Spatiotemporal Analysis of Land Use and Land Cover Changes in District Rahim Yar Khan Using Geospatial Techniques

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Abstract

This paper evaluated the LULC dynamics of District Rahim Yar Khan, Pakistan, within 22 years (2000 2022) by applying geospatial methods such as remote sensing (RS) and Geographic Information System (GIS). The years 2000, 2008, 2013, 2018 and 2022 were selected as the years when satellite data were obtained, and the same years were selected for demographic, industrial and urban data collected from national census reports. After analysing the images, the parameters used to measure vegetation, built-up areas, and water bodies were NDVI (Normalised Difference Vegetation Index), NDBI (Normalised Difference Built-up Index), and NDWI (Normalised Difference Water Index). The land was classified under five categories, namely built-up, vegetation, fallow land, water bodies and barren land, which were supervised. The findings show that built-up areas have increased by 42 km2 in 2000 and 113 km2 in 2022. There were changes in vegetation cover, which reached its highest in 2008 (6485 km2) and lowest in 2018 (5440 km2), with the most significant increase in 2013. Changes in water bodies were also observed, with the lowest value of 159 km2 in 2008 and the highest of 187 km2 in 2018. Barren land reduced to 5468 km2, compared to 6719 km2 in 2012 and 2022, respectively, and fallow land increased to 1415 km2 in 2022, compared to 95 km2 in 2008. These results contribute to understanding the impacts of population increase, urbanisation, and agricultural development on land resources and provide key information for sustainable urban planning, land resource management, and the prediction of future changes in LULC in the area.

Keywords: Remote Sensing; Urbanization; Vegetation Dynamics; Sustainable Development.

Introduction

The surface of the Earth has undergone extraordinary changes worldwide due to human activity, a phenomenon known as land use and land cover (LULC) change. Humans today are the rulers of the world, and they use most of the planet's land for various purposes (Siry et al., 2005). Land use

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and land cover are two distinct terms, but they are interrelated. Land use and land cover.. Land use refers to the human use of land for agricultural, industrial, residential, or recreational purposes, and land cover depicts the physical and biological characteristics of land on the Earth's surface (Dewangkoro & Arymurthy, 2021). When land use changes, land cover usually changes (Prakasam, 2010; Rawat & Kumar, 2015). As people undertake more activities that alter the ecology and environment, LULC changes have been a significant factor in global ecological and environmental change (Zhao et al., 2004; Dwivedi et al., 2005; Fan et al., 2007). The high population in Pakistan has placed tremendous pressure on natural resources. Hence, it is essential to obtain proper, recent, and comprehensive spatial data on LULC changes to support sustainable city development and planning (Miller et al., 1998; Manandhar et al., 2009; Zhang et al., 2017). The importance of researching LULC change at the regional and local scales exceeds that of the global sphere (Mahmood & Pielke, 2014). Local and regional climatic variations have a more substantial impact on vital life-giving resources like food, water, and energy, as well as other components such as human health and ecosystem stability, than global averages. It is therefore imperative to have region-specific LULC measurements (Rounsevell et al., 2014). A significant insight into the patterns of global change is understanding the forces and dynamics driving LULC change. This type of research helps scientists and policymakers simulate future scenarios, promote sustainable growth and development, and create efficient policy frameworks (Munthali et al., 2019). Due to the high rate of rural-to-urban migration over the past decades, urbanisation has been spurred and, therefore, altered LULC patterns (Li et al., 2016). Although the leading cities have been extensively researched, the small urban centres are unexplored (Han et al., 2015; Li et al., 2016). LULC analysis provides essential details about natural landscapes and the degree of human impact on Earth's surface (Gong et al., 2011; Kanga et al., 2013).

The latest remote sensing tools have transformed the process of LULC data Collection and analysis, providing valuable data on forest degradation, wetland loss, agricultural activities, and urban growth (Kanga et al., 2014; Kanga et al., 2015; Singh et al., 2014c). Conventional surveying methods are the best and most effective, but are expensive, time-consuming, and may not be feasible in small or emerging areas. This has led to increased use of Geographic Information Systems (GIS) and remote sensing to monitor and map changes in LULC (Epstein et al., 2002). Such geospatial technologies can be effectively used to collect, model, and visualise data, which is why they are vital for environmental analysis and decision-making (Mishra et al., 2020). Among these tools, it can now be stated that remote sensing and GIS are some of the most successful technologies to use in quantifying and mapping LULC alterations due to their accuracy and scalability (Chen et al., 2005; Nunez et al., 2008; Lu et al., 2004; Rehman et al., 2011). Satellite images are considered a valuable source of land-use data and a helpful tool for identifying, analysing, and tracking environmental dynamics (Singh et al., 2017; Pradhan et al., 2008). Therefore, these technologies are increasingly used to measure and monitor LULC dynamics (Hua, 2017; Mishra, 2016). GIS also helps show, analyse, and combine digital spatial information, which is essential for such evaluations (Reis, 2008; Khan et al., 2016; Zeleke et al., 2001). Moreover, GIS has become a necessary analytical tool that extends beyond spatial representation and can be used in urban planning, disaster management, and environmental impact assessment (Farid, 2002). Researchers in urban studies use GIS to analyse the impacts of urbanisation on the environment, as technology can map the three-dimensional patterns of construction and the spatial growth of city centres and transport systems (Gar-On Yeh & Xia, 2001). Due to the irreversible nature of urban growth, GIS can also forecast future land development patterns (Lee et al., 1998). The applications of remote sensing and GIS in the fields of agriculture, environmental monitoring, and ecosystem management are extensive, and it is needless to mention that they are invaluable for sustainable spatial planning and landscape change identification (Herold et al., 2005; Chen et al., 2005).

Methodology

Overview

Methodology provides an overall guideline and the steps for conducting research systematically, ensuring results are valid and replicable. This paper analysed both spatial and non-spatial data to evaluate changes in Land Use and Land Cover (LULC) in District Rahim Yar Khan using remote sensing and GIS. The methodology included the analysis of satellite images, the computation of vegetation and built-up indices, and the identification of spatial changes (Lu et al., 2019; Foody, 2020).

Data Collection

Data Sources

In this research, secondary data sources were used; therefore, Landsat images were obtained from the United States Geological Survey (USGS) Earth Explorer portal. Population and census data from the Pakistani Bureau of Statistics (PBS) were used to supplement the data. The Landsat data were favoured due to their extended temporal coverage and availability at no cost, which is why these data are appropriate for the analysis of long-term LULC changes (Roy et al., 2014; Wulder et al., 2019).

Satellite Data

A satellite is an artificial device placed into orbit to scan the surface and atmosphere of the Earth. Satellite images have been extensively used in mapping, surveillance, and tracking surface variations over the years (Campbell & Wynne, 2011). Remote sensing provides synoptic, repetitive, and multispectral data on land features, which is essential for examining environmental changes (Jensen, 2015). In the current research, the selection of Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIRS images was based on their spectral and spatial quality, which are appropriate for LULC mapping at the regional level (Zhu & Woodcock, 2014).

Landsat Imagery Used

NASA and USGS led the Landsat program, which has been providing consistent Earth observations worldwide since 1972 (Wulder et al., 2019). To examine multi-decadal land cover changes, five temporal datasets were obtained for the District Rahim Yar Khan, including 2000, 2008, 2013, 2018, and 2022. The data used in each picture were collected during the dry season (January-March) to reduce the effects of clouds and make them comparable (Roy et al., 2014).

Data Analysis

Data analysis was performed using ArcGIS 10.8 and ERDAS Imagine 2015; image preprocessing included radiometric, atmospheric, and geometric alignment. LULC variations were identified using visual interpretation and spectral index analysis (Jensen, 2015). Three major indices have been calculated:

- *NDVI (Normalised Difference Vegetation Index):* Measures the greenness and the biomass of the vegetation (Rouse et al., 1974).

- *NDBI (Normalised Difference Built-up Index):* This index identifies built-up and urban areas (Zha, Gao, and Ni, 2003).
- *NDWI (Normalised Difference Water Index):* This improves the detection of water bodies (McFeeters, 1996).

These indices can give quantitative data on vegetation health, urban sprawl and hydrological patterns (Zhou et al., 2014).

Methodological Framework

The methodology was based on a series of steps from data Collection to spatial analysis and map production. The process included:

- The USGS and PBS data sources were used to collect data
- Image processing and image repair
- Calculation of spectral indices (NDVI, NDBI, NDWI)
- Managed categorisation using ArcGIS
- Detection of change after classification
- Assessing accuracy and validation

This is a systematic method to ensure that LULC change results are reliable and repeatable (Lillesand et al., 2015).

Land Use and Land Cover Change Dynamics

Several biophysical and socioeconomic factors, such as population growth, agricultural intensification and urbanisation, affect LULC dynamics. The population will be retrieved from the Pakistan national censuses (1998, 2017) and estimated for the intervening years. The processes of urbanisation and migration played a significant role in this change in built-up areas, as people moved towards cities with improved amenities (Ali & Piracha, 2016; Mahmood et al., 2021). Other comparable reports have attributed urban growth to increases in built-up density and the loss of vegetation cover in arid areas of Pakistan (Butt et al., 2015; Rahman et al., 2020).

Image Classification

Image classification is the process of assigning pixels to specified land cover classes based on spectral reflectance values (Richards & Jia, 2006). Supervised classification within ArcGIS was conducted in this study to create four major classes of the images based on the use of the Maximum Likelihood Algorithm (MLC):

- Vegetation
- Built-up area
- Water body
- Barren land

Training sampling was conducted through field observations, Google Earth imagery, and expertise. Supervised classification is more accurate than unsupervised methods, particularly when ground truth data is available (Lu & Weng, 2007; Foody, 2020).

Accuracy Assessment

To determine the reliability of classified maps, an accuracy assessment is required. The accuracy measure in this work was computed using the confusion matrix, which compares the ground-truth reference data with the labelled pixels. The following metrics were determined:

- Overall Accuracy (OA)
- Producer's Accuracy (PA)

- User's Accuracy (UA)
- Kappa Coefficient (K)

The classification accuracy of over 85% is usually regarded as a reasonable standard of LULC studies (Congalton & Green, 2019). This is supported by the use of high-quality reference data and field verification to improve the credibility of the end product (Foody, 2020).

Results

Population Growth Trends in Pakistan and District Rahim Yar Khan

One of the significant forces that impacts land use and land cover (LULC) alterations, urbanisation, and resource demand is population growth. The Pakistani population has been steadily rising, from 139.74 million in 2000 to 241.49 million in 2023, for a total growth of about 73 per cent over the 23 years. The number of males grew to 121.71 million, compared to 72.6 million, with a similar growth of 101.97 million compared to 67.1 million for females, as shown in Table 1. The trend in national development reflects the relentless pressure on demographics, leading to rising demand for housing, agricultural land, infrastructure, and industrialisation. In the same case, the District Rahim Yar Khan has recorded remarkable population growth, as depicted in Table 2, which shows the local demographics and migration patterns. By 2000, the population growth rate was 3.36, and the district population was 246,000. The population had risen to 318,000 by 2008, with a mild decline in the growth rate to 3.25. It has been on an upward trend, increasing from 373,000 in 2013 to 438,000 in 2018, with growth rates of 3.04% and 3.30%, respectively. The 2023 census reported a population of 504,000 and a low growth rate of 2.86, suggesting a slowing population growth. However, the population growth rate in Pakistan has been quite strong; in Rahim Yar Khan, it is similar but fluctuates due to local factors such as rural-to-urban migration, urbanisation, and socioeconomic development. This unceasing population growth puts pressure on land resources, hastens urbanisation, and affects land-use patterns in the district, as reflected in the LULC changes examined in this paper.

Table 1: Demographic Growth of Pakistan: 2000–2023

Year	Total population	Males	Females
2000	139740000	72600000	67110000
2005	156010000	80830000	75210000
2010	173500000	89760000	83750000
2015	191710000	99040000	92670000
2020	215250000	111040000	104200000
2023	241490000	121710960	1019779040

Table 2: Demographic Growth of District Rahim Yar Khan: 2000–2023

Year	Population	Growth rate
2000	246000	3.36%
2008	318000	3.25%
2013	373000	3.04%
2018	438000	3.30%
2023	504000	2.86%

Urbanization and Land Use Land Cover Change

Urbanization was seen to be the key factor influencing land use and land cover (LULC) across the District Rahim Yar Khan which is closely associated with high population growth, rural to urban migration and urban industrialization. The rising trend in rural to urban migration of people in search of improved medical services, educational services, transport as well as recreational amenities has caused the growing construction of built-up regions at a high rate with the removal of agricultural and vegetative lands. The presence of educational facilities has also been a major cause of a population influx to urban centers, as educational institutions including Khawaja Fareed University of Engineering and Information Technology (KFUEIT) inaugurated in 2014, Shaikh Zayed Medical College and Hospital and Rahim Yar Khan campus of Islamia University of Bahawalpur have attracted students, professionals and support services to urban centers, driving urbanization by increasing urban density and translating agricultural land into built-up land. Otherwise, urban infrastructure has stimulated urban development as cities have good hospitals and other medical facilities than the countryside thereby leading to the people moving to the urban areas to get better healthcare facilities. Leisure facilities such as parks, restaurants, shopping malls and historical sites are concentrated in cities and this further enhances development of urban land and changes the surrounding land use. Industrialization has also contributed greatly to the changes in land cover since the development of infrastructures and industries in Rahim Yar Khan has transformed the vegetative and agricultural land into industrial and commercial areas. The district has different industries, among which are six sugar mills, one Unilever fertilizer plant, two FFC/FFCL plant, one coca cola plant, three textile factories, one auto industry, 271 brick kilns and 77 flour mills among others, showing the magnitude of industrial activity are displayed in table 3. The resultant process of urbanization, establishment of educational and medical facilities, recreational development and industrialization has resulted in the sustained growth of developed lands, loss of vegetative cover, change in agricultural lands and the general shift in land use and land cover pattern of Rahim Yar Khan, which is all interconnected by the socio-economic and environmental process dynamics that govern Rahim Yar Khan.

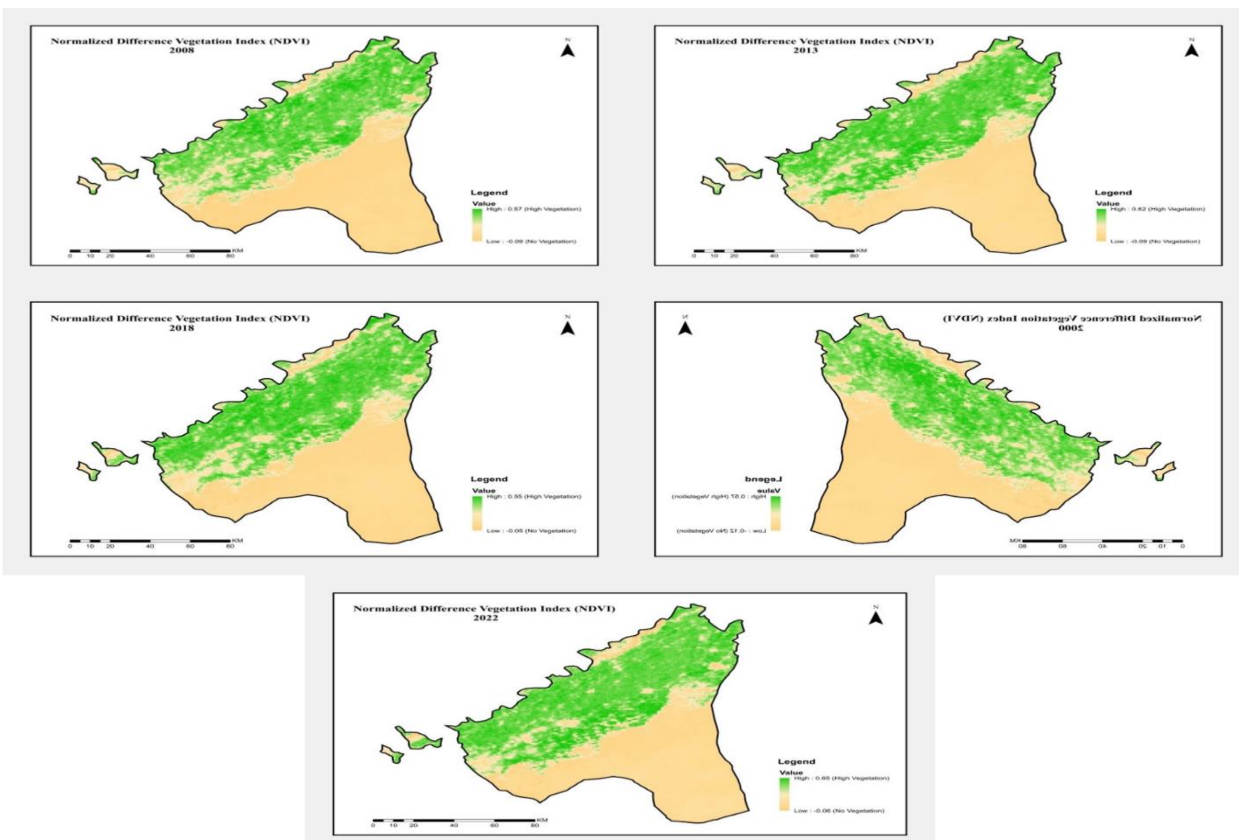
Table 3: Distribution of Key Industrial Establishments in District Rahim Yar Khan

Name of industry	Numbers of industries
Sugar industry	06
Unilever fertilizers	01
FFC and FFCL	02
Coca cola	01
Textile	03
Auto industry	01
Brick kilns	271
Flour mills	77

Vegetation Cover Analysis Using NDVI

Normalized Difference Vegetation Index (NDVI) was used to determine the vegetation cover of District Rahim Yar Khan, shown in figure 1. The district had also low vegetation cover with the range of NDVI between 0.12 and 0.57 in 2000 showing big areas of barren and fallow land. A rise in the vegetation cover was noted by the year 2008 with more regions recording high levels of NDVI than in 2000. On the whole, the discussion indicates that vegetative cover in the district has increased gradually between 2000 and 2008. The District Rahim Yar Khan NDVI analysis of 2008 showed that there was an increase in vegetative cover of the area in 2008 than that of 2000. NDVI 2008 values varied between 0.09 to 0.57 indicating that although vegetation was already more developed, it was not thick or quite healthy. When comparing the NDVI 2000 with the NDVI 2008, it can be indicated that the area was being used more in agriculture in the specified period which indicates a slow increase in vegetative expanses in the district. Analysis of the area of the District Rahim Yar Khan 2000-2022 reveals a different change in vegetative cover over the years. In 2000, the vegetation was sparse with the NDVI values of 0.12 to 0.57. In 2008, the vegetation had grown and it had values of 0.09 to 0.57 and the land with agriculture had increased. There was a decline in vegetation in 2013 than in 2008 but still better than in 2000 with NDVI values of 0.09-0.62. The values of NDVI of 0.05 to 0.55 in 2018 show that the vegetation had been on a downward trend since 2008. There was a slight recuperation in vegetation in 2022, with NDVI values of between 0.06 and 0.65 whether this was compared to 2018, but still below the highest level of 2013. On the whole, the trends of NDVI show variable vegetation covering throughout the years of 22 years.

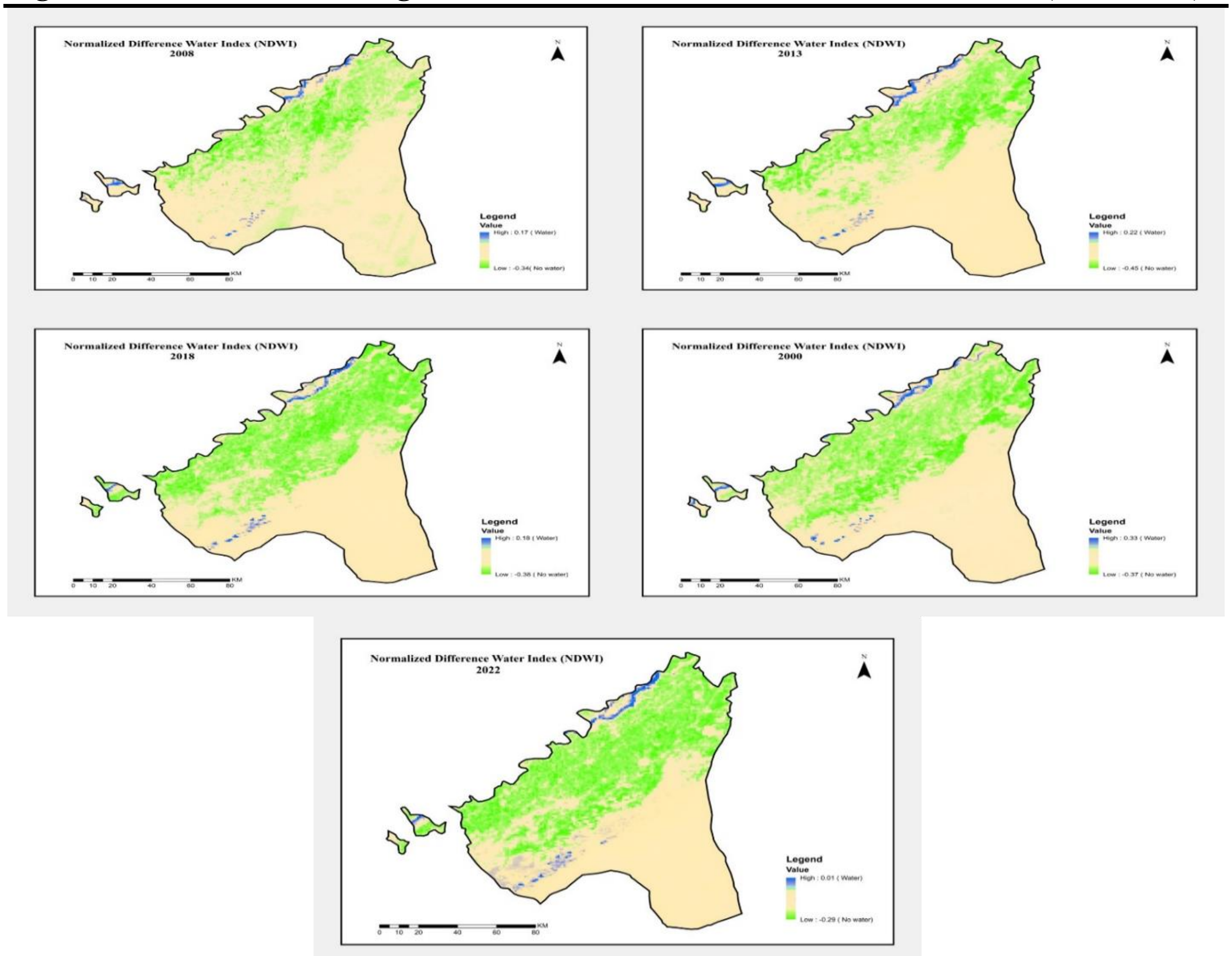
Figure 1: NDVI-Based Vegetation Dynamics in District Rahim Yar Khan (2008-2022)



Water Bodies Analysis Using NDWI

The temporal analysis of surface water distribution of the District Rahim Yar Khan during 2000 to 2022 (NDWI) indicates the temporal changes which are shown in figure 2. The values of NDWI in 2000 ranged between -0.37 and 0.33, which reveals the existence of water bodies that are not numerous as majority of the district contains low amount of water. The water availability declined slightly by 2008 with the values of NDWI of -0.34 to 0.17 indicating a slight decline in surface water as compared to 2000. The values of NDWI are higher in 2013 with a range of -0.45 to 0.22 which means that in 2013 there is increased water presence as compared to 2008 and 2000. The highest increase in water coverage during the study period was found this year even though the values were still moderate. The NDWI values of 2018 were -0.38 to 0.18 which indicated a slight decrease in water coverage than in 2013, yet it was higher than that of 2000 and 2008. Lastly, NDWI values bordered between -0.36 and 0.20 and revealed that there was a gradual change of water resources in comparison to 2018 and that surface water in the district is usually increasing over the 22-year period. In general, the analysis of NDWI in the year of the year shows the oscillations in the availability of surface water, with high rates in 2013 and a slow but consistent improvement in 2022.

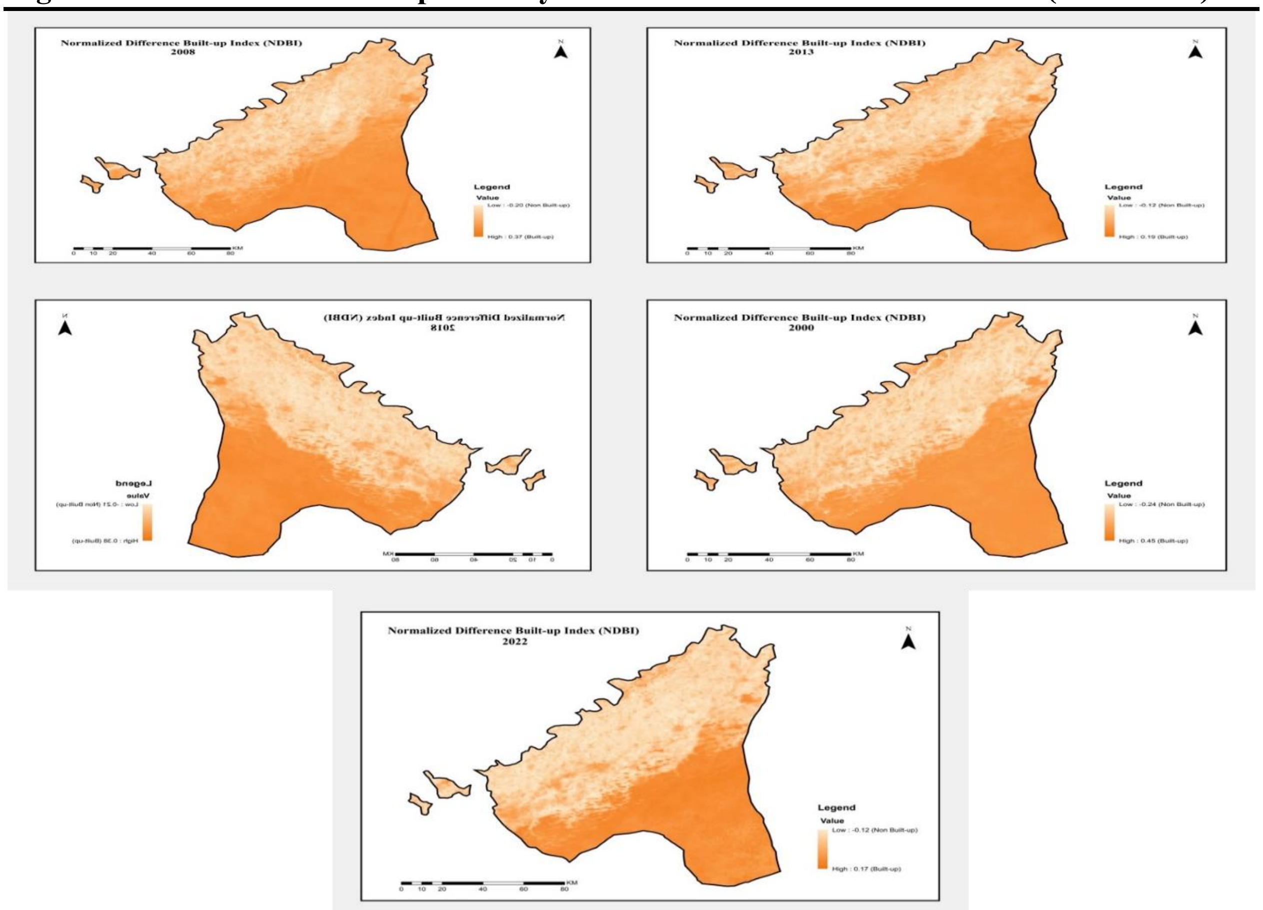
Figure 2: NDWI-Based Changes in Water Bodies in District Rahim Yar Khan (2008–2022)



Built-up Area Analysis Using NDBI

The NDBI analysis of District Rahim Yar Khan of the 2000-2022 period shows the trend of changes in built-up area over the years are displayed in figure 3. Relatively low values of the built-up area, in contrast to vegetation, barren land and fallow land, were found in 2000 where NDBI values varied between -0.24 and 0.45 which showed that most of the area in the district was covered by non-built-up land cover. The built-up area was reduced slightly by 2008 with NDBI between -0.20 to 0.37 indicating a slight reduction in urban or constructed areas as compared to 2000. The NDBI values in 2013 have been between -0.12 and 0.19 with a slight increase in built-up area since the same values in 2008 but still less than the same value in 2000, which means that there is gradual conversion of land to construction and urban development. However, a larger growth in the built-up area was recorded in 2018 with NDBI value between -0.21 and 0.38 which increased the built-up area by a significant margin since the 2013 values were negative indicating a sharp rise in urbanization. The highest level of the built-up area was observed in 2022 throughout the study period, with the NDBI values showing a significant growth in comparison to all the previous years. This proves that urban and built-up land had greatly increased and this forms the high-level of land cover alteration in District Rahim Yar Khan over the 22 years.

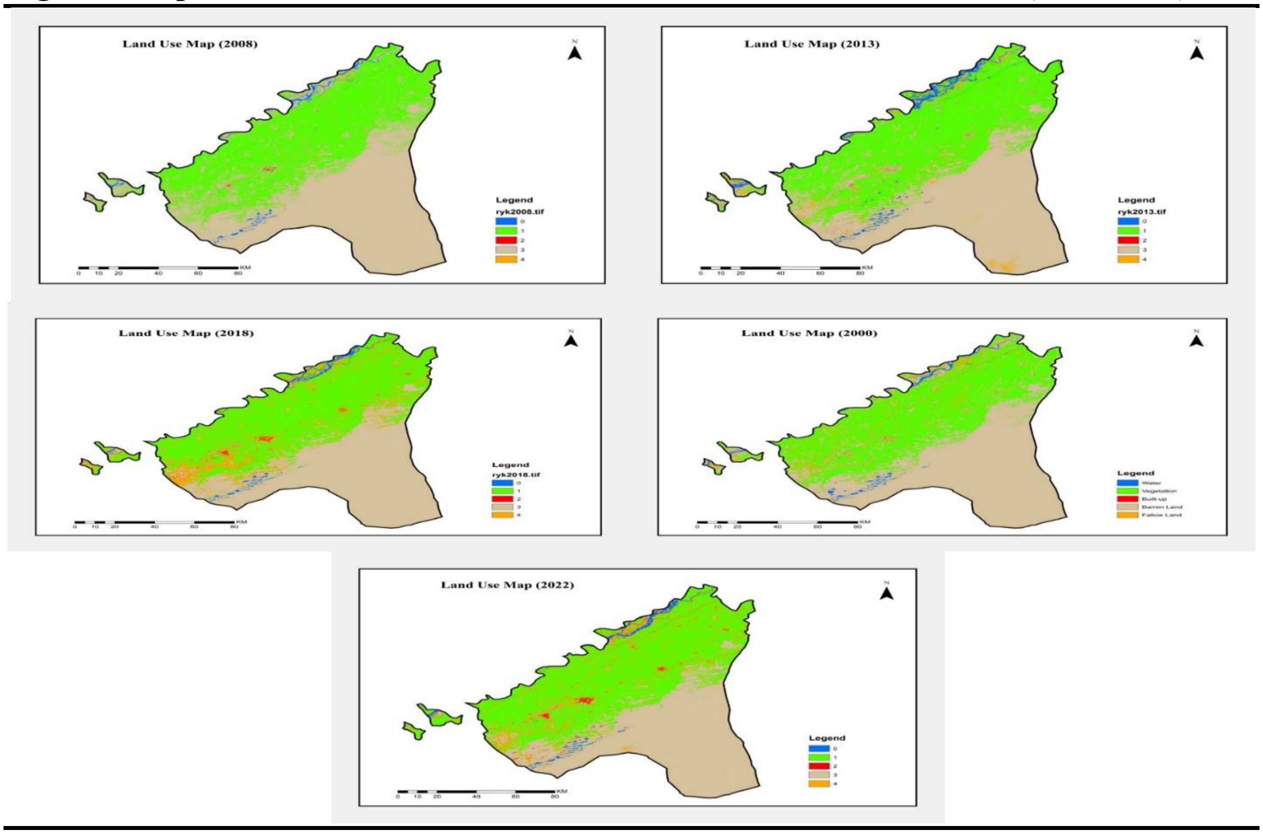
Figure 3: NDBI-Based Built-up Area Dynamics in District Rahim Yar Khan (2008–2022)



Supervised Classification Results

The monitored categorization of satellite photographs from 2008 to 2022 indicated significant alterations in the land use and land covers in District Rahim Yar Khan are depicted in figure 4. In 2008, the classified image recorded a marginal increase in built-up area as compared with 2000 whereas water bodies, barren land and fallow land expanded downwards. On the other hand, vegetation cover improved meaning that there were growth of agricultural areas or forest regions. The 2013 classification showed that the water area had further increased since 2008 which indicated improved supply of surface water. Nevertheless, the vegetation cover decreased in comparison with 2008, but it was still above the situation in 2000. Constructed lands experienced considerable growth and fallow land also experienced significant growth whereas unproductive land experienced slight growth as the land was gradually converted to construction and urban use. Water bodies reduced compared to the year 2013, although water coverage was greater in 2018 than in the years 2000 and 2008. The vegetation remained dwindling and the covered areas continued to increase in size, which shows the further development of urban areas. The area of fallow land showed significant growth and the area of barren land went down indicating the shift in land utilization trends within the period of 10 years. Developed spaces attained the highest limit throughout the 22 years of the research period, which implies further urban growth. Barren land dropped to the lowest level and fallow land was growing and highlights the dynamics of land use between 2008 and 2022. Comprehensively, the classified results under supervision indicate that built-up and fallow areas have been increasing gradually, there is a downward trend on barren areas, changes in water body and changing vegetation cover, which are the overall effects of urbanization, agriculture and other anthropogenic activities IN RYK.

Figure 4: Supervised Classification of LULC for District Rahim Yar Khan (2008–2022)



Statistics of Land Use Land Cover Change

The quantitative analysis of land use and land cover changes in District Rahim Yar Khan from 2000 to 2008 are shown in figure 5 which revealed notable shifts across different categories. The water area decreased from 169 km² in 2000 to 138 km² in 2008, while vegetative cover increased from 5,286 km² to 6,485 km² over the same period. Built-up area declined from 42 km² in 2000 to 24 km² in 2008 and both barren land and fallow land experienced reductions, with barren land decreasing from 6,719 km² to 6,142 km² and fallow land from 679 km² to 95 km². These changes indicate dynamic land use patterns influenced by agricultural expansion, urbanization and natural resource variations. The overall classification accuracy for the LULC maps was shown in table 4 which consistently high across all years, with 0.999 for both 2000 and 2008, 0.9882 for 2013 and 0.9978 for both 2018 and 2022. The Kappa (κ) statistics similarly indicated strong agreement between classified images and reference data, with 0.996 in 2000, 0.9958 in 2008, 0.9792 in 2013, 0.981 in 2018 and 0.994 in 2022, confirming the reliability and accuracy of the supervised classification results.

Figure 5: Land Use Land Cover Area Dynamics (2000–2022)

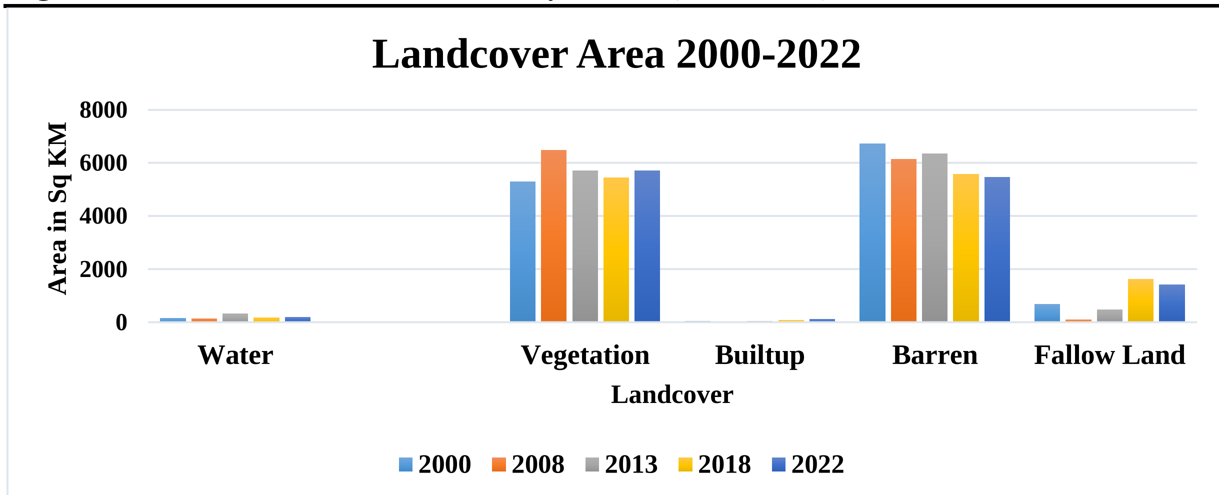


Table 4: Overall Classification Accuracy and Kappa (κ) Statistics

Year	2000	2008	2013	2018	2022
Overall Accuracy (%)	0.999	0.999	0.9882	0.9978	0.9978
Overall Kappa (κ) (%)	0.996	0.9958	0.9792	0.981	0.994

Discussion

The results of this analysis show significant and diverse variations in land use and land cover (LULC) over the 22 years from 2000 to 2022 in District Rahim Yar Khan. These alterations are placed within the broader context of population growth, rural-urban migration, urbanisation, agricultural intensification, and other human-related stresses. The spread of vegetative cover between 2000 and 2008 at the onset, coupled with the loss of water, barren, and fallow land areas, highlights a period in which land was changed into more valuable vegetative cover or agricultural land for agricultural activities. This is in tandem with global trends in the developing world, where human land use increases in response to demographic and economic needs (Rawat & Kumar, 2015). However, in the following years, the statistical data show a change: vegetation cover decreases, built-up areas grow, and fallow land increases. For example, in 2013 and 2018, supervised classification results indicate a decline in vegetative cover, while growths were observed in built-up and fallow areas. The trends overlap with the reported rural-to-urban migration, urban sprawl, and infrastructure growth (Miller et al., 1998, Mishra et al., 2020). Such trends among Rahim Yar Khan drivers can be explained by the demand for improved educational, medical, transportation, and recreational amenities concentrated in urban centres, which are sucking the rural areas and turning neighbouring land into urban areas. The progressive

accumulation to 2022, as indicated by the NDBI and controlled classification points, points to the strain on the remaining natural land cover from urbanisation. The falling barren land implies the conversion of the unused land into either built-up or fallow land. Concurrently, the small rebirth of vegetation and water in 2022 suggests a potential adjustment phase, driven by enhanced land management, policy measures, or changes in agricultural methods. However, these gains failed to restore coverage to previous levels.
Simultaneously, the high overall classification rates (0.999 in 2000 and 2008, 0.9882 in 2013, 0.9978 in 2018 and 2022) and high Kappa values (0.996, 0.9958, 0.9792, 0.981, 0.994) give one the confidence that these changes were substantial and sensible. The evidence base for this research is high quality and indicates that the LULC changes in Rahim Yar Khan are characterised and maintained. The policy and planning implications of these findings are that more built-up land and less natural land cover (vegetation and barren lands) could affect ecosystem services, soil fertility, water balance, and sustainable development. The area is experiencing two-fold stressors: the demand to provide housing and urban infrastructure to more people and the need to preserve productive land and ecological stability. Since the trends of forest cover loss, settlement, and barren land conversion have been seen in similar studies in Southern Punjab and Pakistan in general (Hu et al., 2023; Abbas et al., 2025), the case study by Rahim Yan Kahn supports the local trend and insists on integrated land use planning, monitoring and mitigation measures. The research establishes that the anthropogenic factors of urbanisation, migration, increased agricultural activities, and reduced natural variability of the land in Rahim Yar Khan influence LULC changes between 2000 and 2022. The movement towards more built-up and fallow land reduces barren land, and changes in vegetation and water cover are indicators of a shifting landscape driven by demographic and economic forces. In the future, zoning, green infrastructure, sustainable agriculture, water resource management, and GIS-based monitoring will be strategic interventions to balance development and environmental preservation in the district.

Conclusion

As the current research shows, the District Rahim Yar Khan has undergone primary land use and land cover (LULC) changes over the 22 years from 2000 to 2022. The results indicate a monotonic rise in built-up areas, primarily due to population growth, rural-urban migration, and urbanisation, with natural land cover, including vegetation and baldlands, also showing irregular patterns with slight downturns. Remote sensing and GIS were effective in providing accurate and reliable results, enabling the detection of temporal trends in vegetation, water bodies, fallow, and built-up areas. Vegetation initially increased between 2000 and 2008, but when urban development began, vegetation decreased. In contrast, water bodies and fallow lands showed fluctuating trends depending on land management and farming practices. The high overall classification accuracy and Kappa statistics confirm the strength of the supervised classification results. These developments are significant for sustainable development, resource management, and district planning. The trends observed indicate that human activities, particularly urbanisation and migration, are exerting intense pressure on natural resources, resulting in changes to the ecological and agricultural landscapes. Thus, active planning of the area, such as land zoning, sustainable agriculture, water and plant conservation, and the inclusion of GIS-based observation, is critical to reduce the adverse effects of land cover change. To summarise, this paper notes that monitoring LULC dynamics is essential at all times to support informed decision-making and ensure balanced development of the area without compromising the ecological integrity of District Rahim Yar Khan.

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