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Impact of Urbanization on River Ecology – A GIS Technologies Perspective

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Abstract. Malir River which is the major seasonal river of Karachi once supported the market gardening practiced in Karachi. Its valleys and plains, once comprises the cultivated lands of vegetables and fruits that fulfilled the local market demand. But with a shift in rainfall characteristics, the cultivation also started to recede slowly as many of the crops could not withstand the prolonged drought conditions and farmers were not ready to take the risks and hence abandoned cultivation. Hence, changing climate gives way to the industrialization of rapidly growing urban center which in turn inducing desertification. Since the cultivated land which is supplied with water also is helpful in evapo-transpiration leading to precipitation by taking part in the water cycle. But the whole process was disrupted by the abolition of agricultural activity in the area. The study gives a GIS (Geographical Information Sciences) perspective of Land Use/Land Cover of the southern part of Malir plain near its mouth – the Korangi and Landhi Area which were also the active flood plains of Malir during 1960s. Since the huge urbanization and population growth has led to water scarcity in the area due to the reduction of underground aquifers and the reduction of agriculture, high research efficiency can be achieved using satellite imagery and GIS.

Keywords: Seasonal Rivers, market gardening, Industrialization, active flood plains, evapo-transpiration, GIS and water cycle.

1. Introduction

Overwhelming population leads to increasing urbanization that gives rise to several problems that seriously affect water resources (Khan et al., 2021; Hussain et al., 2022) especially in the under developed world where prior planning is not a matter of concern, just land occupancy is the ultimate goal. The world's urban population is more than the rural population; about 55%was residing in urban areas in the year 2018 increased from 30% in 1950 (UN, 2018). The indifferent occupation of land causes depletion of resources that include the removal of vegetation cover, conversion of arable land into residential land, or industrial area's occupation of dried river beds and even the active flood

plains of perennial rivers that results in calamities during the rainy seasons or storms. Such problems are quite common in the South Asian countries like India, Pakistan and Bangladesh comprising of large river systems of Indus, Ganges and Brahmaputra (Sihag et al., 2021). Transformation of dried river beds and arable land into residential area commercial or industrial areas is common in many urban areas that comprise of seasonal rivers instead of perennial rivers. Depletion and demolition of resources with the increase of population is more common in urban areas as compared to rural areas where population is more dependent upon the machinery and electronic gadgets rather than the works of nature. Since ecosystems in urban areas are strongly influenced by anthropogenic activities, considerably more attention is currently being directed towards monitoring changes in urban land use/land cover (LULC) (Stow & Chen, 2002). Karachi, the major urban center and economic hub of Pakistan epitomize such cases of transformation of land use and vegetative land cover to build up areas.

Karachi comprises of the two seasonal rivers: Malir and Lyari. The two rivers where the fresh water river which was used for drinking and supporting agriculture fields along the banks. In fact, most of the Karachi's industrial areas of Korangi and Landhi were once the active flood plains of Malir River and the residential areas of Liaquatabad and Lyari it were the lush green fields along the banks of Lyari River that are now completely transformed into urban structures. According to Pithawala and Kaye, a large area between the Drigh Road-Gizri Hills and the Ibrahim Haideri-Landhi rise are that of the Malir River with the supply of fresh water being extracted from the alluvium of Lyari River for several years but Malir alluvial deposits are more important water bearing strata. Therefore, a system of wells has been sunk near Dumlotte, beyond Malir. Even the fields were supported by the wells all along the river banks other than the drinking purposes in the villages (Pithawala & Kaye, 1946). Although the two rivers were seasonal, but they were the main sources of agriculture and even fishing. The population increase was tremendous especially after the independence in 1947 due to the influx of migrants from India. The heavy urbanization transformed river's ecology and the valuable flood plain of Malir about twice the length of the Lyari as mentioned by the (Pithawala & Kaye, 1946) has been converted completed to the major industrial area of Landhi and Korangi instead of continuing the agriculture. This has also influenced the water availability and now the city is facing scarcity of water. The water requirement for industrial and domestic purposes is increasing at a much faster rate, especially in the countries with emerging or growing economies, although the demand for water is greater for agriculture purpose (UN WWAP, 2018).

One reason behind the heavy urbanization of the city is its coastal location. A considerable proportion of the world population is situated along or near the coasts, which is about 10% of the earth's land surface (Hinrichsen, 1998). This shows an enormous pressure of population on coastal lands and round the world, coastal lands are highly preferred lands. The population of Karachi increased abruptly due to the influx of migrants after the independence in 1947. But yet it kept on increasing overwhelmingly much after it i.e., during 1980s and onwards just because a huge amount of population from rural and other areas of Pakistan moves to the city in search of jobs. The fact is visible in the (Fig. 1) showing the population of Karachi since 1941. Though the population increased in 1951 and 1961 as compared to 1941 attributed to the influx of migrants from India, but if 1972 is compared to 1998, the increase is significantly more. Unfortunately, due to conflicting information provided by various sources, it is not possible to give exact figures for population growth, so as not to be misleading. However, Figure 1 clearly shows the ratio of the number of inhabitants in different years.

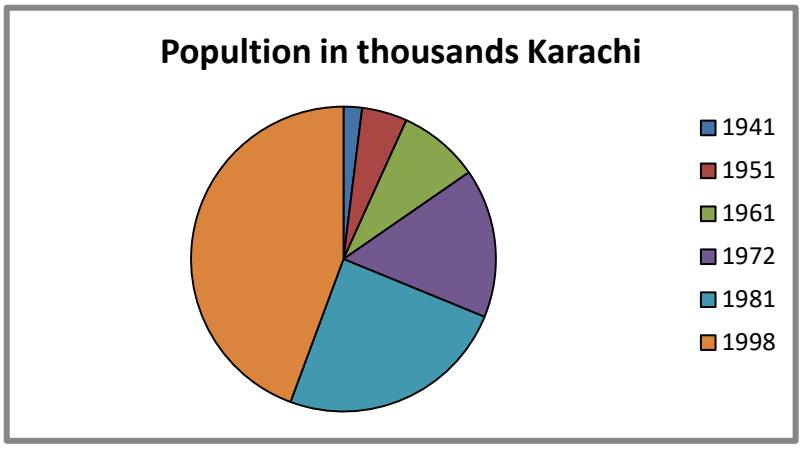

Figure 1. Karachi City Population (in Thousands) 1941-1998 (Source: Federal Bureau of Statistics Division, Government of Pakistan)

There is a dire need to find out the causes of the problems of water shortage, increased infertile soil, removal of agriculture and increased population pressure leading to the drying of Malir River and its gradual conversion into a sewage drain. Hence, the study is performed to achieve the above objective. This may help to find the possible mitigation of the problems.

The whole study is being successfully carried out through the use of remote sensing and GIS techniques. The unique capability of GIS to compile the past and present LULC data along with the picture of the ongoing conditions helps understand the future scenario. This gives and impetus to the future planning and management of any resource being utilized.

The effectiveness of Geospatial techniques in regular monitoring of multitemporal variations

of LULC (land use and land cover) classes has been described by (Kachhwala, 1985; Brondizio et al., 1994; Jensen 2005; Bakr et al., 2010; Ahmad & Quegan, 2012). Prasad et al. (2018) and Mishra et al. (2020) emphasize the perfect insight of RS (Remote Sensing) and GIS technology regarding the provision of spatiotemporal data of land-use maps. Along with their global approval by scientific society for judgement accuracy.

2 Materials and Methods

2.1 Study Area

The Study Area is basically focused upon south eastern Malir River flood plains – the industrial areas mainly and the residential areas of Korangi and Landhi. Malir River is a seasonal river that starts from the confluence of two rivers: Khadeji and Mol east and northeast of Karachi, passes through a wide valley between the Drigh Road hills and the Ibrahim Haideri-Landhi ridge. The River terminates at Gizri Creek which joins with the Korangi Creek before meeting the sea (Fig. 2) (Pithawala & Kaye, 1946).

In the valley of Malir a good market gardening flourished even in the southern flood plains cultivation was practiced. This is the main area that comprises the heavy industrial areas of Korangi and Landhi in Karachi. Most of them were previously the cultivated or virgin lands along the banks of the fresh Malir River. Malir Alluvium for many years provided the entire water supply of Karachi from the wells at Dumlotte while the villages have their individual wells (Pithawala & Kaye, 1946).

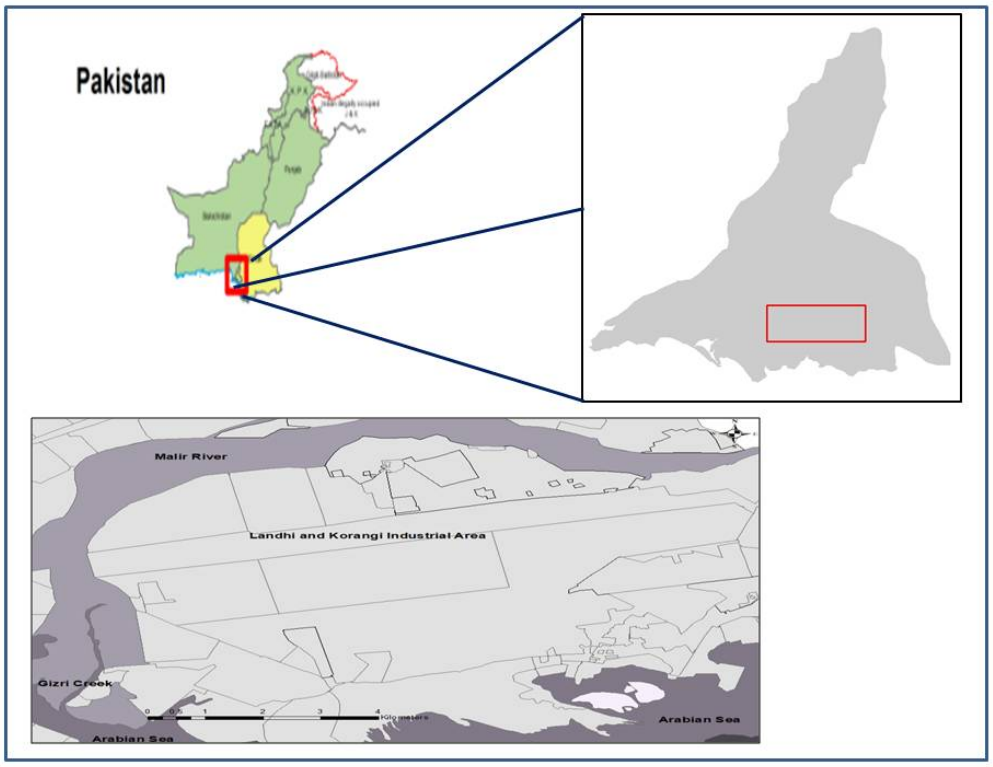

Figure 2. Study Area

2.2 Study Plan

In the current study an Aerial Mosaic of the year 1955, a panchromatic image of Corona for the year 1966, and several multispectral satellite images of LandSat for the year 1973, Land Sat ETM of 2000 and Land Sat ETM, OLI 2013, SPOT for the year1986 and QuickBird were acquired showing the past Malir flood plain and present Landhi and Korangi Industrial Areas of the city were utilized. All the satellite images and map were geometrically corrected, and the images were georeferenced on a single projection UTM WGS 1984. Image enhancement had been performed through ERDAS Imagine 9.2 in order to make the images interpretable. Since the basic purpose was to analyze the changes in the main flood plain of Malir River and the associated agricultural activities through time, vector layers for different land uses and the main Malir channel has been extracted through on screen digitization in an ArcMap 10.1 environment. Later, the maps were compared and analyzed to extract the changes occurred in the main Malir River channel and its associated activities.

3. Results and Discussions

The Aerial Mosaic of the year 1955 (Fig. 3) shows a wider channel of Malir River and a vast area of land covered with a little land use, i.e. villages and a patch of cultivation in the Landhi and

Korangi area on the eastern and southern bank of Malir River, of Ibrahim Haidery and Gizri Creek. Several narrow channels of water or the smaller seasonal streams can also be seen in the area. The features reveal that it was an active flood plain of Malir River during those days. Since a smaller village and the cultivated area of approximately 3 km^2 is situated at a distance from the immediate bank of Malir River. This shows that Malir River overflows further inland during the rainy season. A narrow channel can also be seen branching out north of the mouth of Malir. The land must be fertile and there must be rich underground aquifers that can support strong vegetation and the crops in the lower Malir Basin. Still, these fields exist though dried and many of them converted to residential areas, but in the southern flood plain the lands are converted to the industrial area of Landhi and Korangi.

On the other hand, the satellite image of 1966 (Fig. 4), reveals a different scenario with a broader channel of Malir River showing the flood conditions due to heavy rains in the previous years from 1961–1965 (Table 1), and the development of the industrial area which was established in 1960s but became operational in 1970 **(**Korangi Association of Trade & Industry**,** 2010) with National Oil Refinery situated immediately along the bank of the river. Since It was incorporated in 1963, first lube refinery was created in 1966 (Wikipedia). While the narrow tributary, branching out in the flood plain (Fig. 3) in 1955 aerial mosaic, disappeared in the year 1966 (Fig. 4).

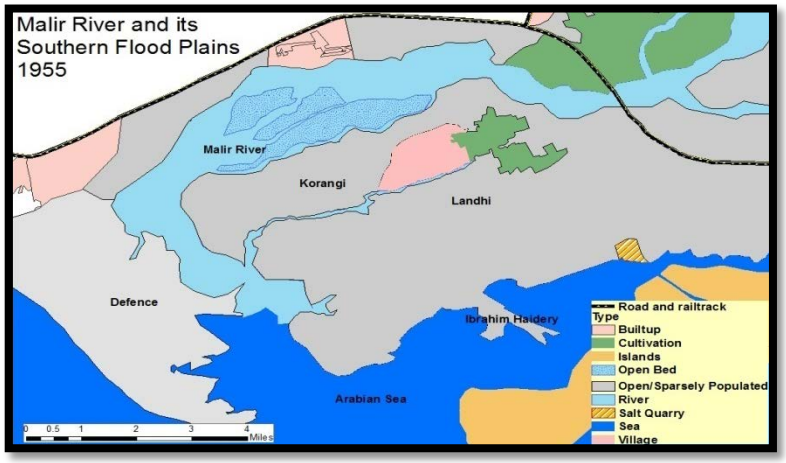

Figure 3. Karachi 1955 showing Malir flood plains of Korangi and Landhi

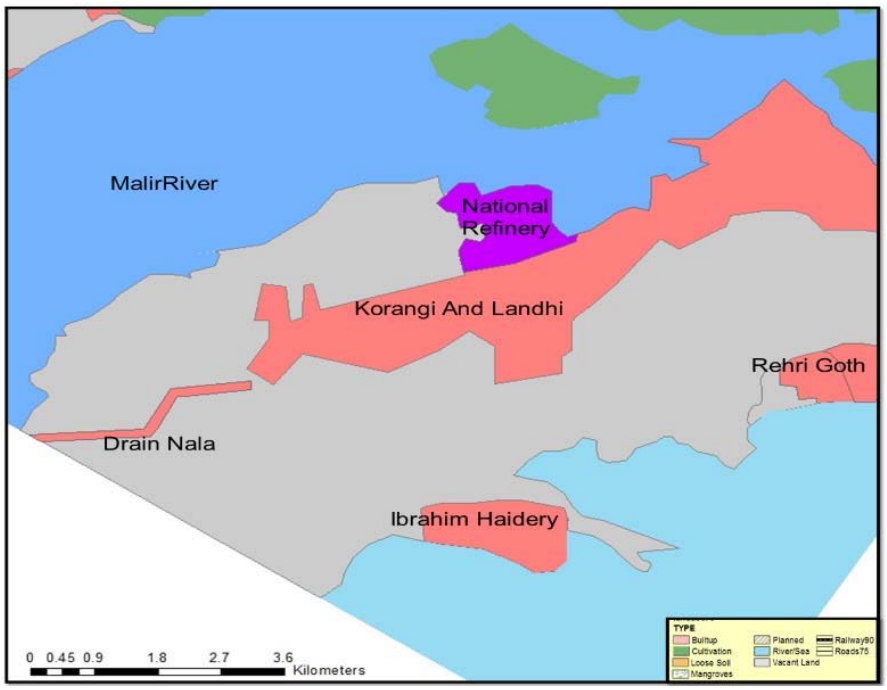

Figure 4. Karachi 1966 showing Malir River and its adjacent industrial area

Table 1. Rainfall in Karachi 1961-1990 (Source: Pakistan Meteorological Department, Government of Pakistan).

Year	Rain (mm)	Year	Rain (mm)	Year	Rain (mm)	Year	Rain (mm)
1961	621.8	1971	68.0	1981	185.0	2000	46.9
1962	278.7	1972	44.2	1982	161.2	2001	100.4
1963	43.7	1973	213.4	1983	281.5	2002	55.8
1964	140.1	1974	7.1	1984	269.3	2003	324.9
1965	129.5	1975	159.9	1985	155.0	2004	65.9
1966	70.1	1976	406.1	1986	92.0	2005	97.2
1967	713.0	1977	439.0	1987	0.0		
1968	29.0	1978	386.5	1988	160.0		
1969	39.4	1979	381.0	1989	189.7		
1970	475.0	1980	193.8	1990	136.4		

Further if the satellite images of 1973 and 1986, (Fig. 5 and Fig. 6), will show a well developed industrial area as well as National Oil Refinery. The small cultivated patch in the middle of the river (Fig. 4) was along the bank of the river; approximately about 4 km^2 provides evidence that the river water retreated to its narrow channel instead of inundating the surrounding area; though the rainfall received during 1973 was 213.4 mm (Table 1). There is no sign of embankments along the Malir River in 1973 which indicates that area still inundated during heavy rainfall.

The aggravated condition can be observed in the year 1986 (Fig. 6), with highly developed industrial area, the Malir River delimited to a narrow channel with progressively decreasing rainfall

and the cultivated patch along the river bank had encroached in to the bed of the river, approximately about 7 km^2. Embankments were created along the river bed and cultivated patches can also be observed on the northern banks; in fact encroached into the bed of the river due to lesser rainfall about 46 mm in the year 1986 and during 1987 there was 0 mm rainfall (Table 1) received in Karachi; attributed to Monsoon failure. Dependency on ground water increased since 1980s. The drain line present along the mouth of the river disappeared in 1986 and even the mouths of the Malir River also seemed to shrink with greater extent of dried land with a patch of mangroves.

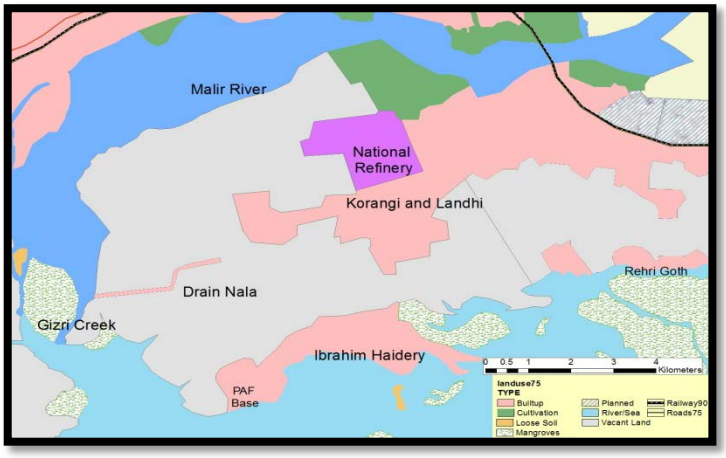

Figure 5. Karachi 1973 showing Malir River and the extent of Industrial Area

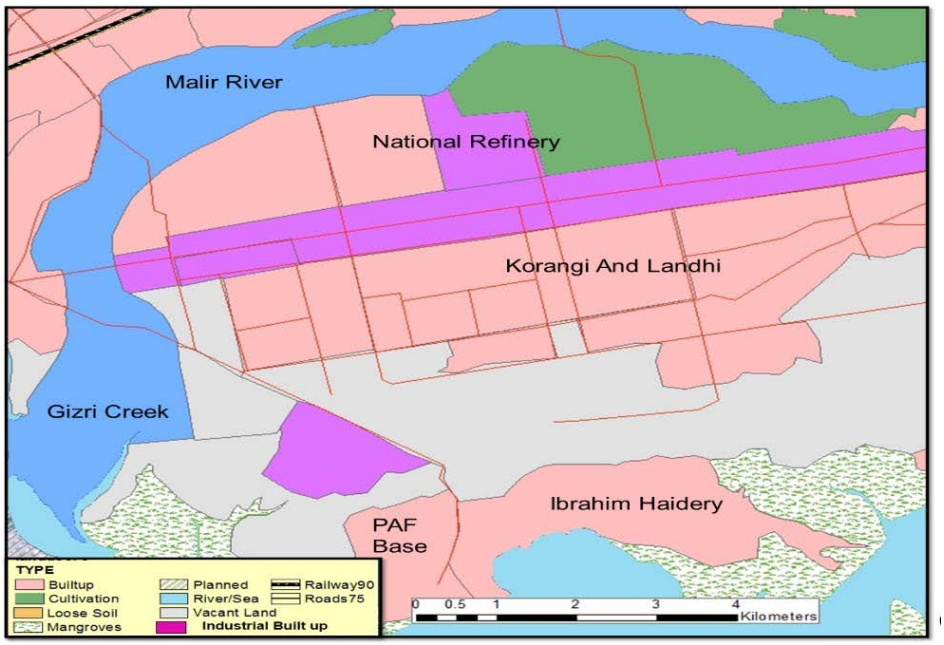

Figure 6. Karachi 1986 showing Malir River and the extent of Industrial Area

Finally the beginning of the present condition of Malir River and its surrounding flood plains of the past is analyzed by studying the 2018 satellite image (Fig. 7), an overwhelming condition is obvious: the highest degree of urbanization can be inferred by the fact that the complete land is occupied by the industrial, commercial and residential land-uses. No vacant land can be observed except a small patch near the mouths of the Malir River that is in fact the swampy land and a few patches near Korangi Fishing Harbor, just north of the Harbor is actually the land where cultivation was discontinued due to unavailability or shortage of water. Some new cultivated areas can be seen where cultivation is possible through sewage water. The most crucial phenomenon that can be observed is that the cultivation along the bank of the Malir River that existed since 1960s and further encroached into the river bed was itself intervened by the built-up land probably residential – a fact that shows the unavailability of water either ground water, rain water or river water.

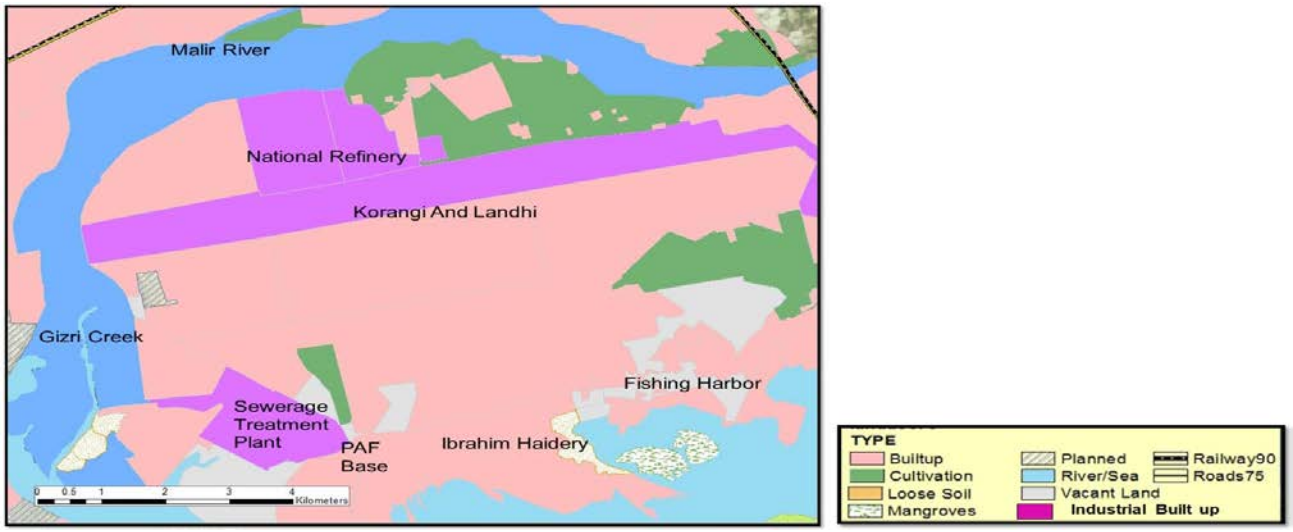

Figure 7. Karachi 2018 showing Malir River and the extent of Industrial Area

4. Conclusion

After studying the development of Malir flood plains from cultivated land to highly concentrated industrial area and vice versa, following facts are concluded:

Malir Flood Plain was a resource with highly fertile land and rich underground water resources.

Hence, it would have been wiser if the flood plains were conserved either as cultivated land or green belt areas by developing farms or gardens.

Instead, the indifferent development of the city without prior planning has engulfed many resources, like this fertile flood plain of Malir.

Had the flood plain been conserved as a cultivated area or a green belt, it would have contributed towards Water Cycle through evapo-transpiration leading to condensation and eventually precipitation as well as it would replenish the underground water reserves.

As an industrial area it has not only degraded the land but also decrease the fertility, contaminated the soil and water resources as well as over extracted the ground water.

References

Ahmad A. & Quegan S., 2012, Analysis of maximum likelihood classification on multispectral data, Applied Mathematical Sciences 6: 6425–6436. https://doi:10.1016/S0034-4257(01)00311-X.

Bakr N., Weindorf D.C., Bahnassy M.H., Marei S.M. & El-Badawi M.M., 2010, Monitoring land cover changes in a newly reclaimed area of Egypt using multi-temporal Landsat data. Applied Geography 30: 592–605.

Brondizio E.S., Moran E.F. & Wu Y., 1994, Land use change in the Amazon estuary: patterns of Caboclo settlement and landscape management. Human Ecology 22(3): 249–278.

Federal Bureau of Statistics Division, 1998, Government of Pakistan.

Hinrichsen D., 1998, Coastal Waters of the World: Trends, Threats, and Strategies. Island Press, Washington D.C.

Hussain K., Khan N.A., Vambol V., Vambol S., Yeremenko S. & Sydorenko V., 2022, Advancement in Ozone base wastewater treatment technologies: Brief review. Ecological Questions 33(2): 7–19. https://doi.org/10.12775/EQ.2022.010

Jensen J.R., 2005, Introductory digital image processing: a remote sensing perspective (third edition)., Pearson prentice hall series in geographic information science. Pearson Prentice Hall, Upper Saddle River, NJ: 373–374

Kachhwala T.S., 1985, Temporal monitoring of forest land for change detection and forest cover mapping through satellite remote sensing. Proceedings of the 6th Asian conference on remote sensing. National Remote Sensing Agency, Hyderabad: 77–83.

Karachi Association of Trade and Industry, 2010. https://kati.pk (Accessed: 10th December 2018).

Khan R.A., El Morabet R., Mallick J., Azam M., Vambol V., Vambol S. & Sydorenko V., 2021, Rainfall Prediction using Artificial Neural Network in Semi-Arid mountainous region, Saudi Arabia. Ecological Questions 32(4): 127–133. https://doi.org/10.12775/EQ.2021.038

Mishra P.K., Rai A. & Raj S.C., 2020, Land use and land cover change detection using geospatial techniques in Sikkim Himalaya, India. Egyptian Journal of Remote Sensing and Space Sciences 23(2): 133–143. https://doi.org/10.1016/j.ejrs.2019.02.001

Pakistan Meteorological Department, Karachi, 2012, Karachi Rainfall Data from 1951–2012.

Pithawala B.M. & Kaye M.P., 1946, Geology and Geography of Karachi and Its Neighbourhood. Daily Gazette Press, Karachi: 06

Prasad G., Vinod P.G. & Shaleena E.J., 2018, Delineation of ground water potential zones using GIS and remote sensing – A case study from midland region of Vamanapuram river basin, Kerala, India. AIP conference proceedings, international conference on electrical, electronics, materials and applied science 1952(1): 20–28. https://doi.org/10.1063/1.5031990

Sihag P., Sadikhani M.R., Vambol V., Vambol S., Prabhakar A.K. & Sharma N., 2021, Comparative study for deriving stagedischarge–sediment concentration relationships using soft

computing techniques. Journal of Achievements in Materials and Manufacturing Engineering 104(2): 57–76. https://doi.org/10.5604/01.3001.0014.8489

Stow D.A. & Chen D.M., 2002, Sensitivity of Multi-Temporal NOAA AVHRR Data of an Urbanizing Region to Land Use/Cover Changes and Misregistration. Remote Sensing of Environment 80: 297–307.

UN (United Nations), 2018, World Urbanization Prospects: The 2018 Revision [key facts]. https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf (Accessed: 7th December 2018)

UN WWAP (United Nations World Water Assessment Programme), 2018, The State of World. https://reliefweb.int/sites/reliefweb.int/files/resources/261424e.pdf (Accessed: 7th December 2018).