Urban Vegetation and Population Variability in Pakistan. A GIS and Remote Sensing Analysis of Peshawar, Karachi, and Lahore (1990-2020)

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Abstract

This research examines urbanization and demographic variations of Peshawar, Karachi, and Lahore that can be found in years from 1990 to 2020, the use of GIS and remote sensing technology has been utilized in this research. The research proposes to use the data from Landsat imagery received through NDVI and NDBI values to have a clear picture of how population changes, urbanization and vegetation cover are related. The research uses two indices: NDVI and NDBI, together with data from the census, to carry out a detailed analysis of the growth of cities, changes in vegetation cover, and the distribution of population. The study reveals distinct trends across the three cities: Lahore and Peshawar among others experience a tangible upsurge in NDBI values with time, implying a fast urban sprawl and an increase in built-up area. As NDVI values fall, it is a tell-tale sign that the urbanization process is accompanied by a reduction in vegetation. Besides, Karachi showed relatively constant NDVI values even in conjunction with the urban growth, however, its NDBI values have increased notably, showing the rapid urbanization without massive vegetation decrease Such facts demonstrate the interplay between urban expansion and ecological changes, thus the need for sustainable city development and green infrastructure is pointed out to decrease the negative aspects. The study also advocates a much clearer perception of urbanization fluctuations at the regional level and suggests consequently designed targeted strategies for urban management and environmental conservation in Pakistan.

Keywords: Urban Vegetation, Population Variability, Karachi, Peshawar, Lahore Pakistan

INTRODUCTION:

Urbanization is a significant worldwide phenomenon that has significant effects on public health, environmental sustainability, and social and economic growth (United Nations, 2018). By way of the urbanization process that is a big deal, there is a public health and environmental sustainability problem; social and economic growth is also affected (United Nations, 2018). Saddled with urban expansion in its largest cities, the bursting of population, repartitioning of land, and changes in environmental patterns have ensued from the process (Imran and Mehmood, 2020). The present-day situation in the country where there are the 'three top cities', Peshawar, Karachi, and Lahore, proves an over-urbanization with all the same effects – air and water pollution, infrastructure spreading, and forested area reduction (Mahboob et al., 2015). The interplay between urban vegetation dynamics and demography has been discussed by several studies and it is crucial for ensuring environment management and efficient planning (Aslam et al., 2021). This study prompts a practice of using facts-based decision-making in urban planning and policy formulation to counteract the effects of urban development on the environment which include water and air pollution, heat islands, and habitat loss. Politicians are capable of adopting certain policies to result in more urban greenery spaces and enhance the quality of life of urban people by evaluating the associations between vegetation, built-up areas, and population change (Estoque & Murayama, 2015). The study of urban area vegetation and human population in Peshawar, Karachi, and Lahore is very vital key to the solution to one of the uncertain problems which is sustainable urbanization in Pakistan. Full integration I policies that balance economic development, protection of natural resources, and social justice, as urban growth picks up around the country (Imran & Mehmood, 2020), must be of paramount importance. This research widens the knowledge about the urban dynamics in Pakistan through complex different factors and resource data. Moreover, it gives recommendations for ensuring the inclusion of resilience in the development of cities that are both safe and pleasant. This study research paper aims to improve knowledge of the spatial relation between urban vegetation change and population growth in Pakistani cities using GIS and Remote Sensing. This study seeks to address this issue by combining research and practical application to guide urban planning and policymaking processes toward the goal of making cities more resilient and sustainable in Pakistan and other regions (Arif et al., 2023). This research is conducted by amalgamating the literature from the urban geography, environmental science, remote sensing, and GIS-related fields that explore the change in urban vegetation cover and population in Pakistani cities. Previously researchers have shown that the presence of green spaces in highly urbanized areas can mitigate some negative effects of urbanization such as heatwaves, air pollution, and mental health issues (Wang et al., 2011). Different studies that examine the role of

remote sensing in green space dynamics concerning population increase in Pakistan cities are rare. The research focuses on investigating the magnitude and intensity of urbanization and its effects on vegetation cover, enabling a better comprehension of the different factors stimulating the growth of Pakistan's urban landscape (Srbinovska, 2015). The present study is conceptualized with this specific goal to provide direct benefit for urban planners, politicians, and environmental professionals of Pakistan. Local authorities will be able to take the lead in the promotion of green infrastructure, urban vegetation, and environment quality by targeting lower-income settlements with less vegetation cover (Soomro, 2021). Through such research, reasons and results for urban growth in Pakistan, especially environmental imbalances that are directly associated with agriculture and population richness, can be better understood. This study will provide evidence that can inform decision-making in the sphere of urban planning and also act as the basis for many policies in that area. the purpose of this project would be to enhance the living conditions and build up the concept of sustainability for the city of Pakistan and other regions. The effects of metropolis life generate greater population growth as well as alteration in land use systems that occur at an increasing rate with the fast-paced urbanization in Pakistan The research is based on innovative remote sensing techniques for the evaluation of urban structural changes in the cities of Peshawar, Karachi, and Lahore throughout 1990 through 2020, giving priority to the measurement of key indicators such as NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up Index). NDVI allows for a very accurate analysis of vegetation status in urban areas, for instance by providing information regarding the location, condition, and variation of vegetation over time (Baqa et al., 2022). The NDBI also assists in spatially recognizing and measuring built areas, which gives insight into the magnitude and characteristics of the processes of urbanization (Varshney, 2013). The research endeavors to address the complicated nature of this chain which supports urban vegetation dynamics, built-up areas, and population sizes through integration. The periods chosen (1990, 2000, 2010, and 2020) will display an elaborate urban structure evolution (of the last 30 years). As a result, the exact trends, occurrence, and critical moments in the correlation between urbanization and population changes will be examined Consequently, this method of the longitudinal study corresponds with other research in Pakistan that was carried out on urbanization and climate dynamics, making it possible to get a comparative outlook (Shah et al., 2022). These techniques are used to analyze the impacts of land-use changes on urban growth and provide a conceptual framework for urbanization analysis. The paper ends by summarizing important discoveries, discussing their impact on the sustainable growth of cities in Pakistan, and suggesting areas for future study, which adds to the growing knowledge of urban processes in developing areas.

MATERIAL AND METHODS:

Study Area:

The study area for this research article encompasses three major cities in Pakistan: Along with these main cities, a significant number of people are infected with the virus in critical situations in Quetta, Peshawar, and Lahore. Peshawar, the capital of Khyber Pakhtunkhwa province in the northwestern part of Pakistan, bordering Afghanistan is about seven miles away from the city Samarkand and two and a half miles away from Jalalabad which is located in the east. It has the longest cultural history in the area and acts as the capital of the main cultural, economic, and administrative Island. Karachi, being the central city of the province of Sindh in the Southern part of the country, is Pakistan's largest city and the economic center as well. Given the fact that Karachi is a major coastal city in the Arabian Sea and trade and commerce, many workers from the different other towns and nations converge and thereby attract a lot of immigrants.

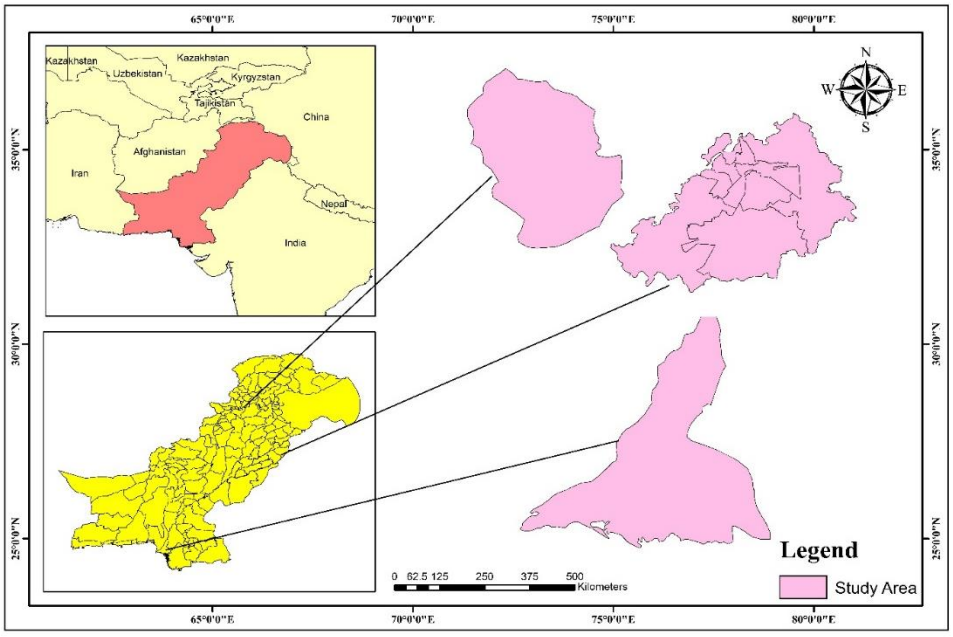


Figure 1: Study Area Map Lahore, Karachi and Peshawar

Lahore, the capital of Punjab province of Pakistan which lies in the north-eastern part of the country, is rightly famous for its cultural affluence, significant historical tangible assets, and its colorful eclectic city life. These cities depict diversities in terms of landscapes, climatic conditions as well as socio-economic status. This implies that they are perfect for studying progress in urbanization, population distribution, and environmental sustainability. The city of Peshawar has a reminiscence of its historical background and is strategically situated in proximity to the Indus Plain. The city has pitched up its urbanization speed and population growth because of

these factors. The City's Scenery has had a noteworthy change, required extending peri-urban areas as well as developing new residential Zones and making commercial zones. Karachi, the largest and most populated city in Pakistan has been confronted with major urbanization challenges where poor planning of effectiveness of infrastructure, housing shortage, and environmental degradation have been on the rise. As the city's spatial development is going far beyond the administrative boundaries, the unplanned settlement (informal settlement) is invading the agricultural land and natural habitats. The capital of Pakistani culture, Lahore, has been also experiencing expansion and modernization of its urban development recently., the fast pace of population increase and the uncontrolled expansion of the city's urban centers have consequently stressed and overwhelmed both the city's infrastructure and social services leading to the ever-present traffic congestion, air pollution, and lack access to the nearby clean water and sanitation systems.

Data Collection:

This research involved the data collecting approach by obtaining different datasets which were analyzed to determine the dynamics of urban vegetation and population variation of Peshawar, Karachi, and Lahore. The study involved spatial and temporal coverage from 1990 to 2020 with satellite imagery acquired from the United States Geological Survey (USGS) among other respected sources. satellite images from the land program of Landsat which is known for its multispectral capabilities were the source of data used in land cover categorization and land cover change detection processing. Concerningly, the population census for our selected cities in the years 1990, 2000, 2010, and 2020 from the official census reports and government sources was gathered. Provided population datasets helped to picture how people are distributed and the density of their hometowns within every body of city movement. The Landsat imagery went through preliminary processing like atmospheric correction and geometric calibration, as part of the procedure, so that the data can be highly accurate and harmonic. Just like census data processing and organizing were conducted, as well as spatial analysis techniques including geocoding of all the population counts corresponding to the administrative boundaries. The combined analyses of remote sensing data along with the demographic information further strengthened the integrity of our work by evaluating the ecological footprint of urbanization and its implications for environment conservation and people's health in Peshawar, Karachi, and Lahore.

Normalized Difference Vegetation Index (NDVI):

Via Landsat multispectral images that include the near-infrared (NIR) and red bands, the Normalized Difference Vegetation Index (NDVI) will be computed. NDVI is a very valuable metric of the condition and density of vegetation, so the higher its values correlated to wider vegetation coverage. The NDVI formula is the process of getting the sum of the reflectance values

of the first and the second bands which are thereafter divided by the reflectance values of the first one. The following formula calculates NDVI: The following formula calculates NDVI:

$NDVI$ = (Near Infrared - Red) / (Near Infrared + Red)

For Landsat 4 - 5 data,

$\boldsymbol{NDVI = (Band\ 4 - Band\ 3) / (Band\ 4 + Band\ 3)}$

For Landsat 8 - 9 data

$\boldsymbol{NDVI = (Band\ 5 - Band\ 4) / (Band\ 5 + Band\ 4)}$

Normalized Difference Built-up Index (NDBI):

Normalized Difference in the Built-up Index (NDBI) will be determined utilizing Landsat multispectral pictures by utilizing the Close Infrared (NIR) and Shortwave Infrared (SWIR) groups. NDBI is an unearthly record made to recognize developed districts in Lahore, Karachi, and Peshawar. To work out NDBI, take away the reflectance worth of the NIR band from the reflectance worth of the SWIR band, then partition by their aggregate. The formula of NDBI is following:

NDBI = (SWIR - NIR) / (SWIR + NIR)

Spatial Analysis:

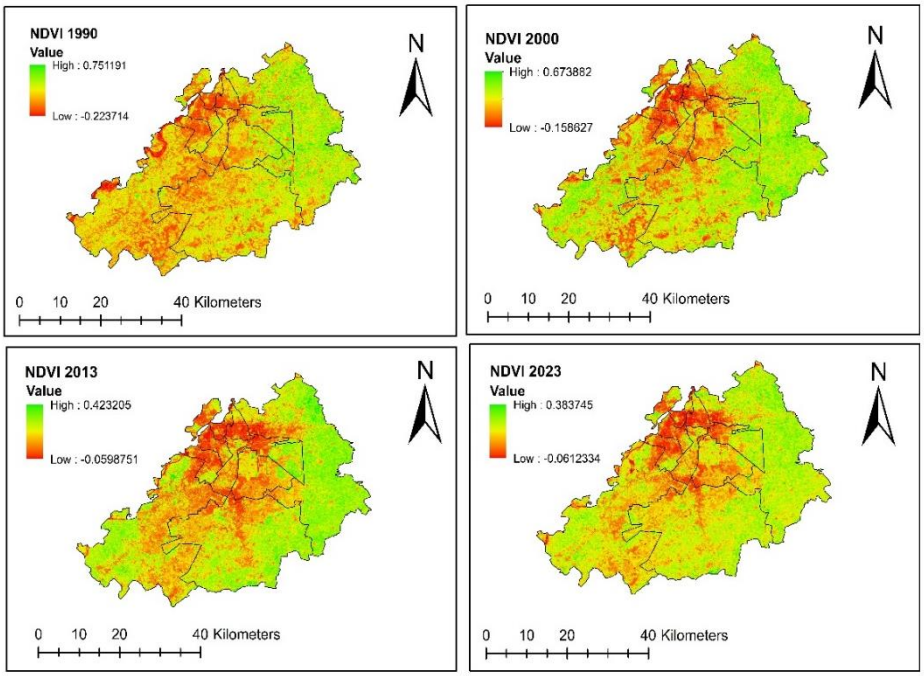
The spatial analysis tools are essential for reading out the variegated relations among urbanization and population change in the study area which is made up of Peshawar, Karachi, and Lahore. Using layover analysis and spatial statistic calculation, the purpose of this research is to understand the underlying spatial signals and correlations among the vegetation cover through NDVI, the expansion of built-up areas through NDBI, and the population fluctuation. Boarding-up analysis, in particular, here processing of different spatial datasets is applied, so the spots where increased urbanization correlates with population mobility are highlighted. Moreover, spatial statistics provide for quantitative representations of spatial autocorrelation, clustering, and dispersion, therefore it gives the axis for the analysis of spatial associations between urbanization indicators and demographic factors. The employment of these spatial analysis tools is aimed at discovering the relationship and spatial pattern of urbanization, i.e., hotspots establishing where urban expansion intersects with the urban population increase factors. Such a spacious approach increases knowledge about the distribution of resources and the interactions of urbanization processes which will then help make targeted interventions and policy actions aimed at an environmentally positive and high-quality for residents in Peshawar, Karachi, and Lahore.

RESULTS AND DISCUSSIONS:

The results of the analysis highlight the evident relationships and evolution trends in the urban vegetation, built-up area expansion, and population capacity of Peshawar, Karachi, and Lahore City during the 1990-2020 period. Vegetation cover on the way of urbanization and land transformation with built-up areas across all three cities shows a strong trend, which could be observed

during the 1984-2020 study period. The gradual rise continues, peaking in Karachi, the highest in the city, and descending in Lahore and Peshawar, the second and the third largest cities, respectively. Among spatial factors, highly populated areas might experience more geographical compactness of urbanization indicators and an increase in land cover and vegetation dynamics. Correlation specifies signification relationships between urbanization indicators and population variability coefficient, the last one indicates that urbanization is driven by population growth rates so land use changes occur. This allows us to bear in mind the challenges paved by urbanization at a fast pace including pollution of the environment, loss of green spaces, and increased susceptibility to environmental change. Policy implications include designing sustainable urban planning strategies, developing green infrastructure, and adopting urban population management measures, all in aid of mitigating pressures. This is important as the country still has ongoing urbanization together with the need to be resilient and livable for the future.

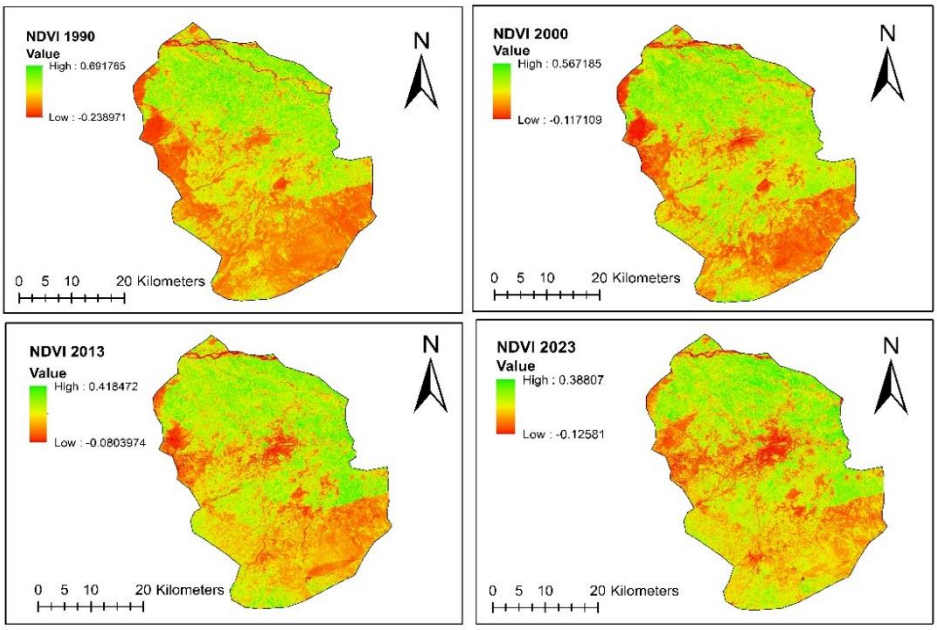
Figure 2: NDVI map of Lahore, Pakistan (1990-2023)



The NDVI map of Lahore Pakistan for the years 1990 to 2023 indicates variation in vegetation coverage. The map shading illustrates alternating shades of green from the deepest green to red color, which corresponds to different NDVI values detected in the different years covered. In 1990, the peak of the corresponding recording was marked 0.751191 signaling a very dense vegetation cover, with the trough that fluctuated at the level of -0.223714 indicating the occurrence of less vegetation. By 2000 the highest

value of NDVI which was 0.673882 was slightly decreased, which signifies the reduction of vegetation density in the area, with the lowest value assumed to be -0.158627. By this tendency, NDVI has continued to decrease lately in 2013, the highest being 0.423205 denoting widespread dry-off, which is mostly in urban areas, with the lowest NDVI being -0.0598751. By 2023 the highest NDVI value also dropped to 0.383745 and the year closed with the lowest value of -0.0612334, which further told us about degradation of vegetation cover. The fact that the NDVI decreased over the years in this area suggests that the rapid urbanization happening there is responsible for the decline in the greenness of spaces as well as for the loss of vegetation cover. The target findings hereby succinctly signal that efficient urban planning measures and the constancy of environmental vigilance are essential troupes in neutralizing the diverse environmental difficulties as a result of urbanization and also in pushing Lahore into resilience.

Figure 3: NDVI map of Peshawar, Pakistan (1990-2023)



The Peshawar, Pakistan, NDVI map, from 1990 up to 2023, shows different vegetation cover trends that are changing with time. The map color scheme uses varying shades between green and red to demonstrate the variation in the NDVI readings with a year range of different years. In 1990, the highest NDVI reading was 0.691765 which corresponded to areas with a high level of vegetation being present, whereas the lowest reading was -0.238971 depicting areas void of vegetation or having just sparse one. The reduction in NDVI slowly went down to 0.567185 by 2000, which manifested itself as a decrease in the vegetation density; the lowest value being -0.117109. In 2013, the trend got worse with the highest NDVI value further dropping to

0.418472 denoting an accelerated dieback of the vegetation not only in urban areas but also in other parts which however still attained values of -0.0803974. By the year 2023, the highest NDVI value has plummeted to 0.38807, wherein the selected highest NDVI value further decreases to indicate a more substantial depletion of the vegetation cover on the farmland, with the lowest- value of -0.12581. The continual gradual fall in the NDVI values throughout the years portrays the concern of urbanization and the change of land use regarding Peshawar's ecosystem which has resulted in the depletion of green spaces and vegetation. This deliberation on these findings has got to do with the necessity of making use of sustainable land management and planting greener to lessen the negative effects that development processes have on the environment of Peshawar and, as a result, develop its resilience against environmental challenges.

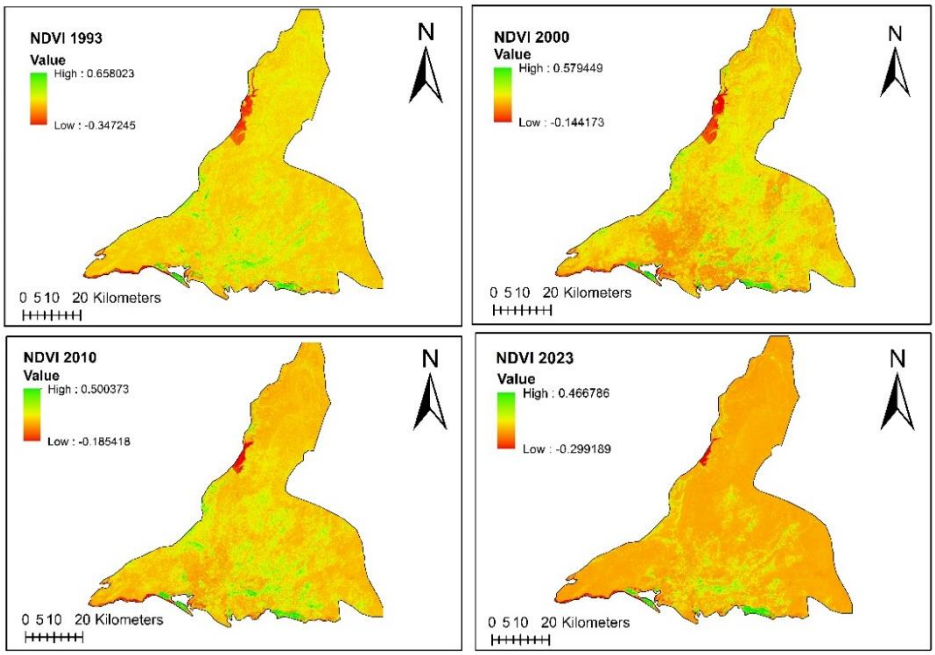


Figure 4: NDVI map of Karachi, Pakistan (1990-2023)

Figure 4 shows the NDVI maps of Karachi, Pakistan over the period 1990 to 2023 not only offer milestones regarding the vegetation renaissance but also inconclusion about the changes in the patterns of vegetation cover. The color-shaded map makes use of dark green colors and red colors indicating min-max values observed through various years. In 1990, the largest NDVI value obtained was 0.658023, which shows the areas where the vegetation cover has sufficient coverage, while the smallest value recorded in the same year was -0.347245 which is problematic for zones where there is no or low vegetation cover. By 2000, the peak NDVI value (0.579449) for the given area was a little lower compared to the previous beginning of the series, revealing that the vegetation status had deteriorated, confirmed by the

minimum value of -0.144173. This further trend was chronicled in 2013, with the highest NDVI value decreasing to 0.500373, demonstrating the continued assessment of vegetative cover, mostly in urbanized areas, while the lowest value was merely -0.185418. Interestingly, by the end of the year 2023, it is seen that the NDVI value has reached its lowest point, where the highest recorded NDVI value is 0.466786, and the lowest value is -0.299189, depicting the continuous decrease of plant cover through the year. The year-on-year decrease in the NIVD values signals the cumulative negative effect of urbanization and land rearrangement that can be seen in the overall ecosystem, including green space reduction and the loss of vegetation cover. This emphasis on the facts emphasizes the necessity of sustainable urban planning schemes and green infrastructure developments to overcome the negatives of cities caused as a result of urbanization on the environment of Karachi and to improve the resilience of the city to environmental issues.

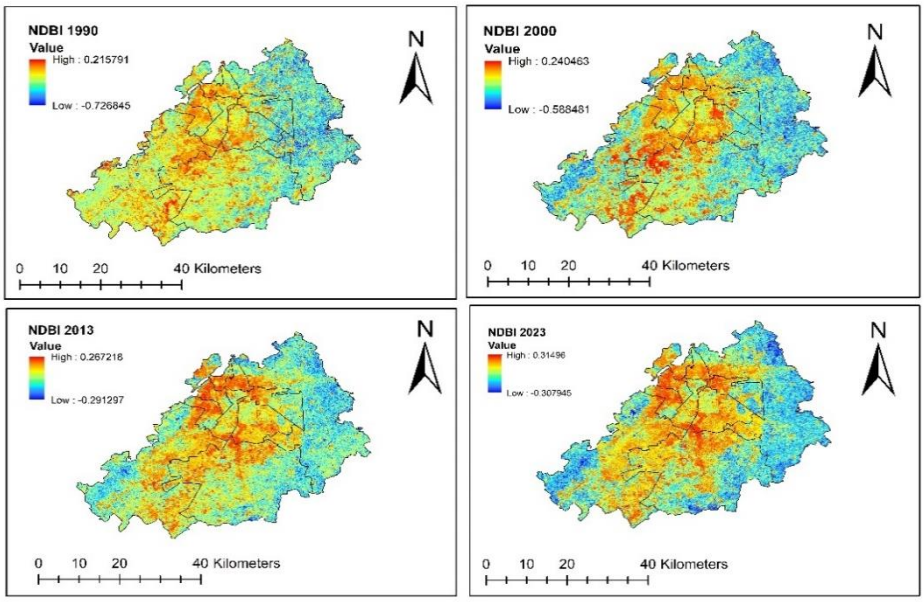


Figure 5: NDBI map of Lahore, Pakistan (1990-2023)

The NDBI maps of Lahore depicting the built-up area expansion over the research period from 1990 to 2023 are significant in helping explore the changing patterns of built-up areas over the period. A particular color scheme (red and dark blue) is used on the map to illustrate the increasing trend in NDBI values from year to year. The historical maximum of NDBI in 1990 was 0.215791, which was typical for a heavily developed area. These areas were at the opposite end of so-called remote and rural areas which had the lowest value of -0.726845. In 2000, the highest index value NDBI raised to 0.240463, which meant that the spatial extent of built-up continued to increase. However, the lowest value was recorded as -0.588481. This trend continued throughout 2013 and into January 2014 with the highest NDBI

value rising to 0.267218, very clearly indicating the continuation and expansion of urban development, while the lowest recorded value was -0.291297. This record-high NDBI value was reported in the year 2023 and it continued to rise to 0.314962, contrasting the earlier built-up areas, indicating further built-up area expansion. The lowest value was recorded at -0.307945. The NDBI values increase progressively with time, earmarking Lahore as the city grows the urbanization process and land transformation, where there is a transition of natural landscapes and green blocks to the built-up infrastructure. The promotion of these conclusions is evidence of the need for the introduction of the eco-friendly planning of the urban areas and land management regulations for minimizing the negative effects of urbanization on the environment of Lahore, thus, guaranteeing the long-term sustainability of urban development.

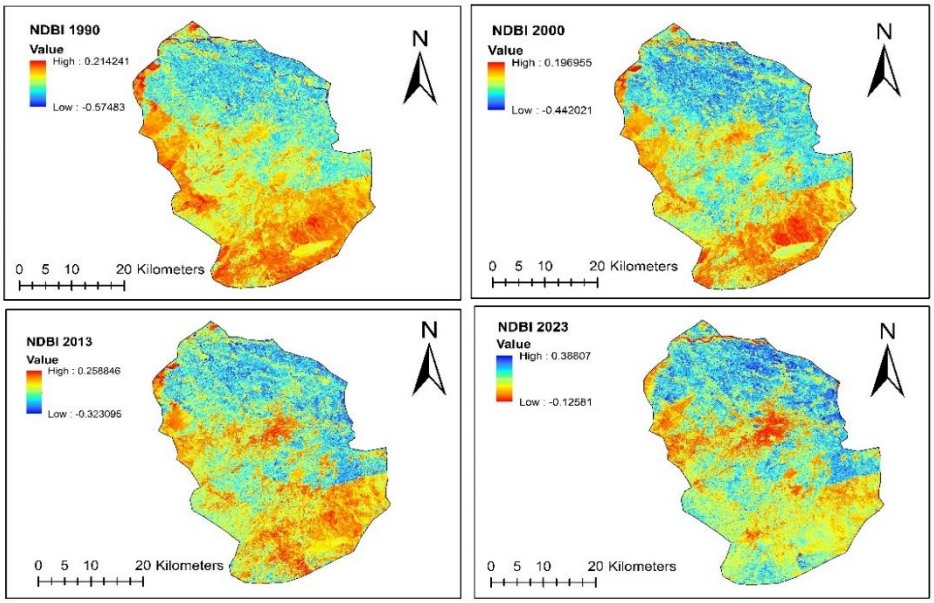


Figure 6: NDBI map of Peshawar, Pakistan (1990-2023)

Figure 6 shows the changing trends in the coverage of built-up areas in Peshawar, Pakistan, revealed in NDBI maps for the years from 1990 to 2023 providing us with a better understanding of how this development and expansion changed over time. The color scheme of the map goes from bright red to dark blue, which reflects a gradual change on a scale from high to low NDVI values detected during different years. In 1990 the quite top value of the NDBI was 0.214241 which meant localities with a high level of built-up development however, the lowest value of the index was -0.57483 which stood for areas where built-up infrastructure was a chance occurrence. By 2000, the peak NDBI value distorted its first slight decline to 0.196955, visualizing the extent of space conversion towards built-up areas, with the lowest recorded value to be found at -0.442021. Through the course of 2013,

this pattern remained unchanged. The NDBI values for the highest-density sector increased to 0.258846, while they reached the minimum at -0.323095 for the closest to the low-density sector. In 2023, the highest NDBI level registered a significant spike up to 0.38807, as construction of built-up areas proceeded at an unusually high pace, and the lowest value was -0.12581. An increasing trend of NDBI values over the years implies that continuing urbanization and land change are happening within Peshawar, which means the area is growing and more areas that were natural landscapes have now been converted to urban areas. These outcomes of the study emphasize the relevance of using sustainable urban planning strategies and proper land management where urbanization is high to neutralize the negative impacts of urbanization in Peshawar's environment and ultimately lead to the sustainability of urban development in Peshawar.

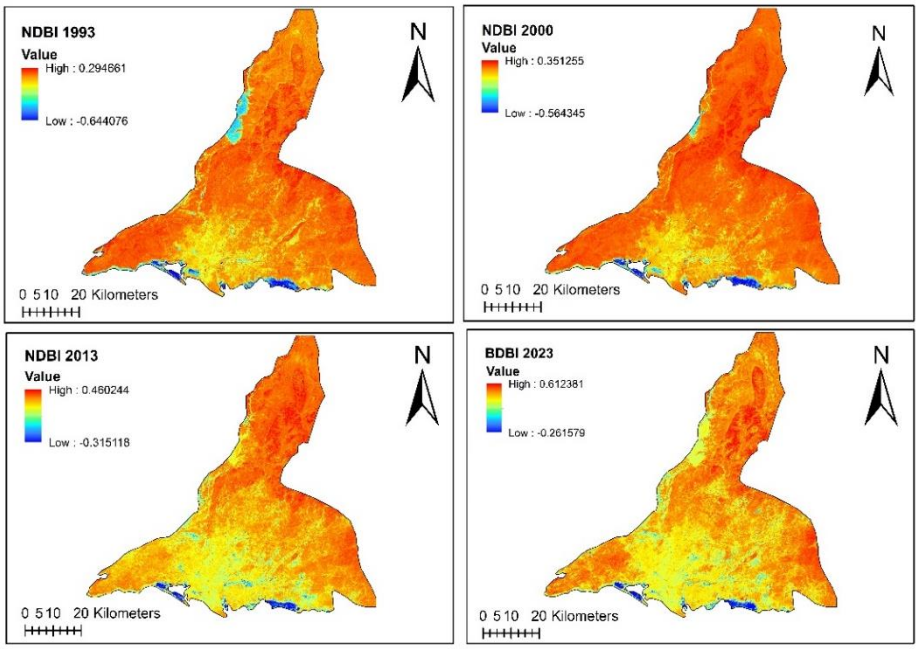


Figure 7: NDBI map of Karachi, Pakistan (1990-2023)

NDBI maps of Karachi, Pakistan covering the time domain of 1990-2023 shed light on the way the built-up area passed different stages of the development phase in this period. An NDBI value color scheme ranges from high to low, starting with yellow and finishing with dark blue going from the red color which corresponds to the values observed across different years. Over a year, from 1990, the NDBI remotely sensed by the Landsat satellite TM channel has recorded a value of +/-0.294661 for the maximum, and -0.644076 for the minimum, which means areas of low and high built-up development respectively. There was a remarkable rise in the maximum NDBI value to 0.351255 in the year 2000, showing the fact that the area of built-up spaces had more intensified expansion. The minimum NDBI value was less than zero

(-0.564345) which provided proof that natural water spaces were now less than before. This trend was present the whole of 2013 when the highest value of Delta NDBI was 0.460244, signifying that while urban development and the built-up environments increased, the lowest value of the Delta NDBI was -0.315118 which signified neglect of urban areas and the development of voids among buildings. By 2023 the biggest value reached 0.612381, which emphasizes the increased growth rate of the built-up area expansion. The poorest value registered is at -0.261579 The increased NDBI counts all these years indicate just steady land transformation processes and urbanization that together go beyond the boundaries as cities are expanding. It is emphatically pointed out that there is a prominent need for urban planning strategies that are environmentally friendly and concern land management practices. This should act as a safeguard and make the process of urban growth in Karachi ecologically safe.

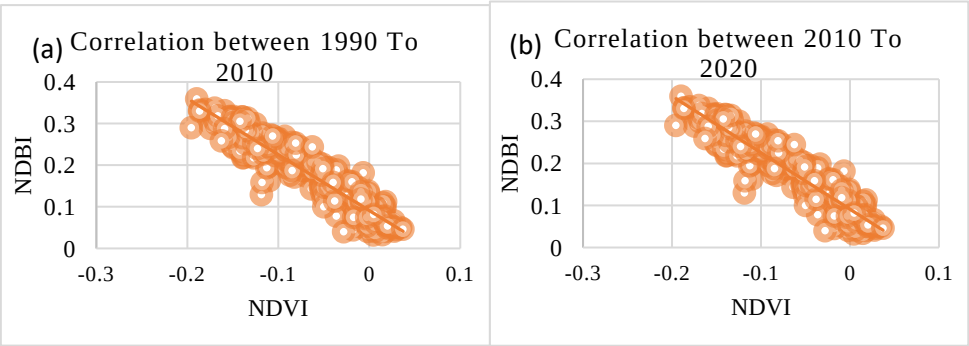


Figure 8: Correlation Analysis of NDVI and NDBI in Lahore, Pakistan. (a) Represent the Correlation Analysis of NDVI and NDBI between (2000-2010) and (b) represent the correlation between (2010 - 2020)

Figure 8 shows a linear graph that was plotted representing the correlation relation between NDVI and NDBI from 1990 to 2000 in Lahore, Pakistan. The graph displayed NDVI values ranging from -0.4 to 0.2 on the x-axis whereas NDBI values (presenting from 0.7 to 0) on the y-axis. The study confirmed the existence of a negative relationship between NDVI and NDBI, whereby the more the growth of the vegetation-covered area diminished throughout the period under investigation, the greater the extent of expansion into the built-up area was determined. As shown in the graphs, the tendency is turned down and is declining, so as NDVI values decrease (reflecting vegetation cover diminishes), NDBI values increase (indicating built-up area expansion). This negative correlation demonstrates the contradicting relationship between the level of urban greenness and built-up infrastructure observed in Lahore, with urbanization being the main driver of changes towards built structures replacing green areas. The correlation between NDVI and NDBI in Lahore, Pakistan, from the years 2010 to 2020 and 1990 to 2000 were plotted using graphs starting from the x-axis, NDVI values (-0.25 to 0.05) and multiple NDBI values (0.4 - 0) label on the In both

analyses, a negative relation between NDVI and NDBI was found, and this implied that as the vegetation area decreased, the area for built-up area expansion was estimated. What the graphs show is a visual depiction of the downward trend that takes place, meaning as NDVI values decline (which means that there is less vegetation cover) the NDBI value increases (pointing to a wider spread built-up area). This inverse relationship points towards the fact that the congestion of infrastructure and building development is causing green areas to be replaced by alien structures in Lahore, which is leading to urbanization. The paper focuses on urban sprawl as a key contributor to the decline of the ecosystem in Lahore, causing vegetation cover to diminish, which interferes with the sustainability of the environment and the strength of urban resilience. Continued urban daylight is bringing about a fierce requirement for green engineering and infrastructure physical exercise interventions that will ease off the impacts of further expansion on the environment of Lahore and would make the city sustainable urban development.

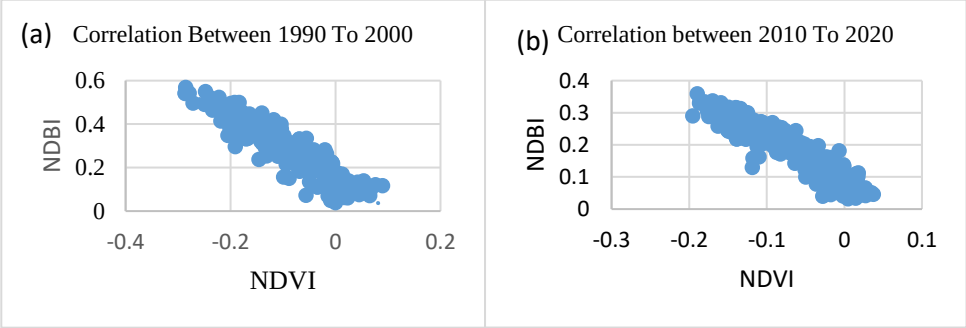


Figure: 9 Correlation Analysis of NDVI and NDBI in Lahore, Pakistan. (a) Represent the Correlation Analysis of NDVI and NDBI between (2000-2010) and (b) represent the correlation between (2010 - 2020)

The 1990 to 2000 data correlations in Peshawar Pakistan (NDVI and NDBI) were analyzed utilizing graphs that had the x-axis with the range -0.35 to 0.15 and the y-axis with the range 0.6 to 0 displayed. The relationship was found to be inverse when analyzing NDBI values with NDVI values, reflecting the fact that with the loss in vegetation area, there was an increase in the scale of built-up areas. In particular, the graphs show a negative direction, implying that as the NDVI values declined (this signifies vegetation cover decreasing), the NDBI values increased (and urban area expansion increased). Through this negative correlation, there is evidence of an inverse relation between the percentage of vegetation cover and the amount of built infrastructure in Peshawar. So, it can be concluded that the process of urbanization tends to cause the swapping of natural areas with constructed structures. Figure (b) shows the NDVI-NDBI correlation of Peshawar, Pakistan from 2010 to 2020 was investigated using a scatter plot that shows the correlation between NDVI (ranging from -0.4 to 0.2) classes on the x-axis and NDBI (varying from 0.35 to 0) on the y-axis. The data

showed that there is an inverse correlation between NDVI and NDBI, and thus the vegetation area decreased and the area of built-up increased over time. For instance, the plots graphically demonstrate the declining trend, which corresponds with the diminishing of NDVI values (that shows the reduction of vegetation cover) and, at the same time, the growing up of NDBI values (that signifies the expansion of the built-up area). Thus, revealing the negative relationship between green space coverage and converting to built-up intensive infrastructure in Peshawar city, means the built-up process driving out nature. The study points a finger at urbanization whose environmental impact in the Peshawar ecosystem is enormous by greatly reducing the vegetation cover which creates difficulties for environmental sustainability and urban resilience. The urbanization of Peshawar, although beneficial, is expected to face multiple environmental issues unless the strategies of urban planning and the development of green infrastructure are employed to control as well as minimize the adverse effects of the expansion of the city on the environment and therefore to ensure the sustainable development plan of the city.

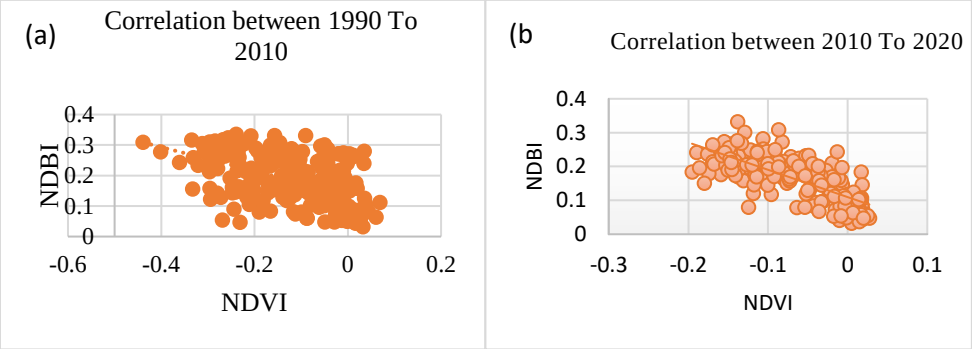


Figure 10. Correlation Analysis of NDVI and NDBI in Karachi, Pakistan. (a) Represent the Correlation Analysis of NDVI and NDBI between (2000-2010) and (b) represent the correlation between (2010 - 2020)

Figures 10 show the correlations between NDVI and NDBI values in Karachi, Sindh, Pakistan, two distinct periods were analyzed: The time frame, 1990-2000 and 2010-2020. As displayed in the regression plot of the decade from 1990 to 2000, NDVI trails with negative values ranged from -0.5 to 0.1 while the measured NDBI shows similar behavior on the positive side of the graph with a range from 0.4 to 0. A link between them was established in the form of a negative correlation between NDVI and NDBI appearing during this stage, meaning the vegetation was decreasing over the time the cities grew and foundations were laid. This tendency is, thus, the result of quick city development processes, which are similar to the ones in the urbanization process. The correlation analysis in the study from 2010 to 2020 reported NDVI values allocated between -0.25 and 0.05 on the x-axis while NDBI values were placed between 0.35 and 0 on the y-axis. Over this period, a similar negative correlation was noticed which further corroborates

the continuous loss of vegetation area, and usurping of natural habitat by the rapidly urbanizing zones.

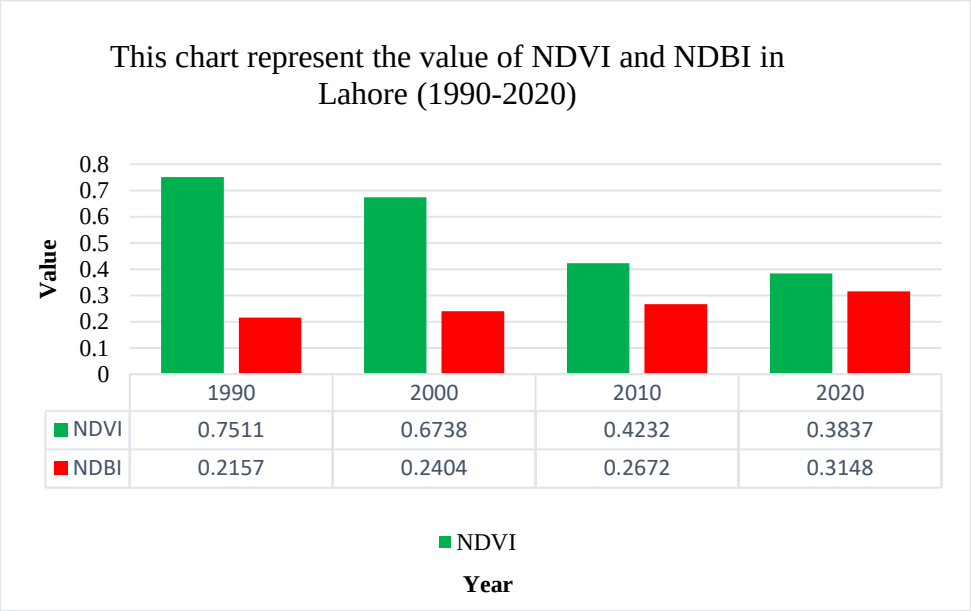


Figure 11: Bar Chart of NDVI and NDBI of Lahore, Punjab, Pakistan.

The bar chart depicts the values of NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up Index) for the cities of Lahore, Karachi, and Peshawar across four different years: the years 1990, 2000, 2010, and 2020. The NDVI index in Lahore in 1990 was 0.7511, while the NDBI index was 0.215. Pakistani cities Karachi and Peshawar had spatial NDVI values of 0.6580 and 0.6918 and NDBI values of 0.2947 and 0.2142 respectively. In contrast to the 2020 values and the downward trend in 2018 and 2019, the year 2000 small decline was seen in all cities with NDVI values recorded at 0.6738 in Lahore, 0.5794 in Karachi, and 0.5672 in Peshawar. Nevertheless, this interval also increased NDBI indices for the cities included. Specifically, for Lahore and Peshawar, the NDBI values were 0.2404 and 0.3512, respectively, and for Karachi, they were 0.1970. NDVI values had decreased by 2010 for all three cities compared to the previous values of 10 years ago which was operating as a reflection of the reduction in vegetation as these areas became more uninhabited. Lahore had 0.4232, Karachi displayed as 0.5004, and the high was Peshawar had 0.4185. Interestingly, the opposite happened – NDBI values went up, showing a growth of the built-up area. The indicator of chronic kidney disease (NDBI) in Lahore grew to 0.2672, while in Karachi and Peshawar, it was 0.4602 and 0.2588 respectively. In the year 2020, the further NDVI values decreased reflecting continuous deterioration in vegetation cover consequently with Lahore in the position of 0.3837, Karachi with 0.4668 and Peshawar is 0.3881. While the value in NDBI was seen to rise magnificently, it implied that the process of urbanization and spread of built areas was still going on,

such that Lahore recorded a value of 0.3148, Karachi 6124, and Peshawar 0.3881. Ultimately, the graph tells us about the seasonal tendencies in NDVI and NDBI parameters, respectively, related to the alteration of the vegetation and urbanization in the cities of Pakistan which have been present for the last three decades.

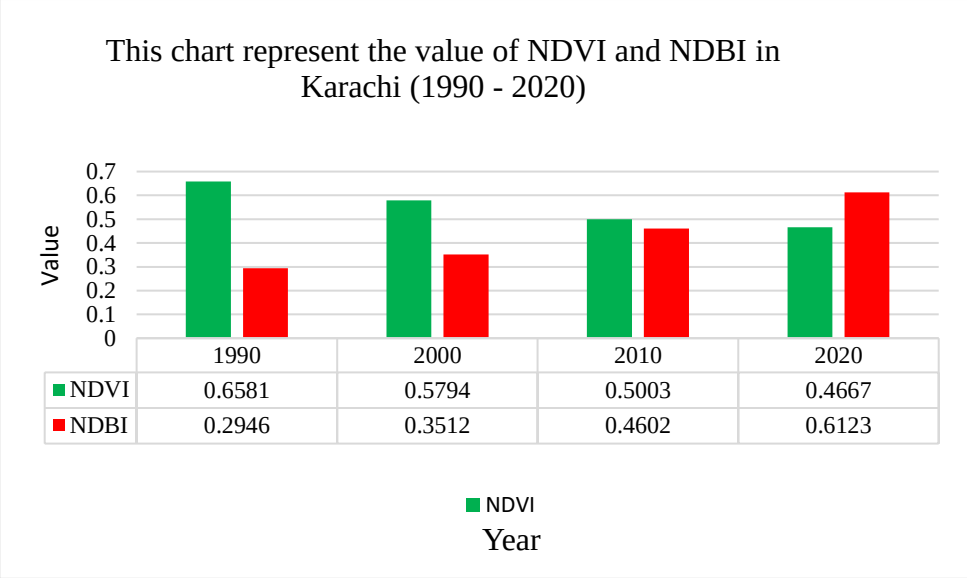


Figure 12: Bar Chart of NDVI and NDBI of Peshawar, Pakistan.

The bar chart illustrates the values of NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up Index) for Peshawar across four different years: My decade will be the 1990s, 2000s, 2010s, and 2020s. The NDVI value of 0.6917 and the NDBI value of 0.1942 that Peshawar had in 1990 indicated deforestation. In the following decade, there was a significant drop in NDVI to 0.5671 in 2000 which indicated a decline in vegetation density, on the contrary NDBI grew up to 0.2142, which suggested some expansion in built-up areas. DNBV further dropped to 0.4184 by the year 2010 showing a further decrease in vegetation coverage whilst NDBI by that time showed a significant increase in 0.2588 suggesting major urbanization and expansion. NDVI values continued to decline in 2020 to 0.3881, demonstrating that the vegetation level had further decreased. NDBI values, on the other hand, significantly increased to 0.4181, showing the acceleration of the urban city spreading. In general, the bar chart illustrates the time series of NDVI and NDBI values capable of reflecting the vegetation cover changes and the urbanization dynamics over the 1990-2020 period in Peshawar.

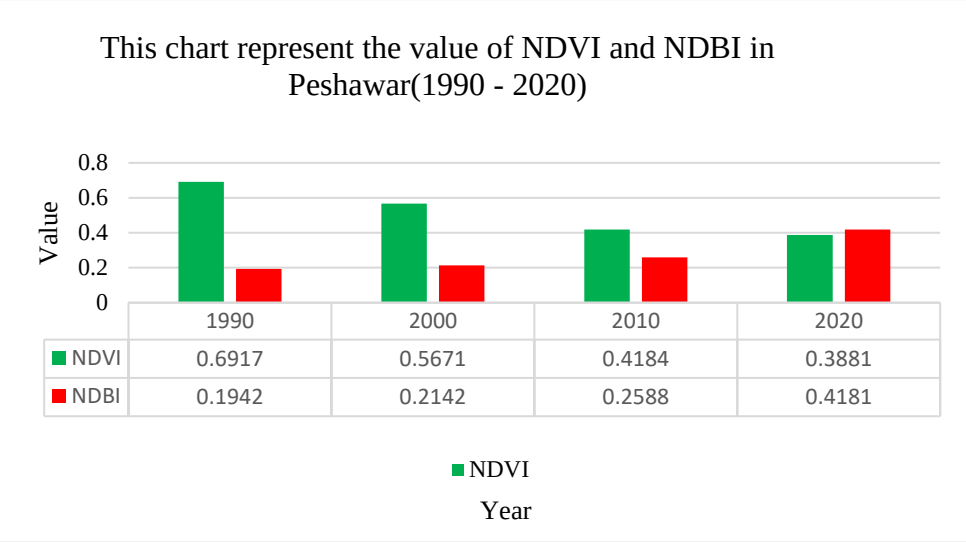


Figure 13: Bar Chart of NDVI and NDBI of Karachi, Sindh, Pakistan.

Figure 13 depicts the NDVI and NDBI values for Karachi across four different years: The respective years 1990, 2000, 2010, and 2020. In the year 1990, the NDVI index of Karachi shows the value of 0.6917, which represents an overall fair amount of vegetation cover along with the NDBI index of 0.1942, which depicts the moderate proportion of built-up areas. Statistics from 2000 show that present vegetation cover declined to 0.5671 level, while a built-up area expansion to 0.2142 rise was noticeable. In 2010 the NDVI decreased again to the level of 0.4184 which means serious loss of vegetation coverage, while the NDBI value simultaneously increased to 0.2588 which indicates increasing urban spaces and built-up areas extension. Although NDVI dropped down again to 0.3881 in 2020, NDBI was still quite high level at 0.4181 indicating more loss of vegetation cover but expansion of the urban activities in Karachi. This chart shows the sustainability patterns of NDVI and NDBI over the three decades of Karachi in temporal trends, based on the changes in vegetation cover and urbanization dynamics.

Table 1: NDVI and NDBI Values of Lahore, Peshawar and Karachi (1990-2020)

Lahore	1990	2000	2010	2020
NDVI	0.7511	0.6738	0.4232	0.3837
NDBI	0.2157	0.2404	0.2672	0.3148
Peshawar	1990	2000	2010	2020
NDVI	0.6917	0.5671	0.4184	0.3881
NDBI	0.1942	0.2142	0.2588	0.4181
Karachi	1990	2000	2010	2020
NDVI	0.6581	0.5794	0.5003	0.4667
NDBI	0.2946	0.3512	0.4602	0.6123

The table demonstrates the NDVI and NDBI metrics for Lahore, Peshawar, and Karachi from 1990 to 2020. In Lahore, the trend of NDVI values has been shown in the form of a continuously declining speed. It declined from 0.7511 in 1990 and continues to further go down making it 0.3837 in 2020. Besides, the NDBIs showed a moderate tendency to grow gradually from 1990 to 2020 as the results portray the increase in the built-up areas from 0.2157 in 1990 to 0.3148 in 2020. Another instance can be found in the case of Peshawar, where both NDVI and NDBI show an opposite trend, with the former being 0.6917 in 1990 but 0.3881 in 2020 and the latter being 0.1942 in 1990 and 0.4181 in 2020 While Lahore shows a decrease in NDVI values over the last 30 years – from 0.6910 to 0.5611 – Karachi displays a relatively stable trend of vegetation from 1990 to 2020 with NDVI values fluctuating between 0.6581 and 0.4667. Nevertheless, there is an obvious rise in NDBIs for the interval that goes from 0.2946 1990 to 2020 (0.6123), which makes us suppose that there is a process of urbanization with areas of construction that are increasing. In general, the table gives an inclusive summary of the changes in the composition of vegetation and urbanization of Lahore, Peshawar, and Karachi in the last thirty years.

CONCLUSION:

In conclusion, the comparison of the results of NDVI and NDBI maps of Lahore, Peshawar, and Karachi for the last 3 decades showed a remarkable contrast in urbanization and vegetation features. NDBI and NDVI display relatively unvarying creeping character of urban growth in both Lahore and Peshawar as demonstrated by the incessant growth of NDBI in the urban areas of these cities accompanied by the gradual drop in NDVI in their peripheries. Likely, the increased rate of forest degradation to planned urban spaces and widespread infrastructure development is the driving force behind this marked change in these cities. The case of Karachi is different due to a slight but distinct tendency of moderate, and stable NDVI readings, meaning that urban growth did not adversely influence the vegetation cover. Nevertheless, the positive NDBI values in Karachi indicate a fast-growing density of built-up areas and urban expansion, although the green area is prone to degradation. This demonstrates the complicated interplays between urban development and change patterns as well as suggests the necessity of sustainable urban planning and nature conservation projects for combating the bad impacts of urbanization on flora wellbeing and ecosystem functioning. Along with that, the cross-city comparisons among these three big cities provide helpful comprehension of the differences in urbanization dynamics within a country as well as the imperative role of different policies for urban management and environmental conservation in Pakistan.

REFERENCES:

1. Richards, D. R., & Belcher, R. N. (2019). Global changes in urban vegetation cover. Remote Sensing, 11(22), 2653. https://doi.org/10.3390/rs11222653
2. Del Tredici, P. (2010). Spontaneous urban vegetation: Reflections of change in a globalized world. Nature and Culture, 5(3), 285-303. https://doi.org/10.3167/nc.2010.050303
3. Neyns, R., & Canters, F. (2022). Mapping of urban vegetation with high-resolution remote sensing: A review. Remote Sensing, 14(3), 580. https://doi.org/10.3390/rs14030580
4. Sieghardt, M., Mursch-Radlgruber, E., Paoletti, E., et al. (2005). The abiotic urban environment: Impact of urban growing conditions on urban vegetation. Urban Forests and Trees, 1(1), 29-40. https://doi.org/10.1007/s10310-004-0011-5
5. Wu, S., Liang, Z., & Li, S. (2019). Relationships between urban development level and urban vegetation states: A global perspective. Urban Forestry & Urban Greening, 39, 59-68. https://doi.org/10.1016/j.ufug.2019.01.013
6. Dobbs, C., Nitschke, C., & Kendal, D. (2017). Assessing the drivers shaping global patterns of urban vegetation landscape structure. Science of the Total Environment, 584-585, 229-241. https://doi.org/10.1016/j.scitotenv.2017.01.189
7. Li, D., Wu, S., Liang, Z., & Li, S. (2020). The impacts of urbanization and climate change on urban vegetation dynamics in China. Urban Forestry & Urban Greening, 51, 126645. https://doi.org/10.1016/j.ufug.2020.126645
8. Melaas, E. K., Wang, J. A., Miller, D. L., et al. (2016). Interactions between urban vegetation and surface urban heat islands: A case study in the Boston metropolitan region. Environmental Research Letters, 11(9), 094027. https://doi.org/10.1088/1748-9326/11/9/094027
9. Mitchell, M. G. E., Wu, D., Johansen, K., et al. (2016). Landscape structure influences urban vegetation vertical structure. Journal of Applied Ecology, 53(5), 1472-1482. https://doi.org/10.1111/1365-2664.12671
10. Shiflett, S. A., Liang, L. L., Crum, S. M., et al. (2017). Variation in the urban vegetation, surface temperature, and air temperature nexus. Science of the Total Environment, 578, 724-733. https://doi.org/10.1016/j.scitotenv.2016.11.167
11. Weber, C. (2013). Ecosystem services provided by urban vegetation: A literature review. In Urban Environment: Proceedings of the 11th Urban Environment Symposium (pp. 161-170). Springer.
12. Saether, B. E., Grøtan, V., Engen, S., Coulson, T., et al. (2016). Demographic routes to variability and regulation in bird populations. Nature, 535(7612), 72-75. https://doi.org/10.1038/nature18639

13. Doak, D. F., Finkelstein, M. E., Bakker, V. J., et al. (2009). Population viability analysis. In Princeton guide to ecology (pp. 480-487). Princeton University Press.
14. Treydte, K. S., Schleser, G. H., Helle, G., Frank, D. C., et al. (2006). The twentieth century was the wettest period in northern Pakistan over the past millennium. Nature, 440(7088), 1179-1182. https://doi.org/10.1038/nature04743
15. Yaqoob, U. (2018). Population distribution and water resources in Pakistan (Doctoral dissertation). University of Venice. Retrieved from https://dspace.unive.it
16. Xu, Y. (2016). NDVI-based vegetation responses to climate change in an arid area of China. Remote Sensing, 8(3), 213-222. https://doi.org/10.3390/rs8030213
17. Xue, J. (2017). Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications. Journals of Sensors, 2017, 1353691. https://doi.org/10.1155/2017/1353691
18. Yang, Y. (2019). Factors Affecting Long-Term Trends in Global NDVI. Forests, 10(5), 372. https://doi.org/10.3390/f10050372
19. Rehman, Z. (2015). Analysis of land surface temperature and NDVI using the geospatial technique: A case study of Keti Bunder, Sindh, Pakistan. Retrieved from ResearchGate.
20. Kshetri, T. (2018). NDVI, NDBI AND NDWI CALCULATION USING LANDSAT 7 AND 8. Retrieved from ResearchGate.
21. Manfreda, S. (2018). On the use of unmanned aerial systems for environmental monitoring.
22. Masood, H. (2015). Application of comparative remote sensing techniques for monitoring mangroves in Indus Delta, Sindh, Pakistan. Biological Forum. Retrieved from ResearchGate.
23. Robinson, P. N., Allred, B. W., Jones, M. O., Moreno, A., et al. (2017). A Dynamic Landsat Derived Normalized Difference Vegetation Index (NDVI) Product for the Conterminous United States. Remote Sensing, 9(8), 863. https://doi.org/10.3390/rs9080863
24. Smith, M. D. (2007). Geospatial analysis: A comprehensive guide to principles, techniques and software tools. Retrieved from Google Books.
25. Pettorelli, N. (2013). The normalized difference vegetation index. Princeton University Press.
26. Eastman, J. R., Sangermano, F., Machado, E. A., Rogan, J., et al. (2013). Global trends in seasonality of normalized difference vegetation index (NDVI), 1982–2011. Remote Sensing, 5(10), 4799-4818. https://doi.org/10.3390/rs5104799
27. Esau, I., Miles, V. V., Davy, R., Miles, M. W., et al. (2016). Trends in normalized difference vegetation index (NDVI) associated with urban

development in northern West Siberia. Atmospheric Chemistry and Physics, 16(14), 9399-9412. https://doi.org/10.5194/acp-16-9399-2016

28. Melaas, E. K., Wang, J. A., Miller, D. L., & Friedl, M. A. (2016). Interactions between urban vegetation and surface urban heat islands: A case study in the Boston metropolitan region. Environmental Research Letters, 11(10), 104002. https://doi.org/10.1088/1748-9326/11/10/104002
29. Mitchell, M. G. E., Wu, D., Johansen, K., & et al. (2016). Landscape structure influences urban vegetation vertical structure. Journal of Applied Ecology, 53(5), 1477-1486. https://doi.org/10.1111/1365-2664.12699
30. Shiflett, S. A., Liang, L. L., Crum, S. M., Feyisa, G. L., et al. (2017). Variation in the urban vegetation, surface temperature, and air temperature nexus. Science of the Total Environment, 599-600, 1763-1773. https://doi.org/10.1016/j.scitotenv.2017.05.011
31. Weber, C. (2013). Ecosystem services provided by urban vegetation: A literature review. In Proceedings of the 11th Urban Environment Symposium. Springer.
32. Richards, D. R., & Belcher, R. N. (2019). Global changes in urban vegetation cover. Remote Sensing, 11(17), 1964. https://doi.org/10.3390/rs11171964
33. Del Tredici, P. (2010). Spontaneous urban vegetation: Reflections of change in a globalized world. Nature and Culture, 5(3), 275-294. https://doi.org/10.3167/nc.2010.050303
34. Neyns, R., & Canters, F. (2022). Mapping of urban vegetation with high-resolution remote sensing: A review. Remote Sensing, 14(2), 314. https://doi.org/10.3390/rs14020314
35. Sieghardt, M., Mursch-Radlgruber, E., Paoletti, E., & et al. (2005). The abiotic urban environment: Impact of urban growing conditions on urban vegetation. In Urban forests and trees (pp. 109-123). Springer.
36. Wu, S., Liang, Z., & Li, S. (2019). Relationships between urban development level and urban vegetation states: A global perspective. Urban Forestry & Urban Greening, 38, 71-79. https://doi.org/10.1016/j.ufug.2018.11.016
37. Dobbs, C., Nitschke, C., & Kendal, D. (2017). Assessing the drivers shaping global patterns of urban vegetation landscape structure. Science of the Total Environment, 592, 171-177. https://doi.org/10.1016/j.scitotenv.2017.03.001
38. Li, D., Wu, S., Liang, Z., & Li, S. (2020). The impacts of urbanization and climate change on urban vegetation dynamics in China. Urban Forestry & Urban Greening, 51, 126662. https://doi.org/10.1016/j.ufug.2019.126662