Innovations

# Monitoring Urban Sprawl and Its Impact on Land Use and Land Cover of Dehradun Master Plan (2001-2020)

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**Received:** 20 April 2022 **Accepted:** 26 May 2022 **Published:** 15 June 2022

***Abstract***

*Urban population has been increasing at a rapid pace everyday with an alarming rate. This increase causes various types of ecological imbalances which in turn affects people living in urban areas. In order to mapping of urban areas becomes very crucial, various techniques and methodologies are being used to evaluate the temporal and spatial domains of urban growth. Thus, urbanization complexities open challenges regarding to study urban dynamics. The aims of this research paper were to quantify the urban growth in Dehradun Planning Area (DPA), the capital of Uttrakhand. Two decades (2001-2020) studies have been performed using urban land cover classes derived from Landsat TM/ETM/OLI satellite data. Built-up area recorded as 4006.3 ha increase in first spell (2001-2011) and 1594.2 ha increase during next spell (2011-2020) of study period. Urban Landscape Analysis Tool (ULAT) was used for urban expansion quantify by generating matrices.Land cover classes was performed with the accuracy of 92.91%, 86.00% and 87.50% respectively for the years 2001, 2011 and 2020. (i) Built-up, (ii) Water and (iii) others. These are the major land cover classes were mapped. Classified maps were further utilized to calculate the degree of urbanization which were based on built-up density of study area, consisting of seven classes (i) Urban built-up, (ii) Sub-urban built-up, (iii) Rural built-up, (iv) urbanized open land (v) Captured open land (vi) Rural open land and (vii) water body. These feature class supervised on the basis of urban reflectance of imageries' cells. Two times footprints maps were also generated for qualitative and quantitative analysis of urban growth in the planning area. The new development areas also mapped as (i) infill, (ii) extension, and (iii) leapfrog were three categories of new developments.*

**Keywords: 1.***Ecological Imbalances, 2.Dehradun Planning Area (DPA), 3.Urban dynamics, 4.New development Areas*

## 1. Introduction

Urbanization has become a common phenomenon in present decade. A surge of urbanization is being experienced by whole world (Shen et al., 2020). In beginning of 20th century, pattern of urbanization in cities of India was restricted within a boundary but later on, due to continuous migration and population expansion growth of the cities started taking place outside the municipal boundary (Brush, 1968). The expansion of urban centers is mostly in an unorganized and unplanned manner which is characterized by uncontrolled development of impervious surfaces (Downs, 1999). The process of urbanization has substantial implications for changes in demographic characteristics and transformation of the physical landscape, unplanned, unsystematic and rapid urbanization can cause profound impacts on various environmental components, especially on land and water (Battista and Vollaro, 2020).

In urban studies, a proper understanding of such structural changes taking place in urban system and addressing the spatial changes going on are of utmost significance (Amin and Fazal, 2012). Process of Urbanization needs to be understood, efficiently monitored and quantified for planning of urban areas. For this, historical background as well as current information about land use and land cover dynamics is required (Zhang and Seto, 2011). A detailed understanding of the dynamics of urbanization induced land-cover change is, therefore, necessary for coping with environmental changes and facilitating sustainability. This is so particularly because most of the urban areas in the world has experienced considerable land-cover changes over the years. Further, these urban areas consume most of the global energy and cause serious environmental problems and degradation of ecosystems through pollution of air, water and land (Yan, Z. et al., 2016).

Changes in the land use patterns have been reported in both developed as well as developing nations, where major source behind these land use changes is considered to be constant migration of rural population in cities for better lifestyle and employment opportunities. (Chikowore and Willemse, 2020; Cui, X. et al., 2019;). Urbanization demands for more resources increases, and there arises an urgent need for more water, energy, electricity and other resources are consumed for production activities, thus, leading to ecological imbalances and uneven distribution of resources. Carrying capacity of the urban centres have been decreasing constantly mainly because of rapid urban growth (Yang et al., 2020). Coping with the problems emerging by the process of urbanization is solely based upon our understanding regarding the components of urbanization such as cluster cities, urban agglomeration, land transformation etc. and studies are based upon variety of perspectives ranging from environmental perspective, socio-economic perspective (Cohen, 2006), loss of ecosystems and habitats (Kath, Maron and Dunn, 2009), rural-urban disparities (Ravallion, Chen and Sangraula, 2007).

The major cause of urbanization is unprecedent growth of pupils and rural-urban migration and can be seen in the process and pattern of urbanization (Chen et al., 2014). After the development process started, refinement of whole rural settlement started (Sankhala and Singh, 2014). Consequently, demands and aspirations of human beings started increasing and character of rural settlements started changing into urban character. It can be seen that most the rural settlements have already merged into nearby urban areas and characteristics of these settlements have transformed into characteristics of urban settlements such as pucca houses, well connected road network, availability of basic infrastructure (Balha and Singh, 2020).

Under the vicinity of Himalayan ranges and Shivalik ranges Dehradun lies. In the year 2000, Dehradun was given the status of separate state. Since then, population of Dehradun is increasing at an enormous rate. In 2001, total population was only 4.48 lakhs which rose to 6.57 lakhs in 2011 (Gupta, K. 2013). Dehradun is considered as a city which is rich in natural green spaces and vegetation with a pollution free essence which is the major attraction for the tourists from India and also from all over the world. But today, the scenario is different as the city is growing in an unplanned manner which was once having mix architectural characteristics within the natural environment such as rivers, slopes for drainage, balanced social-economic settings and construction of paved surfaces (Shah, Ali and Nizami, 2020). The situation of Dehradun seems alarming as haphazard growth of city has been increasing very rapidly which is very unsustainable.

Apparently, on one hand, urbanization is becoming burden for the resources and on the other hand, landscape changes are taking place drastically, thus, the role of urban planning increases. There is a need of efficient and effective policies for the urbanization taking place in a country like India at such large scale. There are various tools and techniques that are being used for planning purposes across the world, but techniques of remote sensing are commonly used mainly due to its efficiency and precision (Mahboob, Atif and Iqbal, 2015). For studying landscape dynamics i.e., urban expansion, land use changes etc. geospatial technologies play a major role in predicting future growth or expansion of the towns and cities (Sharma and Joshi, 2013). The following study is based on geospatial modelling for analyzing the sprawl in Dehradun with the help of Urban Landscape Analyses Tool (ULAT). ULAT is used to analyze the spatial transformations occurring over temporal domain from 2001 to 2020 in Dehradun.

## 2. Study Area

The provisional capital and administrative center of Uttarakhand is Dehradun which comes under the list of Jawaharlal Nehru National Urban Renewal Mission (JNNURM). It is situated in the fertile land of Doon Valley and foothills of the Himalayan Mountains at an altitude of 2200 feet above mean sea level (MSL). Dehradun receives annual rainfall of 2000 mm during the monsoon season with an average temperature of 36° Celsius during summer season and 5.2° Celsius during winter season. The major attraction of the valley is its scenic beauty and salubrious climate and considered as one of the most beautiful resort centers in the country. To the east lies the scared river Ganga and to west lies the Yamuna River. In India, Dehradun is considered as an important educational center as many known universities and institutions such as Forest Research Institute, Zoological Survey of India, Indian Institute of Remote Sensing, Indra Gandhi National Forest Academy, Himalayan Institute of Technology, and Indian Military Academy are situated here.

## 3. Methodology

In the present study, datasets of Landsat 5 and Landsat 8 have been utilized which has been obtained from USGS website. Datasets of two time periods (2001, 2011 and 2020) have been downloaded. Software's such as ArcMap 10.8 and Erdas Imagine 2014 have been used for pre and post image processing. Remote sensing index such as water index and built – up index has been used to extract built – up and non-built – up areas. Moreover, results obtained have been used in urban landscape analysis in order to obtain urban areas, urban footprint and new developed areas (Figure 2).

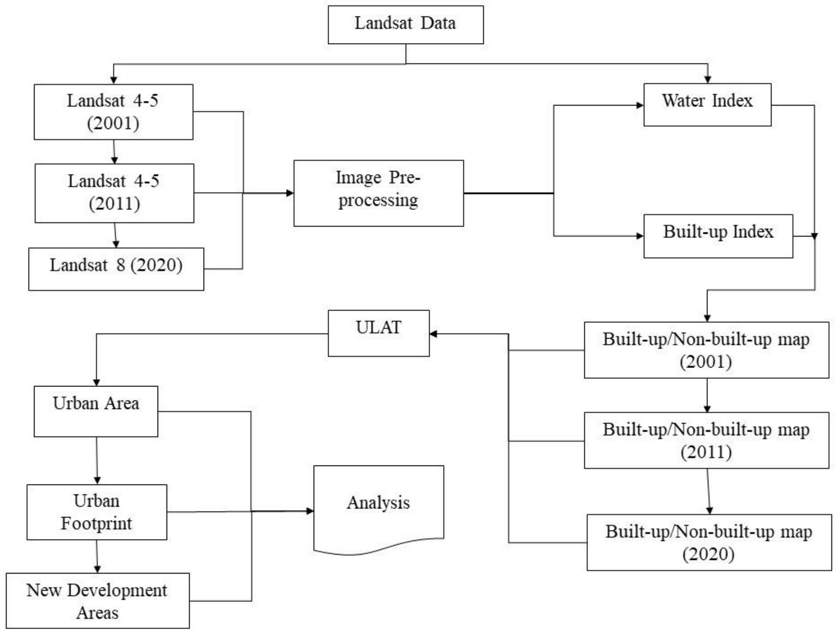


**Figure 2. Methodology for studying the urban landscape dynamics of the study area**

### 3.1 LULC Characterization

For studying urban dynamics, LULC plays significant role for providing information about the landscape which is essential for land resource management and policy making. Thus, first and foremost step was mapping the land use and land cover with the help of maximum likelihood classifier. In mapping LULC of Dehradun, only three main categories have been taken because studying the impact of built-up areas on other categories was the key motive of the study. Three major categories of land cover are: built-up, water body and other. Also, remote sensing indices have been used to map built-up and water bodies and other were put into 'other' category. Temporal land use and land cover map has been prepared for 2001 and 2020. Apparently, for accuracy assessment, user accuracy, producer accuracy and overall accuracy have been computed.

Formula for NDBI: - $Built - up\ Index\ \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$

Formula for NDWI: - $Water\ Index\ \frac{Band\ 1 + Band\ 2 + Band\ 3}{Band\ 4 + Band\ 5 + Band\ 6 + Band\ 7}$

### 3.2 Urban Footprint Mapping

Mapping of Urban footprint has been performed with the help of land use and land cover maps prepared for 2001 and 2020. Urban footprint has been divided into seven major categories based on level or urbanization values and their attributes. The main objective of urban footprint mapping is to categorize the spatial density of urban centers. Few central categories recognized by urban foot print mapping is captured open land and fringed open land respectively. Where, captured open lands are vulnerable to degradation due to other open lands located sparsely and fringe open lands acts as edge disturbance zones because they can get degraded by adjacent environments.

### 3.3 Delineating Urbanized Area

Delineation of urban areas are based upon level of urbanization (Table 1). These maps contain 6 major classes same as urban foot print maps except fringe open land in which under developed land where level of urbanization more than 50 per cent is included. Fringe open lands have a tendency to impact the development of surrounding areas. Thus, identifying areas which are urbanized and are capable of being degraded due to paved surfaces are very crucial. Hence, it can be done with the help of urbanized area map and urban footprint map.

**Table 1: Criteria for categorizing urban area**

| Class | Criteria |
|---|---|
| Urban Built – up | Built – up with more than 50 per cent urbanism |
| Suburban Built – up | Built -up area with 10 – 15 per cent urbanism |
| Rural Built - up | Built -up with less than 10 per cent |
| Fringe Open land | Fully undeveloped land with 100 meters of developed area |
| Captured Open land | Undeveloped Patches (<200 ha) which is completely surrounded by urban built – up, suburban built – up and fringe open land |
| Rural Open Land | Undeveloped, neither fringe not captured open land |
| Water | Water bodies in the LULC classification |

### 3.4 Identifying New Development Areas

Identification of new developments taken place between stated time periods has been performed in this study. New development areas are categorized into three main categories, namely, infill, extension and leapfrog respectively. Areas developed in urbanized open lands, developments taken place in fringe areas and development taken place outside rural open lands are termed as infill, extension and leapfrog respectively.

## 4. Result and Discussion

### 4.1 Land use and Land cover

For the following study, classification of land use and land cover has been performed for three time period (2001, 2011, and 2020). Land use and land cover categories have been divided into three main types, namely, built up, waster bodies and others (Figure 3, Figure 4 and Figure 5). By analyzing the temporal data, it has been found that built up area which shows the urban, peri urban and rural areas indicate an increasing rate. In 2001, total built up area was 7069.80 ha to 11076.10 ha in 2011 and during 2020 it was 12670.30 ha. In case of water bodies, there has been a continuous decreasing trend. Water bodies decreased to 893.91 in 2020, where in 2001 and 2011 it was 1150.48 ha and 1041.20 ha respectively. Similar decreasing trend has been noticed in others category, as with time total area has been decreasing from 27781.72 ha in 2001 to 23884.7 in 2011 and it further decreased to 22437.74 in 2020 (Table 2). Thus, it is evident that built area has been increasing rapidly with time at the stake of water bodies and others category.

**Table 2: Land use and Land cover area in hectares**

| | Area in Hectares | | |
|---|---|---|---|
| **Categories** | **2001** | **2011** | **2020** |
| Built up | 7069.80 | 11076.10 | 12670.30 |
| Water Bodies | 1150.45 | 1041.20 | 893.91 |
| Others | 27781.72 | 23884.7 | 22437.74 |

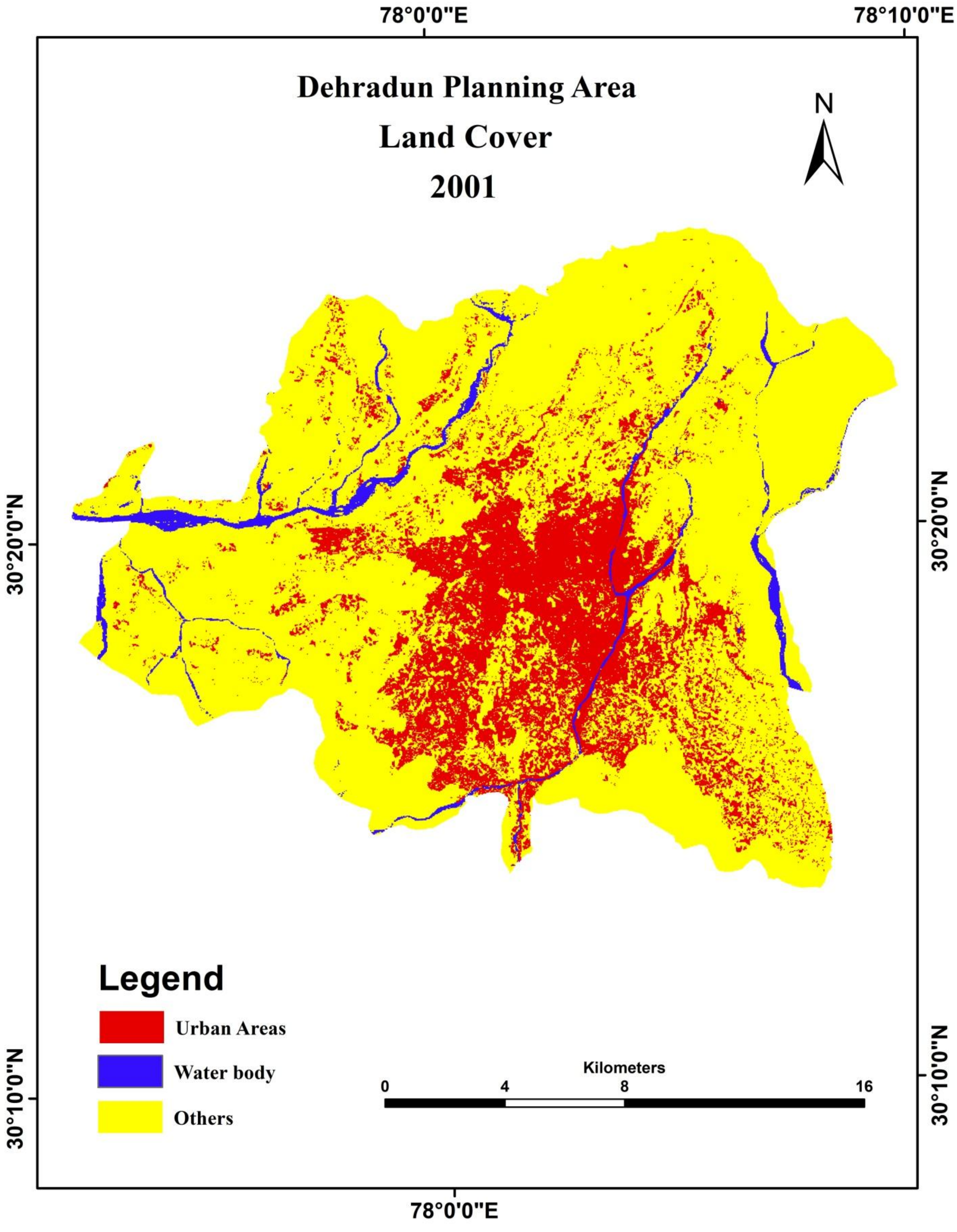


**Figure 3: Land use and Land cover classification of the study area into 3 main categories (2001)**

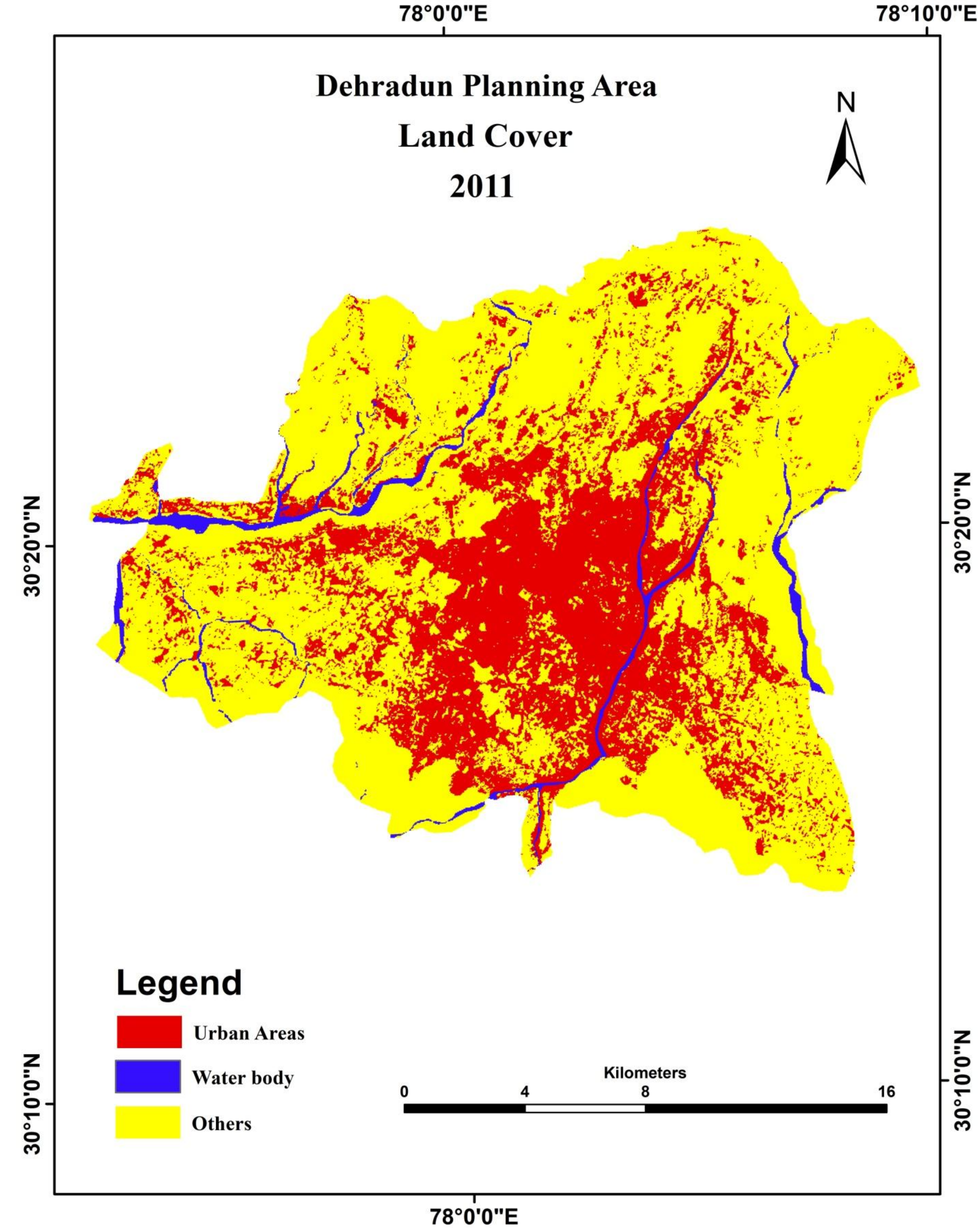


**Figure 4: Land use and Land cover classification of the study area into 3 main categories (2011)**

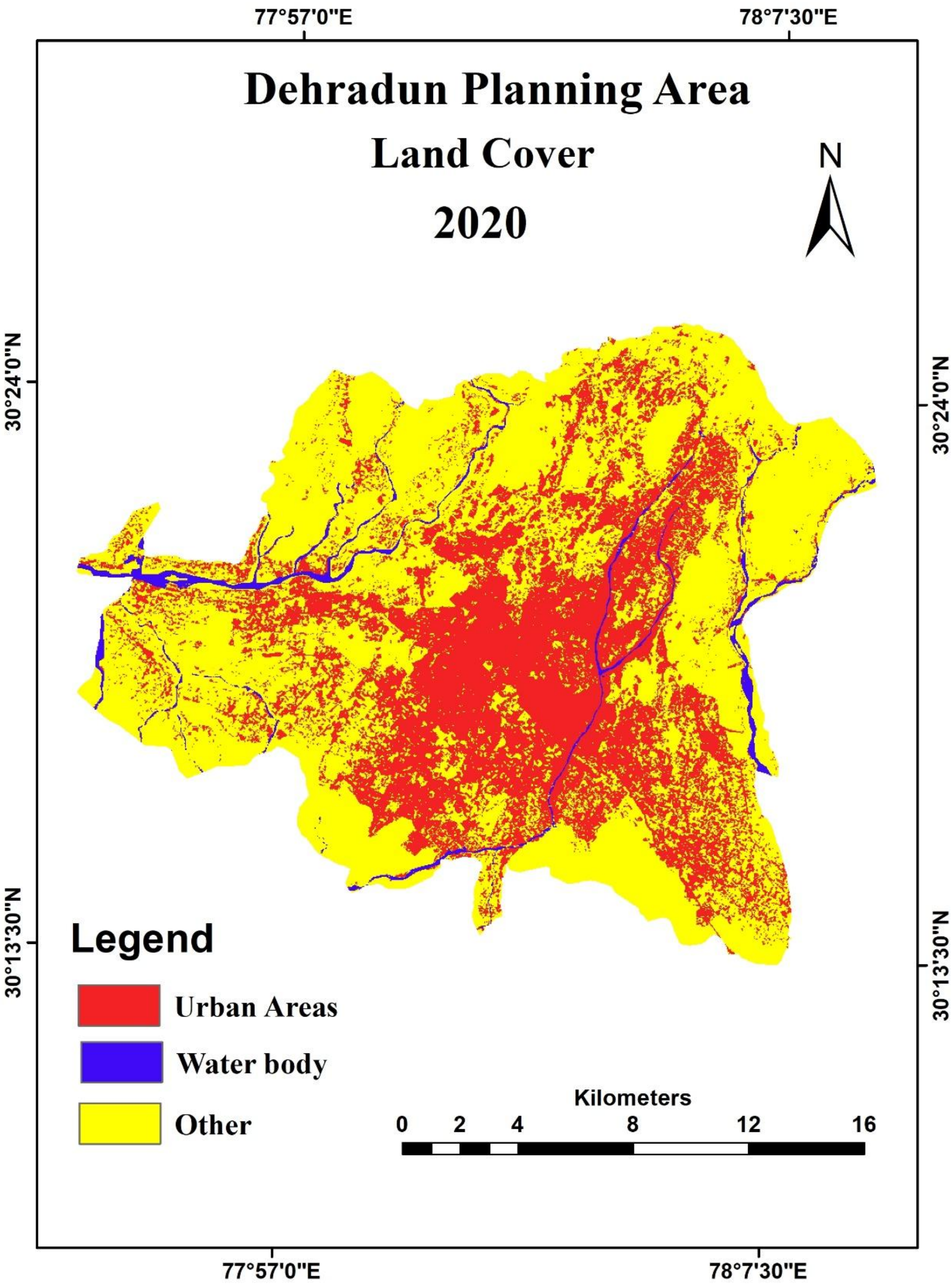


**Figure 5: Land use and Land cover classification of the study area into 3 main categories (2020)**

### 4.2 Accuracy Assessment

Accuracy assessment is performed to verify the allocation of pixels during the classification process. Accuracy assessment has been performed for all three-temporal domains. Computation of user accuracy, producer accuracy and overall accuracy has been done. Highest overall accuracy has been obtained for 2001 (92.91%) with kappa coefficient of 0.8732 whereas, 86.0% with kappa coefficient of 0.7951and 87.50% with kappa coefficient of 0.7097 in 2011 and 2020 respectively (Table 3). Highest user accuracy has been obtained for others category in all temporal domain on one hand and lowest for water bodies one other hand (Table 2). Similar scenario has been noticed in case of producer accuracy.

| | 2001 | | 2011 | | 2020 | |
|---|---|---|---|---|---|---|
| **Category (Urban Footprint)** | **Area (Hectares)** | **Percentage** | **Area (Hectares)** | **Percentage** | **Area (Hectares)** | **Percentage** |
| Urban Built up | 4774.32 | 12.98 | 7110.72 | 19.34 | 8848.17 | 24.08 |
| Sub urban built up | 2530.53 | 6.88 | 3851.73 | 10.48 | 3992.85 | 10.86 |
| Rural Built-up | 376.47 | 1.02 | 290.79 | 0.79 | 249.21 | 0.67 |
| Fringe Open Land | 7154.91 | 19.64 | 9351.23 | 25.44 | 10272.87 | 27.96 |
| Captured Open Land | 689.58 | 1.87 | 1264.5 | 3.44 | 972.99 | 2.64 |
| Rural Open Land | 20086.58 | 54.63 | 13841.6 | 37.66 | 11511.45 | 31.33 |
| Water Bodies | 1150.48 | 3.12 | 1041.20 | 2.83 | 893.91 | 2.43 |

## Table 3: Accuracy assessment of the land use and land cover classification with Kappa Co-efficient

| | 2001 | | 2011 | | 2020 | |
|---|---|---|---|---|---|---|
| | **Producers Accuracy** | **Users Accuracy** | **Producers Accuracy** | **Users Accuracy** | **Producers Accuracy** | **Users Accuracy** |
| **Urban** | 83.93% | 88.68% | 70.00% | 70.00% | 72.73% | 88.89% |
| **Water** | 76.09% | 92.11% | 50.00% | 100.00% | 50.00% | 100.00% |
| **Other** | 81.82% | 88.52% | 88.24% | 78.95% | 96.30% | 86.67% |
| **Overall Accuracy** | 92.91% | | 86.00% | | 87.50% | |
| **Overall Kappa Statistics** | 0.8732 | | 0.7951 | | 0.7097 | |

**4.3 Urban Footprint**

Classification of urban footprint has been done into seven major categories and it signifies spatial density of urban areas for all three-time domains (Figure 6, Figure 7 and Figure 8). Through analyses it was found that urban built-up area contributes 24.08 per cent in 2020, whereas in 2011 and 2001 it was 19.34 per cent and 12.98 per cent only (Table 3). Total built-up area in

Table 4: Urban footprint categories and their respective areas in hectares and percentage

2020 is 8848.17 ha, where it was only 4774.32 ha in 2001. Increasing trend has been observed in sub urban built up and fringe open land as well. Consequently, there has been a decrease in rural built up from 2001 – 2020, which was 376.47 ha in 2001 and in 2020 rural built up is only 249.21 ha only (Table 4). The main cause of decrease of rural built can be conversion to sub urban and urban built up. Whereas declining trend in urban footprint mapping can also be observed in water bodies and rural open land as well. In 2020, total area covered by water bodies in only 2.3%, which was 3.12% in 2001, thus, it reflects the degradation of water bodies with time. Shirking of water bodies can cause various environmental issues for respective surrounding areas as it is the main source of water for to urban dwellers.

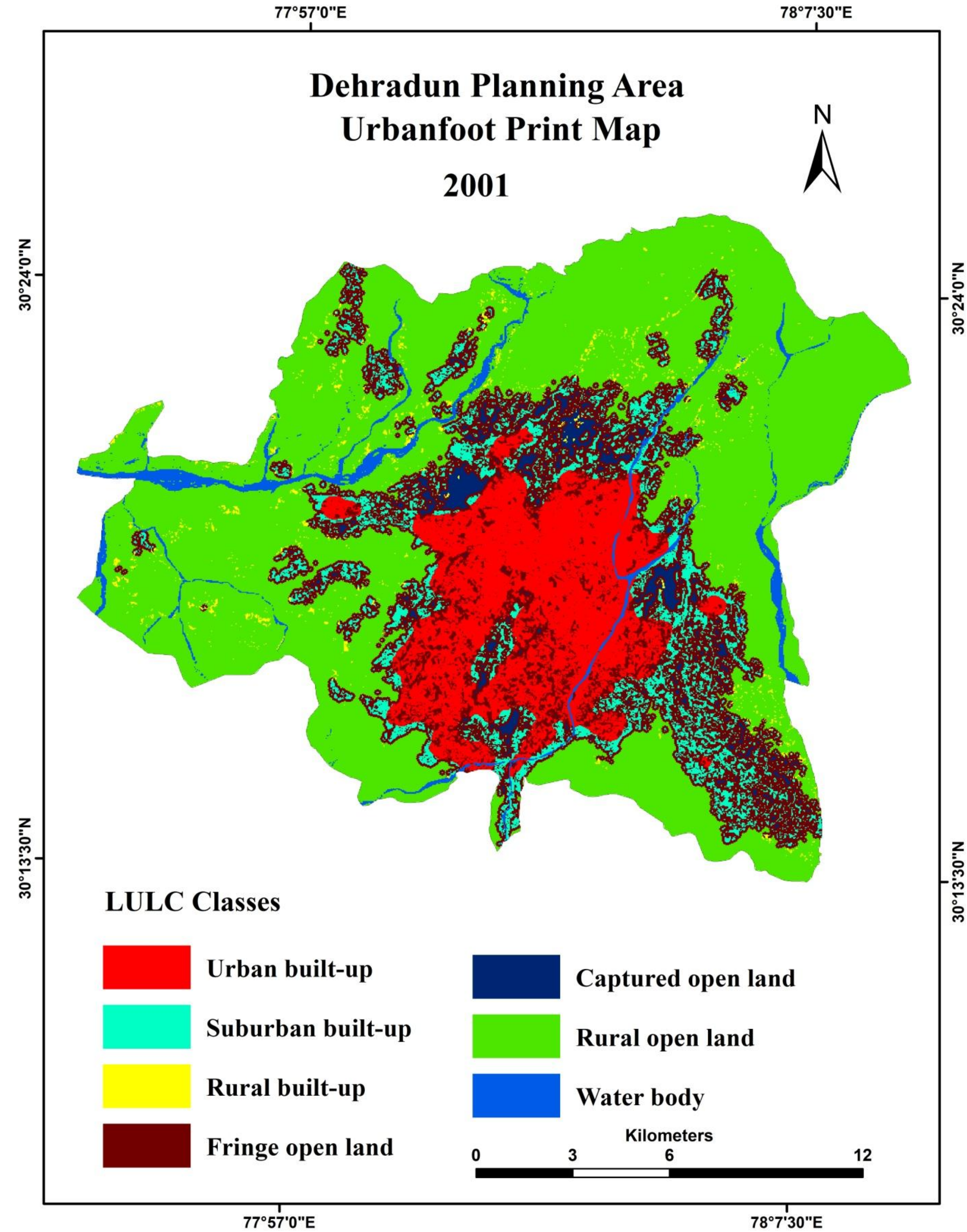


**Figure 6: Urban footprint classification (2001)**

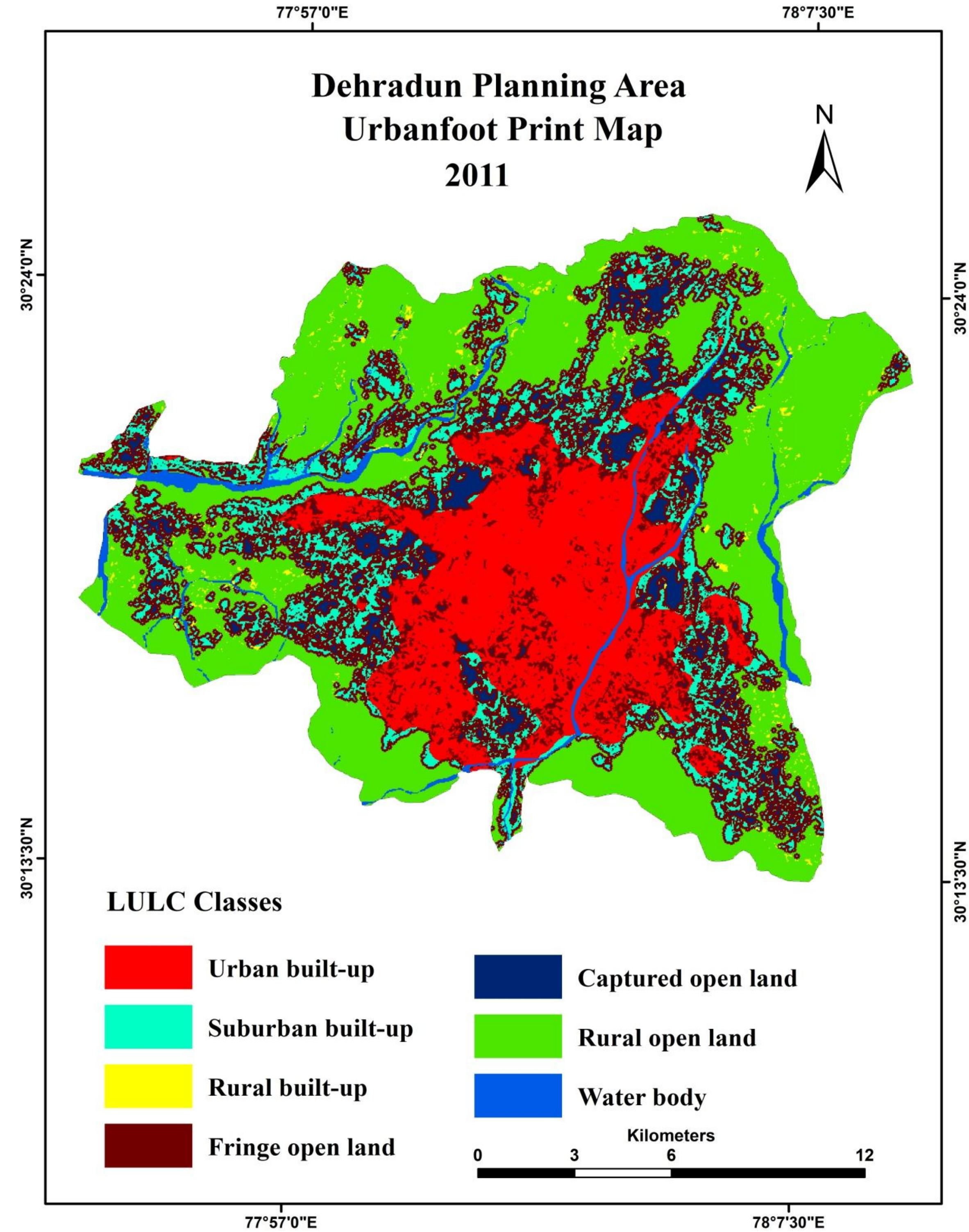


**Figure 7: Urban footprint classification (2011)**

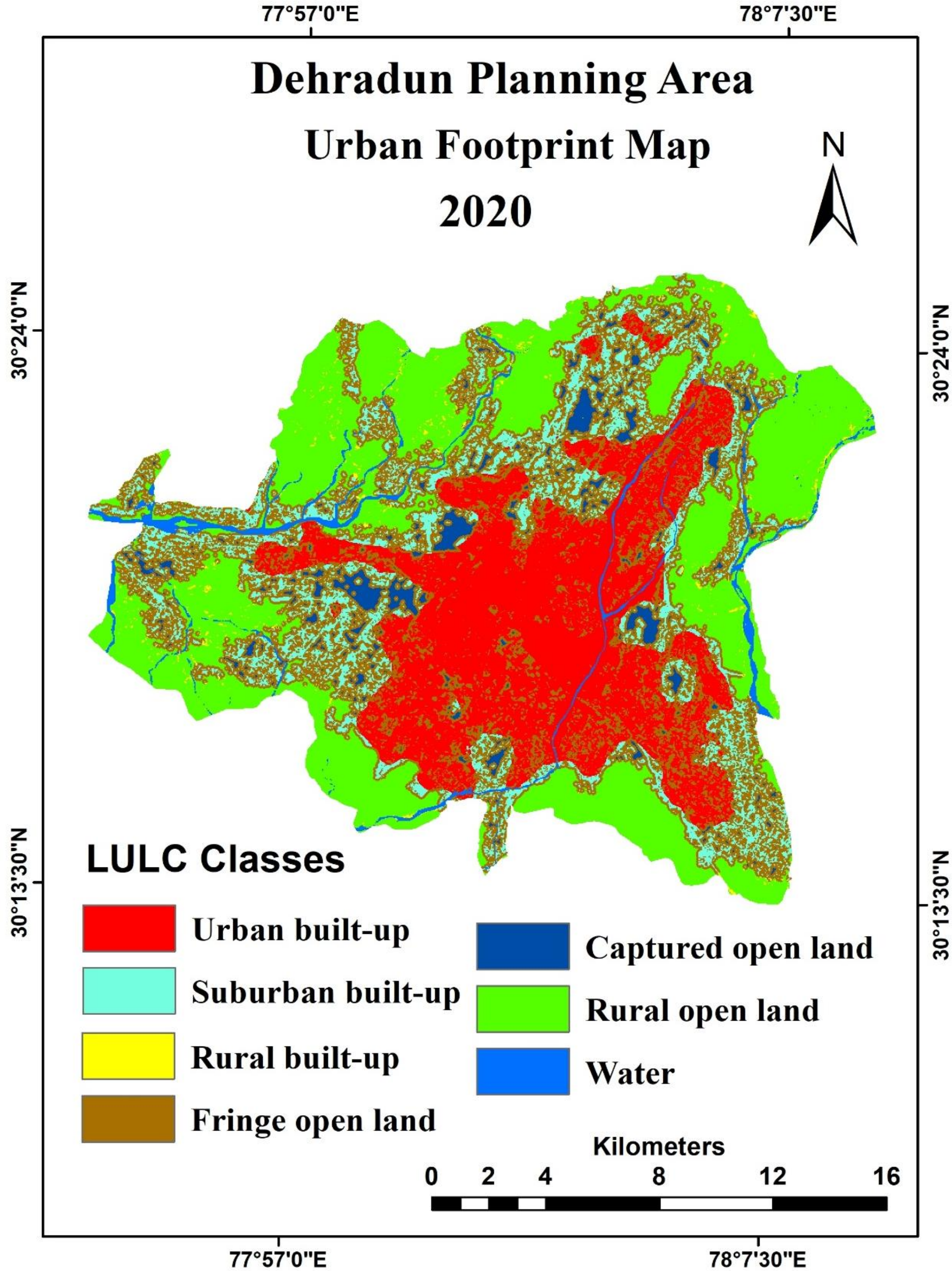


**Figure 8: Urban footprint classification (2020)**

### 4.4 Urbanized Area Analysis

For analyzing the urban area, seven distinctive classes have been considered same as urban footprint mapping. Seven classes taken for analysis or urban area have been taken (Figure 9, Figure 10 and Figure 11). It has been observed that class of high degradation susceptibility in urban areas is urbanized open land because they are present in between lands which are fully developed but they are themselves are undeveloped. The conversion rate of urbanized open land is constantly rising as classes are being converted into urbanized open lands from other categories. In 2020, total open urbanized is 2649.24 which 7.21 percent of total area which was only 1447.92 ha in 2001 covering only 3.93 per cent of total area (Table 4). It has been observed that paved surfaces in urban areas are increasing very rapidly as there is a constant decrease of rural open lands and water bodies, which indicates that there is high demand of living space in core area and peri urban areas as well. Thus, leading to constant decrease of other categories except built up, sub urban built up and urbanized open land which is increasing at constant pace with the passage of time.

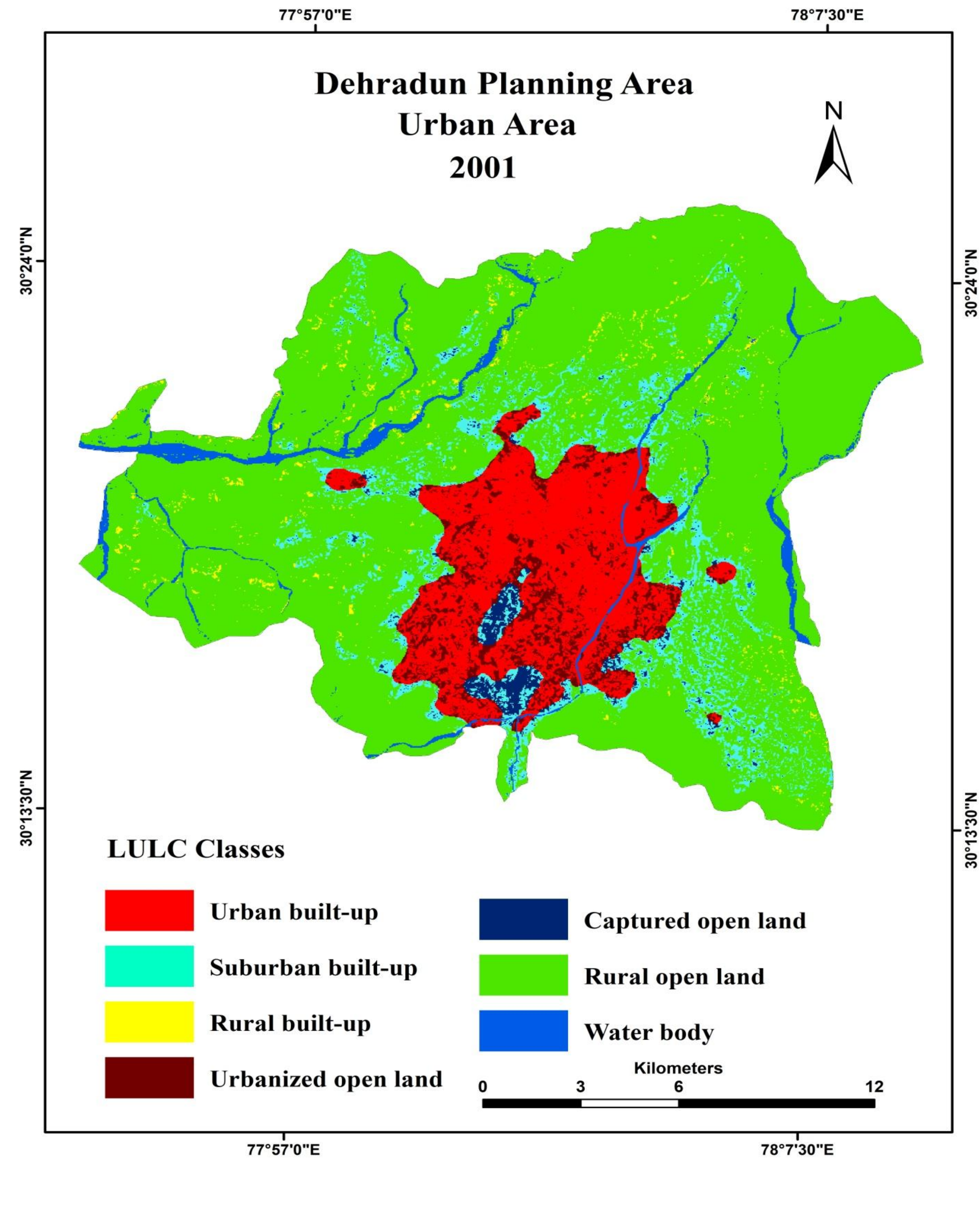


**Figure 9: Urban area (2001)**

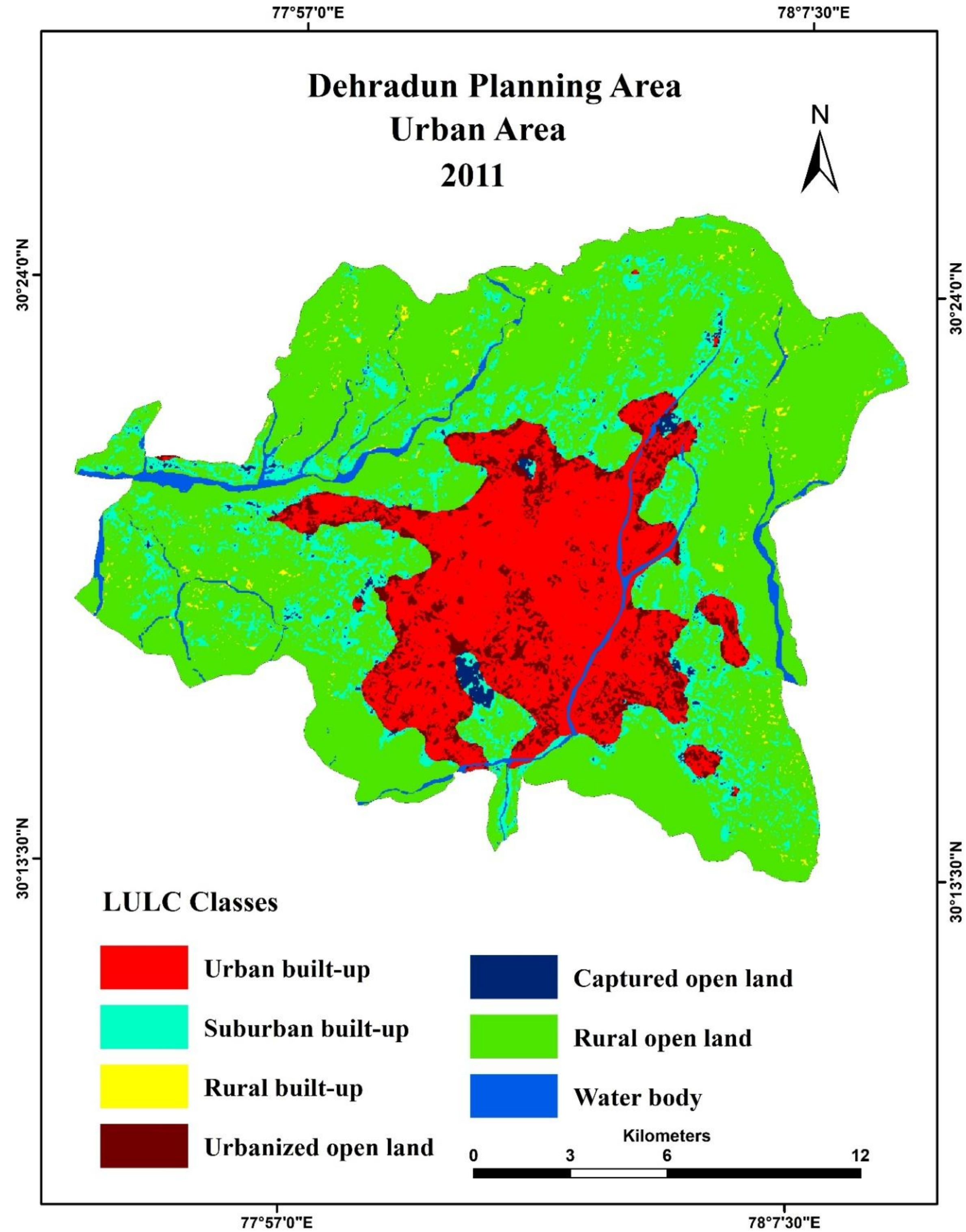


**Figure 10: Urban Area (2011)**

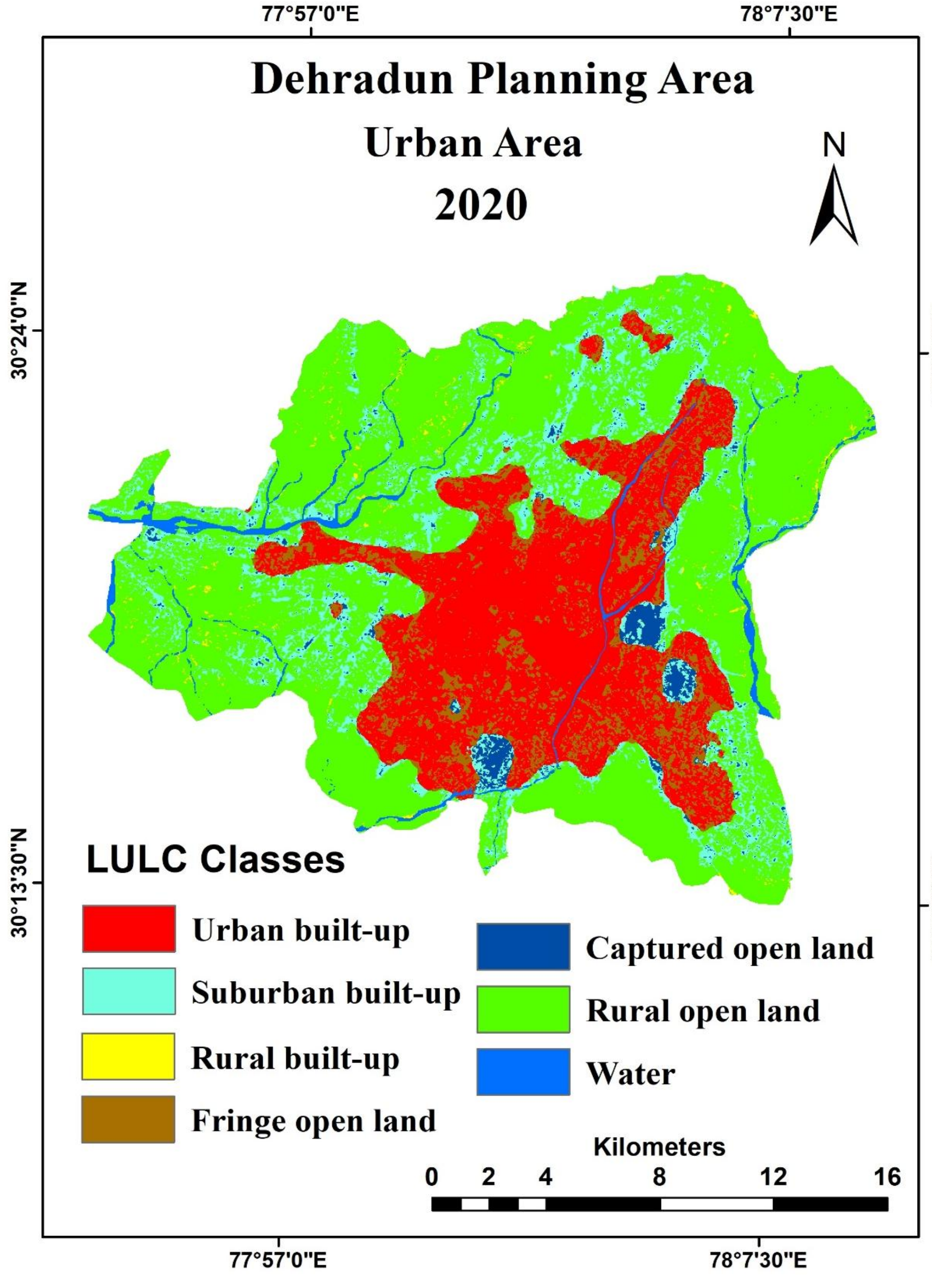


**Figure 11: Urban Area (2020)**

**4.5 New Development Area**

For analyzing the type of urban growth taking place in the city new development area statistics have been used. Whole analyzes have been performed with the help of three broad categories, namely, infill, extension and leapfrog. It has been observed that 20.67 per cent area constitutes of Infill, 68.99 area extensions and leap frog constitutes of only 12.93 per cent (Table 5). Areas developed in urbanized open lands covers a total area of 1247.06 ha which is considered as infill. Similarly, development taking place in peripheral regions and fringe areas covers a total of 4761.81 ha area, which is regarded as extension. Lastly, development taking place outside the rural open lands are considered as leap frog which contributes to a total area of 892.89 ha (Table 4). Infill growth has occurred mainly in the core area as well as areas surrounding core area of the Dehradun city such as Subhash Nagar, Ajabpur Kalan, Brahmanwala, Shakti Enclave, Shewala Kala, Chakrata Road, Kaulagarh and near Shahranpur Road (Figure 12). Similarly, extension growth has been observed mainly in North-east direction, South-east direction and also in West-direction of the city. Extension growth in west direction has been observed near Thakurpur, Ambala-Dehradun-Haridwar Road, Jhewaredi, and Jhajra. In North-east direction majority of extension have been observed, near Rajpur, Doon IT Park, Tarla Nangal and Canal Road, and in north direction also observe near Gopiwala and Purohit wala (Figure 12). Whereas, in South-east direction also, dense extension has been observed near Ranjhawala, Balawala, Nakraunda, Sainik Colony, Gullar Ghati Road, Nehrugram, Manav Vihar and Nathuawala. Leapfrog growth has been observed along with major road networks such as highways and bypass roads. Such type of growth has occurred along Shimla Bypass Road near East Hopetown, Purkul Road near Saloniwala, Mussoorie Road near Koluket village, Theva – Maldevta Road near Bajhet, Sahastradhara Road near Marautha, and NH 72 near Dhulkot Mafi (Figure 12).

**Table 5: Cumulative new developed areas in hectares**

| Category | Area (Hectares) | Percentage |
|---|---|---|
| **Infill** | 1247.06 | 20.67 |
| **Extension** | 4761.81 | 68.99 |
| **Leap frog** | 892.89 | 12.93 |
| **Total = 6901.76** | | |

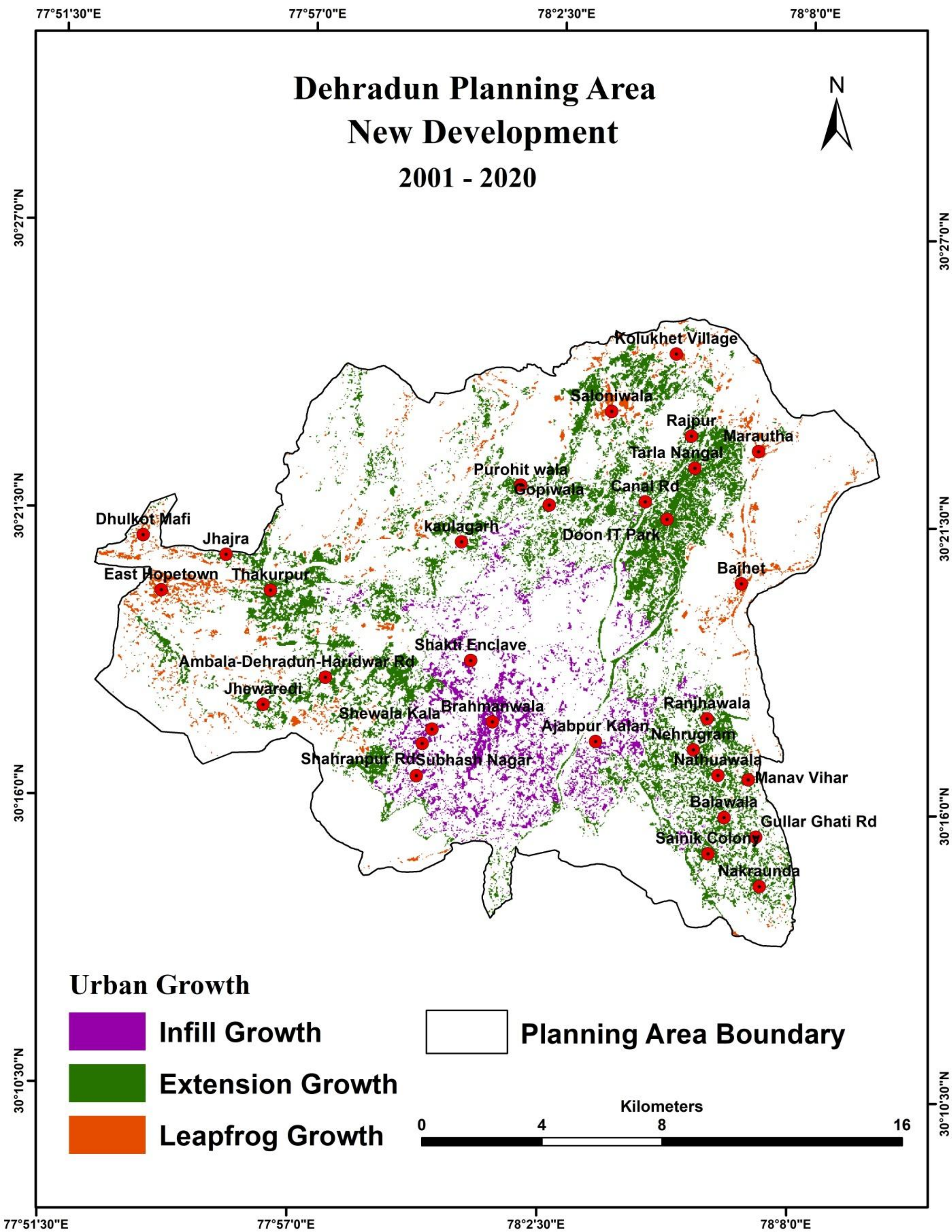


**Figure 12: New Development Areas (2001 – 2020)**

**4.6 Ribbon development across city suburbs**

Through analysis it has been observed that typical ribbon fashion development has been taking place in across Dehradun. Majority of the development has taken place along the road networks and national highway (Figure 13). A 500-meter proximity analysis (buffer) along the main road network has been generated to study the development pattern. Over three decades (2001 – 2020) eight major sites of ribbon development has taken place. Along four locations a large stretch of urbanized area has been observed (areas marked by circles in Figure 14). These four areas developed near Govind Vihar, Rajpur, Tarla Nangal and Chironwali in north – east direction, Thakurpur, Kehri goan and Panditwari in west, Rajpur and Balwala in south – east and Brahmanwala in center.

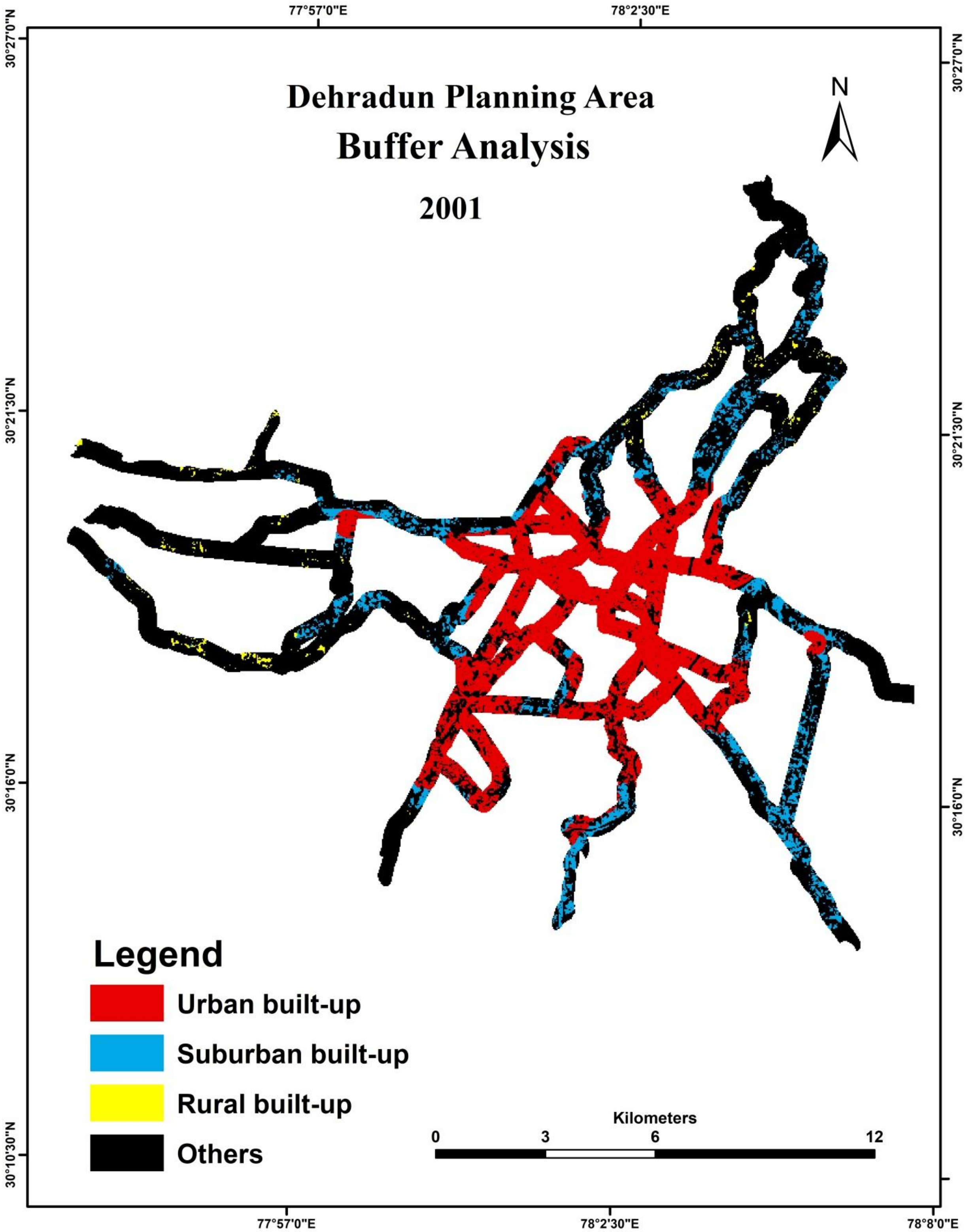


**Figure 13: Buffer Analysis for Ribbon Development (2001)**

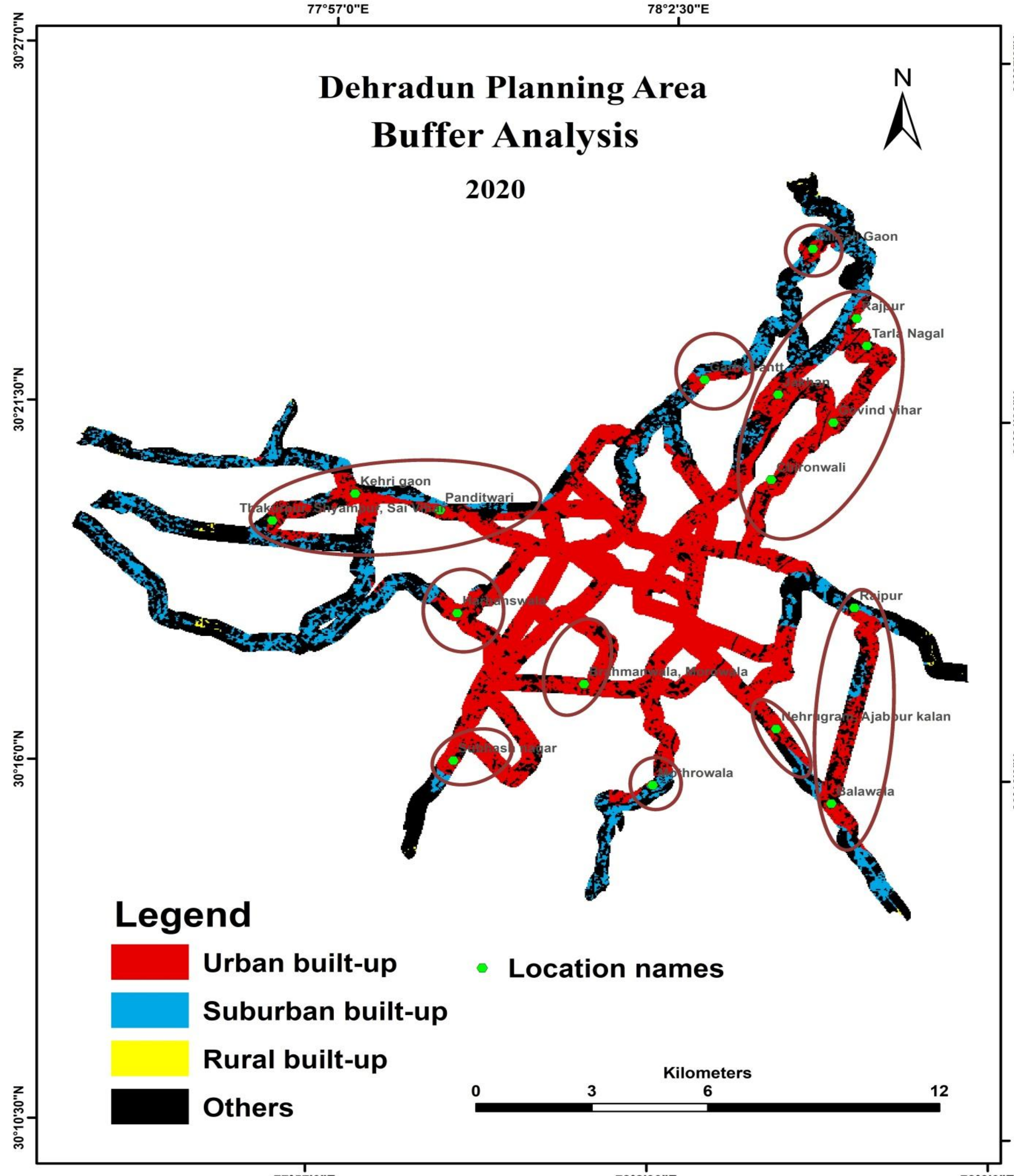


**Figure 14: Buffer Analysis for Ribbon Development (2020)**

## Conclusion

Dehradun became the capital of the recently formed state of Uttrakhand in the year 2000. This led to large scale urbanization and industrialization in the area. Its proximity to the national capital has further accelerated the pace of development and made it the as one the counter magnets in the National Capital Region. The Urban Land Analysis Tool (ULAT) demonstrated that the built-up area has increased from 7069.80 ha in 2001 to 11076.01 ha 2011 and further increase to 12670.30 ha in 2020. In the following analyses or urban area, it has been found that Dehradun has been three types of urban sprawl, namely, infill, extension and leap frog. Newly developed areas constitute 20.67 per cent area of Infill, 68.99 area extensions and leap frog constitutes of only 12.93 per cent. Areas developed in urbanized open lands covers a total area of 1247.06 ha which is considered as infill. Similarly, development taking place in peripheral regions and fringe areas covers a total of 4761.81 ha area, which is regarded as extension. Lastly, development taking place outside the rural open lands are considered as leap frog which contributes to a total area of 892.89 ha. Also, over three decades (2001 – 2020) eight major sites of ribbon development has taken place. Therefore, the following study facilities in understanding different types of urbanization pattern in Dehradun and reflects the importance of urban growth monitoring within the city Studying patterns of urban development facilitates in planning process of urban areas and formulating sustainable plans for city development.

**Disclosure of potential conflict of interests**: The author declare that they have no conflict of interest.

**Data availability statement:** Data will be provided on the reasonable request.

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