ANALYSIS OF URBAN FLOODING DUE TO CLIMATE CHANGE, DURING MONSOON IN ISLAMABAD AND RAWALPINDI

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A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement for the degree in B.S in Environmental sciences

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ABSTRACT

Urban floods are counted as the most devastating natural hazards and the climate change impacts make this hazard more vulnerable, when it hits the densely populated cities of the developing countries, it damages the property and results many casualties. During monsoon season Islamabad and Rawalpindi receives unpredicted intense precipitation, which causes flooding in the low-lying areas of Rawalpindi along Nullah Lai, while Islamabad is the master planned city and affect less. Climate change impacts cause's extreme precipitation events and unplanned infrastructure development occur due to rapid urbanization while completely altering the natural land structure. This research majorly emphasizes on the causes and effects of urban flooding and its impacts on the natural and built environment of Islamabad and Rawalpindi. Study included the qualitative content analysis of urban flooding and analyzed the extreme water events of Nullah Lai for the period of 2010 to 2020. The main purpose to conduct this research was to determine the causes and effects of increase in urban flooding, for this purpose 26 scientific piece of writings (19 scientific published journal articles, 4 websites and 3 reports) relevant to the specific concept of the research problem and research question were reviewed and analyzed. The study found the natural and anthropogenic factors as the main causes of increase in urban flooding, which suggests to install modern technology to predict intense natural weather patterns (precipitation) and must adapt sustainable and resilient infrastructure to control and mitigate future adverse impacts of urban floods in the rapidly urbanized areas.

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ABBREVIATIONS

CDA	CAPITAL DEVELOPMENT AUTHORITY
RDA	RAWALPINDI DEVELOPMENT AUTHORITY
WASA	WATER AND SANITATION AUTHORITY
TMA	TEHSIL MUNICIPAL ADMINISTRATION
RCB	RAWALPINDI CANTONMENT BOARD
IDP	INTERNAL DISPLACED PERSONS
PMD	PAKISTAN METEOROLOGICAL DEPARTMENT
MOCC	MINISTRY OF CLIMATE CHANGE
SWOT	STRENGTHS WEAKNESSES OPPORTUNITIES THREATS

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CHAPTER 1

INTRODUCTION

What do you think of when you think of climate change, may be the extinction of polar bears, may be melting of polar glaciers. Now when you think about climate change you should think about Cities, the places where more than fifty percent of the world population is settled. Cities are the centers of economy for the development of the country and cities are a key contributor to climate change because cities use a large proportion of the world's energy and are responsible for around 70 percent of greenhouse gas emissions, which trap heat and result in the warming of the Earth. Cities are also vulnerable to the impacts of climate change when cities are hit by the natural disasters like floods, storms, and heat waves then it cause adverse impacts on the environment and inhabitants living in it. Due to these disasters large number of the population living in urban areas were affected and casualties occur to the people and even precious lives lost because of the impacts and destruction caused by natural disasters. With the rapid urbanization and development of cities, climate change is making the urban flooding a new worsening threat to the metropolitan cities of the developing countries. The physical damages caused by these disasters to the public infrastructure becomes the major cause of the country's economic loss Earth (THE WORLD BANK, 2020).

Pakistan now in the environment of changing climate receives unpredicted weather patterns during monsoon season and urban areas are now becoming more prone to the impacts of climate change. In Pakistan before the urbanization natural floods were once associated only with the mountainous, coastal, and the adjoining areas of river which were known as flood inundated places, now due to natural land cover change and permanent concrete infrastructure development the urban areas in which we live also become flooded due to intense rainfall during monsoon season (Mir, H. 2005).

The twin cities Islamabad and Rawalpindi fall in the top ten populated cities of Pakistan. According to the number of top ten biggest cities of Pakistan, Rawalpindi ranks on number four and Islamabad falls on number nine. Urban cities are the center source of the benefits that provide a high number of jobs, better education and good health facilities to the settlers.

In developing countries like Pakistan, these facilities attract more and more people towards itself and due to these facilities people leave their existing places, permanently shift, and settle themselves in urban environments. On the other hand, large numbers of Urbanization puts a lot of pressure on the environment, resources availability, infrastructure and other factors. Due to the increase in the number of urban population and to provide settlements for each individual the natural land cover is changing rapidly and most of the natural land is now covered by housing societies, commercial areas, plazas and the entire infrastructure developed by human beings while completely altering the natural land. However, unplanned urban growth is now leading towards many new challenges for both environment and human lives, in many cities of Pakistan infrastructure, public services are exhausted, and the urban ecosystem is leading towards pollution. If you ask any elder local person what Islamabad and Rawalpindi looked like in the past two decades, he will completely explain the different topographic and environmental image of the city. Now, in 2020 if you travel on the same day in Islamabad and Rawalpindi you observe and experience a clearly different view of the city. Just think that what increase in urban sprawl has now done with the natural environment of the city.

According to the Global Climate Risk Index annual report for 2020, which was released by think tank "German watch", Pakistan lost 9,989 lives, suffered economic losses worth $3.8 billion and witnessed 152 extreme weather events from 1999 to 2018. One of the reasons for Pakistan to be continuously ranked high in the long-term index of the report is mainly due to its geographical location (GERMANWATCH, 2020).

Impact of climate change not only altered the hydrologic processes but will also drag the future of urban areas towards the extreme flood disasters. Flooding in the metropolitan areas of Islamabad and Rawalpindi basins is strengthening because of expanding urbanization and environmental change and inconsistency. In a developing country like Pakistan the urban area flood management is not highly advanced or based on the modern technological systems and methods that effectively deals with the urban flooding during intense rainfall in monsoon season. In every monsoon season when extreme rain falls, it exposes the efficiency of twin cities drainage system and makes the urban flooding more severe due to which most of the roads submerged with flood water

and public faces more difficulties. During monsoon season, as compared to Islamabad, major roads in Rawalpindi are submerged with more rainwater and this causes the flow of traffic badly.

"According to the report on Climate change profile of Pakistan 2017, "During 1951–2000, a decrease of 10%–15% in winter and summer rainfall in arid plains and coastal areas was observed while a rise of 18%–32% in the summer rainfall was observed in the core monsoon region of Pakistan. A decrease of 5% in relative humidity was observed in Baluchistan province. Similarly, a decrease of 17%–64% in rainfall was observed during the seven strong El Niño events in the last 100 years. Depressions, storms, and cyclones forming in the Bay of Bengal and Arabian Sea increased in frequency during the last decade of the 20th century, and has been affecting Pakistan as well as other countries in the region. For a long-term precipitation time series, 18 stations with available data from 1901 to 2007, and 5 stations with available data from 1914 to 2007 were used. A 10-year moving average showed that rainfall gradually decreased from 600 millimeter (mm) to 400 mm a year from the early 1900s to 1940. After 1940, an increase of 133 mm was observed. Annual precipitation increased by 61 mm in Pakistan from 1901 to 2007. Monsoon rains increased by 22.6 mm, and winter precipitation increased by 20.8 mm (ASIAN DEVELOPMENT BANK, 2017).

Pakistan is vulnerable to climate change and increase in the frequency and intensity of extreme weather events doubled the monsoon rain causing recurrent intense urban flooding in the metropolitan cities of Islamabad and Rawalpindi, these unpredicted changes in the weather patterns makes the surrounding areas of the upper and lower Lai Nullah Basin highly effected when record break rain falls, as compared to Islamabad, Rawalpindi highly affected due to intense rain fall during monsoon season because Rawalpindi is densely populated and unplanned city, when extreme rainfalls in the twin cities then the highly flood inundated areas affect badly. Every year in the monsoon season Islamabad and Rawalpindi receives the highest rainfalls, when extreme rainfalls during the month of July to august the upper part of Lai Nullah basin catches more rain water and the surface runoff from the upper plain gushed downwards into the lower part of the Lai basin. There are total six main tributaries of the Lai Nullah, three of them originate from the upper plains

of Islamabad and the remaining three from the lower plains within Rawalpindi and collectively fed the Lai Nullah. Margala hills in the upper plains of Islamabad is the starting and the highest area of Lai Nullah basin and the confluence of Lai Nullah at Soan River is the low lying area of drainage basin in Rawalpindi. Lai Nullah makes an entrance into Rawalpindi at Kattarian Bridge and at this point Lai Nullah divides into upper and lower basin, this is the point where we can measure the total discharge of storm water which flows from the upper basin of Islamabad. The area between Kattarian Bridge and Chaklala Bridge is the lowest level ground area in the lower basin and the area frequently becomes inundated when extreme level floods cause overflow of Lai Nullah.

A total of 19 floods event occurred during the 59 year period from 1944 to 2002. Extreme flood years were 1981, 1988, 1997 and 2001. Flooding in 2001 was the largest among the recorded events and was considered as a national disaster. On 23rd July 2001, the rainfall depth of 620 mm was recorded in 10 hours from 0600 to 1600 hours. Estimates indicate a damage/loss of more than USD 0.25 billion to infrastructure, public and private property (Bashir et al., 2010).

Floods oftenly occurs in the coastal areas and surroundings of the river banks, due to the rapid development and increase in the urban population the cities in which we live now become too much compacted and less natural space is left to absorb the rain water. When intense level rain falls in the monsoon season our cities submerged and the flood inundated areas depict as of river like situation, same conditions occur in the twin cities when the monsoon rain falls over the drainage capacity of city's sewerage system. Urban flooding is now a serious challenge to the lives of people and all the developments especially in Pakistan like developing country, we have to renovate the conventional sewerage system and new sustainable sewerage infrastructure should be developed under observing the current climate change and severe weather events of extreme rainfalls, which causes the urban flooding due to which our existing conventional sewerage lines overflow from the storm water and surrounding areas become inundated.

With increase in speed of global climate change and urbanization, the twin cities of Pakistan have been routinely subjected to heavy rains and floods during the monsoon season. The question is how to reduce the impacts of urban floods and to make the urban

infrastructure more resilient which work efficiently during the intense rainfall period of monsoon. This study deeply analyzes the cause and factors of the increase in urban flooding and the consequences of the impacts that occurred on the environment and the people of twin cities.

Global warming and unplanned built environment increase urban flooding events, which threatens the lives and properties of urban residents. During monsoon season in Islamabad and Rawalpindi whenever intense rain cause urban floods, the twin city area management prepares for the post flood rescues instead of building urban sustainable and resilient green infrastructures. The city management can mitigate the urban flood impacts by keeping proper check and inspection of the city drainage system, for this city development authorities should properly work and clean all the drainage lines that are filled with solid waste, the openings of the drainage lines should be closed properly and screens and mesh should be installed at the openings to prevent rubbish being washed into drainage lines. By designing and installing modern sustainable and disaster resilient infrastructure we can mitigate and control the adverse impacts of floods that destroy our precious infrastructure and human lives loss whenever cities hit hard by intense floods, the storm water after mixing with sewerage water stand too long term on the surface breaks out many diseases that adversely impacts the health of people and all these impacts collectively cause economic loss of the country.

Therefore, the proper integration of blue, green, and gray infrastructure should always be considered in future urban planning. Moreover, innovation in drainage facilities, rainwater and sewage diversion, and management system should be carried out to reduce the vulnerability of communities under the impacts of rainstorm and flood. Settlements built-up 20 years ago often have high building coverage ratios. They generally have low scores of community flood resilience in the surveys. The finding proves that old settlements are weak in handling and dealing with external impact. In recent years, the Nanjing Government has done substantial work in the ‘urban double repair’ and ‘rainwater and sewage diversion’ projects. Therefore, the issue of waterlogging has been eliminated in many communities, and vulnerability has been improved (Chen et al., 2020).

1.1 Background

"Islamabad is located at 14 Kms in the North-East of Rawalpindi with an altitudes ranging from 457 to 610 meters. The area of Islamabad is 906.50 square kilometers, further 3626 square kilometers area is known as the specified area, with the Margala hills in the North. Islamabad features an atypical version of a humid subtropical climate, with hot humid summers accompanied by a monsoon season followed by cool winters. The average yearly rainfalls 1143 millimeters (CAPITAL DEVELOPMENT AUTHORITY, n.d.).

Rawalpindi is located on the Potohar plateau in the province of Punjab and lies 14 Kms South-west of Islamabad, the city's climate consists of hot summers and a rainy monsoon season from July to September and winter season remains cold to very cold. Due to the rapid urbanization and climate change impacts the climatic conditions of Rawalpindi is much different from the Islamabad.

"Lai Nullah has a catchment area of 234.8 km2 and a length of about 30 km, stretching from the Margalla Hills at the northwestern edge until Soan River at the southeastern edge. The catchment area is administratively divided into Islamabad in the upper reaches of 144.4 km2 and Rawalpindi in the lower reaches of 90.5 km2. Rawalpindi has been almost fully urbanized with the extremely high population, while Islamabad is the relatively new city established in 1961 and still less populated as compared with Rawalpindi. Lai Nullah Basin receives a heavy rainfall of about 500mm during the monsoon from July to September, which could lead to the large flood runoff discharge. The recent intensive urban development in the City of Islamabad also tends to increase the peak flood runoff discharge. At the same time, the flow capacity of downstream of the Lai Nullah in the City of Rawalpindi has been remarkably reduced due to the illegal encroachment of buildings into the river course and the pile of garbage indiscriminately dumped into the river. Due to the metrological conditions and river channel conditions as described above, the floods frequently overtop the Lai Nullah inflicting sever flood damages particularly in Rawalpindi. The flood in July 2001 caused the worst damage in the basin including death of 74 people and the complete or partial destruction of about 3,000 houses. Public facilities such as transportation and electric power supply had also been completely paralyzed (JICA, CHAPTER 1. INTRODUCTION).

It is acknowledged that urban floods are one of the most destructive natural hazards and a serious challenge to the developing countries, Pakistan being a developing country is one of the most vulnerable country hit hard by the impacts of climate change. The natural impacts of climate change and permanent shifting of urban land cover by human beings are collectively becoming one of the most threat for the inhabitants of Islamabad and Rawalpindi during monsoon season when unexpected extreme rainfalls.

In the developed countries people enjoy the rain of monsoon while in densely populated cities of developing countries like Pakistan people affect from the adverse impacts caused by the extreme rain, one of the main cause the twin cities management failed to cope up with the rain water during monsoon season is due to bad sewerage system which is already filled with the solid waste dumped by the people living around. If solid waste treated properly from nearby areas and the sewerage lines are kept clean properly then no such effects occur. In order to keep our public infrastructure and human lives safe from natural disasters like urban flooding, we have to develop sustainable and green infrastructures that work efficiently under such events.

Topographically Islamabad is located in the upper basin of Lai Nullah, receives less floods, only the Katchi Abadis (Slums) settled around the banks of Lai stream affected during extreme rainfalls. Islamabad falls in the upper plains and serve as a catchment area of storm water in the upstream. As compared to Islamabad, Rawalpindi is much larger and older city and is specially known for its commercial, industrial activities and due to military headquarter situated in the city, is also known as home of army. Islamabad is a planned city constructed in 1960, and sub divided into five zones, and each zone is allotted with an area for specific purpose, zone 1 is designated for urban development and federal government institutions, zone 2 is designated for private housing societies and zone 5 is also planned for urban development whereas zone 3 and 4 are specifically kept as protected area for national park but with increase in urban population these sectors too are changing towards urban developments and natural land is continuously losing its originality.

Heavy rains which lashed the twin cities in wee hours of Thursday morning claimed life of a woman in Kachi Abadi in Sector H-9 when roof of her house collapsed besides causing havoc in the low lying areas of Rawalpindi as water of Nulla Leh gushed into the

houses by more than 3 feet level besides inundating the streets causing huge trouble for the residents. Rescue 1122 officials confirmed about the death of one middle aged woman, Sanika who died in H-9 sector Kachi Abadi when roof fell over her during heavy rains. However, according to Rescue 1122 no casualty was reported in Rawalpindi. Rains which occurred so heavily continued for almost two hours starting from 5 a.m. till 7 a.m. The intensity of rains was as heavy as water in the main channel of Nullah Leh at Gawal Mandi touched up to 20 feet level and the concerned civic bodies sounded sirens asking the people to leave their houses and adopt preventive measures to avert any casualties. Rescue teams of the civic bodies and Rescue 1122 and army reached the flood hit areas in low lying areas to provide relief and assistance to the people. The people of low lying areas including Arya Mohalla, Raja Bazaar, Sadiqabad, Muslim Town, Chamanzar Colony, Nadeem Colony, Jehangir Colony, Dhoke Chiraghdin, Dhoke Farman Illahi, Dhoke Illahi Baksh, Dhoke Khabba, Dhoke Ratta, Dhoke Munshi, Rehmatabad, Dhoke Kala Khan, Banaras Colony, Gulrez, New Kattarian, Railway Colony 1 and 2, Pirwadhai, Bangash Colony, Ganjmandi, certain parts of Asghar Mall Scheme and Satellite Town, Shamsabad were the most hard hit areas. People of these areas who were sleeping had to wake up as soon as water from Leh started to barge into their houses with full force. Children and ladies were shifted to top floor buildings and on roof tops to prevent any mishap. All streets and roads were fully inundated with water. Rain water not also entered houses but also barged into shops in Raja Bazaar, Ganjmandi, Gawalmandi, Dhoke Munshi, Dhoke Khabba, Sadiqabad, and Muslim Town (Ahmed, 2017).

1.2 Problem statement

The scientific literary piece of writing shows us the previous work of researches and represents the permanent evidence of the scientific work that has been completed. Among the environmental issues and natural disasters of the modern world, one of the major concerns is of the urban flooding that is because of natural weather phenomena, climate change and human activities. The analysis of increase in urban flooding is necessary to understand the cause and effect relationship among weather parameters, climate change and human activities which impacts human beings and their natural and

built environment. The researchers has looked at the cause, effects and the impacts of the urban flooding to understand and analyze the problem statement.

1.3 Significance of the study

This research mainly focuses on the analysis of increase in urban flooding in the study area while remaining specific to the scientific concepts and perspectives of the research topic and research questions, for this purpose specific content related with research topic is reviewed and discussed to understand the causes and effects of urban flooding. This research also opens different ways for upcoming researchers to look and understand multiple scientific concepts and hypothesis. It is important in a sense that it also focuses upon the relation between human beings and their own built environment while altering the natural land cover. When intense weather patterns are received by the unplanned and densely populated cities then such conditions of the environment brought urban flooding like natural disasters. The scientific ideas and concepts analyzed and suggested in the study when practically implemented will be helpful to mitigate and control the environmental, infrastructural and economic losses caused by the intense level of urban floods. The study also contributes as much as possible to understand the importance of natural vegetation and plantation to absorb most of the rain water and has potential to control and mitigate the impacts of floods. This study also suggests the environmental preservation while adapting modern and green infrastructure to develop the future settlements in the cities.

1.4 Research objectives

1. This research aims to analyze the cause and effects of increase in urban flooding and its impacts on the humans and their environment.

2. To highlight how human activities altered the natural environment which when receive intense weather patterns (precipitation) can cause urban flooding.

1.5 Research questions

This research aims to find the answers to the following questions.

1. How natural and anthropogenic factors can cause floods in the urban environment.
2. How to find solutions to control and mitigate the impacts caused by urban flooding.
3. What are the impacts of unplanned development on the natural and built up environment of Islamabad.
4. When intense precipitation is received by the upper basin of Nullah Lai, how it affect the population settled along the lower basin of Nullah Lai.

1.6 Literature review

Urban flooding is not only limited with coastal areas or to the river banks, it is caused by extreme runoff in the built environments where the water does not have any place to go. Urban flooding can be linked with major disasters but more frequently it causes the inundation of basements and sewer backups, even small amounts of rain can submerge imperfect infrastructure in many areas, especially in impoverished and socioeconomically separated urban communities (weber, 2019).

Urban floods are the results of hydrological and meteorological extremes, this comprises uncontrolled flows and precipitation in a short period of time. Although, these are not the only causal factors of urban flooding. There are numerous reasons that cause urban surges in Pakistan's major city centers. A few of the key causes are: hydrological and meteorological extremes, unplanned settlements, climate change, ancient sewerage frameworks, overpopulation, and populace deluge in cities due to lack of opportunities and facilities in rural areas (SSToday, 2019).

Being the foremost far-reaching common calamities, flooding can cause billions of dollars' worth of harm each year. Since floods can harm any property in nearly any area, it is vital to memorize almost all the different sorts of foods and how they can influence properties. The main types of floods are (1) flash floods (2) coastal floods (3) river or fluvial floods (4) urban floods and (5) pluvial or ponding floods. Flash floods are fast-moving floods that clear everything in their way, they are caused by overwhelming precipitation or quick snow defrost. These floods cover moderately little area and occurs for less than six hours and the fast moving water can move heavy objects like trees, cars

and rocks. Coastal floods are caused when strong winds move towards a coast, when effective waves break the coasts dyke, the area is commonly flooded. River floods occurs along the river banks and nearby areas when extensive rainfall over an amplified period of time, river floods result in loss of lives and also cause economic damage. Urban flooding happen when the seepage framework in a city or town comes up short to assimilate the water from overwhelming rain. Lack of natural drainage in urban areas can also cause flooding and water flows into streets making the public movement dangerous. Pluvial flooding occur in flat areas where the terrain inefficient to absorb the rain water and pluvial floods are similar to urban flooding but commonly occur in rural areas (PuroClean, 2020).

1.6.1 Hydrological and Meteorological extremes

The recurrence of extraordinary temperature and precipitation have been analyzed from 1965 to 2009 for Pakistan geographically located in South Asia. The study and analyses of 45 years data of temperature and precipitation has been used to calculate the frequency of extreme precipitation and temperature events in Pakistan, the recurrence of extraordinary precipitation events investigation has appeared apparent increment in all the regions of Pakistan (Zahid, M and Radul, G, 2011).

The Punjab is the second largest province after Balochistan, the population of Punjab is 56% of the country's total population and covers 26% of the total area of Pakistan. Punjab is divided into northern and southern regions, according to this division Islamabad and Rawalpindi are included in northern Punjab. Being in northern Punjab, Islamabad and Rawalpindi receives a great sum of precipitation all through the year as compared to the southern Punjab. The twin cities lie in the monsoon zone where the likelihood of interaction of westerly and easterlies climate framework is more, due to which this zone is continuously under the danger of extraordinary occasions of rainfall which will cause torrential rains during the monsoon season (Cheema, S.B and Hanif, M, 2013).

The south Asian summer monsoon straightforwardly influences the lives of nearly one-half of the world's population, with considerable changing of rainfall patterns in the monsoon season and showing different changes between heavy rainfalls and dry spells. With regard to base line (1975-2005) the seasonal cycles appear that winters are warming

more than summers with 6 to 8 °C and shows an overall increase of 3 to 4 mm/day at yearly time scale (Ikram ., et al Afzaal, M, Bukhari, S.A.A, Ahmed, B, 2016).

As Pakistan's annual monsoon comes to an end, the counts of harm and losses have begun to leak in. In the monsoon season of 2019, all the provinces including the capital Islamabad experienced the loss of life, public and private infrastructure damage, and dislocation after areas being inundated by heavy downpours. Historically Pakistan has been affected by extreme floods and other disasters. Since 1900, 67 flooding events have been recorded with details. Floods that occurred during these long time have been related with major infrastructure and life loss. The 2010 was the worst year during which the unexpected floods in Pakistan resulted loss of 2000 precious lives, more than 20 million people affected from the disaster and the damage cost more than $40 billion (King, A and Kugelman, M, 2019).

During 2001 in Pakistan, some parts of the country receives more than normal rain and a few northern areas of the country observed uncommonly high precipitation rate. 23rd July 2001 was the day when heavy precipitation in a cloud burst mold over some of the northern parts of country which are Abbottabad, Islamabad and Rawalpindi. This intense precipitation surpassed the recorded extreme rainfall in Islamabad during a single spell and caused economic and life loss (Basit, A., et al Raza, S.S, Irfan, N, Avila, R, 2012).

The extremes linked with precipitation are among the foremost results of warmer climate. Since 1950, changes in extreme precipitation have been recorded worldwide and at territorial scales. Both the frequency and quantity of heavy precipitation have expanded over most of the land area in the past century. Moreover, human induced earth warming greenhouse gases emissions have a noticeable impact on the shift from moderate to heavy rainfall in china. The extreme events occurred due to intense precipitation are amongst the most impact relevant results of a warmer climate, especially for china, a region which is vulnerable to global warming and with huge population. While understanding the dangers and impacts caused by extreme weather events countries must change and prepare for the mitigation and adaptation planning (Zhang, w and Zhou, T, 2020).

The climatic extremes and temporal change in weather and climate are observed to have an impact on the characteristic of natural environment and the people live in societies.

Hence it is vital to be able to distinguish the event of such changes in the ordinary behavior and must be able to predict the extreme variations in the future, especially our observations demonstrate that increase in weather extremes are rising with frequency and intensity against the historical pattern (Andrew., et al, Minna Raikonnen, Kari Maki, Marta Roca, 2016).

1.6.2 Urbanization and unplanned settlements

The cities of the developing countries are becoming densely populated, with the fast rate of urbanization many recent researches and observations come up with the statistical results which shows increase in the frequency and intensity of short duration extreme precipitation in the urban environments (Zhang L.D, 2020).

Urbanization changes the natural environment both spatially and temporally. Spatial growth is an anticipated circumstance especially in fast growing metropolitan cities of Pakistan like Islamabad. Spatial and temporal changes of the Islamabad were studied from the year 1975 to 2010, Landsat images and Geographical information Systems were used to analyze the land cover change. The study showed that between 1975 and 2010, due to the urbanization the total area expanded from 50 km^2 to 332 km^2, whereas the flora of the Islamabad including the Margalla national park decreased from 465 km^2 to 145 km^2 (Mahboob., et al Atif, Riaz, 2016).

According to the research conducted by using remote sensing data, it was observed that from 1976 to 2019 the natural land cover of Islamabad has been replaced by residential, commercial and industrial infrastructure. The analysis of the study revealed that in four decades, the built up over natural land cover increased from 10.7% to 52.4% and the rapid increasing of the artificial environment occurred as a result of unchecked and unplanned management of the developmental authorities. In the consequence of all these unplanned infrastructure development, the natural topography become fragmented due to which environmental problems appeared and the natural functioning of ecosystem of the habitat impact adversely. The alteration of the natural land structure and all the anthropogenic activities done in these built up environments can contribute to the global warming effects and the region lead towards more unexpected extreme temperature and precipitation patterns (Attaullah., et al Karamat, Moazzam, 2020).

Frequently floods are expected in unplanned settlements, even in season of normal rainfall. Whenever extreme rainfall in the monsoon season and floods occur then this issue becomes a debatable topic but authorities take no action as usual they order to rescue activities, as soon as the rain stops, the happenings and losses are overlooked. Most of the settlements around the flood prone areas are covered by poor communities and whenever flood occurs it damages the household and their belongings (Nchito, 2007).

1.6.3 Climate change in cities and urban flooding

Earth has been warming from the last 150 years, particularly over the final six decades, due to this gradual dynamic warming numerous changes also occurred to the climate of the earth. Thousands of researches conducted by scientists around the globe recorded different changes in weather and climatic conditions like increase in atmospheric temperatures, receiving of irregular extreme precipitation and sea level rising. The annual average temperature of the world that increased for the time period of 1986 to 2016 was recorded 1.2°F (0.7°C). As compared to the past century, the annual average precipitation around the world shows moderately increase. The changes in the global hydrological cycles and mean precipitation is mainly dependent on the earth's energy budget. The more CO_2 will be released into the atmosphere, the more heat will be trapped by CO_2 in atmosphere and this result increases in precipitation approximately 0.55% to 0.72% (1% to 3% per C°). Over the last 110 years, as a result of warming climate atmospheric water vapor increases which ultimately causes extreme precipitation, it has been observed globally that annual maximum daily rainfall has increased by 8.5%. One of the most important drawing factor of change in frequency, duration and magnitude of intense weather events is climate change (Climate Science Special Report, n.d.).

Cities are the places where more than half of the world's population is living and these urban areas are developing with fast rate due to which their boundaries are extending more outwards while compacting the inner free land spaces by densely populated individuals and due to their activities inform of urban infrastructure development. Due to this the urban areas are now emerging as the first responders to mitigate and adapt the climate change. At first urban areas were ignored by the climate change scientists but with the occurrence of many natural disasters, now they are responding towards to mitigate the

impacts occurred by natural disasters like urban flooding. It has been estimated that more than 70% of the global energy related carbon emissions are emitted by cities, this percentage will be rise up more in future as urbanization nowadays is both the need and demand of the modern people. The United Nations evaluated that by 2050, the population of the urban areas nearly coupled from 3.4 billion to 6.3 billion (Cynthia., et al, William, Stephen, Shagun, 2010).

The geography of Pakistan is diverse which covers the northern alpines with glaciers and bordering with Arabian Sea in the southern plains. From north to south five rivers flow between the country. The country receives monsoon rains which starts from the month of June and ends in September, meanwhile the precipitation patterns not remain constant throughout the monsoon season. Whenever extreme precipitation occurs in the monsoon then the densely populated cities and low-lying areas submerged under floodwater and heavy loss occur to the country. Floods in the past tells us about the impacts and damages occurred, the past floods of 1950, 1956, 1957, 1973, 1976, 1978, 1988, 1992 and 2010. The affected areas of these floods are the basins of river Punjab and Sindh (Hashmi., et al, 2012).

Precipitation is a prime phenomenon which direct impact on regional and global climate patterns. Irregular extreme rainfalls may cause natural hazards like floods, droughts and landslides, when these floods hit metropolitan cities than serious impacts occurs. As Pakistan is a vulnerable country to climate change and its impacts, one of the consequences of these impacts are the increase in frequency and intensity of extreme weather events in the past two decades. According to the climate of Pakistan, the country receives more precipitation during the monsoon season, as Islamabad and Rawalpindi falls in the monsoon zone and also receive the first monsoon rains. Lai Nullah is the only natural stream fed by rainwater and passes through the twin cities, every year the surroundings of the stream inundated whenever extreme rainfalls. More than 23 flood events occurred in Lai Nullah from the year 1944 to 2014, and the most catastrophic flood occurred in 2001 causing 74 deaths and number of fatalities in Rawalpindi. Moderate level of flooding has been reported after the 2001 floods and the consequences of these floods may be the devastation of low lying areas of Lai Nullah basin. It is not the solution to rescue after the floods, but it must be the foremost goal of our leaders and urban area management

authorities to adopt and build sustainable infrastructure and development to mitigate the adverse impacts of urban flooding in the future (Rehman., et al, 2018).

Increase in the intensity of precipitation is associated with flooding in cities, the extreme flooding can cause damage to the private and public infrastructure and rebuilding of it consume a large sum of country's economy. It is therefore important to adopt climate resilient infrastructure in the flood prone urban areas (Kaspersen and Halsnes, 2017).

1.6.4 Drainage system of urban areas

Cities are the dynamic places and these areas are constantly increasing in size and population, the constant population increase is keeping pressure on the natural environment and the developed infrastructure. As cities are growing, the existing infrastructure and old drainage system showing less efficiency because they were built over a long time and were developed according to the need of past trends (Porse, 2013).

The function of the city's drainage system is to drain two kinds of water, one is known as the storm or rainwater and the second is wastewater, wastewater is the water coming from kitchens, households, bathrooms and offices. City's drainage system is specially designed to collect and discharge the rainwater through pipes into the river or stream. The twin cities storm water is finally discharged into the Lai Nullah. In Islamabad and Rawalpindi four organizations managed the city's drainage and sewerage system, Capital Development Authority (CDA) Water and Sanitation Authority (WASA), Tehsil Municipal Administration (TMA), and Rawalpindi Cantonment Board (RCB), these organizations are responsible for the drainage service of twin cities. Islamabad is a planned and developed city and have separate drainage system for storm water and waste water discharge, there is only one active wastewater treatment plant in the capital administration and due to the insufficient capacity of the plant most of the wastewater is directly discharged into the Lai Nullah without any treatment. This is the main cause of the pollution of Lai Nullah, the addition of untreated wastewater and solid waste constantly depleting the nature of the stream and the water becoming more toxic because of the addition of every type of waste. In Rawalpindi WASA and TMA are responsible for the maintenance of drainage and sewerage system, RCB is responsible for the drainage and

sewerage services in the cantonment area. However in the TMA area, only 40% sewerage system is applied and the wastewater without any treatment is directly discharged into the Lai Nullah because there is no wastewater treatment plant in the administration of Rawalpindi. This activity directly contributing in the pollution of the stream. No specific details related to sewerage and drainage system were given according to the 1960 master plan of Islamabad but was developed laterally by CDA in 1972. The sewers in Rawalpindi have been constructed in 1960 in the central areas and this old drainage system now becomes overloaded by the overpopulation. The conclusion is that modern resilient and sustainable storm water and sewerage infrastructure must be developed for the twin cities (JICA, DRAINAGE AND SEWERAGE).

1.6.5 Impacts of the 2010 floods on rural and urban areas of Pakistan

The floods of 2010 affected 20 million people in Pakistan. The impacts and results of the 2010 floods were studied during the six months after the occurrence of flood event, with the help of cross sectional survey methodology 1769 households of the most affected 29 districts were surveyed. The results recorded from the study were physical destruction, human live losses, illness, and changes in the wages of the daily base earners. The services affected by floods and cause shortage in the supply of electricity, clean water and sanitation facilities. The results of the flood losses comes out in the figures of 54.8% destruction of homes and caused 86.8% family units to move, while 46.9% live in an IDP camps. The need of the electricity expanded from 18.8% to 32.9% and the scarcity of toilet facilities increases from 29.0% to 40.4%. The loss of income recorded in rural areas is 90.0% and in urban areas 75.0%. The number of human lives loss from the floods are over 1,700, about 1.1 million homes were damaged and 436 health care centers were destroyed. At least the flooding lasted for six months and during this period 46 districts of the country sum up for the loss of $9.7 billion in damages. These floods caused the unexpected damages to the rural economy and the sectors impacted most are livestock, agriculture, seed stocks, fertilizer sector and forestry sector. The countries lost their 80% of food reserves. The urban areas traffic flow is badly affected by the impacts of floods (Kirsch, Thomas D., et al, 2012).

1.6.6 Flood hazard in the Lai Nullah is endemic for the twin cities

The 30 Km long Lai Nullah Basin with a catchment area of 239.8 Km^2 beginning from the upper Margallah hills within Islamabad flowing down through the territory of capital enters into Rawalpindi territory at Kattarian, below Kattarian Bridge the stream then flows down between the center of Rawalpindi area which finally falls into Soan river. Frequently floods occur during monsoon season in the Lai Nullah Basin. Three types of weather systems bring the monsoon rainfall in Pakistan which are; monsoon depressions from the Bay of Bengal, westerly waves from the Mediterranean Sea, and seasonal lows from the Arabian Sea. From 1994 to 2002, total 19 floods occurred in the Lai Nullah Basin, due to which the low lying and surrounding areas of stream always affected. Some of the floods Lai Nullah received in the past years of 1981, 1988, 1997 and 2001 were of extreme category. The intense rainfall during the monsoon season raise the level of water in the Lai Nullah and this cause flooding. The flooding can cause adverse impacts on the environment of Rawalpindi, whereas Islamabad remains safe as compared to its twin city. The 2001 flood in the month of July caused worst damage in the low lying basin of Rawalpindi which take 74 precious human lives and about 400,000 people were affected. The flood entirely damaged 1087 houses and 2448 houses partially damaged. The total loss occurred to the private and public infrastructure was estimated around $ 0.25 billion. While recognizing the damages and economic losses of 2001 Lai Nullah flood, various strategies have been contemplated after the flood event for the Rawalpindi city. The strategies that are considered after the floods were; the alignment and broadening of the stream channel which flows between the congested areas of the city, pitching of the stones along the embankments of the Lai Nullah in order to protect soil erosion and provide safety to the houses located near or on the stream banks, prevention of solid waste disposal into the stream, abolition of encroachments. Apart from the strategies suggested for Rawalpindi, Islamabad administration was also suggested to build flood retarding infrastructure (small dam) for the storage of storm water in the upper lying basin area which will be initially helpful to slow the flood peak discharge that inundates the low lying areas of Rawalpindi. One of the strategical suggestion was the formation of early flood forecasting and flood

warning systems for the twin cities. Under observing all the flood impacts it is highly considered to adopt flood forecasting and warning system for the Lai Nullah basin, apart from the post flood rescue activities it is recommended to install modern flood and water management instruments and institutions responsible for flood management were ordered to build specific units regarding with the flood management and mitigation (WORLD METEOROLOGICAL ORGANIZATION, n.d.).

After the 2010 devastating floods Early warning system for floods have been established for the Lai Nullah basin, which was installed by Japan International Cooperation Agency. Rescue 1122 and Civil Defense Department cooperatively operate the warning system. The populations settled around the Lai Nullah in Rawalpindi are of lower middle class and daily base wagers, one of the bad citizen behavior shows by the surrounding inhabitants is that they dump their solid waste directly into the stream. As Lai Nullah basin is natural rain fed stream, the primary cause of rise in the flooding is the intense rainfall. With increase in population unplanned developments along the banks of stream expanded constantly which keeps continuous pressure on the natural environment of the Lai Nullah and the pollution impacts causes bad odor, unscenic view and most important land pollution, water pollution, due to which different type of diseases break out and cause adverse impacts on human health (Mustafa, D., et al, 2015).

1.6.7 Flood prone areas of Islamabad and Rawalpindi

The flood prone areas in Islamabad are the unplanned settlements that are located and temporarily built along the tributaries of Nullah Lai. The houses built in the slums along the tributaries of Nullah Lai are most prone to the floods because the material used to build the houses are not flood resilient, whenever flood occurs these slums impact badly. Whenever these slums are hit hard by heavy rains and floods serious damage occurs to the physical property and even cause injuries and deaths to the inhabitants of these areas. In Islamabad four slums are very prone to flooding that are built illegally along the tributaries of Nullah Lai. Merra Jaffar is the largest slum which is settled downstream of Jodh Kas, one of the key tributaries of Nullah Lai. Muslim colony is the second slum situated near the stream which feeds the Rawal Lake. The third slum which is located along the saidpur

kas stream is known as 100 quarter and the fourth slum located on the banks of the Kanitawali Kas is known as French colony, these four slums located along the tributaries of Nullah Lai are most prone to the flood in the territory of Islamabad. As Rawalpindi is located in the low lying basin of the Nullah Lai, when water level exceeds 5.5 meters then floods start. The slums of the Rawalpindi are highly affected by flooding which are settled in the low lying areas, the areas which are most prone to the floods are the encroachments along the Nullah Lai. The first location that is prone to the flooding is the surrounding area of the Kattarian Bridge, in 2011 when the flood water level exceeded 5 meters in the Nullah Lai at Kattarian Bridge due to which the banks of the bridge burst. The second location which is prone to the flooding is the surrounding areas of the Ratta Amral Bridge which regularly floods. The third location which floods when heavy rain falls and the water exceeds above normal is the area of Gawal Mandi, due to which the activities of the Gawal Mandi market affect seriously. The fourth location where serious floods occurs is the Aryan Muhalla which is located between Ganj Mandi Bridge and Railway Bridge and the last location where Nullah Lai finally falls into the Soan River. At the confluence of the Nullah Lai and Soan River, Soan camp is located which is also prone to the flooding whenever water level exceeds in the Nullah Lai. Apart from these areas intense level of rain also submerged the unplanned constructed roads and settlements mostly in the Rawalpindi and a few in the territory of Islamabad (UN HABITAT, 2014).

1.6.8 Integrated urban flood risk management

Increase in urban flooding is an important issue especially in the developing countries, the statistical analysis of the past trends in urban flooding shows dynamic increase in the medium scale of floods. The driving factors of the urban flooding are a combination of natural and anthropogenic factors, from this perspective change in the climatic conditions and increase in human population will be the cause of maximum scale and extreme floods in the future. Observing these changing patterns, in future there should be proper urban flood management. The integrated flood management is a response which is likely to be a successful method. In the developing countries the increasing urbanization has affected the exposure and vulnerability of small, medium and large scale floods and

these changes will be the factors of threat which in future may be caused people and their properties at risk. Due to the changes and uncertainties in the future climatic conditions, the developing cities have to adapt flexible and resilient infrastructures for the urban flood risk management. It must be highlighted that integrated flood risk management is the main requirement, the sustainable flood risk management should be developed while observing the holistic approach of the current and future global changing climatic patterns. To make a complete integrated flood risk management, therefore the management authorities should concerned about the different geographical location, population density of the area and the two main sources of flooding which is the global changing climate and regional uncertain precipitation and temperature increase. The integrated flood risk management method has two approaches or measures, structural and non- structural approaches. The structural methods is the installment and application of resilient and sustainable urban infrastructures, the main purpose of these infrastructures is to absorb the more rain water and control the pathways of the storm water runoff, these structures not totally control the floods but can mitigate the impacts and block the pathways of storm water runoff which accumulates on one location. Some of the structures are; permeable paving, green roof rain water harvesting, filter drain, detention pond, rain garden, flood walls and barriers to be placed in the high amount runoff places. Some of the non-structural measures are forecasting and warning systems, search and rescue activities, awareness campaigns, solid waste management, and temporary settlements design and preparing for emergency supply chains (The World Bank, 2011).

CHAPTER 2
MATERIALS AND METHODS

2.1 Data acquisition

To carry out the qualitative content analysis on the research topic "Urban flooding in Islamabad and Rawalpindi due to climate change during the monsoon season". The research problem and question related content was acquired from (published articles, websites and published reports). For this purpose all the material was approached through the google search engine. The literature reviewed for the study was selected between the time periods of 2010 to 2020.

The literature was reviewed for 26 textual documents, among these 10 articles fulfilled the required information of the study area and the remaining 9 articles, 4 websites and 3 reports containing specific information cleared the concepts to understand the phenomena of urban flooding.

Moreover, the extreme water level event records data of the Nullah Lai for the time period of 2010 to 2020 were provided by Pakistan Meteorological Department (PMD) Islamabad.

The policies of Ministry of Climate Change (MOCC) and National Disaster Management Authority (NDMA) were analyzed and highlighted the strengths and weaknesses, for this purpose SWOT analysis is applied to find the gaps within the policies of the concerned organizations.

2.2 Research methodology

The Qualitative content analysis methodology was chosen for the analysis of past literature which is present in the form of textual documents. Content analysis is a research tool in qualitative studies which is used to analyze the textual documents or past literature and utilizing the tool researchers find out the presence of specific words or concepts inside the text. The purpose of selecting content analysis as a research tool is to review the pre literature and to analyze the meanings and relationships of the different themes and concepts and to construct inferences about the information within the texts.

In this study while remaining specific and related to the research problem and questions, content analysis has been done for the specific literature which explain the causes and factors of the increase in urban flooding.

The data acquired from Pakistan Meteorological Department (PMD) Islamabad is plotted in the form of graph and the graphical representation of the recorded statistical data explains the trends of maximum and minimum water level rise between the periods of 2010 to 2020. The statistical observation of the data represents the water level rise in the Nullah Lai at two locations (Kattarian and Gawal Mandi).

2.3 Nullah Lai and its major tributaries

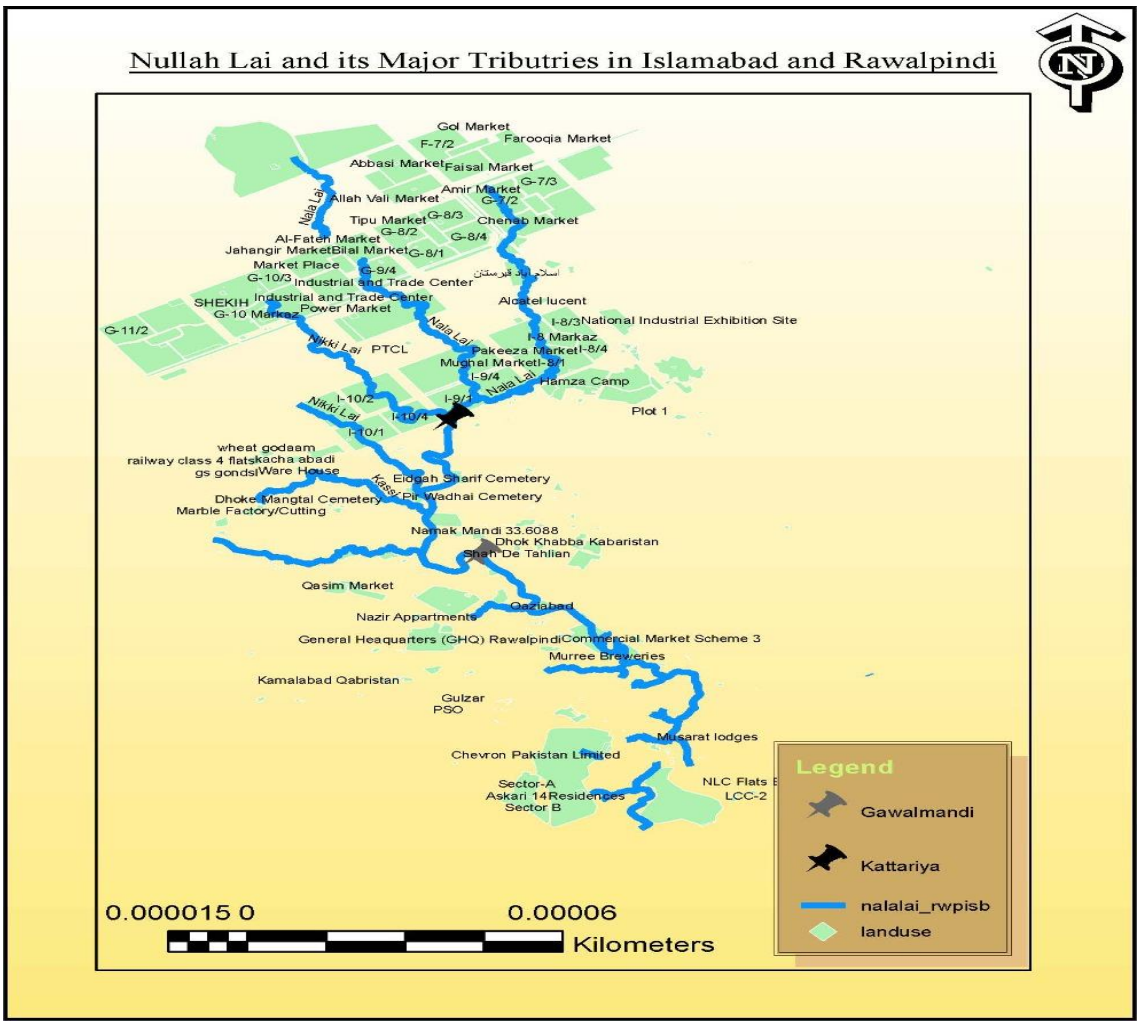

Fig 2.1. Map showing major tributaries of Nullah Lai in Islamabad and Rawalpindi

There are three major tributaries in the upper Lai basin of Islamabad which are Saidpur Kas, Tenawali Kas and Bedarawali Kas. There are also three major tributaries in the low lying basin of Nullah Lai name as Nikki Lai, Pir wadhai Kas and Dhok Ratta Nullah.

The extreme water level event data of the Lai Nullah basin for the time period of 2010 to 2020 was acquired from Pakistan meteorological department Islamabad. The Lai Nullah is the main natural rain fed water catchment basin located in Islamabad and Rawalpindi. The analysis of extreme water level increase has been done by comparing the recorded results for per year, moreover the analysis of the extreme water level has been based on the previously recorded data of the extreme water flow under the Kattarian and Gawal Mandi Bridges. The data provided by PMD was plotted in the form of tables separately for each year. The total rain water that catches by the upper Nullah Lai basin discharge from Islamabad was measured at Kattarian Bridge and the total storm water discharge from Rawalpindi was measured at the Gawal Mandi Bridge.

Following are the representation of data that are recorded for each year and placed in the form of separate tables.

Table 3.1. Extreme water level data of Nullah Lai 2010

Sr. No	**Date**	**Time**	**Kattarian**	**Gawal Mandi**
1	29/07/2010	04: 50 PM	18.01 ft.	15.35 ft.

Table 3.2. Extreme water level data of Nullah Lai 2011

Sr. No	**Date**	**Time**	**Kattarian**	**Gawal Mandi**
1	16/07/2011	07:30 AM	16.24 ft.	8.46 ft.
2	25/07/2011	11:30 AM	16.11 ft.	3.3 ft.

Table 3.3. Extreme water level data of Nullah Lai 2012

Sr. No	**Date**	**Time**	**Kattarian**	**Gawal Mandi**
1	03/09/2012	07:00 AM	15.78 ft.	N/A

Table 3.4. Extreme water level data of Nullah Lai 2013

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	10/08/2013	08:40 AM	24.34 ft.	15.16 ft.
2	13/08/2013	11:30 AM	24.18 ft.	17.85 ft.

Table 3.5. Extreme water level data of Nullah Lai 2014

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	05/09/2014	02:20 AM	11.22 ft.	13.62 ft.

Table 3.6. Extreme water level data of Nullah Lai 2015

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	02/03/2015	07:20 PM	11.22 ft.	13.62 ft.
2	07/07/2015	1:30 PM	23.59 ft.	19.56 ft.
3	11/07/2015	7:20 AM	15.06 ft.	15.45 ft.

Table 3.7. Extreme water level data of Nullah Lai 2016

Sr. NO	Date	Time	Kattarian	Gawal Mandi
1	15/07/2016	3:50 AM	38.5 mm	Rainfall Alert

Table 3.8. Extreme water level data of Nullah Lai 2017

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	12/07/2017	9:00 AM	5.15 ft.	8.28 ft.
2	13/07/2017	7:30 AM	19.32 ft.	16.86 ft.
3	25/08/2017	5:50 AM	11.75 ft.	13.48 ft.
4	01/09/2017	9:50 PM	9.38 ft.	8.69 ft.

Table 3.9. Extreme water level data of Nullah Lai 2018

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	15/06/2018	06:00 AM	Rainfall Alert	37 mm/ 60 min
2	18/07/2018	6:20 AM	Rainfall Alert	36 mm/ 60 min
3	07/08/2018	2:10 AM	14.8 ft.	12.50 ft.
4	11/09/2018	2:10 AM	Rain fall Alert	39 mm/ 60 min

Table 3.10. Extreme water level data of Nullah Lai 2019

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	25/07/2019	9:40 AM	11.0 ft.	10.0 ft.
2	01/08/2019	5:45 AM	15.50 ft.	14.50 ft.
3	07/08/2019	2:20 AM	13.20 ft.	12.50 ft.
4	17/08/2019	5:20 AM	10.2 ft.	10.00 ft.
5	26/08/2019	10:00 AM	10.5 ft.	8.5 ft.

Table 3.11. Extreme water level of Nullah Lai 2020

Sr. No	Date	Time	Kattarian	Gawal Mandi
1	15/05/2020	1: PM	14.0 ft.	13.5 ft.
2	26/07/2020	6:00 AM	10.5 ft.	10 ft.
3	01/08/2020	3:30 AM	11.5 ft.	7.8 ft.
4	14/08/2020	5:10 AM	18.4 ft.	14.7 ft.

These tables represent the extreme water level records in the Nullah Lai measured at the Kattarian Bridge and Gawal Mandi Bridge. According to the date and time the extreme water exceeds were measured in feet's.

CHAPTER 3
RESULTS AND DISCUSSION

The literature reviewed and extreme water level events recorded data of Nullah Lai from the time period of 2010 to 2020 were both analyzed. The study come up with some findings and results, the analysis of the literature found the cause and effects of urban flooding in the study area and the comparison of each year extreme water level data plotted in the form of graphs tells us the trends of the water extreme level in the Nullah Lai.

3.1 Content Analysis Results

The results of the analysis of literature reviewed for this study will be able to explain the causes and effects of urban flooding in the study area.

The main causes of the increase in urban floods for the study area are the irregular regional weather and global climate change patterns and its effects. Punjab is divided into northern and southern regions, according to this division Islamabad and Rawalpindi are located in the northern regions of Punjab. The twin cities fall in the Northeastern monsoon zone of Pakistan and receives the first monsoon rains, the twin cities lie in the monsoon zone where the probability of the interaction of Southwesterly winds and Southeasterly winds is more due to which Islamabad and Rawalpindi are continuously under the danger of extraordinary occasions of rainfall which will cause the torrential rains during the monsoon season.

The monsoon rainfalls in Pakistan are brought by two wind system, the South western winds coming from the Bay of Bengal and the winds coming from the Arabian sea. The wind system that can cause the monsoon rainfall in the study area are due to the South western winds coming from the Bay of Bengal. These are the natural weather and climate patterns which cause intense precipitation and urban flooding occurs. The past floods and the impacts of Nullah Lai were analyzed for Islamabad and Rawalpindi and their comparison shows that the settlements along the Nullah Lai in low lying areas of Rawalpindi were more affected and the 2001 intense rainfall and floods in the stream are the evidence how urban flooding can cause damage to the property and human lives living in the flood prone areas.

The natural intense weather patterns when receive by the built environments can make the urban flood impacts more prone if the city has old drainage infrastructure system and have no specific urban area flood management to control and mitigate the adverse impacts of storm water. The illegal encroachments near the banks of Nullah Lai in Rawalpindi are at high risk of urban floods, as the anthropogenic activities like dumping solid waste into the storm water drainage lines can affect the efficiency of drainage system during the monsoon season when irregular intense rainfalls. The blockage of the drainage lines cause the overflow of storm water and due to this storm water mixes with sewer water and the blocked drainage can cause the flooding which submerged the roads and impact on city's traffic flow, this can also cause the basement fills in the low lying areas and damage the private and public property.

The overpopulation cause rapid urbanization due to which the natural land cover with vegetation altered and replaced by permanent settlements due to this less natural space left to absorb the rainwater. The permanent roads and structures speed up the runoff of rain water and make its way to accumulate and submerged the roads and low lying areas. The altering of the natural land structure shows that most of the natural land in Islamabad and Rawalpindi has been replaced by residential, commercial and industrial infrastructure. The overpopulation of the twin cities revealed increase in the built up over natural land cover. Natural vegetation and plantation plays an important role to control and mitigate the impacts of urban floods and not a single selected piece of literature focuses specifically on the importance of plantation to control flood impacts. The storm water stands too long on the roads if not removed and treated properly then can cause different water borne diseases which can impact on the health of the inhabitants of the environment. The urban floods can cause damage to the both private and public property and intense level of floods can cause injuries and even deaths. For the reconstruction of the damaged property by floods, it takes a large sum of capital and spending too much finance on these activities can cause loss of the economy. The future weather and climatic patterns have been changed by the global climate change and its impacts, for this purpose flood resilient infrastructures must be developed and installed. The analysis of the study tells that the intense precipitation events are increasing but irregularly during the monsoon season.

3.2 Extreme water level events of Nullah Lai

The extreme water level events data obtained from Pakistan Meteorological Department for the period of 2010 to 2020 was represented in the form of graph.

The extreme water level event data represents the water level rise recorded at the Kattarian Bridge and at Gawal Mandi Bridge.

The extreme water level events for the time period of 2010 to 2020 were recorded during the monsoon season (June to august).

The graphical comparison of the recorded trends for each year shows irregular increase in the water level of Nullah Lai at the Kattarian Bridge and at the location of Gawal Mandi Bridge.

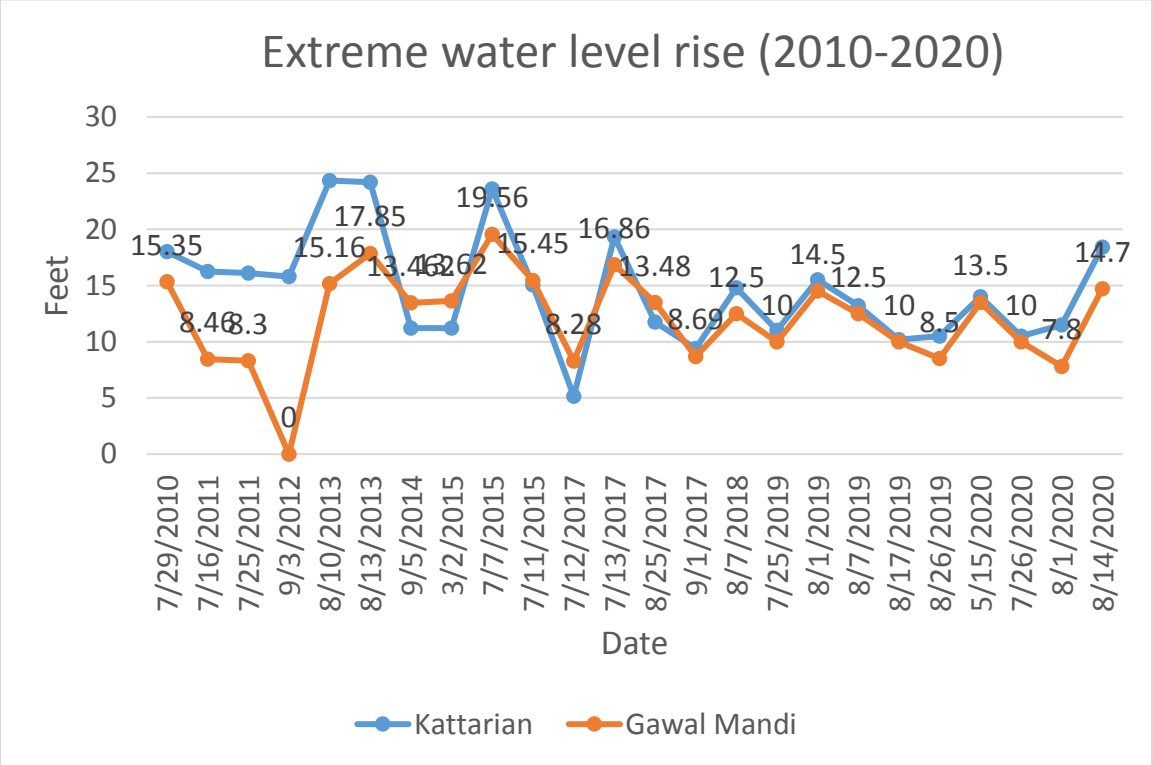

Figure.3.1. Extreme water level rise at Kattarian and Gawal Mandi Bridge (2010-2020).

The maximum water level rise measured was at the Kattarian Bridge in 2013 and the level of water was 24.34 feet.

The minimum water level rise recorded was found to be 5.15 feet at the Kattarian Bridge location.

However the water level at the Kattarian Bridge exceeds above 15 feet eight times and 6 times exceeded above 15 feet at the Gawal Mandi Bridge. The water level exceeded 3 times above 20 feet's at the Kattarian Bridge.

3.3 SWOT analysis for the policies of (MOCC) and (NDMA).

To conduct the SWOT analysis, two government organizations Ministry of Climate Change (MOCC) and National Disaster Management Authority (NDMA) were selected, for this purpose the policies of these two organizations were reviewed and analyzed. The analysis of these policies will be helpful to highlight the strengths and weaknesses within the policies of concerned organizations specifically working on the agenda to minimize the impacts of climate change and natural and human induced disasters and to provide sustainable and hazard free built environments. This analysis also make it more clear that how can we overcome the weaknesses and convert the threats into opportunities and make the policy further more strengthening.

The good policy always focuses more on its internal strengths and never skip any point which explains the strengths of the organization and should also mention the new opportunities which were implemented by the organization and proven efficient in the field. The presence of the evaluation and record of the past disastrous events in the policy itself talks about how to further strengthen the policy while comparing the past events impacts with the current and future predicted risks of the climate change, in a simple manner it focuses on the implementation of strengths to minimize threats of the unpredicted future events if happens. The comparison of the policies also focuses to improve the internal weaknesses of the concerned organizations by taking advantage of the opportunities and the final outcome of the analysis will be to work on the lacking sources which cause threats either lack of experts within the organization to monitor or predict the external threats of natural disasters. This will be helpful to work on the weaknesses to avoid threats.

Table 3.1. SWOT analysis of (MOCC) and (NDMA).

SWOT	**Ministry of Climate Change (MOCC)**	**National Disaster Management Authority (NDMA)**
STRENGTHS	Strengthening of Early warning system (EWS). Presence of coordination between concerned and responsible departments during disasters Preferred and highlighted importance of modern technological system (GIS) Presence of legal framework	Contingency plan is available and policy is developed observing the past and present recorded assessments, vulnerabilities and impacts of natural disasters. Vision to make Pakistan disaster resilient. Command, control and communication (3C) division of (PDMA) and promoting inter-organizational partnerships to take collective measures.
WEAKNESSES	Missing of essential processes like IEE and EIA Less focus on research updated information and strategy on urban flooding is lacking	Insufficient Disaster risk reduction capacity. NDMA also lack risk awareness knowledge. Not specific vulnerabilities highlighted. Lack of updated measures.
OPPORTUNITIES	Urban flood mitigation, monitoring of vulnerable areas, conduct detail research. Implementation of innovative policies and building of resilient infrastructure.	Introduction of modern and advance methods and technologies (EWS). Prepare hazards and risk Maps of prone areas and install resilient machinery and infrastructure. More research is needed. Awareness campaigns.
THREATS	Lack of awareness and risk assessment in knowledge and policies As natural disasters are the major threats	Economic crisis, unavailability of recorded past extreme data, implementation of undetailed policies cause threats, Lack of rescue equipment's.

MOCC mentioned the early warning system in their policy and this shows the importance of advance technologies to monitor and predict floods, implementation of such technologies will be efficient to predict the urban floods and also proven as a best measurement to mitigate an control most of the damages caused by the urban flooding. One of the important thing found in the policy is the mentioning of the coordination between responsible departments during the events of flooding. Remote sensing and GIS is one of the important field upon which more expertise is required to gain. The policy is concerned about the legal frameworks and is much necessary. There are also weaknesses of the policy which doesn't mention the necessary measures like Environmental Impact Assessment and Initial Environmental Examinations, these are essential part for the impact assessment of habitat development and needs proper knowledge about the environment and its vulnerabilities. The weaknesses can be converted into strengths and by strengthening the weaknesses a policy can be developed further strong and getting benefits from the opportunities the threats can easily be converted into strengths.

NDMA prepares contingency plan for every monsoon season which is the main strength found in their policy and it's mentioned in the policy that recorded past floods frequency and its vulnerability caused impacts are reviewed to develop a better plan for the future occurring floods caused by torrential rains. The strongest vision highlighted clearly in the policy is to make all the natural disastrous and vulnerable areas of Pakistan made to be disaster resilient. The 3C division Command, Control and communication is developed by PDMA for the purpose of communication and during the disaster all representatives of coordinating departments report to the 3C in order to receive updates about the events and for this purpose the division set all staff and necessary equipment in working order to quick response in any event. The organization lacks the disaster risk reduction capacity and is the weakness of the policy and also shows the lack of awareness in the policy developers of the organization who are not well aware about the risk assessment and reduction. The weaknesses of the policy provides an opportunity to convert the weaknesses into strengths by conducting more research to know about the unpredicted risks and its vulnerabilities in the future. Whenever intense weather patterns like precipitation creates intense flooding in the area all its risks and vulnerabilities must be recorded, and on the bases of early

predictions awareness campaigns must be initiated to realize people about the threats and vulnerabilities of urban floods.

CONCLUSIONS

In the present study, literature was reviewed to understand the cause and effects relationship of increase in urban flooding in the study area. The selected literature of the study helps to understand the concepts related research problem and clearly differentiated and explained the natural causes and anthropogenic causes of urban floods in Islamabad and Rawalpindi. The data acquired from Pakistan Meteorological Department (PMD) Islamabad for the extreme water level shows the maximum water level, minimum water level and the irregular increase in the water level of Nullah Lai for the time period of 2010 to 2020.

This study was meant to explore and analyze the natural and anthropogenic cause and effects of increase in urban flooding and its impacts on the environment and people of the Islamabad and Rawalpindi. Urban areas all over the world are increasing especially in developing countries and Islamabad and Rawalpindi also facing the issues of overpopulation and urbanization, due to which more settlements are required for each individual living in these metropolitan areas. The impacts of the urbanization altered the natural land structure and replaced by permanent infrastructure and the human activities contributing to altered the regional weather patterns like irregular intense monsoon rainfall.

Islamabad and Rawalpindi lies in the monsoon zone and the twin cities receive the first monsoon rains and the 2001 cloud burst of Islamabad is one of the historical intense rainfall recorded so far due to which intense flood occurs in the Nullah Lai and cause damage to the physical property and human lives. The natural causes of the urban flooding is due to intense rainfall during the monsoon season and two wind systems brings the monsoon rainfall system, the south western winds coming from the Bay of Bengal and the winds coming from the Arabian Sea. The urban storm water drainage system of the Rawalpindi city is too old and unable to efficiently cope up with the monsoon intense rainfalls. In twin cities the areas more prone to urban floods are the slum houses located along the Nullah Lai. More attention should be paid to the climate change and urban flooding impacts of the study area and all related risks should be evaluated. Hence, it is necessary that more studies be carried out to understand the future scenarios of climate change, urban flooding and urbanization impacts on the environment and people, it will be

helpful to understand and act accordingly to the changing natural and human built environment.

RECOMMENDATIONS

- Concerned authorities must take measures to remove the illegal settlements along the banks of the Nullah Lai within Islamabad and Rawalpindi, these slums settled along the Nullah Lai are considered most prone to the floods because during intense rainfall serious damage occurs to the property and people.
- A comprehensive study must be conducted to find the natural and anthropogenic cause and effects of increase in urban flooding in the study area.
- In both, Islamabad and Rawalpindi most prone flood areas must be highlighted because with increase in urbanization might possible new settlements were settled and over flood risk areas.
- More plantation along the banks of Nullah Lai would reduce the flood damage impacts, for this purpose government must initiate tree plantation projects.
- The storm water drainage openings must be closed because people throw solid waste in it and affect the efficiency of drainage during intense rainfalls.
- The surface storm water flow on the roads can be reduced by producing more green belts along and between the roads.
- The storm water drainage lines must be clean properly to drain water efficiently during the intense monsoon rains.
- Proper management should be taken to dispose solid waste from the areas located surroundings of Nullah Lai.
- Flood resilient infrastructure should be installed and therefore integration of blue, green and gray infrastructure should always be considered in future urban planning.
- Moreover, innovation in drainage of rainwater and sewage diversion and management system should be implemented to reduce the vulnerability of inhabitants from the impacts of rainstorm and flood.
- Structural and non-structural policies should be implemented to mitigate and control the impacts of urban floods in the study area.
- Awareness campaigns should be initiated to understand the risks and losses caused by urban floods to the densely populated metropolitan cities.

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