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ASSESSING URBANIZATION-INDUCED ENVIRONMENTAL CHANGE: SPATIAL-TEMPORAL ANALYSIS OF LAND USE AND LAND COVER DYNAMICS OF DISTRICT HYDERABAD, PAKISTAN

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Abstract

This study examines the spatiotemporal dynamics of land use/land cover in Hyderabad district of Sindh, Pakistan, with an emphasis on the effects of urbanization. Five change detection analyses were carried out biennially over a ten-year period using Landsat satellite imagery ranging from 2008 to 2018 including Landsat 4-5 (TM) data from 2008 to 2011 and Landsat 8 (OLI) data from 2013 to 2018. Furthermore, two land use change matrix studies were undertaken covering five-year intervals from 2008 to 2018, while a trend analysis was conducted annually from 2008 to 2018, encompassing a decade of data. Employing visual interpretation techniques and supervised classification methodologies utilizing the maximum likelihood algorithm in ArcMap (version 10.8) software, the study categorized the study area into five distinct classes: vegetation, water body, barren land, farmland, and urban built-up areas. The analysis revealed notable fluctuations in the landscape of the study area over the study period. In the base year of analysis 2008, the study area exhibited proportions of vegetated land, water bodies, barren land, farmland, and urban built-up areas at 13.95% (14,239 ha), 1.40% (1,427 ha), 17.20% (17,558 ha), 62.63% (63,921 ha) and 4.82% (4,922 ha), respectively. By 2018, significant changes were observed including a decline in the vegetated and barren land by 5.24% (5,350 ha) and 14.75% (15,052 ha), respectively. There was an increase in water bodies, farmland and urban built-up areas by 2.13% (2,179 ha), 63.27% (64,581 ha) and 14.60% (14,907 ha) respectively. This study underscores the importance of employing LU/LC change detection techniques to comprehend the impacts of urbanization and the spatial distribution of changes within the Hyderabad district. Through in-depth analysis, it explains the dynamic nature of land use transitions and the implications for urban development and environmental management policies.

1 Introduction

The natural functioning of ecosystems is being significantly impacted by the remarkable rate at which development is turning rural areas into urban areas in recent human history. The integration of remote sensing and geographic information systems (GIS) has been significantly implemented and acknowledged as a powerful and efficient tool for identifying shifts in land cover and urbanization. Remote sensing and GIS are useful tools for LU/LC management because they provide crucial observations and indicate the effects of urbanization on various LU/LC classes [1]. However, a previous study [2] evaluated remote sensing to track urban expansion in the Nanjing metropolitan area and showed how the area's fast urbanization has resulted in significant changes to the land cover. Monitoring changes in urban land use and land cover LU/LC is receiving much more attention these days since human-induced changes have a significant impact on ecosystems in urban settings [3]. The spatial features of LU/LC are helpful for comprehending the diverse effects of human activity on the overall ecological state of the urban environment, making this research especially significant [4].

Human-caused LU/LC change is occurring more rapidly in developing countries than in developed countries, with projections signalling that by 2020, most of the world's megacities will be in developing nations [5]. High urbanization rates in these regions significantly contribute to land-use change, frequently resulting in uncoordinated development with consequences that involve the loss of farmland, open spaces, and ecologically sensitive habitats due to a lack of integrated regional planning approaches [6]. For example, in India, rapid urbanization in Bangalore has resulted in considerable land cover changes, as observed by remote sensing techniques [7]. Remote sensing-based multitemporal land-use change data can be helpful for determining the fundamental shift in LU/LC patterns[8]. Satellite imagery collects multispectral, multiresolution and multitemporal data, which is then transformed into valuable information for figuring out and tracking urbanization processes as well as establishing urban land cover datasets [9]. Geographic Information Systems provides an adaptable platform for entering, analyzing and demonstrating digital information from various sources which is essential for urban feature identification, change detection, and database development [10]. In arid and semi-arid places around the world LU/LC change and environmental consequences caused by unpredictable urbanization are major concerns. The shifting of valuable lands to urban areas in Pakistan's Hyderabad region needs immediate and continuous inspections in order to successfully protect natural resources from variable human influences [11]. Understanding LU/LC variations is critical for enhancing systematic approaches to geo-environmental consequences [12]. Investigations that reveal gaps in shift patterns are critical for understanding the drivers and consequences of land use change[13].

When urbanization is managed, planned and organized properly it may enhance human society. However, unplanned urbanization creates huge challenges. More than half of the world's population resided within cities by 2008, and that figure is projected to increase nearly 81% by 2030 [14]. Planning is the purposeful, structured process of integrating development, effectively addressing the arrangement, use of land and the provision of basic services [15]. Still, there is disagreement in academics about city planning which emphasizes the necessity of an appropriate information system for all planning and development processes[16]. Urban environments nowadays are frequently characterized as expansive territories with divided interactions [17]. For any planning, management, and monitoring programme at the local, regional, and national levels the spatial distribution of LU/LC data is essential because it improves our understanding of land use and is critical to regional development [18]. According to [19], the traditional method of determining changes in land use and cover is expensive, insufficient and has a narrow application. For urban planning purposes remote sensing provides consistent, timely, accurate, and periodic spatial data [20]. Land covers which represent the ecological composition of the earth's surface and instant subsurface serve as sources as well as sinks for the majority of the energy and material transfers and interactions within the geosphere and biosphere. Changes in land cover such as biotic diversity, primary production, soil quality, runoff, and sedimentation rates are incomprehensible without understanding the land-use change that causes them [21]. As a result, land use and cover changes generate adverse effects on the environment at both regional and local levels and may be related to global environmental processes [22]. LU/LC transition has been a traditional and essential research topic on both regional and global scales widely accepted as a key source of environmental degradation and ecological extinction[23]. Human activities frequently accelerate LU/LC, particularly in economically growing regions[24]. Land-use change has an impact on the global environment and sustainable human development, attracting the attention of researchers around the world [25]. In-depth LU/LC studies have provided numerous significant results, including developments regarding spatiotemporal changes in land utilization, the relationship between land-use change and its driving forces, land-use change modelling and land-use change impact [19, 25]. Rapid urbanization has significantly impacted land-use shifts over the last 30 years, changing the land cover types in major cities [26].

As a developing country, Pakistan is shifting from a system of agriculture to an industrialized and information-driven economy. Population growth has been concentrated along major cities, mainly in Karachi, Multan and Hyderabad regions, as well as in the Indus River Delta, where significant land use/ land cover changes have occurred [27]. Significant areas of arable, woodland, grassland and barren land have been rapidly transformed into built-up areas, significantly impacting regional land systems. As land resources decrease, sustainable land use is critical for regional development. Monitoring land-use change and its driving forces in these regions is crucial for better management and use of land resources. Sustainable land use includes developing, utilizing, protection, and controlling land resources that integrate people's relationships with the environment to meet the demands of current and future generations [28]. Understanding the data-driven and spatial characteristics of regional land use, analysing the fundamental driving forces of regional land-use change, assessing the ecological significance of land use, reassembling the land-use structure and investigating the dynamic mechanisms of land-use change are all needed [29]. A comprehensive knowledge of regional land use status and features enables scientific assistance for regional land use management departments in developing sustainable land use policies [25].

In recent years numerous cities in Pakistan have witnessed urbanization which had significant consequences on different LU/LC classes. Hyderabad, Sindh's second-largest urban centre after Karachi needs attention. The main purpose of this study is to observe at urbanization in the study area since 2008 to 2018, assess its impact on different land-use classes and identify high-density urban settings and low-density urban centres. The primary goal of this research is to focus on urbanization and its environmental consequences.

2 Materials and Methods

2.1. *Study Area*

Hyderabad is located at 25.367° N latitude and 68.367° E longitude with an altitude of 13 meters (43 feet) is a prominent city on the eastern bank of the Indus River about 150 kilometres northeast of Karachi as shown in Fig 1. Covering around 104,877 hectares, it is the second most urbanized city in Sindh province after Karachi. The city's strategic location along the Indus River has historically fostered agricultural prosperity and facilitated growth while its proximity to Karachi has amplified its role as a secondary economic centre.

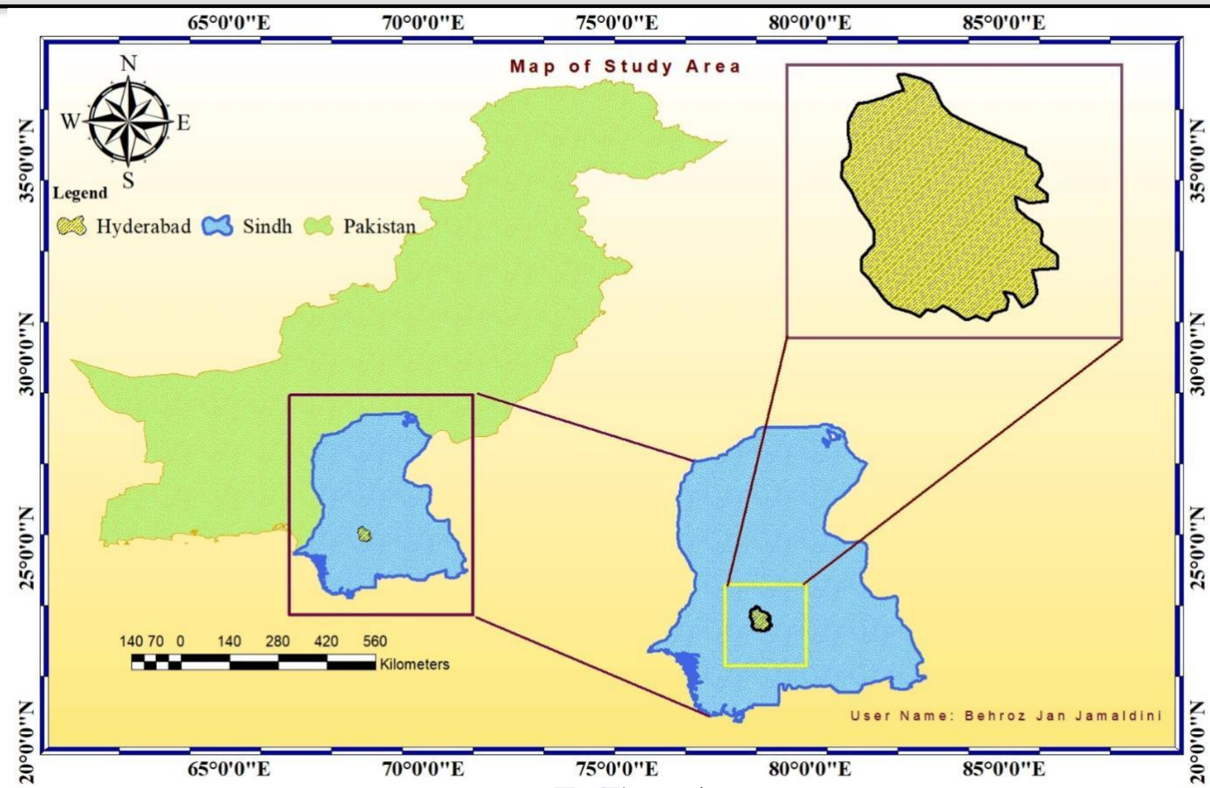

Figure. 1. Location map of the study area2.2. Data Source

In this study cloud-free satellite imagery from 2008 to 2018 were obtained online from the USGS Earth Explorer website in order to classify remotely sensed data [30]. The shapefiles for the study area were obtained from Pakistan's administrative boundaries.

2.3. *Database Preparation and Software Used*

The datasets were processed using ArcMap version 10.8 by ESRI (Environmental Systems Research Institute) [31]. This software was utilized for performing band compositions, atmospheric corrections, creating false-colour composites (FCC) and sub-setting of satellite images to derive the area of study [32] by using geo-referenced line boundaries of Hyderabad block map as the Area of Interest (AOI). Additionally, Tableau Desktop version 10.4 and Microsoft Excel 2016 were also employed in this study for further analysis and visualization [33].

2.4. *Image Pre-processing*

Image pre-processing is an important phase in the identification of urban land cover changes [34]. To effectively and precisely identify land cover changes between consecutive years, atmospheric disturbances must be modelled so that surface reflectance is not affected throughout the detection process [35]. Land cover change detection studies utilizing multi-date remote sensing imagery is highly dependent on accurate radiometric and geometric corrections. Geometric and radiometric correction are significant in multitemporal Landsat imagery [36].

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2.5. *LU/LC Visual Interpretation*

We used ArcMap 10.5 and a supervised classification technique along with the Maximum Likelihood Algorithm (MLA) to create land use and land cover maps. The Maximum Likelihood Classifier (MLC) is one of the most widely adopted supervised classification methods for remote sensing data and it is commonly used to determine land-use change. This approach is based on the probability that a pixel belongs to a given class [37]. The basic theory assumes that these probabilities are the same for all classes and that the input bands comply with normal distributions [38]. However, this method requires extensive computation time, relies heavily on a normal distribution of the data in each input band, and tends to over-classify signatures with relatively large values in the covariance matrix [39]. The method used for classifying the spectral distance is based on the equation for Euclidean distance [40]. The spectral distance approach computes the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature. Compared to other supervised approaches, this approach takes less time to compute but it tends to identify pixels that 'shouldn't be classed and ignores class variability [41].

Five land use/ land cover categories were identified in the study region by drawing polygons for each land-use class to establish a signature file when dealing with supervised classification: (i) Vegetation, (ii) Water Body, (iii) Barren Land, (iv) Farmland and (v) Urban Built-up show in the Table 1. The factors of tone, shape, size, pattern, texture and shadow were employed in the visual interpretation technique which was used to determine these classes.

Table 1: *The Nodes representing different land use categories*

ID	Nodes	Representing land use classes
1	Vegetation	Natural vegetation and grassland
2	Water Body	Lakes, ponds, and river
3	Barren Land	Rock, Sand, and Clay
4	Farmland	Cultivated and agricultural land
5	Urban Built-up	Commercial and residential areas

2.6 *LU/LC Validation*

Historical imageries from Google Earth were utilized for the verification of classified maps from 2008 to 2018. The simulated areas and the LU/LC maps were then compared because Google Earth offers high spatial resolution imagery that reduces inaccuracies and was significant to use historical images from the platform. When utilizing remote sensing data for various investigations Google Earth imagery is a valuable tool for validation because it is widely accessible and free to use. Researchers are employing it exceedingly for LU/LC mapping and related research and is regarded as a source of accuracy [42].

2.7. *LU/LC Change Detection and Transfer Matrix Analysis*

This study shows both LU/LC classification and the detection of changes in the study area. To discover these changes, categorized image sets over a two-year period are compared utilizing cross-tabulation to determine the quantitative and qualitative aspects of the changes between 2008 and 2018. Cross-tabulation analysis allows for analyzing changes in distinct LU/LC classes based on their spatial distribution. A LU/LC change matrix is generated for the years 2008, 2013 and 2018 to display quantitative areal information about total LU/LC changes, as well as gains and losses in each LU/LC type during the specified years.

2.8. *Trend Analysis*

The current research employs a trend analysis methodology to identify the temporal changes among each LU/LC class throughout the study period [43]. Tableau Desktop 10.4 is used to evaluate the attribute outputs of the categorized imagery to generate time-series graphs for the defined land use categories. In general, analyzing the trends allows for identifying novel development patterns and creating strategies that navigate or lead them.

3 Results

3.1. *Visual Interpretation Result*

Hyderabad's 2008 classified map (**Fig.2**) clearly shows that the city is dominated by extensive areas of agricultural and dense vegetation with minimal urban land. (Graph-1) spatial distribution shows that vegetation covers 13.95% (14,239 hectares) of the land, while water bodies compose 1.40% (1,427 hectares). 17.20% (17,558 hectares) of the area is covered by barren land, 62.63% (63,921 hectares) is agricultural-based and just 4.82% (4,922 hectares) is urban land.

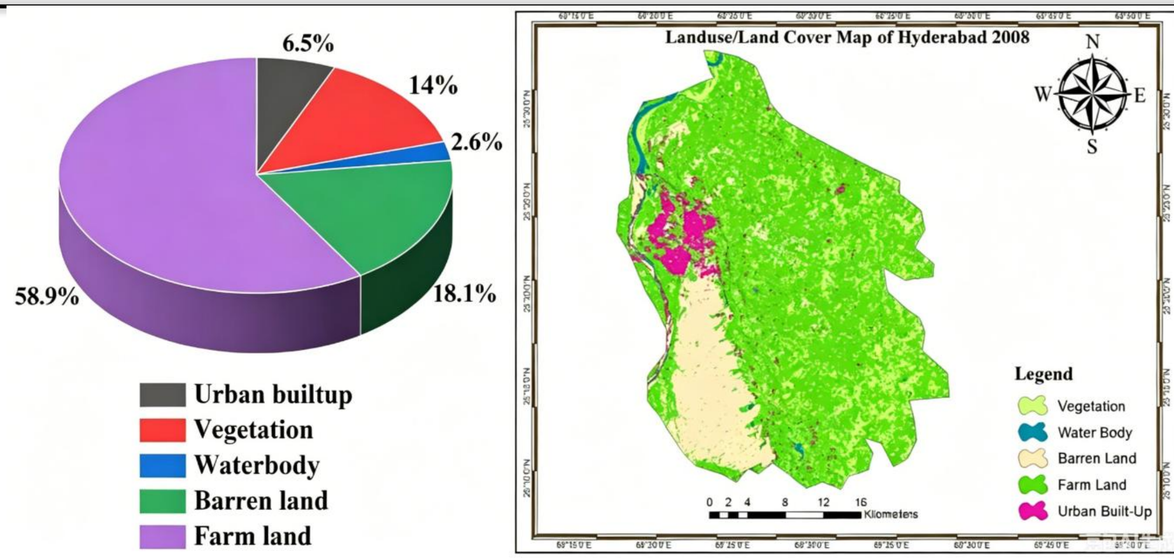
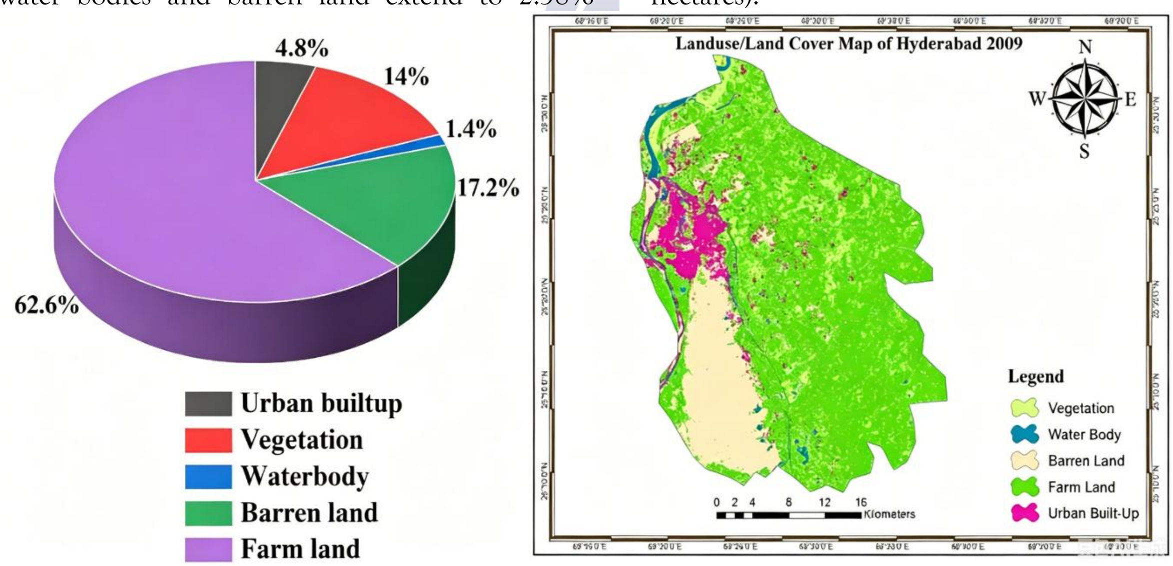


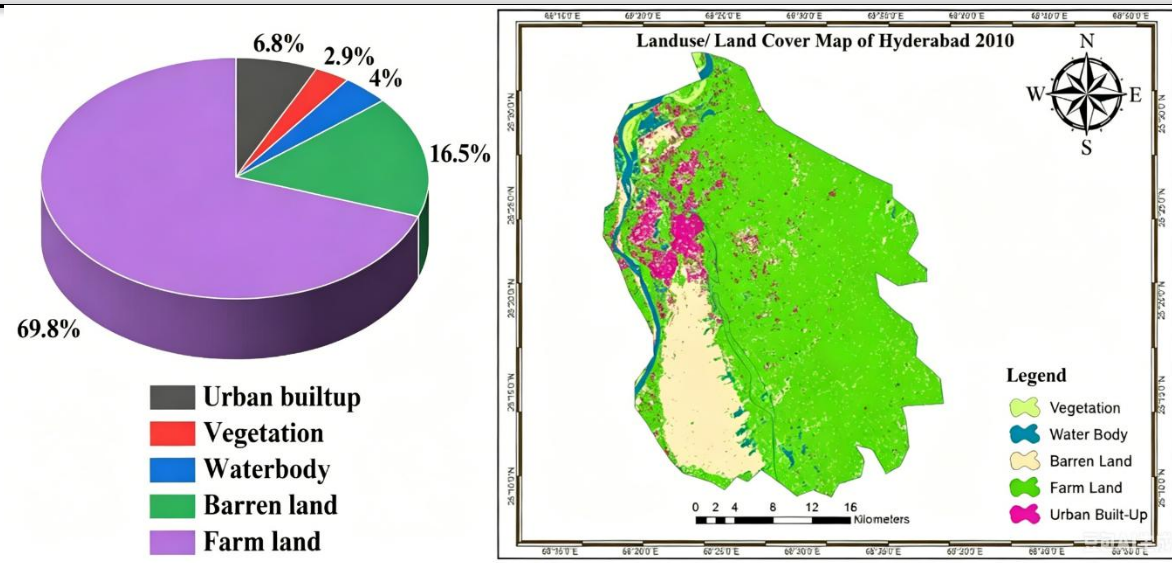
Figure. 2. Hyderabad's 2008 classified map

Proceeding toward 2009 (**Fig. 3**) demonstrates clear indications of urbanization and there are more urban areas, waterways and unused land than the previous year, but it has decreased farmland. Urban areas reach 6.52% (6,657 hectares) while water bodies and barren land extend to 2.58% (2,634 hectares) and 18.09% (18,439 hectares) respectively. These are notable expansions in (Graph-2). On the other hand, agricultural land shrinks to 58.88% (60,098 hectares) whereas vegetated land is constant at 13.95% (14,242 hectares).



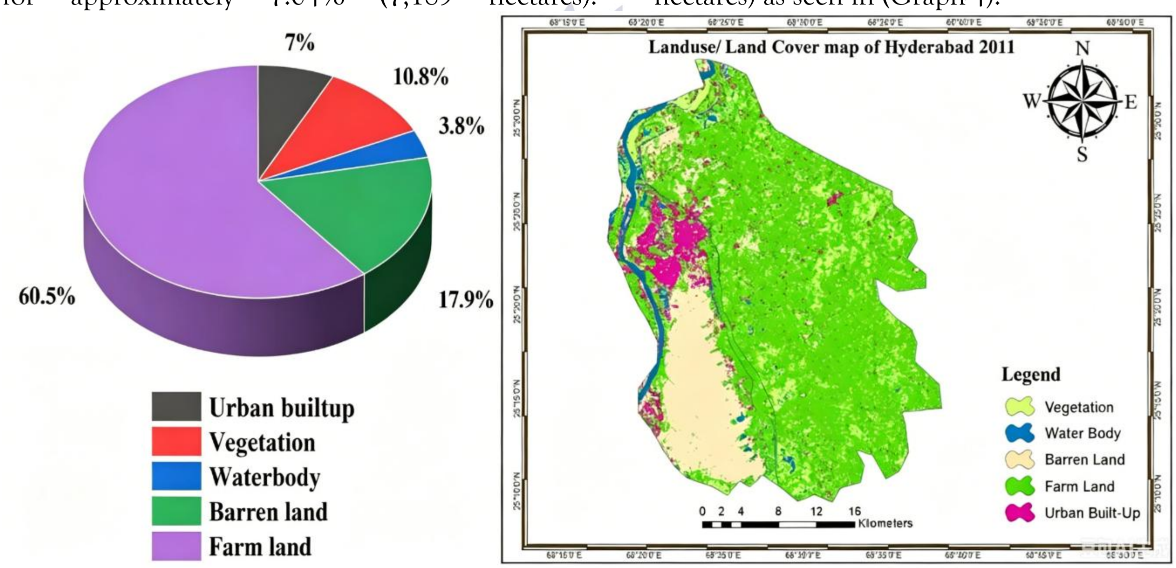
(Figure. 3)

Urban land increased to 6.79% (6,935 hectares) by 2010 according to (**Fig.4**) while water bodies increased to 4.00% (4,087 hectares) as urbanization continued its current trajectory. As demonstrated in (Graph-3) farmland increases significantly to 69.82% (71,264 hectares) but there are minor decreases in both vegetated area and bare land, which remains at 16.45% (16,794 hectares) and 2.93% (2,991 hectares) respectively.



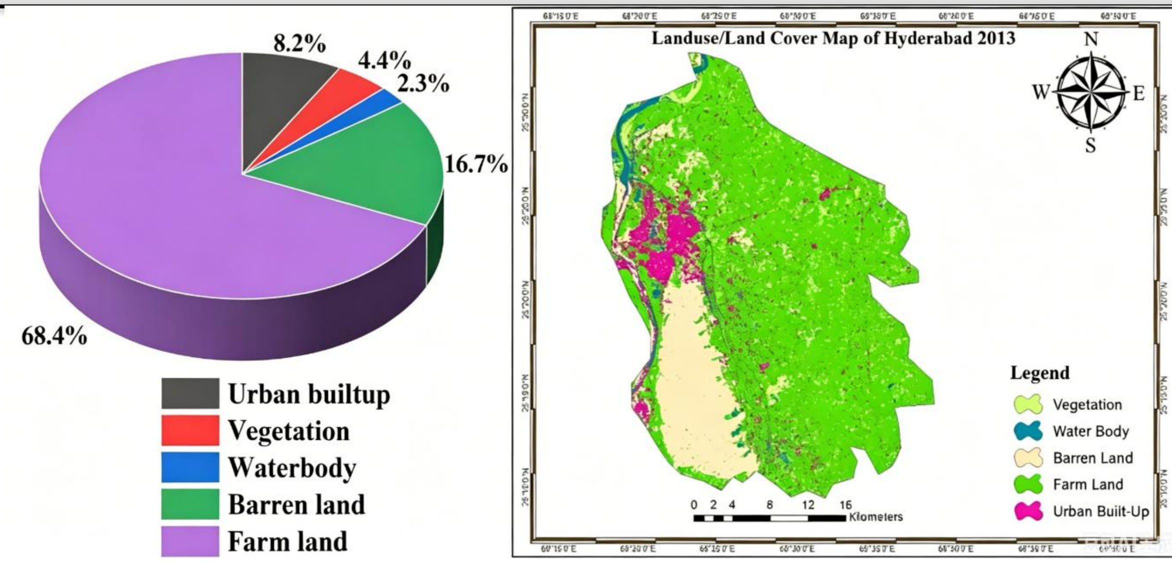
(Figure. 4)

Urbanization is accelerating in 2011 that can be seen in (**Fig.5**) and is the result of a dynamic shift in the landscape. Farmland reduces to 61.82% (61,710 hectares) while urban land accounts for approximately 7.04% (7,189 hectares). Remarkably, there is an increase in both bare land and vegetation with percentages of 17.92% (18,289 hectares) and 10.79% (11,013 hectares) respectively. Whereas water bodies decrease to 3.79% (3,868 hectares) as seen in (Graph-4).



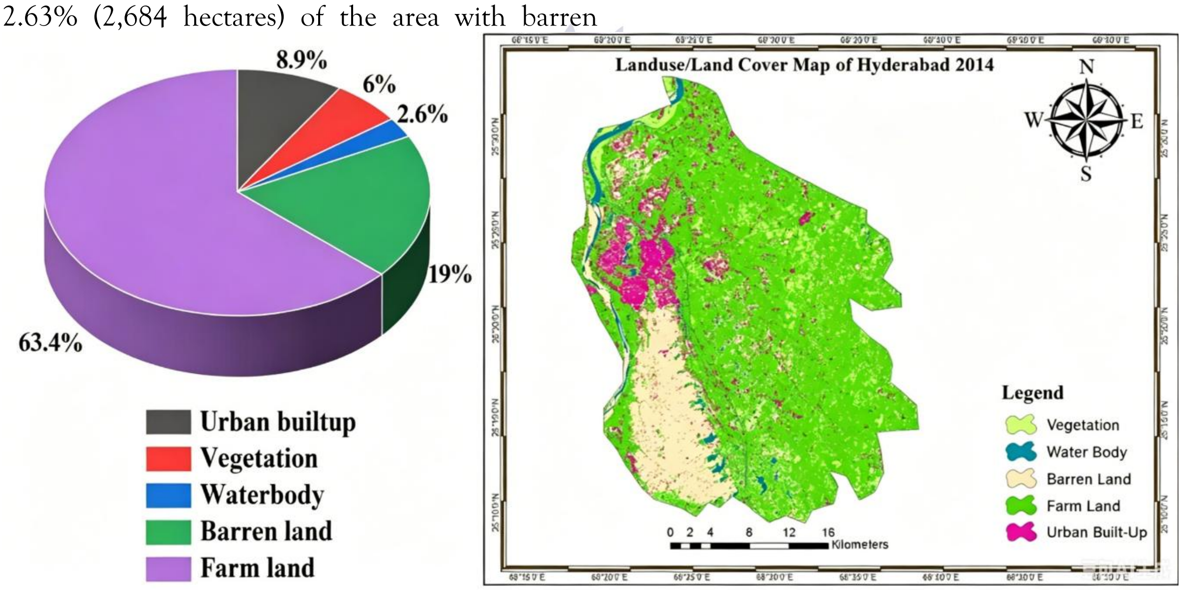
(Figure. 5)

2013 is depicted in (**Fig.6**) as a year of increased farming expansion and urbanization along with decreases in water bodies, vegetated land, and barren land. While farmland covers 68.43% (69,841 hectares) urban built-up areas increase considerably to 8.21% (8,377 hectares). (Graph-5) illustrates the reduction of barren land to 16.68% (17,030 hectares), vegetation to 4.35% (4,441 hectares) and water bodies to 2.33% (2,379 hectares).



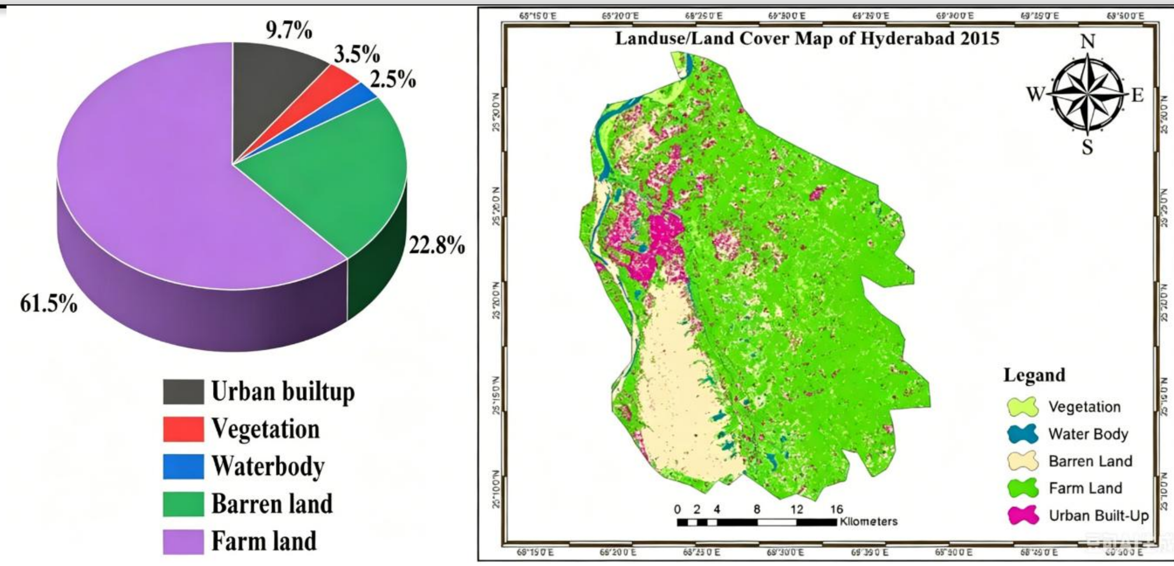
(Figure. 6)

Farmland continues to dominate at 63.44% (64,752 hectares) and urban areas continue to expand reaching 8.91% (9,094 hectares) in 2014, shown in (**Fig.7**). Water bodies constitute 2.63% (2,684 hectares) of the area with barren land accounting for 18.99% (19,380 hectares). Notably, as (Graph-6) shows vegetated land remains comparatively uniform at 6.03% (6,159 hectares).



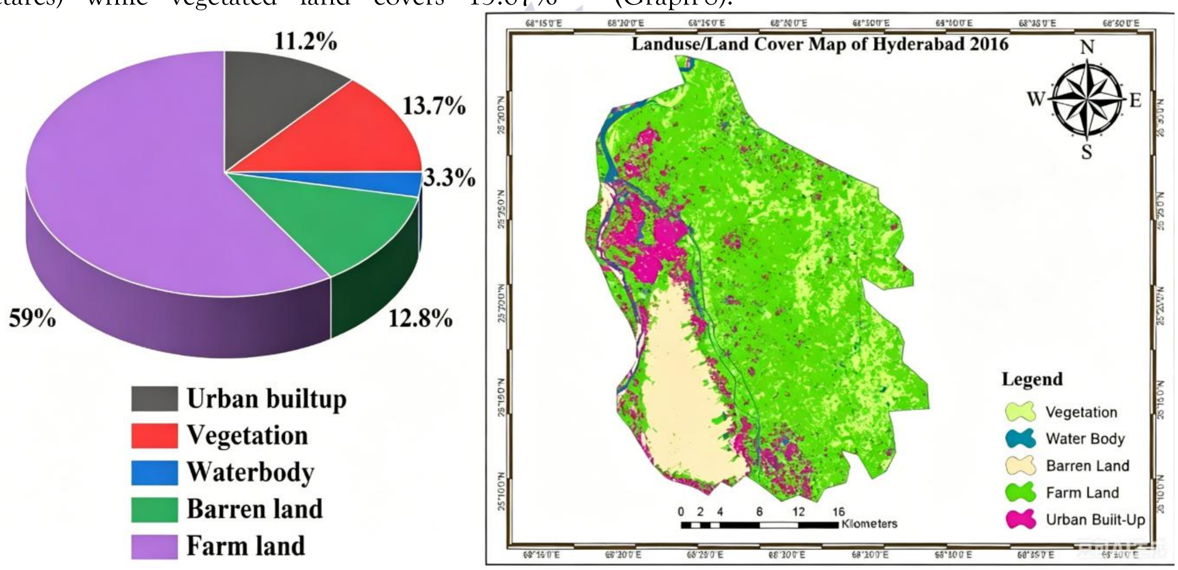
(Figure. 7)

Urbanization process continued in 2015 as shown in (**Fig.8**). Urban built-up areas account for 9.67% (9,871 hectares) of the total, farmland for 61.48% (62,750 hectares) of the land, vegetation for 3.54% (3,616 hectares) and water bodies for 2.50% (2,551 hectares) of the land and barren land for 22.81% (23,280 hectares) of the land emphasizing the dynamics of the transforming landscape as shown in (Graph-7).



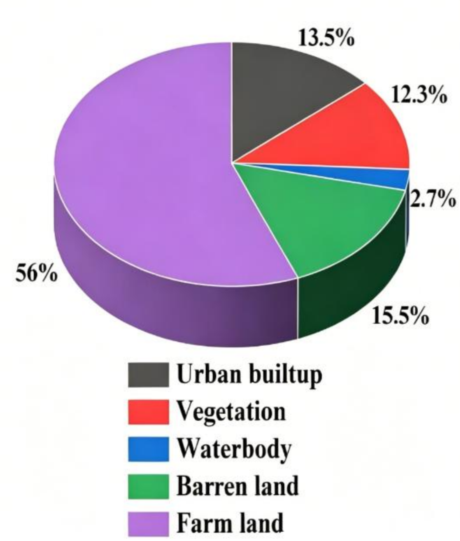
(Figure. 8)

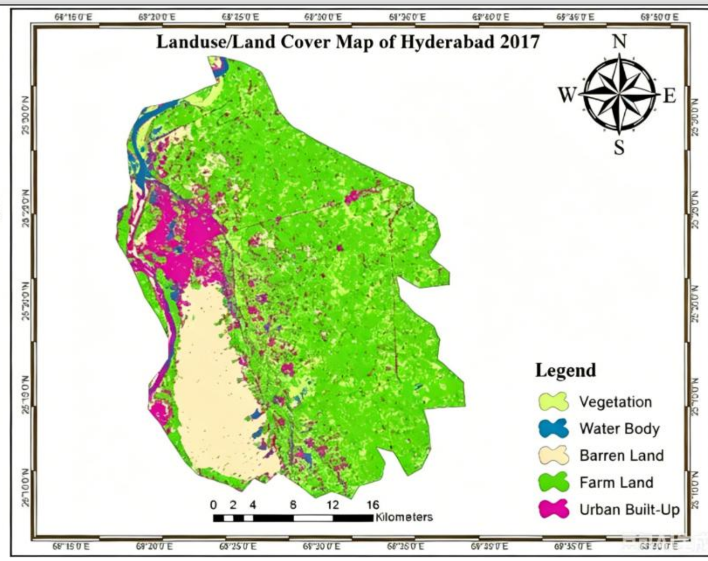
By 2016, as shown in **(Fig.9)** urbanization continues its upward trajectory with urban built-up areas expanding to 11.22% (11,452 hectares). Farmland remains significant at 59.01% (60,229 hectares) while vegetated land covers 13.67% (13,952 hectares) and water bodies comprise 3.26% (3,329 hectares). Barren land occupies 12.84% (13,104 hectares) reflecting the 'landscape's dynamic equilibrium shown in (Graph-8).



(Figure. 9)

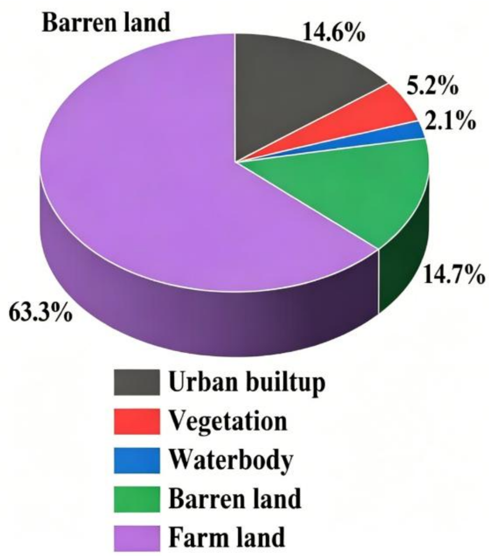
Further urbanization takes place in 2017, as seen in **(Fig.10)** with urban land accounting for 13.50% (13,779 hectares). Farmland continues to take over 56.02% (57,181 hectares) with water bodies and vegetated land covering 2.66% (2,719 hectares) and 12.34% (12,597 hectares) respectively and barren land occupying 15.47% (15,794 hectares) as shown in (Graph-9).

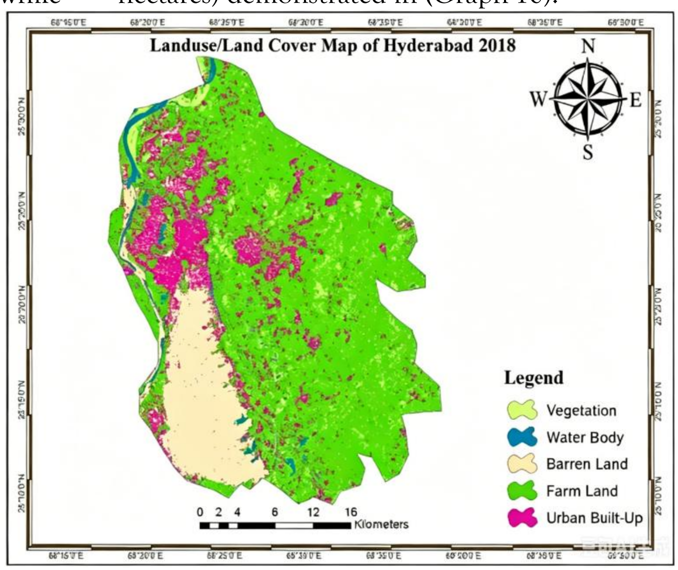




(Figure. 10)

Finally, in the year 2018 as shown in **(Fig.11)** urbanization persists with urban land covering 14.60% (14,907 hectares). Farmland remains predominant at 63.27% (64,581 hectares), while water bodies and vegetated land comprise 2.13% (2,179 hectares) and 5.24% (5,350 hectares) respectively. Barren land occupies 14.75% (15,052 hectares) demonstrated in (Graph-10).





(Figure. 11)

3.2. *Change Detection Analysis Results*

Area and amount of change in different LU/LC classes within the study area from 2008 to 2010.

The results presented in **(Table.2)** provide a comprehensive overview of the changes observed in the study area from the year 2008 to 2010, detailing both the absolute area changes in hectares and the corresponding percentage changes. In this period there was a decrease in the vegetated land area amounting to -11.02%. The water body area exhibited a positive change increasing by 2.61%. There was a slight reduction in barren land totalling -0.75%. Farmland experienced a significant increase of 7.18%, indicating potential shifts in land use patterns favouring agricultural activities. Moreover, there was a noticeable expansion in the built-up area which rose by 1.97% indication of urbanization trends within the study area.

Table. 2: *Area and amount of change in different LU/LC classes within the study area during 2010 to 2013*

	Year 2010		Year 2013		Change in Area		
Land use Classes	Area (Ha)	%	Area (Ha)	%	Difference (Ha)	Total %	Decreased and increased % ±
Vegetation	2991.22	2.93	4439.12	4.35	1447.90	1.42	-48
Water Body	4086.99	4.01	2377.87	2.33	-1709.12	-1.67	42
Barren Land	16794.14	16.46	17027.84	16.69	233.70	0.23	-1
Farmland	71231.89	69.81	69819.49	68.42	-1412.40	-1.38	2
Urban Built-Up	6934.63	6.80	8374.57	8.21	1439.94	1.41	-21
Total	**102038.9**	**100.00**	**102038.9**	**100.00**			

The findings shown in (Table-3) provide a detailed analysis of the changes observed in the study area from the year 2010 to 2013, encompassing both the absolute area changes in hectares and the corresponding percentage changes. During this interval there was an increase in the vegetated land area, accounting to 1.42%. The water body area experienced a reduction of -1.67%, indicative of potential alterations in hydrological dynamics or land use practices. Furthermore, there was a slight increment in barren land totalling 0.23%. Notably, farmland exhibited a decrease of -1.38%, reflecting shifts in agricultural land use patterns. There was an observable expansion in the built-up area which increased by 1.41%, underscoring ongoing urbanization trends within the study area. These results shed light on the dynamic nature of land cover variations and human-environment interactions highlighting the need for sustainable land management practices and informed policy interventions to mitigate adverse impacts and promote balanced development.

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Table. 3. *Area and amount of change in different LU/LC classes within the study area during 2013 to 2015*

	Year 2013		Year 2015		Change in Area		
Land use Classes	Area (Ha)	%	Area (Ha)	%	Difference (Ha)	Total %	Decreased and increased % ±
Vegetation	4439.12	4.35	3616.12	3.54	-823.00	-0.81	19
Water Body	2377.87	2.33	2551.47	2.50	173.60	0.17	-7
Barren Land	17027.84	16.69	23280.30	22.82	6252.46	6.13	-37
Farmland	69819.49	68.42	62720.45	61.47	-7099.04	-6.96	10
Urban Built-Up	8374.57	8.21	9870.57	9.67	1496.00	1.47	-18
Total	**102038.9**	**100.00**	**102038.9**	**100.00**			

(**Table.4**) provides a comprehensive overview of the changes observed in various land use classes within the study area from the year 2013 to 2015. During this period, there was a notable reduction in the vegetated land area which accounts to approximately -0.81%. There was a marginal increase noted in the water bodies indicating potential shifts in hydrological patterns or land management practices. Moreover, there was a substantial increase in barren land which accounted approximately 6.13% of the total land area. Farmland exhibited a significant decrease of -

6.96%, underscoring changes in agricultural practices or land use policies. A modest expansion in the built-up area was observed which increased by 1.47%, reflecting ongoing urbanization trends within the study area.

Table. 4. *Area and amount of change in different LU/LC classes within the study area from 2015 to 2017.*

	Year 2015		Year 2017		Change in Area		
Land use Classes	**Area (Ha)**	**%**	**Area (Ha)**	**%**	**Difference (Ha)**	**Total %**	**Decreased and increased % ±**
Vegetation	3616.12	3.54	12597.28	12.35	8981.16	8.80	-248
Water Body	2551.47	2.50	2718.54	2.66	167.07	0.16	-7
Barren Land	23280.30	22.82	15793.82	15.48	-7486.48	-7.34	32
Farmland	62720.45	61.47	57150.45	56.01	-5570.00	-5.46	9
Urban Built-Up	9870.57	9.67	13778.81	13.50	3908.23	3.83	-40
Total	**102038.9**	**100.00**	**102038.9**	**100.00**			

(**Table.5**) provides a comprehensive analysis of the changes observed in various land use classes within the study area from the year 2015 to 2017, presenting both the absolute area changes in hectares and the corresponding percentage changes. During this interval, there was a significant increase in vegetated land approximately 8.80%. This rise suggests potential ecological restoration efforts or changes in land management practices conducive to vegetation growth. Additionally, an increase in the water body area indicating possible alterations in hydrological regimes or land use patterns affecting water resources. Conversely, there was a substantial decrease in barren land with a reduction of approximately -7.34%, suggestive of transformations in land cover dynamics possibly due to reforestation or agricultural land abandonment. Furthermore, farmland exhibited a notable decrease of -5.46%, indicative of changes in agricultural practices or land use policies during the study period. On the other hand, there was a considerable expansion in the built-up area increasing by 3.83%.

Table. 5. *Area and amount of change in different LU/LC classes within the study area during 2017 to 2018*

Table. 6. *LU/LC Transfer Matrix of year 2008 to 2013 for the study area*

	Year 2017		Year 2018		Change in Area		
Land use Classes	**Area (Ha)**	**%**	**Area (Ha)**	**%**	**Difference (Ha)**	**Total %**	**Decreased and increased % ±**
Vegetation	12597.28	12.35	5347.31	5.24	-7249.97	-7.11	58
Water Body	2718.54	2.66	2178.37	2.13	-540.18	-0.53	20
Barren Land	15793.82	15.48	15051.25	14.75	-742.57	-0.73	5
Farmland	57150.45	56.01	64557.99	63.27	7407.54	7.26	-13
Urban Built-Up	13778.81	13.50	14903.94	14.61	1125.13	1.10	-8
Total	**102038.9**	**100.00**	**102038.9**	**100.00**			

(**Table.6**) indicates the changes in land use in the study area from 2017 to 2018, highlighting differences in both hectares and percentages. During that period, vegetated land decreased by 7.11%, water bodies declined by 0.16%, and barren land decreased by 0.73%. Farmland expanded greatly by 7.26%, while built-up areas increased moderately by 1.10%. These numbers show that land use patterns are shifting, with agricultural and urban regions expanding at the expense of natural and undeveloped landscapes.

3.3. *LULC Transfer Matrix Results*

Table. 7. *LU/LC Transfer Matrix of year 2008 to 2013 for the study area*

	Land Use Classes	Vegetation	Water Body	Barren land	Farmland	Urban Built-Up	Grand Total
Land use 2008	Vegetation	2496.46	249.65	155.41	10947.08	383.67	14232.27
	Water Body	12.39	1107.77	80.52	154.49	71.14	1426.32
	Barren land	5.96	110.07	14358.29	2254.51	827.58	17556.41
	Farmland	1904.25	793.42	2030.01	55444.66	3730.46	63902.80
	Urban Built-Up	20.06	116.96	403.60	1018.74	3361.72	4921.09
	Grand Total	**4439.12**	**2377.87**	**17027.84**	**69819.49**	**8374.57**	**102038.9**

An analysis of land encroachment was conducted between 2008 and 2013 using a LU/LC transfer matrix (**Table.7**). The matrix illustrates the shifts in land use/ land cover types providing statistics about the degree of conversion that was seen throughout the specified period interval. Significant land conversions into urban areas are shown in the table. Urbanization resulted in the conversion of 116.96 hectares of water bodies and about 20.06 hectares of vegetated land showing significant encroachment on hydrological and natural ecosystems. Moreover, a significant amount of barren land roughly 403.60 hectares was turned into urban areas highlighting the loss of land that might potentially be utilized for ecological or agricultural purposes. Furthermore, a significant amount of farmland of about 1018.74 hectares was converted into an urban area which indicates the expansion of urbanization.

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Table. 8. *LU/LC Transfer Matrix of year 2013 to 2018 for the study area*

	Land Use Classes	Vegetation	Water Body	Barren land	Farmland	Urban Built-Up	Grand Total
Land use 2013	Vegetation	1453.35	62.69	20.66	2746.14	156.38	4439.12
	Water Body	154.13	1383.85	216.65	499.61	123.47	2377.87
	Barren land	32.63	139.59	13201.27	1274.14	2376.93	17027.84
	Farmland	3582.69	442.45	1049.55	57001.49	7746.54	69819.49
	Urban Built-Up	124.51	149.68	563.12	3036.30	4500.52	8374.57
	Grand Total	**5347.31**	**2178.27**	**15051.25**	**64557.69**	**14903.84**	**102038.9**

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To gain insights into land encroachment across different land categories from 2013 to 2018, a LU/LC transfer matrix (**Table.8**) was constructed. The matrix facilitates the analysis of transitions between various land use/cover types during the specified period, shedding light on the extent of conversion observed. The table illustrates significant conversions of land into urban areas indicating the expansion of urbanization over diverse land cover types. Approximately 124.51 hectares of vegetated land and 149.68 hectares of water bodies underwent conversion into urban areas, reflecting the encroachment on natural habitats and aquatic ecosystems. Moreover, a substantial area of barren land accounts approximately 563.12 hectares was transformed into urban areas which highlights the loss of potentially available land for agricultural or ecological purposes. A significant portion of farmland encompassing approximately 3036.30 hectares underwent conversion into urban land underscoring the rapid pace of urban expansion and its implications for agricultural productivity and land use dynamics.

3.4. Trend Analysis Results

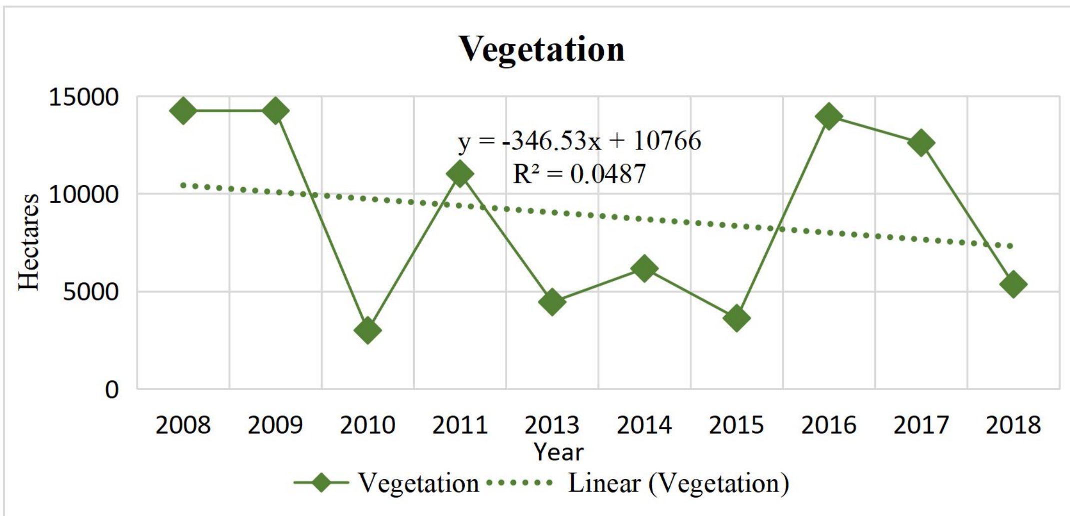

Figure 12. Showing Temporal change in Vegetated Lands of the study area

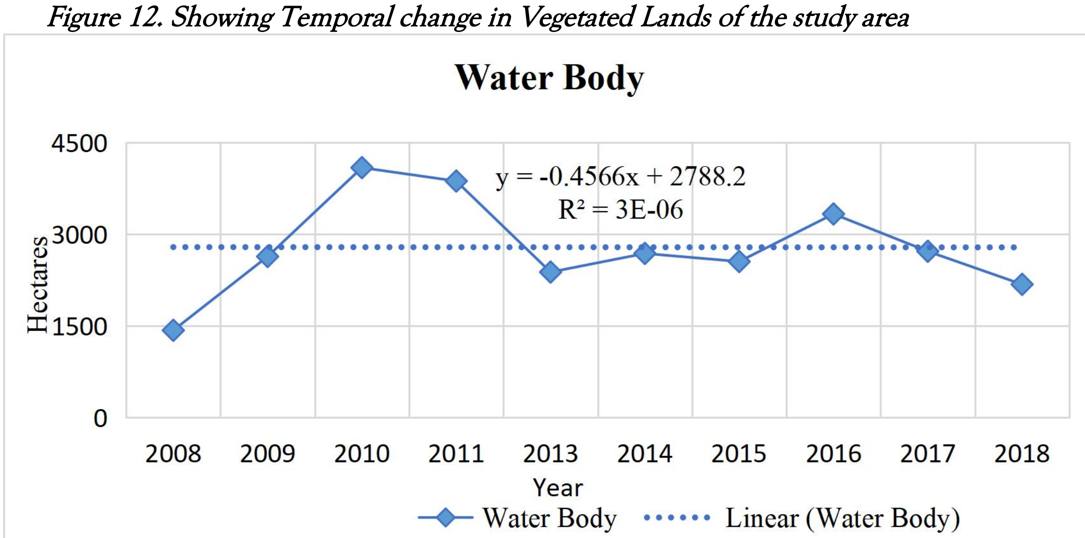

Figure 13. Showing Temporal change in Water Bodies of the study area

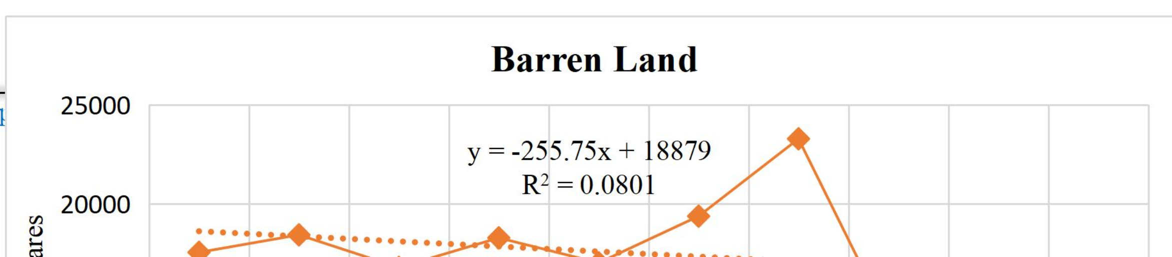

Figure 14. Showing Temporal change in Barren Land of the study area

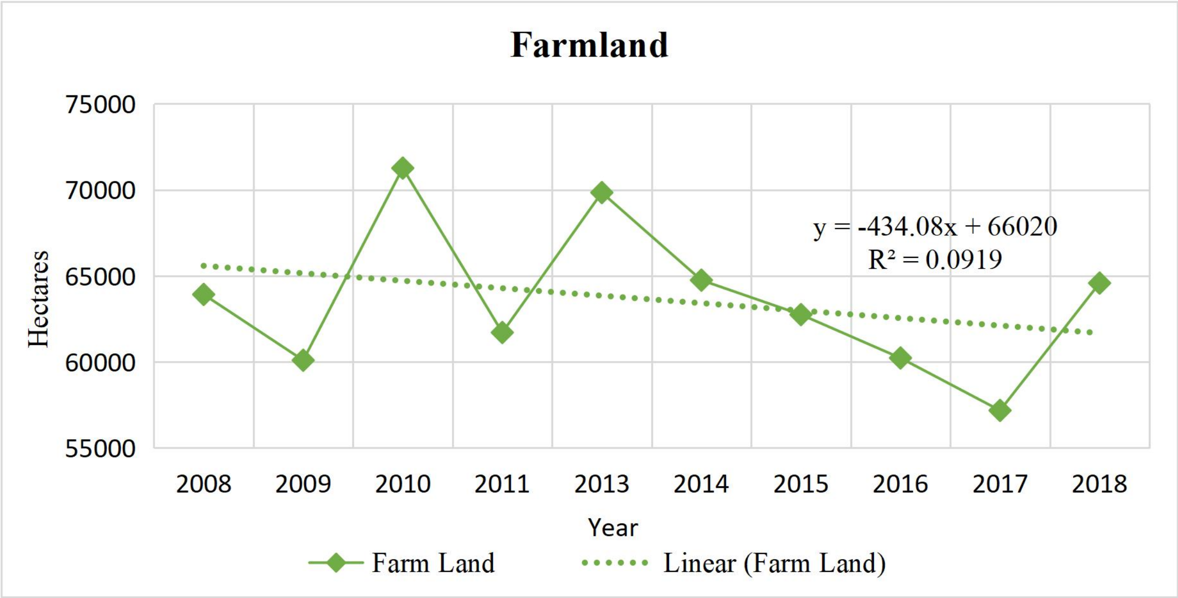

Figure 15. Showing Temporal change in Farmlands of the study area

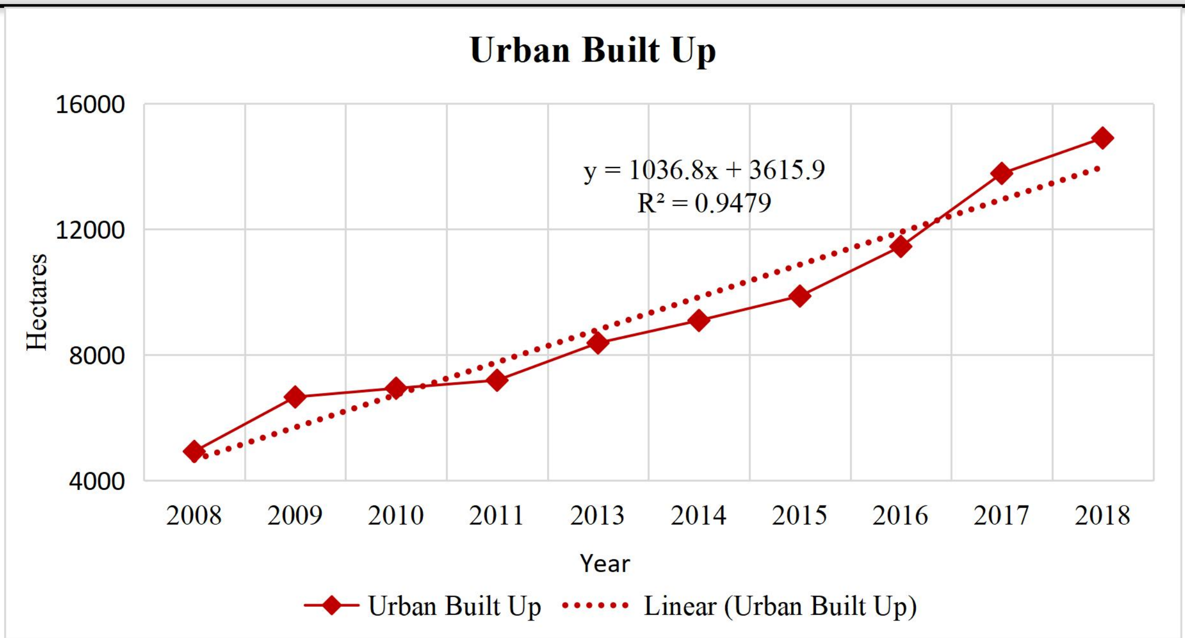

Figure 16. Showing Temporal change in Urban Lands of the study area

3.5. *Vegetation:*

(Fig-12) demonstrates the temporal variations in vegetated land from 2008 to 2018. The trend line shows a downward tendency over ten years with variations indicating dynamic alterations in land use. The vegetated landscape experienced a considerable loss during the 2010 floods decreasing below 5,000 hectares. The subsequent years showed alternating shifts with short periods of recovery preceding further reductions demonstrating the complex interactions of natural and human factors influencing vegetation dynamics.

3.6. *Water Bodies:*

(Fig- 13) shows the temporal shifts of the water bodies in the research area between 2008 and 2018.The trend line shows varying patterns in the amount of water over the given time, with noticeable rises and decreases. After the first reduction of water bodies in 2009 there were variations in the range of 3,000 to 4,500 hectares till 2011. Different trends were seen in the following years with a large rise in water bodies in 2016 and a subsequent fall in the last two years highlighting the dynamic nature of hydrological processes and the difficulties associated with managing water resources.

3.7. *Barren Land:*

The temporal changes in barren land from 2008 to 2018 are shown in (Fig-14) demonstrating a progressive conversion of barren land to urban areas during the study period. Up to 2015 the linear trend line shows an upward trend in the extent of barren land illustrating processes of land change caused by land use change and urbanization.

3.8. *Farmlands:*

The trends and variations in the amount of farmland from 2008 to 2018 are shown in (Fig-15). The trend line illustrates variations in the amount of farmland with substantial decreases shown after the 2010 floods. Irregular variations were observed in the following years which demonstrated that vulnerable agricultural landscapes face pressures towards land use conversion and extreme events.

3.9. *Urban Built-up Area:*

The temporal variations in urban built-up areas within the study area between 2008 and 2018 can be seen in (Fig-16). The linear trend line indicates the unsustainable increase in urbanization and land development operations demonstrating a continuous growth in urban land expansion throughout the given period. To reduce adverse environmental impacts and promote adaptability in the context of rapid urbanization, sustainable

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land use planning and management strategies are desperately needed.

4. Discussion

The secret shift of agricultural fields to urban areas has serious consequences for food security, livelihoods, and environmental sustainability. According to the Hyderabad Development Authority (HDA) the Qasim Abad sub-district has seen significant land conversion with an estimated 1,419 hectares of agricultural land lost to urbanization. This trend indicates a wider phenomenon of urban sprawl and land use change caused by population increase, urbanization and development demands. Indeed, the overall population of Hyderabad district has increased by 44 percent in the last 36 years (from 1981 to 2017) with Qasim Abad sub-district experiencing the greatest population growth rate at 269 percent followed by Latif Abad sub-district (58 percent) Hyderabad rural (41 percent) and Hyderabad city sub-district (37 percent). These demographic shifts emphasize the critical need for long-term urban planning, land use management and population growth management measures for addressing the socioeconomic and sustainability challenges associated with rapid urbanization and land development in the area.

The results of spatial analysis suggest that Latif Abad sub-district within the Hyderabad district provides an ideal environment for urban development due to the large number of less valuable land and large areas of barren land. Whereas, for sustainable long-term development in this region provincial government must implement extensive urban planning and policy measures. Alternatively, the existence of the Indus basin in the study area makes the Hyderabad district unsuitable for industrial development due to the possible adverse impact of industrial waste on the basin. Despite its ideal climate and proximity to freshwater resources Latifa bad sub-district requires enhanced urban planning strategies to ensure future expansion and development sustainably. Pakistan is home to about 200 million people and is the sixth most populous region in the world. This highlights the significance of solving urbanization concerns. During 1998 and 2011, Hyderabad's population density exceeded that of Karachi indicating significant urbanization with nearly 40,000 persons per square kilometre. Hyderabad has one of the highest population densities in the country with official numbers showing a 3.6 percent annual rate of population growth. The devastating 2011 Sindh floods which were caused by exceptionally high precipitation are responsible for the decrease in urbanization that was seen in the northern region of the research area between 2010 and 2011. Millions of people were affected by the floods which caused severe damage to infrastructure, transportation networks and agricultural fields throughout Sindh province including Hyderabad district. Over 80,000 individuals in Hyderabad were affected, resulting in a large decrease in urban land in the northern region [44] .

On a regional scale environmental factors drive landscape changes through human activity and fundamental driving forces. Important land use/land cover LU/LC types in the study region have been converted to urban areas due to a variety of factors including business expansion, employment possibilities, family conflicts concerning land transmission and a demand for increased property values. Furthermore, this trend has been significantly driven by issues including water scarcity, decreasing agricultural productivity and infrastructure development. The interconnection between land cover change and urbanization highlights the necessity of coordinated development strategies and sustainable land management techniques. Initiatives to address the impacts of climate change, improve rural livelihoods and improve fundamental necessities in rural regions can all help to mitigate the challenges towards urbanization. To assure the long-term resilience and prosperity of urban areas, authorities must give priority to suitable urban planning, infrastructure development and environmental conservation.

5. Conclusion

This study concludes that urbanization in diverse land use patterns can provide major financial, political, environmental and social issues. Valuable lands are lost as urban land expands into agricultural and vegetated areas and increasing population demands the utilization of more

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natural resources. According to the study urban built-up land in Hyderabad district has increased from 4.82% to 14.60% during a decade which is alarming. This expansion could negatively impact farmland productivity for crops such as wheat and cotton displacing nearly 20,000 farmers and raising import costs. As a result, the government must provide fundamental needs including food, shelter, schooling, healthcare and recreational facilities. Urbanization also results in challenges with transportation, sanitation, water and sewerage, pollution, conflict and crime. These land use changes may result in people losing their land and becoming unemployed. To overcome these concerns government must implement rules and regulations to protect valuable land use types. Land conflicts must be managed with the involvement of all stakeholders through an effective land use policy. To protect land use in its cultural, social and ethical context a rapid implementation of economic rent laws and a customized land use security, approach is needed.

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