharge may all be changed using LU/LC. Increased surface runoff and conversion of forested area to agricultural land are frequently connected.

One of the most common natural dangers, flooding is anticipated to become increasingly frequent because of changing land use, changing land cover, and changing climate. By 2050, however, it's predicted that 66% of people would reside in cities. 40% of the world's land will be in flood-prone areas soon, 90% of land usage and land cover will be in Asia and Africa, and flooding will harm a growing number of people.

It is essential to comprehend how peak discharge and the flood regime will be affected by land-use change to prepare for future development in the basin and prevent floods downstream. Floods are a type of natural catastrophe that can happen because of both excessive rainfall and altered land usage.

Geographic information systems (GIS), the study of land use and land cover, and hydrology are all growing in importance as tools. This is because a significant amount of the information needed for hydrological and land-use/cover studies may be easily collected from pictures with just partial detection. Remote detection enables fast mark acquisition across large regions. The unsettling markers are used to extract data on land use and land cover. Using picture-order techniques, changes in land-use and land-cover may be broken down over any amount of time using data from the Landsat Multi Scanner (MSS) and Landsat Topical Mapper (TM) (Hu & Shrestha, 2020).

2.5 LANDSAT IMAGES CLASSIFICATION

The extent of land use and cover change in the sub-catchment was examined using GIS and satellite data. Information from land sat pictures may be gleaned using statistics on land usage, precipitation, and river flow. Land usage is now expanding quickly, which has several significant implications. Some of these effects include environmental degradation, disputes over natural resources, deforestation, erosion, and decreased river outflows.

Changes in the Earth's system and climate change are mostly attributed to changes in land use and land cover (LULC). Because any change in land cover alters the amount of evaporation, transpiration, and heat emission on the ground surface, it has a considerable influence on the Earth's radiation balance and contributes to climate change. Urban usage represented up to 10% of the watershed following the supervised categorization of Landsat photos from various years into distinct classifications. It is crucial that land use be controlled in order to ensure water supply and prevent hydrological processes from being hampered. The relationship between biophysical and human factors is what drives land-use change. Additionally, there are the potential repercussions on social and physical components. Extreme human use of land resources has resulted in significant changes in land use and land cover throughout human history. According to estimates, 46% of the earth's surface is yet undeveloped. The amount of forest on the planet's surface has decreased from 50% to 30% for 8000 years ago.

2.6 HYDROLOGIC MODELING USING HEC HMS

To evaluate the impact of LULC on basin- and even global-scale hydrological processes, hydrological models are frequently utilized. The criteria for choosing hydrological models are determined by the study's objectives and the data that are available. Past studies have shown that the Hydrologic Modeling System (HEC-HMS) of the Hydrologic Engineering Center (HEC) may be used to predict how changes in land use and/or climate might affect the hydrology of various catchments (Du et al., 2019b).

The rainfall-runoff model explains how rainfall and runoff interact in a catchment area. In response to input data on rainfall for the target catchment, the model will forecast surface runoff in the channel or river system. For rainfall-runoff models, a variety of software programs are available, each with a unique combination of benefits and drawbacks. A well-liked program for creating rainfall-runoff models is the HEC Hydrologic Modelling System (HEC-HMS).

To simulate every hydrologic activity in a dendritic catchment, the HEC-HMS model was created. The model will imitate rainfall-runoff and routing systems in a real or hypothetical watershed. Predictions will be made on the time, stage, and flow of rainfall entering the catchment. The hydrographs provided by the program may be utilized for a variety of tasks, such as reservoir construction, urban drainage design, flood forecasting, and water availability. Based on the increase in stream flow in the river system, the impact of land-use change in the watershed may be analyzed using a combination of HEC-HMS and GIS (Hu & Shrestha, 2020).

Large numbers of parameters are required for the distributed hydrological model's calibration and validation, which is problematic in an area with few observational data (Chen et al., 2009). The physical structures of the distributed and lumped hydrological models are substantially identical. A lumped hydrological model views the whole basin as a single grid, which is the key difference. In a lumped hydrological model, conceptual parameterization is straightforward, and computation is rapid. Basic monthly water balance models are simple to calibrate, require minimal input, and provide a conceptual foundation. For attribution analysis, the lumped hydrological model—more particularly, the Budyko framework—is thought to be helpful. It is an easy method of modelling runoff within a watershed. It has been used successfully in many different circumstances (Hu & Shrestha, 2020).

To estimate the amount of runoff generated within a certain watershed, a thorough understanding of rainfall-runoff processes is required. To develop projects for long-term water resources, it is essential to understand direct runoff in a specific watershed. Using a modelling method and evaluating rainfall division and the key variables launching runoff may substantially simplify calculating stream flow and flood peaks. The modelling approach employed is typically influenced by the goal, the availability of data, and the ease of usage. Rainfall-runoff models are often used for a few operations such as flood modelling, water level monitoring under varied flow conditions, and flood prediction. There are two types of hydrological models: deterministic and stochastic. The deterministic models will not produce randomness, whereas the stochastic models will provide somewhat random results (Al-Mukhtar & Al-Yaseen, 2019).

The US Army Corps of Engineers developed the Hydrologic Modeling System (HEC-HMS) in 1998 to simulate hydrological processes in basin systems (USACE, 2018). The deterministic, semi-distributed HEC-HMS model, which can simulate precipitation-runoff and route hydrologic processes, employs both a conceptual and empirical technique. The computer program is a modelling system that shows several types of basins. HEC-HMS is a powerful tool for hydrological modelling since it can mimic both short-term and long-term events, and it can be utilized in both large and small, urban, and natural environments (Koutroulis & Tsanis, 2010).

The object-oriented, lumped rainfall-runoff HEC-HMS model makes complex issues simpler by dividing them into smaller, more manageable components. This model shows how the watershed is a cohesive system with hydrological processes. The model's separate component replicates the precipitation-runoff cycle for a particular aspect, while other components are merged to represent the watershed's physical processes. A flood hydrograph is produced by integrating the impacts of each component.

By breaking complicated problems down into smaller, more manageable components, the object-oriented, lumped rainfall-runoff HEC-HMS model makes complex problems easier to understand. This model demonstrates the interconnectedness of the watershed with respect to hydrological processes. While other components are combined to depict the physical processes of the watershed, the model's distinct component replicates the precipitation-runoff cycle for a specific aspect. The effects of each element are integrated to create a flood hydrograph (Du et al., 2019b).

Additionally, the HEC-HMS calculates runoff volume using different base-flow models and direct runoff models. There are nine different loss algorithms included some for continuous simulation and others for event simulation. There are also seven other unique transformation techniques accessible. For example, the Snyder Unit Hydrograph and Clark Unit Hydrograph techniques have been successfully employed in various locations to anticipate long-term stream flows. The peak flow, which corresponds to the greatest downstream flooding, is the most crucial element of the hydrograph for analyzing a flood event. Peaks that are significantly less than the maximum, however, may indicate increased water levels rather than necessarily a flood. Tropical regions can use the HEC-HMS hydrological model. The topography, soil type, and land use of the research region serve as the foundation for the model.

For the Toikanbetsu River basin in Japan, several studies have used runoff models. The findings show that excessive agricultural expansion has seriously harmed the rainfall-runoff system, with a drop in infiltration and an increase in surface runoff. They gave examples of how riparian ecology, and the hydrological system are impacted by land development. Instead of using in-situ data, hydrological models are frequently used to calculate surface runoff, river runoff, and inundations. In hydrological modelling, field observations and data from remote sensing are both very helpful. Rapid changes in land use have a significant impact on a basin's water resources because they alter hydrological processes as infiltration, evaporation, and surface runoff.

Because to advancements in remote sensing technology, changes in land usage may now be identified. It is possible to calculate changes in land use over time, such as urbanization, deforestation, agricultural decline, and wetlands degradation, due to the nature of remote sensing data collection. Researchers were able to gain a better understanding of how changing land use has affected river basin hydrology by using hydrological models that take changing land use over time into consideration. The magnitude and timing of flood peaks are only two examples of the many hydrologic and geomorphic changes brought on by anthropogenic land use changes. Using a conceptual rainfall-runoff model, much research investigated the impact of land use change on runoff in 95 catchments in the Rine River basin. According to their findings, higher summer storm peak discharge is related to more urbanization. Increased afforestation was also shown to considerably lower peak and overall runoff volume. The Bayesian Method is used to condition rainfall-runoff models for ungauged basins and land use impact applications.

Finding the optimal collection of parameter values that results in the best fit between the model and the observations was the goal of model calibration. A split sample method and streamflow observation data gathered at the watershed's outflow were used to calibrate and validate the HEC-HMS model.

2.7 EFFICIENCY CRITERIA

2.7.1 NASH–SUTCLIFFE COEFFICIENT (NS)

A normalized statistic technique known as NSE is used to determine the relative amount of noise in relation to the information presented. NSE values vary from -1 to 1.0, with 1.0 representing the ideal value. Values which lie between zero and one are usually considered acceptable level work. If NES > 0.5, the simulation of the model is often regarded as good, Or Nash–Sutcliffe Coefficient is used to “analyze the simulation power of hydrological models”. The governing equation is given below:

$$NS = 1 - \frac{n(\sum_{t=1}^{T}(Qot - Qmt)^2}{n(\sum_{t=1}^{T}(Qot - Qo^2)}$$

Where, $\overline{Qo}$ is the mean observed discharges, Q_{mt} is modeled discharge at time t, Q_{ot} is observed discharge at time t.

*Nash–Sutcliffe efficiency can range from −∞ to 1.

2.7.2 COEFFICIENT OF DETERMINATION (R^2)

R^2 may be regarded as a very excellent way for indicating the consistency between the stimulated data and observed data by using the best fit line as a guide. Its range spans from 0 to 1. The variance error decreases as the value increases. Any number greater than 0.5 is within the acceptable range. This is the “Square of correlation coefficient” (Moriasi et al., 2015). It is calculated as,

$$R^2 = \left(\frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\{n\sum x^2 - (\sum x)^2\}\{n\sum y^2 - (\sum y)^2\}}}\right)^2$$

*Coefficient of determination value range from 0 to 1

2.7.3 ROOT MEAN SQUARED ERROR (RMSE)

The RMSE is a “quadratic scoring rule which measures the average magnitude of the error” (Chai and Draxler, 2014). It is calculated as,

$$\text{RMSE: } \sqrt{\left(\frac{1}{n}\sum_{i=1}^{n}(model_i - Observed_i)^2\right)}$$

* RMSE can range from 0 to ∞.

2.7.4 PERCENT BIAS:

PBIAS calculates the average tendency of computed numbers to differ from observed numbers by smaller or bigger amounts. Low levels of PBIAS are an indication of the model simulation's accuracy. Positive PBIAS values indicate model underestimation bias, while negative PBIAS values indicate model overestimation bias. For a time, step of one month, the range of PBIAS values is 15% to 25% for runoff and 30% to 55% for sediment output. The model can be used to simulate the catchment if results fall within these bounds.

CHAPTER 3

METHODOLOGY

3.1. GENERAL

Land use changes are a significant component of development activities that have an impact on water resources. By altering the hydrological cycle, this shift can influence the hydrology of a watershed. Changes in the process of runoff production result from human alteration and development activities in a catchment region because the infiltration rate is lowered. Ground water recharge is reduced, and runoff volume is increased as a result of urbanization. Deforestation causes an increase in sedimentation, which shortens the lifespan of a water reservoir. Land use impacts the global hydrological cycle by changing the pattern of precipitation and temperature, according to studies employing several climate models. Land use change impacts can have a big influence on small basins.

The Simly reservoir, the biggest source of drinking water for residents of Pakistan's capital Islamabad, served as the subject of this study. The Simly Dam provides water to the Capital Development Authority at a rate of up to 2.5 cubic meters per second. Simly Dam's current storage capacity is 32219 acre-feet. Simly Dam's storage capacity has decreased by 2.36% when compared to its actual storage capacity, which is the result of changes in land usage. The effects of land use change on the sustainable management of water resources must thus be assessed.

3.2. STUDY AREA

The Soan River, which rises in the Murree Mountains, is a significant tributary of the Indus River and the principal source of water for Pakistan's Potohar plateau. The Soan River passes via the hydrological gauging stations at Chirah and Dhoke Pathan before emptying into the Indus River as shown in (**Error! Reference source not found.**). The Soan River Basin has an levation range of 265 to 2274 m and 6896 km^2.

3.3. LOCATION

A seasonal river in the Pothowar area of Punjab, Soan flows from the Murree Mountains through Rawalpindi, Fateh Jung, Pindi Ghab, Talagang, and Mianwali before joining the Indus River close to Jand (Iqbal et al., n.d.) has five major streams (Jalil & Khan, 2012). The Simly Dam was constructed on the Soan River in 1983 to meet the city of Islamabad's water demands. Korang, Khad, Lei, Ling, and Rumli are significant River Soan tributaries. Khad Nullah is the name of the principal feeder that rises from the Pabuchhian springs and joins the Soan River not far from Chappar. The Ling stream originates from several springs in Kotli Sattian and flows through the districts of Rawalpindi and Chakwal before joining the Soan River not far from Sihala Mirzian. Nullah Lei runs through Margallah Hills before separating into upper and lower Korang over which Rawal Damisbuilt, in contrast to Nullah Korang, which starts from Margallah Hills and flows through Islamabad and Rawalpindi before entering the Soan River at Soan Camp. The Soan River is 274 kilometres long. The Soan River Basin is a semi-arid basin between 32.6° and 33.9°N and 72.4° and 73.5°E, having a catchment area of 6475 sq. km up to the Dhoke Pathan Gauging Station.

According to the current study, the basin's mean annual temperature varies between 8 and 18 °C, and the average annual precipitation from 1983 to 2012 is thought to have been 1465 mm. About all the flow originates from streams that are monsoon-fed, and the slope of the basin ranges from mild to severe. The Simly Dam, the main water supply for Pakistan's capital city of Islamabad, draws water from the Soan River. It also provides the main water source for irrigation in the Potohar plateau. 60% of the population in the basin resides in rural regions where agriculture is the primary industry. Over the past 10 years, several governmental and private initiatives have been built to fulfil the water demands of agriculture, including the construction of micro dams, ponds to collect rainwater, and structures to save soil water; Punjab Planning & Development Department 2015.

Water resource managers and experts from around the world have utilised a variety of techniques for many years to determine the effects of various factors on streamflow change. Yet, all of these processes may be impacted by the vagueness and inconsistent nature of attribution results. Even within the same research area, it is not obvious which factor—among anthropogenic activities and climate change—contributes the most to streamflow fluctuation. In this study, human activities and climate change are both viewed independently to assess their individual effects. The hydrological system is vulnerable to anthropogenic activity and climate change in humid areas. As it is a typical wet basin, the Soan River Basin, a left bank tributary of the Indus River basin, is selected as an example study. The Soan River watershed has experienced significant changes in both climate and land use over the past few decades. As previously stated, a quantitative assessment of the effect of anthropogenic activities and climate change on runoff in a particular basin is essential for better planning and management of water resources due to the variety of various locations. This is the first attempt in the Soan River Basin to use trend analysis of hydrological indicators to link differences in runoff to climate change and human activities (Shahid et al., 2018).

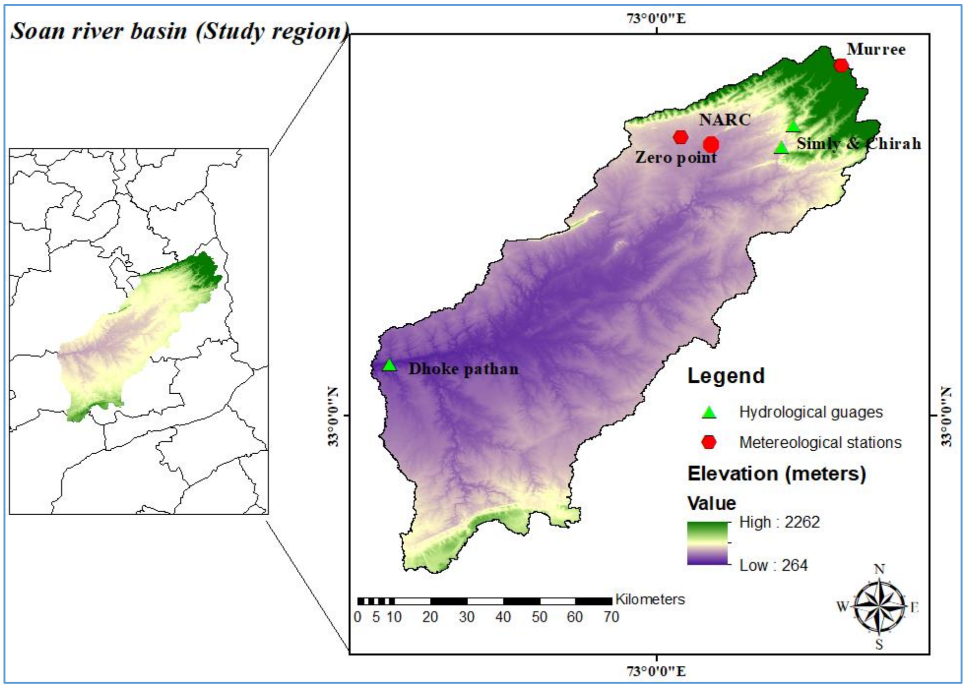


Figure 3. 1Study area: Soan River Basin

3.4. METHODOLOGY:

The methodology shown in (Figure 3. 2)has been adapted for this research:

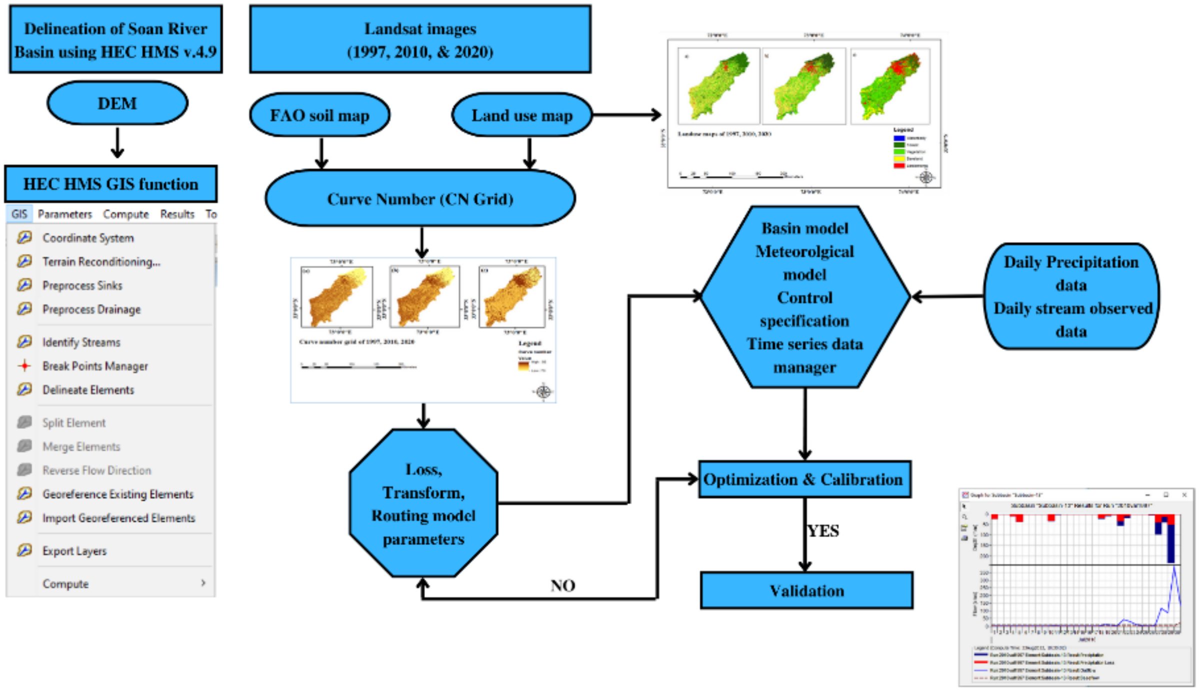


Figure 3. 2 Schematic diagram of methodology adopted.

3.5. DATA SETS

Hydro-meteorological (rainfall and streamflow) and physiographic (digital elevation model, land use/cover, and soil type) databases are the two main types of input data used in rainfall-runoff modelling. Data on elevation, land use/cover, soil, percent impervious area, and hydrographs are all necessary to build a HEC-HMS model. Hydrologic parameters and stream/sub-basin characteristics were computed using these datasets. The meteorological information at the Murree station and the Islamabad (ZP) station was provided by the Pakistani meteorological service in Islamabad. WAPDA Islamabad provides information on the intake and outflow of Simly Dam.

The data sets include:

Table 3. 1 Meteorological data collection source and duration

DATA	SOURCE	DURATION
Rainfall data and Temperature data	PMD, Islamabad	1960-2018
Rainfall data	NARC, Islamabad	1960-2010
Inflow and outflow data	WAPDA Simly Dam	1983-2020
DEM (30m) Land-Sat images	EARTH EXPLORER, USGS	1997, 2010

3.3.1. HYDRO-METEOROLOGICAL DATA

The precipitation data was procured from institution like Pakistan meteorological department Islamabad, Water and power development authority and National agriculture and research center.

3.3.2. DEM (DIGITAL ELEVATION MODEL) OF SOAN RIVER BASIN

A Digital Elevation Model (DEM) is a depiction of the topographic surface of the Earth's bare land, free of vegetation, habitation, and other surface features. It is taken from the USGS Earth Explorer data sharing website.

DEMs are produced using several sources. In the past, topographic maps were the primary source of USGS DEMs. DEMs created from high-resolution lidar and IfSAR (Alaska only) data are gradually replacing those ones.

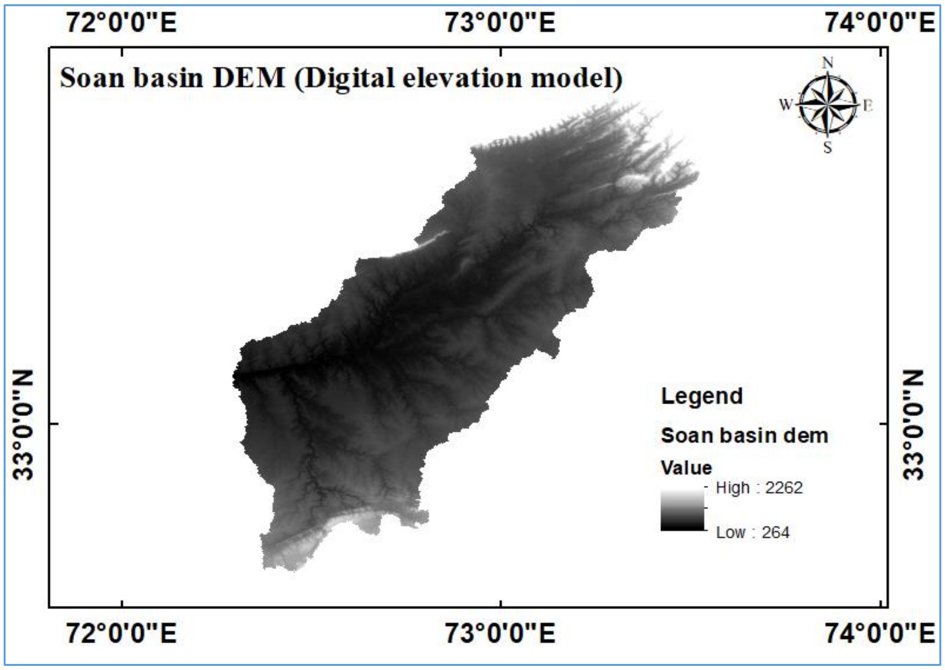


Figure 3. 3 Digital Elevation Model of Soan River Basin

The Soan River Basin (SRB) DEM was imported into HEC HMS (version 4.9), and the GIS feature of HEC HMS was used to complete the processes required to create the ARC map. After selecting "UTM ZONE 43N Wgs84" as the coordinate system, fill and flow direction were crucial tasks to complete as shown in the Figure 3. 7.

3.3.3. SOIL DATA

Most of the soils in the Soan River Basin are noncalcareous alluvial and loess plains, which are deep, diversified, and have adequate drainage. They range in type from clay loam to silty clay loam. Both Hydrological Soil Groups C and D are present in the Soan River Basin, with HSG Type D being the main soil type as shown in Figure 3. 4.

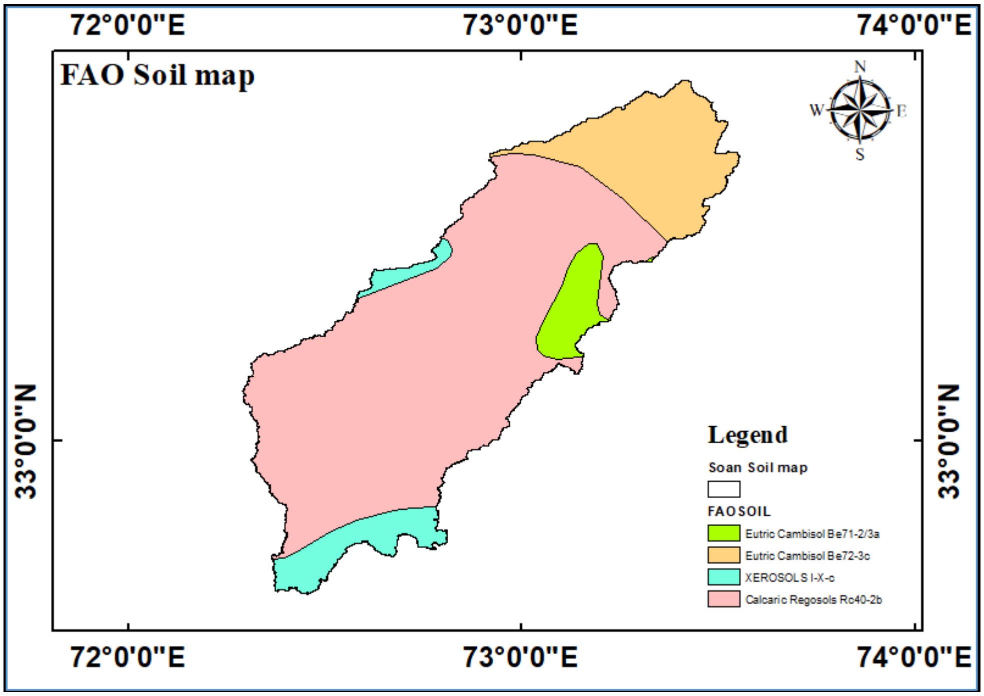


Figure 3. 4 Soan River Basin FAO Soil map

Table 3. 2 FAO Soil classification to HSG soil group

FAO soil classification	Soil Texture	HSG
Be71-2/3a	Clay-Loam	D
Be72-3c	Clay	C
I-X-c	Loam	D
Rc40-2b	Loam	D

3.3.4. LAND-USE IMAGES

Using remote sensing software, the land cover pattern in the watershed of the Soan River was examined (Arc Map). Depending on the flood episodes, Glovis.org, a USGS extension, has provided land-use imagery from 1997 and 2010. In this step, LANDSAT scene tiles were used to extract Soan Catchment data using ArcGIS. Supervised classification techniques and the maximum likelihood algorithm were used to classify land uses. Soan Catchment was divided into five categories: vegetation, water bodies, barren terrain, built-up areas, and forests.

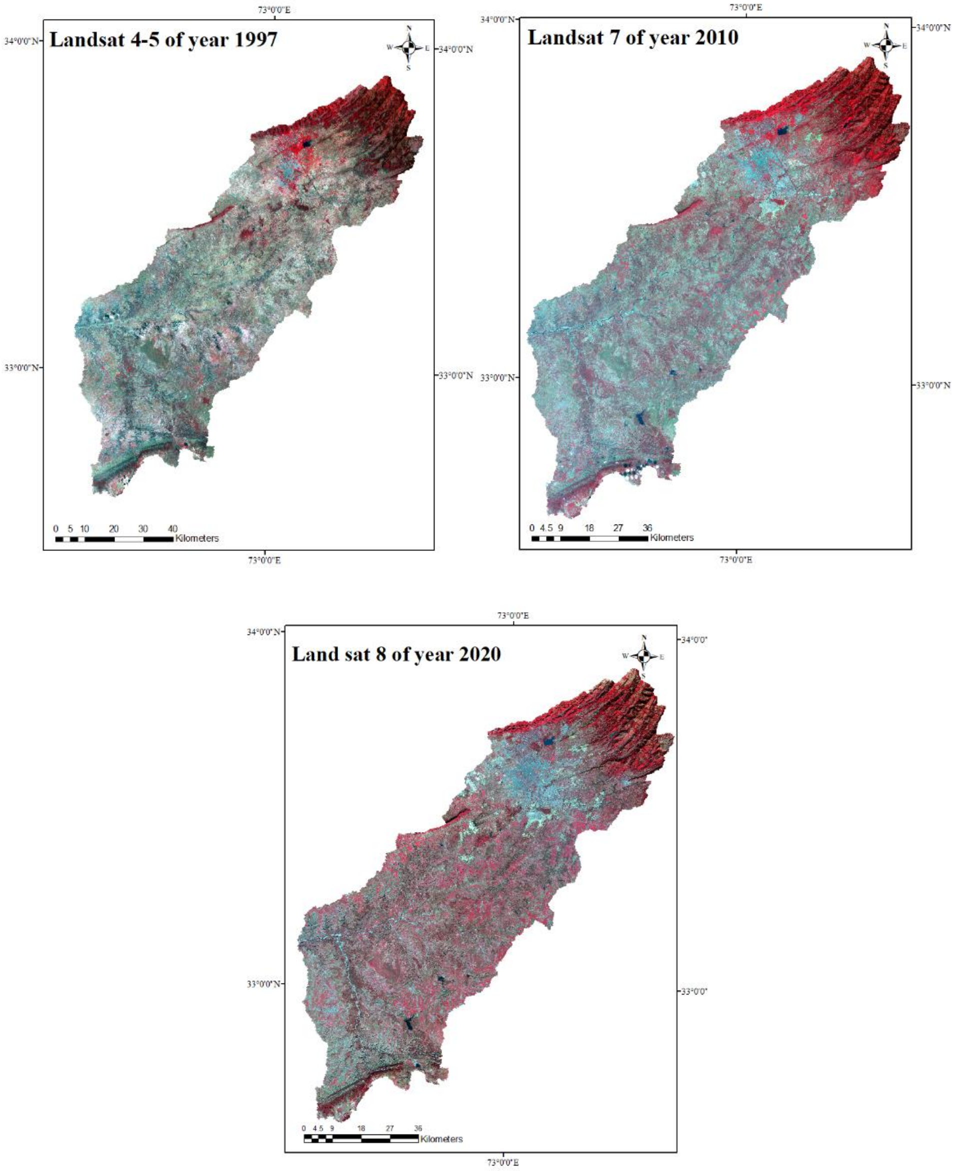


Figure 3. 5 a) Land-sat images 1997, 2010 & 2020.

Since the basin has various land-use features, the land-use and soil data were combined in HEC Geo HMS to create a curve number grid. This required us to employ GIS capabilities in HEC HMS to assign curve numbers to the various sub-basins that were created.

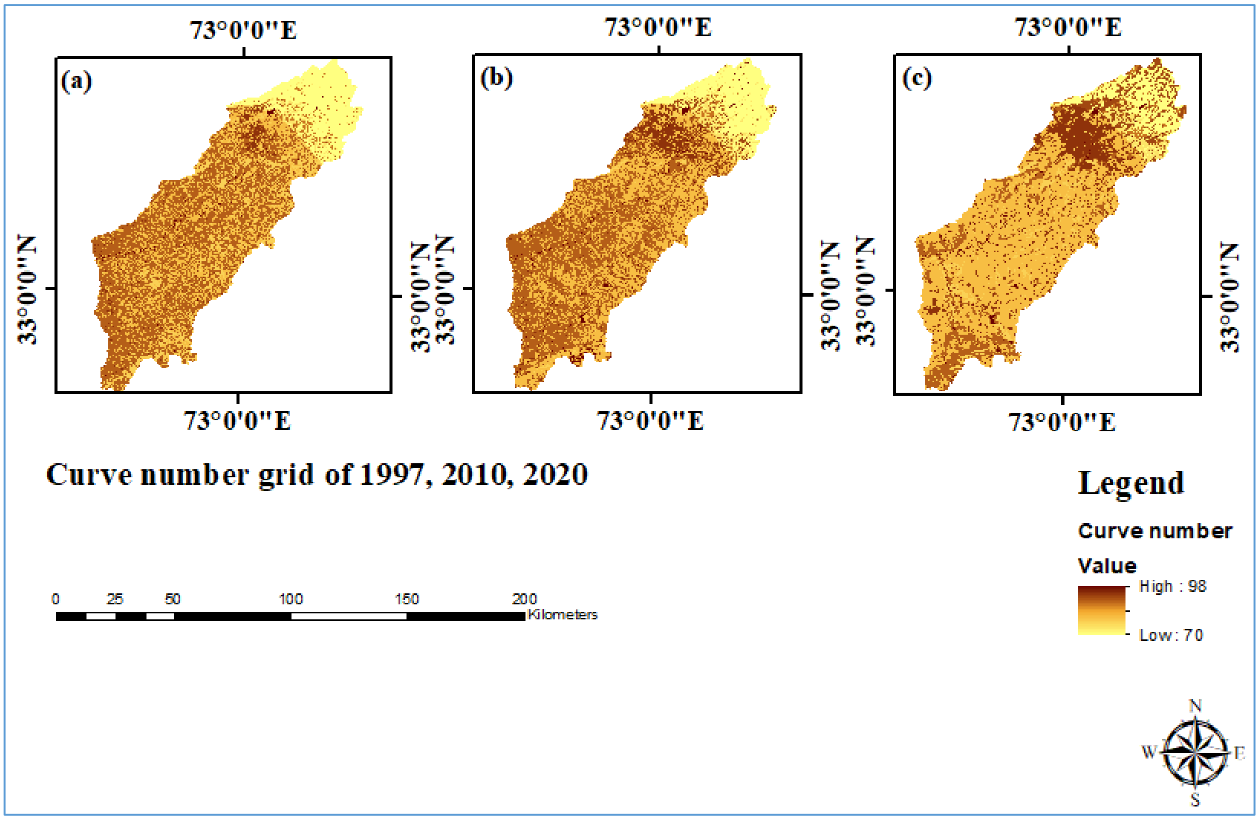


Figure 3. 6 (a) Curve number grid of 1997 (b) Curve number grid of 2010 (c) Curve number grid of 2020

3.6. HYDROLOGICAL MODELING SYSTEM

Hydrological models are commonly employed to quantify the effects of LULC on hydrological processes at basin- and even global-scales. The selection criteria for the hydrological models are determined by the study's aims and the data's accessibility. The Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) has been used to forecast how changes in land use and/or climate might influence the hydrology of different catchments. (Du et al., 2019b).

The rainfall-runoff model explains the relationship between rainfall and runoff in a catchment region. The model will calculate the amount of surface runoff that will enter the channel or river system in response to input data on rainfall for the target catchment. There are several software packages for rainfall-runoff models available, and each has advantages and limitations of its own. The HEC Hydrologic Modelling System is one of the most used software tools for creating rainfall-runoff models (HEC-HMS).

The HEC-HMS model is an object-oriented, lumped, and semi-distributed model for rainfall-runoff that simplifies complicated issues by breaking them down into manageable chunks. The watershed is demonstrated by this model to be a unified system with hydrological processes. A distinct component of the model simulates the precipitation-runoff process for a specific aspect, and other components are combined to simulate the physical processes of the watershed. The result of integrating the effects of each element is a flood hydrograph.

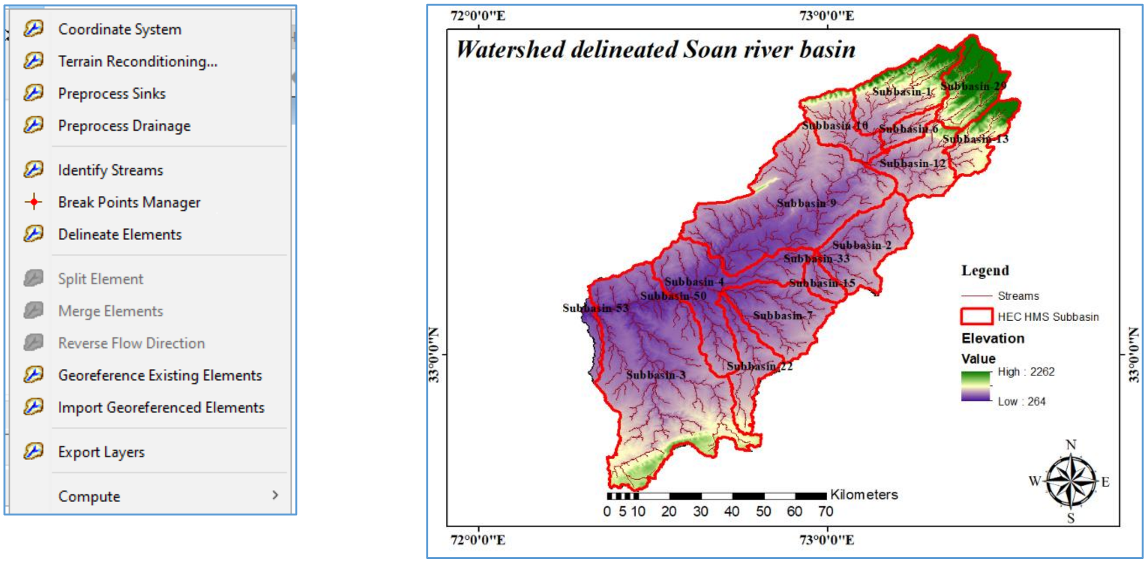


Figure 3. 7 GIS functions in HEC-HMS v. 4.9 and Delineated raster

HEC HMS simulation classifies different function into different models, upon using different parameter providing the data related to specific model, helps HEC HMS runs the simulation.

- **Basin model:** This component describes the basin's physical features, including basin characteristics and representations of runoff processes such as loss, transform, base-flow, and routing algorithms.
- **Meteorological model**: Precipitation, evapotranspiration, and snowmelt are all defined by this component.

- **entereddata manager:** Time-series data, gridded data, and paired data can all be entered into this component as necessary data for initial conditions, boundary conditions, or parameters.
- **Specifications for control:** This part is used to manage simulations.

3.6.1. LOSS METHOD

The levels of CN change with soil cover and moisture, even though moisture variation was not taken into consideration in this experiment. Second, the storage factor, which will affect the simulation for a watershed like RCW with a mix of agricultural and urban land cover, is not taken into consideration because this approach only considers the direct proportionality of rainfall and runoff.

3.6.2. TRANSFORM METHOD

A transform technique is used to determine direct runoff from additional precipitation in the watershed region at the outflow. SCS provides the SCS Unit Hydrograph Transform Technology, which is developed from averages of unit hydrographs from runoff and rainfall for several agricultural basins in the US (Hydrologic Modeling System HEC-HMS Technical Reference Manual CPD-74B, 2000).

$$Tc = \frac{(L^{0.8} \times (S+1)^{0.7})}{(1900 \times Y^{0.5})} \tag{1}$$

L= Hydraulic length (ft)

Y= Basin slope

S= Maximum retention after runoff calculated using Curve number as

$$S = \frac{1000}{CN - 10} \tag{2}$$

T_{lag} was calculated using following equation:

$$\mathrm{Tlag} = \mathrm{tc} \times 0.6$$

(3)

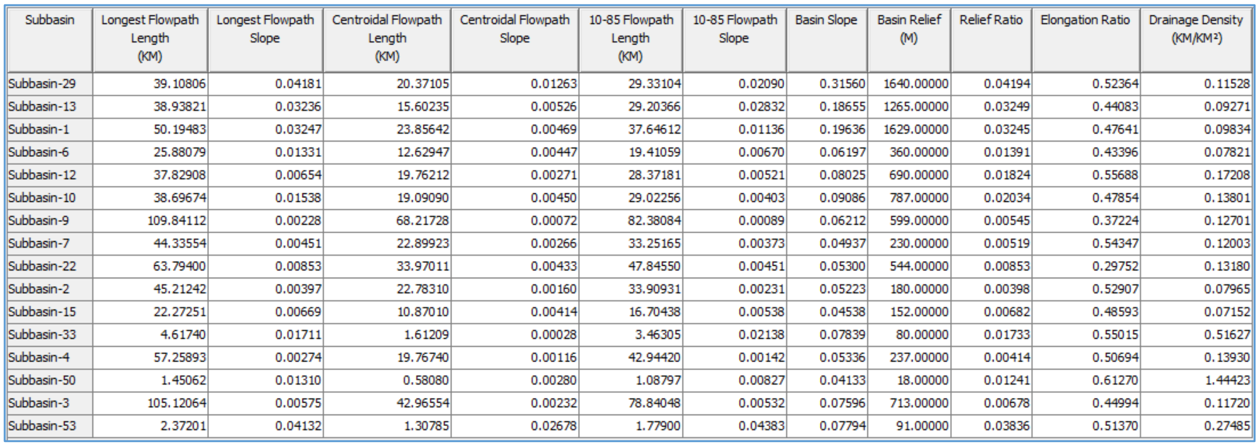
The recession model used in this work provides an explanation for the drainage process from natural storage in a watershed. It is crucial to specify the baseflow parameter in flood studies because it indicates the lowest river depth at which additional runoff accumulates. Following is an expression for the relationship between baseflow Q_t at any time t and a starting value Q_0 (*Hydrologic Modeling System HEC-HMS Technical Reference Manual CPD-74B*, 2000):

$$Q_t = Q_0 \times k^t \qquad (4)$$

Q_0= Initial baseflow

k= Exponential recession constant

Figure 3. 8 HEC HMS sub-models and parameters



Subbasin	Longest Flowpath Length (KM)	Longest Flowpath Slope	Centroidal Flowpath Length (KM)	Centroidal Flowpath Slope	10-85 Flowpath Length (KM)	10-85 Flowpath Slope	Basin Slope	Basin Relief (M)	Relief Ratio	Elongation Ratio	Drainage Density (KM/KM²)
Subbasin-29	39.10806	0.04181	20.37105	0.01263	29.33104	0.02090	0.31560	1640.00000	0.04194	0.52364	0.11528
Subbasin-13	38.93821	0.03236	15.60235	0.00526	29.20366	0.02832	0.18655	1265.00000	0.03249	0.44083	0.09271
Subbasin-1	50.19483	0.03247	23.85642	0.00469	37.64612	0.01136	0.19636	1629.00000	0.03245	0.47641	0.09834
Subbasin-6	25.88079	0.01331	12.62947	0.00447	19.41059	0.00670	0.06197	360.00000	0.01391	0.43396	0.07821
Subbasin-12	37.82908	0.00654	19.76212	0.00271	28.37181	0.00521	0.08025	690.00000	0.01824	0.55688	0.17208
Subbasin-10	38.69674	0.01538	19.09090	0.00450	29.02256	0.00403	0.09086	787.00000	0.02034	0.47854	0.13801
Subbasin-9	109.84112	0.00228	68.21728	0.00072	82.38084	0.00089	0.06212	599.00000	0.00545	0.37224	0.12701
Subbasin-7	44.33554	0.00451	22.89923	0.00266	33.25165	0.00373	0.04937	230.00000	0.00519	0.54347	0.12003
Subbasin-22	63.79400	0.00853	33.97011	0.00433	47.84550	0.00451	0.05300	544.00000	0.00853	0.29752	0.13180
Subbasin-2	45.21242	0.00397	22.78310	0.00160	33.90931	0.00231	0.05223	180.00000	0.00398	0.52907	0.07965
Subbasin-15	22.27251	0.00669	10.87010	0.00414	16.70438	0.00538	0.04538	152.00000	0.00682	0.48593	0.07152
Subbasin-33	4.61740	0.01711	1.61209	0.00028	3.46305	0.02138	0.07839	80.00000	0.01733	0.55015	0.51627
Subbasin-4	57.25893	0.00274	19.76740	0.00116	42.94420	0.00142	0.05336	237.00000	0.00414	0.50694	0.13930
Subbasin-50	1.45062	0.01310	0.58080	0.00280	1.08797	0.00827	0.04133	18.00000	0.01241	0.61270	1.44423
Subbasin-3	105.12064	0.00575	42.96554	0.00232	78.84048	0.00532	0.07596	713.00000	0.00678	0.44994	0.11720
Subbasin-53	2.37201	0.04132	1.30785	0.02678	1.77900	0.04383	0.07794	91.00000	0.03836	0.51370	0.27485

Figure 3. 9 Subbasin characteristics in HEC HMS

CHAPTER 4

RESULTS AND DISCUSSIONS

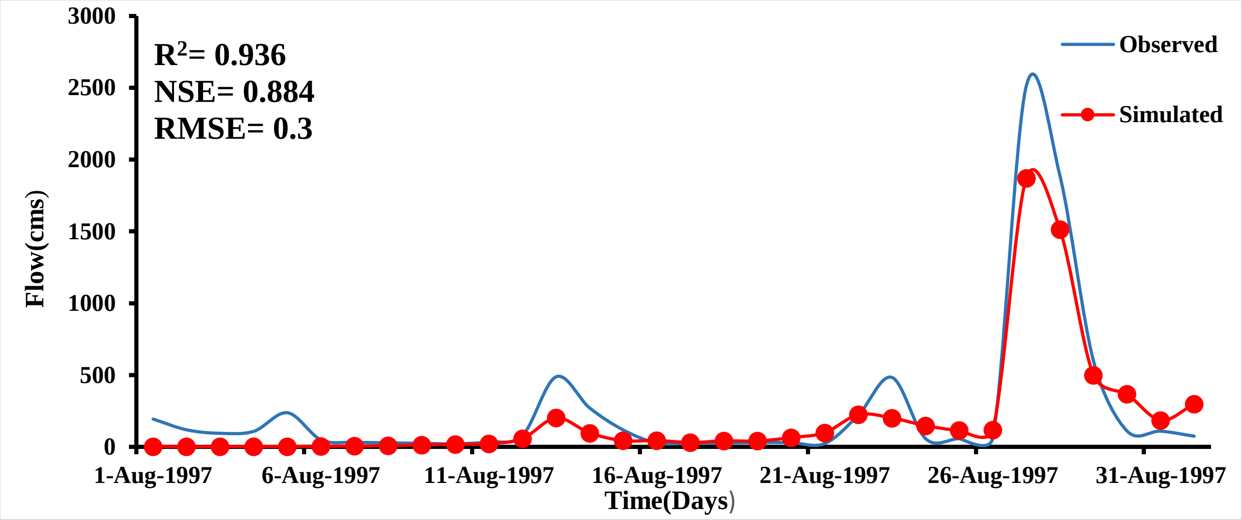
4.1 GENERAL

This section firstly presents the model calibration and validation results, then characterizes LULC changes in the study area, and lastly presents the effects of LULC change on flood regime in SRB.

4.2 CALIBRATION AND VALIDATION RESULTS IN HEC-HMS

The hydrological model must go through model calibration, using following steps, (1) Running the simulation (2) Comparison with observed values (3) Adjust input parameters to be within the reasonable range. The simulation is run through the set of input parameters for SRB, and then calibration is performed using trial and error approach till the simulated and observed values are within the feasible range. The calibrated model must also be validated. This is often done by keeping the calibrated parameters the same and just changing the precipitation/ rain gauge data. The 1997 and 2010 land-use data and precipitation data were used to simulate two flood events. The model compares real and simulated flood hydrographs and was calibrated for 1997 and verified for 2010. For all instances, there is good agreement between the observed and modelled flood hydrographs. When the efficiency is better than 0.6, the simulation results are trustworthy, according to NSE coefficient. The NSE value in calibration is above 0.6. The mean correlation coefficient (R^2) is 0.93 for calibration period and 0.87 for validation period.

The parameters determined during calibration in 1997 have been used without alterations except Curve number in validation for 2010 event. As, curve number is the factor representing land-use change.



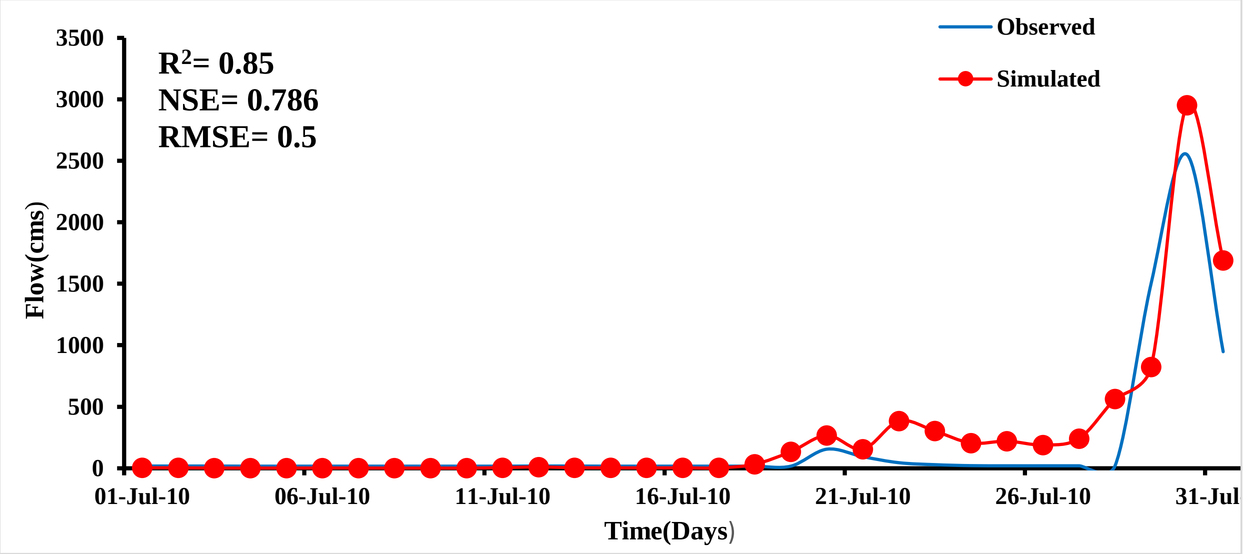


Figure 4. 1 Comparison of observed and simulated flood hydrograph

Table 4. 1 Summary of peak flood and flood

Year	**Simulated flood peak (m^3/sec)**	**Observed flood peak (m^3/sec)**	**Simulated flood volume (mm)**	**Observed flood volume (mm)**
27-Jul-97	1982	2512	78	103.59
30-Jul-10	2995	2549	92.88	67.11

4.3 ACCURACY ASSESSMENT OF LAND-USE MAPS, USING CONFUSION MATRIX:

The Land use maps were created using the maximum likelihood approach, supervised classification of Land Sat images. The land use maps accuracy assessment was carried out using stratified random sampling using 100 points on average involving a confusion matrix.

Confusion matrixes were formed, and, in the end, the overall accuracy and Kappa index were calculated. The overall accuracy and Kappa index for 1997, 2010, and 2020 land use maps were **80% and 0.75**, **83% and 0.81**, **85% and 0.82.**

And the results are as follows:

Table 4. 2 Accuracy assessment of LULC maps

Parameter	1997 LULC maps	2010 LULC maps	2020 LULC maps
%Of correctness	80%	83%	85%
Kappa Coefficient	0.75	0.81	0.82

4.4 LAND-USE LAND COVER CHANGES IN SRB

Land use land cover effects water shed characteristics, such as increasing surface runoff, decreasing infiltration thus affecting hydrological cycle of watershed. As, in Soan River Basin it also has an effect on flood regimes by increasing peak discharge from 1997 to 2020 by 5.35 %. The land cover of forest decreased from 25% in 1997 to 13% 2010, and bare land decreased from 46% in 1997 to 38% in 2010, Vegetation (Agricultural land) increased from 25% in 1997 to 39% in 2010, and settlement increased from 3% in 1997 to 9% in 2010 that experienced the LULC changes.

The land use effect on the flood regime of Soan River Basin has been carried out by considering the met, and Landsat data. The collected data showed that the discharge has been increased by 5.3% due to increase in land use change i.e., impervious surface by almost 50% of Soan River

Basin

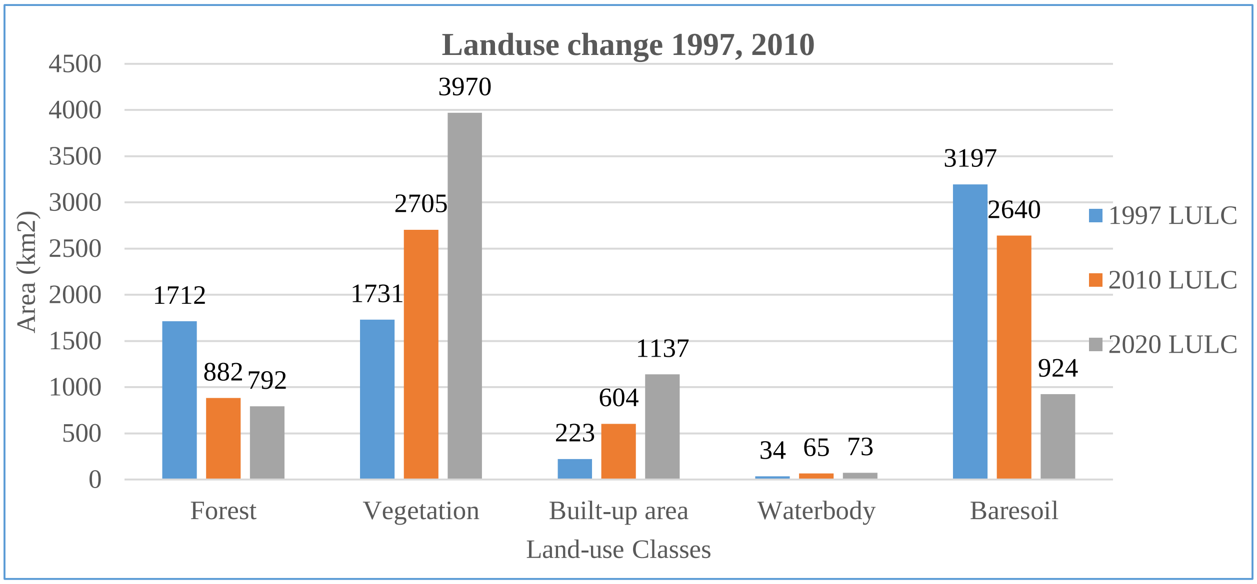


Figure 4. 2 Proportions of land-use change in 1997, 2010, 2020

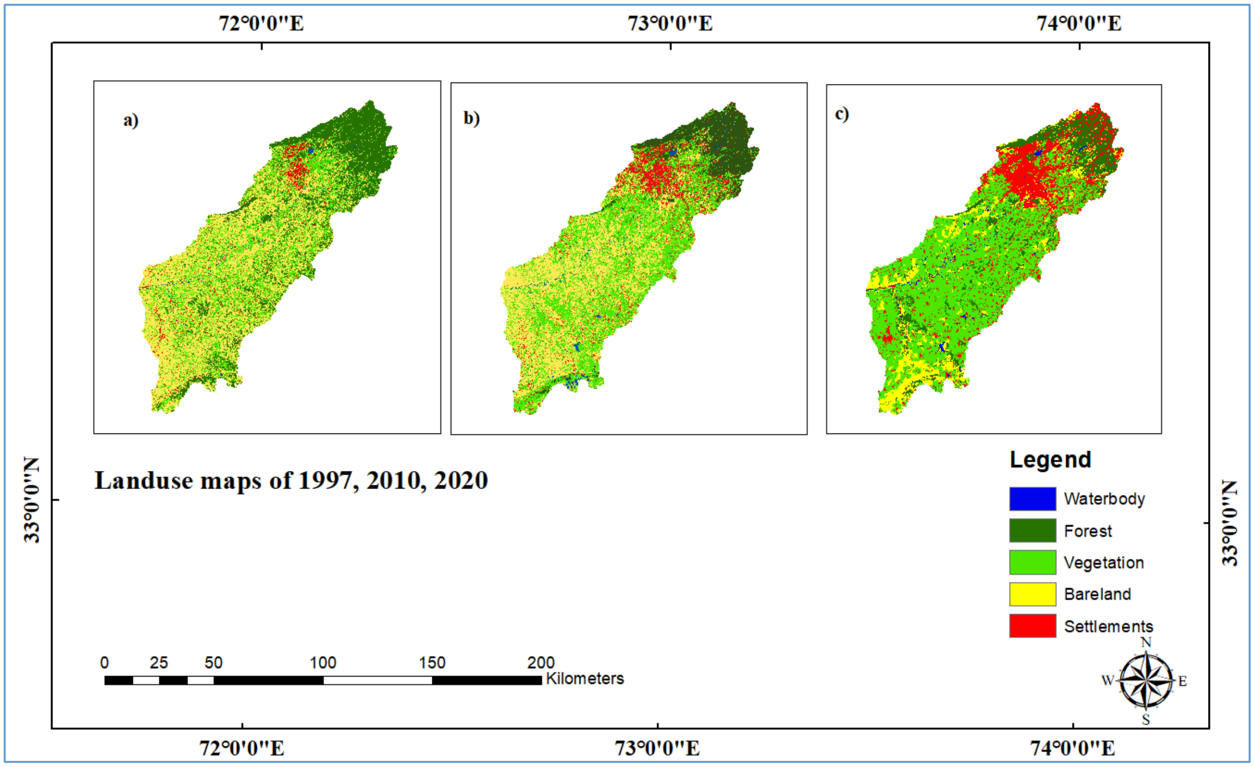


Figure 4. 3 Land-use maps (1997, 2010, & 2020)

4.5 IMPACT OF LAND USE ON FLOOD PEAK

Floods are a great threat to properties, livestock, and life of human. The major causes of flash floods are extreme rainfall events that happen for short duration of time but with great intensity. As there is an increase in surface runoff mainly due to Land-use and cover change, LULC planners need to identify the possible factors. The impact of LULC on flood regime was assessed by CN and impervious percent as both can be used to consider the LULC. The impervious percentage is the portion that is covered by built-up area or impenetrable concrete. The CN value indicated type of soil, land use and basin's moisture condition, which denotes surface runoff. LULC changes occurred between 1997, 2010 and 2020 in SRB, so there has seen increasing peak discharges at outlet of the basin. To further confirm this, the calibrated model was again ran for the same rainfall event but for different LULC changes than peak discharges were compared under 1997 Land-use land cover, 2010 and 2020 Land-use land cover. The simulated peak discharge for 1997 LULC was 2383 m^3/sec, for 2010 LULC it was 2442 m^3/sec and for 2020 LULC it was 2462 m^3/sec. That means after an increase in impervious percentage from 3% to 17% there was 80 m^3/sec or 3.32% increase in flood peak at the outlet of Soan River Basin. These scenarios give some light on the effects of LULC change, particularly the rise in impervious area brought on by suburban development, across the course of the watershed as a whole and under conditions of similar rainfall patterns. The annual peak discharges at outlet of SRB from (1995 to 2013) were plotted using linear trend to support our argument as shown in (Figure 4. 5) that peak discharge has an increasing trend annually. Even if there are climate fluctuations to consider, urban development's increased impervious surface should be the main contributing element to the rise in stream flow discharges.

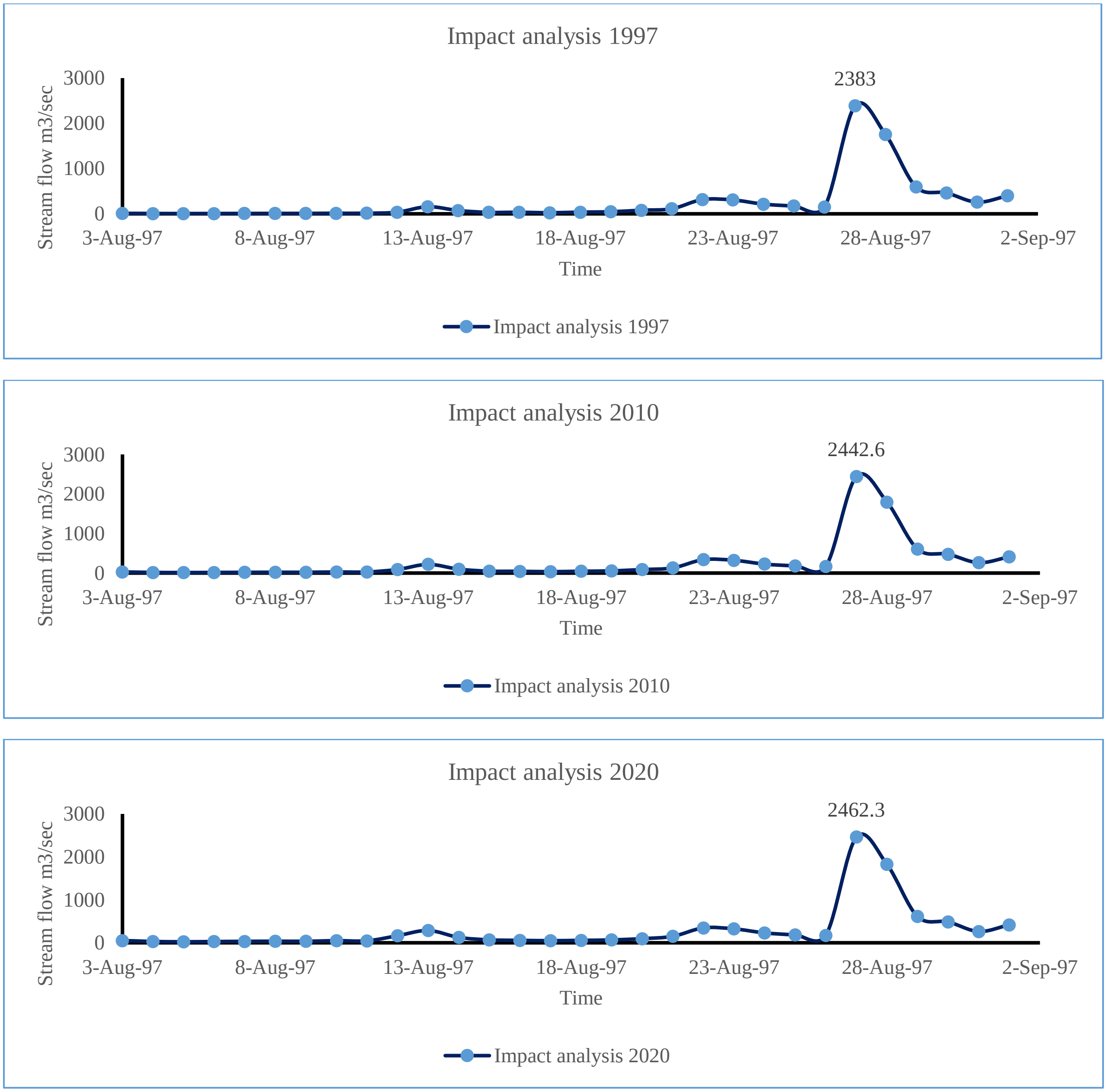


Figure 4. 4 Impact analysis on flood regime using LULC of 2020

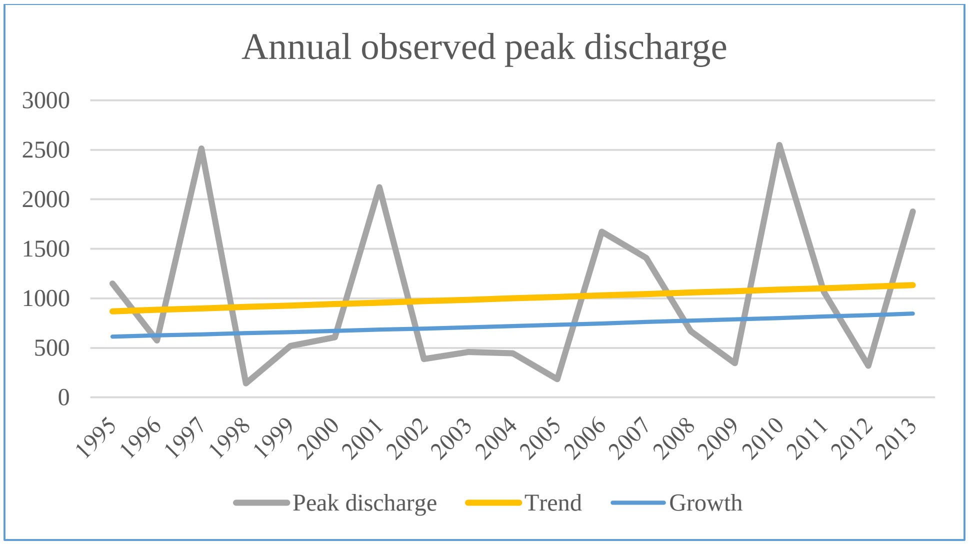


Figure 4. 5Annual peak discharges (1995 to 2013)

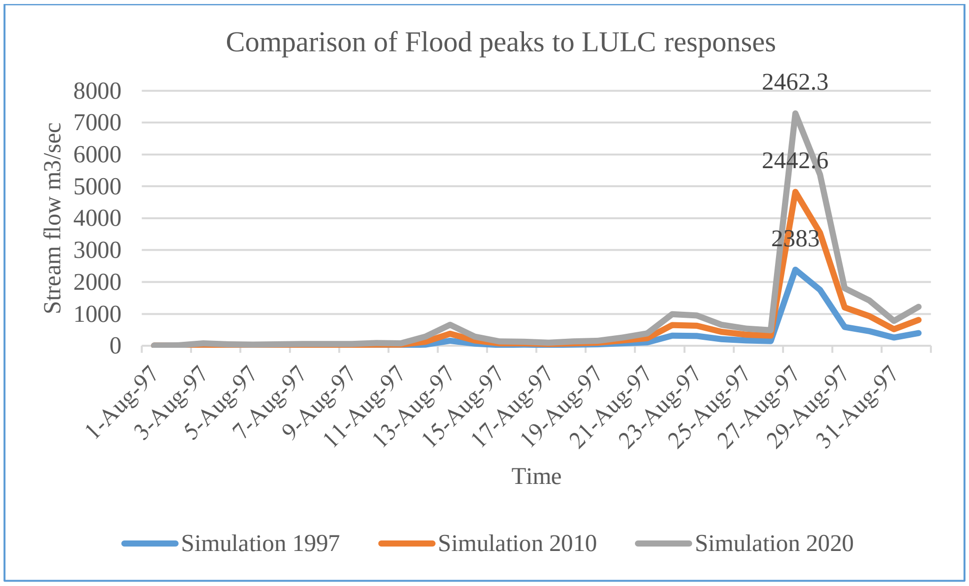


Figure 4. 6 Comparison of Flood peaks to LULC responses

4.6 IDENTIFICATION OF SIGNIFICANT LAND COVER CHANGE IN SRB (1980-2020)

The LULC change in SRB is noticeable as shown in Figure 4. 2, Different years had different significance land use as in 1997 the bare land covered most of the Soan River Basin, and forest and vegetative land covered 25%, Built-up area covered 3% and water body covered approx. 1% of total Soan River Basin. In year 2010, vegetative and bare land covered most of the area by 39, and 38% respectively, with 13% of the area as forest and built-up area covering 9% and water body covered approx. 1% of total Soan River Basin. In 2020 vegetative land covered most of the area of Soan River Basin by 55%, built-up area will slightly increase with 17% of total area, forest and bare land covered 14% and 13% of total Soan River Basin area. The significant LULC category is Vegetative land that was 25% in 1997, 39% in 2010, and 55% in 2020 has been experiencing an increase.

Table 4. 3Responses of the peak flood flow to the land use changes of 1997, 2010, 2020 (Event of 1997)

Catchment	LULC conditions	Impervious percent	Simulated peak flow m^3/sec	Increase m^3/sec	Flow volume (mm)
Soan River Basin	1997	3	2383	0	95.5
Soan River Basin	2010	9	2442	59	102.68
Soan River Basin	2020	17	2462	79	108.77

4.7 ADAPTATION STRATEGIES TO REDUCE THE URBAN FLOOD EVENTS IN THE STUDY AREA

Land use change is the main cause of urban flooding as many impervious surfaces reduce permeability to groundwater. As most of the runoff/flow is generated by urban areas. (Muis et.al 2015) (Muis et al., 2015) evaluated two adaptation strategies (1) Urban planning of new areas and (2) Protection enhancement against floods. The flooding risk can be reduced by limiting urban land in prone areas. They assumed low flood protection standard 10-year return period, the flood risk is reduced by 53%, and the flood protection corresponding to 100 years could reduce flood risk by 93%.

There are a few strategies to help reduce flood hazards in the basins under development. The areas that are prone to urban floods should not have urban settlements and should be converted to parks or playgrounds. Expansion of drainage systems to increase their capacity for high flow and using techniques that help in infiltration a storage of water in soil column such as permeable pavements, and reduction of impermeable surfaces. (Fs07603, n.d.)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

The impact of land use and cover change on the flood regime was found as shown in Figure 4. 6. The studies of peak flood response to LULC change or urbanization are of great importance to urban planners and water resources managers in the basin. This research has utilized tools like ARC map (GIS), and flood hydrographs calculated by HEC HMS to assess the land-use change impact on flood regimes. This research has been conducted in the Soan River Basin, an area (of 6896 km^2). The following are the conclusions drawn from this study:

1. The Land-use land cover change varied spatially such as the artificial surfaces increased from 1997 to 2020 i.e., from 3% to 17%. The significant land-use change was of vegetative cover including (Agriculture, grass, etc) has increased from 25% in 1997 to 55% in 2020. The major urbanization or urban area expansion rate occurred at Rawalpindi and Islamabad of approximately 500 km^2 in 2020.
2. The peak flood flow and flood volume increased from 1997 to 2020 by 79 m^3/sec and 13 mm with increasing urbanization and the flows were observed at the outlet.
3. Soan River Basin has more of the area covered by arable or vegetative cover that is why it had a little effect on elevated peak. Whereas as per the imperviousness, it has increased in the Rawalpindi and Islamabad region and green cover has decreased significantly in the region.
4. The accuracy of the HEC HMS simulation has been improved significantly with the Nash Sutcliffe coefficient for calibration being 0.886, R^2 0.94. Peak flow has increased significantly to 79 m^3/sec when the impervious ratio grew from 3% in 1997 to 17% in 2020.
5. The urban area at Islamabad and District Rawalpindi has increased to 500 km^2 in year 2020 that may have an impact on peak flows as shown in (Figure 4. 4, Figure 4. 6).

5.2. RECOMMENDATIONS

1. In recent years Islamabad and Rawalpindi region has experienced rapid urbanization. Collectively as a whole watershed Soan River Basin didn't show that much change in peak flow with a rise in impervious area in above mentioned region. So, it is recommended that one observed station should be available with the data at common outlets of both regions i.e., Islamabad, and Rawalpindi.

2. The impact of land use has been shown in this research but the combined effect with climate change should be seen on the flood regimes.

3. The data of stream flow is available till 2013 (used for this study), it should be updated so, that flood plain manager can update their flood frequency analysis and flood maps in areas where urbanization has taken place recently. Urban planners can use streamflow data combined with precipitation data to provide a solution for reducing surface runoff in an urban area.

4. The gridded precipitation and stream flow data should be used to see the model performance.

5. The software other than HEC HMS shall also be used to find out the impact of land use on flood regime and compare the result with HEC HMS.

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