C40 CITIES Climate Action Planning

The Urban Unit
Urban Sector Planning & Management Services Unit (Pvt.) Ltd.

UNDP

Climate Change Risk Assessment (CCRA)

Karachi Climate Action Plan (K-CAP)

Document Information

Lead author

The Urban Unit' K-CAP Team

Reviewer

Climate Promise UNDP Pakistan
C40 Team

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Abbreviations

CAP	Climate Action Plan
CAMS	Copernicus Atmospheric Monitoring Services
CBD	Central Business District
CCRA	Climate Change Risk Assessment
CFCs	Chlorofluorocarbons
CH4	Methane
CO2	Carbon Dioxide
EPA	Environment Protection Agency
EbA	Ecosystem-based Adaptation
GDP	Gross Domestic Product
GMW	Global Mangroves Watch
HEC-RAS	Hydrologic Engineering Center - River Analysis System
H_2O	Water vapour
HH	House Hold
HFCs	Hydrofluorocarbons
ILO	International Labor Organization
in	Inches
INFORM	Index for Risk Management
IPCC	Intergovernmental Panel on Climate Change
km^2	Square Kilometers
KMC	Karachi Metropolitan Corporation
LST	Land Surface Temperature
$\mu g/m^3$	Microgram per cubic meter
mm	millimeter
mol / m 3	mole per meter cubed
NAO	Noth Atlantic Oscillation
N_2O	Nitrous Oxide
O_3	Ozone
PFCs	Perfluorocarbons
PM	Particulate Matter
PMD	Pakistan Meteorological Department
PSLM	Pakistan Social and Living Standards Measurement
RCP	Representative Concentration Pathways
SF6	Sulphur Hexafluoride
SST	Sea Surface Temperature
UHI	Urban Heat Island
UNFCCC	United Nations Framework Convention on Climate Change
USGS	U.S. Geological Survey
WB	World Bank
WMO	World Meteorological Organization

Glossary[1]

Aerosole	A suspension of airborne solid or liquid particles, with typical particle size in the range of a few nanometres to several tens of micrometers and atmospheric lifetimes of up to several days in the troposphere and up to years in the stratosphere
Anthropogenic	It results from or is produced by human activities.
Climate	In a narrow sense, climate is usually defined as the average weather -or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities- over a period ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.
Climate Change	The United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods.
Climate Extreme	The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. When a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., high temperature, drought, or heavy rainfall over a season). For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes'.
Climate Finance	There is no agreed definition of climate finance. The term 'climate finance' is applied to the financial resources devoted to addressing climate change by all public and private actors from global to local scales, including international financial flows to developing countries to assist them in addressing climate change.
Climate Governance	The structures, processes, and actions through which private and public actors seek to mitigate and adapt to climate change.
Climate Risk Assessment	It seeks to understand the likelihood of future climate hazards and the potential impacts of these hazards on cities and their inhabitants. The assessment is an essential tool for prioritizing actions and investments in climate adaptation and resilience.
Climate Sensitivity	The change in the surface temperature is in response to a change in the atmospheric carbon dioxide (CO2) concentration or other radiative forcing.
CO2-equivalent Emission (CO2-eq)	The amount of carbon dioxide (CO2) emission that would have an equivalent effect on a specified key measure of climate change, over a specified time horizon, as an emitted amount of another greenhouse gas (GHG) or a mixture of other GHGs. A mix of GHGs is obtained by summing the CO2-equivalent emissions of each gas.
Drought	An exceptional period of water shortage for existing ecosystems and the human population (due to low rainfall, high temperature, and/or wind).
Emission Pathways	Modeled trajectories of global anthropogenic emissions over the 21st century.

[1] Terminologies and definitions used in the reports are consistent with those used in the IPCC Sixth Assessment Report (AR6) https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_Annex-I.pdf

Emission Scenario	A plausible representation of the future development of emissions of substances that are radiatively active (e.g., GHGs or aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy, and land use) and their key relationships. Concentration scenarios, derived from emission scenarios, are often used as input to a climate model to compute climate projections.
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.
Greenhouse gases (GHGs)	Gaseous constituents of the atmosphere, both natural and anthropogenic, absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4), and ozone (O3) are the primary GHGs in the Earth's atmosphere. Human-made GHGs include sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs); several of these are also O3-depleting (and are regulated under the Montreal Protocol).
Grey infrastructure	Engineered physical components and networks of pipes, wires, tracks, and roads that underpin energy, transport, communications (including digital), built form, water and sanitation, and solid-waste management systems.
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
Hazard Assessment	Hazard assessment: This will include finding information about past heat waves, droughts, storms, and floods, and analyzing historic climate trends and future projections across different scenarios. Hazard maps are particularly effective in linking climate science to vulnerable locations.
Impact	The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be considered consequences or outcomes and can be adverse or beneficial.
Impact Assessment	Climate change impacts are the consequences of climate change for social, natural, and economic capital in your city. This assessment seeks to diagnose and prioritize these impacts. It usually requires input from a range of stakeholders and relevant city sectors. For example, the image below demonstrates how droughts are expected to impact Kuala Lumpur, with the larger sphere representing a larger impact.
Informal Settlement	A term given to settlements or residential areas that by at least one criterion falls outside official rules and regulations. Most informal settlements have poor housing (with widespread use of temporary materials) and are developed on land that is occupied illegally with high levels of overcrowding. In most such settlements, provision for safe water, sanitation, drainage, paved roads, and

	basic services is inadequate or lacking. The term 'slum' is often used for informal settlements, although it is misleading as many informal settlements develop into good-quality residential areas, especially where governments support such development.
Net zero CO2 Emissions	Condition in which anthropogenic CO2 removals balance anthropogenic carbon dioxide (CO2) emissions over a specified period.
Resilience	The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure. Resilience is a positive attribute when it maintains the capacity for adaptation, learning, and/or transformation.
Risk	In the context of climate change, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Risks can arise for example from uncertainty in the implementation, effectiveness, or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.
Risk Assessment	This helps cities identify their key climate risks and create a concrete strategy to address them. It helps to inform the prioritization of actions and investment into climate adaptation and resilience, enabling cities to take ambitious action.
Urban Heat Island (UHI)[2]	Heat islands are urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

[2] https://www.epa.gov/heatislands

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A | Overview

General

Karachi's Climate Change Risk Assessment (CCRA) Report is prepared under the Karachi Climate Action Plan (K-CAP) Project. The report provides the prevailing risks and hazards, likelihood of future climate hazards and the (sectoral) impacts of these hazards on Karachi City and its inhabitants. This activity involves identifying the city's current and future climate-related hazards, assessing the impacts on people, sectors, and systems, and developing a comprehensive climate change risk assessment in line with the UNDP strategic plan[3] and C40´s CAP Framework and Cities Climate Transition Framework[4] requirements, as well as CCRA guidelines[5].

According to the CAP Framework, a Climate Action Plan demonstrates a city's contribution to the goals of the Paris Agreement based on the following four key components:

1. Develop a pathway to deliver an emissions-neutral city by 2050 at the latest and set an ambitious6 interim target and/or carbon budget.
2. Demonstrate how the city will adapt and improve its resilience to climate hazards that may impact it now and in future climate change scenarios.
3. Outline the social, environmental, and economic benefits expected from implementing the plan, and improve the equitable distribution of these benefits across the city's population.
4. Detail the city's governance, powers, and the partners who need to be engaged to accelerate the delivery of the city's mitigation targets and resilience goals.

Concerning these components, the key objective of this CCRA is to **provide an evidence-based assessment that forms a concrete baseline for Karachi City to understand the level of climate risk across the sectors, so that a well-planned (and informed) Climate Action Plan can be developed for the city**. Conclusively, the output from this assessment informs the Karachi City's adaptation goals and strategies, and the prioritization of climate actions for achieving long-term climate resilience.

A1. City Profile

Karachi, a sprawling metropolis on the Arabian Sea, boasts a distinctive administrative and physical geography that significantly shapes its urban dynamics. It is one of the megacities of the world and the provincial capital of Sindh. The topography of the city comprises both flat and undulating plains with urban extent towards the North and mountains to the West. Two rivers, Malir and Lyari pass through the city flowing towards the south and fall into the Arabian Sea.

[3] UNDP Strategic Plan (2022-2025) aims to build resilience: strengthening countries and institutions to prevent, mitigate, and respond to crisis, conflict, natural disasters, climate, and social and economic shocks. https://www.undp.org/publications/undp-strategic-plan-2022-2025

[4] This framework provides an enhanced focus on climate adaptation, resilience, and equity, as well as on governance and decision-making, implementation planning, monitoring, evaluation, and reporting, to support cities to mainstream climate actions. https://www.c40knowledgehub.org/s/article/Cities-Climate-Transition-Framework?language=en_US

[5] https://www.c40knowledgehub.org/s/guide-navigation?language=en_US&guideRecordId=a3t1Q0000007IEWQAY&guideArticleRecordId=a3s1Q000001iahxQAA

[6] steep/steady decline or early/late peak depending on a city's GHG per capita and GDP per capita

CITY PROFILE

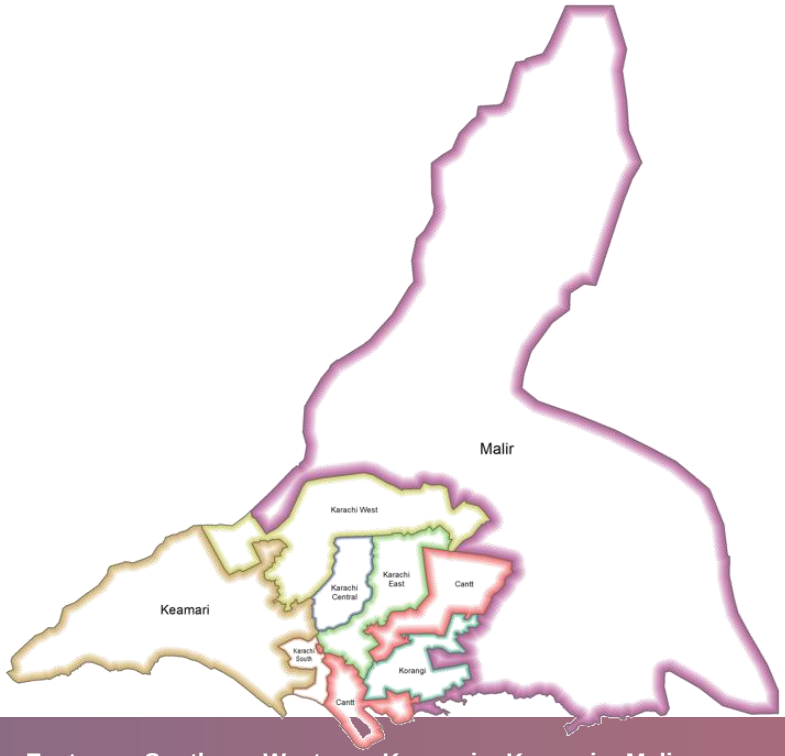
24.8607° N and 67.0011° E

Seven Districts
Karachi West, Karachi South, Karachi Central, Malir, Keamari, Korangi and Karachi East

20.38 Million People

25 Towns and 246 Union Councils

4,115 people per sq. km



Administrative Units / Key Characteristics	Karachi Division	Central District	East District	South District	West District	Keamari District	Korangi District	Malir District
Population*	20.38 M	3.82 M	3.95 M	2.33 M	2.68 M	2.07 M	3.13 M	2.40 M
Pop. Growth*	4.1	4.3	5.45	4.71	4.35	2.07	3.29	3.79
Households HH*	3.43 M	0.65 M	0.66 M	0.42 M	0.46 M	0.32 M	0.49 M	0.41 M
Avg. HH Size*	5.93	5.86	5.94	5.47	5.76	6.47	6.34	5.77
Area (km^2)**	3,640	64	159	81	88	761	95	2,487
Climate Conditions**	Warm & Semi-Arid – Mild Climatic Conditions							
Average Rainfall (mm/year)**		194.77	159.55	173.75	166.84	165.23	173.75	173.75

Sources:

** Population Census 2023, Pakistan Bureau of Statistics, Government of Pakistan*

*** Sindh Hazard and Risk Atlas 2022 and Disaster Management Plan of Karachi Districts 2022, PDMA, SUPARCO, World Bank and GoSindh*

A2. Methodology

Karachi's Climate Change Risks and Vulnerability Assessment is aligned with the C40 Cities' Climate Change Risk Assessment (CCRA) Modules/Guidelines. This alignment was achieved through the consideration of screening parameters related to historical climatic trends and future projections, drawing upon global models and assessment reports such as those from the Intergovermental Panel on Climate Change - IPCC, as well as national and local plans. The assessment of climate and air pollution risks was conducted spatially and temporally, examining the relationship between various parameters that increase a community's exposure or sensitivity to climate risks, while potentially decreasing or limiting their adaptive capacities during extreme events.

Spatial analysis, facilitated by GIS and remote sensing technologies, was employed to identify areas more susceptible to climate or air pollution risks. These tools enable the identification of areas that are more exposed to climate or air pollution risks, allowing for a granular understanding of spatial patterns and distributions. By leveraging these technologies, stakeholders can identify specific locations that require immediate attention and prioritize resources accordingly.

Moreover, the assessment incorporates data on weather patterns and air pollution, which are monitored over time to analyze past trends and associated impacts. Socio-economic sensitivities were mapped using data from the Pakistan Bureau of Statistics 2017/2023, visualizing and overlaying risk layers at the district level to pinpoint potentially vulnerable districts and localities within the city. KMC's services and amenities data were spatially visualized to identify underserved neighborhoods with poorer adaptive capacities. This allows for targeted interventions aimed at strengthening infrastructure and improving access to services, thereby enhancing overall resilience. Finally, these various datasets were correlated to illustrate the interlinkages between climate risks, air pollution risks, socio-economic sensitivities, and compromised access to infrastructure and services.

In summary, the CCRA report provides a comprehensive and integrated approach to assessing climate and air pollution risks and vulnerabilities. By aligning with established frameworks, leveraging spatial analysis and remote sensing technologies, and incorporating socio-economic considerations, the assessment enables stakeholders to identify key risk factors, prioritize interventions, and build resilience in communities facing the impacts of climate change and air pollution.

B | Climatic Context

Risk and Hazard Assessment

Pakistan is persistently ranked as one of the most vulnerable countries with high-risk levels and low response to manage the risks and vulnerabilities.

Figure 1. Pakistan's Ranking with Reference to Climate Change Risks, Exposure, Vulnerability and Management

Pakistan is one of the most vulnerable countries to extreme climatic events (Ranked 8th in 2022), with estimated damages and losses of 18 billion USD in the last decade.[11] In the latest ranking – Index for Risk Management INFORM 2024 – Pakistan stands at 23rd number in terms of high risk/severity of the impacts of Climate Change. The overall performance in managing climate change placed it in the 30th position concerning lower progress in renewable energy, inadequate climate policies, and higher levels of GHG emissions, followed by higher consumption of energy. World Resource Institute has categorized Pakistan as an 'extremely high baseline water stress' country of the world and ranked it in 14th position[12]. This indicates the overall state of the environment and climate change is not satisfactory and needs concrete efforts to bridge these critical gaps.

With a potential increase of 1.3°C–4.9°C temperature in the next 60-70 years in Pakistan, cities of Pakistan are at higher risk of the devastating impacts of extreme climatic events. Karachi is one of the largest metropolises in the world – home to 20.38 million people - facing higher risks and vulnerabilities to climate change. Increased water shortages, changes in weather patterns, storms, coastal and urban flooding, poor air quality, and more frequent extreme climatic events like heatwaves and flooding, affect the lives and livelihoods of millions of people. The city ranked 1st in the Climate Risk and Hazard Assessment Classification of Pakistan[13]. Rapid and unplanned urbanization, inadequate climate action planning policies and management frameworks, and limited institutional and financial capacities, are some of the contributing factors that are increasing climate change risks in Karachi City.

[7] https://www.germanwatch.org/sites/default/files/Global%20Climate%20Risk%20Index%202021_2.pdf
[8] Inter-Agency Standing Committee and the European Commission, INFORM Report 2023; Shared evidence for managing crises and disasters, European Union, doi:10.2760/073809 https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/Country-Risk-Profile
[9] https://ccpi.org/country/pak/
[10] Inter-Agency Standing Committee and the European Commission, INFORM Report 2023; Shared evidence for managing crises and disasters, European Union, doi:10.2760/073809 https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/Country-Risk-Profile.
[11] . World Bank, 2017. Improving Pakistan's fiscal resilience to natural disasters. World Bank News, 6 13.
[12] https://www.unsdsn.org/sdsn-pakistan-mobilizes-experts-around-water-safety-security-and-population-health#:~:text=Pakistan%20ranks%2014th%20among%20the,its%20outlook%20depends%20on%20management
[13] Chaudhry, Q. 2017. *Climate Change Profile of Pakistan*. Asian Development Bank, Philippines. doi.org/10.22617/TCS178761

Table 1: District-Level Climate Risk and Hazard Assessment Classification[14]

Rank	District	Flood Risk	Earthquake Risk	Tsunami Risk	Cyclone Risk	Drought Risk
1st	Karachi	4	5	5	5	5
	Scoring Key					
	Very High	High	Medium	Low	Very Low	Non-Hazard
	5	4	3	2	1	-

Table 2: Bottom 10 Liveable Cities in the World[15]

City	Location	Rank	Index	Stability	Healthcare	Culture & environment	Education	Infrastructure
Douala	Cameroon	164	46.4	60.0	29.2	51.2	41.7	42.9
Kyiv	Ukraine	165	44.0	40.0	41.7	54.2	75.0	23.2
Harare	Zimbabwe	166	43.8	40.0	29.2	56.7	66.7	35.7
Dhaka	Bangladesh	166	43.8	50.0	41.7	40.5	75.0	26.8
Port Moresby	Papua New Guinea	168	43.4	30.0	41.7	49.8	58.3	46.4
Karachi	Pakistan	169	42.5	20.0	50.0	38.7	75.0	51.8
Lagos	Nigeria	170	42.2	25.0	37.5	54.4	41.7	53.6

Rating description

Rating	Description	Suggested allowance (%)
80-100	There are few, if any, challenges to living standards	0
70-80	Day-to-day living is fine in general, but some aspects of life may entail problems	5
60-70	Negative factors have an impact on day-to-day living	10
50-60	Liveability is substantially constrained	15
50 or less	Most aspects of living are severely restricted	20

The Global Livability Index 2023 Report ranked Karachi as 5th bottom city in the world concerning its performance in managing multiple sectors

Table 3: A Snapshot from World Air Quality Report 2023

City	2023	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2022
Karachi	56.4	98.9	65.1	53.5	28.2	27.0	30.2	32.1	30.1	43.2	38.2	121.0	109.7	50.6

[14] Chaudhry, Q. 2017. *Climate Change Profile of Pakistan*. Asian Development Bank, Philippines. doi.org/10.22617/TCS178761
[15] Economist Intelligence Unit (EIU). (2023). The Global Livability Index 2023.

B1. Climate Risks

The temperature changes are reportedly more pronounced in the southerly regions of the country, covering southern Punjab, Sindh, and Balochistan, with a rise of almost 0.91°C – 1.12°C in winter warming. In contrast, the change/rise in daily average maximum temperature is higher than the average temperature, with almost 0.87°C change witnessed between 1961–2007.

As Karachi is located in the northern hemisphere, the primary factor influencing its arid climate is the shift of the Hadley circulation cell towards the north, which enhances the high-pressure system. The typical stratus clouds and sea breeze are found along Karachi's coastal areas. A slight seasonal transition brings moderate winters from mid-December to mid-February due to north easterly currents, influenced by local instability conditions. This is followed by a long, hot, and humid summer lasting from April to September, trailed by monsoon rains occurring from July to September. . In general, Karachi's climate is influenced by El-Nino Southern Oscillation, Westerlies, Indian Ocean Dipole and Noth Atlantic Oscillation (NAO).

Sindh, particularly, Karachi City, is facing multiple climatic challenges such as more frequent heatwaves in the urban centers; a decrease in mean rainfall along coastal belts (10%–15% since 1960 - leading to drought conditions) affecting wetlands and mangrove ecosystems; more frequent storms; intense daily rainfalls leading to urban flooding.

This section particularly focuses on the key climatic hazards and risks to Karachi City. A total of five indicators are evaluated to assess its climate risk context. These are;

a) Urban Heat Risk

The Berkeley Earth Data estimate warming between 1900–1917 and 2000–2017, showing 0.9°C of warming in the vicinity of Karachi City, increasing advents of heatwaves.[16]

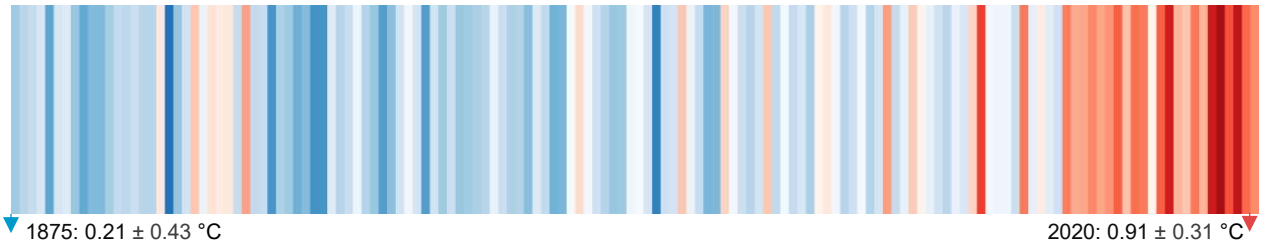


Figure 2. Warming Stripes of Karachi City[17]

Ed- Hawkins climate vertical stripes transitioning from blue to red presenting the graphic visualization of historical long-term yearly averaged over Karachi as illustrated in Figure 3. The last decade has witnessed a notable rise in temperatures, possibly attributable to several contributing factors such as inadequate urban planning, the changing day arcs of the sun, emissions from vehicles and industries, and variations in coastal sea breezes[18].

[16] https://data.berkeleyearth.org/locations/24.92N-67.39E#
[17] Ibid
[18] Amjad, M.; Khan, A.; Fatima, K.; Ajaz, O.; Ali, S.; Main, K. Analysis of Temperature Variability, Trends and Prediction in the Karachi Region of Pakistan Using ARIMA Models. *Atmosphere* **2023**, *14*, 88. https://doi.org/10.3390/atmos14010088

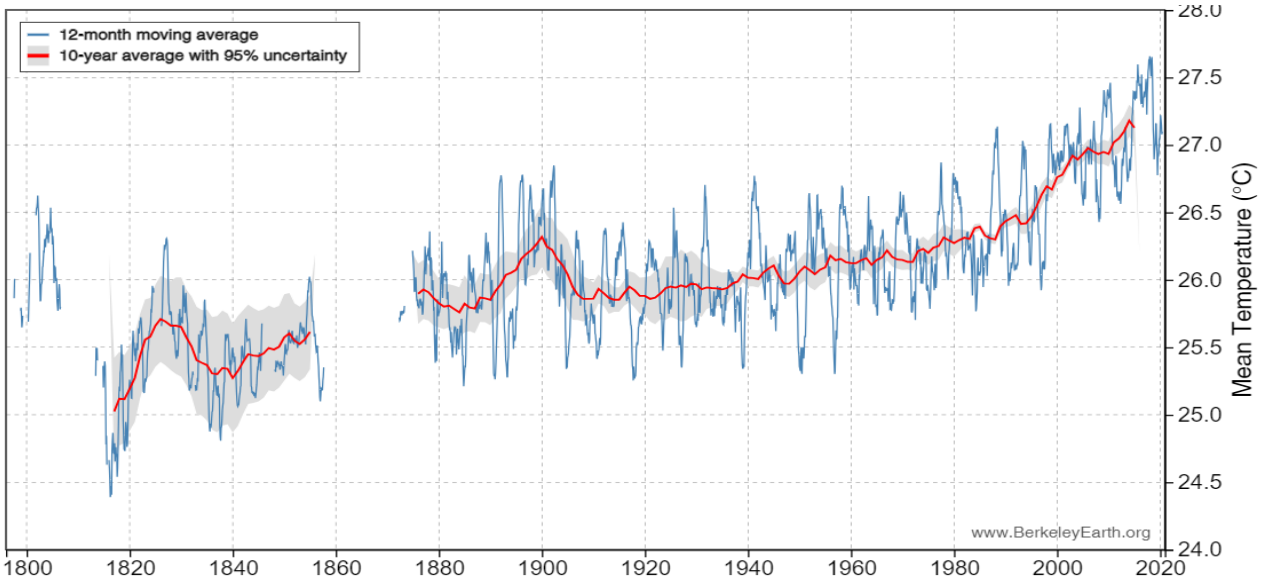


Figure 3. Mean Temperature Change of Karachi City °C

A detailed assessment of Urban Heat Risk was carried out for this CCRA Report that involves analyzing both non-spatial and spatial parameters. Non-spatial parameters comprehend air temperature and anomalies utilizing Pakistan Meteorological Department (PMD) data spanning from 1979 to 2020, sourced from the Karachi Airport Monitoring Station. Spatial analysis of heat risk utilizes Land Surface Temperature (LST) data from Landsat 8 (USGS), aiding in the identification of local areas more susceptible to heat stress, commonly referred to as the Heat Island Effect.

- ## Temperature Trend Analysis

The temperature trend analysis of Karachi City demonstrates consistent warming over 42 years. The below figure exhibits the maximum, minimum, and average monthly temperatures of Karachi for the years 2001-2022 acquired from Merra-2 reanalysis data. The maximum temperature range is 27 to upwards of 42 °C. The average temperature range is 21 – 34 °C. The minimum monthly temperature range is 12 to 30°C. The homogeneous pattern of average temperature is observed over Karachi.

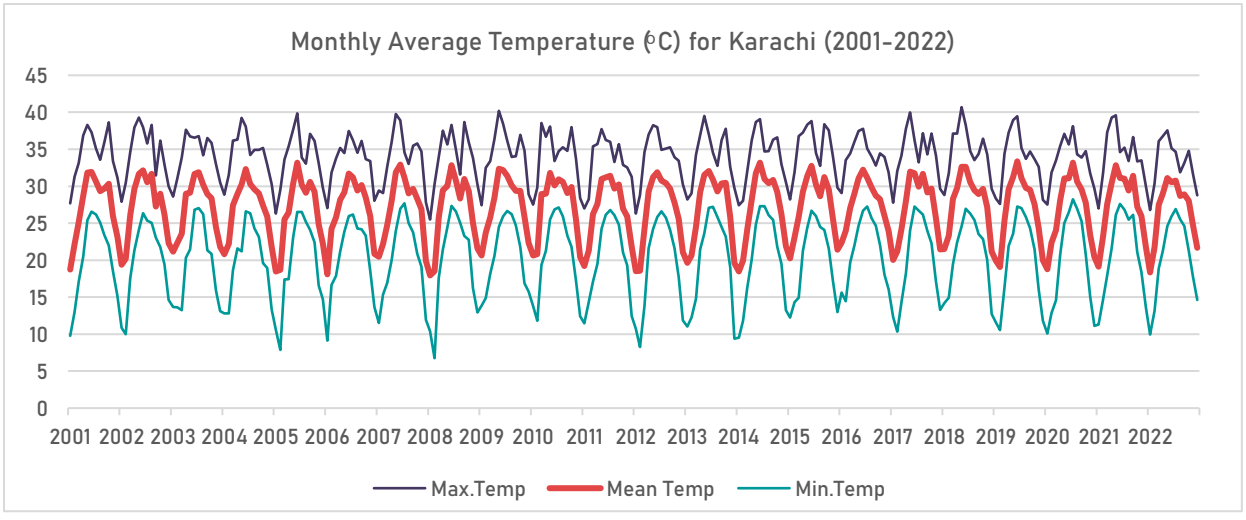


Figure 4. Monthly Average Maximum and Minimum Temperature in Karachi (2001-2022)

- ## Annual Air Temperature Anomalies

There has been a noticeable increase in the frequency of warmer years, with the most recent eight years demonstrating an average departure of 0.5°C from the baseline average air temperature (1980-2023). Over the period from 1980 to 2023, 27 years experienced temperatures surpassing the baseline average air temperature of 32.2°C. Except 2008, every year since 1997 has been categorized as a warm year. Notably, 2015, 2016, 2018, and 2021 stand out as the warmest on record, with a departure of over 0.7°C, as depicted below.

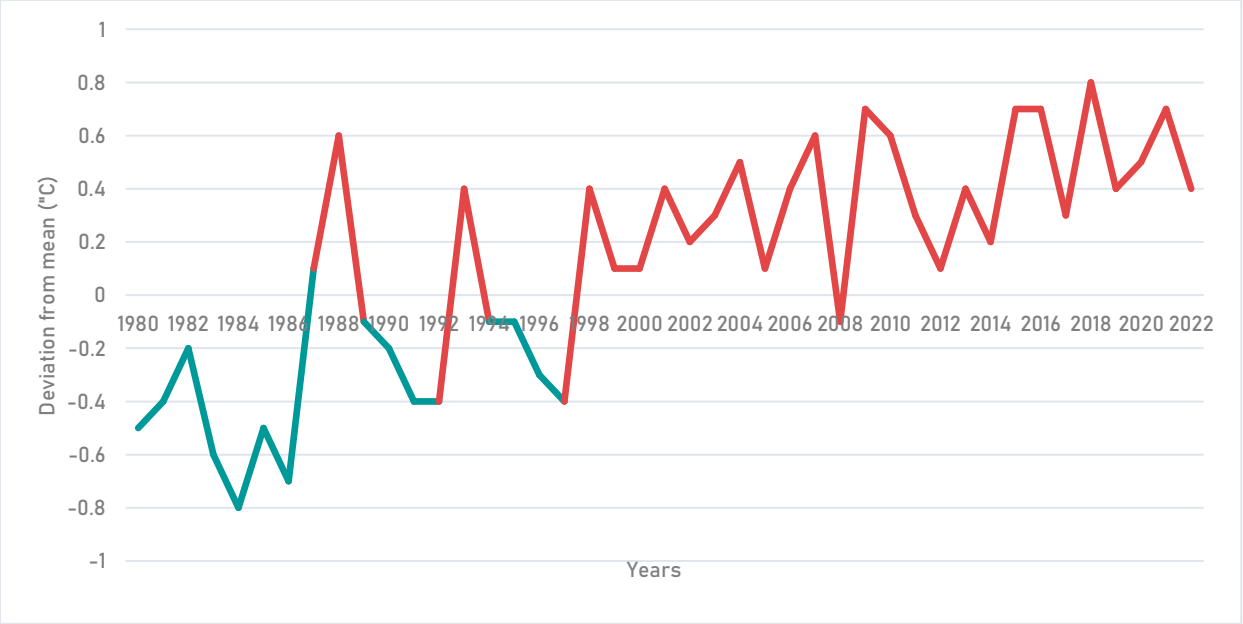


Figure 5. Temperature Anomalies (1980-2022)

- ## Heatwaves – Extreme Heat Episodes

The Karachi City is emerging from the clutches of a deadly heatwave. The peak of warmth occurs from May to July, featuring 30-year daily averages ranging between 30.3°C and 31.4°C. A prolonged low-pressure system over the Arabian Sea suppressed ocean breezes, resulting in temperatures exceeding 113°F (45°C) in June for the 23 million inhabitants. The intense heat caused disruptions in both electricity and water services, rendering life nearly impossible in the region. This combination of high severity and frequent occurrences has had a significant impact on the area.

In 2015, an unprecedented heat wave hit Karachi City with temperatures as high as 49°C, making it the deadliest climatic event in the history of the sub-continent. The deadly heatwave caused over 1,200 deaths and more than 65,000 cases of heat illnesses were reported during the extreme wave.[19]

[19] Commissioner Office, Karachi; CDKN Karachi Heat Wave 2015: A Visual Guide; Commissioner Karachi. 2017. Karachi Heatwave Management Plan: A Guide to Planning and Response. https://ghhin.org/wp-content/uploads/HeatwaveManagementPlan.pdf

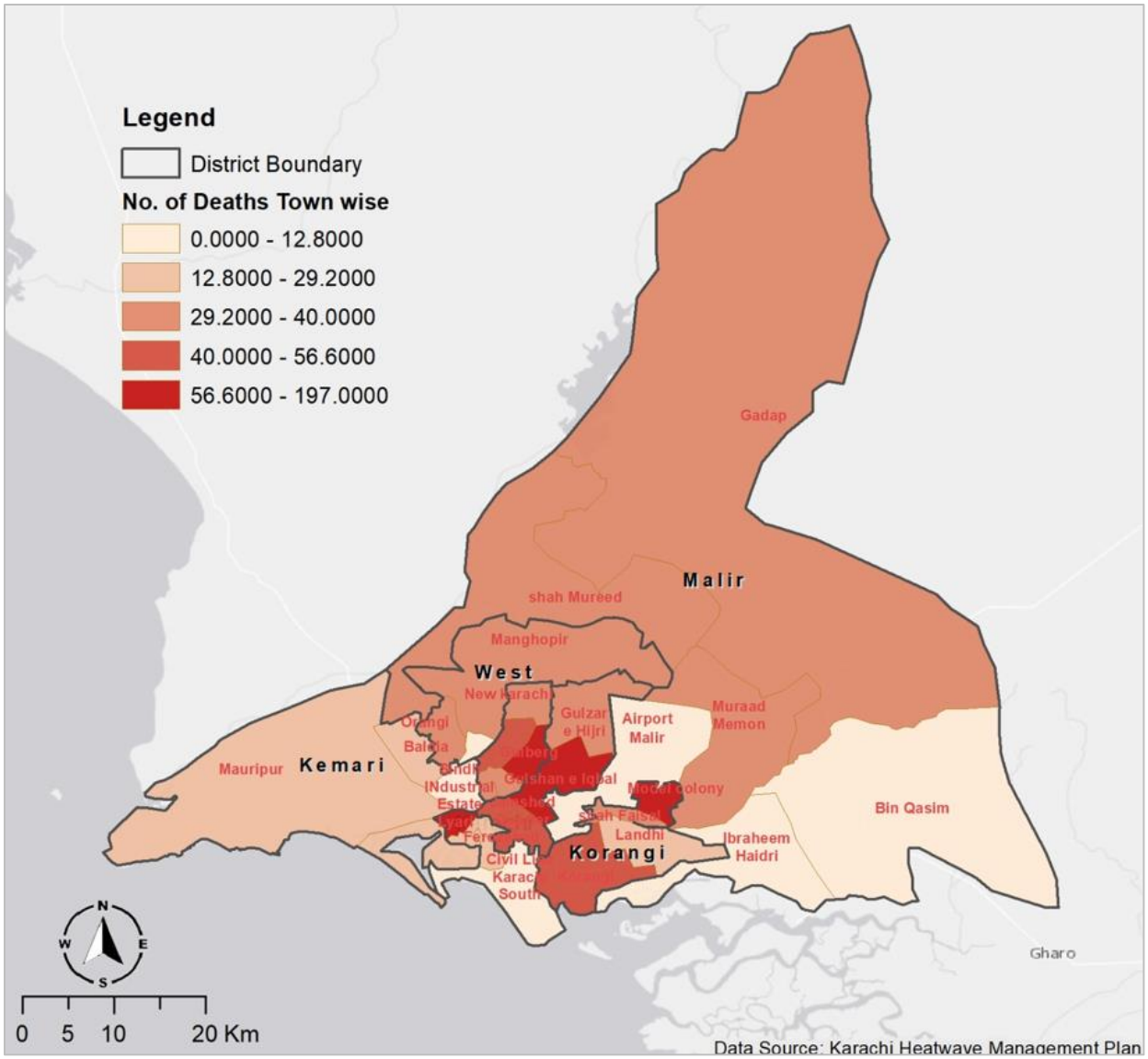


Figure 6. Town-wise Heatwave Vulnerability based on Total Deaths in Karachi City in 2015[20]

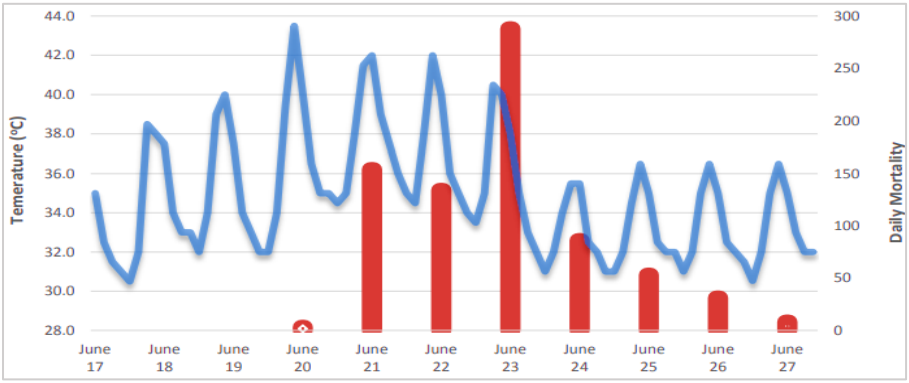


Figure 7. Temperature Increase and Daily Mortality Rate in Karachi City – June 2015

[20] Ibid

Narrowed and Dark Streets of Karachi
Source: The Urban Unit, 2024

In this report, heatwave days are defined as “those with Tmax (maximum daily temperature) equal to or exceeding the 90th percentile of temperature records for at least six consecutive days in a year”.

According to this definition, “between 1980 and 2023, a total of 28 heatwave events were recorded. The years with observed heatwave events include 1980, 1981, 1985, 1986, 1995, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2012, 2015, 2022, and 2023. **The analysis reveals that, from 1980 to 2023, more than half of the observed heatwave events (17 out of 28) occurred in the last 16 years.”**

The heat stress is now becoming a regular feature of the city. In the year 2022, the heatwaves reported in March, which was the highest since 1901. Following heatwaves, the city is also facing outbreaks of Malaria, dengue, and gastro-intestinal diseases (indirect long-term hazard/threat as a consequence of extreme heat episodes).

Box 1: The Culprits of Deadly Heatwave in Karachi - 2015

“The intensity and prolonged nature of the heatwave in June 2015 were unusual for the residents of Karachi, a home to over 20 million people from diverse socio-economic backgrounds. The causes of the heatwave were a combination of environmental, meteorological, and demographic factors. Contrary to popular belief, most of the casualties were not a direct result of high temperatures but were attributed to factors such as prolonged exposure to the sun, inadequate ventilation in housing, lack of natural cover, dehydration due to fasting, month of Ramadan (fasting from dawn to dusk), concrete and paved infrastructure (buildings, roads, etc.), extended power outages, and interruptions in water supplies."

Source: Multi Hazard Vulnerability and Risk Assessment: Informed Disaster Management Plan of Sindh. 2023-2032. PDMA. SUPARCO, World Bank and Government of Sindh

Source: https://www.dawn.com/news/1450467

- ## Urban Heat Island Effect

The rapid urbanization, coupled with global warming, has led to the Urban Heat Island (UHI) effect in Karachi, evident in the built-up area maps for 1990, 2000, 2013, and 2023. The prevalence of UHI poses a significant heat wave hazard, particularly affecting vulnerable populations. With increasing global warming and inadequate coping strategies, UHI is expected to emerge as a major health risk for vulnerable populations in mega-cities like Karachi.

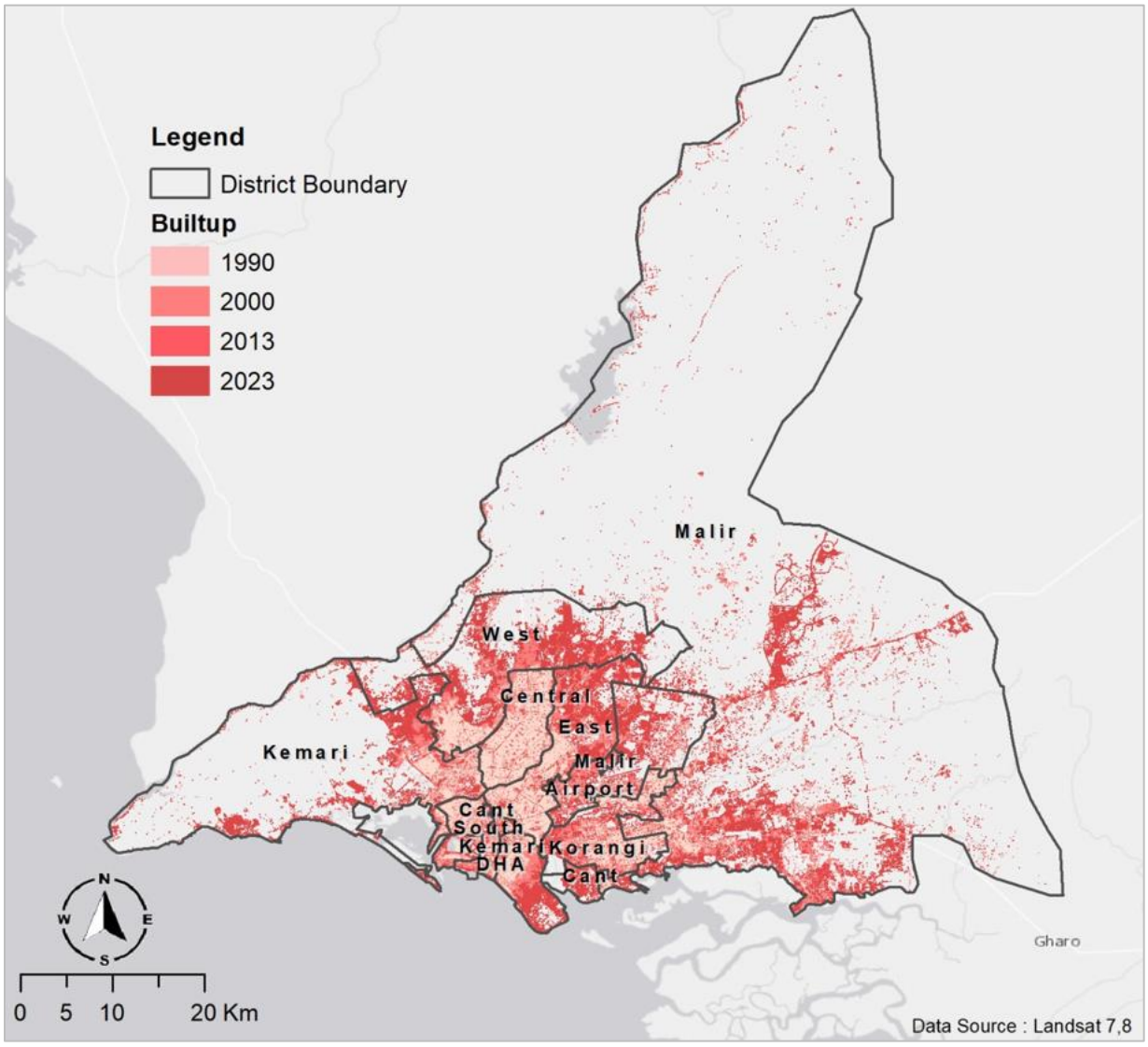


Figure 8. Built-up Area Growth in Karachi[21]

- ## Land Surface Temperature (LST) Analysis

LST Analysis from 2013 to 2023 for Karachi City, indicates a notable escalation in constructed spaces and concrete structures within the Central Business District (CBD), located at the city's core. The built-up area increased 99% from 270 km^2 to 538 km^2. On the other hand, grass and shrubland, Agriculture areas, and mangroves decreased by 45%, 59%, and 23% respectively. This has led to a conspicuous elevation in LST when compared to previous years, given the expansion of built-up areas and disappearing green areas.

[21] Data Source: Landsat 7,8, Prepared by the Urban Unit, 2024

Interestingly, non-built-up regions (in the Malir district area) exhibit higher LST values than the built-up areas in the central part of the city. This peculiarity is attributed to the presence of dry mountains and barren sandy land in these rural/non-built-up areas of Karachi, resulting in higher LST values as shown below;

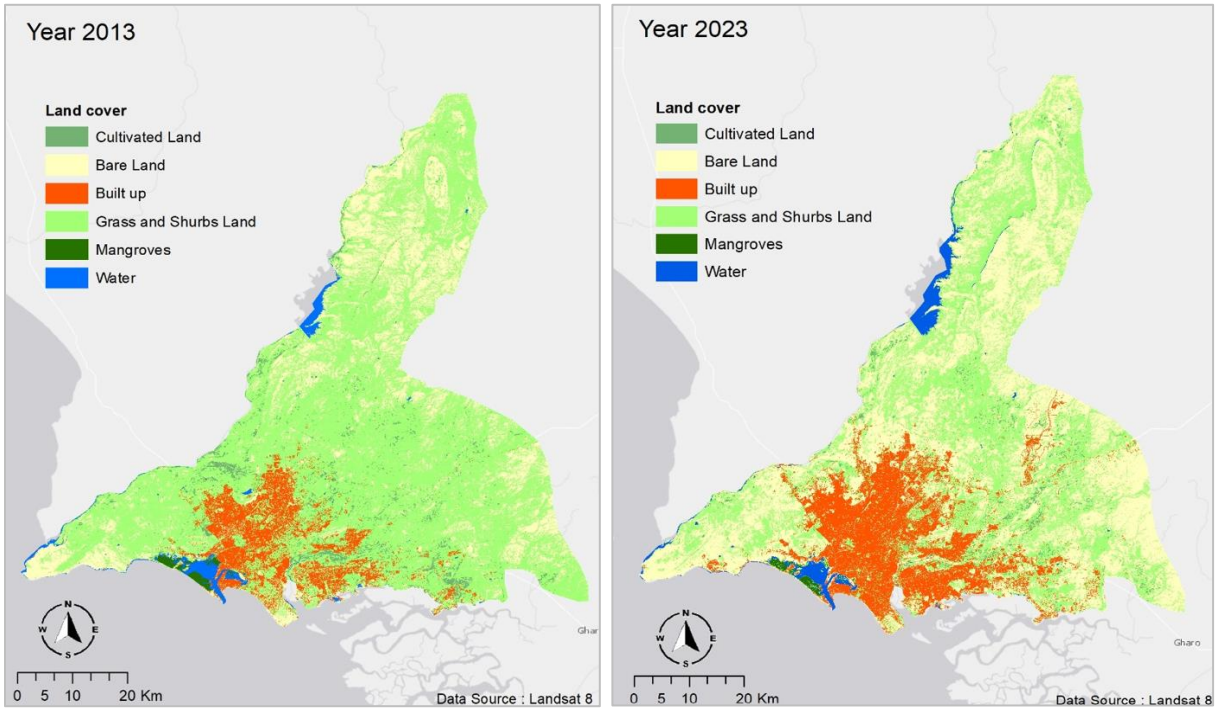


Figure 9. Landcover Change in Karachi (2013 - 2023)

These figures indicate that the growing built-up area in the central part of the city is contributing to the increase in LST. If this trend persists, the rising LST in the central part is likely to surpass that of the surrounding rural areas shortly.

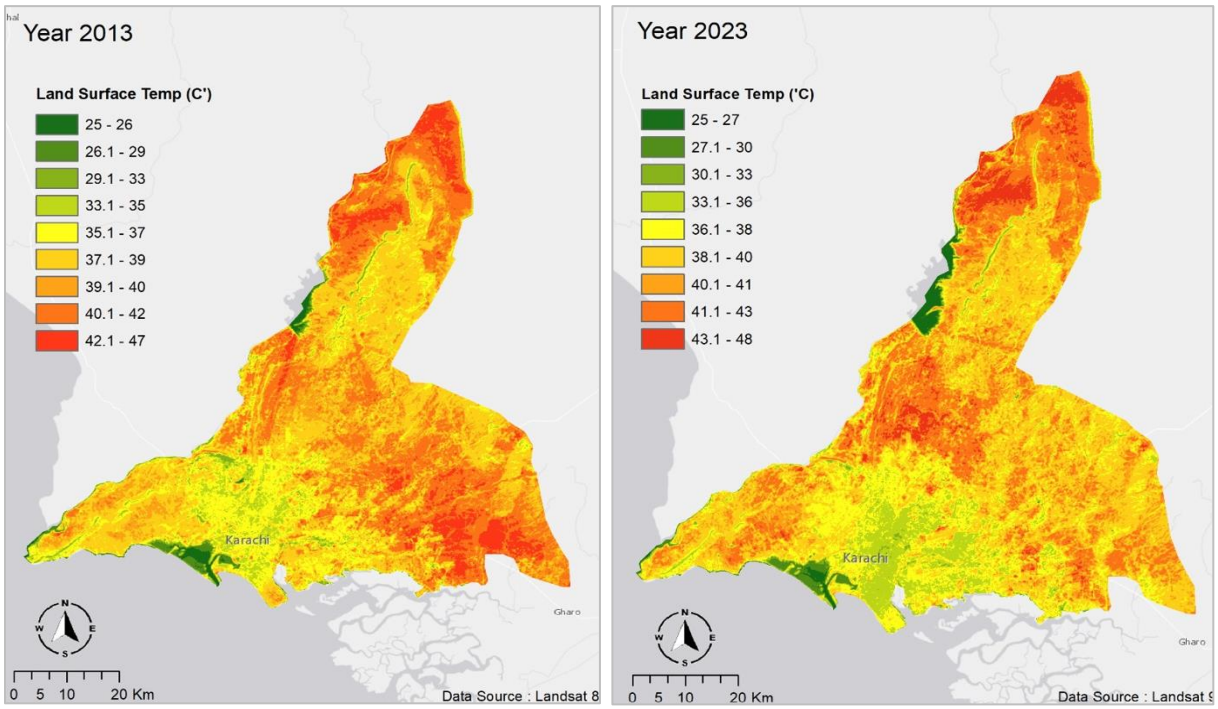


Figure 10. (a) Land Surface Temperature 2013 (b) Land Surface Temperature 2023

Mangroves play an integral role in regulating the local environment and influence daily temperatures. The literature is evident that deforestation and degradation of mangrove forests are some of the prime contributors to increased climatic events.[22] Untreated wastewater (municipal and industrial), unsustainable fishing practices, illegal mangrove harvesting, and cutting of trees for firewood, fodder, etc. are contributing to the loss of these precious ecological resources in the city and along the coastal belt of the region.

Source: Slow but steady destruction of mangrove cover around Karachi - Pakistan – DAWN News, Published February 3, 2019, https://www.dawn.com/news/1461469

LST 2023 correlation with Land use indicates that the surface temperatures in built-up areas are significantly high, particularly in mine, dump, and construction sites which are warmer than neighboring urban fabric by about 3°C. Similarly, residential, industrial, commercial, public & military units with larger built-up footprints display higher surface temperatures (almost 8-10°c higher) compared to the vegetated areas, mangroves, and inland waters.

- ## Heat Exposure and Vulnerability

The assessment[23] revealed that the suburbs and southeast of the Karachi districts are comprised of low-income residents, specifically in Karachi Central, and Karachi South districts. Based on the equal interval method, the area proportion of each grade from low to high was as follows: 23.52%, 71.07%, 3.36%, 1.64%,

[22] Arshad, A., Ashraf, M., Sundari, R. S., Qamar, H., Wajid, M. Hasan, M. 2020. Vulnerability assessment of urban expansion and modeling green spaces to build heat waves risk resiliency in Karachi. International Journal of Disaster Risk Reduction. 46: 101468. ISSN 2212-4209, https://doi.org/10.1016/j.ijdrr.2019.101468

[23] Wu, Xilin, Qingsheng Liu, Chong Huang, and He Li. 2022. "Mapping Heat-Health Vulnerability Based on Remote Sensing: A Case Study in Karachi" *Remote Sensing* 14, no. 7: 1590. https://doi.org/10.3390/rs14071590

and 0.42%. Karachi Central and Karachi South showed high-level sensitivity, while Karachi West, Karachi East, And Malir North showed medium-high sensitivity. Other areas showed medium-low grades and even below. The results indicate that Karachi Central is comparatively more sensitive than other districts and could become a worst-hit area during heat waves, thus needs interventions to mitigate these impacts.

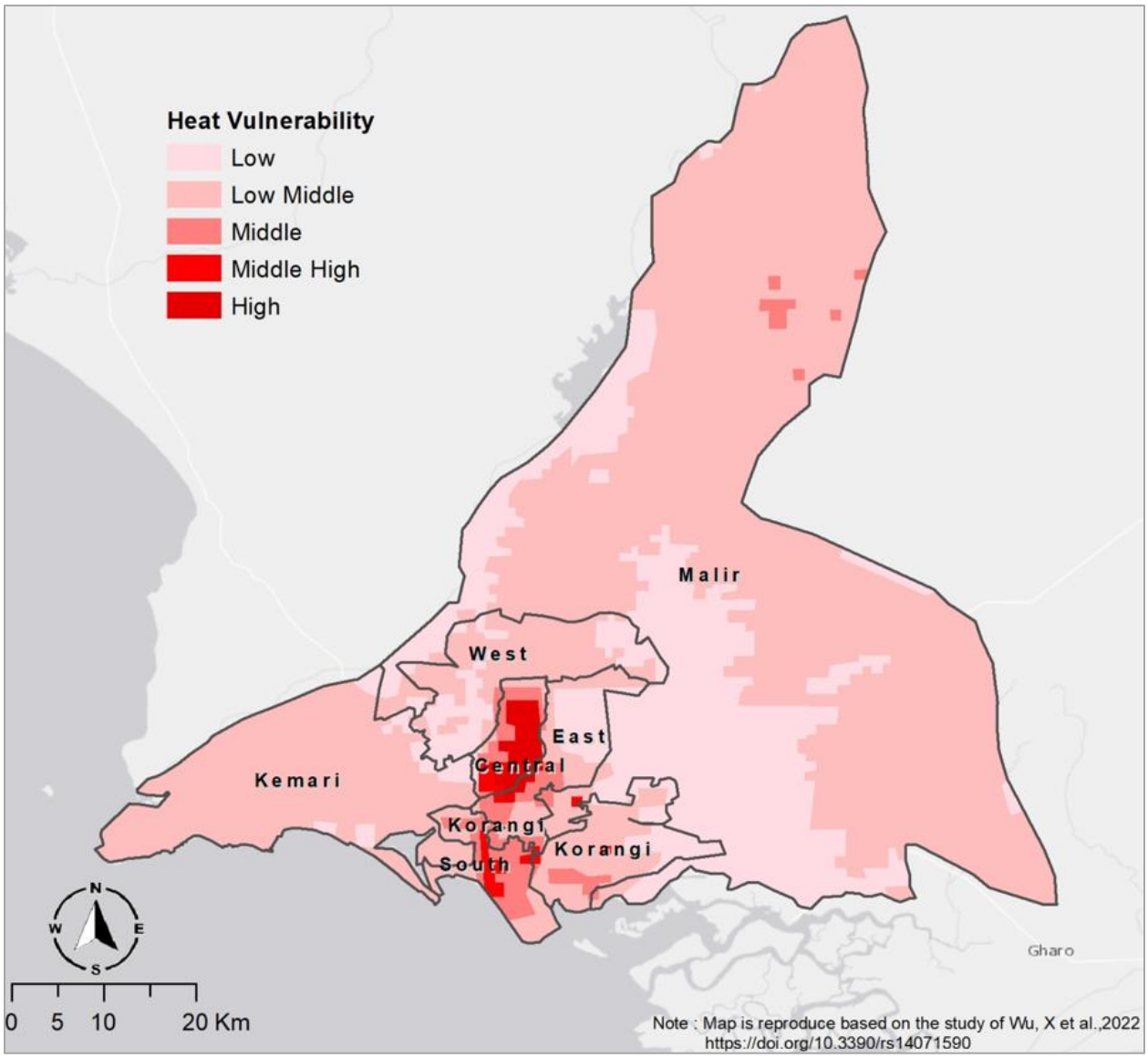


Figure 11.Heat Vulnerability in Karachi

A study on the cities' vulnerability to extreme heat waves identifies Karachi (and Lahore) as the most vulnerable cities to extreme heat events. The study reported that the vulnerability of these cities is higher even under lower emissions pathways, leading to serious health hazards.[24]

- ## Future Heat Risk

According to the National Adaptation Plan 2023 Report, Pakistan is projected to experience an average temperature increase of approximately 1.0°C under both Representative Concentration Pathways (RCP) 4.5 and RCP 8.5 scenarios from 2006 to 2035. Under RCP 4.5, the average temperature increase projected

[24] Matthews, T., Wilby, R.L. and Murphy, C. 2017. Communicating the deadly consequences of global warming for human heat stress. Proceedings of the National Academy of Sciences, 114, 3861–3866. URL: https://www.pnas.org/content/114/15/3861

for the period 2041-2070 is 2.1°C across the country, while under RCP 8.5, the temperature is expected to rise by an average of 3.0°C. Moving ahead towards the far future period (2071-2099), temperatures are predicted to increase by an average of 2.6°C under RCP 4.5, with the highest increase occurring over NP at 2.8°C, followed by MR at 2.7°C.

A notable temperature rise is projected under RCP8.5 with an average increase of 5.1°C throughout Pakistan. Among the sub-regions, Sindh is predicted to have the highest minimum and maximum temperatures, averaging 25.4°C and 37.8 °C, respectively in both baseline/observed, mid, and far future periods. During the 2041-2070, temperature rise of 2.2°C and 3.1°C are projected under RCP 4.5 and 8.5 respectively, while by the end of the century (2071-2099), increases of 2.7°C and 5.2°C are forecasted for RCP 4.5 and 8.5 respectively. National Adaptation Plan exhibits the highest minimum and maximum temperature in observed/baseline as well as future periods with the average of these variables reaching 25.4°C 31 and 37.8°C at the end of the century, respectively, under RCP8.5 for Sindh province. In 2041–2070, the temperature is projected to increase by 2.2°C and 3.1°C while at the end of the century (2071–2099), 2.7°C and 5.2°C increases are projected for RCP 4.5 and 8.5, respectively.[25]

According to the IPCC A6 Atlas projections for Karachi are shown below[26]. It indicates that towards the conclusion of the century, mean temperatures are anticipated to rise by 1.1-1.2oC following SSP1-2.6 and by 4.1-4.6°C under SSP5-8.5.

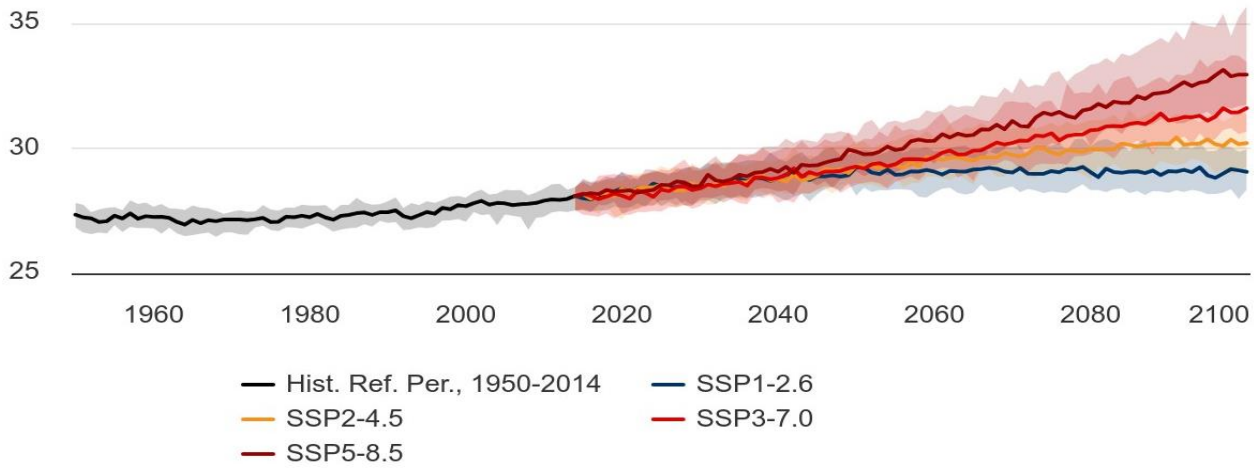


Figure 12. Projected average mean surface air temperature of Sindh, Pakistan (Ref. Period: 1995-2014)[27]

The maximum temperatures, particularly the number of days exceeding 35°C annually, are projected to escalate by 17-19 days with SSP1-2.6 and by over 40 days under SSP5-8.5. According to risk categorization (2080-2099) by the World Bank Climate Change Knowledge Portal, Karachi comes under extreme heat and extreme population class.[28]

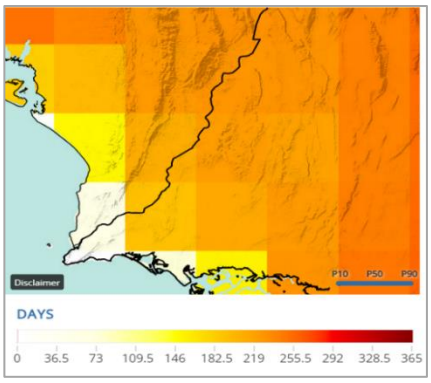


Figure 13. Projected No. of hot days (Tmax>35°C) for 2080-2099 (Annual) for Karachi, Pakistan

[25] National Adaptation Plan. 2023. Ministry of Climate Change and Environmental Coordination. https://unfccc.int/sites/default/files/resource/National_Adaptation_Plan_Pakistan.pdf
[26] https://climateknowledgeportal.worldbank.org/country/pakistan/climate-data-projections
[27] Ibid
[28] Ibid

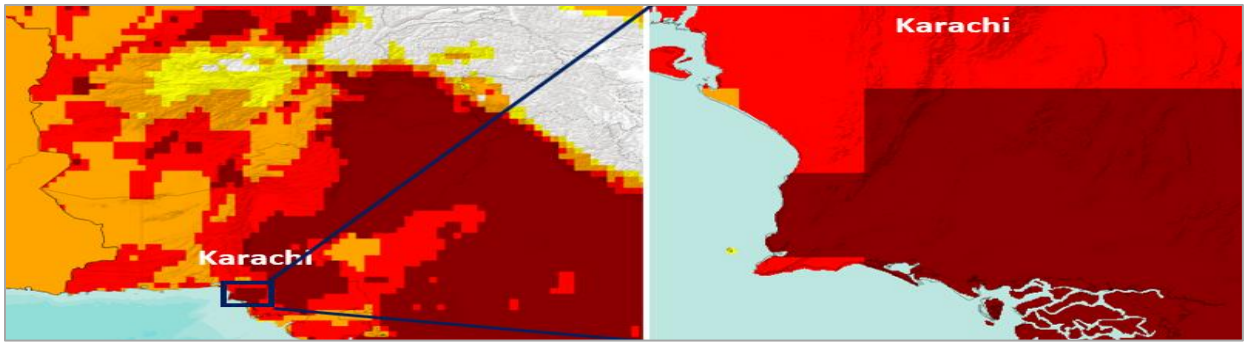


Figure 14. Categorization of Temperature-based Heat + Population Risk for 2080-2099; Karachi

b) Flood Risk

Pakistan primarily receives rainfall from two major weather systems: the Western disturbance which occurs in the winter months and brings light rain, and the monsoon, which produces heavy rainfall during the summer months from June to September. Karachi, generally located beyond the reach of these systems due to its geographical position, occasionally experiences rain from slow-moving weather systems. Additionally, tropical cyclones, typically happening between April-June and September-October, serve as another source of heavy rainfall for Karachi [29]. The precipitation stripes of Sindh Province indicate high variability in the intensity of the rainfall, with a slight increase in the last decades[30], as shown below.

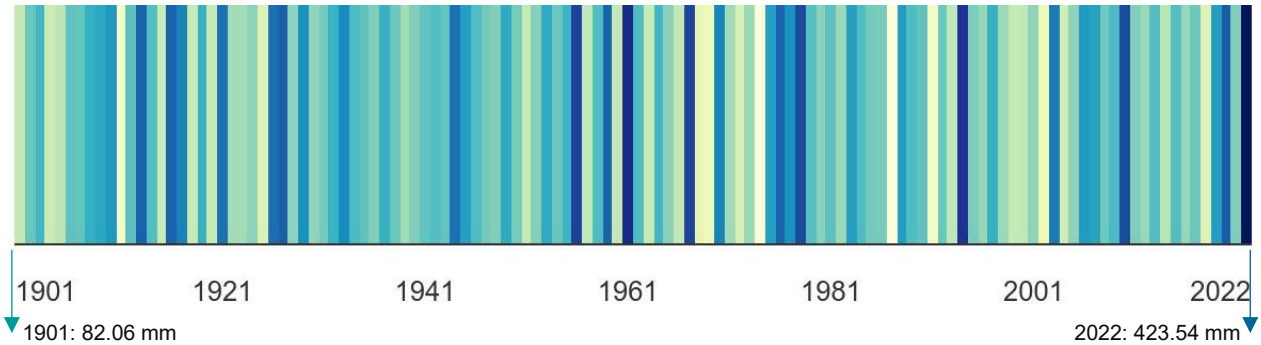


Figure 15. Observed Annual Precipitation (1901 – 2022), Sindh Province

Whereas, annual anomalies of Karachi City[31] indicate that the number of dry years increased significantly from 1993 – 2005 and 2012 - 2018[32], with more intense

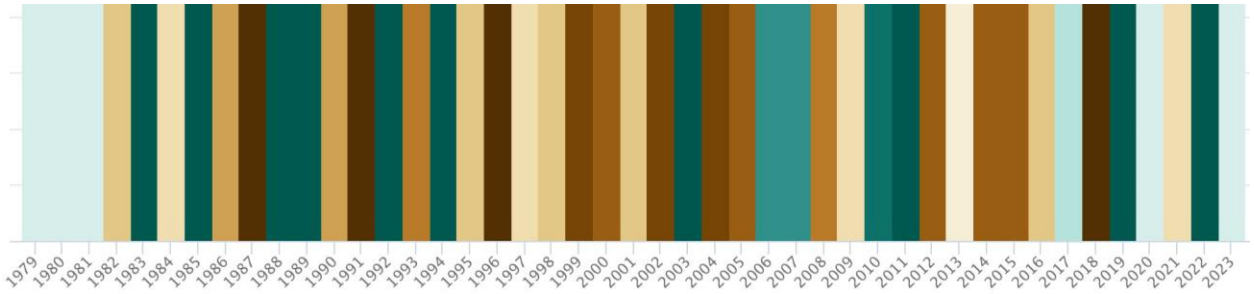


Figure 16. Mean Yearly Precipitation Trend and Anomaly (1979 – 2023), Karachi

[29] Yasmeen, Z. (2011). Inversion layer and its environmental impact over Karachi. *Pakistan Journal of meteorology*, *7*(4), 53-62.
[30] https://climateknowledgeportal.worldbank.org/overview
[31] https://www.meteoblue.com/en/climate-change/karachi_pakistan_1174872
[32] Except years 1994, 2003, and 2017

Reports show that the sea level along the Karachi coast has risen about **10 cm** during the last century. The projections indicates that this sea-level rise will continue, up to 60 cm, if sound mitigation measures are not being taken. This increase will most likely affect the low-lying coastal areas of Karachi in the South toward Keti Bander and the Indus River delta.

Source: Chaudhry, Q. 2017. Climate Change Profile of Pakistan. Asian Development Bank, Philippines. doi.org/10.22617/TCS178761

Karachi is vulnerable to four types of flooding;

Urban Flooding

Caused by heavy rainfall and can result in the overflow of drainage systems.

Karachi: the 2nd largest settlement area exposed to pluvial flooding mainly due to low-quality infrastructure[33]

Pluvial Flooding

Flooding from rivers or streams in low-lying areas - Malir and Lyari rivers are the main culprits

Sewer Flooding

Karachi's storm drains are being used as sewers and get blocked during heavy downpours.

Tidal Flooding

Result in storm surge.

Tidal flat topography and dense population and industrial activities along the coastal areas of Karachi, increased its vulnerability as compared to the other cities of Sindh and Balochistan.

[33] Pakistan ranks 105 out of 140 countries in the quality of its infrastructure (WEG Global Competitiveness Index). World Bank Country Climate and Development Report. 2022.
https://documents1.worldbank.org/curated/en/099950111072234047/pdf/P17671804998b80030ac4f0233dc0b995ba.pdf

Box 2: Climate Sensitivities of Rerhi Goth and Hundreds of other villages of Eastern Coast of Karachi

Karachi's population along coastal belt is bloomed significantly over the last few decades.

The coastline along Rerhi Goath (~1050km) is severely exposed to climate change risks, such as coastal erosion, sea-level rise, tidal flooding, and saltwater intrusion. The villagers fall in low-income quantile, thus the poverty level, inadequate amenities, limited access to basic services are some of the key factors that has increased their vulnerabilities to climate change. Access to safe drinking water is a continuous struggle for the resident of Rerhi Goth. The water tankers bring water for the local people to meet their need from a nearby dam which costs these poor people at Rs. 3,200 - 3500 ($ 9 – 13 @278.12/$) per 5000 gallons. Unfortunately, this water is also not clean, leading to multiple infection diseases. News reported higher level of skin infections, gastrointestinal and kidney diseases.

Improper solid waste management and presence of a number of small-scale factories (mainly textile and chemical ones) has further deteriorated ecological conditions in the area, and badly affecting the environmental and human health of the Rerhi Goth villagers.

Source: The Urban Unit KCAP Team Field Visit 2024 and Arab News. August 2, 2019. https://www.arabnews.com/node/1537811/%7B%7B

- ## Extreme Rainfall Events

Karachi City's rapid urbanization and population increase are making it more susceptible to the effects of flash floods. During the Monsoon season (July to September), the risk of urban flooding is usually higher in the city which causes extreme disruption in routine activities and damage of infrastructure.

The Asian monsoon onset in Karachi is characterized by low atmospheric pressure and high humidity, leading to the increased precipitation. In both 2020, 2022 &2023, These intense precipitation events may arise from the convergence of a diffuse tropical depression and a mesoscale low during the South Asian Summer Monsoon [34] [35]. Such unpredictable precipitation is an inherent aspect of Karachi's climate.

Karachi has 58 storm water drains (nullahs) which are connected with two non-perennial rivers i.e. Malir River and Liari River, that cross the densely populated areas in Karachi before falling out into the Arabian Sea. Malir River basin has a large network of streams but rapid urban sprawl and encroachment, resulted in the stream abatements[36].

Unfortunately, there is widespread encroachment on practically all natural drains and nulahs. Karachi has experienced intense downpour events, which caused colossal damage to lives, and halted transportation and communication for several hours. A record-breaking unprecedented precipitation event of 223 mm of rainfall received in Karachi on August 27th, 2020, in one day, caused catastrophic inundations in the major areas[37].

[34] https://reliefweb.int/report/pakistan/rapid-need-assessment-report-monsoon-rains-karachi-division-24th-27th-august-2020.
[35] https://pakistanweatherportal.com/2022/09/02/causes-of-2022s-super-flood-in-pakistan/.
[36] Rasool, U., Yin, X., Xu, Z., Padulano, R., Rasool, M. A., Siddique, M. A., ... & Senapathi, V. (2023). Rainfall-driven machine learning models for accurate flood inundation mapping in Karachi, Pakistan. Urban Climate, 101573.
[37] https://iips.com.pk/urban-flooding-the-case-of-karachi/ ; https://www.iied.org/urban-flooding-case-karachi

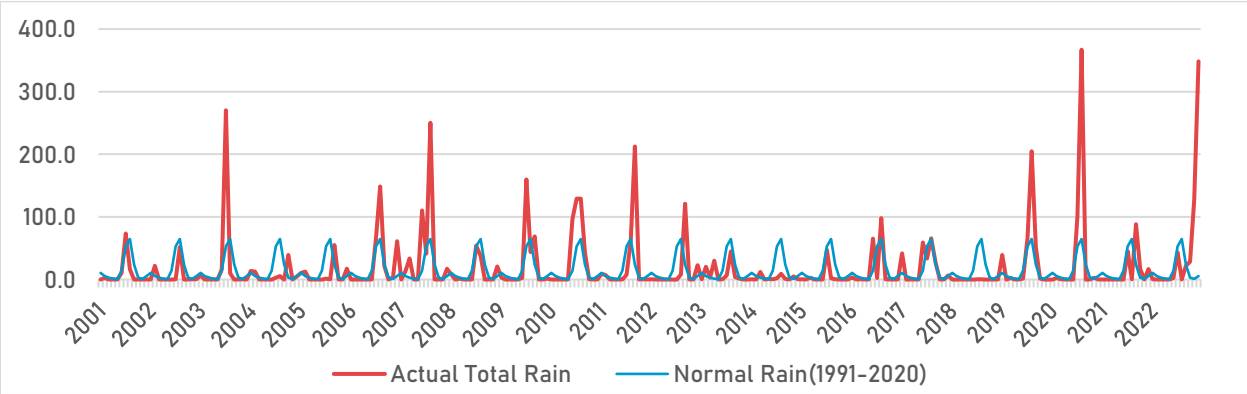


Figure 17. Total Monthly Rain (mm) against Normal Rain - Merra-2 Reanalysis Data

- ## Flooding Risk Analysis

A higher concentration of flooding hotspots is evident in South and Central Karachi based on waterlogging/flooding data gathered from the literature.

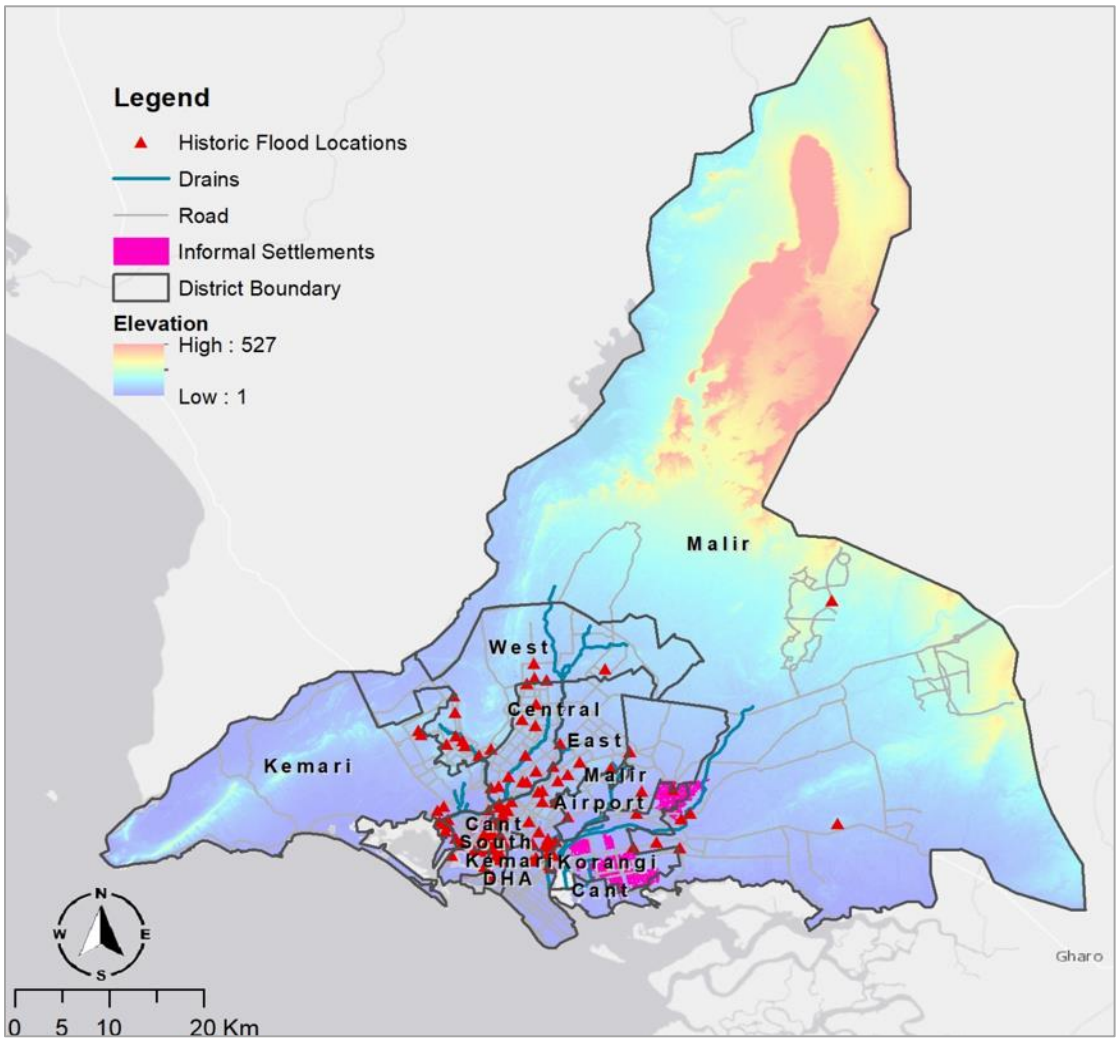


Figure 18. Historic Flood Location Map of Karachi

By overlaying these hotspot locations with information on informal settlements, we discern areas of overlap. This analysis allows us to identify regions where vulnerabilities associated with flooding coincide with the presence of informal settlements. Approximately 6.85% population of Karachi is susceptible to flooding, situated within a 250-meter buffer zone surrounding the flooding hotspots as shown in the following figures. The subsequent examination of these overlapping areas can inform strategies and recommendations for mitigating the impact of flooding.

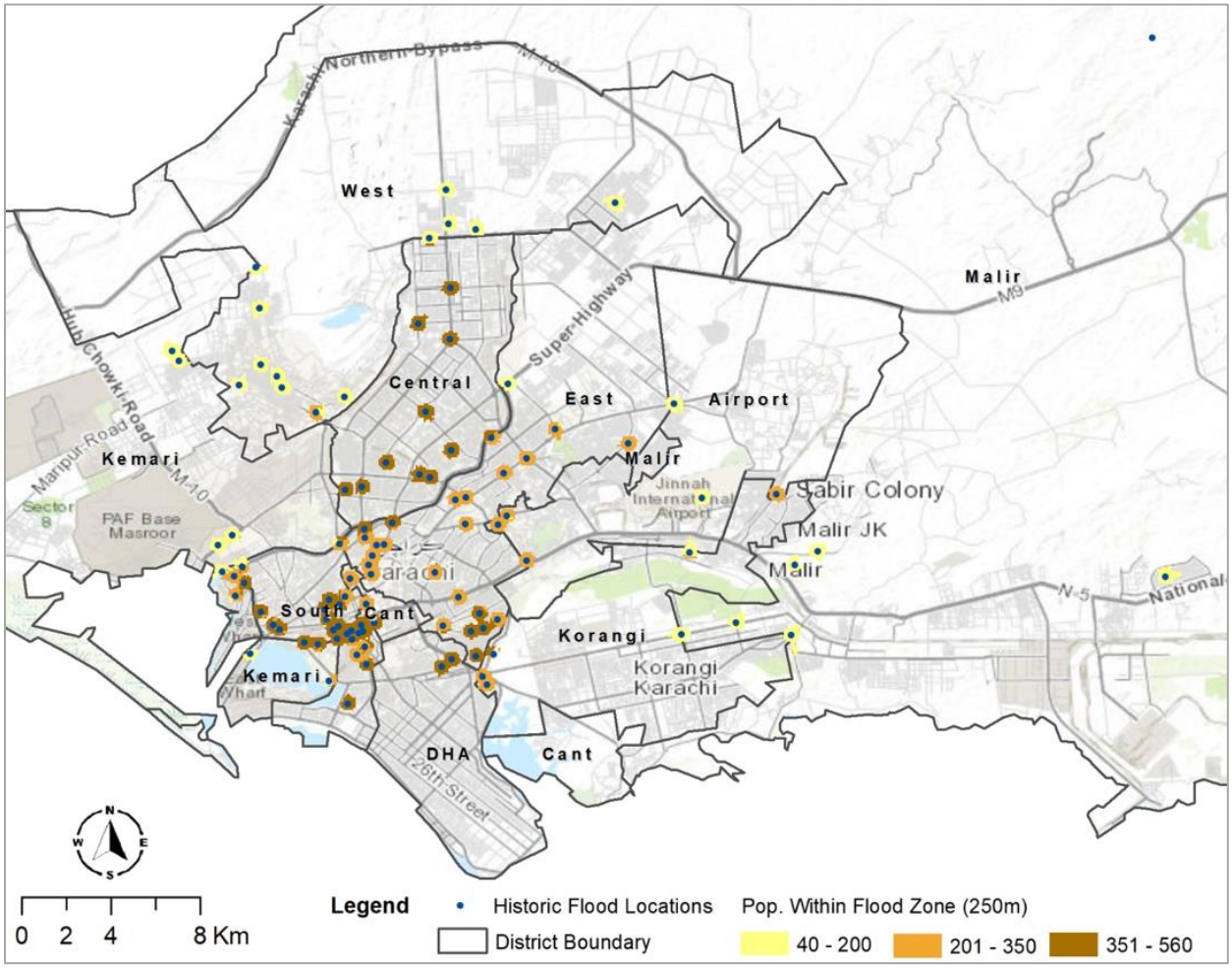


Figure 19. Affected Population Due to Urban Flooding in Karachi[38]

105 hotspots
based on historic floods

6.85% Population
situated within a 25 m buffer zone)

A total of 105 hotspots are marked across the city based on the historic flood locations. Spatial locations of flood hotspots show that the South and East districts are most vulnerable to the risk of flooding with 28 and 23 hotspots respectively (approx. 50%). The areas include; Machar Colony, Kharadar Colony, and I. I Chandigarh Road, Sada Town, Shahra-e-Liaquat, Shahra-e Faisal, Ghareebabad, Azizabad, Shah Faisal town, Malir cantonment, Surjani Town, Gadap Town, North Nazimabad, North Karachi, Jinnah Old Terminal,

[38] Source; The Urban Unit, 2024

Tariq Road, Gulshan-e-Maymar, Defence View, North Karachi interchange flyover, Gulshan-e-Iqbal, FC Area, Saddar, Shahrah-e-Faisal, Guru Mandir, Nazimabad and Gulistan-e-Jauhar.

- ### Urban / Pluvial / Sewer Flooding

Karachi has faced severe monsoon-related issues over the past 40 years due to a compromised drainage system. Pakistan Country Climate and Development Report (2022) highlights Karachi as the 2nd largest settlement area exposed to pluvial flooding (after Lahore). The report links this issue with low-quality infrastructure[39]

The storm water drains (nulahs) in Karachi are two seasonal rivers, the Lyari and the Malir that begin in the foothills of the Kirthar range and run parallel to one another for about 14-20 kilometres. 58 storm water drains (or nulahs) transport water from their catchment areas, and over 600 smaller drains feed into these nulahs.

Source: Geo News. Jul 05 2022. https://www.geo.tv/latest/423936-watch-why-karachi-floods

The 1977 floods, with 267 deaths and extensive displacement, highlighted the impact of encroachments along the Malir River. Old city areas, commercial hubs, and low-lying regions face recurrent flooding. Inadequate stormwater drainage in inner-city localities like Gulshan-e-Iqbal, particularly along University Road, the Societies Union area on Shahrahe-Faisal, and Tipu Sultan Road, experiences severe flooding. Similarly, Katachi abadis in Mehmoodabad and Manzoor Colony, situated along the Malir River, are significantly impacted by excessive flooding and stagnant water.

Based on the assessment done in 2020[40], the flood vulnerability map indicates that a significant portion of District South, along with sections of District West, Korangi, and East, exhibits a very high vulnerability.

[39] World Bank. 2022. Pakistan Climate and Development Report. https://documents1.worldbank.org/curated/en/099950111072234047/pdf/P17671804998b80030ac4f0233dc0b995ba.pdf
[40] Nizamani, J. A. (2020). Assessment of different hazards and vulnerabilities with sparse data in coastal city of Karachi, Pakistan (Master's thesis, Middle East Technical University).

These areas characterized by very high vulnerability typically experience dense population, low elevation, and frequent flooding.

Conversely, most parts of District West and Malir display low or very low vulnerability, attributed to factors such as low population density, infrequent flooding, and higher elevation. The vulnerability in these regions is primarily influenced by social factors like high population density and a history of recurrent flooding (flood frequency).

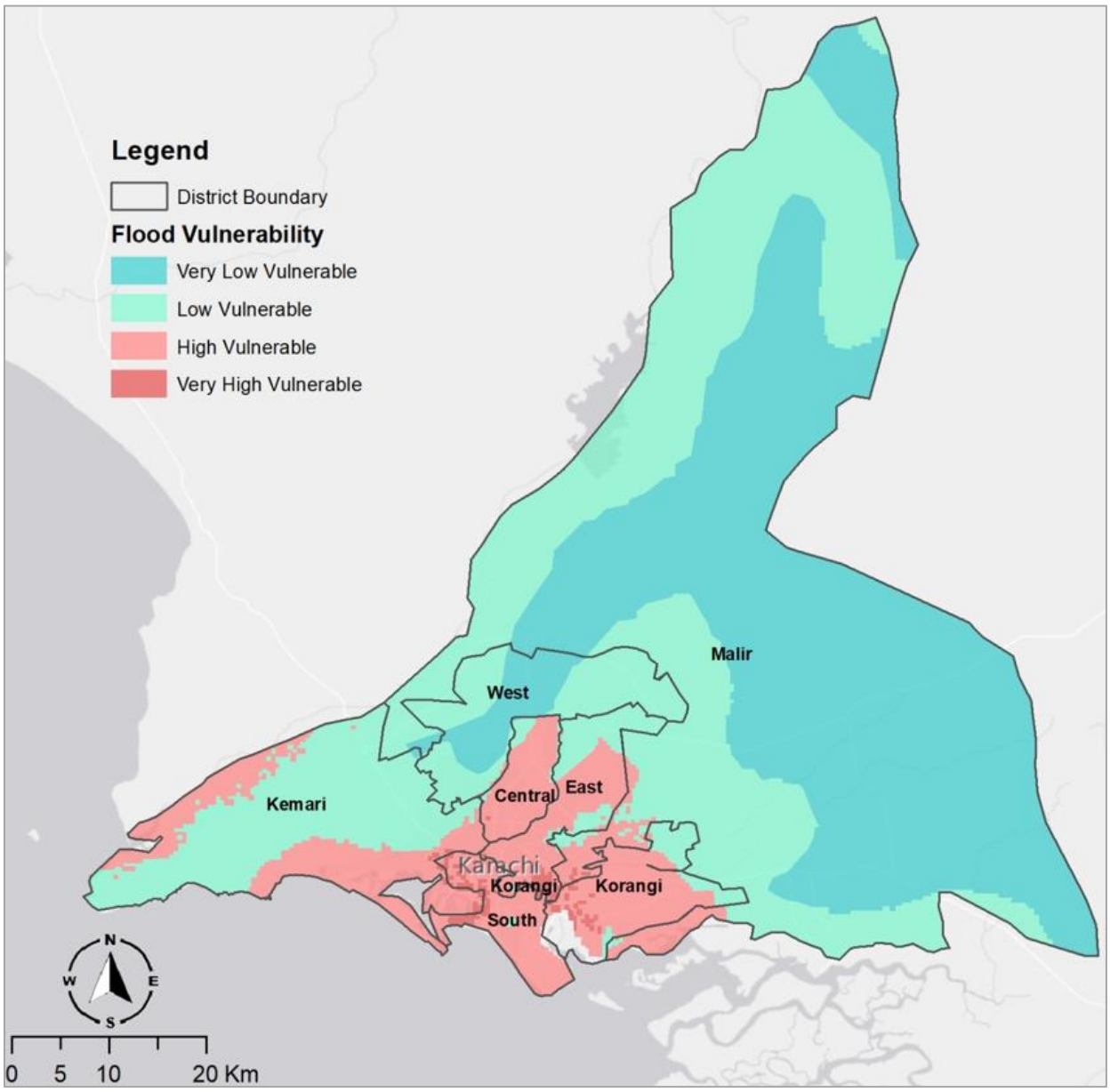


Figure 20. Flood Vulnerability - Karachi[41]

Encroachments on natural drains and nullahs have exacerbated the problem. Solid waste is another area of concern that clogged drains and increased flood risks.

[41] Source: The Urban Unit, 2024

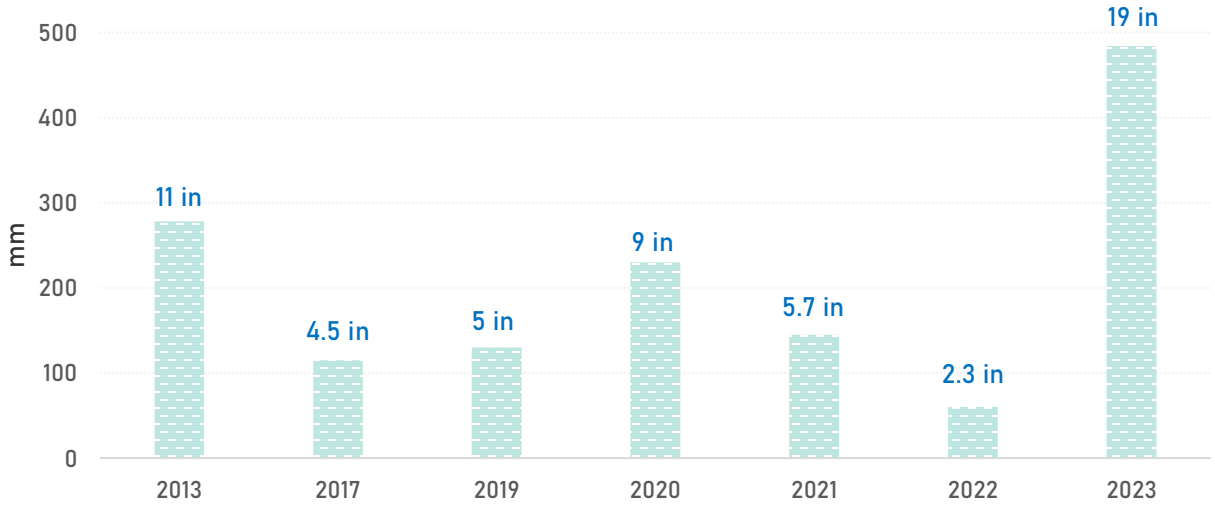
Figure 21. Situation of Solid Waste along the Lyari River[42]

- ## Future Flood Risk

In the recent past, several incidents of heavy rain showers were reported that resulted in urban flooding causing havoc due to severe interruption of socio-economic activities and paralyzing the life of residents of Karachi city. Some of the heavy rainfall events observed in Karachi during the past few years which is multiple times higher than the average annual rainfall are tabulated here;

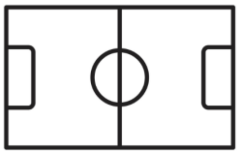
[42] Source: The Urban Unit, 2024

Table 4: Seven Years Maximum Rain Fall Data (in 24 Hrs.) of Karachi City



How much is an inch of rainfall?[43]

Rainfall is typically measured by the depth of water within a rain gauge, giving it merely a one-dimensional aspect. In a three-dimensional world, that means it can be spread across a particular area, and therefore has a volume.

1 Inch = ?		
Typical Roof	An Acre of Land	Football Field
		
1,743 gallons	27,154 gallons	35,897 gallons

The rising trend of extreme rainfall events in Karachi during the past few years that resulted in urban flooding shows that such events will increase multifold in the future. The same has been predicted, where the rainfall is projected to have an increasing high inter-annual variability with a total amount of precipitation increasing annually.

The climate change projects predict that the average largest one-day precipitation anomaly and five-day precipitation anomaly for 2020-2039 is 15mm, with an overall precipitation change of 15 percent in both SSP1-2.6 and SSP5-8.5 scenarios. Similarly, the climate change projects predict that the average largest one-day precipitation anomaly for 2040-2059 ranges from 7mm to 14mm, whereas the average largest five-day precipitation anomaly for 2040-2059 ranges from 45 mm to 63 mm with overall precipitation change ranges from 13 percent in SSP1-2.6 to 20 percent in SSP5-8.5 scenarios[44].

[43] https://weatherworksinc.com/news/midwest-how-much-is-an-inch-of-rain
[44] Climate Change Knowledge Portal, The World Bank Pakistan - Mean Projections Expert | Climate Change Knowledge Portal (worldbank.org)

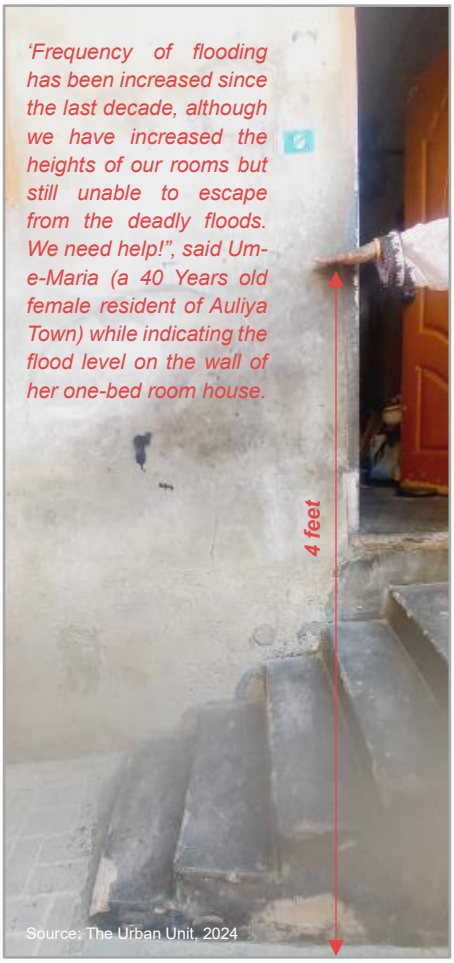
Box 3: The Cry of Lyari People – A Case of Hasan Auliya Town

Lyari River is one the longest river in Karachi city which passes through four out of six districts and four main industrial estates of Karachi. A sizeable population of low-income groups in Karachi city is living on the riverbank of the Lyari River. Some of these settlements are very old (before the partition) and some were settled due to the consequences of historic migrations of Karachi.

Hasan Auliya Town is known to be one of the oldest settlements in Karachi (more than 125 years). Most of the people residing there belong to the Baloch Community and many of them lived there for generations. They are low-income groups, living in congested un-plastered RCC houses with multiple stories. From 1970 onwards, a large number of male populations worked in the Middle East as laborers and workers; whereas in Karachi the male population was involved in labor work (construction sector, workshops, and factories) as drivers; and females as sweepers and maids. The prevailing socio-economic conditions have already made them a vulnerable population, and this vulnerability has been further exacerbated due to extreme climatic events, like heatwaves, flooding, and drought/water stress.

In 2018, the new Lyari Expressway (16km highway) on both sides of the Lyari River relocated some of the settlements and left the areas as open space which took no time to become a huge dumpsite, leading to another health issue and nuisance and a source of methane production!

Source: Tariq, M., Faisal, F., Arif, M., Naz, R., & Amanat, M. (2019b). Exploring sustainable solution for wastewater treatment; a case study of Lyari river (BS Thesis, NED University Karachi); https://newslinemagazine.com/magazine/highway-to-hell/



'Frequency of flooding has been increased since the last decade, although we have increased the heights of our rooms but still unable to escape from the deadly floods. We need help!", said Um-e-Maria (a 40 Years old female resident of Auliya Town) while indicating the flood level on the wall of her one-bed room house.

Source: The Urban Unit, 2024

Source: The Urban Unit, 2024

Source: The Urban Unit, 2024

Najma Bibi (70-year-old female) outlined the continuous health-related issues of her grandchildren.

"Diarrhea, skin infections, and flu become a constant part of our children's lives, and we have no money for healthcare"

"During hot summers, we spend our noon sitting under the Layari Express Overhead Bridge. This is our tree, our room, and playground of our kids!"

Source: The Urban Unit, 2024

"We need a space to play – a playground and clean drinking water"

"Can we get rid of mosquitoes? We can't sleep at night."

Children (Age 3 – 11) of Hassan Auliya Town

Source: The Urban Unit, 2024

c) Drought Risk

Sindh can be geographically categorized into four zones: the eastern desert, the western hilly/mountainous area, the southern coastal region, and the irrigated agriculture area in the middle. Approximately 60% of its land is arid, receiving an average rainfall of 5 inches during the monsoon season and minimal precipitation in December and January. Inhabitants of arid regions rely on scarce rainfall for livestock farming and cultivating millet crops. Insufficient rainfall, coupled with global climatic influences, diminishes water supplies in the Indus River System. Sindh, being situated at the end of the system, often bears the brunt of these effects. Additionally, two-thirds of groundwater is brackish, and 80% of agricultural land is impacted by waterlogging and salinity.[45]

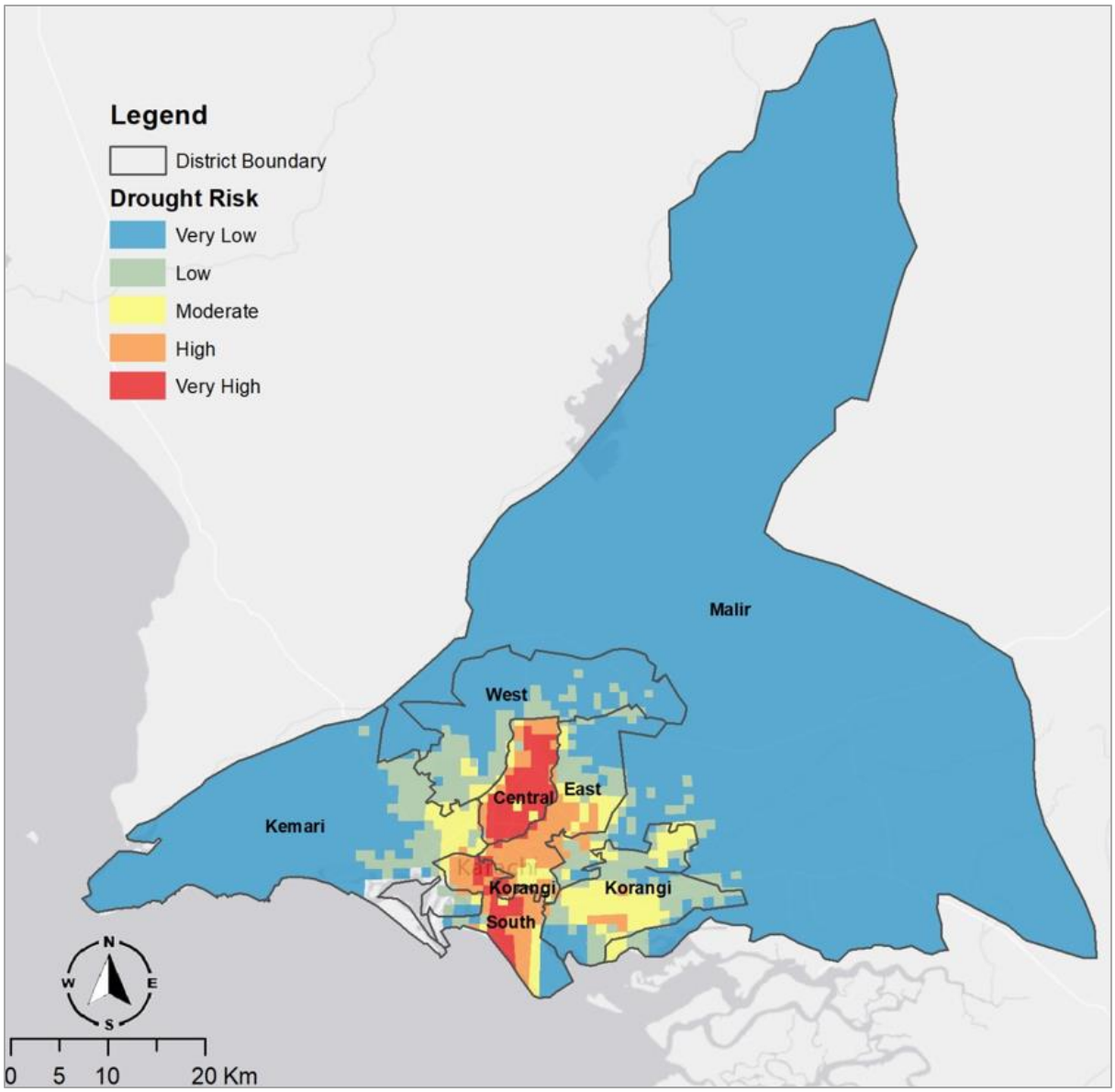


Figure 22. Drought Risk - Karachi[46]

[45] Multi Hazard Vulnerability and Risk Assessment: Informed Disaster Management Plan of Sindh. 2023-2032. PDMA. SUPARCO, World Bank and Government of Sindh

[46] Source: The Urban Unit, 2024

The node area in Karachi is predominantly exposed to hazards, with the southwest section experiencing a higher frequency of drought hazard events compared to the southeast, where occurrences are relatively low. The majority of the south coastal area encounters moderate hazard events, while the northeast part is particularly affected by severe hazard incidents[47].

The map (Figure 22) highlights that densely populated areas are at a heightened risk of drought, with urban zones, especially in the central, southern, and eastern sectors of Karachi, facing severe drought risks. The northeast and northwest regions are less susceptible, while the southwest and south coastal areas experience elevated drought risk due to factors like high population density and low groundwater levels. Priority attention is recommended for the central, southern, and eastern regions of Karachi in national drought mitigation efforts due to their higher vulnerability compared to other areas.

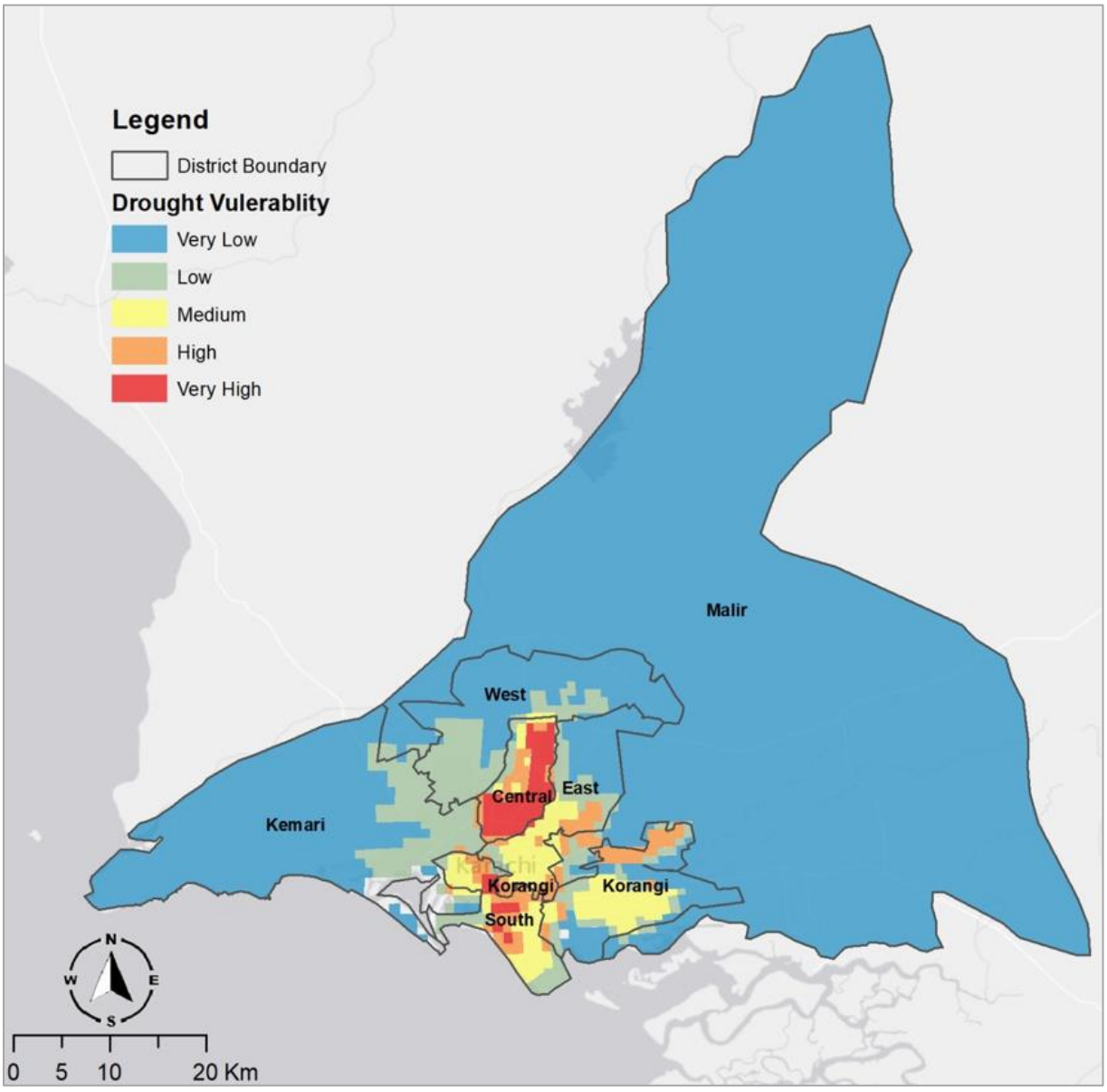


Figure 23. Drought Vulnerability - Karachi[48]

[47] DOI: 10.1080/19475705.2022.2090863

[48] Source: The Urban Unit, 2024

The vulnerability map (Figure 23) highlights that the central, eastern, and southern areas of Karachi are the most susceptible to drought. These regions are characterized by high urban land coverage and elevated poverty rates, contributing to their limited capacity to adapt to drought conditions due to poor socio-economic conditions. On the contrary, the least vulnerable areas are identified in Malir and certain parts of the western region of Karachi. In summary, the southeastern and southwestern zones are particularly prone to drought.

d) Coastal Risks

- ### Sea Surface Temperature

The analysis of Sea Surface Temperature (SST) trends for Karachi, utilized satellite-based historical time-series data spanning the last 19 years, from 2000 to 2019. The findings reveal an insignificant increase in SST, averaging 0.0138 °C per year, indicating a subtle upward trajectory.

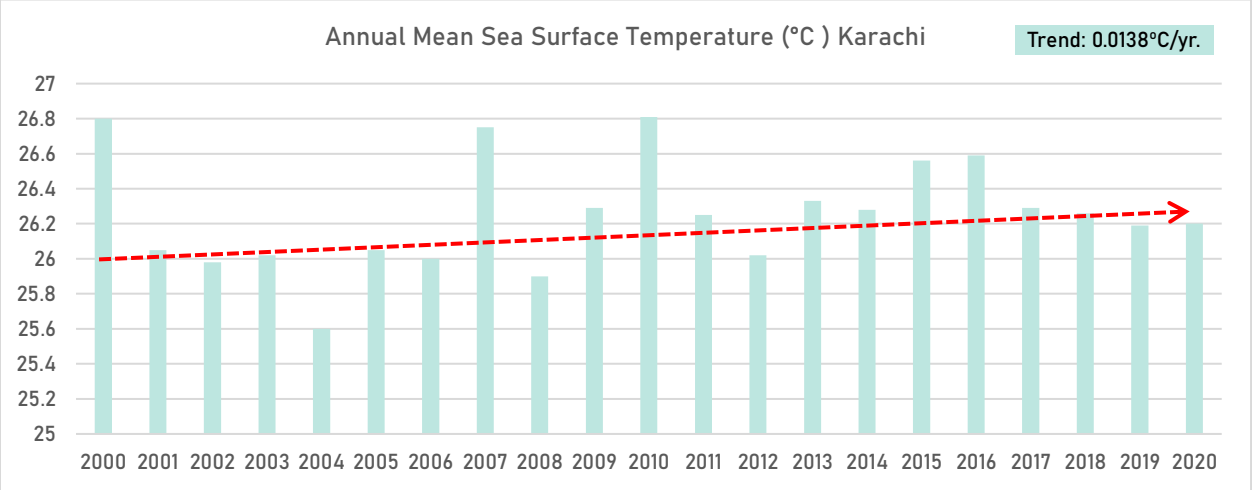


Figure 24. Trend Analysis of Sea Surface Temperature of Karachi

Future SST values are projected using linear regression based on historical data, with a confidence level of 95%. Projections suggest a more pronounced upward trend, with SST expected to rise by 0.35 °C by 2045.

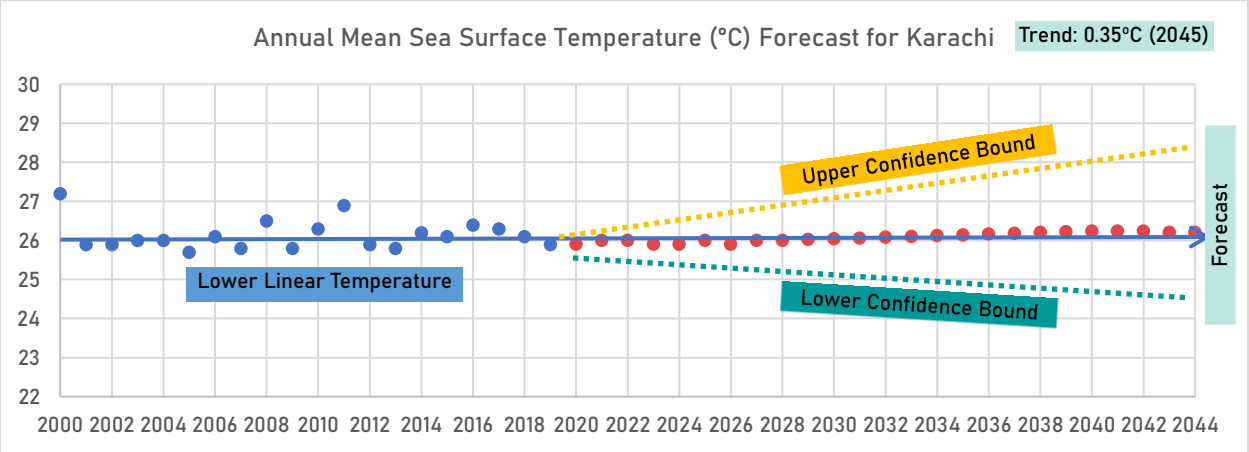


Figure 25. Sea Surface Temperature Forecast of Karachi

This escalation could directly contribute to a rise in sea levels along the coast of Karachi. Notably, global SST is forecasted to surge by 1.9 °C by the century's end, resulting in a projected global sea-level rise of 56 cm, as indicated by a study[49].

- **Storm Surges and Sea Level Rise**

Other than urban flooding, the storm surge and sea level rise are impacting the coastal towns of Karachi City. These damages are not just impacting residential and commercial areas, but also affecting sensitive government installations. Loss of livelihoods to fishing communities and a continuous threat to the biodiversity and the ecosystem should not be ignored either. Recently, in June 2023, heavy rains and storm surges due to the Biparjoy Cyclone badly affected the coastal belts of Sindh, which were already recovering from post-2022 floods.

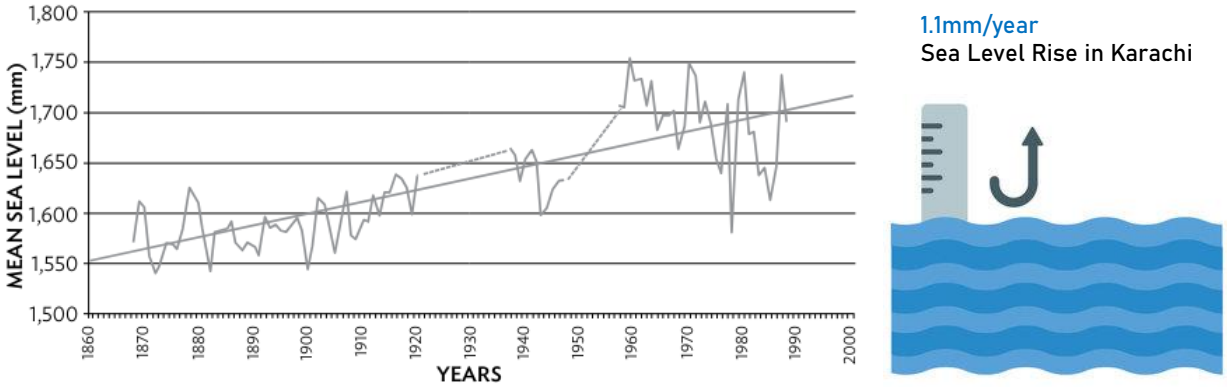


Figure 26. Rise in mean seal (mm) in the last century[50]

Analyzing sea levels concerning extreme events is crucial, particularly due to the scarcity of recent studies conducted on the Karachi coast. There is a notable lack of evidence regarding such investigations. Predicting and understanding extreme sea level events can be achieved by examining their correlation with tidal fluctuations and meteorological extreme events[51].

The low-land plains of Karachi (and Hyderabad) are also vulnerable to the impact of cyclones and storm surges. Most of the settlements in the coastal areas of Karachi fall under the 10-20% probability list. Broad areas of high flood hazard are also located in the western and southern districts of Karachi. As a result, areas with a medium to high risk of flooding are located where watercourses flow through the urbanized areas on lower-lying terrain. The notable areas included Defence, Ibrahim Hyderi, Kehkshan, Gabo Pat, 100 Qurts, Chakra Goth, Rehri, Cattle Colony, and Kemari.

Table 5: Population at Risk Due to Storm Surge[52]

District	Taluka	The estimated population likely to be affected	Household
Clifton Cantonment	Ibrahim Hyderi	24,039	4,007
	Defense	177	30
Karachi South	Kehkeshan	12,377	2,063
Karachi West	Gobo Pat	8,749	1,458
Korangi	100 Quarts	12,578	2,096

[49] Naseer, T., Vignudelli, S., & Zaidi, A. 2020. Study of Sea Surface Temperature (SST) and Sea Level Rise (SLR) Along Karachi Coast using Satellite Data, Pakistan.
[50] Source: M. M. Rabbani et al. 2008. The Impact of Sea Level Rise on Pakistan's Coastal Zones - In a Climate Change Scenario. 2nd International Maritime Conference at Bahria University, Karachi.
[51] Sayol, J. M., & Marcos, M. (2018). Assessing flood risk under sea level rise and extreme sea levels scenarios: application to the ebro delta (Spain). *Journal of Geophysical Research: Oceans*, *123*(2), 794-811.
[52] Ibid

District	Taluka	The estimated population likely to be affected	Household
	Chakra Goth	2,034	339
	Rehri	2,708	451
Korangi Creek Cantonment	Ibrahim Hyderi	86,831	14,472
Malir	100 Qurts	1,542	257
	Cattle Colony	6,758	1,126
	Chakra Goth	138	23
	Ibrahim Hyderi	43,303	7,217
	Rehri	56,241	9,374
Manora Cantonment	Keamari	5,874	979
Total		**263,349**	**43,892**

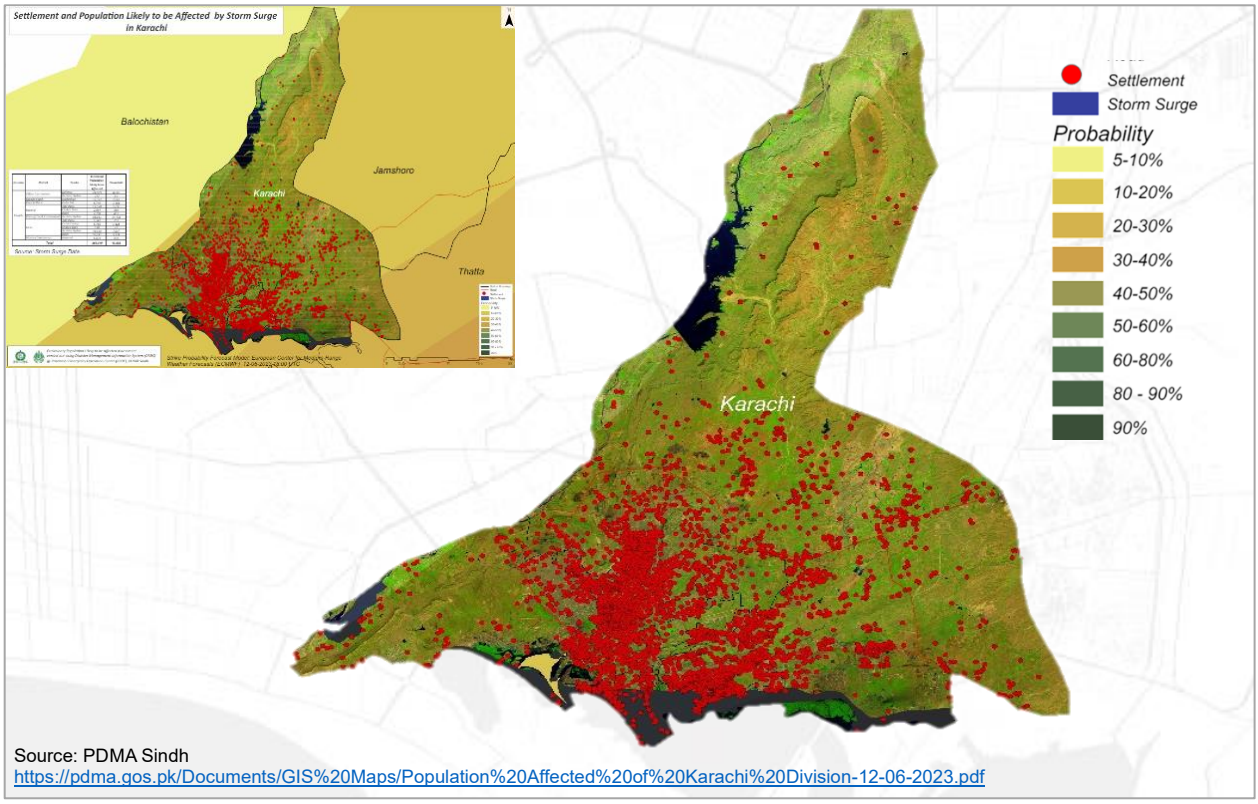


Figure 27. Settlement and population likely to be affected by Storm Surge in Karachi [53]

- ## Mangroves Assessment

The coastline of Sindh is approximately 350 km long, further divided into two geographical pockets: the Indus Delta and the Sandspit. The Sandspit, with central coordinates of 24.8399N Latitude and 66.9478E Longitude and a geographical area of 68 km^2, is located southwest of Karachi.

Using Landsat-5 TM, Landsat-7 ETM+, and Landsat-8 OLI satellite datasets, the Areas of mangroves for each year were calculated and assessments were made for the years 2010, 2013, 2015, 2020, and 2023 satellite datasets.

[53] https://pdma.gos.pk/Documents/GIS%20Maps/Population%20Affected%20of%20Karachi%20Division-12-06-2023.pdf

Mangroves cover assessment based on Landsat 30 m spatial resolution at five different intervals (2010-2023), derived from Maximum Likelihood Classification, and Global Mangroves Watch (GMW), revealed that the area under mangroves in 2023 decreased to 11.74 km^2, as exhibited below.

Table 6: Mangroves Area Estimation (2010, 2013, 2015, 2020 and 2023)

Sr. No	Year	Mangroves Area
1	2010	12.51 sq. km.
2	2013	12.65 sq. km. ↑
3	2015	13.27 sq. km. ↑
4	2020	13.16 sq. km. ↓
5	2023	11.74 sq. km. ↓

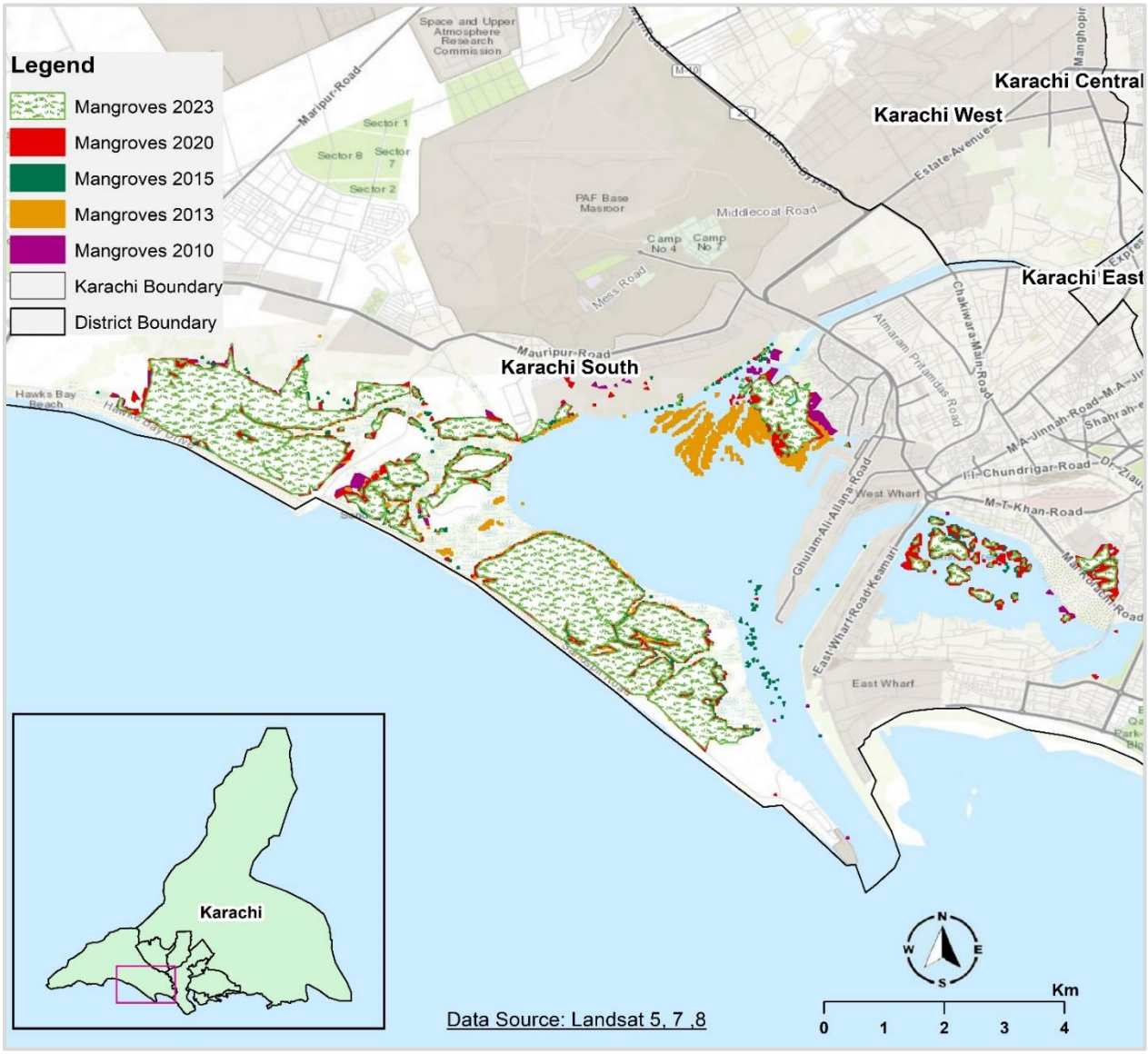


Figure 28. Mangrove Change Detection Map (2010 – 2023)[54]

[54] Data Source: Landsat 5, 7, 8, prepared by the Urban Unit, 2024

WWF reported land allotments as the main reason behind the reduction of mangroves around the city.[55] The field assessment and consultations revealed that illegal fishing nets beneath mangrove roots are not just threatening mangroves but also damaging marine life especially baby prawns.

- ## Coastal Dynamics (Shoreline Change)

The coastline of Karachi spans approximately 100 kilometers from the Gharo Creek in the east to the River Hub in the west. A historical study utilizing satellite imagery from 1976 to 2018, combined with historical topographic maps and medium to high-resolution imagery (30m and 3m), was conducted to monitor shoreline changes along the Karachi coast [56].

The shoreline of Karachi city was divided into two zones for analysis: the eastern zone covering 25 kilometers and the western zone covering 29 kilometers as illustrated in the figure.

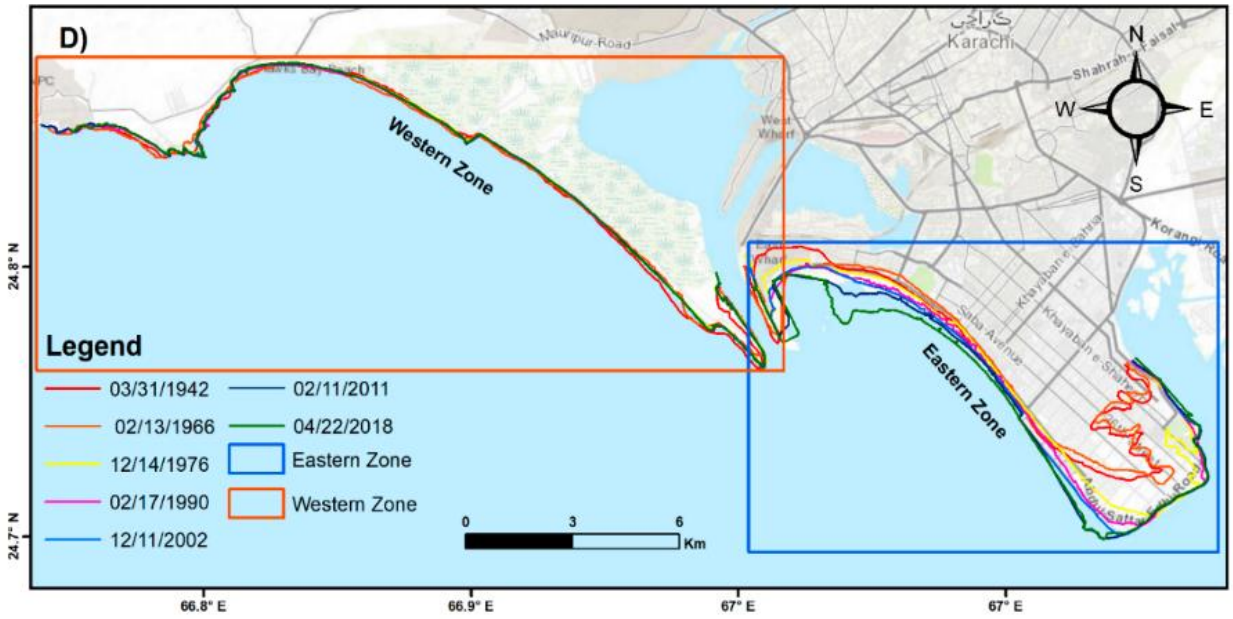


Figure 29. Historical shoreline positions of the Karachi coast in the eastern and western zones[57]

The results of the study revealed that 95% of transects within the eastern zone experienced accretion, with an average rate of 14 meters per year, indicating rapid shoreline advancement primarily due to urban development. Conversely, 74% of transects in the western zone exhibited erosion, with an average rate of -1.15 meters per year, signaling the degradation of rocky and sandy beaches caused by marine processes. In the eastern zone, 94% (23.5 km) of the shoreline was identified as highly vulnerable, contrasting with the more stable conditions observed in the western zone, attributed to minimal human activity.

It is advisable to implement effective coastal protection measures and adopt comprehensive coastal management strategies in ocean-facing coastal regions to mitigate the erosive impact of the ocean. Additionally, there is a suggestion to revise the master plan for Karachi's coastal areas, ensuring it aligns with principles of environmental conservation and sustainable coastal development, placing greater emphasis on coastal safety.

[55] https://www.dawn.com/news/1780530
[56] Nazeer, M., Waqas, M., Shahzad, M., Zia, I., & Wu, W. (2020). Coastline vulnerability assessment through landsat and cubesats in a coastal mega city. Remote Sens. 12, 749.
[57] Ibid

- ## Future Coastal Risk

An online-based Coastal Risk Screening Tool displays an interactive map illustrating areas threatened by sea level rise and coastal flooding. It combines the most advanced global model of coastal elevations with the latest projections for future flood levels [58]. The tool was utilized to forecast the land projected to be below the annual flood level in 2050. **The map reveals that a significant portion of Karachi's coastal areas, including Hawksbay, Manora Island, DHA, Korangi Industrial Area, Ibrahim Hyderi, and Korangi Fish Harbour Authority, will be submerged.**

Several studies revealed that there is a high probability that the sea surface temperature and sea level in Pakistan will increase. Additionally, there is a high chance of coastal floods, coastal erosion, and marine heat waves in Pakistan in the future. Furthermore, according to the IPCC AR6 regional factsheet for Asia, the relative sea level in the region has risen at a pace surpassing the global average, resulting in coastal area erosion and shoreline recession.

Figure 30. Land projected to be below annual flood level in 2050[59]

An increase of 1.1 millimeters per year in sea level has been documented along the coast of Karachi [60]. Another study revealed that the Karachi coastline underwent erosion at a rate of approximately 2.43 ± 0.45 meters per year[61]. Moreover, a comparable trend analysis was conducted for Sea Surface Temperature (SST) using historical data, revealing an increase of 0.0138°C per year. Utilizing these historical records, the SST for the subsequent 25 years was forecasted. The projected SST indicates a higher value of 0.35°C by the year 2045. Due to a lack of resources, capacity, and infrastructure, it is impossible to establish SLR as a current risk for the city. The global projections serve as a cautionary message to the region, emphasizing the importance of implementing coastal adaptation strategies and preparing for forthcoming risks.

[58] https://coastal.climatecentral.org/
[59] Ibid
[60] Naseer, T., Vignudelli, S., & Zaidi, A. (2020). Study of Sea Surface Temperature (SST) and Sea Level Rise (SLR) along Karachi Coast using Satellite Data, Pakistan.
[61] Kanwal, S., Ding, X., Sajjad, M., & Abbas, S. (2019). Three decades of coastal changes in Sindh, Pakistan (1989–2018): A geospatial assessment. *Remote Sensing*, *12*(1): 8.

The Untold Story of Mal Island

Mal Island is the 14th creek from Ibrahim Hyderi. The name "Mal" derives from the local tradition of fighting, which was a beloved sport among the island's inhabitants. All of the residents of Mal Island migrated completely in 1960. They dispersed to various locations such as Thatta, Badin, Sujjawal, Ibrahim Hyderi, and others, choosing destinations based on their preferred occupations. For instance, those associated with fishing settled in Ibrahim Hyderi, where they continued in the same occupation. Some have diversified into shipbuilding and engine repair, still linked to the fishing industry. Others, primarily involved in grazing and cultivation, relocated to areas like Thatta and Sujjawal.

The rising sea levels were a common issue that was not even considered an issue until it resulted in multiple challenges. As an adaptive measure, the Residents used to construct clay boundaries called "Gaar," 4-6 feet high around their homes, or preferred higher ground for their homes. The Mal islanders primarily engaged in fishing, livestock grazing, and cultivation, with fishing being the dominant occupation; and transactions or the economy on the Mal Island remained rooted in a barter system; in which everything was traded through fish, whether it is milk, pulses or herbs; they trade their commodities for living.

However, the intrusion of ocean water eventually led to land salinization and soil erosion, severely affecting cultivators and grazers. Although fishermen initially prospered, the decline in freshwater flow from the river Indus disrupted the livelihoods of all the people on Mal Island. Seawater intrusion hindered the ability of grazers and cultivators to yield as per the island's requirements. Meanwhile, fishermen, though having fish, were unable to barter for basic commodities due to the collapse of the barter system and lacked the means to transport their catch to the nearest city. Consequently, an imbalance emerged within Mal Island society. The barter system collapsed, and eventually, all inhabitants had to migrate as sustaining social life became untenable.

Today, on Mal Island, out of all the grazing animals that once inhabited the island, only camels can survive. They rely on water supplied by any passing boat from the creek once a week, as camels can go without water for 7-10 days.

The 'Mal Mahala' where the Mal Islanders (Climate Migrants) are currently living, is a low-lying low-income area where the residents of Mal Island are living in miserable conditions. Conclusively, the vulnerabilities of already challenged communities of Mal Island didn't reduce and they are still struggling with the consequences in the form of aggravated socio-economic and climate vulnerabilities.

Source: The Urban Unit, 2024
Picture of the painting of Mal Island mounted in Fisherfolk Forum Office

Source: The Urban Unit, 2024

Figure 31. Sea Level Rise warning sign mounted in Ibrahim Hyderi near Mal Islanders' Neighbourhood

Source: The Urban Unit, 2024

Figure 32. Emergency Response Awareness Messages Painted on Mal Islander's Neighbourhood

e) Air Pollution

Most environmental issues confronting Karachi are attributed to its dense urban formation and increasing population. It has been estimated that the urban footprint of Karachi has increased by 29% since 1998. The high incidence of air, land, and water pollution resulting from poor waste management, vehicular pollution, and industrial wastes, cause a high rate of diseases in the residents of Karachi. It is estimated that the environmental health costs in Karachi range between 30-40 million annually, which is about 10% of the provincial GDP[62].

Karachi Metropolitan Corporation (KMC) recognizes the significance and opportunity for enhancing climate action through improved air quality. Any action taken in the context of reducing GHG emissions will improve the socio-economic situation of the residents while also improving the local climate and air quality. While the air pollution control strategies have the potential to reduce human exposure to contaminants by improving air quality, they can also influence the implementation of SDG-13: Climate Action by reducing GHG emissions and saving emission control costs in Karachi which make up 0.32% of the national GDP63.

The current section is a baseline assessment of historical trends and concentration of air quality in Karachi. It mainly focuses on the criteria of air pollutants, their sources, and potential impacts in the context of climate vulnerability and adaptation. Sindh Environment Protection Agency published its quality standards in 2016, as tabulated below;

Table 7: Ambient Air Quality Standards – Sindh EPA SEQS 201

Pollutants	Sindh Environmental Quality Standards 2016	
	Daily	Annual
Sulfur Dioxide (SO2)	120 µg/m^3	80 µg/m^3
Nitrogen Dioxide (NO2)	80 µg/m^3	40 µg/m^3
Ozone (O3) – 1 Hour	130 µg/m^3	
Suspended Particulate Matter (24-Hour)	500 µg/m^3	120 µg/m^3
Respirable Particulate Matter PM10 (24-Hour)	150 µg/m^3	40 µg/m^3
Respirable Particulate Matter PM2.5 (24-Hour)	75 µg/m^3	-
Carbon Monoxide	5 mg/m^3 (8 hrs.)	10 mg/m^3 (1 hr.)

- ### Concentration of Particulate Matter:

A combination of both liquid and solid particulates suspended in air from the particulate matter. They affect the quality of air across the world because of increasing urbanization and have serious implications for the economy, local climate, and health[64]. Particulate Matter Pollution is one of the leading causes of premature adult deaths in Pakistan. World Health Organization estimates 30 and 25 deaths per 100,000 people attributed to outdoor and indoor pollution, respectively.

The World Air Quality Report concludes that residents in Karachi city have lost 2.7 years from their average life expectancy because of high exposure to poor air quality[65]. The research study that formed the basis of the development of the Air Quality Life Index at the University of Chicago reported that sustained exposure to an additional 10µg/m3 of PM10 and PM2.5 concentrations lessens average life expectancy by 0.64 and 0.98 years, respectively[66]. Considering the linkage between PM exposure and adverse health impacts, the Pakistan Environmental Protection Agency (PAK-EPA) published stricter limits for the 24-hour concentration

[62] World Bank. (2015). Sustainability and Poverty Alleviation: Confronting Environmental Threats in Sindh, Pakistan. Directions in Development. Washington, DC: World Bank.
[63] Mir, K. A., Purohit, P., Cail, S., & Kim, S. (2022). Co-benefits of air pollution control and climate change mitigation strategies in Pakistan. Environmental Science & Policy, 133, 31-43.
[64] Kaufman, Y. J., Tanré, D., & Boucher, O. (2002). A satellite view of aerosols in the climate system. Nature, 419(6903), 215-223.
[65] University of Chicago. (2023). Pakistan Fact Sheet. Air Quality Life Index.
[66] Ebenstein, A., Fan, M., Greenstone, M., He, G., & Zhou, M. (2017). New evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River Policy. Proceedings of the National Academy of Sciences, 114(39), 10384-10389.

of PM2.5 which is 35µg/m3. However, Sindh Environmental Quality Standards specify the 24-hour PM2.5 standards as 75 µg/m3.

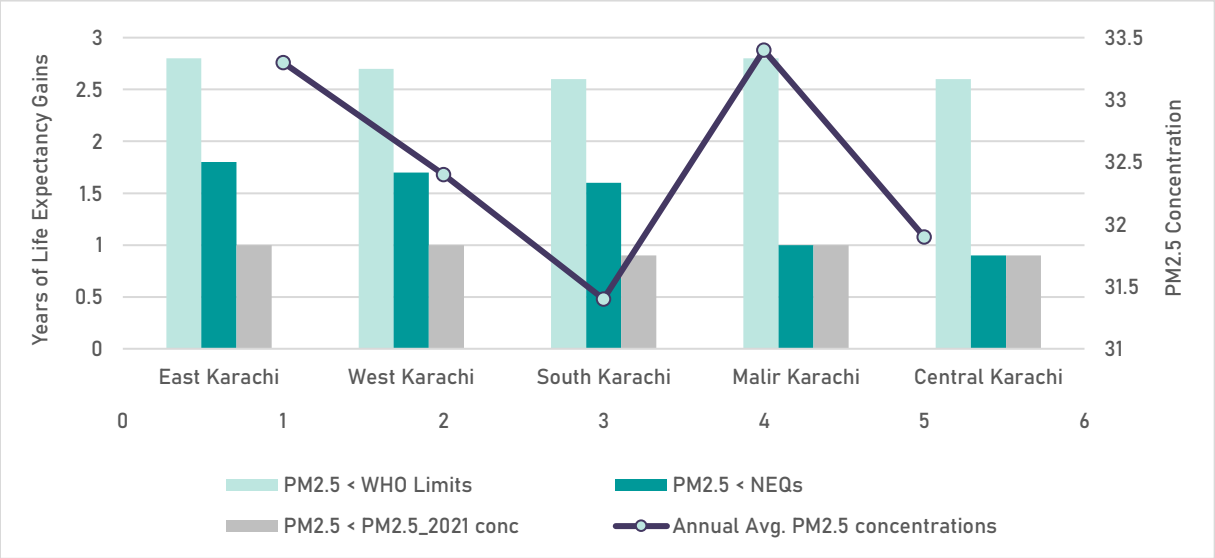


Figure 33. A Comparison of Gain in Years of Life Expectancy in Different Areas of Karachi and PM2.5 Concentration[67]

In contrast to the dense network of ground-based particulate matter monitoring equipment in various metropolitan cities of the world, Karachi does not have an adequate number of equipment for air quality profiling and source-based apportionment. There are 3 air quality monitoring sensors installed in Karachi, the details of which are as follows;

Table 8: Air Quality Monitors in Karachi

Sr. #	Monitors	Location	Parameters	Time Period
1	Continuous AQMS Beta-Attenuation Monitor (BAM)	US Consulate Karachi	PM2.5	May 2019-Present
2	Purple Air Low-Cost Sensor	Magnificence Center Railway Road Karachi	PM2.5, PM10	March 2022-Present
3	Gaia Air Quality Monitor	University of Karachi	PM2.5, PM10	May 2023- Present

The data from these air quality monitors is openly available and is used for profiling the air quality in Karachi. The Annual Average Concentration of PM2.5 is given below. The results show that the concentration increased from 44 µg/m3 to 54 µg/m3 from 2019-2021. A lower concentration in 2019 and 2020 represents the impact of the COVID-19 lockdown in Karachi City. The low economic activity resulted in lower emissions from industrial and transport sources, and therefore the pollution was less68. An increase in concentration was observed in 2021, because of the restoration of all economic activities after COVID-19. The degrading air quality in Karachi is consistent with the post-COVID trend observed in other South Asian cities[69]. The peak in concentration in 2021 is consistent with the findings of the report published by Clean Air Asia. A comparison of average annual air quality in 31 major cities of the world from 2018 to 2021, shows that the

[67] Source: AQLI, Pakistan Fact Sheet, 2023
[68] Sipra, H., Aslam, F., Syed, J. H., & Awan, T. M. (2021). Investigating the Implications of COVID-19 on PM2. 5 in Pakistan. Aerosol and Air Quality Research, 21(2), 200459.
[69] Banerji, S., & Mitra, D. (2022). Assessment of air quality in Kolkata before and after COVID-19 lockdown. Geocarto International, 37(21), 6351-6374.

increase in PM2.5 concentrations in Karachi was the highest among all other countries followed by Berlin, Islamabad, Manila, and Phnom Penh70.

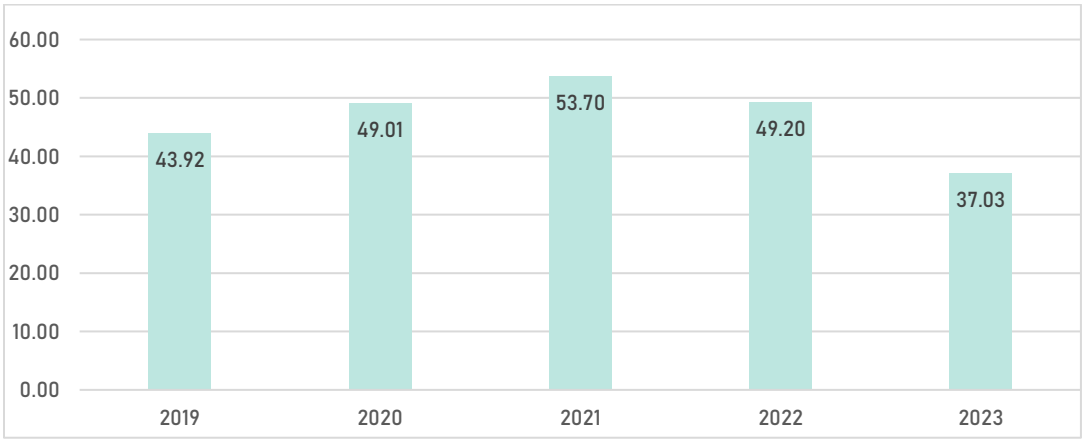


Figure 34. Annual Average PM2.5 Concentration (2019-2023)

The daily average $PM_{2.5}$ variations June 2019 to October 2023) show peak concentrations of 221.5 µg/m^3, 191.08 µg/m^3, and 233 µg/m^3 on January 13, 2021, January 22, 2022, and January 12, 2023, respectively. This shows elevated levels of $PM_{2.5}$ concentrations in the winter season in all years. The maximum recorded summer season concentration is 87 µg/m^3 on June 22, 2022. The daily variations in $PM_{2.5}$ concentrations are influenced by both anthropogenic and natural factors as well as the local meteorological conditions.

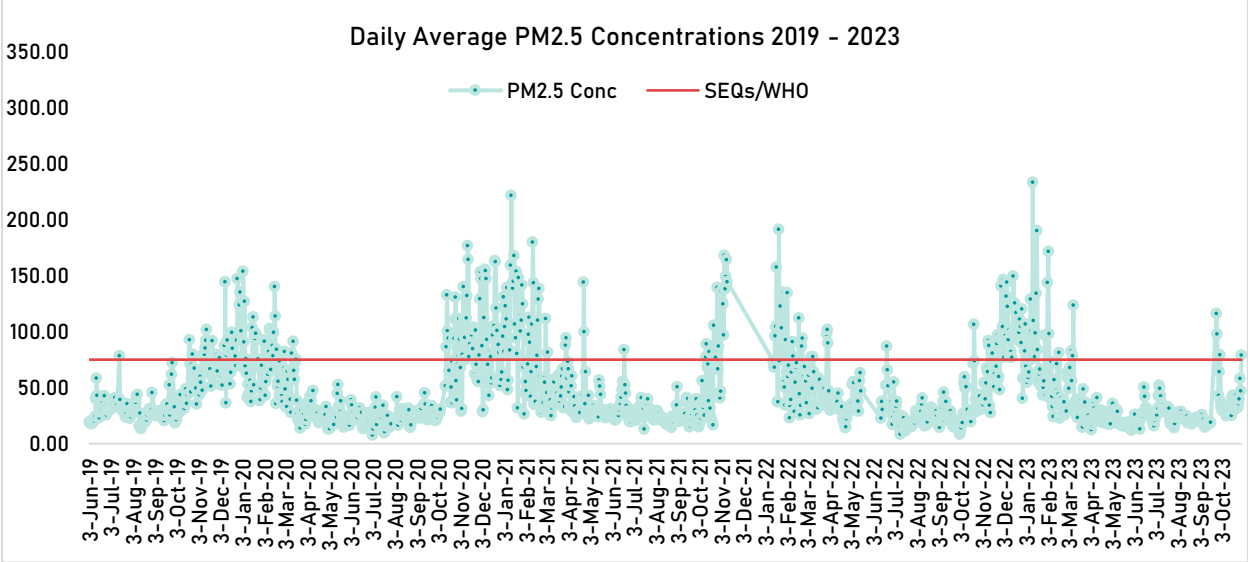


Figure 35. Daily Average PM2.5 Concentrations (June 2019 to October 2023)

The monthly average concentrations of PM2.5 from May 2019 to October 2023 show higher concentrations of PM 2. in the Winter season (from Oct to Feb) due to the temperature inversion phenomena. Concentrations are lowest in the post-monsoon period (July and August) because of the washing-out effect of rainfall on the contaminants[71].

[70] CleanAir Asia. (2022). China's 10-Year Path Toward Clean Air: An Asian Perspective. China Air Special Issue.
[71] Ouyang, W., Guo, B., Cai, G., Li, Q., Han, S., Liu, B., & Liu, X. (2015). The washing effect of precipitation on particulate matter and the pollution dynamics of rainwater in downtown Beijing. Science of the Total Environment, 505, 306-314.

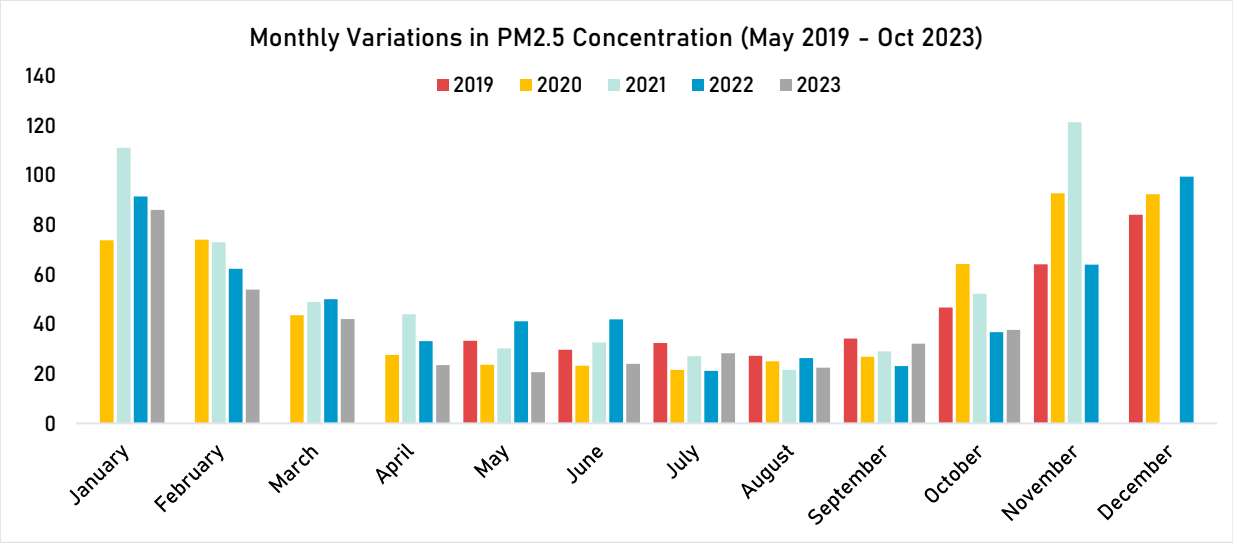


Figure 36. Monthly Average PM2.5 Concentration ug/m3 (2019-2023)

Uniformity of trend can be observed in the hourly average concentration of PM2.5 in Karachi from May 2019 to October 2023. Figure 8 represents the diurnal variations of PM2.5. The concentration increases two times each day that is during midnight (12:00 AM) and in the morning (8:00 AM). The peak at the midnight may be due to the increase in several diesel trucks entering the city as well as the temperature inversion phenomenon which occurs as the temperature drops in urban areas. The peak in the morning can be explained by the increase in the number of on-road vehicles during office and school timings. The decrease in the concentration of pollutants in the afternoon can be attributed to atmospheric dilution of pollutants under convective action. It can be observed that hourly averaged concentrations were highest in 2021 and lowest in 2023.

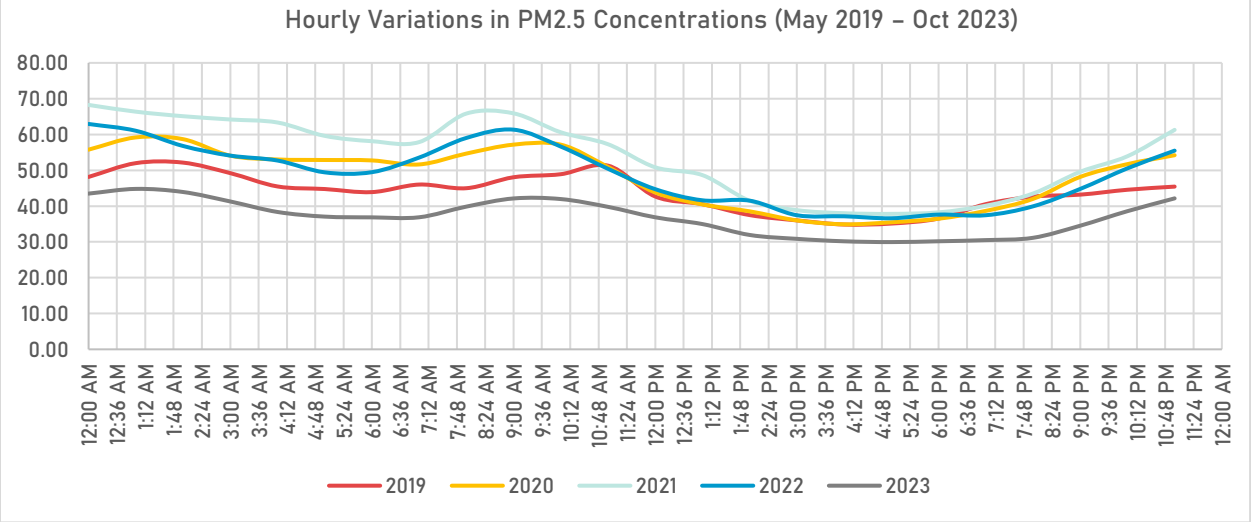


Figure 37. Hourly Average Concentration of PM2.5 (2019-2023)

- ## Concentration of Carbon Monoxide:

Due to the absence of continuous ground-based carbon monoxide analyzers, data has been obtained from Sentinel 5P, a satellite-based data source. The seasonal variations represent an increase in concentrations in the winter season followed by autumn and the spring season.

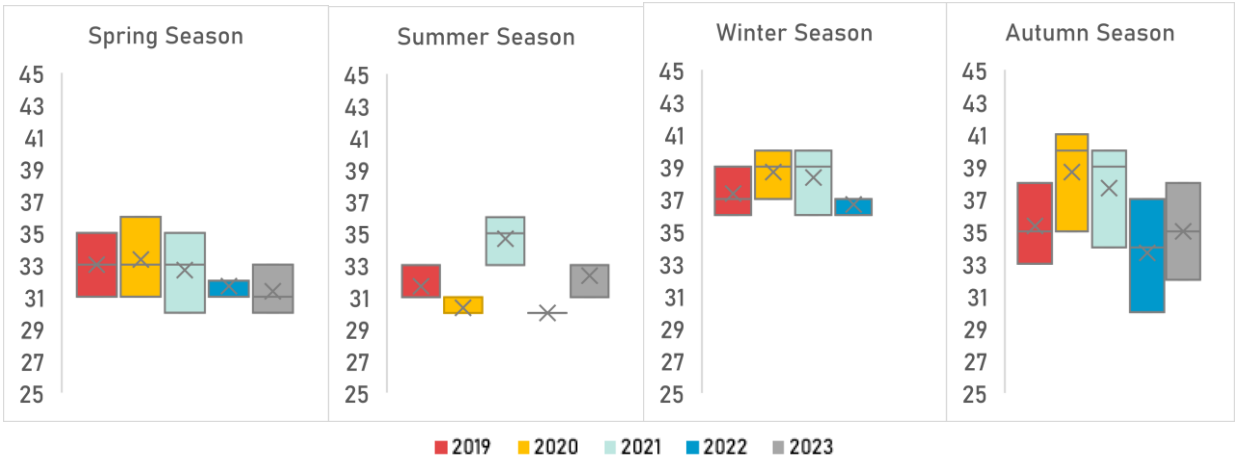


Figure 38. Average Seasonal Concentration (x10^-3 mol/m²) of Carbon Monoxide (2019-2023)

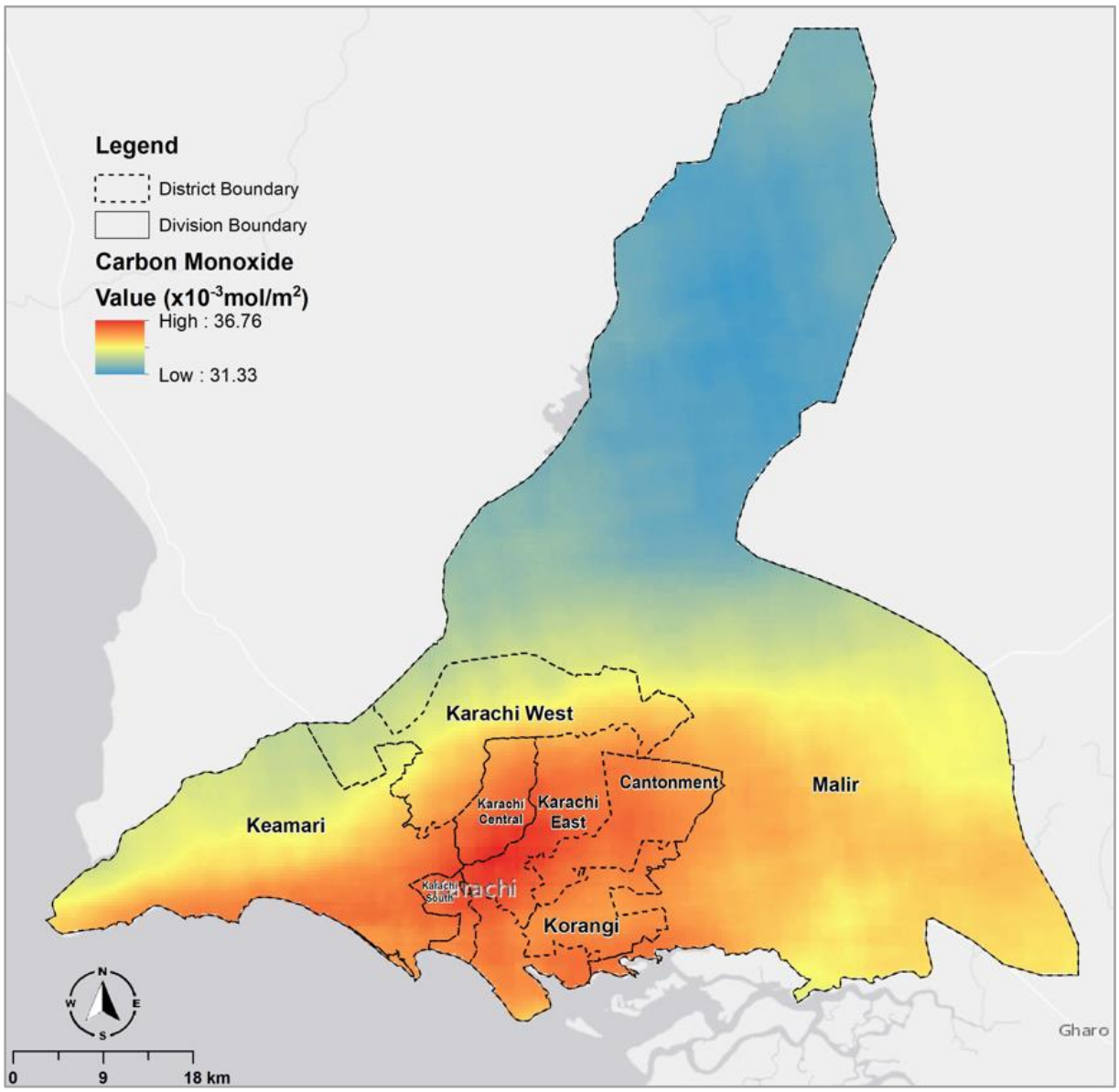


Figure 39. Annual Average Concentration of Carbon Monoxide (Nov 2022 – Oct 2023)

Carbon Monoxide is mainly emitted during incomplete combustion in automobile exhaust engines and the burning of solid waste and biomass[72]. The spatial presentation of the annual average CO concentration shows that Karachi East and Karachi Central are the most polluted areas, followed by Karachi South, Cantonment, and Korangi Districts.

- **Concentration of Nitrogen Dioxide:**

Nitrogen Oxides mainly originate during the combustion of diesel and petrol in light-duty and heavy-duty vehicles. Annual Average concentration of Nitrogen Dioxide in Karachi, presented in Figure shows that the most populated areas with high commercial, industrial, and residential activity are the most polluted.

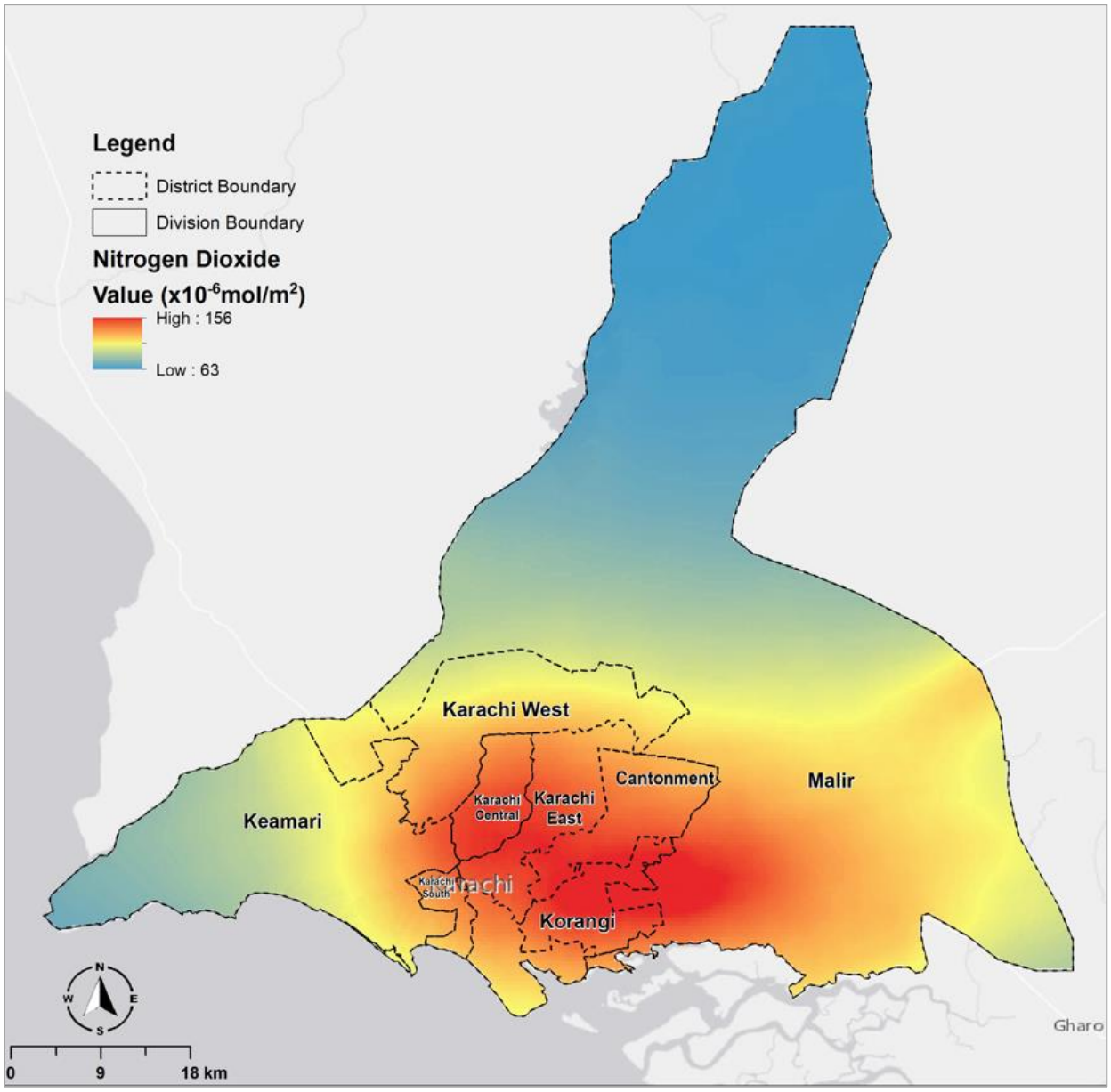


Figure 40. Annual Average Concentration of Nitrogen Dioxide (Nov 2022 – Oct 2023)

[72] Moyebi, O. D., Sannoh, F., Fatmi, Z., Siddique, A., Khan, K., Zeb, J., ... & Khwaja, H. A. (2023). State of gaseous air pollutants and resulting health effects in Karachi, Pakistan. Environmental monitoring and assessment, 195(2), 266.

Using CNG as a fuel source in domestic cooking also adds NOx into the air. High concentrations in the winter season are attributed to stagnant air mass and higher atmospheric stability resulting in lower dispersion and dilution of pollutants. On the other hand, concentration decreases in the summer season because of sea breeze coming from the Arabian Sea and an increase in convective layer height to allow maximum dispersion of pollutants[73].

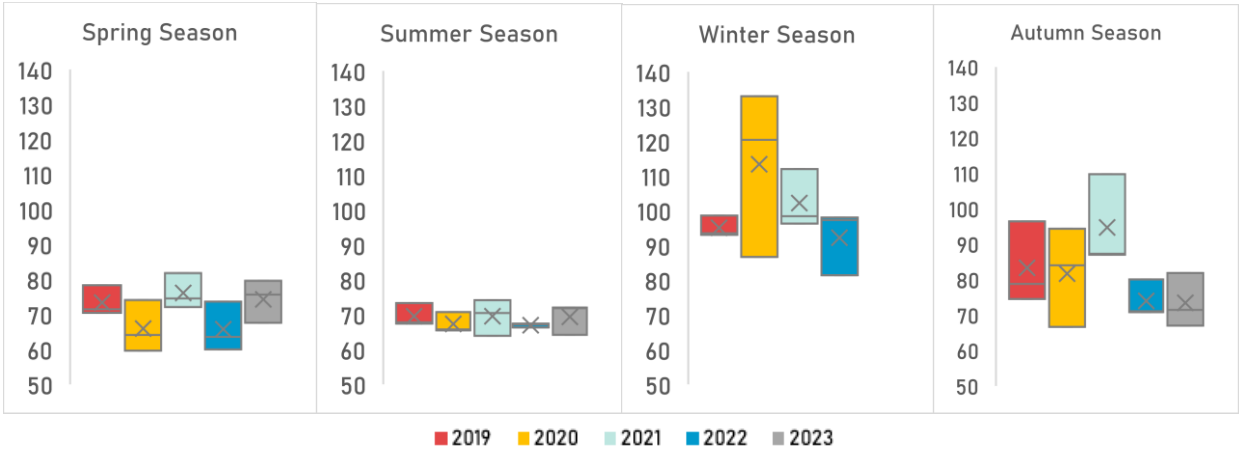


Figure 41: Average Seasonal Concentration (x10^-6 mol/m²) of Nitrogen Dioxide (2019-2023)

- **Concentration of Sulfur Dioxide:**

Burning of sulfur-containing fuel such as diesel and coal in oil refineries, power plants, heavy-duty vehicles, industrial manufacturing, and heat generation in low-income areas causes SO2 emissions in the air[74]. Data from Sentinel-5P is used for tracking the seasonal and annual average concentrations of Sulfur Dioxide in Karachi. The concentration of Sulfur Dioxide is recorded as the highest among all other pollutants in Karachi city, making it the key pollutant.

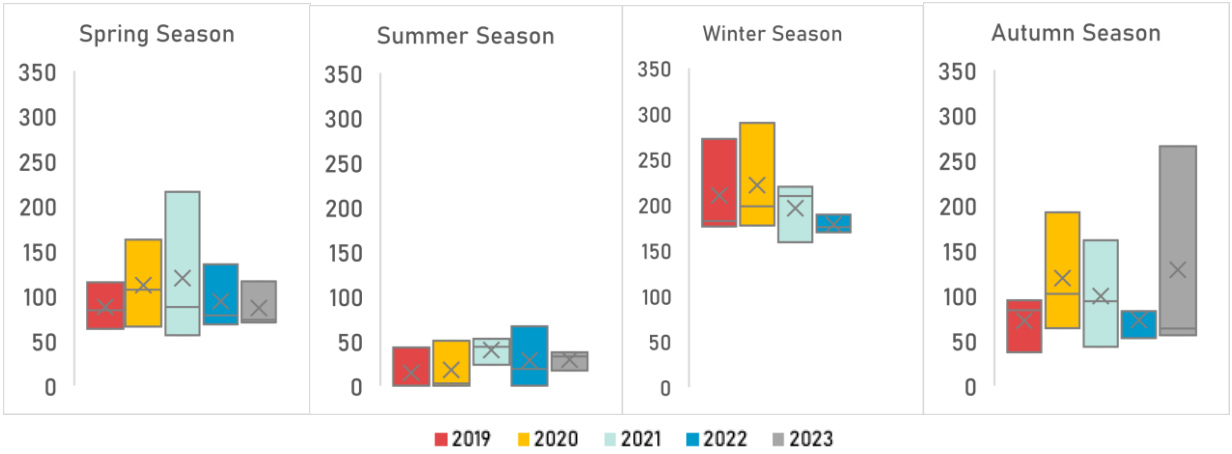


Figure 42: Average Seasonal Concentration (x10^-6 mol/m²) of Sulfur Dioxide (2019-2023)

The maximum annual average concentration recorded is 237 moles per square meter based on vertical column density in the outer boundary of Karachi City.

[73] Ibid
[74] Moyebi, O. D., Sannoh, F., Fatmi, Z., Siddique, A., Khan, K., Zeb, J., ... & Khwaja, H. A. (2023). State of gaseous air pollutants and resulting health effects in Karachi, Pakistan. Environmental monitoring and assessment, 195(2), 266.

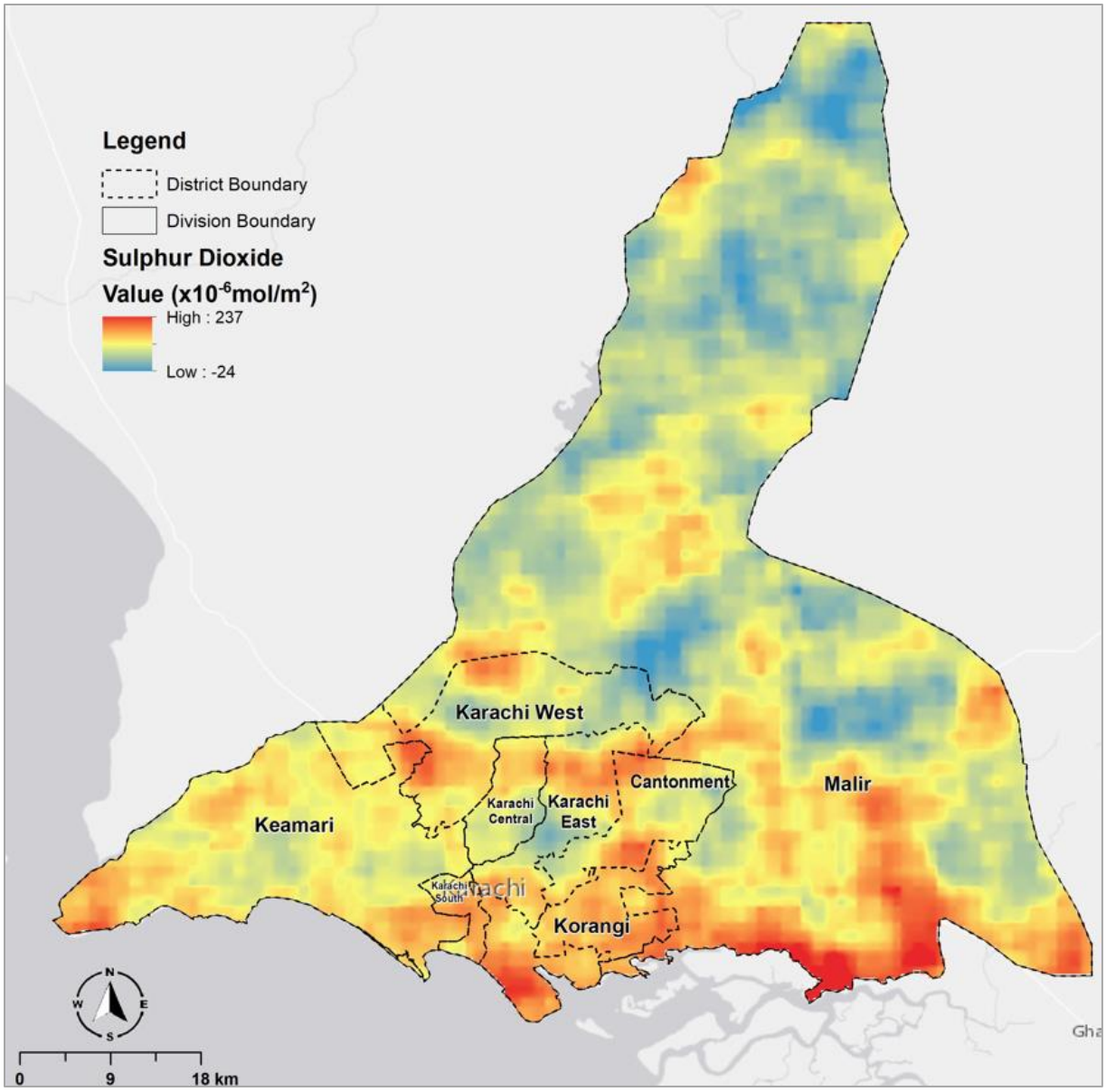


Figure 43. Annual Average Concentration of Sulfur Dioxide (Nov 2022 – Oct 2023)

- ## Concentration of Ozone:

Ozone forms as a product of the chemical reaction between nitrogen oxides and volatile organic compounds in sunlight, thus it is a secondary pollutant. High concentrations of Ozone have been reported in Karachi city. The emissions from the transport sector, oil refineries, manufacturing activities, open refuse burning, and residential combustion are responsible for the formation of Ozone[75].

[75] Moyebi, O. D., Sannoh, F., Fatmi, Z., Siddique, A., Khan, K., Zeb, J., ... & Khwaja, H. A. (2023). State of gaseous air pollutants and resulting health effects in Karachi, Pakistan. Environmental monitoring and assessment, 195(2), 266.

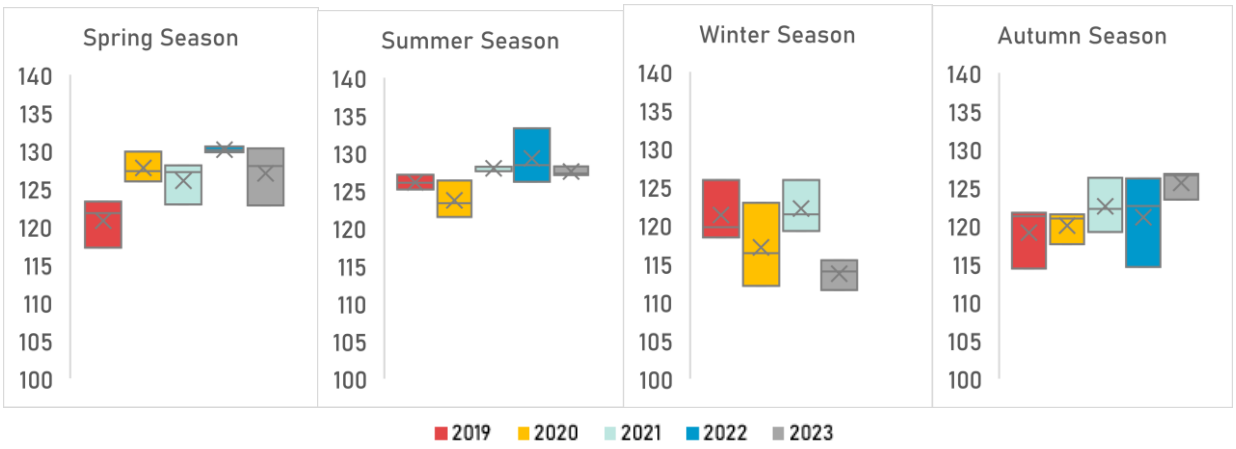


Figure 44. Average Seasonal Concentration (x10^-3 mol/m²) of Ozone (2019-2023)

The annual average concentration of Ozone is high in the western and southwestern parts of Karachi city.

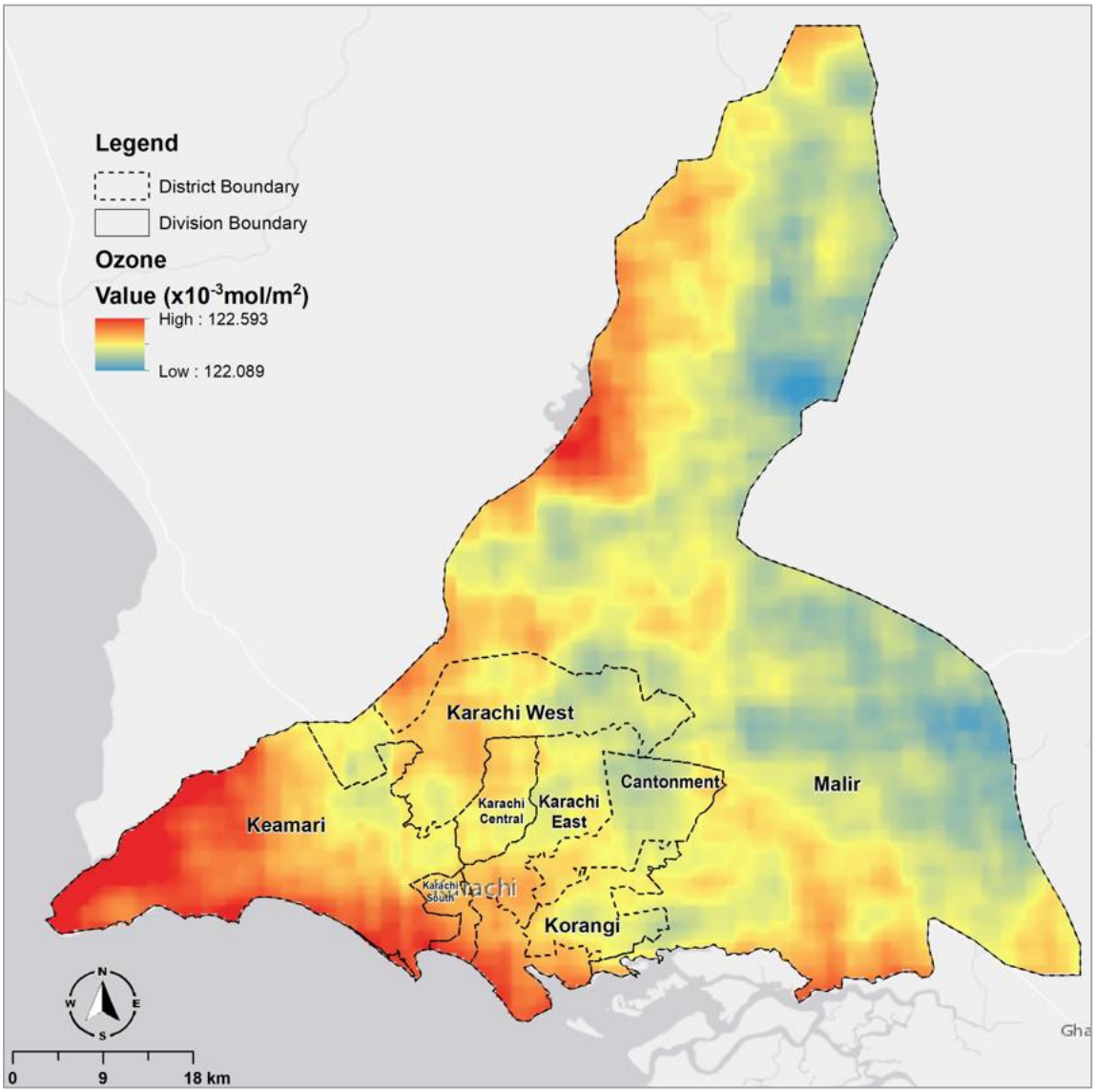


Figure 45. Annual Average Concentration of Ozone (Nov 2022 – Oct 2023)

- **Concentration of Aerosols:**

Aerosols are a combination of solid and liquid particulate matter with a complex chemistry, originating from both natural and anthropogenic sources. They have the potential to alter cloud properties, influence air quality, and cause public health concerns, making them crucial components of the tropospheric atmosphere[76].

The annual average concentration obtained from the Snetinel-5P satellite was used for hotspot analyses of aerosols in Karachi. The central region of Karachi with high urban density is the hotspot of aerosol concentration, as given below;

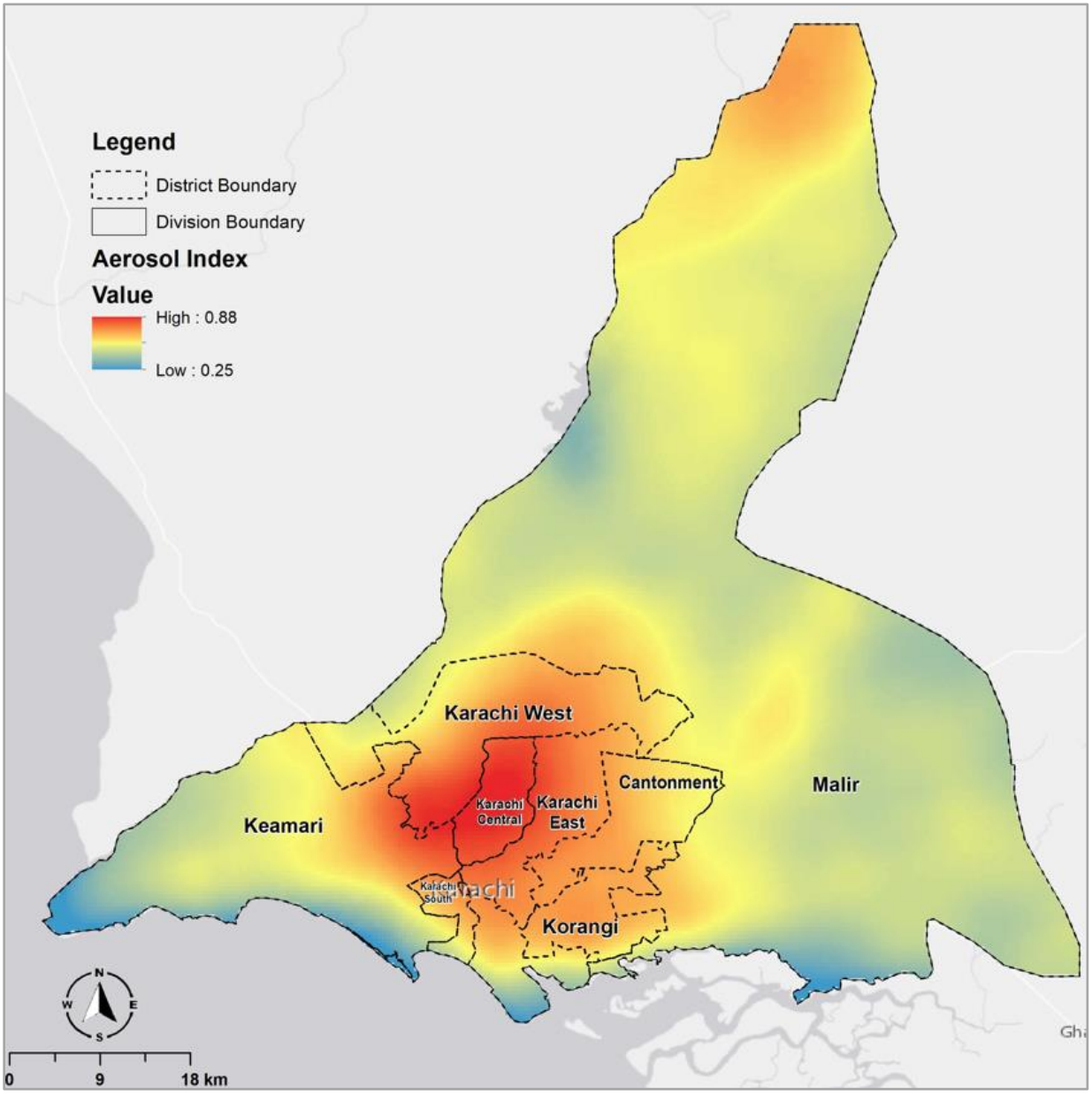


Figure 46: Annual Average Concentration of Aerosol Index in 2022

[76] Tariq S, Ul-Haq Z, Mahmood K, Rana AD (2018) Spatio-temporal distributions and trends of aerosol parameters over Pakistan using remote sensing. Appl Ecol Environ Res 16:2615–2637.

The data for Aerosols has been obtained from the Climate Action Center in Karachi. Its published report "Cleaning Karachi's Air" provides a deep insight into the sources of pollutants in Karachi. The report uses the Copernicus Atmospheric Monitoring Services (CAMS) Portal to access aerosol data for Karachi city[77]. The obtained dataset is used for trend analysis given in the below figures.

The aerosols present over Karachi city are predominantly from natural sources, i.e., sea salt and dust, whereas 34% are from anthropogenic activities[78]. The organic matter and sulfate aerosols are mainly contributed by fossil fuel combustion and biomass burning in the industrial and transport sectors. Black Carbon is emitted from the industrial combustion of sulfurous fuel. The monthly variations of these aerosols are influenced by the dominant anthropogenic activities in the area and the meteorological conditions.

Higher concentrations are reported in the winter season and lower in the summer season. Moreover, the atmospheric residence time of these aerosols also determines their concentration in the atmosphere recorded by satellite data. Black Carbon has the least residence time while other aerosols remain in the troposphere for longer periods[79].

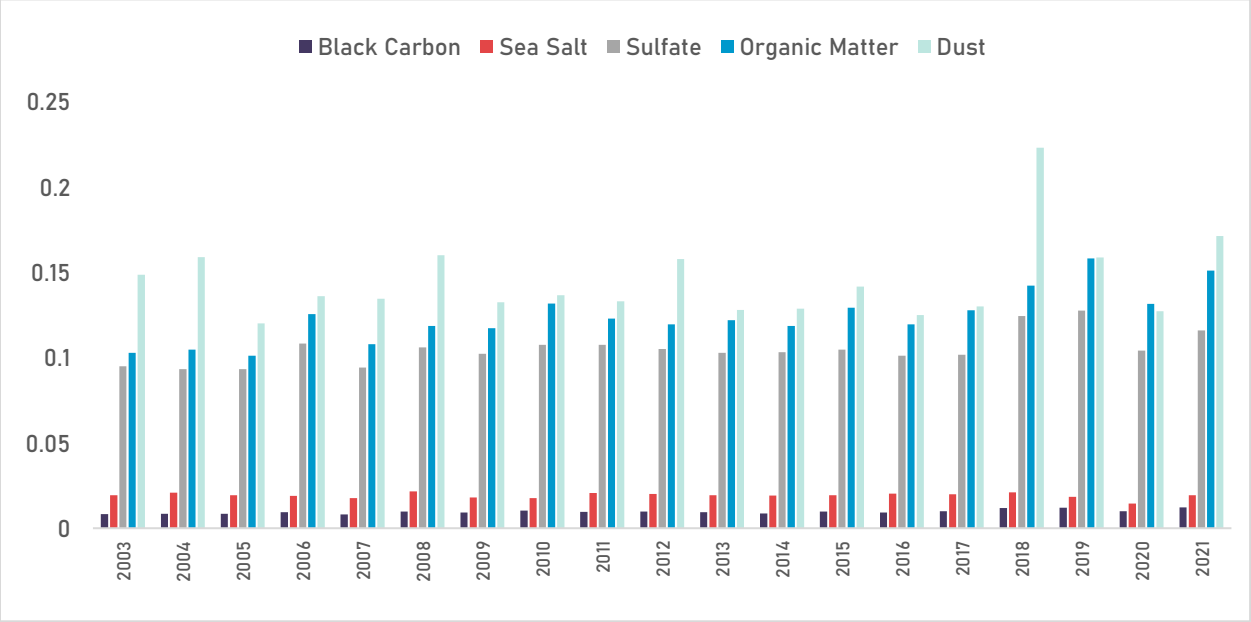


Figure 47. Annual Average Concentrations of Aerosols in Karachi[80]

The highest concentration of total aerosols was recorded as 0.522 in 2018, and the key constituent was dust aerosols. An increasing trend can be observed in annual average concentrations of aerosols over the years in Karachi.

Moreover, the Monthly Average Concentration of Aerosols in Karachi from 2003 to 2021 exhibits that the concentration of organic matter increased with decreasing dust concentrations, indicating the higher influence of anthropogenic activities on the local environment of Karachi.

[77] Darya Labs. (2021). Cleaning Karachi's Air. A Study for Air Quality Trends and Major Air Pollutants in Karachi. Climate Action Center. (Available at: https://cackarachi.com/air-quality/#dearflip-df_739/13/)
[78] Khan, M., Tariq, S., & Haq, Z. U. (2023). Variations in the aerosol index and its relationship with meteorological parameters over Pakistan using remote sensing. Environmental Science and Pollution Research, 30(16), 47913-47934.
[79] Ali, G., Bao, Y., Ullah, W., Ullah, S., Guan, Q., Liu, X., ... & Ma, J. (2020). Spatiotemporal trends of aerosols over urban regions in Pakistan and their possible links to meteorological parameters. Atmosphere, 11(3), 306.
[80] Darya Labs. (2021). Cleaning Karachi's Air. A Study for Air Quality Trends and Major Air Pollutants in Karachi. Climate Action Center. (Available at: https://cackarachi.com/air-quality/#dearflip-df_739/13/)

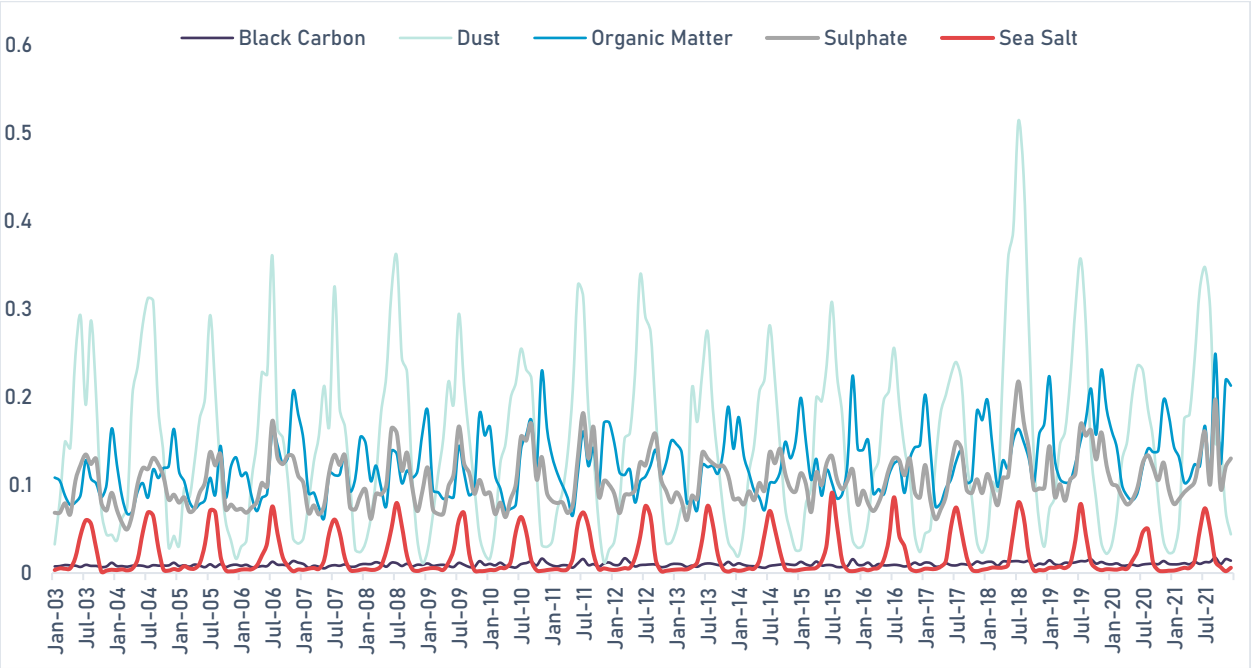


Figure 48. Monthly Average Concentration of Aerosols in Karachi (2003 – 2021)[81]

[81] Darya Labs. (2021). Cleaning Karachi's Air. A Study for Air Quality Trends and Major Air Pollutants in Karachi. Climate Action Center. (Available at: https://cackarachi.com/air-quality/#dearflip-df_739/13/)

C | Vulnerabilities Assessment

This section integrates multiple indicators across demographic and socio-economic contexts to capture the multidimensional characteristics of socioeconomic vulnerability. Taking population data from Census 2017 and PSLM 2019-20[82], district-wise assessment is conducted to analyze the literacy rate and gender distribution within the city. By examining these indicators at the district level, the framework provides socio-economic perceptions and identifies vulnerability. Additionally, gender distribution data is collected to understand gender imbalances. This includes examining the gender-based access to resources ratio, and participation in economic activities.

C1. Socioeconomic Indicators

a) Access to Information

An assessment exercise has been undertaken utilizing Census data from 2023 and 2017 sourced from the Pakistan Bureau of Statistics. The assessment primarily focuses on households with access to the internet, Mobile phones, computers, laptops, and tablets within the city of Karachi. The objective of this evaluation is to comprehensively analyze and understand the status of house ownership throughout Karachi.

Parameters	Percentage	Vulnerability	Methods Used	Data Source
Households Owning Mobile	97.58%	Negative Relation	(Total households having each of the specified assets / Total households) * 100	PSLM 2019-20
Households Owning PCs with Internet	51.32%			

District-wise assessment of asset ownership shows that Malir District has the lowest percentage of households owning Mobile (96.46%) and Korangi District has the highest percentage (98.68%) using Mobile within the households. Karachi West District has the lowest percentage of households owning Internet facilities (37.28%) while Karachi East District has the highest percentage (67.61%).

b) Access to Educational Institutions

Based on PSLM 2019-20 data, the literacy rates vary across districts in the Karachi division. Korangi district has the highest overall literacy rate at 84%, with the highest female literacy rate at 80%. Conversely, Karachi West district has the lowest literacy rate at nearly 67%, along with the lowest effective female literacy rate at 59%.

Examining gender imbalance, the sex ratio in Karachi is reported as 110.52. Among the districts assessment, Malir district has the highest percentage of sex ratio at 114.91, while Karachi Central district has the lowest percentage at 107.92. Almost 62.23 % population of Karachi have access to education services. South District (Agra Taj colony, Bahar colony, Kutchi colony, Gulistan colony, Saeedabad, Baloch para, DHA phase 2, Khayaban-e-bahria), Kemari (Machar Colony, Baldia, Gulshan Ghazi) and district West

[82] Pakistan Social and Living Standards Measurement (PSLM), 2019-20
https://www.pbs.gov.pk/sites/default/files//pslm/publications/pslm_district_2019-20/PSLM_2019_20_District_Level.pdf

(Mominabad, Muslim Abad, Islamia colony, Manzoor Nagar, Ajmair Nagri, Surjani Town Sector 1 and 6A) are some of the unserved areas which don't have access within 1km radius.

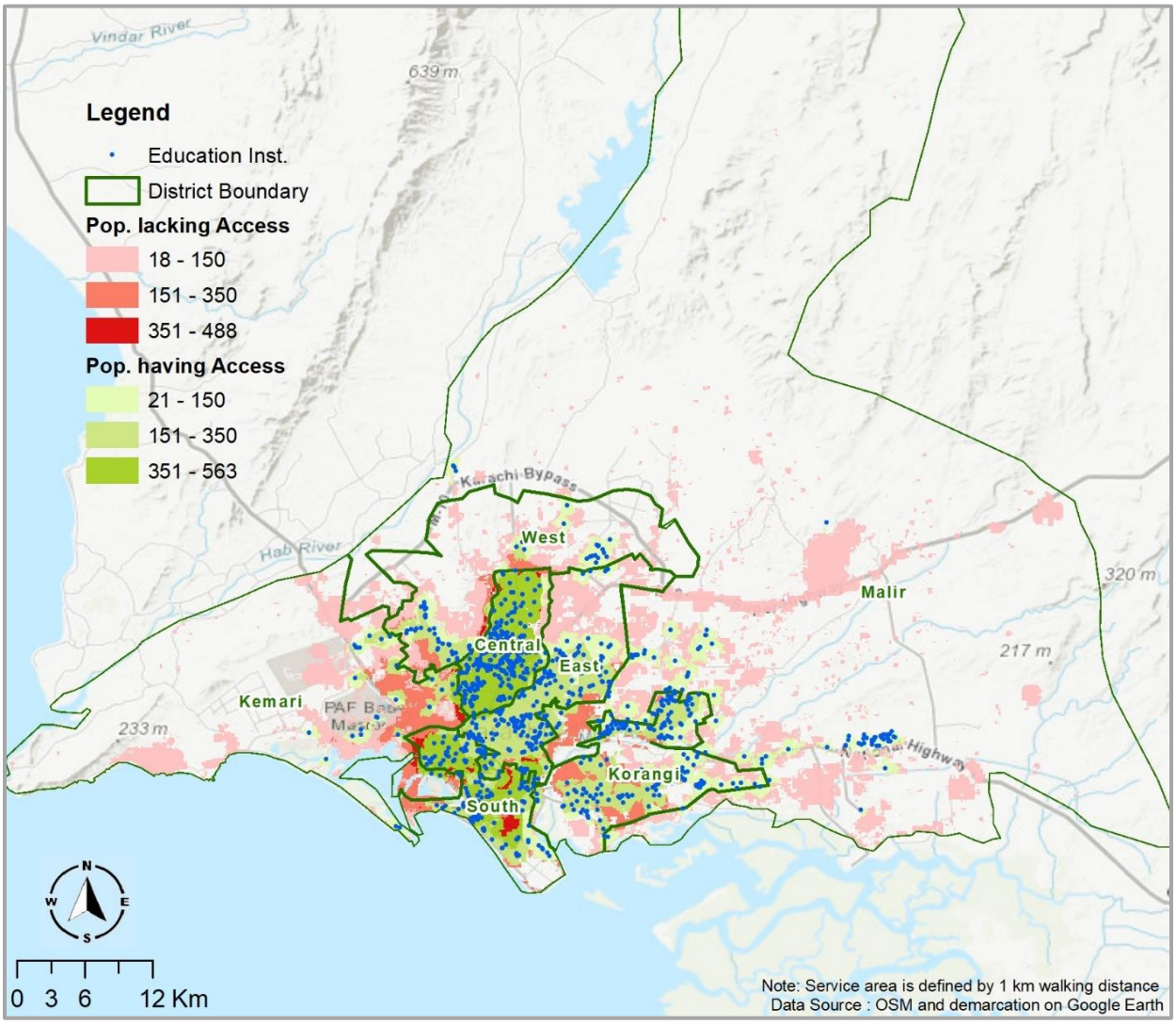


Figure 49. Access to Educational Institutes

Vulnerability to climate and air pollution-induced risks is assessed across three dimensions: socio-economic factors, the physical built environment, and infrastructure & services.

c) Home Ownership

An assessment exercise has been conducted using Census 2023 and 2017 data from the Pakistan Bureau of Statistics, focusing on house listing and housing data. The evaluation aims to analyze and comprehend the house ownership status in the city of Karachi. Leveraging statistics from the population censuses, the main findings of this work are reflected upon.

Parameter	Percentage	Vulnerability	Methods Used	Data Source
Percentage of Own Houses	59%	Negative Relation	(Total households having ownership of the property they reside at/Total households)* 100	PSLM 2019-20

The Population Census 2023 figures for housing in Karachi pose significant challenges, as there are 3.44 million households for a population of 20.383 million with an average household size of 5.93. Between the last two censuses, Karachi's population increased by 4357987, at a growth rate of 4.10, which works out to about 708852 houses which is half of the officially estimated demand.[83]

On average, almost 59% of Karachi's population resides in their 'own' houses, while 32% live in rented houses, 5.98% live freely, and 2.9% reside in subsidized housing.84. The district-wise assessment shows that the Karachi South District has the lowest percentage at 10.92%, and Karachi West District has the highest percentage of households, at 23.65%, living in 'own' houses.

C2. Physical Environment Aspects

a) House Condition

In district-wise assessment, Malir District has the lowest Percentage of Households with RCC/BCC material at 48.79 % while Karachi South District has the highest percentage at 84.48%. Karachi South district has the lowest Percentage of Households with sheet/Iron/cement nearly 3.4% while Malir district has the highest percentage at 30.43%. Karachi Central District has the lowest percentage of households with T-R/Guard material at 10% while Karachi West District has the highest percentage at 22 %.

Parameter	Vulnerability	Methods Used	Data Source
Households with Temporary Roofing Material	Positive Relation	(Total households having predominant roofing material categorized as temporary/Total households) * 100	PSLM 2019-20

b) Access to Daily Urban Recreation Spaces

Recreation spaces, often the open public greens, act as cushions to floods and temperature-dampening resources at both neighborhood and city levels. Proximity to such breathing spaces reduces long-term exposure to both air pollution and high surface temperatures

Parameter	Vulnerability	Methods Used	Data Source
Access to parks and playgrounds	Negative Relation	1000 m walking distance is considered a serviced area for parks and playgrounds	OSM, Google Earth
Illustrative Case of Vulnerability to Climate-Induced Hazard			
Urban Heat Risk	Positive Relation	Area > 30'C LST overlaid on the population grid having limited access to recreational spaces.	Landsat 9 (USGS)
Urban Flood Risk	Positive Relation	250m buffer polygon is overlaid to the population grid that has access to recreational spaces.	Analysis

Out of Karachi's population, 19.24 % have access to daily urban recreation space within 1 km whereas 80.76 % do not have access to any daily urban recreation space within a 1-kilometer radius. However, in the event of a flood, the portion of Karachi's population with access to a daily urban recreation space may potentially decrease from 19.24 % to 18.35%. District South (Gulberg Town, Civil Lines Karachi) has the highest accessibility to parks and grounds. But it may reduce during flood events.

[83] Pakistan Bureau of Statistics, Population Census, Table 1: Households, population, household size and annual growth rate.
[84] Pakistan Bureau of Statistics, Table 7.4: Percent distribution of households by housing tenure.

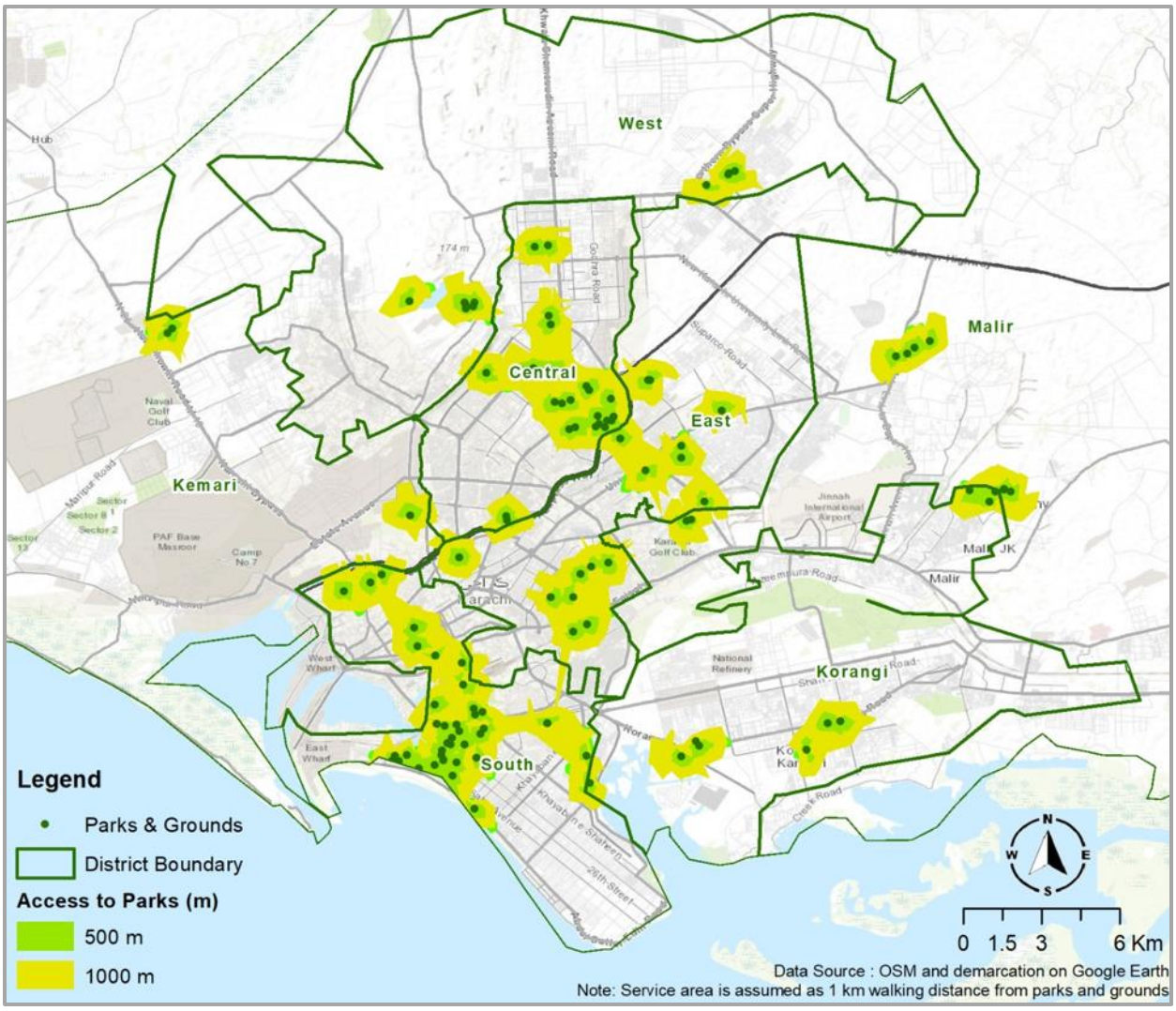


Figure 50. Access to Parks and Grounds in Karachi[85]

A minimum of 24.24 % who lack access to a daily urban recreation space within specified thresholds, categorized as the unserved population, are also exposed to heat stress (<30°C), thereby worsening their vulnerability due to the compounded risks. District Korangi areas Mominabad, Begum Khursheed Road, and Malir JK have the highest population exposed to these overlapping risks.

C3. Infrastructure and Service Aspects

a) Access to Sanitation

Assessing latrine availability In Karachi City, as a whole 53.51 % of households had a latrine within the housing unit of ownership in 1998- Census. The percentage of shared latrines and those having no proper latrines was 44.32 and 2.18 respectively. Karachi East District, Karachi South District, and Korangi District have 100% availability of sanitation facilities (Latrine/flush) within the premises of households, while Malir District, Karachi West District, and Karachi Central District have 98% of Latrine/Flush facilities within the premises.

[85] Source: The Urban Unit 2024

Parameter	Vulnerability	Methods Used	Data Source
Latrine Availability	Negative Relation	Percentage of households having latrine facility within premises	PSLM 2019-20
Unhygienic Sewage Disposal Methods	Negative Relation	Percentage of households following unhygienic sewage disposal methods including open pit latrines, open drains, removal by humans, etc.	
Unhygienic Wastewater Disposal Methods	Negative Relation	Percentage of households following unhygienic wastewater disposal methods	

b) Access to Clean Cooking Fuel

The analysis relied on Census 2017 house listing data to assess and determine the percentage of households utilizing LPG, biogas, or cooking gas for cooking purposes, aiming to gauge access to clean cooking fuels within households.

Parameter	Percentage	Vulnerability	Methods Used	Data Source
Access to Clean Cooking Gas	97.4%	Negative Relation	Percentage of households using gas as cooking fuel	PSLM 2019-20

District-wise assessment of Karachi Division shows that Malir district has the lowest Percentage of Households with access to LPG/ Biogas /cooking gas (88.12%), while Karachi South district has the highest percentage (99.71%).

c) Access to Electricity

Census 2017 house listing and housing data have been used for assessment and mapping to evaluate the percentage of households with electricity as the main source of lighting. District-wise assessment of Karachi Division shows that Malir district has the lowest Percentage of Households with access to LPG/ Biogas /cooking gas (88.12%), while Karachi South district has the highest percentage (99.71%).

Parameter	Percentage	Vulnerability	Methods	Data Source
Access to Electricity	98.7%	Negative Relation	Percentage of households having electricity as the main source of lighting	PSLM 2019-20

d) Access to Health Services

The analysis revealed that 82.06 % of Karachi's population has access to health facilities within a 5-kilometer radius.

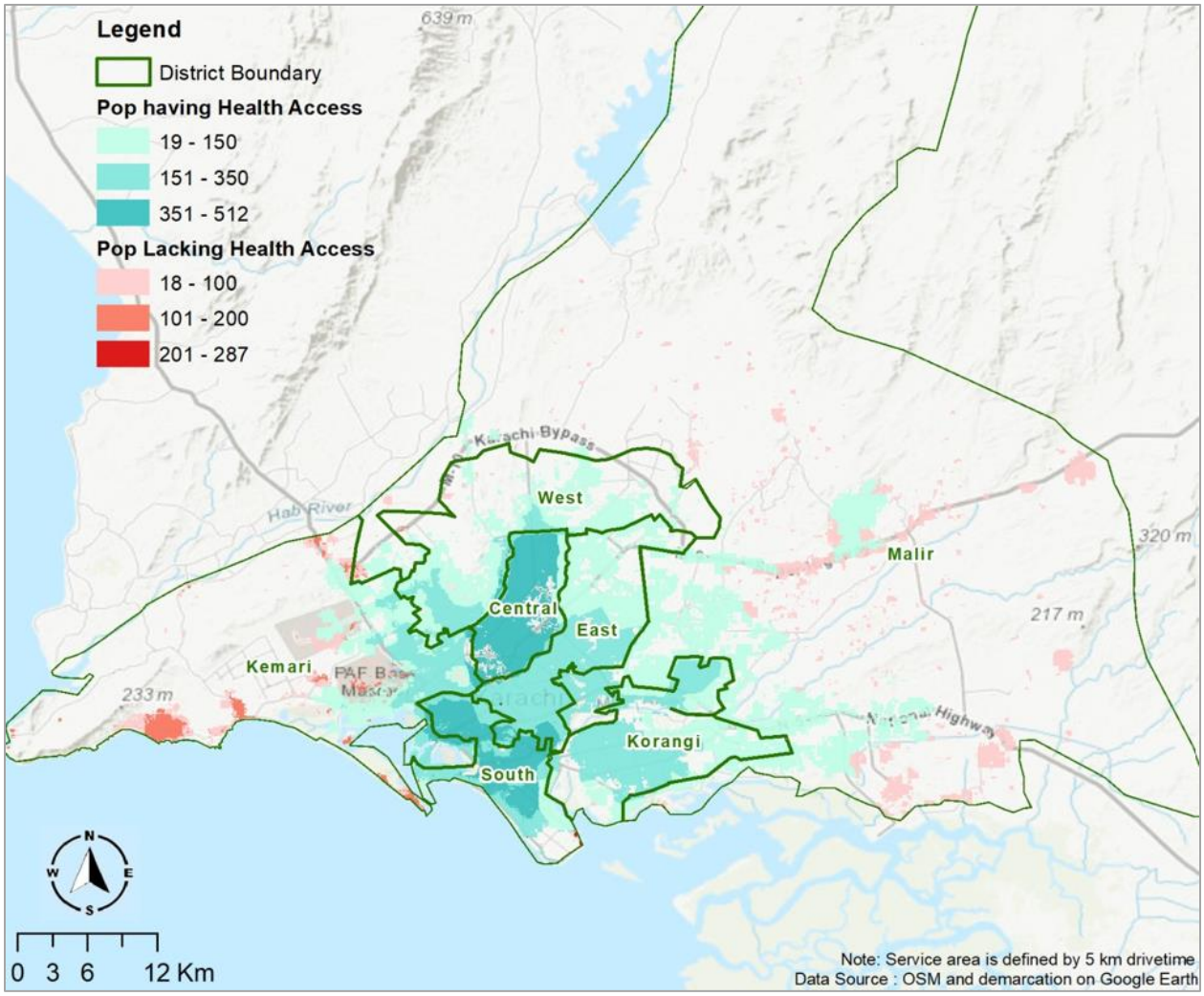


Figure 51. Access to Health Services[86]

During a flood event, the proportion of Karachi's population with access to a healthcare facility within a 5-kilometer radius potentially decreases from 82.06% to 75.8%. This reduction in access could significantly impact the timely provision of medical assistance, particularly for the poorer population, who may face financial constraints and rely on public transportation. District Central and East have the highest accessibility rates, with 100% of their population having access to a healthcare facility. Additionally, 9.7 % of Karachi's population, deemed as the unserved population due to the absence of access to healthcare facilities within the specified thresholds, also faces exposure to heat stress (at 30°C). This exacerbates their vulnerability by compounding overlapping risks. Among these areas with overlapping risks, District Malir has the highest population exposure.

Parameter	Vulnerability	Methods Used	Data Source
Access to Health Facilities	Negative Relation	The population within a 5 km drivetime polygon around health facilities points.	OSM, Google Earth
Illustrative Case of Vulnerability to Climate-Induced Hazard			
Urban Flood Risk	Positive Relation	250m buffer polygon is overlaid to a population grid that has access to health facilities.	Analysis

[86] Source: The Urban Unit 2024

Parameter	Vulnerability	Methods Used	Data Source
Urban Heat Risk	Positive Relation	Area > 30'C LST overlaid on the population grid having limited access to Health care facilities.	

e) Access to Transit Stations

In the event of a flood, the percentage of Karachi's population able to access a mass transit station within 1 kilometer potentially decreases from 22.75 % to 19.42 %.

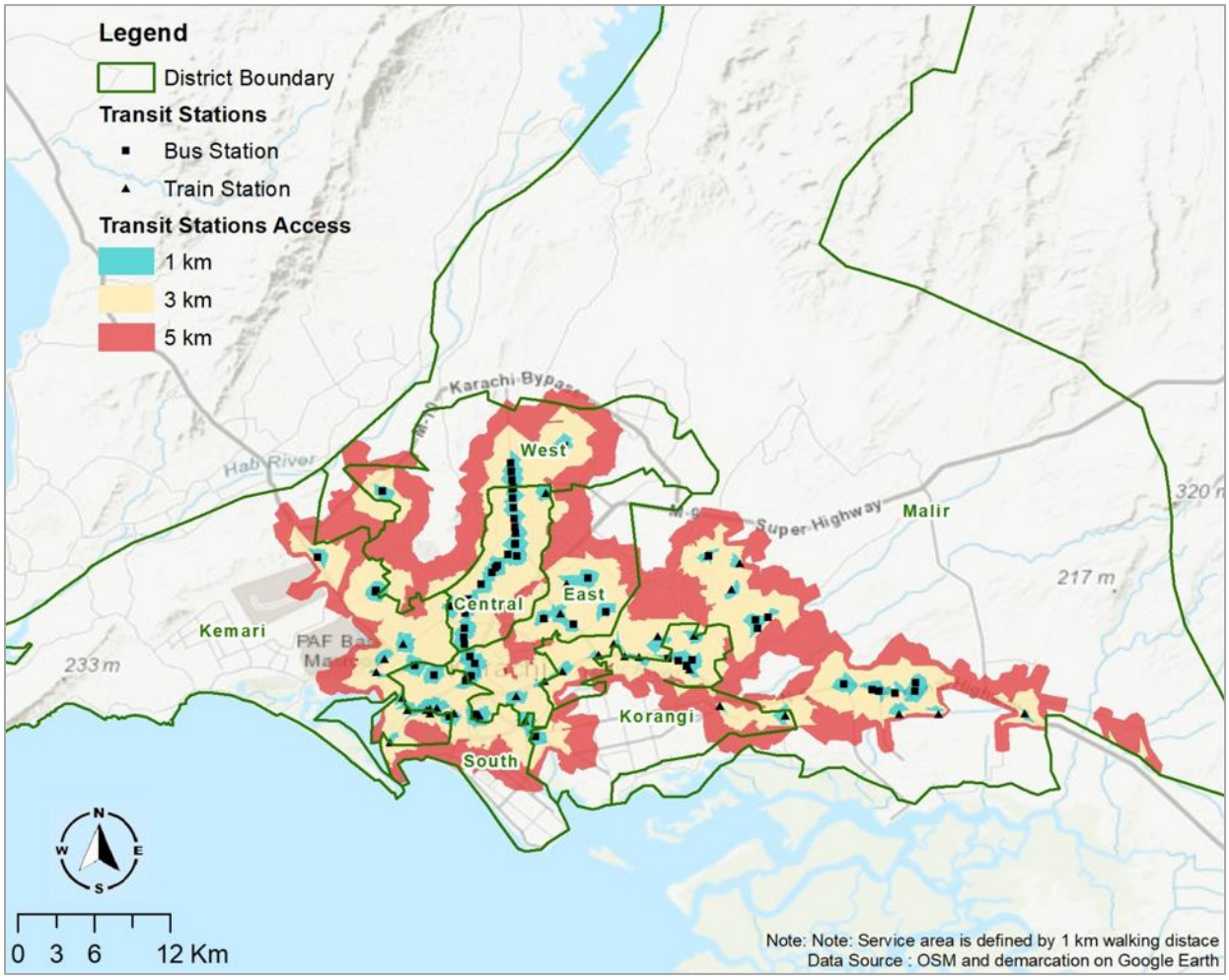


Figure 52. Access to Transit Stations in Karachi[87]

Central district, ranks highest where 40% of its population (the highest in the city) has access to such stations. Whereas District Korangi ranks lowest in terms of access to transit stations making its population more vulnerable.

Parameter	Vulnerability	Methods Used	Data Source
Access to Bus and Railway stations	Negative Relation	1 km walking distance to each transit station is considered as access.	OSM, Google Earth

[87] Source: The Urban Unit, 2024

Illustrative Case of Vulnerability to Climate-Induced Hazard			
Urban Flood Risk	Positive Relation	250m buffer polygon is overlaid to the population grid that has access to transit stations.	Analysis

The transit stations which are limited physical access during floods are Power House Chourangi Station, Nagan Chourangi, Model Park Station, Karachi University Railway Station, Shah Abdul Latif Station, Patail Para Station, Numaish Station, Halt railway station and Qayyumabad Station.

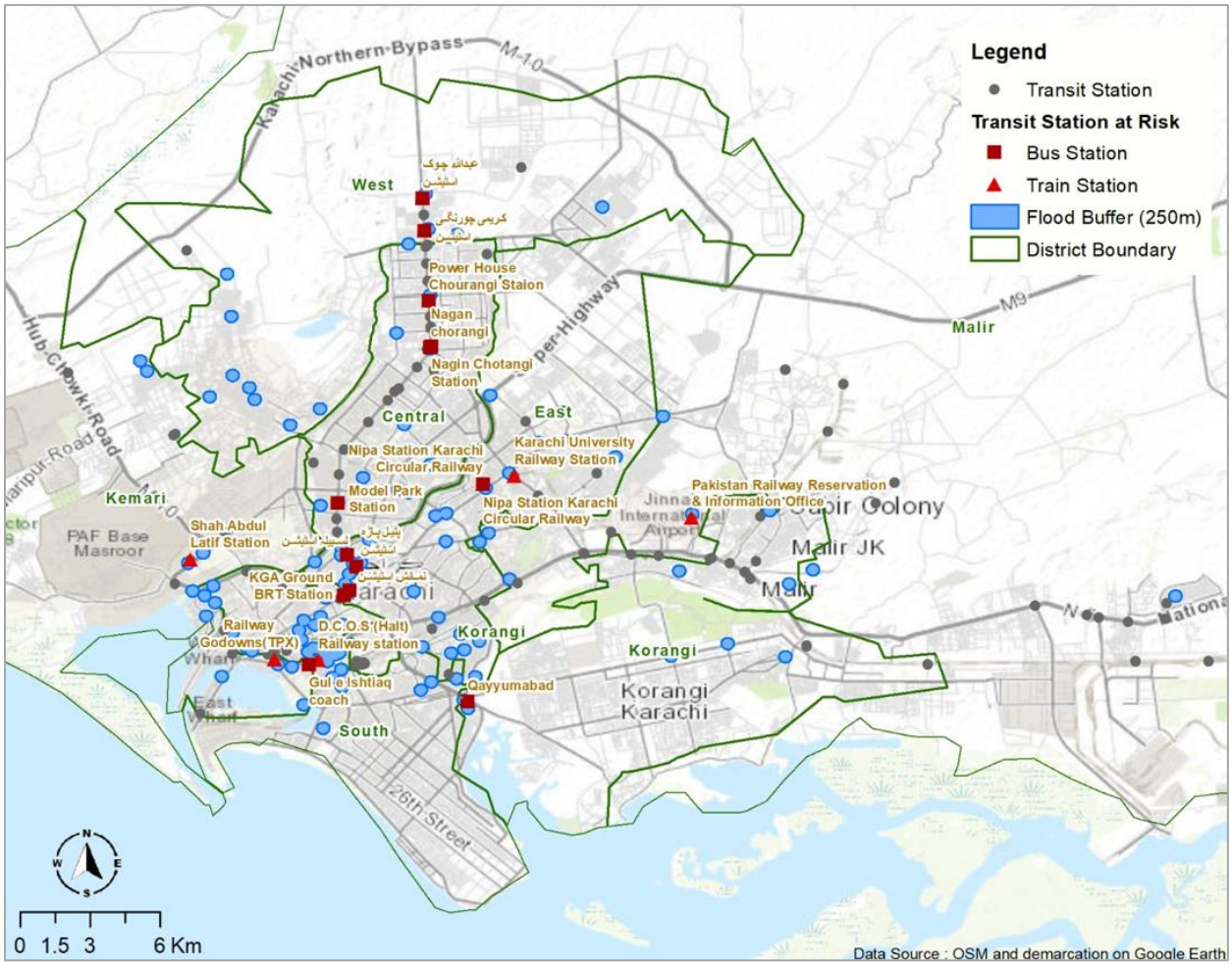


Figure 53. Transit Stations with Limited Access during Flooding in Karachi[88]

f) Access to Fire Stations

Approximately 70 % of Karachi's population, has access to fire stations within a five-minute response time. Karachi has 21 fire stations, including mini stations. However, areas such as Gulshan Hadeed, Khaiabad, Gulshan e Bahar, and Surjani Town Sector 1, 2, and 4, which are densely populated, fall beyond the five-minute response time, as indicated in the following map;

[88] Source: The Urban Unit 2024

Parameter	Vulnerability	Methods Used	Data Source
Access to the Fire Station	Negative Relation	Population coverage within 5 minute's drive time service area around the fire station's location	OSM, Google Earth
Illustrative Case of Vulnerability to Climate-Induced Hazard			
Urban Heat Risk	Positive Relation	Area > 30'C LST overlaid on the population grid having limited access to fire stations	Analysis
Urban Flood Risk	Positive Relation	250m buffer polygon is overlaid to the population grid that has access to fire stations	Analysis

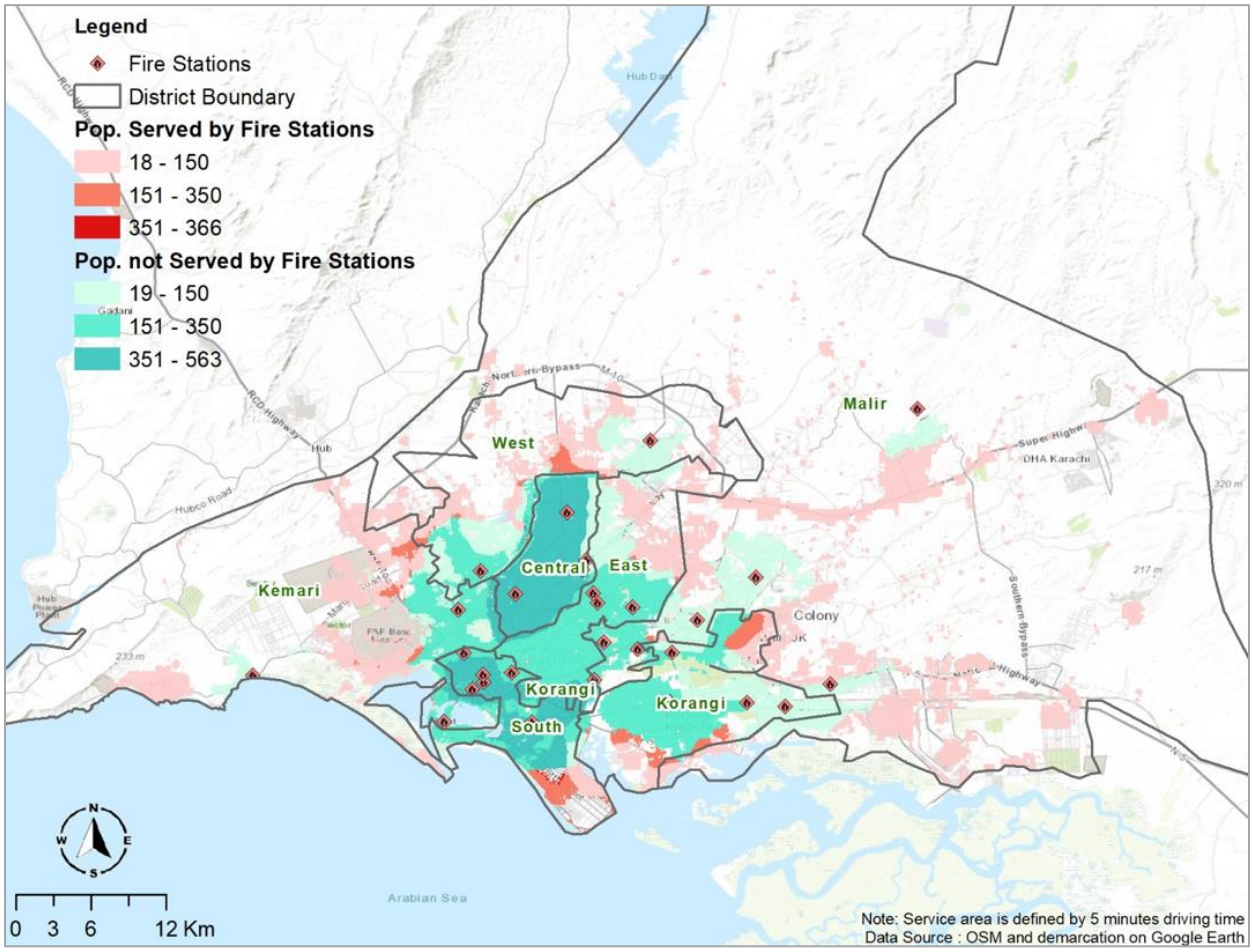


Figure 54. Access to Fire Stations in Karachi[89]

During a flood event, the percentage of Karachi's population served by all fire stations within a five-minute response time potentially decreases from 70% to 67%. Districts South and East, housing the largest population where 100% of its residents live within a five-minute response time, could potentially see this reduced to 67% during a flood. This prolongs the time required for rescue and recovery efforts, consequently enhancing vulnerability.

[89] Source: The Urban Unit 2024

Furthermore, 30% of Karachi's population, categorized as the un-serviced population due to the lack of fire service coverage within the standard five-minute response time, are also exposed to heat stress (<30°C). This compound risk worsens their vulnerability. District Korangi (Jaffae-e-Tayayar Society, Malir town, Bhatia Colony), District East (Sachal Goth), and District West (Surjani Town sector 1) are exposed to these overlapping risks.

D | Impacts Assessment

Chapters A-C indicate multiple climatic risks, hazards, and vulnerabilities and their impacts on Karachi City considering non-climate-related factors such as demography, socio-economic conditions, infrastructure like health, roads, buildings, and urbanization trends. This particular chapter provides qualitative assessments of the impact of climate hazards on key city sectors in Karachi City including water and sanitation, transport, health, energy, and biodiversity.

Climate Hazards	Water & Sanitation	Transport	Health	Energy	Biodiversity
 **Heat Waves**	• Greater demand for water during extreme heat episodes from already stressed water utilities of Karachi • Consumers transition towards more costly service options for water supply • High prrice of non formal water supply through vendors	• Extreme heat episodes coupled with the blooming population density in the inner city, risen traffic congestion, non-resistent fabric of roads (and buildings) leading to more pronounced heat island effect. • Thermal expansion and deformation of road infrastruture due to extreme heat episodes • Bukled road infrastcuture due to heat • Heat waves can damage transportation infrastructure and pose	• Increasd pressure on health and emergency response infrastructure • Psychological and social stresses • Outbreaks of malaria, dengue fever, and multiple gastroenteritis diseases. • citizens' risk of stroke, heart disease, and asthma.	• Increased in energy consumption for cooling leading to extreme energy shortages / load sheddings • Substantial energy loss due to limited efforts to promote energy conservation • Consumers transition towards more costly service options for water supply	• Shrinking green cover of Karachi City and extreme heat events are badly affecting local biodiversity. • Rise in the air and water temperatures affecting marine life. • Fatal impacts on city's biodiversity (including Zoos and Safaris) during heatwaves.

Climate Hazards	Water & Sanitation	Transport	Health	Energy	Biodiversity
		challenges for maintenance and construction. Higher temperatures can put stress on bridge infrastructure through thermal expansion of bridge joints and paved surfaces, and deterioration of steel, asphalt, protective cladding, coats and sealants.			
 **Flooding**	• Water supply services disturbed due to infrastructure damage • Sewerage and drainage infrastructure damage	• Connectivity disturbed due to infrastructure damage • Movement of goods and services impacts	• Health services impacted due to infrastructure damage • Contamination and Sprout of diseases like typhoid, cholera, and hepatitis from flood and sewer water • Contamination of water supply lines with seweage and impacting the health of community	• Power supply affacted due to infrastructure damage • Electric shocks to community due to breakdown of system and open wires	• Species migration pattern disturbs • Depending upon flood duration, the severity of impacts on insects and local flora and fauna varies. • Reduce species' ability to find food, shelter and reproduce
 **Droughts**	• Livelihoods of Goths/villages are highly dependednt on groundwater for farming and daily uses. Drought conditions resulting in lowering water	• High water demand and lower or declining may cause subsidence (the sinking of the ground) and destabilize the ground or	• Health and nutrition issues in most vulnerable groups leading to increase burden on health sector.	• Dought conditions reduce electricity production from plants that require cooling water for operation, however, no	• Loss in plant growth and reduce vegetation in Karachi city which is already facing loss in green cover

Climate Hazards	Water & Sanitation	Transport	Health	Energy	Biodiversity
	table and decreasing aquifers yield to very low level. • Greater water demand due to drought conditions , leading to more stress on water utilities. • Awareness, education and initiatives in water conservation, water harvesting and waste water recycling are non-significant leading to severe water stressed conditions.	ground-based infrastructures. However, this sector is not impacted by this hazard recently. •	• Migration and low quality of health and hygiene	significant impact is reported on this sector.	• Threat to local biodiversity of the city. • Loss of green spaces and cover
 **Sea-Level Rise and Tidal / Coastal Flooding**	• Water supply services disturbed due to infrastructure damage and inaudation of structure . • Wastewater treatment plants in the coastal zone of Karachi are impacted due to coastal flooding. • Salt water infiltration and the corrosion is impacting WWTPs • The material or substrate for sewer pipes are damaged by water table rise in	• Changes in harbor facilities to manage storm surges and high tides • Increased erosion of infrastructure. • Flooding of terminal areas of ports and infrastructure damage	• Increased health issues, soecifically due to containmnation and outbreaks of infectious diseases due to coastal flooding in low lying areas of Karachi, leading to increased vulnerabities	• Power supply affacted due to infrastructure damage	• Salt water intrusion and tidal flooding impacting local biodiversity and thus directly affecting fishing communities livelihood and ecosystem deterioration. • Increased flooding in coastal areas and estuaries, are negatively impacting wetlands and local biodiversity, mainly turtles and fishes.

Climate Hazards	Water & Sanitation	Transport	Health	Energy	Biodiversity
	the coastal areas and erosion.				

In the latest intense rainfall in Karachi (February 3, 2024), almost 700 power feeders tripped, and power was cut out for a longer time in most of the affected areas. The low-lying areas were submerged and around 60 – 80 mm of rain was recorded in a short span of time. Landhi, DHA, North Nazimabad, Nipa, Korangi, Clifton, II Chandigarh Road, Saddar, Gulistan-e-Jauhar, Keamari, Bolton Market, Liaquatabad, Surjani, Gulshan-e-Iqbal, and North Karachi were the areas that experienced heavy rainfall and flooded badly.

Figure 55. Damage to the Road Infrastructure in Karachi During 2020 Floods[90]

Figure 56. A snapshot of overflowing gutters on the main roads of Karachi in Feb 2024 Floods[91]

Other than these sectors, some key socio-economic impacts are as follows;

- ## Climate Migration

The 2021 report on climate-induced migration[92] underlined the fact that **the massive shrinkage of the Indus Delta in the past two decades has led more than 1.2 million people to migrate towards Karachi City.**

The trend towards permanent migrations is higher nowadays due to frequent and extreme climatic events. The residents of coastal regions like Keti Bander and Kharo Chan are moving towards big cities like Karachi.

[90] Pakistan - Deutsche Welle – DW. 2021. https://www.youtube.com/watch?v=2iuT6-udu_0
[91] The Express Tribune. 2024. https://tribune.com.pk/story/2455448/seaview-opened-a-new-branch-internet-reacts-to-karachis-urban-flooding-after-heavy-rains
[92]Research report on Climate Induced Migration: Global discourse, local realities and governance https://islamic-relief.org/wp-content/uploads/2022/05/IRWClimateInducedMigration_Digital-V2.pdf

Those who have fewer resources try to settle in the urban slums of intermediate cities, while those with high resources turn towards Karachi and other neighboring cities.

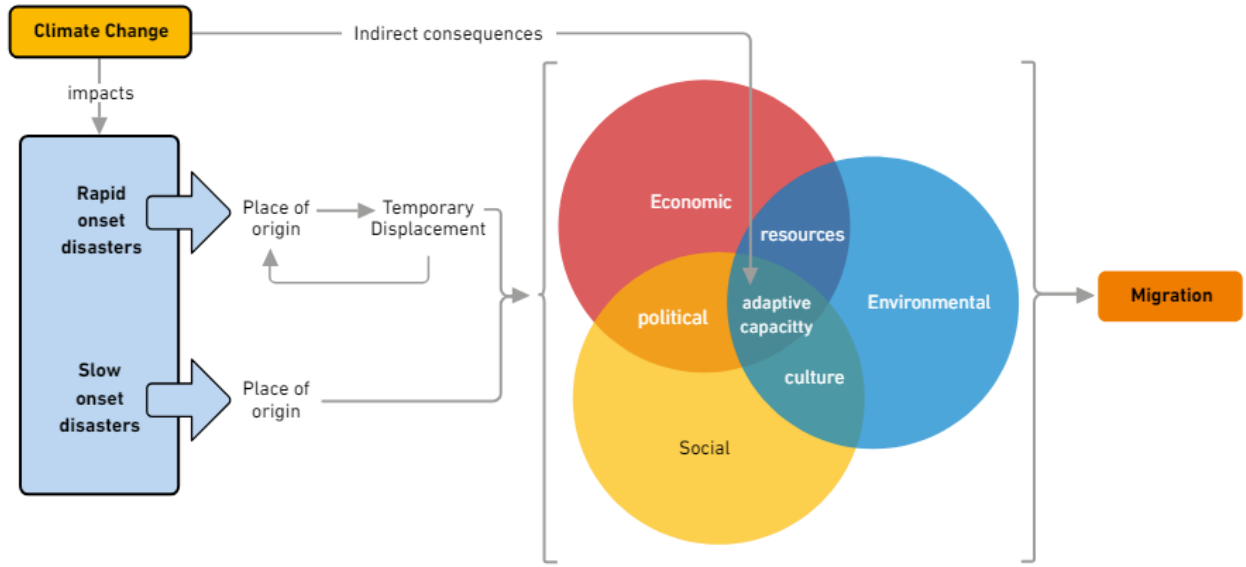


Figure 57. Climate-Induced Migration Flow[93]

Residents carry belongings as they wade through a flooded area during a heavy monsoon rains in Karachi in August 2020 *Image: picture-alliance/AP Photo/F. Khan*

This migration from Balochistan towards Karachi due to longer and repeated spells of drought is also common. Saltwater intrusion, sea level rise, and cutting of mangrove forests along the banks of the Delta

[93] Retrieved from https://islamic-relief.org/wp-content/uploads/2022/05/IRWClimateInducedMigration_Digital-V2.pdf Pg. 51.

are other factors that are increasing climate-induced migrations towards Karachi city, putting additional pressure on the city's resources and urban/municipal services and more encroachments and densification of urban slums.

Figure 58. In-country climate-induced migration patterns[94]

The 'Migration' could be an adaptation strategy to tackle climate change impacts and may help in getting more employment opportunities, leading to better well-being. However, the complex relationship between the climatic, socioeconomic, political, and cultural factors, in the case of Sindh (and Karachi) indicates that climate-induced migrations are the result of inadequate adaptation and mitigation strategies (poor climate resilience).

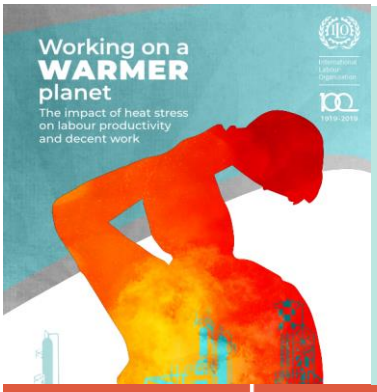
The migrations and socio-economic factors are directly related either they are self-decided or by push factors due to negative climatic/environmental impacts. Without having access to the regular migration channels, coupled with low socio-economic profile (e.g. education and skills), the vulnerability of migrants in the region further increases. Moreover, the intensity of these impacts varies disproportionately among the women because of their traditional role as homemakers/caretakers and negatively impacts them in terms of nutrition, food, diseases, stress, and conflicts. Cultural norms also restrict their movement and heat stress and other climatic risks badly affect them.

[94] Ibid

Fish farming communities living along the coastal belt are forced to migrate because of intense and frequent climatic events. A study[95] indicates that communities residing near the Indus Delta and Coastal belts of Sindh have strong attachments to their native areas and they highly resist moving to the cities or neighboring areas as they fear the loss of identity. The community leaders who migrated from the coastal belt shared that the migration disgraceful for them as they lost their influential position.

- ## Labor Productivity and Heat Stress

A study on the impacts of climate change on the health of Karachi City indicates that heat-related deaths will likely increase under both low and high-emission scenarios, leading to a substantial impact on labor productivity.[96]



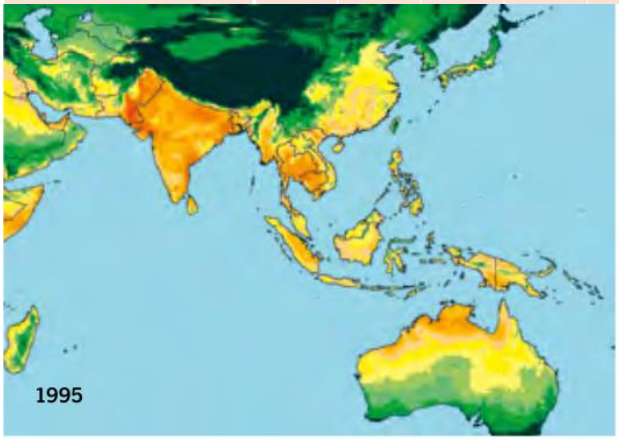
Box 4: The Impact of Heat Stress on Labor Productivity

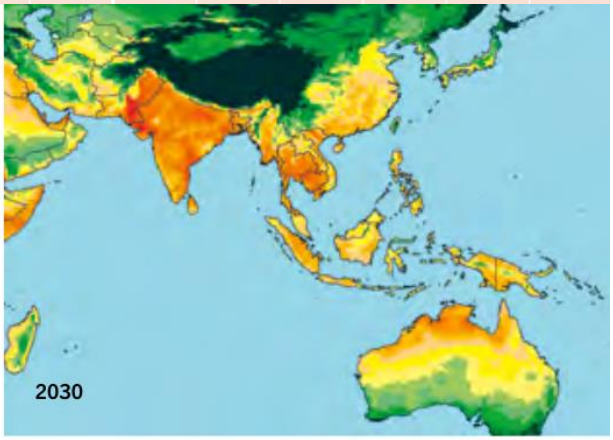
International Labor Organization ILO estimated that;

> **"Pakistan is expected to lose more than 5.5 % of working hours in 2030 owing to excessive heat, prompting an increasing number of people to migrate"**

Source: Working on a warmer planet: The impact of heat stress on labour productivity and decent work. International Labour Office – Geneva, ILO, 2019. ISBN 978-92-2-132968-8. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_711919.pdf

Country	1995						2030					
	Agriculture (in shade) (%)	Industry (%)	Construction (in shade) (%)	Services (%)	Total (%)	Total (thousand full-time jobs)	Agriculture (in shade) (%)	Manufacturing (%)	Construction (in shade) (%)	Services (%)	Total (%)	Total (thousand full-time jobs)
Pakistan	6.19	3.68	6.19	1.12	**4.19**	**1439**	8.83	5.83	8.83	2.22	**5.54**	**4603**





Note: The maps show averages of daily maximum WBGT during the hottest month for 1995 and projections for 2030. The estimates for 1995 are based on a 30-year average for the period 1981–2010, and the projections for 2030 on a 30-year average for the period 2011–40 with adjustment of the value at the midpoint (2025) to give the projected level in 2030 for each country.

[95] Research report on Climate Induced Migration: Global discourse, local realities and governance https://islamic-relief.org/wp-content/uploads/2022/05/IRWClimateInducedMigration_Digital-V2.pdf

[96] Maryam Salma Babar et al., "Impact of climate change on health in Karachi, Pakistan," The Journal of Climate Change and Health 2 (May 2021): 100013, https://doi.org/10.1016/j.joclim.2021.100013.

The International Labor Organization (ILO) report[97] related excessive heat stress with occupational health risks and identify its impacts on worker/labor's work capacity, productivity, and physical health. The report further explains that temperatures above 24–26°C are linked with reduced productivity, whereas, the reduction level may reach to 50% in 33–34°C.

According to the 2030 projections (from the 1995 baseline), Pakistan could lose 5.5% working hours due to a rise in temperature – extreme heat stress, whereas the percentages further increase to 8.83% when considering the Construction (in shade) as an individual parameter (Box 4).

Whereas, the GDP losses due to the heat stress impacts on labor productivity are also higher (~5.8%) in Pakistan under a 1.5°C global warming scenario in 2030.[98]

- **Other Associated Issues**

Multiple other factors are increasing climate risks and vulnerabilities at a substantial level. For instance, inadequate affordable housing and poor urban planning led to settlements around nullahs and drains. Encroachments around Gujjar Nullah and Lyari River are the prime examples. Improper solid waste management results in clogging of drains – the natural response system of the city – and increasing flood risks.

Figure 59. Blockage of Drains and Encroachments in Karachi in One Frame[99]

A modeling exercise using a HEC-RAS hydraulic model by the World Bank[100] was done for Karachi City to assess the role of solid waste management in reducing the impacts of floods in the city. The study considered a baseline scenario of existing indentation and blockage of channels due to solid waste and an improved scenario considering that drains are free from solid waste and are flowing smoothly as a natural

[97] Working on a warmer planet: The impact of heat stress on labour productivity and decent work. International Labour Office – Geneva, ILO, 2019. ISBN 978-92-2-132968-8. https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_711919.pdf

[98] GDP loss is calculated by multiplying the equivalent number of full-time jobs lost by GDP per worker. Source: ILO estimates based on data from the ILOSTAT database and the HadGEM2 and GFDL-ESM2M climate models.

[99] Pakistan - Deutsche Welle – DW. 2021. https://www.youtube.com/watch?v=2iuT6-udu_0

[100] World Bank. 2022. Pakistan Climate and Development Report. https://documents1.worldbank.org/curated/en/099950111072234047/pdf/P17671804998b80030ac4f0233dc0b995ba.pdf

response system. **The results revealed a 30% reduction in the flood risk through proper waste management (blockage-free drains) in Karachi City.** Hence, the management of solid waste will not just provide mitigating effects due through GHG reductions but predominantly increase the adaptive capacity of the city to manage intense rainfalls. Similarly, proper urban planning and enforcement as well as provision of affordable housing could reduce the risk and vulnerability of the population situated in the high-risk areas.

Figure 60. Ill-planned Urban Development[101]

Figure 61. Faqeer Colony, Orangi Town, Karachi – A Bloom of Grey Infrastructure[102]

Lack of green cover and ill urban planning is leading to heat stress in the city and urging for concrete actions at local level.

[101] Ibid
[102] Ibid

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The CCRA Report indicates a number of challenges that Karachi City is presently facing concerning to climate change, but along with this it brings an opportunity for evidence-based climate action planning; setting up goals/targets/milestones; identification and prioritization of actions for adaptive and mitigative measures, and an updated governance & execution framework to implement a sound action plan to minimize the devastating impacts of climate change on the infrastructure, human health and biodiversity of Karachi City.”