

MAPPING URBAN FLOODING DYNAMICS IN SAADI TOWN, KARACHI: A STUDY OF CAUSES, IMPACTS, AND MITIGATION STRATEGIES

YASMEEN ANIS* • AIMEN FAISAL • SEHRISH FATIMA • SHEEBA AFSAR

Department of Geography, University of Karachi, Karachi, Pakistan

*Corresponding author: yasmeen.anis@uok.edu.pk

ABSTRACT

Urban flooding is a booming concern in cities worldwide, which also includes areas of Karachi, Pakistan. Saadi Town is a residential area in Karachi facing this problem during the rainy season. The study examines the reasons and the effects of flooding in Saadi Town, and it focuses more on rapid urbanization occupying the dried seasonal river beds, with an inadequate drainage system, or even the blockage of natural drainage and the change in the climate. Landsat images from the years 1986 and 2023 have been utilized to investigate the changes in vegetation, water bodies, and urbanization to understand the dynamics of flooding. The study emphasizes the need for sustainable urban planning and reveals the important infrastructure along with challenges of urban sprawl. There is a dire need for Landuse planning that encompasses better infrastructure along with the preservation of green spaces that can mitigate flooding and withstand harsh weather events.

KEYWORDS: Urban Flooding, Urbanization, Seasonal Riverbeds, NDVI, NDBI, NDWI, Saadi Town

1. INTRODUCTION

Karachi, Pakistan's leading industrial and financial hub, has evolved from a small fishing village during British rule into one of the country's largest urban centers (Khuhro&Mooraj, 1997). The unplanned settlement of ever-increasing population, overburdened the drainage system, give rise to urban flooding (Hasan & Raza, 2012). Contrary to rural areas where bare soil increase water infiltration to the ground, urban areas frequently display cemented surfaces like roads and buildings, pavements etc. that hinders water absorption, results in the form of flooding of low-lying areas and roads and streets.

Several factors lead to urban flooding, besides tremendous urbanization without planning that engulf the surrounding natural land cover replacing it with concrete and asphalt giving rise to blockade of infiltration of water. Outdated or poorly maintained drainage system, further give impetus to surface runoff to flow within the built-up areas during heavy rainfall. Climate change is the dilemma of today's world; observed in the form of increased intensity and frequency that further put additional stress over poorly maintained drainage network.

Well planned urban areas are the solution towards minimizing urban flooding; for instance, properly planned and frequently maintained drainage systems, implementation of green infrastructure such as rain gardens and permeable surfaces and above all avoiding the natural streams and drainage channels while planning and constructing housing societies which are usually ignored due to prolonged aridity as in the case of Saadi Town, Karachi.

The study is carried out to analyze the causes and consequences of urban flooding in the city of Karachi, by focusing Saadi Town. Further to work out and suggest the possible measures to minimize the problem. It critically analyses the impacts of rapid urban growth, insufficient or poorly maintained drainage system, the blocking of natural drainage, with the overwhelming climate change leading to urban flooding.

The aim of this study is to analyze the social, economic, and environmental impacts of flooding on the residents of urban areas. This in turn; enlightens the importance of implementing effective flood management strategies in residential areas like Saadi Town. The research provides a deep insight of factors responsible for urban flooding in Karachi and to provide recommendations for improving flood resilience in Saadi Town and similar urban areas. The main objective of the study is to focus mainly; The causes of urban flooding encountered during the heavy rainfall and their overwhelming impact on the urban areas. To achieve the above main objectives following objectives are followed: To prepare a comprehensive map of the study area. To find out the vegetation condition, NDVI is calculated. To calculate the NDWI of the study area, which gives an idea about the moisture content of the soils of the study area. To calculate NDBI to find out the cemented surfaces that prevent the absorption and infiltration of flood water. To perform Landuse/ Landcover (LULC) classification to find out The study represents a unique overview of all the causes responsible for urban flooding, mostly the man-made due to the indiscriminate occupation of land regardless of prior planning.

1.1. Study area

Saadi Town, a residential area in Karachi, Pakistan, has increasingly experienced urban flooding in recent years. It is located at 24.9064° N latitude and 67.1239° E longitude. The Malir River borders the town to the east and often overflows during heavy rains, causing waterlogging in surrounding areas. The Karachi Northern Bypass to the west can impede the natural flow of rainwater, further contributing to flooding (Figure 1).

Malir Cantonment is present to the north of Saadi town, while the Safoora Chowrangi intersection marks its southern boundary. These geographical features, and the unstoppable hasty urbanization and insufficient drainage

Mapping Urban Flooding Dynamics in Saadi Town, Karachi: A Study of Causes, Impacts, And Mitigation Strategies

infrastructure, contribute to the frequent flooding issues faced by residents of Saadi Town. One of the major issues is the blockade of natural drainage channel- a tributary of Malir River that recharges during the rainy season (Figure-2). Malir itself is a seasonal river.

Urban flooding in Saadi Town has become a significant issue disrupting the daily life of civilians, infrastructure, and the local economy. These issues can be resolved by improving drainage systems, implementing prior urban planning practices, and raising awareness about the importance of sustainable development in flood-prone areas.

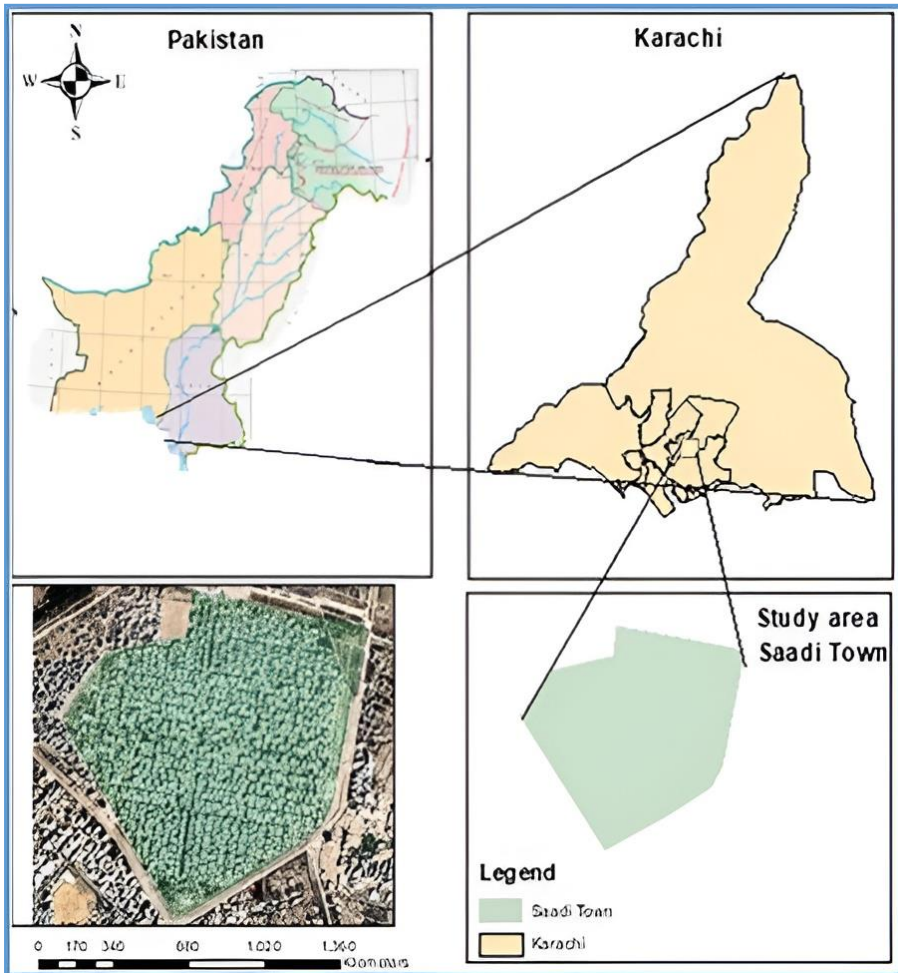


Figure 1: Study Area

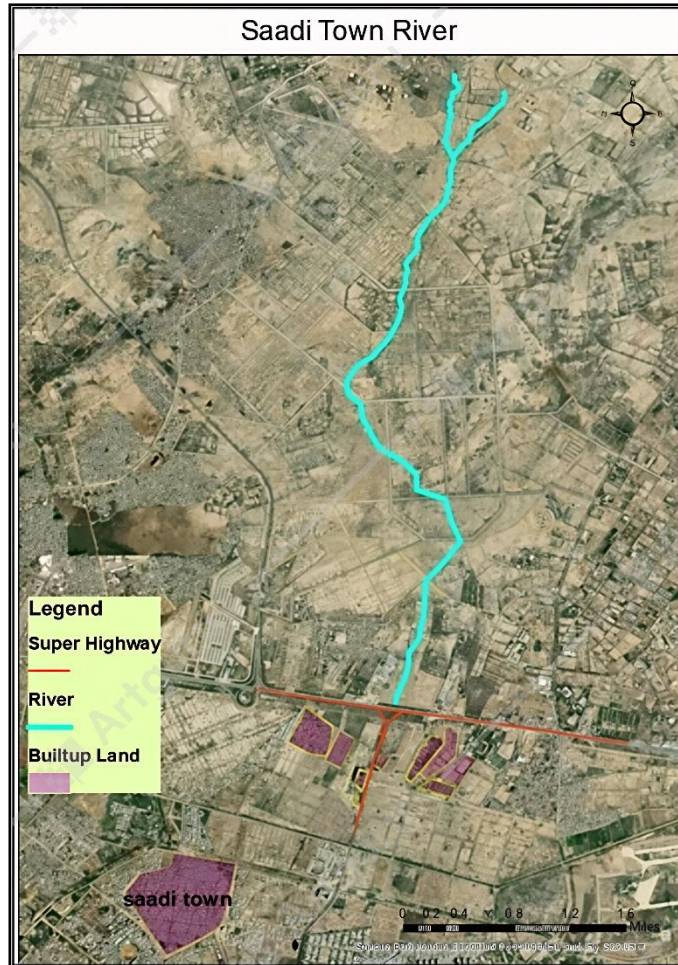


Figure 2: River Channel blocked, North of Saadi Town

1.2. Literature Review

Saadi Town has undergone a rapid urban growth as a residential society with in a short span of time, resulting in both developed residential society as well as its over whelming unforeseen issues . The accelerating settelement of population, burgeoning infrastructure, including transportation network, utility lines, and different landuses.

The multi-spectral satellite images e.g. Landsat are very effective for such studies as they provide information about several environmental conditions regarding vegetation and surface moisture conditions at different scales. (Nath & Deb, 2010 and Acharya & Lee, et al. 2018).

After examining 45 lab studies about urban flooding, the study breaks into 4 parts: the water being flown in single street corners, how the water flows between streets and sewers, how the water flows around barriers, and how it behaves in places imitating real cities. It also focuses what these studies

Mapping Urban Flooding Dynamics in Saadi Town, Karachi: A Study of Causes, Impacts, And Mitigation Strategies

are measuring, mapping urban floods is tricky because water flows in many different ways. This review helps scientists understand how to map, portray, and understand urban floods (Mignot et al., 2019).

Schreider et al studied the impact of climate change on flooding. They study how floods in cities might get worse because of more CO₂ in the air. They studied three areas in southeastern Australia where floods could be a problem: the Hawkesbury–Nepean corridor, the Queanbeyan, and Upper Parramatta Rivers. They found that if there's double the CO₂ in the air, there could be a lot more damage from floods, especially to buildings. The study shows that floods could happen more often and be bigger in these areas because of climate change. The importance of using models that show how rainfall affects flooding is quite prominent to understand these changes better (Schreider et al, 2000).

The vegetation cover plays important role by obstructing the floods. The presence of vegetation and its health in and around Saadi Town is analyzed by applying NDVI (Normalized Differentiated Vegetation Index). Using vegetation indices, which measure the amount of greenness, is one of several approaches for analyzing seasonal variations in vegetation using satellite imagery (Meneses Tovar, 2011). It is desirable to assess the effect of spatial resolution on the NDVI measurement to compare NDVI at various spatial resolutions over the same surface. Sub pixel variability is expected to induce inaccuracies in the NDVI estimates at different resolutions since vegetation cover might be highly varied in space (Jiang et al., 2006)

Estimation of growth and health of vegetation cover through remote sensing techniques are quite effective as emphasized by Xue&Su (2017). Sha Huang and Tang, L et al. (2021) examine the spectral characteristics of vegetation and the applicability of vegetation indices in environmental research.

2. MATERIALS AND METHODS

To calculate the NDVI, NDWI, NDBI, and LULC of Saadi town, Landsat 5 and Landsat 9 satellites images were acquired for the year 1986 and 2023 and comparative analysis was carried out. All the data was downloaded from various sources especially the USGS for satellite images.

2.1. NDVI

The normalized difference vegetation index (NDVI) is used to evaluate the vegetation cover. It is an effective method to quantify the plant density, and monitoring variations in health of green cover.

Following is the formula for calculating NDVI:

For Landsat 9: $NDVI = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$

For Landsat 5: NDVI (Band 4 – Band 3) / (Band 4 + Band 3)

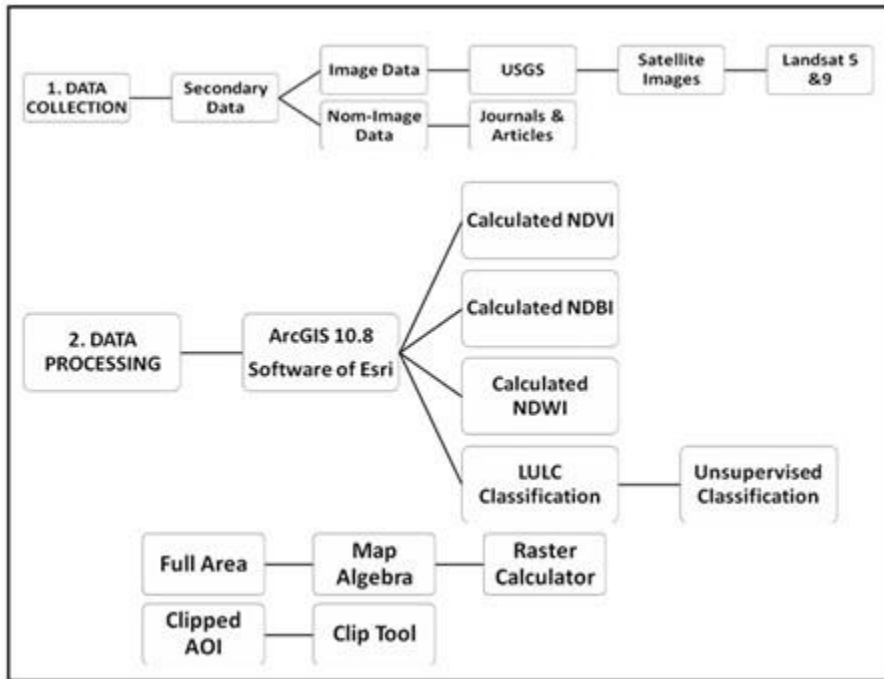


Figure 3: Research Framework

2.2. NDWI

It is derived from satellite data, specifically the Near-Infrared (NIR) and Short-wave infrared (SWIR) channels, as introduced by Gao in 1996

For Landsat 9: NDWI (Band 5 – Band 6) / (Band 5 + Band 6)

For Landsat 5: NDWI (Band 2 – Band 4) / (Band 2 + Band 4)

2.3. NDBI

The Normalized Difference Built-up Index (NDBI) highlights urban and built-up areas by utilizing

the Near-Infrared (NIR) and Short-wave Infrared (SWIR) bands. It is calculated as a ratio; such that the variations in terrain signatures and atmospheric conditions are minimized.

For Landsat 9: NDBI (Band 6 – Band 5) / (Band 6 + Band 5)

For Landsat 5: NDBI (Band 5 – Band 4) / (Band 5 + Band 4)

2.4. LULC

Land Use/Land Cover (LULC) typically involves categorizing human activities and natural features on the landscape within a specific time frame, using

established scientific and statistical analysis methods on relevant source materials.

2.5. Software used

ArcGIS Online and Google Earth Pro were mainly used for mapping Land cover and its variation through time and to perform all the spatial analysis.

These platforms assist the monitoring of trend, patterns and extent of urban flooding, LULC classification and the integration of different datasets.

3. RESULTS AND DISCUSSION

By extracting NDVI, NDWI, NDBI and mapping LULC of Saadi Town, interesting facts are revealed about the urban flooding event in the area. The Normalized Difference Vegetation Index (NDVI) map Figure 4 depicts the vegetation cover, Areas with higher NDVI values are indicates extensive vegetation cover, which can help in reducing the risk of flooding. The NDVI maps, shows that vegetation was abundant in the year 1986 as compared to the year 2023.

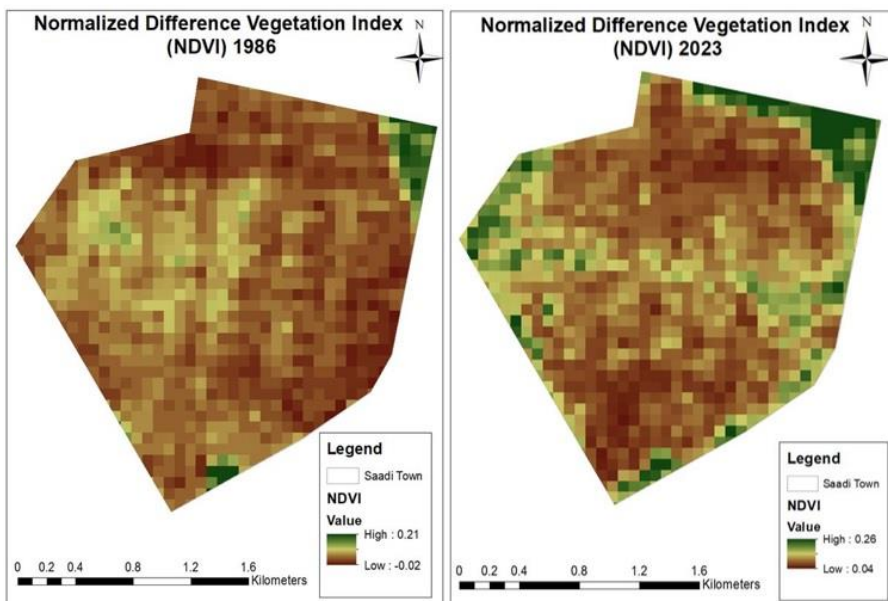


Figure 4: NDVI of Saadi Town

Figure 5 shows the Normalized Difference Water Index (NDWI). Higher values point towards the presence of water bodies like ponds, reservoirs and moisture contents of the soil etc., whereas low values suggest a lack of significant water bodies. The maps above illustrate that the water index was higher in 1986 compared to 2023.

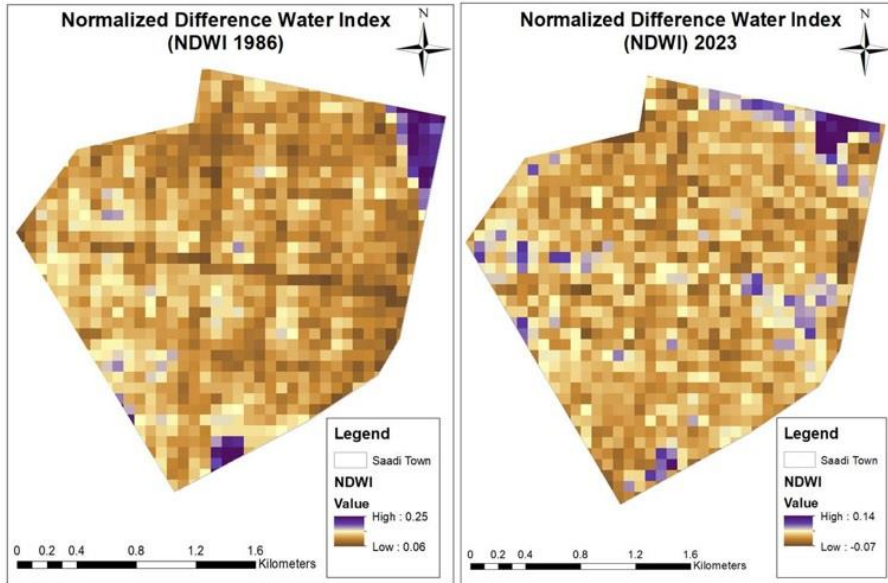


Figure 5: NDWI of Saadi Town

the Normalized Difference Built-up Index (NDBI) map, Figure 6 represents the extent of urbanization and built-up areas in Saadi Town. Urban areas with high NDBI values are more prone to flooding due to the increase in impervious surfaces, which prevent water from soaking into the ground. The NDBI map can help identify areas that are at higher risk of flooding due to extensive urbanization. The maps indicate that the built-up index was low in 1986 but raised markedly by 2023.

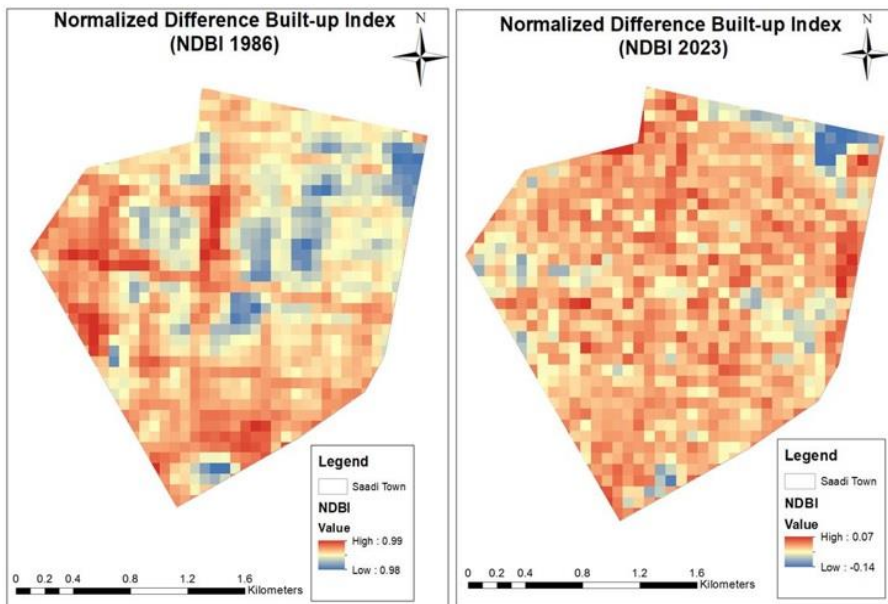


Figure 6: NDBI of Saadi Town

Figure 7 shows the Land Use and Land Cover (LULC) pattern of Saadi Town. The LULC map suggests the different types of land uses through built-up areas while land cover shows the vegetation extent water bodies and barren land. The presence of greater land cover in the year 2023 was alarming and indicates greater risk of urban flooding since barren land or bare soil absorbs more water as compared to cemented surfaces.

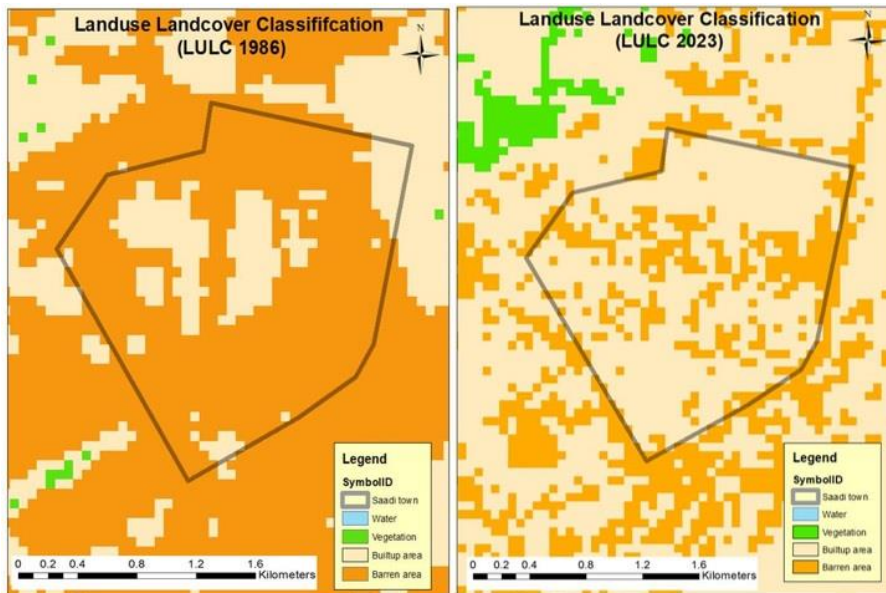


Figure 7: LULC Classification of Saadi Town

The analysis of NDVI, NDBI and NDWI maps along with LULC classification provides a deep insight of urban flooding incident in Saadi Town. By thoroughly studying the pace of changing vegetation cover, water bodies, built-up land and other land cover types, urban planners and policy makers can set up their future planning strategies in a well-planned manner to minimize the risk of urban flooding and resilient areas that can with stand other extreme weather events.

4. DISCUSSIONS

One major factor associated with urban flooding is the occupancy of dry beds of seasonal streams for residential purposes, as is the case of Saadi Town (Figure 2). Saadi Town and its surrounding areas are situated in the passage of a seasonal stream –a tributary of the Malir River.

The analysis of the development of Saadi town by using Landsat 5 and Landsat 9 satellite imagery from 1986 to 2023 tells us about the important transformations and Obstacles. The sudden invasion of people has exhausted the infrastructure, such as roads, water supply, and educational institutions, and the change in the landscape is visible.

The inspection of NDVI, NDWI, NDBI, and LULC values tells us about the visible fluctuations in water, vegetation, and built-up areas due to urban sprawl. By analyzing these changes, we can easily feel the importance of sustainable urban planning. Improvement in the infrastructure, land use management, and green space preservation is gravely essential for the area's livability. By labelling these problems, the negative impacts of the rapid urbanization in Saadi town will be mitigated easily.

5. CONCLUSION

The case study of Saadi Town reveals the fact that most factors of urban flooding are human induced. Settlement of residential schemes lacks prior planning. Vegetation cover is frequently cleared regardless of its impact, and open spaces shrink with the emergence of urban infrastructure that prevents the absorption of water into the ground. Therefore, it is concluded that, despite climate change, urban flooding is the result of indiscriminate occupancy of land without planning.

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Mapping Urban Flooding Dynamics in Saadi Town, Karachi: A Study of Causes, Impacts, And Mitigation Strategies

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