Spatially Contextualizing Rural Land Transformation in Peri-Urban Area: A case of Jalandhar City, Punjab (India)

Ratnam, R.* and Kaur, R.
Department of Geography, Panjab University, Sector-14, Chandigarh-160014, India
Email: rahulratnam333@gmail.com*
**Corresponding Author*

DOI: https://doi.org/10.52939/ijg.v19i2.2561

Abstract
The advent of market liberalization in 1990 brought various forms of transformation, principally land transformation, to Indian cities and their respective peri-urban areas. The Jalandhar city and surrounding rural area from an agrarian state (Punjab) of India provide exemplified setting in this respect. A period of 30 years (1991-2021) has been selected to assess land transformation's magnitude, intensity, and direction. The applicability of different spatial data and methodologies helped analyze the facets of land transformation in quantitative and qualitative terms. The results highlight a massive rural land transformation due to the development of various urban corridors and institutional & commercial set-ups in the city fringe by converting and usurping prime agricultural land and increasing land fragmentation. The built-up class has seen a growth of more than 200 per cent in these decades at the cost of 22 per cent of cropland and other studied classes.

Keywords: Land transformation, Land fragmentation, Peri-urban, Jalandhar

1. Introduction

For many decades the urban demand for underdeveloped land around an urban center and further across the urban-rural fringe has been constant [1]. Such space beyond the city limits, where urban and rural elements co-exist, regulates the land dynamics and brings about a conspicuous change in land use and associated features over time [2] and [3]. The resultant space leads to building a peri-urban zone or peri-urbanization [4]. The inadequate planning efforts and policy formulations for the peri-urban interface make it more vulnerable to change [5]. Most of this was triggered by the unrestrained urban sprawl of the cities. In the name of development and to support the growing population, the annexation of peripheral undeveloped land or mostly agricultural/farmlands transforms its existing land use but also brings disorganization to the entire peri-urban ecosystem. There's always an interrelationship between extensive complex city systems with various surrounding subsystems and the amendment in one followed to other systems [6]. Thus, a piece of comprehensive knowledge about the relationship between land use-land cover changes and consequent land dynamics is vital [7].

In India, the rate of urbanization and engulfing adjoining lands through lateral spread takes the count of million-plus cities from 23 in 1991 to 53 in 2011 [8] (no recent data on the same has been released). Nearly 90 per cent of these cities are part of urban agglomerations which traverse the city limits (municipal boundaries) in one way (natural growth) or another way (political inclusion of neighboring units) [9] and [10]. The most significant metros' outward growth has resulted in increasingly frequent and intricate contact with the rural areas surrounding them as well as progressive modifications to their land uses and professions of the locals, turning them into semi-urban or "peri-urban" areas. Such Indian city surroundings have previously been researched, particularly concerning their ties to the city on an economic and social level [11]. Like, the extension of municipal limits of Indian cities to their suburbs was traced effectively by Kundu [12], highlighting the merging of numerous neighboring towns/cities with the primary urban center halving their numbers from 1991 to 2001. Being the second most populated country in the world [13], the apparent impact of the growing population on land dynamics cannot be denied. There has been a long-term bidirectional causal relationship between population growth and urban land expansion [14].

The Indian Economic Survey (2021-22) [15] ranked the state of Punjab at the third position in total foodgrain production in the country, after the states of Uttar Pradesh and Madhya Pradesh, with 29.77 million tons of production. But in the level of urbanization, Punjab is way ahead of both these states. Punjab's urbanization rate, i.e., 37.5 per cent [16], ordered it to the seventh position among other states (excluding union territories) in the country. Since the advent Green Revolution, the state of Punjab received the tag of an agricultural state. Maintaining the gross cropped area with the sprawling cities is impractical. Around 82 per cent of the state's total area is comprised of the net sown area [17], and the growth of urban centers will undoubtedly come at the cost of this cropped land.

There are two million-plus cities in the Punjab, Amritsar and Ludhiana. The next plausible million-plus city in the state will be Jalandhar, which recorded a population of 862,886 in 2011 [18]. One of the reasons behind this is Jalandhar city's rate of expansion in its surrounding rural area in the last couple of decades. It has led to a massive transformation of prime agricultural land into non-agricultural uses like residential complexes, commercial services, industrial set-ups, educational services, health services, recreational joints, food courts and government & private offices. Jalandhar city lies at the center of the state, referring to its efficient connectivity with all the parts of the state; it also caters to one of the most fertile fields. The conversion of the natural condition of lands to human-altered situations, e.g., agricultural to built-up, changes the land use pattern, which is generally irreversible [19]. The present research is an effort to put a sense of the growing city and subsequent loss of its hinterland. The study tries to determine the causes and consequences of repressive land transformation and visualize the legitimacy of infrastructural development on the face of the most advanced agriculturally-developed land.

2. Material and Methods

2.1 Study Area

The current research takes Jalandhar city and its surrounding 175 villages and 13 other administrative units as the research units for evaluation (Figure 1).

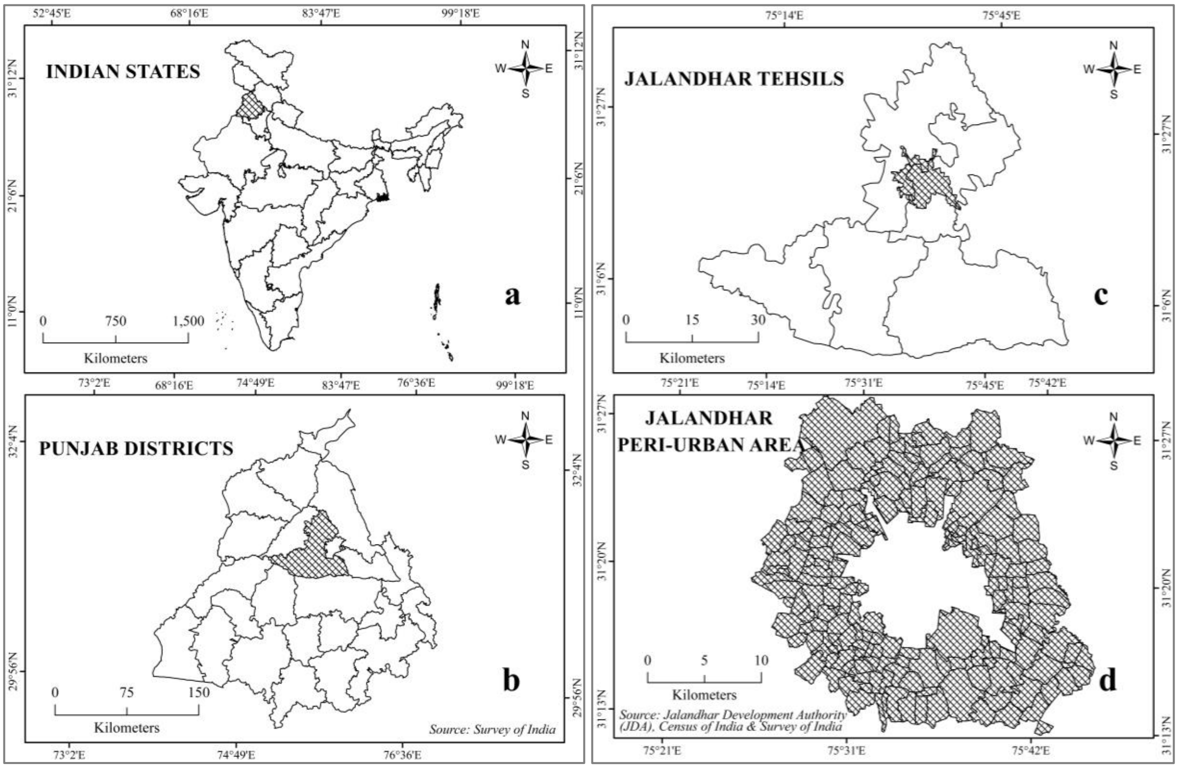


Figure 1: Location of the study area administrative divisions-wise: **a**. Location of Punjab State in India; **b**. Location of Jalandhar district in Punjab State; **c**. Location of Jalandhar city in the Jalandhar Tehsils; **d**. Delineated study area (2021) comprising villages, towns and outgrowths around Jalandhar city

As the city boundary changed twice in thirty years, the whole city area is also included in the analysis. In India, villages constitute the prime agricultural land around the city; thus, taking villages is categorically suitable to check the occurrence of other land uses over them. And the inclusion of villages infers to the rural land, which further aids in contextualizing its transformation.

2.2 *Data Acquisition*

The implementation of spatial angle to trace the earth's physical changes makes it the most viable technology to incorporate [20] [21] and [22]. It gives a true-to-ground assessment of the changes that occurred. This research includes multispectral satellite data, especially from the Landsat series, to assess the magnitude, intensity and direction of rural land transformation in Jalandhar Periphery for the last thirty years, i.e., from 1991 to 2021. The details of Spatial Data utilized in the study are mentioned in Tables 1 to 4. The spatial resolution for the selected sensors is 30 meters with 6-band spectral resolution and 8-bit & 12-bit radiometric resolution, respectively. The month of October, which is generally free from any cloud cover, being a post-monsoon period in India, is selected for satellite images. Four topographical maps prepared by the Survey of India are also procured to check the local details. Different administrative boundaries are procured from various government offices and portals. The reconnaissance surveys have been followed by collecting ground control points, in 2021, across the study area.

2.3 *Data Processing*

An exhaustive range of geospatial methods has been implemented to analyze the spatial data. The prime requirement is to delineate the peri-urban area of Jalandhar City. The municipal corporation boundary (2016) of Jalandhar city is acquired and georeferenced for the accurate distinction of the city limits along with the reference from Survey of India toposheets. A buffer of 5 km from the city limits has been selected to cover all the surrounding rural areas. Its extension beyond the 5 km includes the area of the neighboring district, i.e., Kapurthala. However, some of the villages of Kapurthala's jurisdiction, in the West and South-east directions of Jalandhar city, become part of Jalandhar city's periphery in the analysis. These villages are included to provide an equivalent structure around the city to assess rural land transformation. This initial data-processing aims to delineate the peri-urban area and prepare a base map extrapolating an area of interest (AOI) for further analysis. The consequent AOI extracts the study area from the 1991 and 2021 Landsat-series satellite images. Both the satellite images are subjected to the Maximum Likelihood Classification Algorithm, one of the robust methods to classify satellite images [23] and [24], by supervising seven classes, i.e., Built-up land, Cropland, Fallow land, Vacant Land, Vegetation (natural), Waterbody, and Others under ERDAS Imagine software. The vacant land primarily includes empty residential and commercial plots with demarcated concrete walls and government & privately-owned land for development purposes. An accuracy assessment has followed the classification.

Table 1: Satellite data

Type	Data	Sensor	Path & Row	Bands	Year	Procurement
Raster Images	LANDSAT 5	TM	148 - 38	1,2,3,4,5,7	Oct-91	USGS-online
	LANDSAT 8	OLI	148 - 38	2,3,4,5,6,7	Oct-21	USGS-online

Table 2: Toposheet

Type	Number	Scale	Year	Procurement
Hardcopy Topographical Map	44M/11, 44M/12, 44M/15 & 44M/16	1:50,000	2019	Survey of India (SOI)

Table 3: Administrative map

Type	Level	Year	Procurement
Hardcopy City Map & Digital Village Boundaries	City Level	2016	Jalandhar Municipal Corporation Office, Survey of India
	Village Level	2011	

Table 4: Ground control points

Type	Description	Year	Procurement
GPS Point File	For ground verification inferring accuracy assessment	2021	Field Visits

Table 5(a): Accuracy assessment statistics for classified image (1991)

Classes	Reference Totals	Classified Totals	Number Corrected	Producer's Accuracy	User's Accuracy	Kappa Statistics
Built-up	102	127	93	91.18%	73.23%	0.66
Cropland	233	218	199	85.41%	91.28%	0.93
Fallow land	80	53	50	62.50%	94.34%	0.93
Others	34	48	24	70.58%	50.00%	0.44
Vacant land	27	33	14	51.85%	42.42%	0.36
Vegetation	10	7	6	60.00%	85.71%	0.85
Waterbody	14	14	14	100.00%	100.00%	1
Overall Accuracy	**81.00%**					
$\mathbf{K}_{hat}$	**0.74**					

Table 5(b): Accuracy assessment statistics for classified image (2021)

Classes	Reference Totals	Classified Totals	Number Corrected	Producer's Accuracy	User's Accuracy	Kappa Statistics
Built-up	27	31	25	92.59%	80.64%	0.78
Cropland	132	139	131	99.24%	94.24%	0.93
Fallow land	59	55	47	79.66%	85.45%	0.83
Others	77	76	65	84.41%	85.52%	0.84
Vacant land	22	15	12	54.54%	80.00%	0.79
Vegetation	17	18	15	88.23%	83.33%	0.82
Waterbody	16	16	16	100.00%	100.00%	1
Overall Accuracy	**88.85%**					
$\mathbf{K}_{hat}$	**0.82**					

A reconnaissance survey was carried out for ground truthing, under which 350 points were collected across all seven classes to verify the classification scheme of the 2021 classified image. For the 1991 classified image, 210 points from google earth pro were fetched. The accuracy assessment statistics are given in Tables 5a (1991) and 5b (2021). Further, post-processing includes, firstly, the changes in land use-land cover classes from 1991 to 2021, followed by the preparation of the transformation matrix tracking the extent to which one land use class supplanted the other. The transforming classes affect underlying land, especially rural land, by making it heterogeneous. The statement was authenticated by calculating landscape metrics under FRAGSTAT software to determine the land fragmentation levels in the study area and rationalize the transformation of rural land in the peri-urban area of Jalandhar city.

At last, qualitative assessment, including field visits, field observations, interviews with locals and filling-up of questionnaires, was carried out. It also validates the results from the quantitative assessment of rural land transformation.

3. Results and Interpretation

The supervised classification results on the raster images of the Jalandhar city and periphery produced an unambiguous visual interpretation of changes between 1991 and 2021. The changes are reasonably perceptible in comparative Figures 2 and 3. The classified images are further undertaken for post-processing to understand the absolute changes on the land, wherein two separate steps are followed. In the first one, the particular area of each class is calculated with a comparison of both years. (Table 6)

The output of the first step explicitly depicts the proportional change in the selected seven classes. The classification statistics highlighted a threefold increase in the built-up class of Jalandhar city and its periphery from 1991 to 2021, i.e., from 39.26 km^2 to 131.74 km^2. The class has seen the highest percentage change of 234.65 over thirty years (Figure 4). The total coverage of the study area is 593.81 km^2, out of which the maximum proportion is covered by agricultural land, including cropland and fallow land. It was 420.91 km^2 in 1991, which declined to 340.34 mi^2 in 2021. Along with this, vacant land has also grown up in these 30 years. It increased to 54.56 km^2 in 2021 from 17.83 km^2 in 1991. It experienced the second-highest positive percentage change of 206.26. Apart from these two classes, all other (five) categories have seen negative percentage change, of which vegetation suffered a maximum loss of 46.32 km^2 of area, accounting for an 82.15 per cent decline from 1991 to 2021.

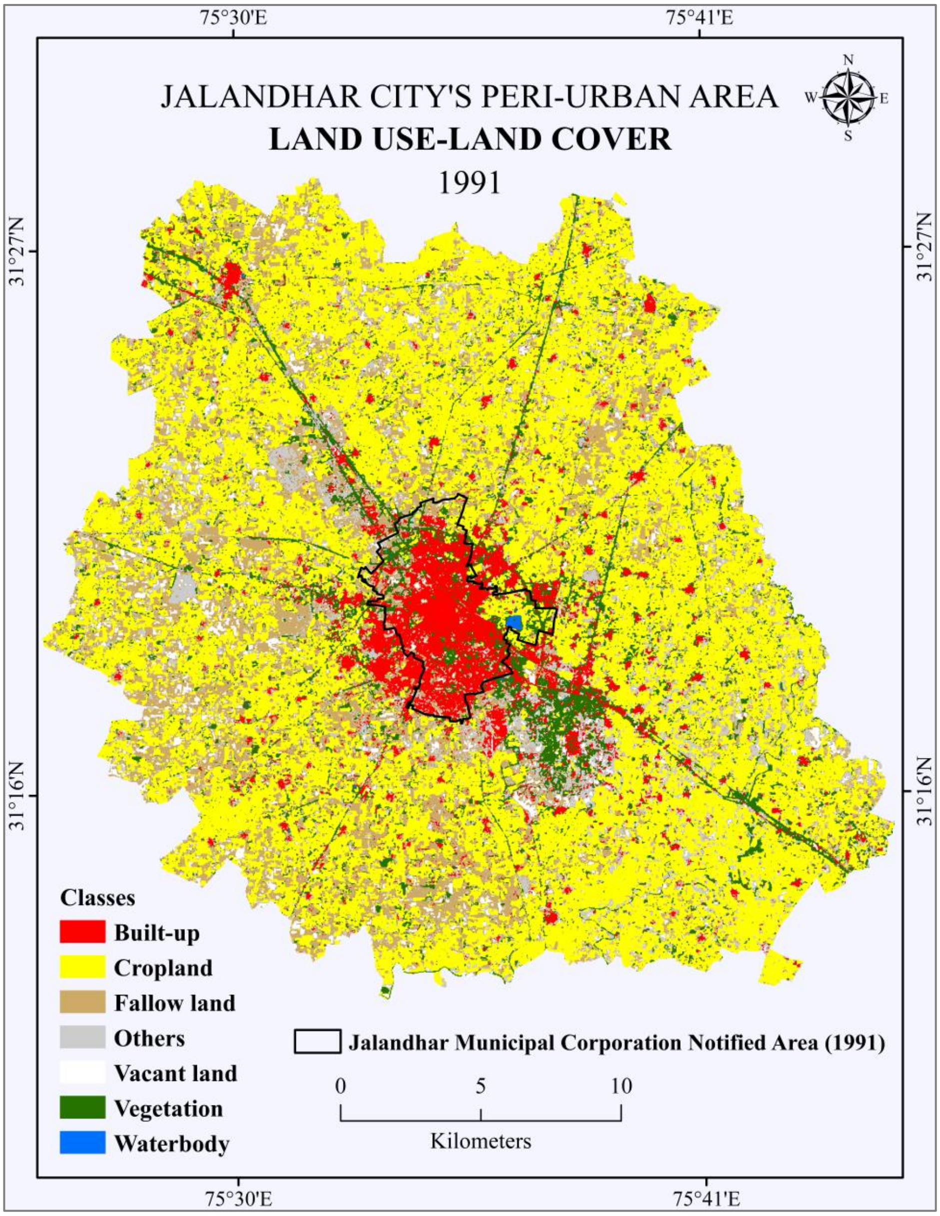


Figure 2: Land use-Land cover classification (1991)

Table 6: Proportional change of Land use-Land cover classes in 1991 & 2021

Class Name	Area (sq. km)-**1991**	Area (sq. km)-**2021**
Built-up	**39.26**	**131.74**
Cropland	**322.07**	**263.8**
Fallow land	**98.84**	**76.54**
Others	**59.02**	**56.75**
Vacant land	**17.83**	**54.56**
Vegetation	**56.38**	**10.06**
Waterbody	**0.41**	**0.36**

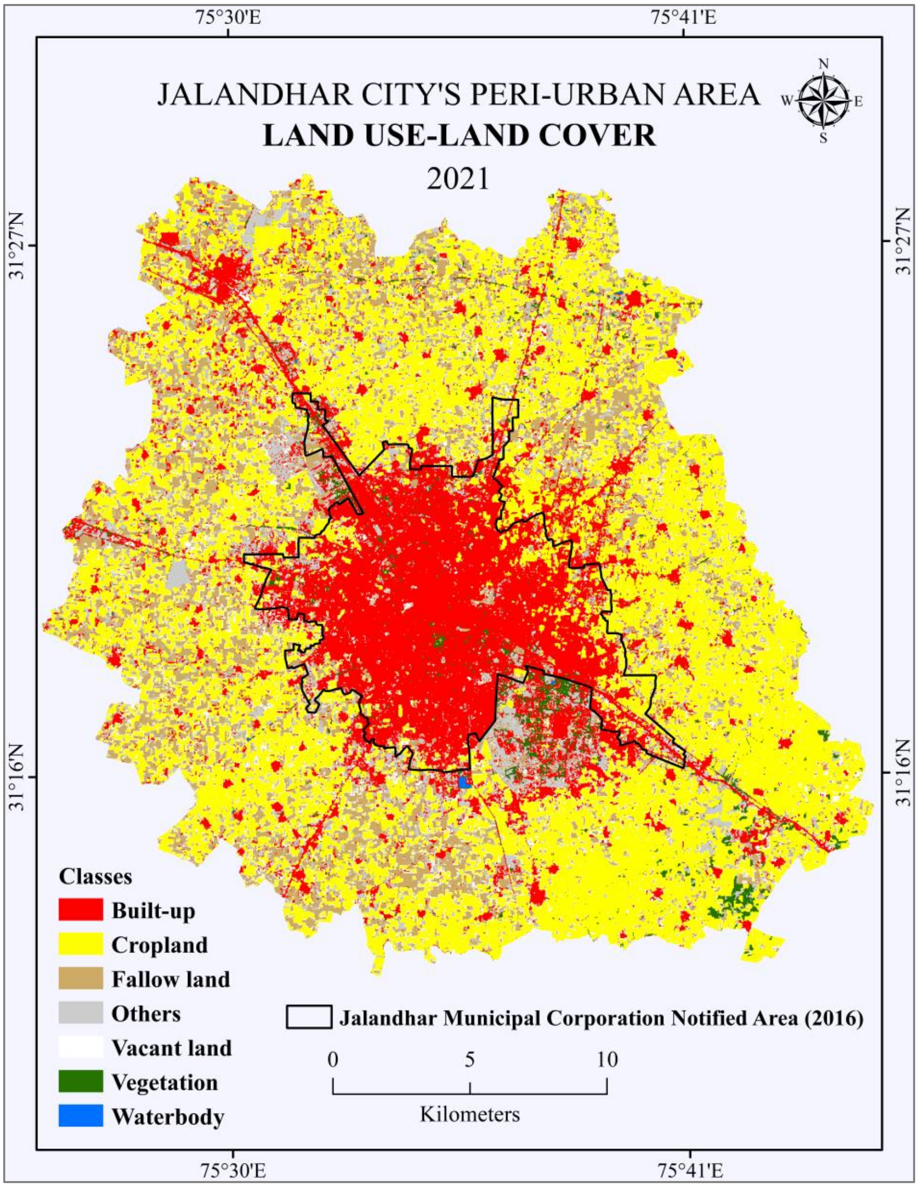
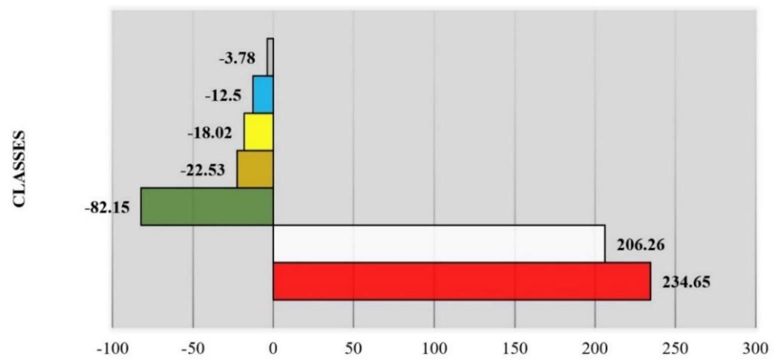


Figure 3: Land use-Land cover Classification (2021)

It is followed by agricultural land, which declined by 40.55 per cent over these three decades. The drop of 80.57 km^2 of agricultural land in three decades is alarming. The changes in the remaining two classes, i.e., waterbody and others' land uses, are somewhat minimal. The overall picture of these two years of Jalandhar city portrays the magnitude of change that occurred on the fertile ground in 30 years. The changes are substantial and cannot be ignored unless the relative change is deduced among individual classes. The second step in post-processing analysis addresses this facet.

The second step involves the calculation of transformation statistics of individual classes by referring ascend of one type of class over other, meaning to say the occurrence of one class type on the land at the cost of another or the withdrawal of other. The primary explanation of transformation in the current study denotes the conversion of one land use type into another. It is of significant importance as it elucidates the underlying reasons behind land use transformation, viz., land transformation. The thematic images of 1991 and 2021 are brought into a matrix union, overlaying one image (2021) over the other (1991). Further, it determines the occurrence of a new class over a spot or area by comparing it with the below image. Once a new category has been detected, it records both values (land use class types) of the same spot or area in both images.



	Percentage Change
Others	-3.78
Waterbody	-12.5
Cropland	-18.02
Fallow land	-22.53
Vegetation	-82.15
Vacant land	206.26
Built-up	234.65

Figure 4. Percentage Change of Land use-Land cover Classes from 1991 to 2021

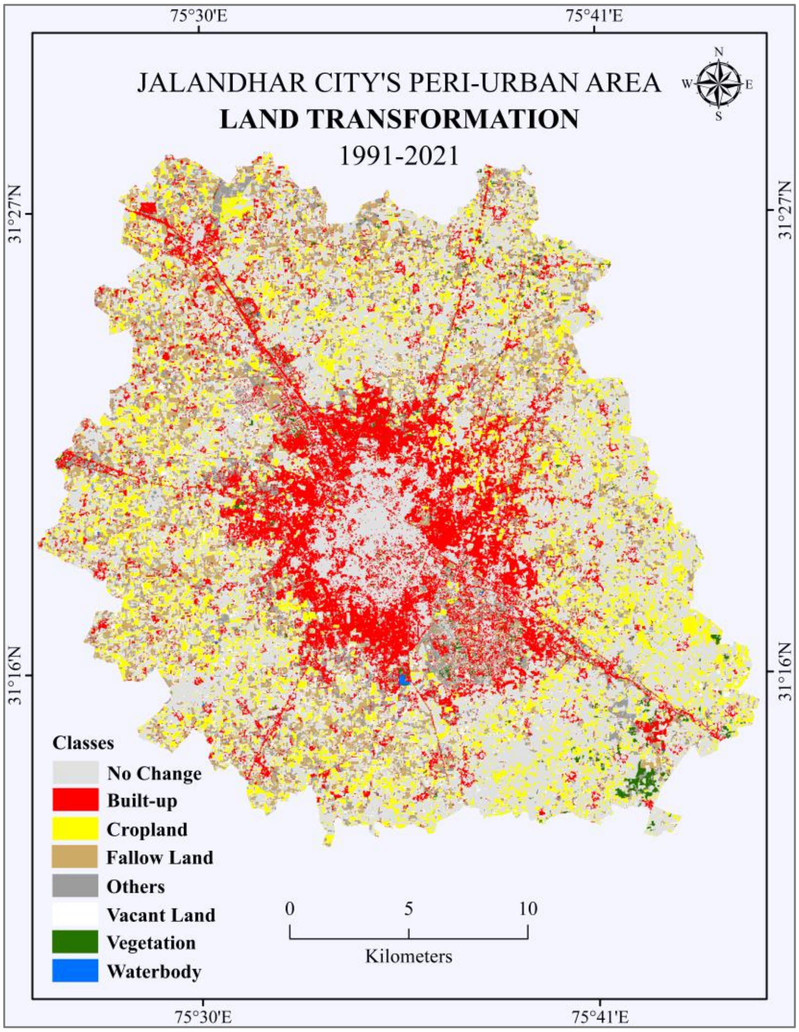


Figure 5: The transformed classes in 2021 (from 1991)

Table 7: The magnitude of Land use-Land cover classes transformed from 1991 to 2021

		2021 (sq. km)							
	Classes	Built-up	Cropland	Fallow land	Others	Vacant land	Vegetation	Waterbody	**Total**
1991 (sq. km)	Built-up	32.72	**2.83**	**1.33**	**1.18**	**0.67**	**0.51**	**0.02**	39.26
	Cropland	**36.78**	181.41	**41**	**28.3**	**30.87**	**3.6**	**0.11**	322.07
	Fallow land	**22.12**	**33.96**	19.04	**11.56**	**11.17**	**0.93**	**0.06**	98.84
	Others	**16.72**	**20.4**	**7.23**	8.01	**5.44**	**1.19**	**0.03**	59.02
	Vacant land	**3.31**	**6.63**	**3.47**	**2.29**	1.89	**0.22**	**0.02**	17.83
	Vegetation	**19.84**	**18.52**	**4.44**	**5.39**	**4.5**	3.59	**0.1**	56.38
	Waterbody	**0.25**	**0.05**	**0.03**	**0.02**	**0.02**	**0.02**	0.02	0.41
	Total	131.74	263.8	76.54	56.75	54.56	10.06	0.36	

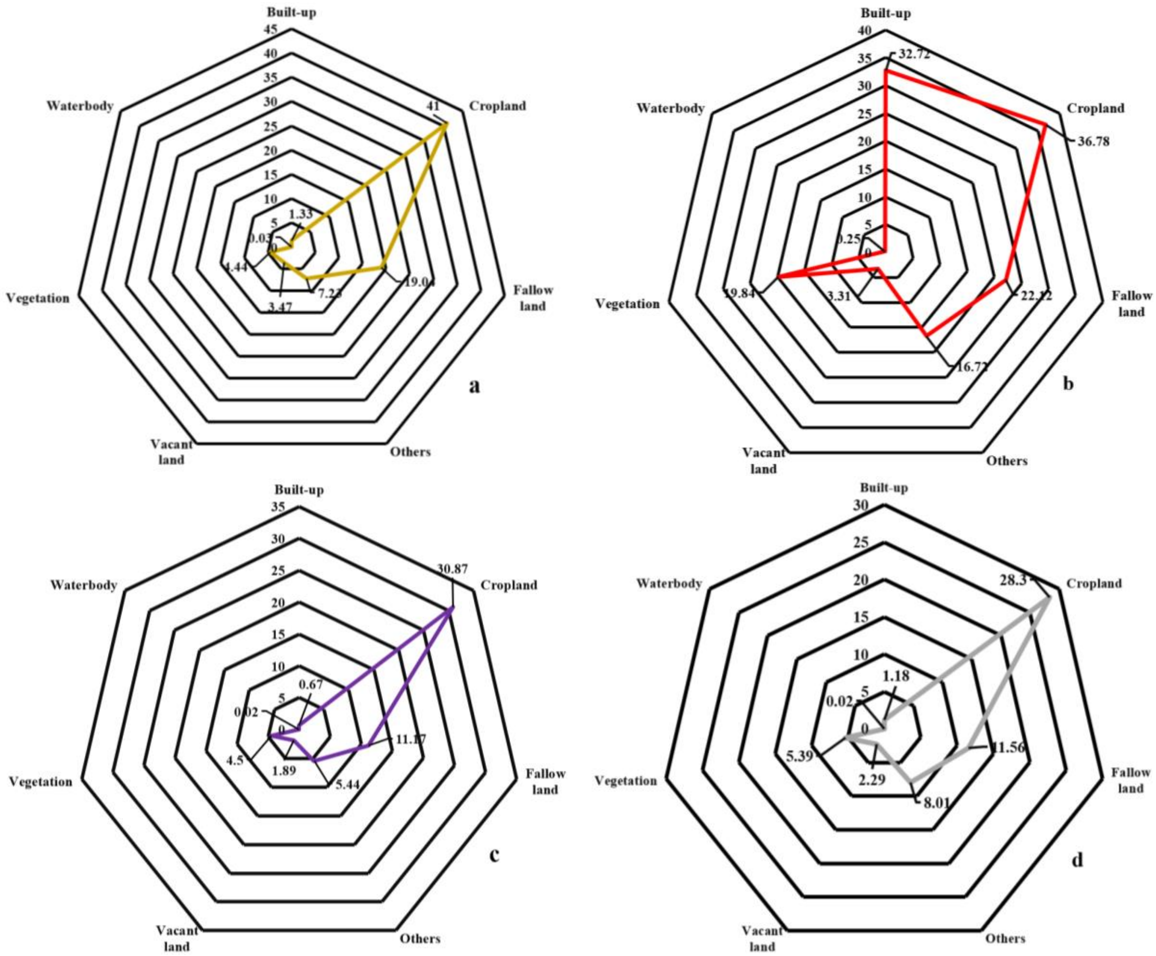


Figure 6: Highest Land Transformation of Cropland into **a.** Fallow land; **b.** Built-up; **c.** Vacant land; and **d.** Others. Charts also show how much the rest of the six classes transformed into portrayed (four) classes.

As both the images are in the same reference system, i.e., UTM WGS84, it is possible to overlay both. And it is also to calculate the area of the transformed class. The analysis output produced two files, one a raster image (Figure 5) assigned with the same color scheme as in the classified images to provide the accurate assumption of occurrence of a particular class (wherever there's no change, light grey color is given). And second, an attribute table notifying the proportional estimates in terms of area for each transformation category that occurred over the place. The resultant attribute table has been redesigned into a change matrix (Table 7) to get an apposite view of the magnitude of change within land use classes.

The red color in Figure 5 illustrates the built-up expansion into the city's periphery. The linear features prominently highlight the road widening and roadside developments. These have entirely dissected the Jalandhar periphery. Apart from this, spots of red can be seen all over the periphery inferring the progression in village built-ups. The actual depiction of urban land transformation comes from Table 7. The first column, where the magnitude of transformation under cropland and fallow land to built-up, is noticeably recorded for 2021. It accounts for 58.9 km^2 of land transformed into built-up class from 1991 to 2011. The proportion of transformation in agricultural land use to built-up is the largest among any other kind of transformation that occurred on this land. It corroborates the urban expansion to its hinterland and the massive transformation along the way. The vegetation (natural) class is second on the list, which received a maximum shift of 19.84 km^2 into built-up land use. The other columns of the Table 7 also highlight a few more dimensions, like, the transformation of cropland to fallow and vice-versa is almost proportional. But the conversion of both these classes to vacant land is questionable. Around 31 km^2 of cropland has been transformed into vacant land (the highest of all transformations within a vacant category). An adequate graphical representation of the principal classes that majorly transformed the cropland is highlighted in Figure 6; the magnitude of transformation by these classes is more than 26 km^2, with the highest by fallow land followed by built-up, vacant land and in last others. As seen in Figure 6(a)-6(d), all the spokes are towards the cropland, illustrating that these classes have caused the cropland to its maximum, compared to other classes. Thus, cropland had majorly transformed into fallow land, built-up, vacant land and others. Another trend from this group of Figure 6 highlights that in the case of built-up class (6b), the plot area between the spokes is the widest of all, referring to the maximum transformation led by this class onto other classes. All these stats need a connecting cord to complete the picture about the reasons for such transformation. These and some more explanations are evaluated further under qualitative assessment. The analysis up till this point builds the context of land transformation in and around a city. Still, to create a perspective on rural land transformation, there's a need to concentrate on the rural land which lies outside the city limits. Thus, the next step in the process includes only rural land (peri-urban) surrounding Jalandhar city. An appropriate picture of rural land transformation also needs to be portrayed; the Jalandhar city limits for 1991 are considered under this step. It fairly reflects the intensity of rural land transformation in these 30 years.

The third and last step in the post-processing analysis considers the spatial metrics. In urban studies, the implementation of landscape ecology's approach to studying the pattern of urban spatial structure has expanded its horizons to assess the land dynamics adequately. The spatial metrics, also known as landscape metrics, have improved urban land use mapping over the years [25], [26], [27], [28], [29], [30], [31], [32], [33], [34] and [35]. The spatial metrics can be implemented at patch, class and landscape levels, but only class and landscape-level metrics have been applied in the present study. As the city expands, it merges into rural areas and makes a heterogenous form [36], fragmenting the existing land use. The applied metrics effectively evaluate various aspects of rural land fragments in the periphery of Jalandhar city.

3.1 Class-level Metrics

Five spatial metrics are applied at the class level, i.e., on selected seven classes. These are Class Area (CA), Percentage of Landscape (PLAND), Number of Patches (NP), Patch Density (PD), and Largest Patch Index (LPI) (Table 8). The first one, *Class Area* (CA), determines the total area covered by each of the seven classes. The second one, PLAND, ascertains the percentages of the corresponding patch types of each class comprised in the landscape.

Table 8: Calculated Class-level Metrics for the Peri-urban Area of Jalandhar City

Class	Class Area (CA) (m^2)	Percentage of Landscape (PLAND)	Number of Patches (NP)	Patch Density (PD)/(m^2)	Largest Patch Index (LPI)
Builtup	**10160.8**	**17.89**	**16793**	**0.3**	**10.8538**
Cropland	**27243.05**	**47.97**	**4437**	**0.08**	**12.5219**
Fallow land	**7659.05**	**13.48**	**11233**	**0.2**	**0.2889**
Others	**6435.42**	**11.33**	**17242**	**0.3**	**0.3405**
Vacant land	**4462.4**	**7.86**	**37074**	**0.65**	**0.0197**
Vegetation	**805.76**	**1.42**	**3195**	**0.06**	**0.0736**
Waterbody	**29.65**	**0.05**	**88**	**0.001**	**0.0206**

Percentage of Landscape (PLAND): It equates (Equation 1) the total sum of the areas of all the patches of the respective classes, divided by the entire landscape (study) area. It is further multiplied by 100 (to convert to a percentage) [37].

$$\text{PLAND} = P_i = \frac{\sum_{j=1}^{n}(a_{ij})}{A}(100)$$

Equation 1

The index corresponds to the Landscape Similarity Index, which depends upon the abundance of particular patch types on the landscape. As the chosen area is primarily rural, cropland occupies the largest parcels in the whole landscape, i.e., 27243.05 m^2 making 47.97 per cent of the total area, 56796.13 m^2 (beyond the 1991 city limits). It is followed by the built-up class covering 17.89 per cent of the whole area, which may not seem alarming. When the proportion of built-up is seen in context to other classes, like fallow land (13.48 per cent), others (11.33) and vacant land (7.86 per cent) (Table 8), which are likely to transform into urban features, then it is indeed an issue to discuss.

The next index on the *Number of Patches* (NP) proves it to some extent. It accounts for the total number of patches in each class. Vacant land comprises the maximum number of patches on the studied landscape, followed by others and built-up patches. Less number of patches in the largest covering cropland class represents the large-sized fields of rural areas. The fourth index under class-level metrics is *Patch density* (PD), a promising indicator to depict the land fragmentation scenario. It gives the ratio of the number of patches of a particular class to the total study area (Equation 3). The scenario compliments the NP and points to the highest density of 0.65 per square meter for vacant land. It is exceptionally high and fairly unveils fragments spreading across the landscape and depicts the level of fragmentation. And there are reasonable chances that most of these fragments will transform into built-up, as highlighted under qualitative assessment further under discussion. The proportion of built-up and others classes' patch density is around 0.3 per square meter, respectively, which is nowhere considered a smaller dimension. The significant number of patch densities in four categories of vacant land, others, built-up and fallow land directly pinpoint the severity of land fragmentation in the study area.

The last index under class-level is the *Largest Patch Index* (LPI), giving the percentage ratio of the largest patch area of each class to the study area. LPI equates (Equation 2) the area of the largest patch of each patch type in a class divided by the total landscape area, which multiplies 100 for a percentage [37].

$$\text{LPI} = \frac{max_{j=1}^{n}(a_{ij})}{A}(100)$$

Equation 2

As mentioned earlier, cropland with a smaller number of patches and more extensive areal coverage represents bigger fields, validates the last index, where the highest LPI of 12.5219 per cent is for cropland only. Trailing it quite closely is built-up with 10.8538 per cent of LPI, undoubtedly building the most substantial connection between rural land and its urban characteristics in terms of built-up class. The availability of the largest patch indexes of cropland and built-up classes also endorses the delineation of the peri-urban area for the current study. Considering the remaining five classes, both are not much fragmented, but negligible LPIs of the remaining classes indicate the fragmented smaller patches.

3.2 Landscape-level Metrics

Five landscape-level metrics are calculated, three of which are similar to class-level metrics. These are *Total Area* (TA), which gives the landscape's total area, i.e., 56796.13 m^2 (Table 9); *Number of Patches* (NA) confers the total number of patches in the whole study area, which come to around 90062 in the number. The third one is *Patch Density* (PD) equates (Equation 3) the total number of patches in the landscape, i.e., 90062. The output gets the result in square metres.

$$\text{PD} = \frac{N}{A}$$

Equation 3

The patch density of the peri-urban landscape comes to 1.5857 per square meter. The statistic indeed illustrates the extent of land fragmentation in the peri-urban area. The transformation of rural parcels to urban or non-rural fragments proves the rural land fragmentation in the study area. As this index also serves as a good heterogeneity index, the higher density of patches in the studied landscape showed more spatial heterogeneity. The fourth landscape-level metric is *Simpson's Diversity Index* (SIDI). It equates (Equation 4) by subtracting the sum, across all the seven classes, of the square of the proportional abundance of each patch type, from 1.

Table 9: Calculated Landscape-level Metrics for the Peri-urban Area of Jalandhar City

Total Area (TA) (m^2)	**56796.13**
Number of Patches (NP)	**90062**
Patch Density (PD)/(m^2)	**1.5857**
Simpson's Diversity Index (SIDI)	**0.7005**
Modified Simpson's Diversity Index (MSIDI)	**1.2057**

The SIDI's value denotes the diversity in the landscape in terms of probability. It is based on the likelihood that any two randomly selected patches are of different class types. Its values range from 0 (for just one patch) to 1 (patch richness); thus, the higher the index value, the greater the diversity of the landscape [37].

$$\mathrm{SIDI} = 1 - \sum_{i=1}^{7} P_i^2$$

Equation 4

Its value come-out as 0.7005, a bit near 1, highlighting the diversity of patches in the peri-urban area of Jalandhar city. It tells the increase in the number of different classes' patches making the landscape more diverse; therefore, fragmentation escalates. It also underlines the fact there's a proportional distribution of 70 per cent of total rural land among seven selected patch types.

The last landscape-level metric is the *Modified Simpson's Diversity Index* (MSIDI). It equates (Equation 5) by subtracting the logarithmic sum, across all the seven classes, of the square of the proportional abundance of each patch type, from 1.

$$\mathrm{MSIDI} = 1 - \ln \sum_{i=1}^{7} P_i^2$$

Equation 5

The resultant value of 1.2057 compliments the SIDI in terms of higher diversity, further, more spatial heterogeneity. As it is the modification in the previous index's equation, the inherently probabilistic nature of Simpson's index has been overruled. It converts the index, similar to Shannon's diversity index, into a more generalized diversity index [38]. Thus, the value of MSIDI is without any upper limit, and the output from the equation upholds the diverse nature of the studied peri-urban area. The index affirms the area's high levels of land fragmentation, which also elucidate the intensity of rural land transformation.

4. Discussion

The maximum proportional change of 234.65 per cent (Figure 4) by built-up class over 30 years on the peri-urban land of Jalandhar city exhibits the enormous infrastructural growth in the region. The sprawling nature of the Jalandhar built-up class has eaten up its surrounding agricultural land. The percentage increase in the vacant land explains that private developers buy the agrarian land and keep it idle for some years so that it will be easy for them to regularize the land conversion laws of the state. The loss of vegetation from the study area primarily results from the widening of the roads over the years, which commenced with cutting trees. These trees had been there to provide shade to the passersby, a long traditional move in India. Removing vegetation aggravated the transformational drive in the region, allowing rural fields to come in direct contact with the roads, which earlier used to act as a buffer between the two. The inclusion of neighboring villages within the city limits over 30 years has remarkably transformed its periphery in the name of development drive. And also, to support the growing population, the coming-up of the built-up class is no surprise. Once in the city's jurisdiction, the land cannot sustain its rural characteristics. All such revelations are recorded in the qualitative assessment while extensive primary surveys of the study area in the past five years. Numerous other reasons have played a crucial role in these transformations that have been discussed further.

4.1 Causes

The unplanned urban area expansion has been the primary cause of the massive rural land transformation. There are enough illegal colonies (not approved by the government) around the Jalandhar municipal boundary. Most of these colonies are on the west side of the periphery towards Kapurthala road, and few are on the east side of the periphery. And this is also one of the reasons the northern side of the city experienced less transformation compared to other directions. Secondly, extensive wedding gardens (palaces) are constructed along the highways. As Jalandhar is a vital city in Punjab, ostentatious Punjabi culture weddings demand big resorts and lawns. But the city is getting agglomerated, and there is hardly any space for such occasions. Due to this cause-and-effect relationship, numerous marriage palaces have come up in the periphery. It is because of the hefty income from such marriages and lower maintenance costs. There are many agricultural spots which have transformed into such palaces, especially areas along the roads. The roads running (linear extension) in the South-east and west directions in Figure 5 are the National Highways, which experienced such changes at a large scale. Thirdly, setting up gigantic Educational Institutes. Over the years, some new educational set-ups have emerged in the periphery. In these, there are prominently three universities which have turned up over the agricultural land. These universities are Lovely Professional University (L.P.U) (2005), Phagwara; Dayanand Anglo Vedic (D.A.V.) University, Samastipur (2013) and I.K. Gujral Punjab Technical University (1997), Kapurthala in the south-east, west, and north-east directions, respectively, around Jalandhar city. Astoundingly, all these universities are along the major national highways of the country. Their establishment in the rural areas is transforming the surrounding agricultural lands. Fourthly, change in the administrative status of villages. There are six new towns, i.e., Dhin, Khambra, Sansarpur, Sufipind, Sarai Khas and Raipur Rasulpur, which have gained status from villages to towns. Because their infrastructural amenities have increased or, better to say, transformed from rural to urban characteristics, and these have been adjoining the city limits. Fifthly, evolving commercial townships. A significant development in the study area has been broadening two lanes into four and four lanes to six-lane highways in these 30 years. It has brought many commercial players to use the adjoining agricultural land along the road for commercial use, like shopping malls, offices, food courts, and local dhabas (roadside food stalls). Lastly, as already mentioned, broadening the roads to four and six lanes has consumed agricultural land along the way. Along with this, the road and its barriers, especially six lanes, collectively stretch around 125 meters at some points, earlier just 30 meters in width. It not only ate up the agricultural land but also vanished the old traditional dhabas along the roadside – hitting on the livelihood of the poor. And above that, the maximum transformation has occurred along these roads in and around the city. Out of six national highways across the study area, National Highway 1 has witnessed a major rural land transformation. It is the first and only highway which has extended to six lanes. The Lovely Professional University, Phagwara, has only emerged along this highway.

4.2 Consequences

The influence of these continual rural land transformations is visible. The consequences have been tracked down in various field visits to the study area. The first and most significant is the loss of agricultural land of around 80.57 km^2 over the study period. Most farmers lost their land in road-broadening projects and received inadequate compensation. Few of them who sold out their lands near roads turned to private jobs in the city. In the lure of benefits, others open business outlets on their agricultural land along national highways. But some landlords give away their lands to private companies to earn hefty incomes. It leads to the ultimate agricultural land fragmentation in the peri-urban area. Secondly, such transformation in the rural areas changes local people's livelihood. During the interview with farmers, many disclosed a complete change in the villagers' livelihood, especially those closer to the city or highway. The farmers also revealed that the new generations are no longer interested in agricultural activities and prefer private jobs in the institutions and commercial complexes in their surroundings. Even their houses are equipped with all the modern urban amenities as most have agricultural land, which they bargain at higher prices to open a private business or fly abroad. These days they hire migrants from Bihar and Uttar Pradesh (other states) to cultivate their fields. Thirdly, such changes in villagers' livelihood also altered their social life. In interview schedules, it has been revealed that nowadays young generation doesn't prefer to live in joint families, which is a real essence of village life in Punjab. Because of the proximity to the city, most of them aspire to live in a city. Above this, to bring up their social status, most of the residents of the villages send their children to study in city schools and colleges or newly opened institutions. All such courses alter the real essence of the village's social life. They are more into a stick-to-your-business approach, avoiding helping hands to the masses and seeking more and more profits. Lastly, compromising the nature of the land – the fertility of the land. Most villagers are negotiating with their actual habits to become a modern trend. Few of them feel ashamed of being part of village culture. In another round of compromised situations, to earn, they use enough fertilizers in their field to get a huge yield and, consequently, sell it at reasonable prices in the city markets. But the actual nature of the agricultural land is deteriorating using these fertilizers. Some also quote a reason for supporting the growing population, which is indisputably accurate but not in line with sustainability.

5. Conclusion

This study evidently contextualizes the facets of rural land transformation around the Jalandhar peri-urban area, where built-up land use leads to a massive positive change in and around the city from 1991 to 2021. This change has come up at the cost of surrounding agricultural land. The transformation of rural land has brought not only urban amenities but also urban lifestyles and facilities. The Jalandhar periphery is undergoing a massive transformational change, from big shopping malls and wedding palaces to vast university campuses. The villages nearby, surrounding the city, or along the road have endured maximum changes, which denotes the magnitude and direction of transformations. The level of land fragmentation substantiates the intensity of transformation that occurred in the area. There's a dire need to address all such issues to create a sustainable peripheral environment which will cater to urban and rural features amicably; otherwise, an unplanned land transformation like the above will indeed invite many conflicts in future.

Acknowledgements

The authors are grateful to the *Department of Geography, Panjab University, Chandigarh*, for providing them with all the means, from Remote Sensing and GIS software to GPS handheld device, to complete this research. We are also grateful to the *locals* who helped us discover the ground realities behind the rural land transformation and for sharing their in-depth knowledge about their surroundings.

References

[1] Hushak, L. J., (1975). The Urban Demand for Urban-Rural Fringe Land. *Land Economics*, Vol. 51(2), 112-123.

[2] Mondal, D. and Banerjee, A., (2021). Exploring Peri-Urban Dynamism in India: Evidence from Kolkata Metropolis. *Journal of Urban Management*, Vol. 10(4), 382-392.

[3] del Mar López, T., Aide, T. M. and Thomlinson, J. R., (2001). Urban Expansion and the Loss of Prime Agricultural Lands in Puerto Rico. *Ambio: A Journal of the Human Environment*, Vol. 30(1), 49-54.

[4] Narain, V., Anand, P. and Banerjee, P., (2013). *Periurbanization in India: A Review of the Literature and Evidence*. Report for the Project: Rural to Urban Transitions and the Peri-Urban Interface. *SaciWATERs*. 1-27. http://www.saciwaters.org/east-west-center/pdf/status-paper.pdf.

[5] Shaw, R. and Das, A., (2018). Identifying Peri-Urban Growth in Small and Medium Towns Using GIS and Remote Sensing Technique: A Case Study of English Bazar Urban Agglomeration, West Bengal, India. *The Egyptian Journal of Remote Sensing and Space Science*, Vol. 21(2), 159-172.

[6] Boonchoo, K., (2018). Urban Land use Changes Prediction by Using a CA-Markov and Logistic Regression Analysis. *International Journal of Geoinformatics*, Vol. 14(2), 35-43.

[7] Ramadan, E., Al-Awadhi, T. and Charabi, Y., (2021). Land Cover/Land use Change and Climate Change in Dhofar Governorate, Oman. *International Journal of Geoinformatics*, Vol. 17(4). 41–47. https://doi.org/10.52939/ijg.v17i4.1949

[8] Sudhira, H. S. and Gururaja, K. V., (2012). Population Crunch in India: is it Urban or Still Rural?. *Current Science*, Vol. 103(1), 37-40.

[9] Shaw, A., (2005). Peri-Urban Interface of Indian Cities: Growth, Governance and Local Initiatives. *Economic and Political Weekly*, Vol. 40(2), 129-136.

[10] Vishwanath, T., Lall, S. V., Dowall, D., Lozano-Gracia, N., Sharma, S. and Wang, H. G., (2013). *Urbanisation Beyond Municipal Boundaries: Nurturing Metropolitan Economies and Connecting Peri-Urban Areas in India* (No. 75734). Washington, DC: The World Bank. DOI: 10.1596/978-0-8213-9840-1

[11] Ramachandran, R., (1992). *Urbanisation and Urban Systems in India*. OUP Catalogue, Oxford University Press, 9780195629590, November (Reprint 2014 - 27th Impression).

[12] Kundu, A., (2003). Urbanisation and Urban Governance: Search for a Perspective Beyond Neo-Liberalism. *Economic and political Weekly*, Vol. 38(29), 3079-3087. https://www.jstor.org/stable/4413810.

[13] World Bank. (2021). *Population, Total, Data*. Available at: https://data.worldbank.org/indicator/SP.POP.TOTL.

[14] Tin, S. N. and Muttitanon, W., (2021). Analysis of Enhanced Built-up and Bare Land Index (EBBI) in the Urban Area of Yangon, Myanmar. *International Journal of Geoinformatics*, Vol. 17(4). 85–96. https://doi.org/10.52939/ijg.v17i4.1957.

[15] Ministry of Finance, Government of India, (2022). *Economic Survey 2021-22*. Department of Economic Affairs. https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/index.html.

[16] Gover Government of India. (2019). *Handbook of Urban Statistics*. Ministry of Housing and Urban Affairs (MoHUA). https://mohua.gov.in/pdf/5c80e2225a124Handbook%20of%20Urban%20Statistics%202019.pdf.

[17] Grover, D. K., Singh, J. M., Kaur, A. and Kumar, S., (2017). State Agricultural Profile-Punjab. *AERC Study No.* 44. 1-80. http://aercpau.com/assets/docs/AERC%2044.pdf.

[18] Ministry of Home Affairs, Government of India. (2022). *Primary Census Abstract 2011* |

Tables. Office of the Registrar General & Census Commissioner, India. https://census india.gov.in/census.website/data/tables.

[19] Al-Awadhi, T., Ramadan, E. and Charabi, Y., (2017). Urban Development and Land use Change Patterns in Muscat City, Oman. *International Journal of Geoinformatics*, Vol. 13(4), 45-55.

[20] Onojeghuo, A. R. and Onojeghuo, A. O., (2015). Spatial Dynamics of Urban Transition using Remote Sensing. *International Journal of Geoinformatics*, Vol. 11(1). 21-32, https://journals.sfu.ca/ijg/index.php/journal/article/view/595

[21] Usha, N., Thukaram, M., Mohandas, C. and Naveenchandra, B., (2014). Urbanisation Study with Land use/Land Cover change Detection for the Environmental Impact on Climate Change using Remote Sensing and GIS Technology A Case Study of Udupi Taluk, Karnataka State, India. *International Journal of Geoinformatics*, Vol. 10(2). 31-40. https://doi.org/10.52939/ijg.v10i2.375

[22] Amin, A. and Fazal, S. M., (2012). Quantification of Land Transformation using Remote Sensing and GIS Techniques. *American Journal of Geographic Information System*, Vol. 1(2), 17-28. DOI: 10.5923/j.ajgis.20120102.01

[23] Paudel, S. and Yuan, F., (2012). Assessing Landscape Changes and Dynamics Using Patch Analysis and GIS Modeling. *International Journal of Applied Earth Observation and Geoinformation*, Vol. 16, 66-76. https://doi.org/10.1016/j.jag.2011.12.003.

[24] Singh, S. K., Laari, P. B., Mustak, S. K., Srivastava, P. K. and Szabó, S., (2018). Modelling of Land use Land Cover Change Using Earth Observation Data-Sets of Tons River Basin, Madhya Pradesh, India. *Geocarto International*, Vol. 33(11), 1202-1222.

[25] Noda, A. and Yamaguchi, Y., (2008). Characterising Urban Sprawl Using Remote Sensing and A Simple Spatial Metric for a Medium-Sized City in Japan. *International Journal of Geoinformatics*, Vol. 4(1), 43-50.

[26] Dietzel, C., Herold, M., Hemphill, J. J. and Clarke, K. C., (2005). Spatio-Temporal Dynamics in California's Central Valley: Empirical Links to Urban Theory. *International Journal of Geographical Information Science*, Vol. 19(2), 175-195.

[27] Gustafson, E. J., (1998). Quantifying Landscape Spatial Pattern: What is the State of the Art?. *Ecosystems*, Vol. 1(2), 143-156.

[28] Herold, M., Scepan, J. and Clarke, K. C., (2002). The Use of Remote Sensing and Landscape Metrics to Describe Structures and Changes in Urban Land uses. *Environment and Planning A*, Vol. 34(8), 1443-1458.

[29] Herold, M., Goldstein, N. C. and Clarke, K. C., (2003). The Spatiotemporal form of Urban Growth: Measurement, Analysis and Modeling. *Remote sensing of Environment*, Vol. 86(3), 286-302.

[30] Herold, M., Liu, X. and Clarke, K. C., (2003). Spatial Metrics and Image Texture for Mapping Urban Land use. *Photogrammetric Engineering & Remote Sensing*, Vol. 69(9), 991-1001.

[31] Herold, M., Couclelis, H. and Clarke, K. C., (2005). The Role of Spatial Metrics in the Analysis and Modeling of Urban Land use Change. *Computers, Environment and Urban Systems*, Vol. 29(4), 369-399.

[32] Luck, M. and Wu, J., (2002). A Gradient Analysis of Urban Landscape Pattern: A Case Study from the Phoenix Metropolitan Region, Arizona, USA. *Landscape Ecology*, Vol. 17(4), 327-339.

[33] O'Neill, R. V., Krummel, J. R., Gardner, R. E. A., Sugihara, G., Jackson, B., DeAngelis, D. L., Milne, B. T., Turner, M. G., Zygmunt, B., Christensen, S. W. and Dale, V. H., 1988. Indices of Landscape Pattern. *Landscape Ecology*, Vol. 1(3), 153-162.

[34] Schneider, A., Seto, K. C. and Webster, D. R., (2005). Urban Growth in Chengdu, Western China: Application of Remote Sensing to Assess Planning and Policy Outcomes. *Environment and Planning B: Planning and Design*, Vol. 32(3), 323-345.

[35] Turner, M. G., Gardner, R. H., O'neill, R. V. and O'Neill, R. V., (2001). *Landscape Ecology in Theory and Practice*. Springer New York.

[36] Aguilar, A. G., Flores, M. A. and Lara, L. F.m (2022). Peri-Urbanization and Land use Fragmentation in Mexico City. Informality, Environmental Deterioration, and Ineffective Urban Policy. *Frontiers in Sustainable Cities*, Vol. 4, 1-19.

[37] McGarigal, K., & Marks, B. J. (1995). *FRAGSTATS: spatial pattern analysis program for quantifying landscape structure*. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 122 p. https://www.fs.usda.gov/research/treesearch/3064.

[38] Pielou, E. C. (1975). Ecological diversity New York. *NY: Wiley [Google Scholar]*.