Impact of Urbanization on Land Use and Land Cover: A Geospatial Investigation of Taluka Khairpur, Pakistan (2000-2020)

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Urbanization is a major driver of land use and land cover (LULC) changes, profoundly affecting agricultural land and promoting urban expansion. Recent studies indicated that urban development often occurred on the most fertile and productive land, contributing significantly to the reduction of arable land in the outskirts of cities. The present study is an attempt to investigate the rapid urban expansion and its impact on LULC changes in Taluka Khairpur. It provides a detailed 20-year (2000-2020) analysis that has not been previously addressed. Satellite images for the years 2000, 2005, 2010, 2015, and 2020 were downloaded from the United States Geological Survey (USGS). ArcGIS was utilized for supervised classification of LULC classes including built-up areas, agricultural land, barren land, desert, and waterbodies. The study revealed significant changes in LULC over 20 years. The built-up area in Taluka Khairpur increased by 131.59 km² (221%) during the study period, which resulted in conversion of other LULC categories into urban land. Such as Agricultural land decreased by 34.40 km² (47.25%), barren land by 80.89 km² (34.74%), desert area decreased by 6.74 km² (2.56%), and waterbodies by 9.57 km² (3.64%). This study highlighted the significant urban expansion and reduction in agricultural and natural land cover in Taluka Khairpur, underscoring the need for sustainable urban planning and environmental conservation.

Keywords: Agricultural Land Deflation, Pearson Correlation, District Khairpur, Geospatial Analysis, Urban Sprawl

Introduction:

Urban sprawl, characterized by the uncontrolled and haphazard expansion of urban infrastructure into the surrounding areas, including agriculture, forests, and rangeland, poses significant challenges to the sustainable environment and urban planning [1]. This phenomenon involves the conversion of undeveloped or rural lands into urban areas, leading to profound changes in land use and land cover (LULC) patterns [2, 3]. The driving forces of LULC change are numerous, which can be categorized into direct and potential factors: direct factors include the expansion of settlements, industrial and infrastructural development, while potential factors include changes in natural environment, government policies, population dynamics, economic influences and technological advancements [4, 5]. However, the rapid changes in LULC are often marked by urban sprawl, farmland displacement, and deforestation, leading to the loss of arable land, habitat destruction, and a reduction in natural green areas [6]. Sprawl typically occurs at the urban fringes, either through radial development or along highways, resulting in extended urban growth [5]. Areas affected by dispersed growth or sprawl often lack essential services such as treated water, electricity, and sanitation. Studies indicate that rapid urbanization frequently happens when rural areas face economic stagnation and a lack of job opportunities, causing many rural residents to migrate to cities. Consequently, urban population and concomitant demand for housing and infrastructure increased, which stimulates the encroachment of urban areas into surrounding rural lands [7].

In Pakistan, LULC change studies have gained great significance. Researchers have investigated critical changes in LULC from different parts of the country [4, 6, 8-13]. They have highlighted various driving forces behind these changes; however, the most important are increasing population, economic growth, and concomitant infrastructural development [8, 11-13], particularly near the urban centers, which has accelerated urbanization [14]. The rate of urbanization in Pakistan is alarmingly high, with major cities such as Karachi, Lahore, and Faisalabad experiencing significant urban growth. For instance, Karachi's urban growth reportedly increased very sharply in the last three to four decades [15-17]. The main drivers of urbanization in Pakistan include unemployment, population growth, the pursuit of better work opportunities, and essential services like education, health, and transportation [18].

The present study is conducted in Taluka Khairpur, which is the most urbanized area among the other Talukas due to the existence of Khairpur city, which is ranked the 12th largest city of Pakistan [17]. Rapid urban expansion and other LULC changes have been observed over the last few decades, necessitating a comprehensive and in-depth understanding. In this context, the primary objectives of this research paper are to quantify LULC changes in Taluka Khairpur using GIS and remote sensing techniques, and to investigate the impact of urban expansion on LULC changes. By understanding these changes, the study aims to contribute to the sustainable management of land resources and the formulation of effective urban planning strategies. This research will provide valuable insights into the dynamics of LULC changes and urbanization, aiding policymakers and urban planners in developing strategies to mitigate the adverse effects of urban sprawl and promote sustainable urban development.

Methodology:

Study Area:

Taluka Khairpur is one of the seven Talukas of the district Khairpur. It has an area of 481.7 Km^2 and, according to the 2017 census report, has a population of 440,412 persons [17]. Taluka Khairpur is the most urbanized among the other talukas due to the existence of Khairpur city, which is ranked the 12th largest city of Pakistan. Additionally, the seven Talukas of Khairpur District consisted of 17 other significant towns or urban settlements. Geographically, it is situated between 27°3'12" to 27°33'34" north latitude and 68°42'36" to 68°47'00" east longitude and has an elevation of 61 meters above mean sea level.

The population of Taluka Khairpur is increasing with an explosive growth rate of 2.93% persons per annum during 1998 and 2017. The population density is 752.8 persons per square kilometer. The urban population (52.6%) is slightly more than the rural population (47.4%)[17]. However, rapid urbanization has been observed over the last two decades, and it has been further accelerating. The urbanization trends in Khairpur are marked by the transformation of fertile agricultural lands into housing societies. This is a threat to food security and environmental well-being, highlighting the need for comprehensive urban planning and sustainable land use management to mitigate the adverse effects on agricultural productivity and environmental sustainability.

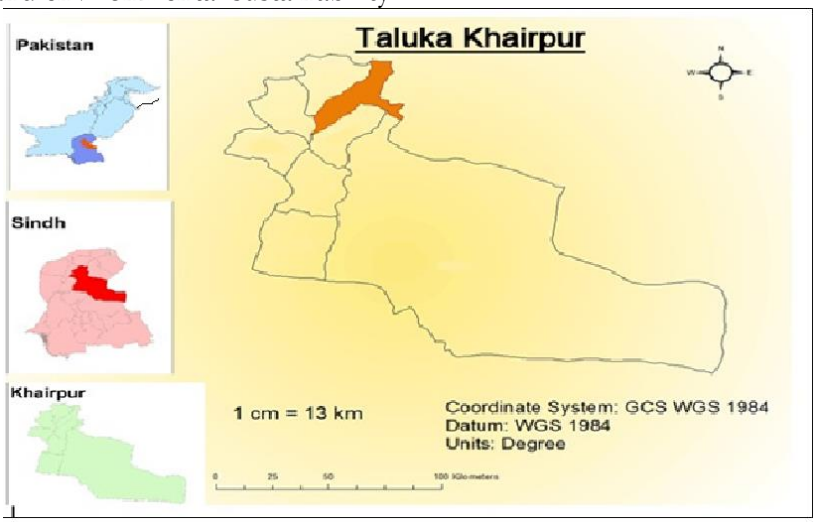

Figure 1. Location map of the study area

Data Collection:

This study is based on geospatial technologies, i.e., remotely sensed data and GIS techniques. The remote sensing data of Landsat satellite images of 30-meter spatial resolution with less than 10% could cover was downloaded from the official website of the United States Geological Survey (USGS) based on 5 year temporal gaps from 2000 to 2020. Satellite images of Landsat 5 Thematic Mapper (TM) of 2000, Landsat 7 Enhanced Thematic Mapper (ETM+) of 2005 and 2010, and Landsat 8 Operational Land Imager (OLI) of 2015 and 2020 were downloaded freely. Further details of the images are given in Table 1.

Table 1. Satellite images utilized for this study

Sr. No.	Satellite	Month	Year	Spectral resolution No. of Bands	Spatial Resolution(m)	Coordinate system
1	Landsat 5	September	2000	7	30	WGS 1984 UTM Zone 42
2	Landsat 7	September	2005	8	30	
3	Landsat 7	September	2010	8	30	
4	Landsat 8	September	2015	11	30	
5	Landsat 8	September	2020	11	30	

Source: USGS, 2000, 2005, 2010, 1015 & 2020

Preprocessing:

The first 7 bands of all the images were stacked together, and a color composite was developed in ArcGIS. Area of Interest (AOI) was extracted through an extract by mask operation using the shapefile of Taluka Khairpur from all the images. False color composite using the band combinations of 4, 3, 2 for images of Landsat 5 and 7, and bands 5, 4, 3 for images of Landsat 8 were utilized for classification. The image's visibility was enhanced through stretching the histogram using standard deviation stretch. Based on the previous

literature [4] cf., five LULC classes, i.e., agricultural land, built-up area, barren land, desert, and waterbodies were developed.

Image Classification:

For creating a signature file, the computer was trained by taking a training sample from each LULC class separately for each Image. More than 60 samples were taken from each class, which covered the entire study area. The signature file was developed in ArcGIS, and images were classified using the maximum likelihood supervised classification algorithm. The area for each class from all classified images was calculated in square kilometers using the field calculator.

Pearson Correlation Coefficient:

The data was tabulated in MS Excel for all the data years, and change was calculated for each class for the entire study period from 2000-2020. The tabulated data were inserted into the Statistical Package for Social Sciences (SPSS), and Pearson correlation coefficient statistics were calculated to find the impact of built-up area on other LULC classes.

Results:

The results of this study reveal high-level changes in different LULC classes. Built-up area has increased by 221.3% from 59.5 km^2 in 2000 to 191.1 km^2 in 2020, which resulted in a diminution of the rest of the LULC classes. Such as built-up area mostly encroached upon agricultural land in the vicinity of settlements. Therefore, Agricultural land has decreased by 52.7% from 65.2 km^2 in 2000 to 30.8 km^2 in 2020. The built-up area in Taluka Khairpur has not only encroached upon agricultural land but also into desert areas, barren land, and waterbodies. All these LULC classes have a continuous decline in their land area. Such as the desert area has decreased by 6.7% during the entire study period, barren land has decreased by 80.9% and waterbodies by 9.6%. Further details about the changes in LULC classes have been presented in Table 2 and Figure 2.

Table 2. LULC Change (2000-2020)

LULC Classes	2000		2005		2010		2015		2020		Change (2000-2020)	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Desert Area	32.0	6.7	29.2	5.9	29.0	6.1	27.6	5.7	25.3	5.3	-6.7	-21.0
Barren Land	299.1	62.1	288.8	58.1	263.0	55.3	222.7	46.2	218.2	45.3	-80.9	-27.0
Built-up area	59.5	12.3	92.6	18.6	128.5	27.0	175.1	36.4	191.1	39.7	131.6	221.3
Agricultural land	65.2	13.5	47.8	9.6	41.1	8.7	39.9	8.3	30.8	6.4	-34.4	-52.7
Water Bodies	25.9	5.4	23.2	4.7	20.1	4.2	16.4	3.4	16.4	3.4	-9.6	-36.9
Total	**481.7**	**100**	**481.7**	**100**	**481.7**	**100**	**481.7**	**100**	**481.7**	**100**		

Source: USGS, 2000, 2005, 2010.2015, 2020

The Pearson correlation coefficient has shown a strong inverse correlation of built-up area with all other LULC classes. The built-up area has a strong inverse correlation (-0.945) with desert area, Barren land (-0.990), agricultural land (-0.927), and waterbodies (-0.993). All these values are statistically significant (the p value was 0.05), which means that the occurrence of the correlation values is not by chance, but the influence of built-up area on the other LULC is a reality.

Table 3. Pearson correlation coefficient between built-up area and other LULC classes

		Desert	Built Up Area	Barren land	Agricultural Land	Waterbodies
Built Up Area	Pearson Correlation	-.945*	1	-.990**	-.927*	-.993**
	Sig. (2-tailed)	.016		.001	.023	.001
	N	5	5	5	5	5
*. Correlation is significant at the 0.05 level (2-tailed).						

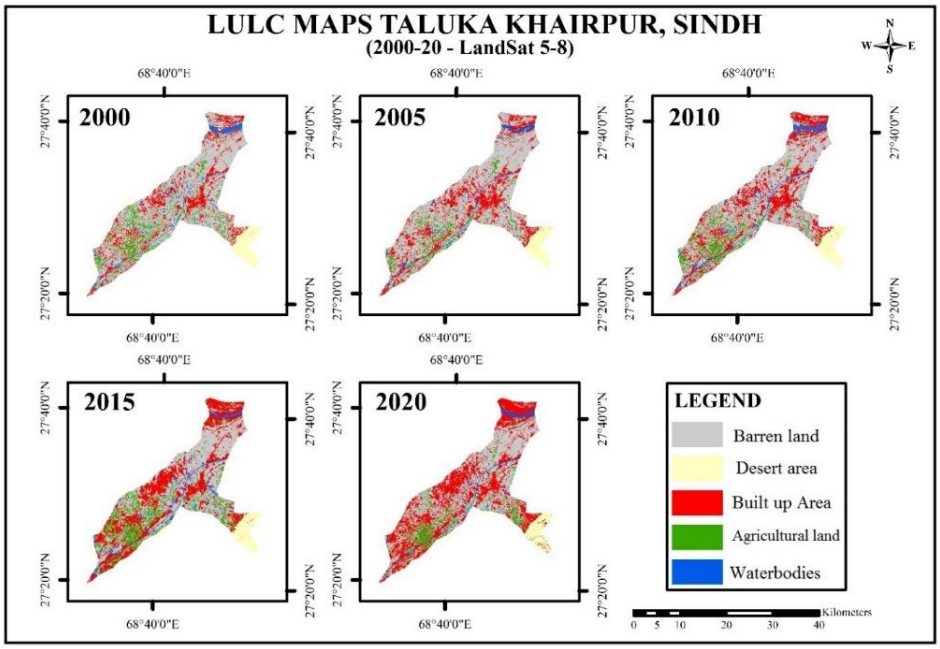

Figure 2. Land Use land Cover maps 2000-2020;
Source: Classified Landsat satellite images of 2000, 2005, 2010, 2015, and 2020

Discussion:

The result of the study reveals that there has been a notable rise in built-up area, mostly at the expense of waterbodies, agricultural land, desert regions, and barren land. This pattern is in line with recent research that found comparable patterns of changes in LULC around the world. For example, a study by [19] discovered that the National Capital Region of India had a considerable reduction in agricultural land and forest cover as a result of built-up area expansion. Similarly, a study by [20] found that in China's Yangtze River Delta, urbanization led to the conversion of grassland and agriculture to built-up regions. Recent research further supports the substantial inverse association between built-up area and other LULC classifications. For instance, a study by [21, 22] discovered a substantial inverse relationship between Southeast Asian agricultural land and urbanization. According to the study of [23], built-up area and urban expansion have negative impact on water quality and aquatic biodiversity in the Lake Victoria watershed of Kenya. Moreover, the increase of built-up areas has resulted in a drop in desert area, barren terrain, and waterbodies. Such as, [24] discovered that Jordan desert ecosystems were degrading as a result of rapid urbanization.

Similarly, urbanization in Pakistan has led to significant conversions of agricultural land into urban areas, resulting in decreased agricultural productivity and food security [25]. A study conducted in Lahore found that urbanization resulted in the loss of over 114,000 hectares of agricultural land between 1972 and 2010 [26]. Displacement of farmers and rural communities is another critical issue in Pakistan, resulting in the loss of traditional farming knowledge and practices [27]. A study in Sindh reported a 20% increase in rural outmigration during 2010 to 2023 due to declining agricultural viability, affecting agricultural productivity and food security [28]. To mitigate these impacts, research suggests adopting sustainable urban planning, agricultural land preservation, crop intensification, and rural development strategies.

Conclusion:

The results of this study have uncovered remarkable transformations in different LULC classes. Built-up area has increased by 221.3% which is more than other LULC classes. Thus, all the other LULC categories have decreased considerably, i.e., agricultural land reduced by 52.7%, desert area by 21.0%, water bodies by 36.9%, and bare land by 27.0%. These changes are mainly attributed to urban expansion all around the Khairpur city. The results also

reveal that large parcels of agricultural land have been converted to urban areas, resulting in the loss of precious fertile land and creating an issue of crop production deficiency.

Such a large amount of conversion is a serious threat to the sustainability of the ecosystem, water availability, and food security in the study area. The results highlight the necessity of agricultural land conservation and sustainable urban planning. Future studies are required to examine meteorological and socioeconomic aspects to provide a thorough framework for land management that strikes a balance between environmental preservation and urban growth.

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