The Role of Industries in Accelerating Climate Change: A Case Study of Karachi (SITE Industrial Area)

Rufia Izhar[1], Sheeba Afsar[1], Sumaiya Bano[2], Shajeea Hasnain
Department of Geography, University of Karachi, Karachi-75270, Pakistan
Department of geography, Federal Urdu University of Arts, Science and Technology
***Correspondence**: roofiaizhar@gmail.com, sheebanaeem@uok.edu.pk, sumiahmed564@gmail.com

Citation | Izhar. R, Afsar. S, Bano. S, Hasnain. S, "The Role of Industries in Accelerating Climate Change: A Case Study of Karachi (SITE Industrial Area)", IJIST, Vol. 07 Special Issue. pp 57-65, July 2025

Received | July 12, 2025 **Revised |** July 25, 2025 **Accepted |** July 30, 2025 **Published |** Aug 01, 2025.

Karachi, Pakistan, is a densely populated city with a strong industrial presence, and it is increasingly threatened by climate change. This includes rising temperatures and changes in rainfall patterns. This paper examines how these climatic changes affect key industries in Karachi. It looks at how higher temperatures and limited water resources, intensified by the city's extensive concrete and industrial development, create operational and economic challenges for various sectors. This study utilized a combination of satellite datasets (Landsat 8 and 9), climatic data (CHIRPS), and ancillary data (KDA maps) to analyze environmental changes in Karachi's SITE area from 2015 to 2025. The analysis included rainfall analysis, LULC change detection, NDVI and LST trend analysis, and random point sampling for site-specific correlation. The presented results are accompanied by a narrative interpretation of environmental changes and their implications on the SITE industrial zone. This study examines the impact of climate change and urban-industrial growth on Karachi's SITE area from 2015 to 2025. The findings reveal environmental stress due to declining vegetation cover and rising land surface temperatures, likely driven by unregulated industrial expansion and rainfall variability. However, signs of ecological recovery in 2025 suggest potential benefits from natural regeneration or better land management. To enhance climate resilience, the study recommends promoting urban greening, controlling industrial sprawl, improving water management, adopting climate-friendly practices, and regular monitoring using satellite data and GIS tools. By adopting climate-resilient practices and transitioning to low-carbon technologies, Karachi's industries can reduce their environmental footprint and contribute to a more sustainable future.

Keywords: Climate Change, Vulnerabilities, Risk, Geo-Statistical Techniques, Resilience.

Introduction:

Karachi's Industrial Landscape: Karachi is a major industrial hub in Pakistan, with six major industrial zones: **SITE** (Sindh Industrial and Trading Estate), Landhi Industrial Area, Korangi Industrial Area, Federal B Area Industrial Zone, North Karachi Industrial Zone, and Bin Qasim Industrial Zone (Government of Sindh, n.d.). These industrial zones have played a crucial role in Pakistan's economic growth and development (Khan, 2018).

History of Industrialization in Karachi: The history of industrialization in Karachi first began in the 19th century with the setup of the first processing factory (Soda Ash). Pre-1947 Industrial pioneers like Jamshed Nuserwanji (Sindh Patent Tiles and Soda Water) and others contributed heavily to Karachi's industrial growth (Hasan, 2015). After Independence, Quaid-e-Azam Mohammed Ali Jinnah inaugurated a textile factory, marking the beginning of industrialization in Karachi (Figure 1). During Ayub Khan's era, industrial expansion exploded with SITE, Manghopir, emerging as a large industrial enclave with over 2000 factories and significant investment (Khan, 2018).

Climate Change Impacts: Karachi's industrial zones have played a crucial role in Pakistan's economic growth and development. Karachi's industrial zones, while driving economic growth, also contribute to greenhouse gas emissions and climate change (IPCC, 2021). Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events pose significant risks to industrial operations, infrastructure, and supply chains (World Bank, 2020).

Case Study: The current study focuses on one of Pakistan's largest and well-established industrial zones, SITE Industrial Area. Industrial zones such as Karachi's SITE drive economic development by offering organized infrastructure, vital services, and specialized facilities for production and logistics (Khan, 2018). By clustering together industries, these zones leverage proximity to ports and transport hubs, drawing in foreign investments and boosting access to skilled labour while also supporting services (Government of Sindh, n.d.), ultimately enhancing productivity and global competitiveness (World Bank, 2020).

Objectives:

To maintain the existing spatial distribution of Industries over the study area.

Investigate industrial strategies and policy measures that account for climate change impacts, mitigation, and adaptation. Use various spatial and geo-statistical techniques to examine the concentration of industries and their relative importance in the context of climate change.

Establish a comprehensive picture of the present distribution of industries within the region's geographical and climatic context, providing a foundation for future research, planning, and climate-resilient development.

Figure 1.SITE Industrial Area (Source: Author)

Study area:

SITE is a town in the western part of Karachi, Sindh, Pakistan. It is named after the Sindh Industrial and Trading Estate (SITE), which forms the heart of the town (Government of Sindh, n.d.). The town is bordered by Gadap Town, Liaquatabad, North Nazimabad, Lyari, Saddar, and Kiamari. Also, neighboring towns are Baldia and Orangi to the northwest (Karachi Metropolitan Corporation, n.d.). S.I.T.E has developed into the largest industrial area in Pakistan with more than *2,000* industrial units on 4,500 acres (18 km^2) of land. The estate benefits from its proximity to the Port of Karachi and the various roads connecting it to the rest of Pakistan (Pakistan Bureau of Statistics, n.d.).

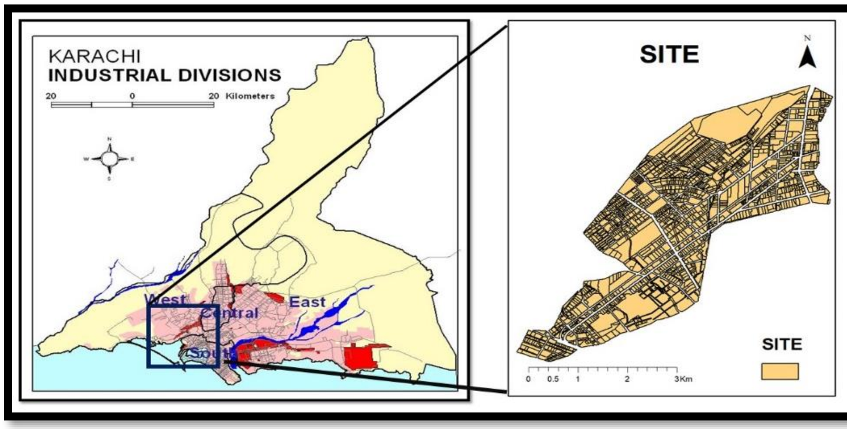

Figure 2. Study Area

Methodology:

Data Collection:

Both satellite and climatic datasets, along with KDA (Karachi Development Authority) maps, were utilized in this study:

SRS data: Landsat 8 and Landsat 9 data for the years 2015, 2020, and 2025 were acquired from the USGS Earth Explorer platform. These datasets provided the necessary spectral bands for LULC classification, NDVI, and LST extraction.

Climatic Data: Monthly precipitation data for July 2015, 2020, and 2024 were sourced from the CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) platform.

Ancillary Data: Hard copy maps and a shapefile of the SITE boundary were used for digitization, area masking, and geospatial referencing.

Data Processing:

Preprocessing: Bands were stacked and stitched as needed, and the imagery was clipped to the SITE boundary.

LULC Classification: LULC classification was applied to derive land use and land cover categories. Post-classification refinement was done using field knowledge and visual interpretation.

NDVI Calculation: The NDVI was computed using the formula: NDVI = (NIR - Red) / (NIR + Red), where NIR and Red represent the corresponding bands from Landsat imagery.

LST Extraction: Land Surface Temperature was calculated using thermal bands (Band 10), converting digital numbers to radiance, then to brightness temperature, and finally adjusting for land emissivity using NDVI-based classification.

Rainfall Interpolation (IDW): CHIRPS monthly rainfall rasters were spatially clipped to the SITE boundary. To generate smooth spatial rainfall surfaces, Inverse Distance Weighting (IDW) interpolation was applied using ArcGIS. This method estimated rainfall distribution based on the spatial proximity of available grid points, allowing a continuous representation of rainfall intensity across the SITE region.

Data Analysis:

Rainfall Pattern Analysis (IDW): Rainfall data from CHIRPS were interpolated using the Inverse Distance Weighting (IDW) method to generate spatially continuous rainfall surfaces. These interpolated layers allowed visual comparison of rainfall intensity across years and were used to analyze spatial correlations with NDVI and LST distributions.

LULC Change Detection: The classified maps for 2015, 2020, and 2025 were compared to detect spatial trends in land use change.

NDVI and LST Trends: NDVI and LST maps were analyzed for spatial variation and temporal trends. Their values were statistically analyzed across periods and land cover types.

Random Point Analysis: Randomly distributed points across the SITE area were used to extract NDVI, LST, and rainfall values. This enabled site-specific analysis and statistical correlation between vegetation health, surface temperature, and rainfall levels.

Data Presentation and Interpretation

Map Layouts: Thematic maps showing LULC, NDVI, LST, and rainfall distribution across years.

Charts and Graphs: Bar charts and scatter plots were created to visualize trends and relationships among variables.

Tables: Summary tables were generated for change detection, random point values, and statistical comparisons.

Narrative Interpretation: A detailed written analysis accompanied the visuals, interpreting environmental changes and their implications on the SITE industrial zone.

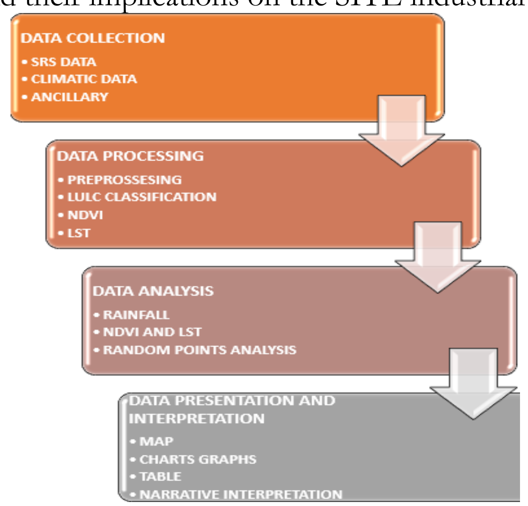

Figure 3. Methodological Framework

Result and Discussion:

Land use and Landcover of the Site Industrial Area:

Most of the area (71%) comprises industrial land use, followed by residential land use (20%), which contributes mainly to the spatial pattern of land uses there and climate change of the respective area (Table 1, Figure 4 & Figure 5).

Rainfall, Natural difference vegetative index (NDVI), and Land surface temperature (LST):

The rainfall distribution over SITE is illustrated for the years 2015, 2020, and 2023, reflecting inter-annual variability in precipitation patterns. In 2015, rainfall across the SITE region ranged between 120 mm and 200 mm, with most areas showing relatively moderate rainfall, especially in the southern and southwestern zones. By 2020, a substantial increase is evident, with SITE receiving between 540 mm and 580 mm—nearly triple the 2015 values—indicating an unusually intense monsoon season. In 2024, rainfall decreases from the 2020 peak but remains elevated compared to 2015, ranging from 250 mm to 350 mm. SITE records around

340–350 mm, reflecting a more balanced distribution. The shift over time suggests a trend of increasing rainfall variability, with the 2020 spike potentially linked to extreme weather events. These patterns may have implications for flood risk, drainage planning, and urban infrastructure resilience while also highlighting fluctuations in the site's hydrological conditions, which can affect agriculture, groundwater recharge, and ecosystem dynamics (Figure 7).

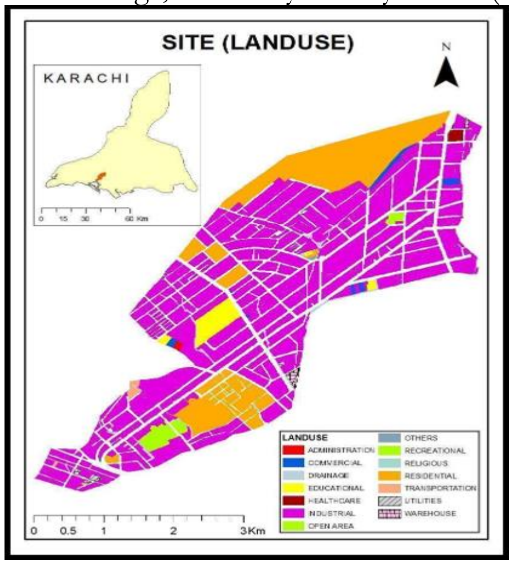

Figure 4. Land Use and Land Cover of Industrial Site Area

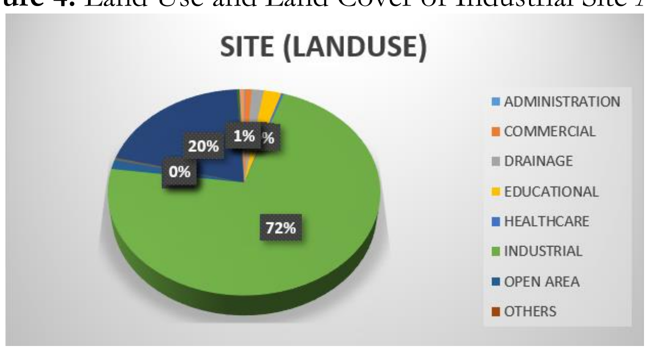

Figure 5.LULC of SITE Area

Table 1. Site Area, Land Use, and Land Cover

LAND USE	AREA (SQUARE METER)	AREA (%)
ADMINISTRATION	14792.625	0.113
COMMERCIAL	113275.560	0.863
DRAINAGE	207832.689	1.584
EDUCATIONAL	302316.543	2.304
HEALTHCARE	41493.249	0.316
INDUSTRIAL	9443443.783	71.965
OPEN AREA	189429.442	1.444
OTHERS	6510.196	0.050
RECREATIONAL	39538.618	0.301
RELIGIOUS	3963.881	0.030
RESIDENTIAL	2634726.711	20.078
TRANSPORTATION	47106.643	0.359
UTILITIES	10387.486	0.079
WAREHOUSE	67411.435	0.514
TOTAL AREA	**13122228.861**	100.000

The NDVI (Normalized Difference Vegetation Index) for SITE during June is shown for the years 2015, 2020, and 2025. NDVI reflects vegetation health, with green areas indicating dense, healthy vegetation and brown/yellow areas representing sparse, stressed, or degraded vegetation. In 2015, healthy vegetation was primarily concentrated in the southern and southwestern parts of the site, while other areas showed limited greenery. By 2020, there was a slight decline or stagnation in vegetation cover, with more brown and yellow zones emerging, suggesting possible land degradation, increased human activity, or urban expansion. However, by 2025, a clear improvement is evident, with enhanced greening across much of the site, particularly in the central and northern regions. This greening indicates a recovery or restoration of vegetation, potentially due to conservation efforts, natural re-growth, or improved land management. The maximum NDVI value increases from 0.211783 in 2015 to 0.236832 in 2025, reflecting a positive overall trend in vegetation health and density over the decade (Figure 8).

The Land Surface Temperature (LST) maps for SITE illustrate changes in ground temperature over time. Warmer colors (red/yellow) indicate higher temperatures, while cooler colors (blue) represent lower temperatures. In 2015, SITE shows a mix of temperature zones, with cooler areas concentrated in the north and southwest and warmer zones scattered in the center and southeast. From 2015 to 2020, high-temperature zones expanded significantly, especially in the central and southern regions, suggesting a rise in overall land temperature, likely due to vegetation loss or urban expansion, as supported by NDVI trends. By 2025, there will be a noticeable reduction in red zones and an increase in blue, particularly in the southern and northwestern parts, indicating partial temperature recovery. This cooling trend aligns with improved vegetation cover observed in the 2025 NDVI map. Overall, LST peaks in 2020, followed by partial mitigation by 2025 (Figure 9).

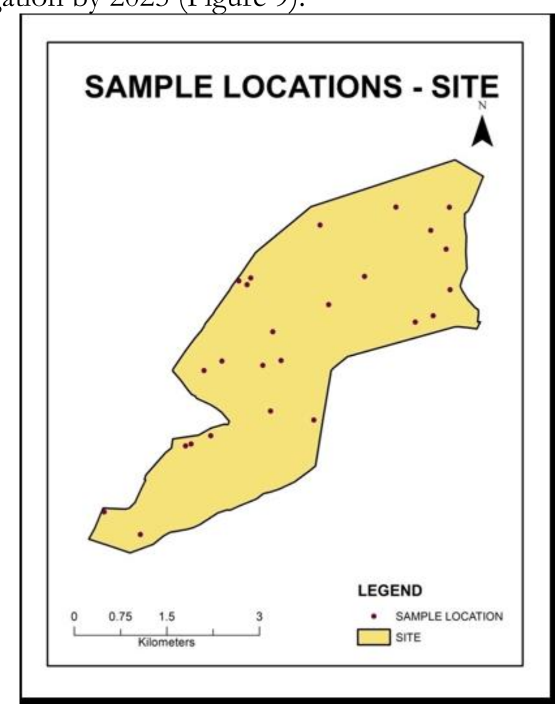

Figure 6. Site Area: Random Points

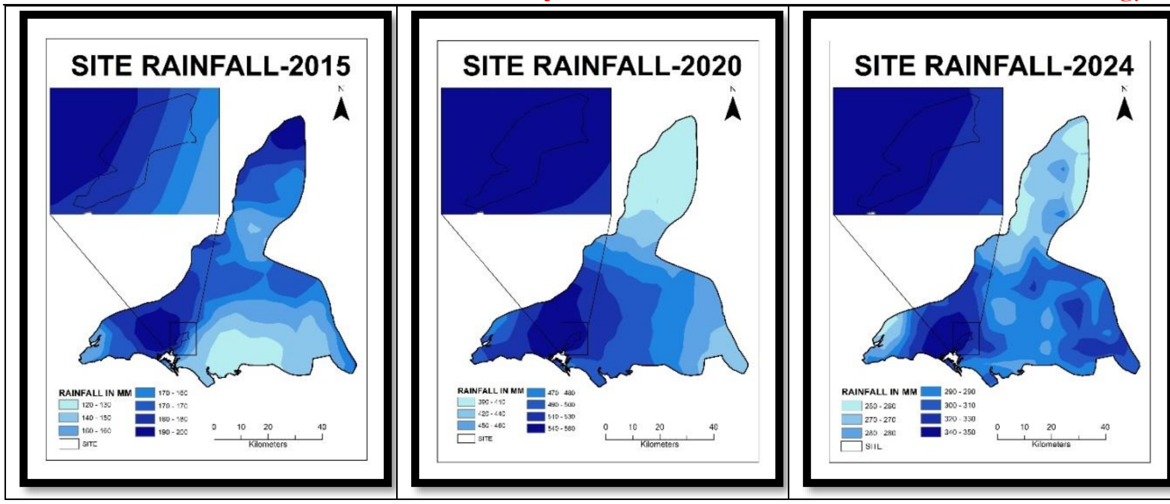

Figure 7. Site Area; Rainfall (2015-2023)

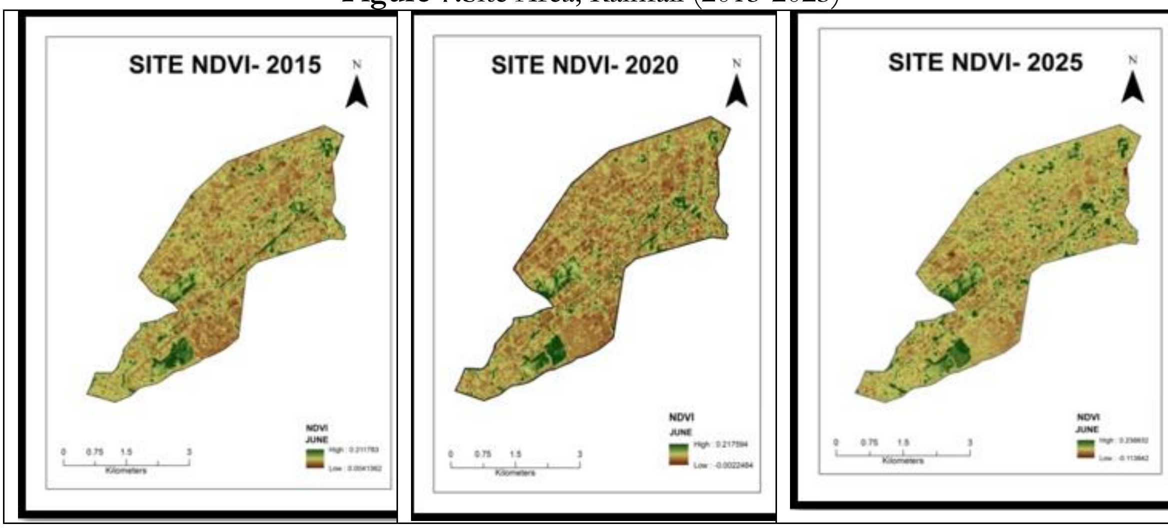

Figure 8. Site Area; NDVI (2015-2025)

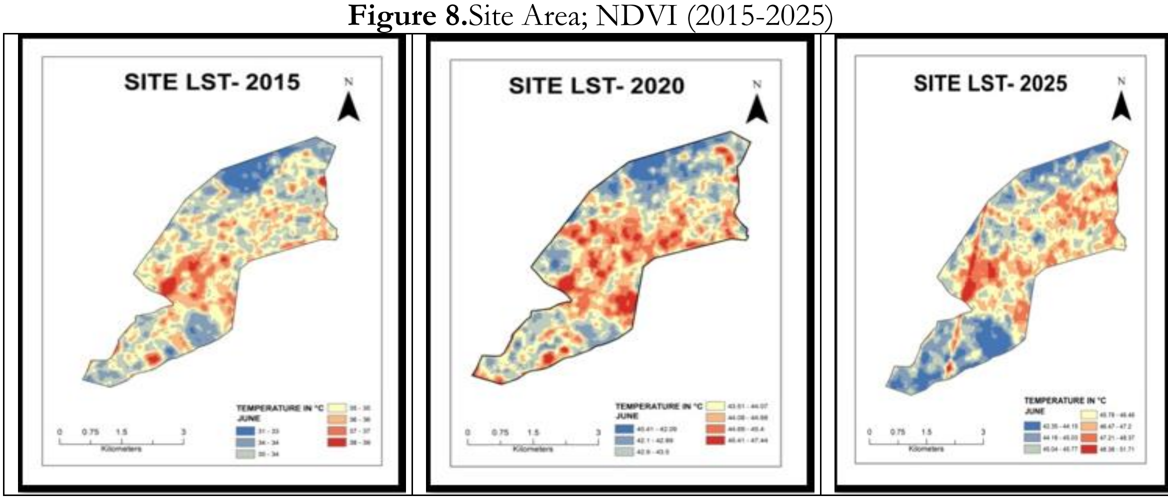

Figure 9. Site Area: LST (2015-2025)

Table 2.NDVI and Temperature (^{O}c) Of Random Points (2015-2025)

RANDOM POINTS	2015		2020		2025	
	LST	NDVI	LST	NDVI	LST	NDVI
1	32.98	0.05	42.34	0.05	44.28	0.06
2	34.46	0.02	44.21	0.02	45.92	0.02
3	34.02	0.05	43.89	0.06	45.77	0.06

4	35.77	0.02	44.29	0.00	45.93	0.02
5	34.60	0.03	43.10	0.03	47.40	0.03
6	33.37	0.05	43.26	0.04	46.38	0.05
7	33.77	0.05	43.49	0.09	47.05	0.10
8	35.51	0.04	45.84	0.05	47.88	0.05
9	34.60	0.03	43.43	0.05	46.46	0.03
10	35.01	0.05	43.75	0.04	47.15	0.05
11	33.29	0.04	43.09	0.03	44.65	0.04
12	34.94	0.05	43.69	0.06	45.77	0.06
13	31.60	0.04	41.11	0.04	44.13	0.04
14	33.89	0.06	43.94	0.08	45.12	0.07
15	33.29	0.06	43.12	0.04	44.14	0.05
16	33.52	0.05	42.86	0.08	45.14	0.06
17	35.16	0.05	43.72	0.03	46.61	0.03
18	35.41	0.04	45.27	0.07	47.29	0.03
19	34.90	0.04	44.67	0.04	45.90	0.04
20	34.04	0.03	43.36	0.03	45.62	0.03
21	34.25	0.08	42.70	0.07	44.70	0.09
22	34.40	0.06	44.68	0.05	47.66	0.05
23	33.47	0.05	43.58	0.04	46.00	0.05
24	35.17	0.06	41.75	0.10	46.57	0.08
25	37.71	0.04	46.14	0.04	48.86	0.02

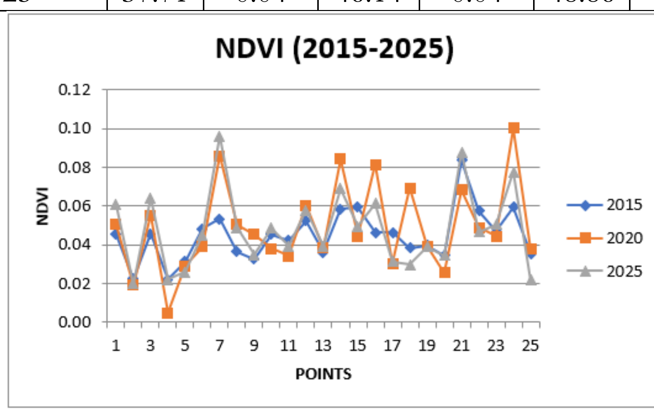

Figure 10.NDVI of Random Points

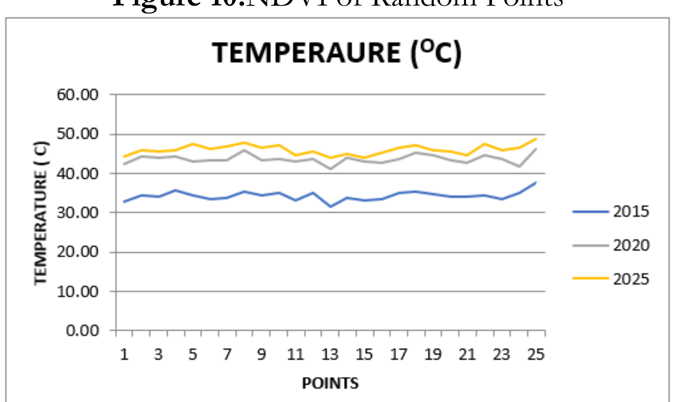

Figure 11.TEMPERATURE (^{O}C) OF RANDOM POINTS (2015-2025)

Conclusion and Recommendation:

This study highlights the impact of climate change and urban-industrial growth on the SITE area in Karachi from 2015 to 2025. A decline in vegetation cover and a rise in land surface temperatures between 2015 and 2020 suggest increasing environmental stress, likely driven by unregulated industrial expansion and rainfall variability. However, by 2025, signs of ecological recovery—such as improved NDVI and cooler temperatures—point to potential benefits from natural regrowth or better land management. Rainfall patterns, marked by extreme variability, further underline the area's vulnerability to climate change. These fluctuations not only affect vegetation health but also have implications for water availability, heat exposure, and overall urban livability. Overall, SITE reflects the broader challenges of urban-industrial areas under climate pressure, but also shows that recovery is possible with targeted action and informed policy support.

To enhance climate resilience in SITE, urban greening should be promoted through tree planting and green infrastructure. Green corridors can help regulate temperature and support biodiversity within the industrial landscape. Land use planning must control industrial sprawl and protect open spaces to maintain ecological balance. Improved water management—such as rainwater harvesting and storm water reuse—can help buffer rainfall variability and reduce flooding risks. Industries should adopt climate-friendly practices to reduce emissions and surface heat retention. Regular monitoring using satellite data and GIS tools can guide adaptive strategies and timely interventions. Lastly, local engagement and policy alignment with national climate strategies are essential to ensure inclusive, long-term, and sustainable development in Karachi's industrial zones.

By adopting climate-resilient practices and transitioning to low-carbon technologies, Karachi's industries can reduce their environmental footprint, mitigate climate-related risks, and contribute to a more sustainable future.

References:

1. Government of Sindh. (n.d.). Sindh Industrial and Trading Estate (SITE). Retrieved from (link unavailable)
2. Pakistan Bureau of Statistics. (n.d.). Industrial Statistics. Retrieved from (link unavailable)
3. Hasan, A. (2015). Understanding Karachi: Planning and Reform for the Future. City Press.
4. Khan, S. R. (2018). Industrialization in Pakistan: A Review. Journal of Economic and Social Development, 14(1), 1-15.
5. World Bank. (2020). Pakistan: Climate Change and Economic Development.
6. Idrees, M., Nergis, Y., & Irfan, M. (2023). Industrial Emission Monitoring and Assessment of Air Quality in Karachi Coastal City, Pakistan. Atmosphere, 14(10), 1515. (link unavailable)
7. Intergovernmental Panel on Climate Change (IPCC). (2021). Climate Change 2021: The Physical Science Basis. Cambridge University Press.
8. U.S. Geological Survey. (n.d.). *EarthExplorer*. U.S. Department of the Interior. https://earthexplorer.usgs.gov/
9. Climate Hazards Center. (2024). CHIRPS v3.0 annual global rainfall data (2015, 2020, 2024) [GeoTIFF data set]. University of California, Santa Barbara. https://data.chc.ucsb.edu/products/CHIRPS/v3.0/annual/global/tifs/
10. Climate Hazards Center Infrared Precipitation with Stations version 3. CHIRPS3 Data Repository https://doi.org/10.15780/G2JQ0P (2025).