GEOGRAPHICAL ANALYSIS

RESEARCH ARTICLE

Analysis of the Spatial Patterns of Urban Growth in Rudrapur City

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OPEN ACCESS

Received: 11.08.2023

Accepted: 21.09.2023

Published: 15.10.2023

Citation: Begum A, Tiwari PC, Maithani S. (2023). Analysis of the Spatial Patterns of Urban Growth in Rudrapur City. Geographical Analysis. 12(2): 1-6. https://doi.org/10.53989/bu.ga.v12i2.23.4

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Funding: None

Competing Interests: None

Published By Bangalore University, Bengaluru, Karnataka

ISSN
Print: 2319-5371
Electronic: XXXX-XXXX

Abstract

Incessant urban growth has drastically transformed the urban landscapes. This has necessitated understanding of the spatial and temporal patterns of urban growth. Hence, the current research attempts to study and analyze the spatio-temporal patterns of urban growth using Urban Landscape Analysis Tool (ULAT) in the city of Rudrapur, Uttarakhand. In this study, land cover maps having three classes of urban, water-bodies and others are used to extract the degree of urbanization in the study area for the period 2009-2019. Subsequently, the Urbanized Area (UA), Urban Footprint (UF) and New Development (ND) maps are the resultant outputs generated. The urbanized area (UA) determined three levels of spatial density in the built-up area, namely, built-up area, the urbanized open land, and the captured open land. Similarly the urban footprint (UF) also discerns the built-up area, the fringe open land, and the captured open. New development map had the following three classes, infill (newly developed pixels that are in the urbanized open); extension (newly developed pixels that are in the fringe open land of the previous time period); and leapfrog (newly developed pixels that are outside of the rural open land of the previous time period). The sub classes of the built-up area give insights to the changing morphology of the city with time. The findings of the study suggest that the pattern transformation in the city of Rudrapur is taking place towards the north, north-western and south-eastern directions. Hence, this study enables in understanding and analyzing the urban expansion and its patterns; and eventually the identification of the priority areas for better planning and management of the city for sustainable urbanism.

Keywords: Urban Growth; Urban Landscape Analysis Tool; Spatial density

Introduction

Urban growth is the dynamic process of converting land cover to built-up areas. The city expansion is the resultant implications of technological, socio-economic and political forces to the land. The city expansion accelerates the pressure on the resources and forces the city limits towards the periphery, causing intensified haphazard urban development and poor quality of life. The uncontrolled expansion makes alterations (namely, conversion of non- built-up to built-up)to the land use patterns, resulting in fragmentation of urban morphological structure and exerting major influences on the urban system, as a whole[(1)].

Rudrapur, the Himalayan city, has undergone through the process of tremendous urban growth. Accelerated population growth, upgraded road infrastructure, tourism etc have remarkably contributed to the development of the city. It can be noted that, expeditious and persistent urban growth is accountable for dramatic landscape transformation at varied scales in the city. As a matter of fact, these alterations have increased the fragility and vulnerability of the city urban system.

The process of urban growth is unstoppable but can be directed with the utilization of scientific knowledge and integrated land use planning and interventions of geospatial technologies. Geospatial technologies facilitate feature extraction [2], monitoring, analysis of patterns, sprawl quantification etc. In fact, Remote Sensing and Geographic Information System (GIS) integration have extensively aided the challenge in investigating the complex and dynamic urban systems. Spatial metrics [3]; an approach that fosters the quantification of spatial element in urban structure. Similarly, density is a significant dimension of urban expansion [4]. Thereupon, this research paper pertains to comprehend, quantify and analyze the dynamics of urban growth patterns of Rudrapur, with the application of the geospatial technology and Urban Landscape Analysis tool (ULAT) period 2005-2018 for sustainable development.

Study Area

Rudrapur is one of the fastest growing cities and second most populous city of Kumaun region, Uttarakhand and is located at the foothills of Himalayan mountain range. Rudrapur is considered as a significant commercial centre of Udham Singh Nagar district of Uttarakhand, due to the development of The State Infrastructure and Industrial Development Corporation of Uttarakhand Limited (SIIDCUL).

Additionally, the population of the study area has tremendously increased from 88,815 (2001) to 1,54,554 in 2011 [5]. The high growth rate in the city can be attributed to the development of SIIDCUL and as a consequence, the exodus of population from the hills in search of jobs and better quality of life. This growth rate has forced to city expansion towards the periphery and inclusion of rural areas into the city limits. Rudrapur has included 11 rural areas into its municipality and doubled its ward boundaries from 20 to 40 wards in the year 2018. This fact forms the rationale in undertaking this research work in this city.

Materials and Methods

Data

This study incorporates multi-spectral satellite imageries- LISS IV and Sentinel II imageries were acquired from National Remote Sensing Centre (NRSC) and European Space Agency (ESA) respectively. The LISS IV data has a spatial resolution of 5.8m operating in three spectral bands B2 (Green), B3 (Red) and B4 (NIR). Sentinel 2 imagery has 10m spatial resolution with 4 spectral bands- B2, B3, B4 and B8. The datasets used in this study was for the time period of 2009-2018.

Urban Landscape Analysis Tool (ULAT)

Urban Landscape Analysis Tool (ULAT) was applied to enumerate the dynamics of land transformation pattern in the study area. This tool has been developed by Center for Land Use Education and Research (CLEAR), University of Connecticut. The tool is contemplated in identification and classification the developed areas (on the basis of the varying densities) and the underdeveloped areas (that are susceptible to degradation). Urban Footprint (UF), Urbanized Area (UA) and New Development lands are the results drawn from the application of this tool. This tool definitely, is significant in the study of urban growth and ; thereupon; it is quite relevant to this research work.

LULC Characterization

Land Use Land Cover (LULC) map of an area furnishes with the information on the existing land features. This map helps in efficient and optimal utilization and management of land resources and eventually guide in future prospects of development. LULC classification is the pre-requisite in geospatial analysis and it deals with the assignment of pixels into features and then to particular class of LULC.

In this research work, the remotely sensed images LISS IV and Sentinel II were classified using supervised algorithm of Maximum Likelihood Classification (MLC) with broad major classes of Built-up, Water and Others in a GIS platform for the years 2009, 2013 and 2018. The planning boundary was extracted from the Master Plans 2031. The LULC maps individually were generated with the overall classification accuracy rate of 89%, 91% and 90% for the imageries of 2009, 2013 and 2018 respectively. The kappa statistics drawn from the maps obtained were 0.87 (2009), 0.85 (2013) and 0.89 (2018). The results of the classification algorithm were distinctly justified by the above given accuracy statistics.

Delineation of Urban Footprint and Urbanized Areas

Urban Footprint and Urbanized Area determines the built-areas having three major levels of spatial densities. This tool is based on the two fundamental parameters namely, urbanness and edge-disturbance zone [6]. Urbanness is the percentage of developed pixels in a circular neighbourhood with a radius of 564 metres (covering an area of 1 sq km) (Figure 2). The edge-disturbance zone is the decay-prone area on the edge of the developed lands.

Urban Footprint is broadly classified into three classes namely, built- up, fringe open and captured open lands (Table 1). On the other hand, the urbanized area incorporates the built-up area, the urbanized open and the captured open areas (Figure 1). It has been found that built-up areas with low spatial densities engulf open areas more than those with greater densities. The region of edge disturbance includes the fringe open land. Since the seized open land is cut off from other open places, it is most affected by degradation.

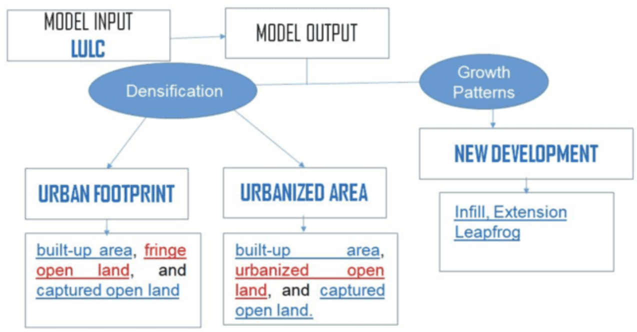

Fig. 1. Methodology flowchart of the model

Conversely, Urbanised open terrain predominates in densely populated areas and is probably quite vulnerable to development (Table 2). Due to their isolation from the neighbouring developed regions, the captured open is vulnerable to urban deterioration. Both the urbanised area and the urban footprint have seven classifications, with the exception of the urbanised open area in the urbanised area replacing the fringe open land in the urban footprint.

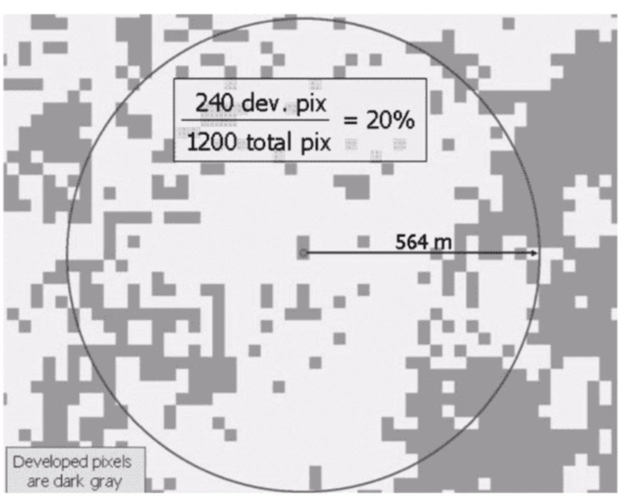

Fig. 2. ULAT Parameter, Source: CLEAR, UCONN

Identification of New Development Areas

New development areas manifest the dynamics of built-up pixels in the study area between two time periods. These areas are those that had undergone transformation from non- built-up to built-up areas between the earlier and the later stages. New developed areas definitely, reflect the urban expansion in the city. Broadly, they are classified into three classes, namely Infill, Extension and Leapfrog (Table 3).

Results and Discussion

Land Cover Characterization

The land use land cover (LULC) map statistics designates that the urban expansion has doubled its growth during 2009-2018 period in the city of Rudrapur (Figure 3). The urban (built-up) area was 20.23 square kilometres in 2009, which has grown into 27.81 square kilometres in 2013 and finally rose to 38.34 square kilometres in the year 2018. On the contrary, the other class (incorporating the vegetation, agricultural lands, fallow lands etc.) exhibits a decreasing trend. In 2009, the other class had an area of 80.5 square kilometres (sq kms), which dropped to 72.89 square kilometres in 2013 and further into 62.20 square kilometres in 2018 (Figure 3).

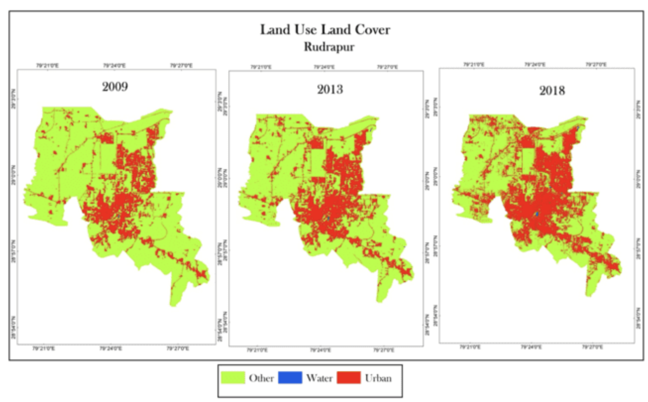

Fig. 3. Land Use Land Cover Maps

Further, it has been observed in the table (Table 4) that the class water had escalated from 0.02 square kilometres (2009) to 0.06 square kilometres (2013) and then 0.22 square kilometres (2018). The water category remained more likely stable due to the seasonal differences of the satellite imageries acquired for this research work.

Assessment of Urban Footprint

Urban Footprint is the amount of built-up corresponding to the reduction of other classes of land use land cover (LULC). The Urban Footprint furnished with seven major classes, namely, Urban Built-up, Sub-Urban Built-up, Rural Built-up, Fringe Open Land, Captured Open Land, Rural Open Land

Table 1. Urban Footprint Classification

Class	Criteria
Urban Built-up	Built-up pixels with urbanness>50%
Suburban Built-up	Built-up pixels with urbanness 10-50%
Rural Built-up	Built-up pixels with urbanness <10%
Fringe Open	Undeveloped pixels within 100 meters of developed pixels
Captured Open	Patches of undeveloped pixels (<200 hectares), that are completely surrounded by the urban built-up, suburban built-up, and fringe open land pixels
Rural open	Undeveloped pixels not classified as fringe or captured open land
Water	

Table 2. Urbanized Area Classification

Class	Criteria
Urban Built-up	Built-up pixels with urbanness > 50%
Suburban Built-up	Built-up pixels with urbanness 10 - 50%
Rural Built-up	Built-up pixels with urbanness < 10%
Urbanized Open	Undeveloped land with urbanness > 50%
Captured Open	Patches of undeveloped pixels (< 200 hectares), that are completely surrounded by the urban built-up, suburban built-up, and urbanized open land pixels
Rural open	Undeveloped pixels not classified as urbanized open or captured open lands
Water	

Table 3. New Development Classification Parameters

Class	Criteria
Infill	Newly developed pixels that are in the urbanized open land of the previous time period.
Extension	Newly developed pixels that are in the fringe open land of the previous time period.
Leapfrog	Newly developed pixels that are outside of the rural open land of the previous time period.

Table 4. Land Use Land Cover Classes

Classes	2009	2013	2018
Other	80.50	72.89	62.20
Water	0.02	0.06	0.22
Urban	20.23	27.81	38.34

and Water (Figure 4).

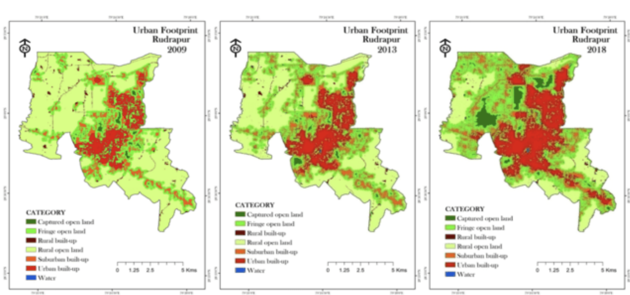

Fig. 4. Urban Footprint Maps

The area of the urban built-up class for the study area has increased from 9.99 square kilometres in 2009, to 15.36 square kilometres in 2013 and finally rose to 25.02 square kilometres in the year 2018. Likewise, the sub-urban built-up land has grown from 8.65 square kilometres (2009) to 11.17 square kilometres (2013) and 12.11 square kilometres (2018). Correspondingly, Fringe open land had grown from 20.55 square kilometres to 25.78 square kilometres to 33.27 square kilometres during 2009-2018 time periods.

Unlikely, the rural built-up and rural open land classes had a declining trend over the years. The Rural built-up had decreased from 1.53 square kilometres (2009) to 1.25 square kilometres (2013) to 0.65 square kilometres (2018). The Rural open land had a sharp drop from 58.75 square kilometres in 2009 to 45.68 square kilometres in 2013 and 25.46 square kilometres in 2018. Although, the Capture open land had a increment from 1.26 square kilometres to 3.89

square kilometres during the same period.

Urbanized Area Analysis

The Urbanized Area yielded with the major classes of Urban Built-up, Sub-Urban Built-up, Rural Built-up, Urbanized Open land, Captured Open land, Rural Open land and Water. It can be observed from the Figure 5 that the Urban built-up, Sub-urban built-up, Urbanized open land and Captured open land classes had an increasing trend during 2009- 2018.

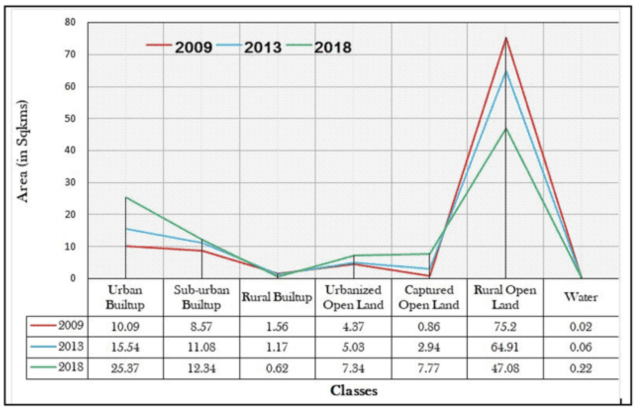

Fig. 5. Urban Area Analysis

The urban built-up had grown from 10.09 square kilometres to 15.54 square kilometres and finally to 25.37 square kilometres in 2009, 2013 and 2018 respectively. Similarly, the sub-urban built-up had grown from 8.57 square kilometres to 12.34 square kilometres during 2009-2018. Contrary to this, the rural built-up and rural open land had decreased during this time period. In fact, the rural open land had a sharp decline in its area from 75.2 square kilometres to 47.08 square kilometres. The urbanized open land had also increased from 4.37 square kilometres to 7.34 square kilometres during this period. Due to seasonal differences, the water class remained almost stable during this time period.

New Development

The New Development output of the tool is indicative of the categories of the urban growth process, namely, Infill, Extension and Leapfrog (Figure 6). Infill areas are those areas that have newly developed areas from the urbanized open land. Similarly, the extension and leapfrog are new developed areas in the recent period once which were fringe open land and rural open lands in the previous years.

It is quite visible from the Figure 6 that the extension process had a major subjugation over the infilling and leapfrog development processes in the study area. Apparently, the Extension process had over-powerd the other processes due to the establishment of the State Infrastructure and Industrial Development Corporation of Uttarakhand Limited

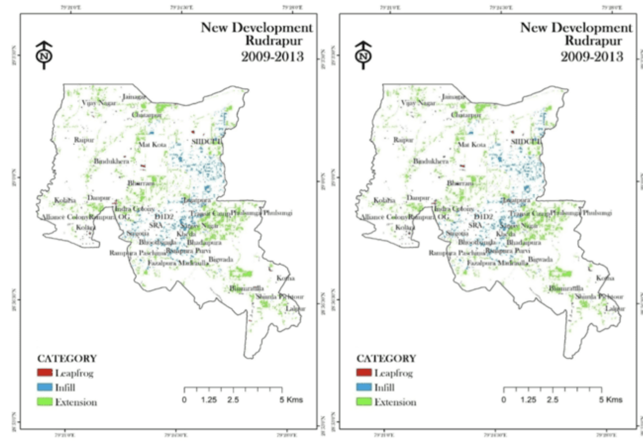

Fig. 6. New Development Maps

(SIIDCUL).

It can also be referred (from the Figure 6) that the municipal area (core) of the Rudrapur city is predominant with the infilling process of urban growth. Infill is more or less concentrated in the Jagatpura and the surrounding central part of the city. While the areas developed due to the extension process had emanated towards north-west, west and south-east directions of the city. Simultaneously, the areas developed through Leapfrog process is apparent in discontinued and found in patches at the outskirts of the city. Areas namely, Raipur, Bindukhera and Bigwada has grown due to leapfrog development, is found to be of dispersed pattern of urban growth in the city.

Table 5. New Development statistics

Class	2009-2013	2013-2018
Leapfrog	0.35	1.16
Infill	1.89	3.17
Extension	5.32	6.54

The Table 5 shows the area that had newly developed due to extension is maximum, i.e 5.32 square kilometres during 2009-2013, which eventually rose to 6.54 square kilometres during 2013-2018.

The share of area under Infilling process had increased from 1.89 square kilometres to 3.17 square kilometres during 2009-2013 and 2013-2018 respectively. Similarly, the areas developed through leapfrog development process had also rose from mere 0.35 square kilometres to 1.16 square kilometres during the same period.

It is quite evident in the Figure 7 that urban growth had taken place maximum within 100 meters buffer from the highways and the roads and this expansion is due to the extension process. Followed by the urban expansion within the buffer of 200 meters and then 300 meters from the roads of the city. Descending away from the highways and the roads, primarily buffers of 200 meters and 300 meters; infilling and leap frog development processes are prominent in the development of new areas in the city during 2009-2018.

As a matter of fact, urban growth has grown immensely around the major highways and roads namely, National Highway 9, National Highway 109 and National Highway 309, which are the life-lines of the city (Figure 7), connecting through the national capital (Delhi) to state capital (Dehradun) and parts of Uttar Pradesh like Saharanpur, Bareilly and different locations of Uttarakhand state.

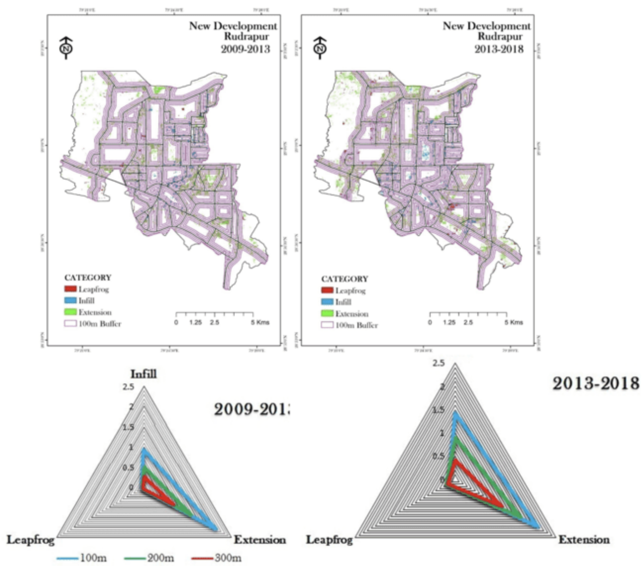

Fig. 7. Ribbon Development

Conclusion

This research work endeavours to make a study in understanding the patterns of the morphological structure and the dynamics of urban growth in the study area. This study incorporates multi-spectral temporal satellite images for the years 2009, 2013 and 2018 for LULC maps generation for the study area in comprehending and assessing the spatial extent of urban growth in the city.

Consequently, ascertaining the spatial expansion in varying densities was the primary aim of this research. The Urban Footprint and the Urbanized Area analysis were the resultant outputs of the study. These maps were further classified into sub-categories on the basis of different levels of densities. New development map is the key result of the tool (ULAT), which furnishes three major patterns of development processes namely, Infilling, Extension and Leap-frog development. These categories and sub-categories of spatial patterns of expansion vividly, aids in identification, detection, demarcation of urban growth process in the city. Usage of this tool in a GIS domain definitely helps in understanding the urban growth in the city. Hence, this study is widely applicable in the urban planning and studies in comprehending urban growth.

The results of this work should certainly, provide the inception information in better comprehension of the existing status of urban morphology and growth, which further stimulate the land use planning and development approaches affirming sustainable development in the study area, using geospatial technology. This research, undoubtedly demonstrates the urban expansion in the city and this will eventually enables the administrators and the policy makers in better and efficient planning of the city.

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