**ADVANCE SOCIAL SCIENCE ARCHIVE JOURNAL**
Available Online: https://assajournal.com
*Vol. 05 No. 01. Jan-March 2026*.Page#.621-634
Print ISSN: 3006-2497 Online ISSN: 3006-2500
Platform & Workflow by: Open Journal Systems

# Effects of Urban Expansion on Vegetation and Water Bodies in Nawabshah City, Sindh, Pakistan

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**ABSTRACT**
*Urbanization has become a significant basis of environmental change, especially in cities that are fast developing as in the case of developing countries. Nawabshah, which is the fifth biggest city in Sindh province, Pakistan has had great spatial development in the last thirty years and this has caused great change in land use and land cover specially, change in vegetation and water. This paper examines spatio-temporal changes of urban expansion and its effects on vegetation and water bodies in Nawabshah city between 1990 and 2024 based on multi-temporal imageries of Landsat and remote sensing (RS) technology that are combined with Geographic Information Systems (GIS). Supervised classification was used to determine the land use which was classified under built-up areas, vegetation and agriculture, open areas and water bodies. Changes were measured by statistical analysis such as descriptive statistics, ANOVA and urban expansion intensity (UEI). It was found that the built-up area has expanded 4.57 km² in 1990 to 11.27 km² in 2024, the vegetation and agriculture area had decreased from 41.48 km² to 29.65 km², and the water bodies had also decreased from 1.23 km² to 0.68 km². The disadvantages of urbanization in terms of ecological effects, such as the loss of habitat, the decrease in the green cover and water stress are highlighted in these changes. The paper highlights that there is a need to be sustainable in planning urban centers, growth and conservation of green infrastructure in order to reduce environmental degradation in the rapidly growing urban centers.*

***Keywords:*** *Urban expansion, Vegetation loss, Water bodies, Remote Sensing, GIS, Nawabshah*

## 1. INTRODUCTION

Urban geography consists of cities, towns and space structure and it is mainly concerned with the historical background of the cities and their development on the growth pattern and environmental consequences (Madison, 1976; Johnson, 2013). Urban settlements are founded on several conditions among them being the physiography, geomorphology, water availability and accessibility to transport systems (Hnátova& George, 1984; Borchert, 1996). Traditionally, the position of cities in such civilizations like the Indus Valley, Mesopotamia, Egypt and ancient China was planned to maximize the natural resources and trade (Hammond, 1972; Sharma and Pahuja, 2017; Scarre et al., 2021). Contemporary use of the term urban is based on the Latin urbanus which means urbanity, city living and urbanized areas (Branam, 2012; Pratama, 2023).

In 1712 with the invention of the steam engine by Thomas Newcomen, the beginning of the Industrial Revolution which consequently altered the settlement patterns across the world forming the basis of urban agglomerations and the necessity to study urban spatial development (Allen, 1978; Knight and Harrison, 2013). Later, urban theories formulated conceptual approaches like the Concentric Zone Model, Sector Model and Multiple Nuclei Model describing urban structure and patterns of development (Burgess, 1925; Harris and Ullman, 1945). These models are very useful to urban planners, policymakers and geographers in examining how the process of urbanization operates and its effects on the environmental resources.

The fifth and biggest urban center in Sindh and the Headquarters of Shaheed Benazirabad district, Nawabshah city has witnessed high urbanization in the recent 30 years. Its historical evolution was very much dependent upon the introduction of railway lines during the British colonial era that made it turn into a transport center and agro commercial center (Tahir, 2021; Bombay, 1927). The geographic position and good irrigation methods in addition to fertile land were some factors that attracted traders, craftsmen and migrants and this resulted in increase in population and space gradually grew up. The population of Nawabshah in 1981 was 102,139 that have reached up to 363,138 in 2023; this highlights the fact that the city put a lot of strain, in terms of land and natural resources (Pakistan Bureau of Statistics, 2023).

The urban growth compels various effects on environmental resources. More specifically, vegetation and water bodies that play an essential role in ecological stability, climatic control as well as human health are at high risk of intrusion and degradation. Urbanization causes agricultural territories to change to developed ones, the loss of green areas and the alteration of hydrologic processes, which causes the fragmentation of habitats and the lack of water (Macharia, 2018; Wei and Ewing, 2018). Rapid urbanization that has triggered land use changes, migration and industrialization in Pakistan present environmental problems especially in the case of mid-sized cities such as Nawabshah (Ranagalage et al., 2021; Mangi et al., 2020).

Spatial-temporal patterns of vegetation and the water bodies of urban areas are important to the sustainable planning of the city. It has rendered remote sensing (RS) and Geographic Information Systems (GIS) to be essential in any urban research that offers viable, reliable and affordable methods to track changes in land cover with time (Longley et al., 2005; Romero-Calcerrada et al., 2008; Zhijun et al., 2009). Although significant research has been done on large metropolitan areas in Pakistan, but few studies have been conducted on the extended cities such as Nawabshah which serves as a source of the importance of carrying out in-depth research on the effects of urbanization on the vegetation cover and water resource.

**1.1 Study Area**

Nawabshah city is geographically situated at 26.2407°N 68.4105°E latitude and longitude, respectively in Shaheed Benazirabad district in the Sindh province, Pakistan. It is the 27$^{th}$ largest and fifth largest city in Sindh and Pakistan. Traditionally, the area has been in existence since the times of Indus Valley Civilization (Mughal, 1990). Nawabshah is a transport center which links other major cities by road, rail and air with a rich agricultural hinterland. The urbanization of the city has been fast because of population increase, internal migration, industrialization, and resettlements (Hussain, 2018; Tahir, 2021).

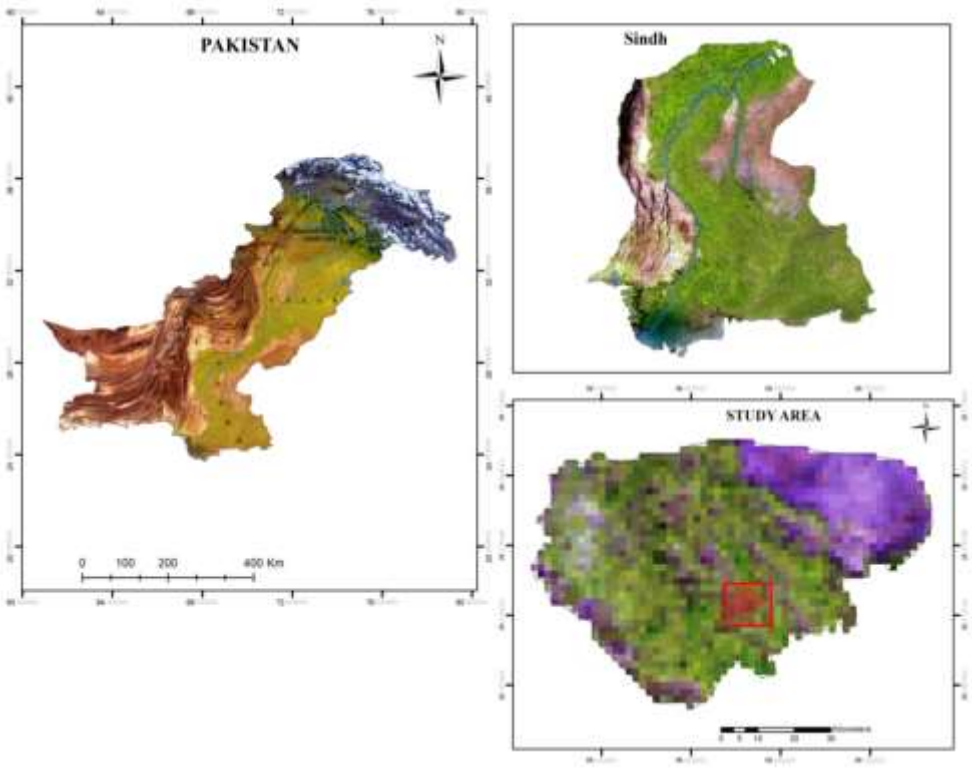



Figure: 1 Location map of study area

**1.2 The objectives of this study are**

(i) Quantify the spatial and temporal changes in vegetation and water bodies in Nawabshah city from 1990 to 2024;

(ii) Analyze built-up area growth and assess the intensity of urban expansion using the Urban Expansion Index (UEI); and

(iii) Evaluate the implications of land use changes for urban sustainability and environmental planning using RS, GIS, and statistical analyses.

## 2. LITERATURE REVIEW

Urbanization is a significant trend in the world that transforms the sceneries, changes ecosystem and impacts biodiversity. It has always been indicated that the process of urbanization causes a high level of reduction in vegetation cover, turning agricultural lands into cities and a greater level of land fragmentation (Seto et al., 2011; Yang et al., 2013). Economic incentives usually exceed the rate of population increase, which causes rapid urbanization with resulting massive land conversion (Atack et al., 2022). Baker (2012) pointed that some of the environmental threats that present challenges to urban regions around the world include heat waves, urban flooding and degradation of green cover as a result of unplanned growth. On the same note, De Sherbinin et al. (2012) and Leal Filho et al. (2018, 2021) pointed out that urban sprawl is a source of ecological stress associated with the loss of vegetation and natural bodies of water. These are the environmental difficulties that should highlight the significance of tracking the land cover and planning sustainable urban development.

Water bodies are essential for Urban landscapes to mitigate heat island and contribute to the ecological balance, as well as groundwater recharge and biodiversity (Dodman et al., 2022; Maity et al., 2022). The researches in cities, such as Riyadh (Yip, 2018) and Dhaka (Dewan and Yamaguchi, 2009), indicate that with urbanization, water bodies tend to diminish and

experience changes in hydrological regimes, which decreases the amount of surface water. Remote sensing and GIS analyses offer a strong tool producing the ability to measure these losses and to comprehend the spatial patterns of urban encroachment of the water resources (Zhang et al., 2018).

The population of Asia is estimated at about 60 percent of the global population and the South Asian nations are undergoing rapid urbanization that started in the 1970s (Hugo, 2019; Jing et al., 2020). There has been widespread land use change in the cities of India, Pakistan and Bangladesh, whereby agricultural and vegetation cover has depleted greatly owing to the development of the urban areas (Liu et al., 2018; Ali et al., 2023). This has particularly been observed in urban population in Pakistan whereby the population grew by 17.8% in 1951 to 38.04% in 2023, the boom was because of internal migration, industrialization and population increase (Qasim et al., 2023). In Sindh, the city cross-linked growth is rapidly increasing as KhairpurMirs and in 2020, the settlement expanded covering 21.16% (Chandio, N. H., and Shirazi, S. A. 2022).

There are a few studies of medium-sized cities such as Nawabshah, but there are some indications of a major growth in built-up areas, agricultural lands invasion and loss of vegetation and water bodies (Mangi et al., 2020; Ajani and van der Geest, 2021). IMPEC has been proven to be useful in the evaluation of the effects of cities on vegetation and hydrology with previous studies in Pakistan and additional research on Islamabad (Hassan et al., 2016) and Karachi (Zafar, 2014) using RS and GIS. In particular, quantitative evaluation of vegetation changes and water bodies in terms of space and time is missing in Nawabshah. This research aims at bridging this gap by combining RS, GIS and statistical results in order to give a step-by-step assessment of environmental effects caused by urban enlargement in three decades.es.

## 3. METHODOLOGY

### 3.1 Data Acquisition

Multi-temporal Landsat images were obtained from the United States Geological Survey (USGS) Earth Explorer portal (https://earthexplorer.usgs.gov/) for the years 1990, 2001, 2013, 2020 and 2024 (Table 1). Landsat 5 TM was used for 1990 and 2001, while Landsat 8 OLI was used for 2013, 2020 and 2024. Images were acquired between April 15$^{th}$ and May 31$^{st}$ to ensure minimal cloud coverage. A total study area of 54.69 km², encompassing the current urban extent of Nawabshah city, was analyzed.

**Table 1 Remote Sensing Data Acquisition for Nawabshah City**

| Landsat Image | Acquisition Date | Code |
|---|---|---|
| **Landsat 5 TM** | 19 May 1990 | IM1990 |
| **Landsat 5 TM** | 22 May 2001 | IM2001 |
| **Landsat 8 OLI** | 23 May 2013 | IM2013 |
| **Landsat 8 OLI** | 24 April 2020 | IM2020 |
| **Landsat 8 OLI** | 27 April 2024 | IM2024 |

### 3.2 Image Classification and Land Use Categories

The study applied supervised classification using ArcGIS and ENVI software to categorize land cover into four classes:

1. **Built-up Area** – formal/informal residential areas, industrial, administrative, transport, and communication networks.
2. **Vegetation & Agriculture** – cropland, grassland, shrubs, and natural vegetation.
3. **Open Area** – barren land, unused spaces, and fallow areas.
4. **Water Bodies** – canals, rivers, lakes, reservoirs (Table 2).

**Table 2. Classification Scheme for Land Cover**

| Class | Description |
|---|---|
| **Built-up Area** | Residential, industrial, and transport infrastructure |
| **Vegetation & Agriculture** | Cropland, grasslands, shrubs, vegetation |
| **Open Area** | Barren land, open landscapes |
| **Water Bodies** | Rivers, canals, lakes, reservoirs |

### 3.3 Urban Expansion Intensity (UEI):

After Liu, Liu (2020), the intensity of urban growth will be analysed. The data for urban expansion will extracted from land use for different years. The study will employ the urban expansion index and sources of urban growth to examine the spatiotemporal characteristics of the city (Liu, Liu et al. 2020).

Following equations will be utilized to observe the rate and trend of its expansions:

$$I_{ue} = \frac{\Delta U_{ij}}{\Delta t_j \times TLA_i} \times 100\% \qquad (1)$$

Where $I_{ue}$ is the UEI, $\Delta U_{ij}$is the urban expansion area of city i in period j, $\Delta t_j$ is the time interval, and $TLA_i$ is the total land area of city i.

The following equation will be used to evaluate the encroachment of urban expansion(Liu, Liu et al. 2020):

$$P_{ij} = \frac{A_{ij}}{A_i} \times 100 \qquad (2)$$

where $P_{ij}$is the proportion of the land use type j being converted to urban land in city i; $A_{ij}$ is the area of land use type j occupied by urban expansion in city i; and Ai is the total area of urban expansion in city.

### 3.4 Accuracy Assessment

The assessment of the accuracy was performed by Region of Interest (ROI) samples, compared to field data and Google Earth images. The whole classification was measured concerning accuracy and the Kappa coefficient per year (1990-2024). Each land cover was calculated in terms of producer and user accuracies.

### 3.5 Statistical Analysis

The classified data were analyzed using Microsoft Excel with descriptive statistics (mean, median and standard deviation, range, standard error, level of confidence 95% and ANOVA (single-factor and no replication). These were analyses that best measured vegetation changes and water bodies under their levels of change in connection with the study period and the significance of these changes.

## 4. RESULTS

The time-by-time Landsat analysis shows a sharp and an ongoing increase in constructed space in the city of Nawabshah, 1990-2024. The constructed land area expanded to 11.27 km$^2$ in 2024 compared to 4.57 km$^2$ in 1990 (Figure 2, Table3), which shows that it had grown more than twice within 34 years. This growth has increased significantly since 2013, the period of which coincides with the heightened regional migration, infrastructural growth after floods, etc. The Urban Expansion Intensity (UEI) analysis also reveals the extent of this growth in the sense that a larger percentage of the total land area in the city was turned to built-up land over the period of analysis which represents a high level of spatial urbanization.

Unlike the development of the constructed regions, vegetation and the agricultural lands demonstrated a significant reduction during the same time span. The overall vegetation and

agricultural area had dropped to 29.65km$^2$ in 2024 as compared to 41.48km$^2$ in 1990 (Figure 3,Table3). The statistical result proves that such reduction is considerable and ANOVA variance is 38.67 and the coefficient of determination (R 2 = 0.824) is high, which means that a strong temporal change in land cover occurs (Table 4). The shrinkage of vegetated and agricultural lands has a spatial relationship with the growing urban areas and is due to the urban expanse of productive land to residential, commercial and infrastructural purposes.

The transformation of the landuse in Nawabshah is dynamic, which is further emphasized by alterations in open spaces and water bodies. The decrease in open areas was 7.41 km$^2$ in 1990 to 4.65 km$^2$ in 2013 and then an explosion in 2024 to 13.09 km$^2$, which is mainly associated with land reclamation following the flood and spontaneous development works (Figure4, Table3). Water bodies, on the other hand, had a general negative trend in that of 1.23 km$^2$ in the year 1990 to 0.68 km$^2$ in the year 2024. In spite of the fact that a certain temporary increase is provided in 2020, statistical analysis shows that there is a moderate change over time (R 2 = 0.424). The decline in the level of surface water is a collective effect of urban intrusion, alteration of drainage systems, canal sedimentation as well as changes of weather and climatic conditions (Figure 5, Table 3 and 4).

Table 3 Show Class changes from 1990 to 2024

| Year | Built-up Area (km²) | Vegetation & Agriculture (km²) | Open Area (km²) | Water Bodies (km²) |
|---|---|---|---|---|
| **1990** | 4.570718 | 41.477679 | 7.412347 | 1.232892 |
| **2001** | 7.738961 | 40.113173 | 6.166733 | 0.669190 |
| **2013** | 7.965598 | 41.725925 | 4.652303 | 0.669190 |
| **2020** | 10.842542 | 29.971198 | 12.551598 | 1.327208 |
| **2024** | 11.268406 | 29.648125 | 13.086843 | 0.680699 |

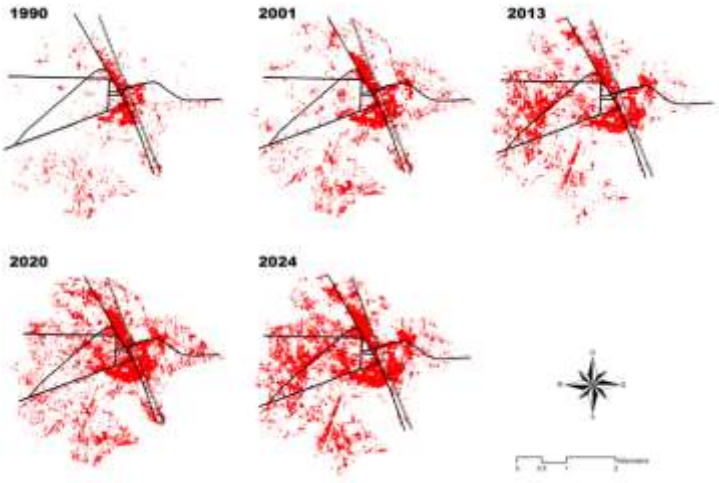



**Figure 2.**Built-up area expansion in Nawabshah

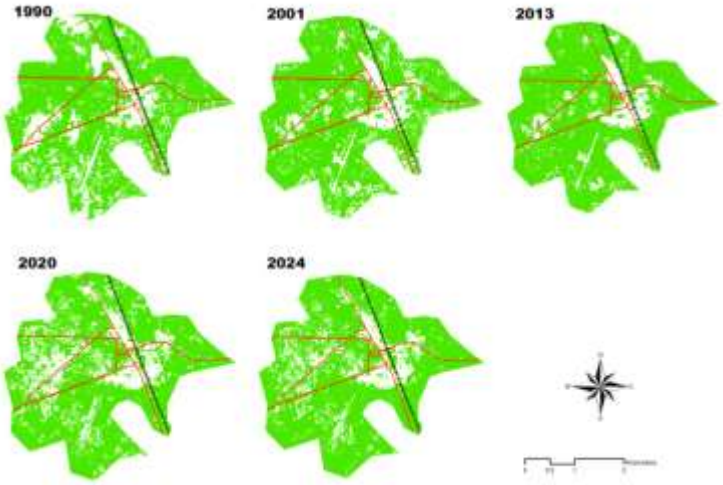



**Figure 3.** Spatial distribution of vegetation & agriculture

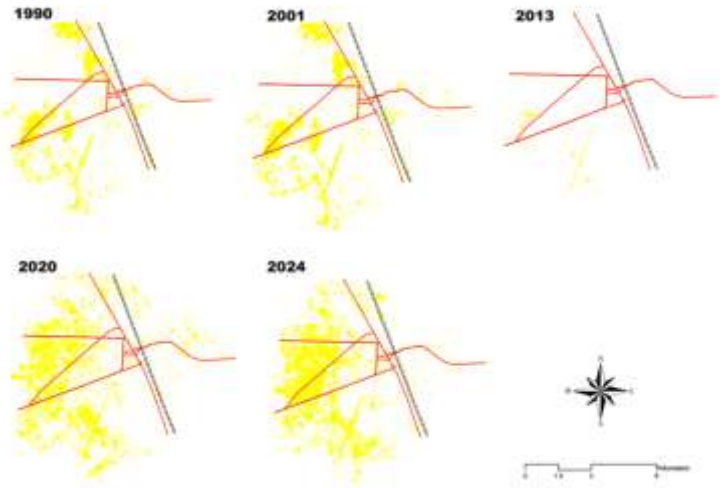



**Figure 4.**Open area changes in Nawabshah city

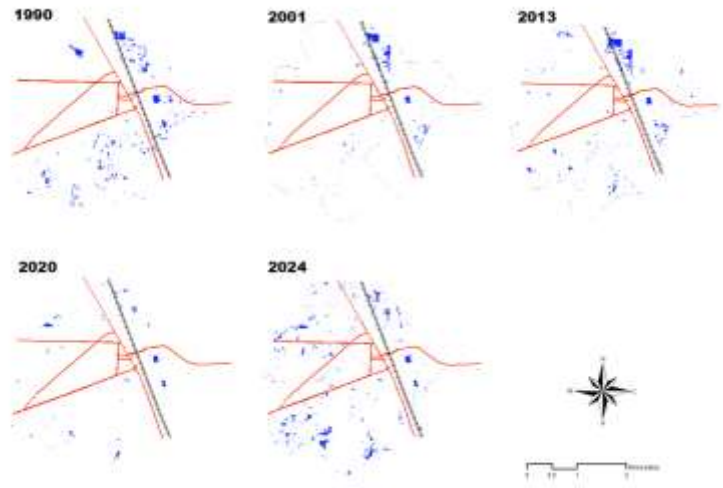
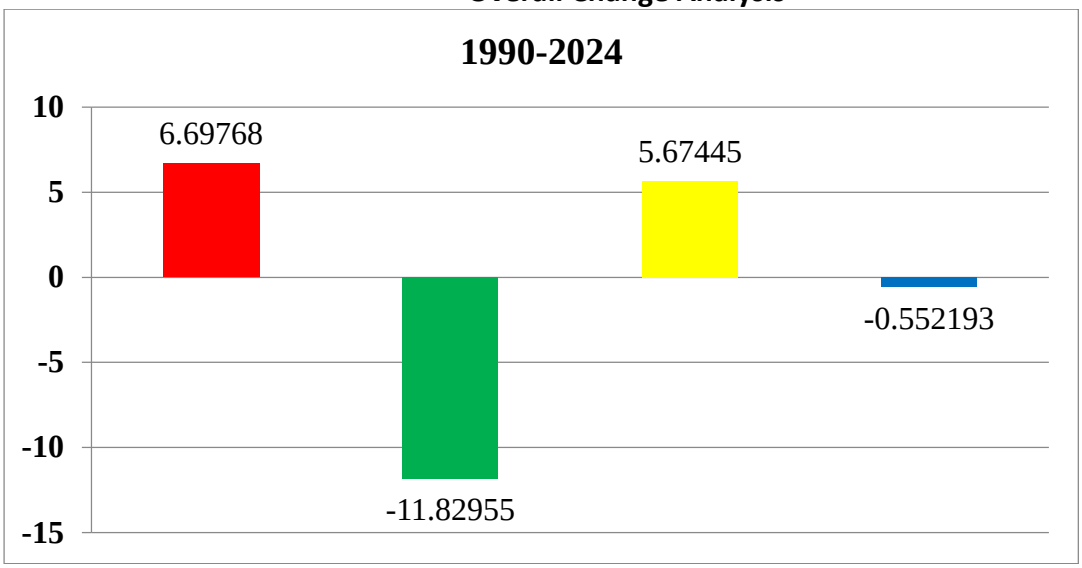


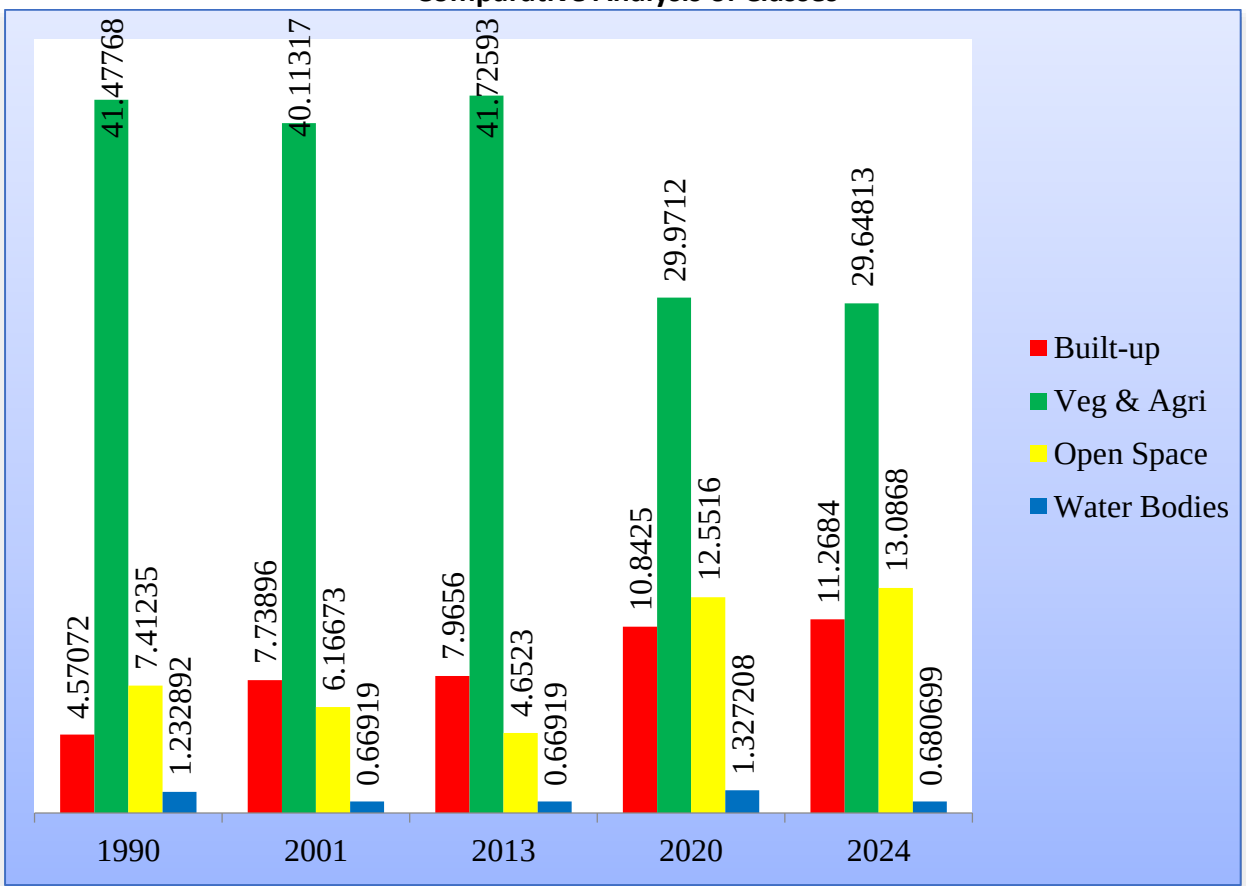

**Figure 5.** Water bodies decline in Nawabshah

**Effects of Urban Expansion on Vegetation and Water Bodies in Nawabshah**

**Overall Change Analysis**




**Comparative Analysis of Classes**



### 4.1 Accuracy Assessment

The overall accuracy of classification ranged from 80.31% (1990) to 87.77% (2001) with Kappa coefficients between 0.6255–0.7943, confirming high reliability of RS-based classification (Tables 4). Producer and user accuracies for built-up areas and vegetation and agriculture were consistently above 75%, while water bodies and open areas showed relatively lower accuracies due to spectral similarity and seasonal changes.

Table 4. Accuracy Assessment for 1990–2024

| Land Cover Class | Year | Mean Area ($km^2$) | Std. Dev | Range | Confidence Level (95%) | ANOVA Variance | Overall Accuracy (%) | Kappa Coefficient | Producer Accuracy (%) | User Accuracy (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Built-up Area** | 1990 | 4.571 | 2.714 | 6.698 | 3.369 | 7.363 | 80.31 | 0.706 | 84.93 | 99.36 |
| | 2001 | 7.739 | 2.714 | 6.698 | 3.369 | 7.363 | 87.77 | 0.794 | 96.88 | 96.54 |
| | 2013 | 7.966 | 2.714 | 6.698 | 3.369 | 7.363 | 82.92 | 0.626 | 87.23 | 62.71 |
| | 2020 | 10.843 | 2.714 | 6.698 | 3.369 | 7.363 | 86.68 | 0.758 | 95.64 | 79.66 |
| | 2024 | 11.268 | 2.714 | 6.698 | 3.369 | 7.363 | 86.68 | 0.758 | 87.45 | 47.75 |
| **Vegetation & Agriculture** | 1990 | 41.478 | 6.218 | 12.078 | 7.721 | 38.670 | 80.31 | 0.706 | 83.72 | 75.39 |
| | 2001 | 40.113 | 6.218 | 12.078 | 7.721 | 38.670 | 87.77 | 0.794 | 95.11 | 84.52 |
| | 2013 | 41.726 | 6.218 | 12.078 | 7.721 | 38.670 | 82.92 | 0.626 | 91.59 | 86.31 |
| | 2020 | 29.971 | 6.218 | 12.078 | 7.721 | 38.670 | 86.68 | 0.758 | 78.96 | 96.04 |
| | 2024 | 29.648 | 6.218 | 12.078 | 7.721 | 38.670 | 86.68 | 0.758 | 82.05 | 73.92 |
| **Open Area** | 1990 | 7.412 | 3.825 | 8.435 | 4.749 | 14.628 | 80.31 | 0.706 | 68.38 | 59.24 |
| | 2001 | 6.167 | 3.825 | 8.435 | 4.749 | 14.628 | 87.77 | 0.794 | 53.91 | 76.67 |
| | 2013 | 4.652 | 3.825 | 8.435 | 4.749 | 14.628 | 82.92 | 0.626 | 65.95 | 74.19 |
| | 2020 | 12.552 | 3.825 | 8.435 | 4.749 | 14.628 | 86.68 | 0.758 | 100.0 | 53.57 |
| | 2024 | 13.087 | 3.825 | 8.435 | 4.749 | 14.628 | 86.68 | 0.758 | 59.96 | 81.50 |
| **Water Bodies** | 1990 | 1.233 | 0.412 | 0.972 | 0.512 | 0.170 | 80.31 | 0.706 | 59.32 | 66.04 |
| | 2001 | 0.669 | 0.412 | 0.972 | 0.512 | 0.170 | 87.77 | 0.794 | 50.00 | 100.0 |
| | 2013 | 0.669 | 0.412 | 0.972 | 0.512 | 0.170 | 82.92 | 0.626 | 61.05 | 74.36 |
| | 2020 | 1.327 | 0.412 | 0.972 | 0.512 | 0.170 | 86.68 | 0.758 | 100.0 | 100.0 |
| | 2024 | 0.681 | 0.412 | 0.972 | 0.512 | 0.170 | 86.68 | 0.758 | 52.56 | 63.57 |

**4.2 Discussion**

The findings of the present paper demonstrate a clear empirical data that Nawabshah city has experienced rapid and sustained urbanization over the period of 1990 to 2024 which has resulted to serious environmental degradation mostly in the form of vegetation and water bodies. Rise in the built-up area, 4.57 $km^2$ to 11. 27 $km^2$ has validated a long-term tendency of horizontal urban development in lieu of compact development. This trend is consistent with classical urban geography views in the Introduction, in which the components of accessibility, infrastructure development and economic functions are the main determinants of the spatial growth in city centres (Burgess, 1925; Hoyt, 1939; Harris and Ullman, 1945).

This uncontrolled urbanization has led to the observed reduction of about 28 per cent of the vegetation and agricultural land. As it is emphasized in the Literature Review, many studies worldwide have confirmed that one of the direct environmental effects of urbanization is vegetation loss (Seto et al., 2011; Yang et al., 2013; Xu et al., 2020). Those results of Nawabshah do not only verify these tendencies but show that the rates of vegetation loss in the medium cities can be even as high as in bigger urban centres. Other studies have shown similar results in Pakistan by Mangi et al. (2020) and Ranagalage et al. (2021) that lack of proper land-use control systems hastens the transformation of productive land into built-up lands in Pakistan.

Ecologically, the decrease in the vegetation has several implications. The vegetation is plagued by the fact that it is of significant importance in controlling urban micro-climates, in sustaining the biodiversity and also soil stability. According to Wei and Ewing (2018), the deterioration of green cover increases the impacts of urban heat islands and decreases cities ability to cope with the increase in temperature. The vegetation loss is prone to escalate the heat stress and augment the energy demand coupled with worsened overall urban environmental condition in the semi-arid environment of Nawabshah which already has high levels of climatic stress. Besides, the agricultural areas are decreasing in size, diminishing the agro-commercial base of the city in the past (Bombay, 1927; Tahir, 2021) and weakening the livelihoods and food systems of the locals.

The depletion of water bodies by about 45% during the period of study is one of the most hazardous effects that were determined on the environmental front in this study. Although the past research has tend to focus on the variability and changes in rainfall as the main cause of water bodies diminishment (Dewan and Yamaguchi, 2009; Dodman et al., 2022), results of Nawabshah indicate that humans have more significant contributions. The invasion of canals and the drainage systems, sedimentation and reclamation of the post-flood lands have all contributed to the long run degradation of the surface water resources. The observation of the temporal elevation in the water bodies of 2020, and sharp decrease in 2024, empirically supports the argument put forward on the basis of research by Zhang et al. (2018) that temporarily hydrological changes would obscure the long-term structural degradation in the absence of long-term data.

Another aspect that is observed in the study is that open space and urban development are intricately connected. The rise in the open land since 2013 is dynamic post-flood and careless land clearing, so the urbanization in Nawabshah is not linear in nature but is subject to fluctuations in the environmental occurrences. The same observation has been noted in fast growing urban centers of South Asia cities in which disasters tend to reorganize the land-use structure without any form of structured recovery planning (Baker, 2012; Leal Filho et al., 2018).

The reliability of RS and GIS in long-term monitoring of urban environmental features is correct with high levels of classification according to the Kappa coefficients and methodological validity of going past earlier studies (Longley et al., 2005; Romero-Calcerrada et al., 2008). Such use of Urban Expansion Intensity (UEI) at the urban scale level also supports the analytical framework showing that it is an efficient method of quantifying the rate, scale of urban growth in medium-sized cities, in accordance with Liu and Liu (2020).

On the whole, the urbanization of Nawabshah cannot be discussed only as demographic event because it is the structurally conditioned process which is predetermined by migration, development of infrastructure, economic changes and reconstruction of disaster. The changes in the environment associated with the loss of vegetation, destruction of water bodies and growing land fragmentation are in line with the global and national literature, but the local institutional and planning restraints amplify them. It is probable that the further development of urban areas will spell out a further ecological degradation, the escalation of climate vulnerability, and the lack of sustainability of urban environment without the included land-use planning and environmental management.

## 5. CONCLUSION

The study on the spatial-temporal evaluation of urban sprawl and its environmental consequences in Nawabshah city between 1990 and 2024 to address the research gap, namely the critical one concerning the medium-sized cities of Pakistan. Combining the multi-temporal Landsat data with the use of Remote Sensing, GIS, Urban Expansion Intensity (UEI), and statistical data make the research a powerful and quantitative evidence of the long-term land use transformation and ecological degeneration.

The findings depict high expansion in the built-up land area with a high loss in vegetation land and water bodies. The decrease in the green and agricultural land by 28 percent and water bodies by 45 percent denotes the environmental effects which are at least at par and in certain cases higher than what has been experienced in large urban centers. Such results break the existing assumption on urban studies that extreme environmental pressure is a feature of megacities.

This study is an in-depth study that is carried on to 2024 to capture more recent urban dynamics that were largely not portrayed in previous studies despite their impact on post-flood urban situations. The results indicate that the major causes of the long-term loss of water bodies in Nawabshah are urban encroachment and the growth of infrastructure as opposed to the climate variability. Methodologically, the effective implementation of UEI in the city level presents a good example of applying the same to other mid-size cities in Sindh and South Asia to analyze their urban growth. The research proves that urban sprawl is occurring in mediums of big cities such as Nawabshah rapidly, unplanned and environmentally unfriendly. These findings underscore the urgent need to enact sustainable urban planning, development of green infrastructure and integration of water resource. This change of the scholarly focus of studying megalopolis to under-researched urban centers is a significant contribution to the literature of urban geography and urban environmental planning and highlights the need to have a more comprehensive approach in extending sustainability-oriented policies onto all levels of cities in Pakistan and South Asia in general.

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