DOI: 10.18485/ijdrm.2024.6.1.6

Research article

Changes in Lulc and Drainage Network Patterns the Cause of Urban Flooding in Karachi City

Ayesha Iftikhar[1*], Jawed Iqbal[1]

[1] National University of Sciences and Technology (NUST) Rislpur Campus, Pakistan

[*] Correspondence: ayeshakhan3359@gmail.com, Tel: +923139183608

Received: 15 April 2024; Revised: 1 June 2024; Accepted: 15 June 2024; Published: 30 June 2024

Abstract: Karachi is a strategic city in Pakistan that was once known as a fishing village. An increase in industrialization and urbanization had been seen in the city. Karachi's land use, land cover as well as drainage networks have been changed because of Industrialization and urbanization. Flooding in Karachi because of late summer season monsoon rainfall has resulted in urban flooding. Poor urban planning and management had severely affected both rivers and linked tributaries. This study used secondary data that shows changes in LULC and poorly maintained drainage networks are the factors that caused urban flooding in Karachi. DEM, GIS, and SRTM have been used to mark the boundaries of Karachi and drainage networks on the digitized map. These maps could be utilized for improving the natural drainage networks as well as flood mitigation and preparedness measures. This study may provide a guideline to disaster planning, management, and development authorities.

Keywords: Urban flood, Monsoon rainfall, Karachi, Drainage networks, Land use, Land cover, DEM, GIS, SRTM

1. Introduction

Karachi, one of the largest cities of Pakistan having a population of twenty million is the most populated metropolitan and is situated on the southern coastline of the country and is connected to the Arabian Sea. In the start, the city was inhabited by a community that used the sea for carrying out fishing which after some time turned into a port that was then used for carrying out trading with international communities. Sixty percent of tax revenue and fifteen percent of GDP were generated by trading and fishing and were collected by FBR.

But as a result of urbanization and industrialization change in the climate has been observed. Because of this climate change all of the areas surrounding Karachi city have been greatly affected. These effects resulted in extreme heat causing deaths (Ghumman and Horney, 2016), urban flooding resulting in disruption of city activities as well as seawater intrusion (Zia, 2017).

Monsoon rains of historic magnitude recently wreaked havoc in Pakistan, notably in Karachi, where both the volume and quantity of land inundated were unprecedented. Between the 24th and the 27th of August, the city of Karachi saw record-breaking rainfall, with 230 mm of rain falling on a single day on August 27. The National Disaster Management Authority estimates 184 deaths in rain-related accidents across the nation, with 80 deaths in Sindh and 47 fatalities in Karachi alone, according to the statistics. Drowning, electrocution, and falling roofs were the causes of these deaths. In all, Karachi received 604 millimetres of rain in August, making it the wettest August in 89 years. The monsoon's fury was compounded by antiquated flood warning equipment, failed drainage, and crippled infrastructure, missing or blocked nullahs, damaged or closed down electrical supplies, flooded homes, and economic and infrastructural losses in all regions of the city, causing mayhem across the metropolis. Water logging, flash floods, and power outages beset the city during this strong rainy wave.

The goal of this study is to determine and assess the preliminary causes of floods in Karachi. Monsoon rains are most common in Karachi from June to September. Karachi receives an average of 174.6 millimetres (6.87 inches) of rain each year (1981-2010). Water logging, urban floods, and power outages beset the city during this strong rainy wave. The year 1967 had the most annual rainfall, with 713 millimetres. The city received the most rain in a single day on August 27, 2020, when 230 mm of rain fell on the city. The amount of rain increased in the city in 2003, 2006, 2007, 2009, 2010, 2017, and 2019. The study aimed to determine how changes in drainage networks, land use and land cover are responsible for urban flooding in Karachi city.

2. Methodology

The methodology adopted for this research was based on secondary data. With the help of secondary data new maps were created using DEM, GIS. These maps will show how with time urbanization, industrialization, population growth and climate change have made Karachi city prone to urban flooding. Flood and rainfall data were obtained from the Climate Ministry and Pakistan Meteorological Department. The obtained data was then incorporated into the DEM and GIS software from where the maps were developed that showed how urbanization, climate change and industrialization have changed the drainage patterns over time and led to the increased amount of urban flooding in Karachi in the past few years.

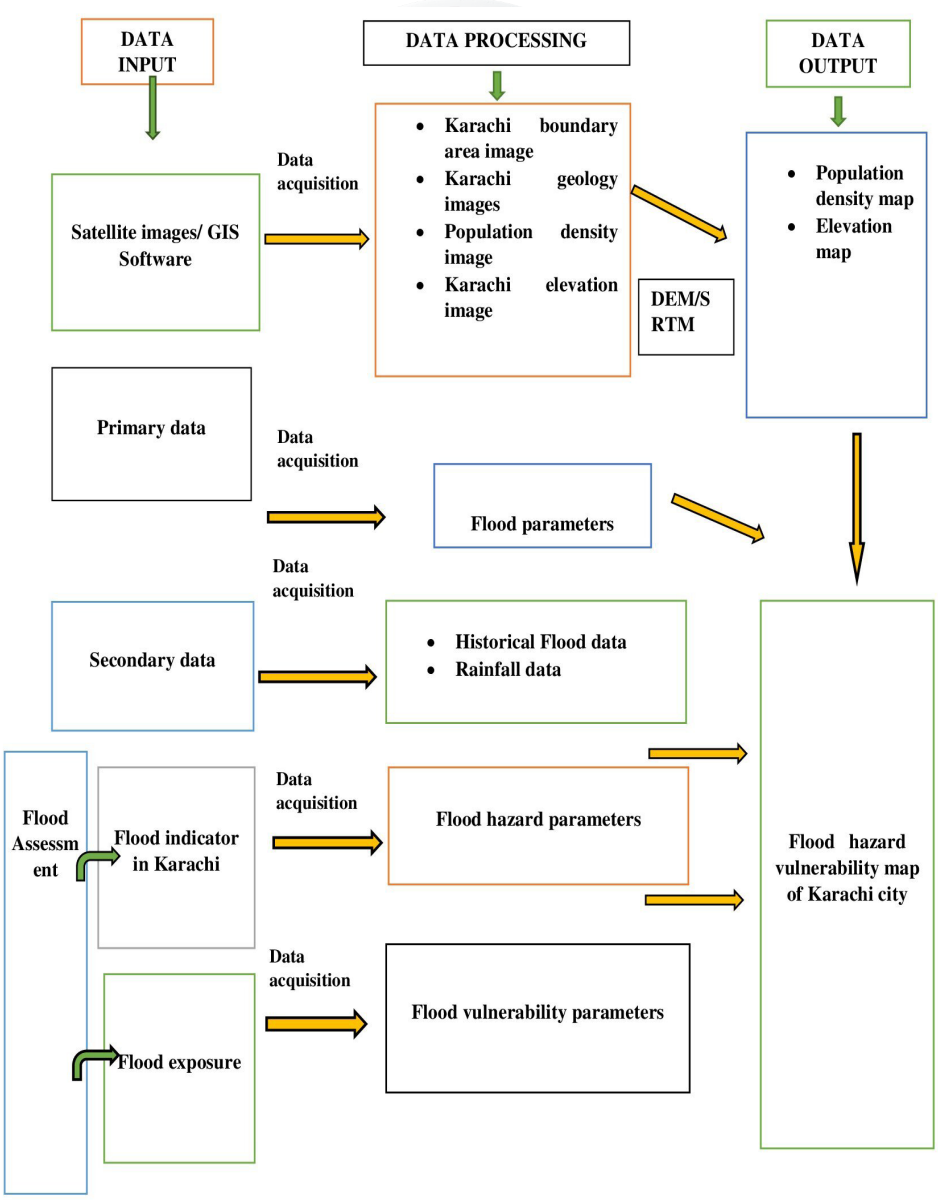

Figure1. Flowchart of Methodology.

3. Result and Discussion

3.1. Analysis

Secondary data regarding LULC and drainage networks obtained from different sources was utilized, analyzed, processed, and interpreted with the help of DEM, GIS, and SRTM in the form of maps.

3.2. Flooding in Karachi

For the treatment and dumping of municipal as well as industrial wastewater into the Arabian Sea two rivers are used in the Karachi city namely Lyari and Malir (Akhtar, 1997). For the draining of monsoon rainwater these two rivers play a vital role but because of the rapid increase in urbanization and encroachment toward the bank of the rivers a decrease in the drainage efficiency of these rivers has been observed (Zafar & Zaidi, 2016). Although most of the city's industrial and sewage wastewater drainage to the Arabian Sea took place through the Lyari River because of the population living along the bank of the river it became susceptible to flooding threatening and risking the lives of about 0.8 million individuals (Mansoor & Mirza, 2007; Irfan, 2018). As the Malir River passes from within Karachi city's mostly densely populated areas and is larger as compared to the Lyari River flooding caused by this river is extreme and worst (Ahtar & Dahnani, 2012).

Table 1. Major floods in Karachi City

Flood year	Rainy hours	Rainfall (mm)	People Killed
1953	24	278.1	-
1977	24	207	248
1984	24	298.4	150
2003	48	284.5	-
2005	-	77	13
2007	-	110.2	228
2009	-	80	-
2010	-	191	21
2011	4	245	20
2013	-	147	-
2015	-	145	-
2019	-	150	28
2020	72	345	50

Table 1 shows the major flood events that took place in Karachi resulting in a large number of causalities. Since the flood event had been occurring more likely it seems that the measures adopted for prevention and flood control were inefficient and insufficient resulting in loss of life, property and critical facilities.

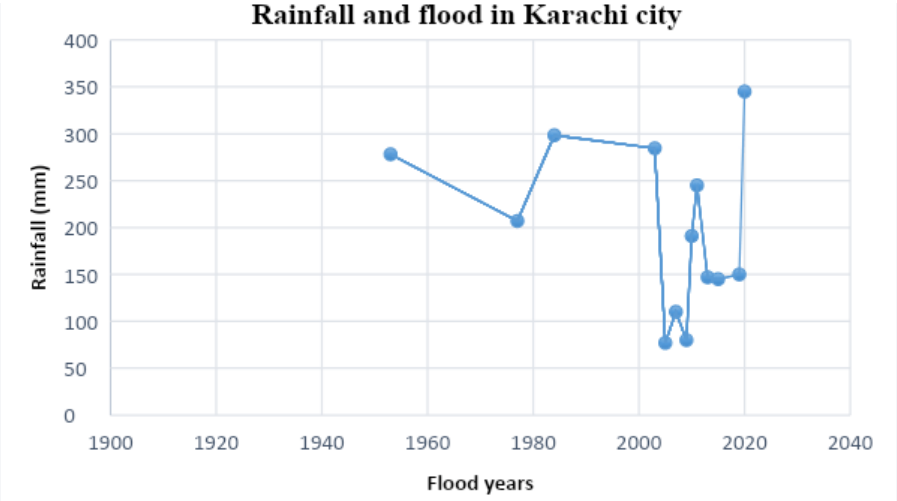

Figure 2. Shows the relation between Flood years and Rainfall occurred in Karachi city

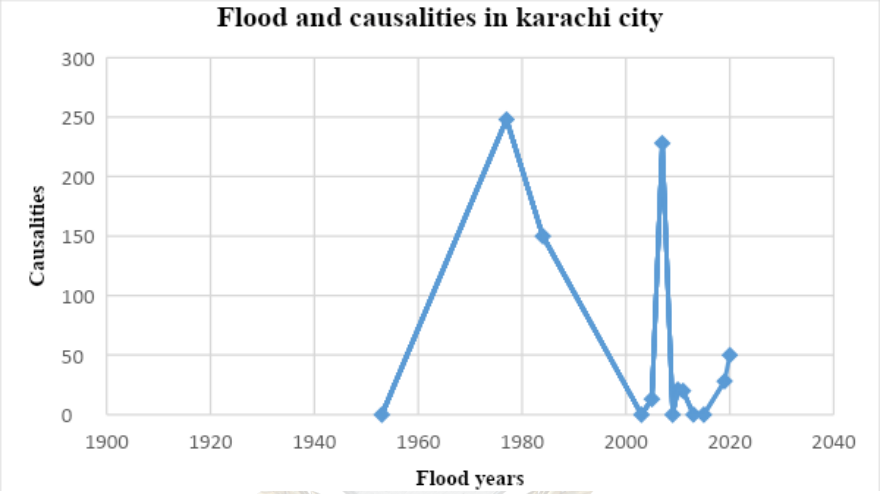

Figure 3. Shows the relation between Flood years and Causalities that took place in Karachi city

3.3. Land cover of Karachi city

One of the biggest and largest cities in Pakistan is Karachi which has a population of about more than 9.8 million inhabitants living there (GOP, 2000). A digital thematic map has been developed to monitor the land use and land cover of this megacity. For the classification and distribution of Karachi land use/cover multispectral data Landsat-5 thematic mapping has been used.

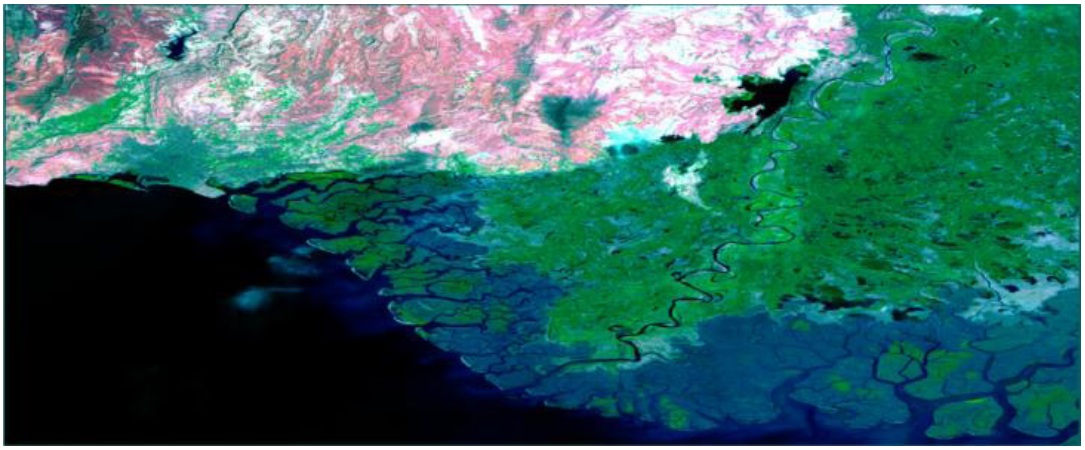

Figure 4. Spatial view of Karachi using Landsat-5

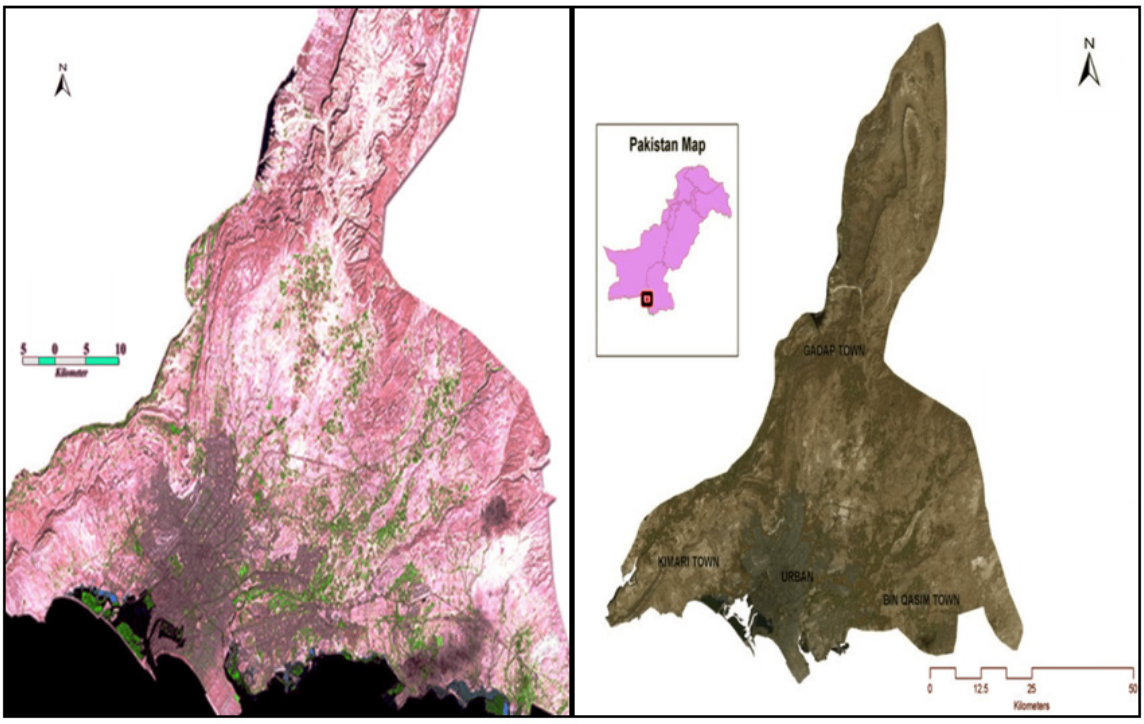

Figure 5. Study area-Karachi city (Satellite images)

A map has been developed that shows the classification of this land cover into eleven sections. From the data obtained it has been concluded that about 79.9% of the area consists of barren land, seawater, and mountains. 4.9% of the land has been covered by vegetation.15% of the area has been used as urban land which is increasing day by day due to population growth. As a result of urbanization and population, growing land is being cleared to make space for people to live.

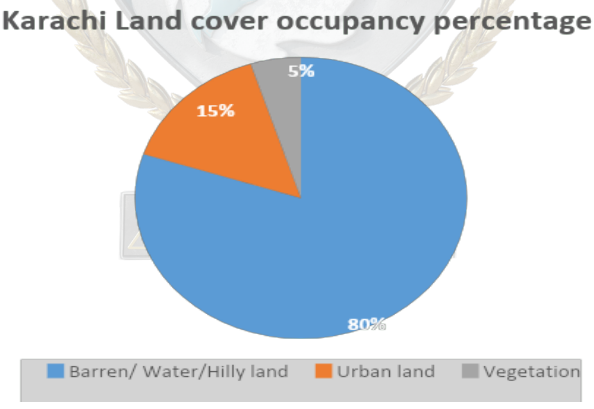

Figure 6. Different occupancy percentages of the Karachi land cover

Karachi city is a mixture of hilly, coastal and plain land. It has been found from the images developed that the plain area is 740 square miles. Out of this area, urban settlements occupy about 25% of this land while the rest being too far from the settlement is not in use by the people and is also hilly. Because of urbanization, there are chances that in the future an increase in urban land use and cover will occur around the area of Malir, Gadap, and Hawksbay. An expansion of about more than 75% has been seen from the image that shows an increase in coastline area that has occurred as a result of the built environment as compared to the past because of the shore repossession around DHA and Clifton. The Arabian Sea is located on the southern side of the city. The figure below shows the overall land cover of Karachi city.

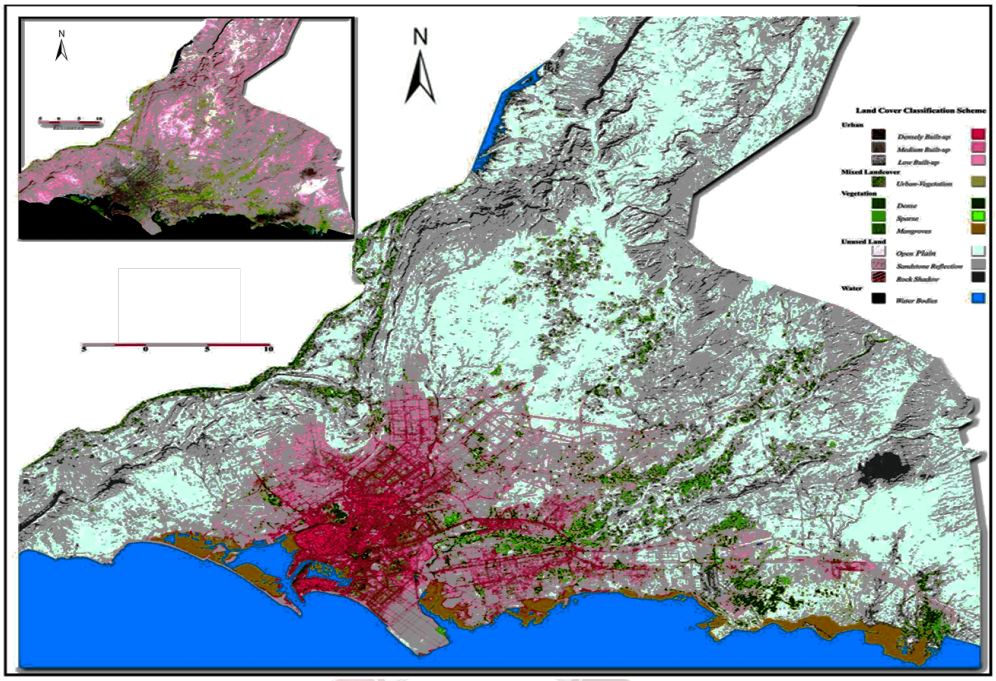

Figure 7. Classification of Karachi land covers area

The classification figure 7 of Karachi land cover shows four groups among which the most visible is the one having dense built-up land use/cover and the areas that come under it are Liaquatabad, Nazimabad, Shah Faisal Colony, and Shireen Jinnah colony. Since the activities related to economy and residents had been increasing as compared to the past, the areas under this group have become fully occupied and resulted in the mixed-use of land for different purposes. Transportation routes like roads had covered up all the available areas along with which population growth has reached as high as 1,800 persons per acre (URC, 2002). From the thematic map, it has been devised that sub-urban areas and city periphery areas come under the heading of low built-up areas and it includes DHA phases 4 and 5, Krangi Town, Gulshan-e-Hadeed, and Gulshan-e-Maymar. From the map generated it is seen that in the densely built-up class, there is no vegetation whereas medium built-up shows vegetation and the areas that come under this are Nazimabad, Clifton, Shahrah-e-Faisal as well as DHA.

3.4. Land use of Karachi city

There is a dependency between infrastructure and land use both of which are responsible for triggering different hazards. With the increase in urbanization land in Karachi has been cleared for obtaining space to build houses, industries, roads, etc. Since all of the areas are covered by impermeable construction substances there is little or no space left for the infiltration of rainwater that then leads to flooding. Although better facilities of life are being enjoyed by the people, it triggers many hazards that when not controlled properly lead to disaster in that area like floods, earthquakes, and hurricanes thus creating social instability in the city (Barrow, 1995).

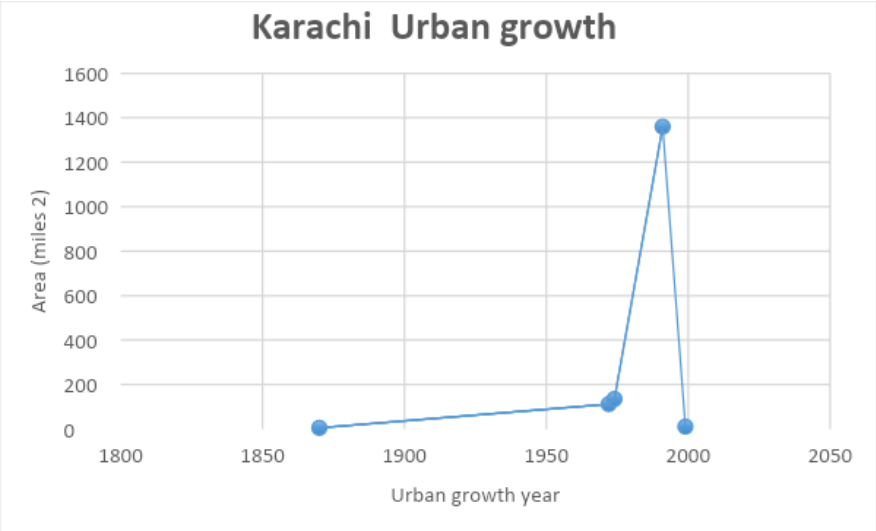

Figure 8. Karachi Urban growth

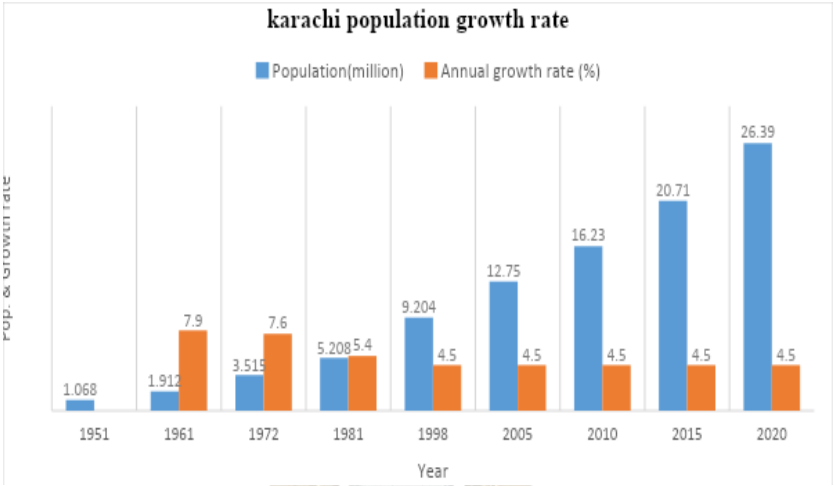

Figure 9. Graph Karachi population growth rate

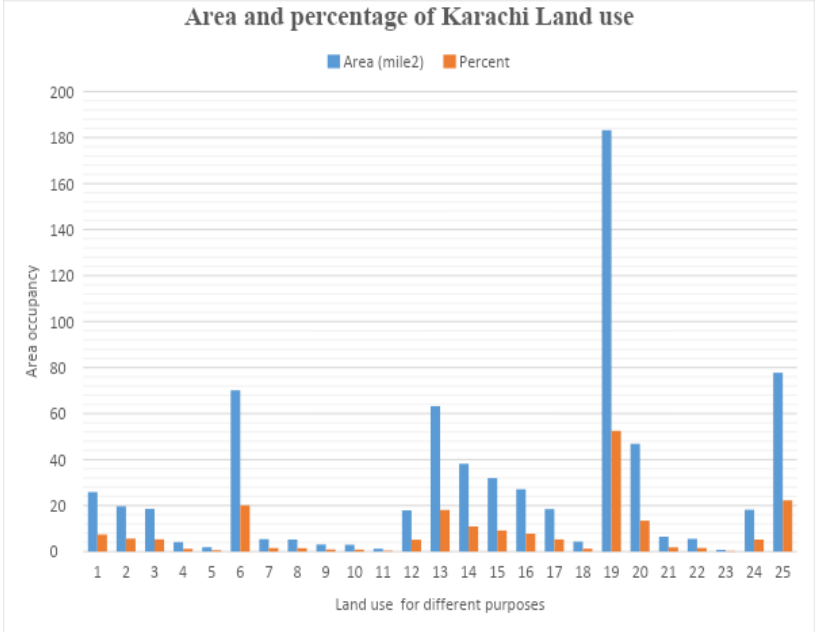

Figure 10. Graph Area and percentage of Karachi land use

Figure 11. Land use of Karachi city

3.5. Stormwater Drainage

For Stormwater, due to excessive rainfall the process of collection, transference, and discarding along with the main stormwater infrastructure preservation and channelization is carried out by the KWSB. There are about 40 main nullahs and drains that are 167 km long. The discharge point of these is the Lyari and Malir rivers that pass through the district of the city. The Stormwater drainage system also deals with the disposal of wastewater due to which preservation of the drains and nullahs is ignored and results in dense and heavy encroachment of the drainage lines as well as excessive amounts of waste being disposed of in these lines resulting in flooding.

3.5.1. Karachi's main drainage networks

About 44 drains of stormwater in Karachi had been devised which includes mapping of the drainage network of Karachi. Existing drains have eight networks that are identified. These networks are named Gujjar, Manzoor, South, Korangi, Orangi, West, Malir, and East network. The drainage networks of Karachi are shown in the figure given below which based on districts are further classified into 7 networks.

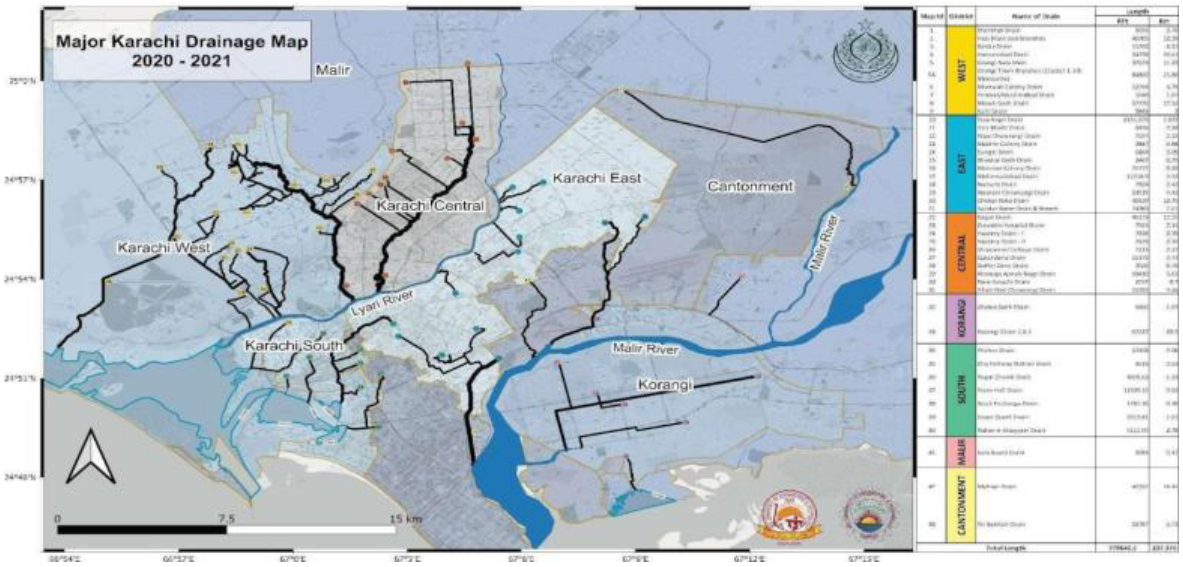

Figure 12. Karachi's main drainage networks

3.6. Impact of change in LULC on the Karachi drainage and river system

With the help of satellite images, the change in the land use and land cover of Karachi city has been mapped. This map shows how over the past fifteen years changes in the land area, vegetation, and agricultural land have been affected because of rapid urbanization and poor development planning. Vegetation has increased from 3.6 to 5.2%, land area has also increased from 9.7 to 21.5% whereas agricultural area has decreased from 7.3 to 5.9%. The map given below shows how changes in the land cover and land use have affected the drainage and sewerage networks throughout the city. Most of the blockages along with the city drainage networks, Malir, and Lyari rivers are caused by the development of agriculture as well as urban land.

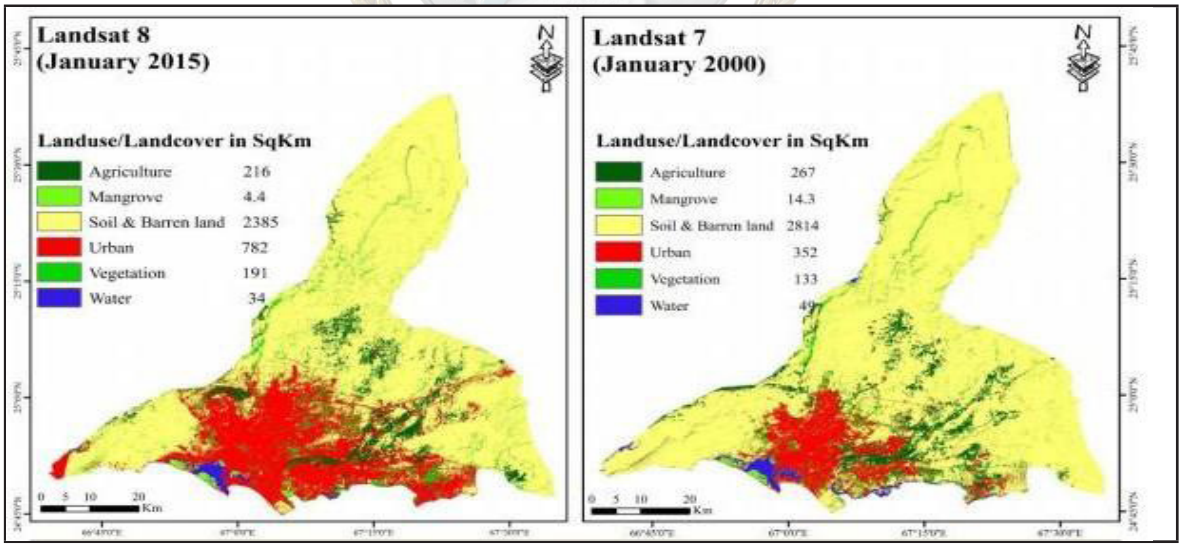

Figure 13. Impact of change in LULC on the Karachi drainage and river system

Because of the poor control and management of solid waste, an increase in the generation of waste has been observed from 2001 to 2020 ranging from 6500 to 150000 tons. With time, the drainage networks as well as riverbeds were encroached by illegal embankments, irrigated crops, land encroachment, dumping of waste as well as urban development (Odero & Mahiri, 2022; Cvetković & Martinović, 2020; Faicel, 2022). Due to the increased production and poor management, it has become very difficult to manage because of this the overall system of the Karachi drainage has been severely affected.

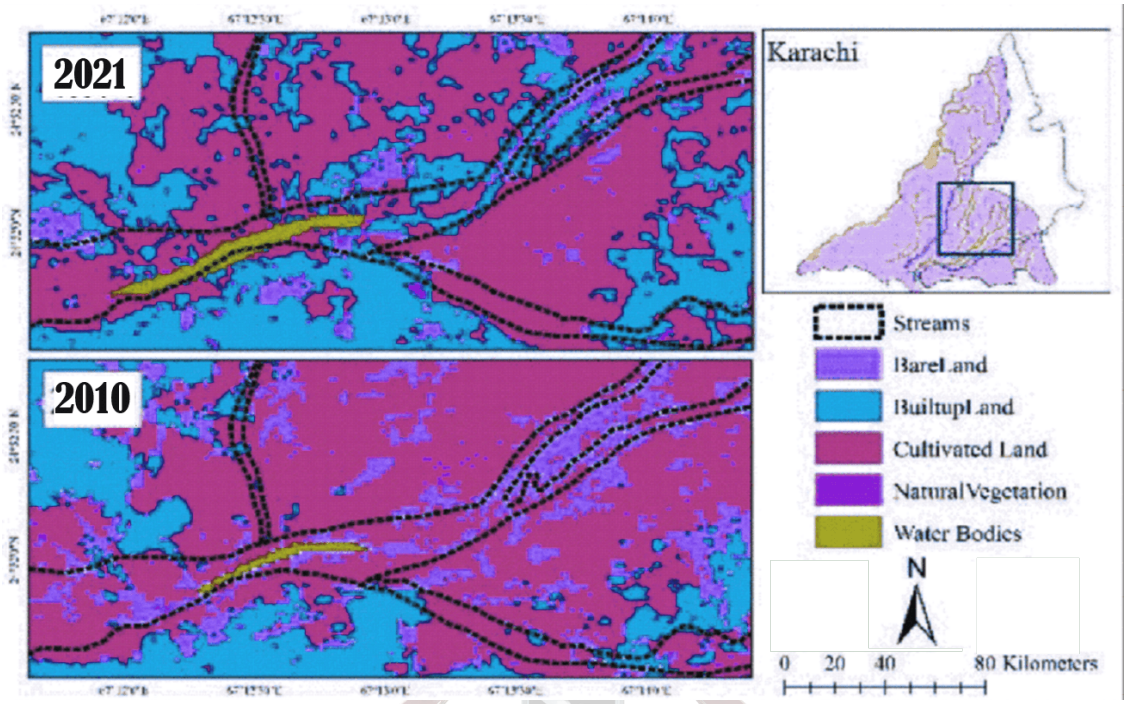

Figure 14. Blockages in the riverbeds because of urbanization

4. Recommendation

A master plan for the whole city drainage and stormwater needs to be developed and implemented that will focus on repairing, cleaning, and covering the drains, sewage networks, and tributaries, as well as the solid waste accumulated in the drainage pipes, should be reduced and recycled. Construction of trunks and plantation of trees along the bank of the nallahs should be done as it reduces the effect of the flood since they will act as natural barriers. Also, all the illegal settlements around the bank of the nallahs should be shifted to some other safe place as these not only are prone to flood but also cause a reduction in the width of the size of the drain. Green infrastructure should be promoted in the city that will increase the infiltration of water and will stop encroachment in the city thus the cost of the drainage system would be reduced.

5. Conclusion

It has been concluded that urbanization and population growth have caused a change in LULU and drainage networks of Karachi city. As the population has increased area is reduced and people are forced to live along the bank of the drains and tributaries which not only makes the width of these drains shorter but also makes these settlements vulnerable to flooding. Lack of proper implementation of policies related to the sustainable development of social housing a large amount of sewage by the residents has continuously been discharged into the nullahs and drains. Because of the lack of any alternate option, the formal developments have started to use drains and nullahs as a place for disposal which causes the clogging of the drains and the tributaries because of the sludge present in the sewage. As the population is increasing day by day the drain areas are being covered with illegal settlements causing choking and blocking of nullahs and drains.

Author contributions: The corresponding author Ayesha Iftikhar contribution includes: Analyzing the data, Using Software to develop the maps, writing the original draft, reviewing and editing. The second author Dr. Jawed Iqbal contribution includes: Investigating, Supervision, and Visualization.

Funding: There was no funding for this research.

Acknowledgements: In the end, we would like to thank the Climate Ministry and Pakistan Meteorological Department who helped with data collection.

Conflicts of interest: "The authors declare no conflict of interest."

References

1. Akhtar, S., & Dahnani, M. (2012). Surface water drainage and flooding in Karachi city. Sindh University Research Journal-SURJ (Science Series), 44(1).
2. Akhtar, W., Ali, I., Zaidi, S. S. H., & Jilani, S. (1997). The state of pollution levels of Karachi harbour and adjoining coastal water. Water, air, and soil pollution, 94(1- 2), 99-107.
3. Cvetkovic, V., & Martinović, J. (2020). Innovative solutions for flood risk management. International Journal of Disaster Risk Management, 2(2), 71-100.
4. Faicel, T. (2022). Flood policy in Algeria. International Journal of Disaster Risk Management, 5(1), 27-39.
5. Ghumman, U., & Horney, J. (2016). Characterizing the impact of extreme heat on mortality, Karachi, Pakistan, June 2015. Prehospital and disaster medicine, 31(3), 263-266.
6. GOP, (2000). Province Census Report of Sindh, Pakistan Demographic Survey 1998, Federal Bureau of Statistics, Statistics Division, Government of Pakistan, Islamabad
7. Irfan, M., Kazmi, S. J. H., & Arsalan, M. H. (2018). The sustainable harnessing of the surface water resources for Karachi: a geographic review. Arabian Journal of Geosciences, 11(2), 24.
8. Mansoor, A., & Mirza, S. (2007). Waste disposal and streamflow quantity and quality of Lyari River. Indus Journal of Management & Social Science (IJMSS), 1(1), 70-82.
9. Odero, N. A., & Mahiri, I. (2022). The Complacency of Flood Victims, Socio-Economic Factors, and Effects and Vulnerabilities of Floods in Lower Kano Plains, Kisumu County, Kenya. International Journal of Disaster Risk Management, 4(2), 59-77.
10. URC, (2002). Poor Civic Facilities Due to Lack of Master Plan, Facts and Figures, Urban Resource Center, 10(1), Pakistan, pp. 1
11. Zafar, S., & Zaidi, A. (2016, July). Flash floods in the Malir basin due to urbanization. In the 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp. 4481-4484). IEEE.
12. Zia, I., Zafar, H., Shahzad, M. I., Meraj, M., & Kazmi, J. H. (2017). Assessment of seawater inundation along Daboo Creek area in Indus Delta Region, Pakistan. Journal of the Ocean University of China, 16(6), 1055-1060.