Spatio-Temporal Analysis of Urban Growthin Aizawl City, Mizoram

Abstract

Urban growth and land use land cover changes have been increasing recently due to growing population and infrastructure development. The present study examined the urban growth in Aizawl city during 1991 to 2021 using remote sensing and GIS. Land use land cover of Aizawl city has been examined using with supervised classification and acquired data has been utilized to analyse urban growth within the study area. The study reveals that land use and land cover of Aizawl city has been changing rapidly due to urban growth. The declining forest cover and barren land with increasing urban land and agricultural land clearly defines transformation of land use classes due to urbanization. The results highlight a clear expansion and directional trend of urban area indicating considerate changes in the distribution of urban growth. This research contributes to a deeper understanding of the relationship between land use land cover and urban growth providing a foundation for future studies and practical applications in monitoring and planning sustainable city.

Keywords: Urban growth, Land use land cover, Aizawl city, Remote Sensing and GIS.

Introduction

Urbanization has become a main issue all over the world, transforming natural land into man-made surfaces.Despite the fact that urban regions occupy merely 3% of the earth's surface, the unrestrained urbanization which results from increasing population leads to ecological and socio-economic challenges within urban areas (Liu and Lathrop 2002). Urban growth became the determining factor of changes in population, socio-economic and environment in the past few years (Kafy et.al., 2021). In emerging countries like India, urban growth is swelling in an unplanned and haphazard manner, which can be considered as one of the main characteristics of urbanization (Krishna-Hensel, 1999). The growth of urbanization will continue in the future as far as the urban areas in developing countries keeps on increasing.

Urban development marksconversion of land from open fields and green spaces to built-up areas to satisfy desires of urban habitants (Liong et.al.,2021). Due to rapid urbanization, vegetation, forest land, marshlands, water bodies, and open spaces undergo rapid change (Ding & Shi, 2013). This has been considered as the main cause of land cover changes as a result of

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transformation of vegetation cover into built-up areas and various others land use, along with the increase in population and related economic venture (Weng, 2001). Thus, urbanization is an important determining factor of change in land use land cover, as it is transformed into built-up areas, it has diminished vegetation cover of an area (Kafy et.al., 2021). The change of land features from one class to another has a significant impact on the local and regional environment (Rousta et.al., 2018).Increase in size and quantity of urban clusters determines the relative significance of urban environment throughout the world (Yue et.al., 2005). As people choose to settle in urban areas, this rapid urbanization poses significant challenges to the urban environment, resulting in a risk to the environmental sustainability (Li et.al., 2010).

Aizawl city,the most densely populated and economic hub of the state has experienced substantial urbanization over the last thirty years, which has led to considerable expansion both horizontally and vertically. The city's growth has been expanding significantly over the last few decades in an unplanned and haphazard manner. This rampant urbanization poses a serious threat every year to several key issues including environmental degradation, traffic congestion and unplanned development. Not only this, the city has also lost its green space, leading to depletion of vegetation within the city and the surrounding areas, which has posed adverse effect on environmental quality. Thus, due to environmental deterioration, the city has been experiencing several landslides every year, claiming lives of numerous people.

The advancement of remote sensing and Geographic Information System (GIS) has enabled spatial scientists to investigate urban growthanalysis from spatial-temporal perspectives. Satellite images obtained from the Landsat series are used to observe changes in land use land cover as well as urbangrowth. The main objective ofthe study is to assess the land use land cover changes in the study area, and how these changes determine the urban growth. The study also focuses on the analysis of urban growth during the last three decades. A comprehensive study on the land use land cover change on urban growth is important for experts and planners to mitigate land use land cover change and contribute to sustainable urban planning. As urban population continues to increase, examining spatio-temporal changes in urban or outlying areas will become increasingly important (Small, 2001). Giving the continuously rising in both population and size, more reflection in the approach of sustainable approaches to urban and peripheral land development will become gradually more significant (Vitousek et.al., 1997).

Materials and Methods

Study area

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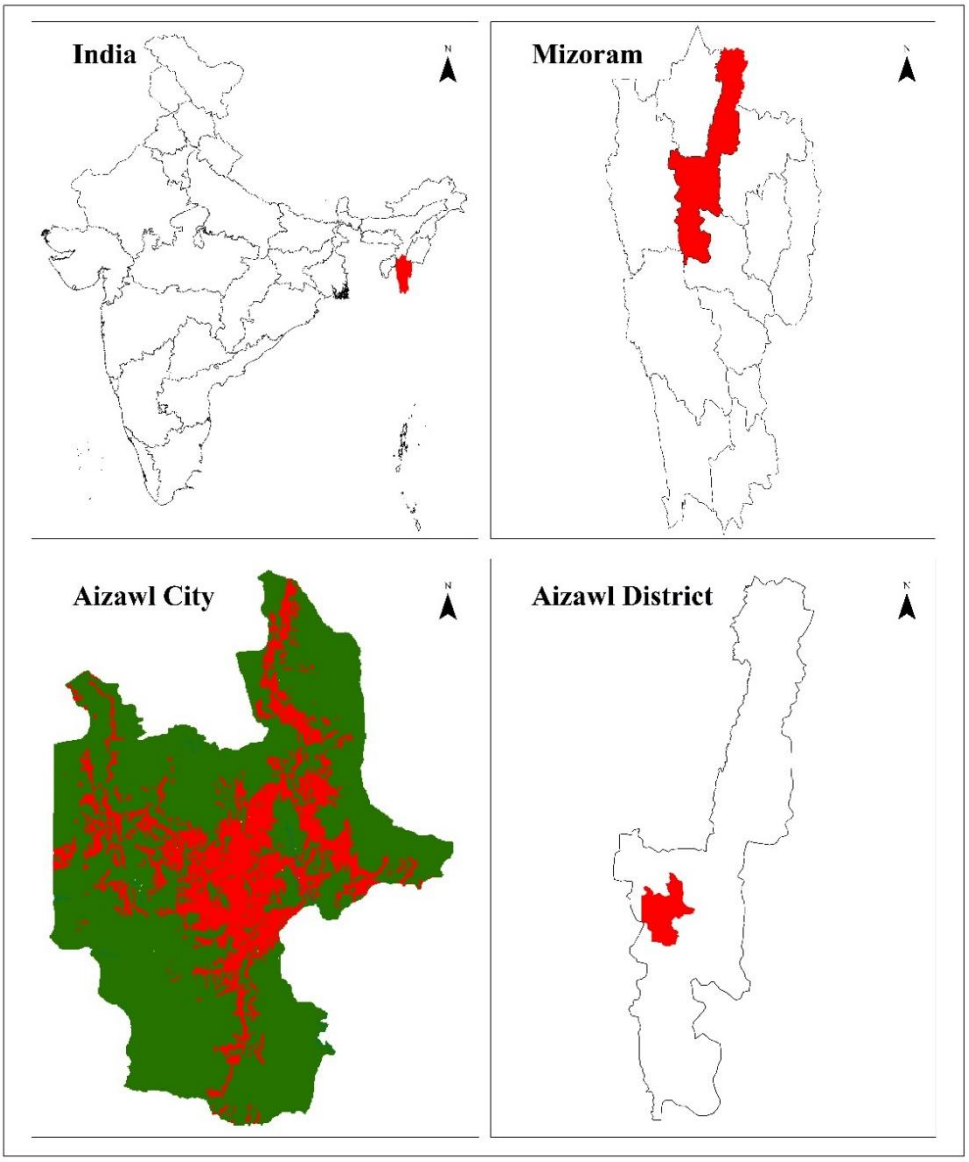
Aizawl city is the capital of Mizoram locating in the north-eastern part of India. The study area is administered by Aizawl Municipal Council (AMC). The geographical location of the study lies between 92°36´46´´E to 92°46´53´´E longitude and 23°39´46´´N to 23°48´46´´N latitude in the northern part of the statecovering an area of about 102.25 sq. km. The topography of Aizawl city is generally undulant with broken hilly ranges with steep slopes. According to 2011 census, the population of Aizawl is 2,93,416 persons which comprises 26.89 per cent of the total population of Mizoram and the density is 113 persons per sq.km which is highest among the states of Mizoram. The location map of the study area is shown in Figure 1.

Figure 1 Location map of study area

Data Source



The study uses Landsat-5 TM and Landsat-8 OLI/TIRS satellite imageries for the year 1991, 2001, 2011 and 2021 with cloud cover less than 10 % which were downloaded from the United States Geological Survey (USGS) Earth Explorer (https://earthexplorer.usgs.gov/). The satellite imageries which have been used in the present study and the date of acquisition is highlighted in Table 1. The study area map was downloaded from open source, digitized and georeferenced using ArcMap10.3. The data were analysed and processed using GIS software such as Erdas Imagine 9.1, ArcGIS 10.3 and QGIS 3.42. The acquired data have been used to analyse the urban growth in the study area.

Table 1 Data used in this study

Satellite Imagery	Date of Acquisition	Path	Row
Landsat 5 TM	19 - 11 - 1991	136	44
Landsat 5 TM	19 - 11 - 1991	136	44
Landsat 5 TM	30 - 01 - 2001	136	44
Landsat 5 TM	30 - 01 - 2001	136	44
Landsat 5 TM	10 - 11 - 2011	136	44
Landsat 5 TM	10 - 11 - 2011	136	44
Landsat 8 OLI	05 - 01 - 2021	136	44
Landsat 8 OLI	05 - 01 - 2021	136	44

Methodology

Land Use Land Cover Classification

Land use land cover classification was done to measure the changes of LULC and urban growth of the study area. The satellite imageries for the year 1991, 2001, 2011 and 2021 were classified using Erdas Imagine 9.1 software by supervised classification algorithm. The imageries have been classified into five LU/LC classes of forest, urban land, barren land, agricultural land and waterbodies. The changes of LU/LC for each class have shown in Table 2.

Urban growth analysis

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To analyse the urban growth of Aizawl city during 1991 to 2021 the study utilized the land use land cover map of the study area. The observed data has been further classified into urban and non-urban area where urban area denotes the area covered by urban land while non-urban area represents the area other than urban land comprising of non-urban area such as forest, barren land, agricultural and waterbodies. The observed urban growth map has been divided into four zones of north-west, north-east, south-east and south-west to analyse the spatio-and temporal urban growth of the study area.

Results

LULC changes in Aizawl during 1991 to 2001

Land use land cover changes in Aizawl city during 1991 to 2021 show significant transformation due to urban growth (Figure 2). Table 2 highlights the changes in LULC between 1991 and 2021. Forest area reduced from 73 km² in 1991 to 62.81 km² in 2021 indicating a steady and significant reduction. Urban land has increased from in 1991 to in 2021 which signifies rapid urbanization during this period. The year between 2011 to 2021 demonstrates the most accelerated urban growth with an increase of 8.11 km² during the study period. The area occupied by barren land fluctuates between 1991 and 2021 expanding significantly from 2.75 Km^2 in 1991 to 6.24 Km^2 in2001, however, it reduced from 2001 to 2011 with a decrease of 3.44 km², where open areas were transformed into urban land or agricultural land. Between 1991 and 2021 the area covered by agricultural land experienced consistent growth from 1.44 km² in 1991 to 5.18 km² in 2021. Waterbodies decline continuously from 1991 to 2021 with a total loss of 0.42 km².

Table 2 LULC Change during 1991 to 2021

	Area (Km^2)				**Changes in area (Km^2)**		
	1991	**2001**	**2011**	**2021**	**1991-2001**	**2001-2011**	**2011-2021**
Forest	82.73	77.19	71.13	62.81	-5.54	-6.06	-8.32
Urban land	15.10	16.56	23.41	31.52	1.46	6.85	8.11
Barren land	2.75	6.24	2.80	2.93	3.49	-3.44	0.13
Agricultural land	1.44	2.14	4.90	5.18	0.7	2.76	0.28
Water bodies	0.49	0.39	0.28	0.07	-0.1	-0.11	-0.21
	102.52	102.52	102.52	102.52			

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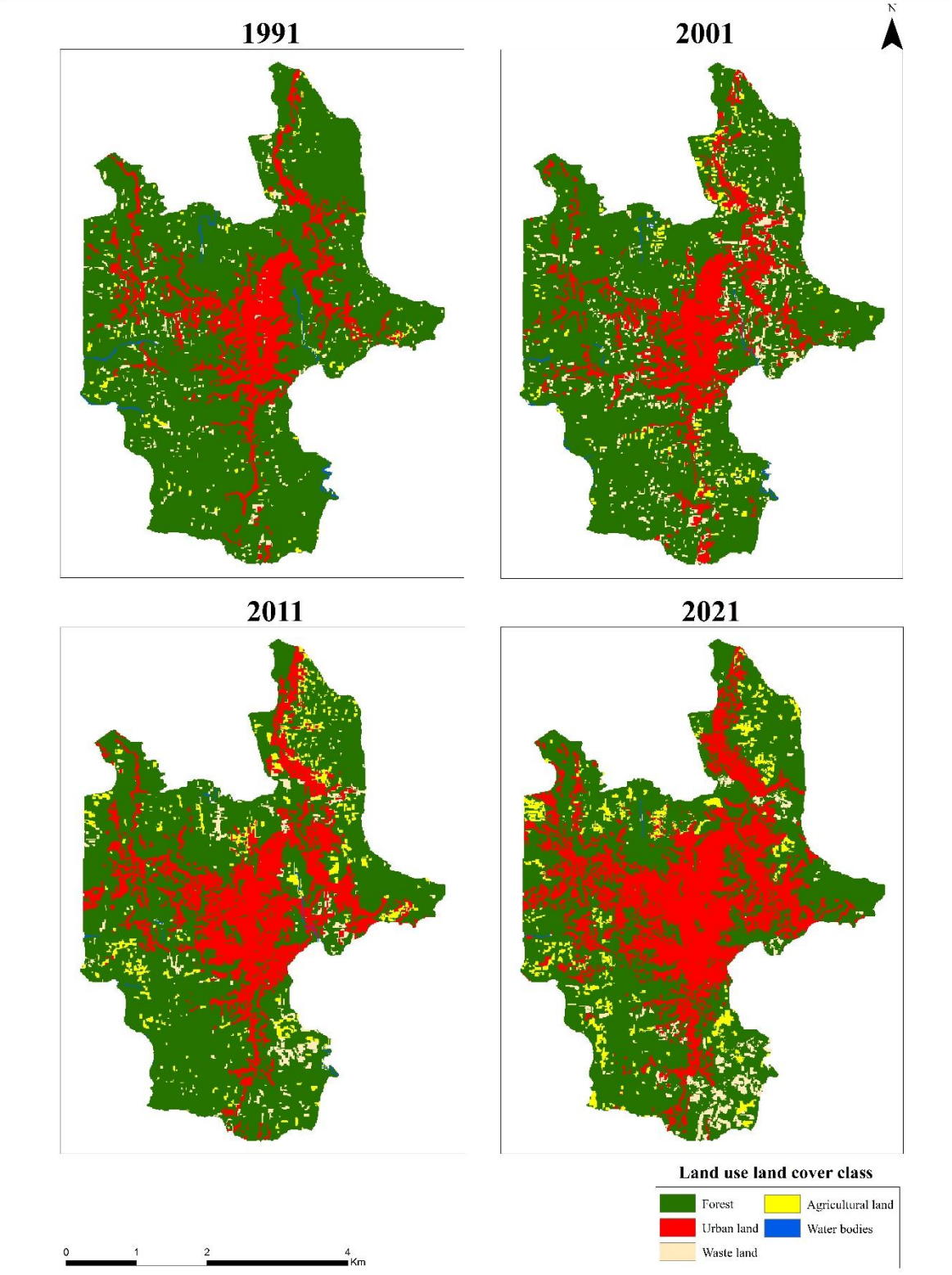

Figure 2 Land use land cover change map of Aizawl city

Urban growth Analysis during 1991 to 2021

The spatio and temporal analysis of urban growth in Aizawl indicates a distinct and ongoing growth in urban areas, with a gradual reduction in non-urban areas. Table 3 highlights the area covered by urban and non-urban area in different zones over the last three decades within the study area. The percentage and changes of urban area during 1991 to 2021 is shown in Table 4. The overall urban area experienced a notable increase from 15.10 km² in 1991 to 31.52 km² in 2021, with a total growth of 16.42 km² while non-urban area diminished from 87.41 km² in 1991 to 71.00 km² in 2021, reflecting a considerable conversion of land for urban areas.

The urban expansion map of Aizawl city (Figure 3) shows that the growth of urban areas expands like a radial pattern from the central ridge towards the outward periphery following major transport corridors which reveals ribbon-like developmentalong the north-south axis. The urban growth pattern of Aizawl city reveals that urban growth is deliberate between 1991 and 2001 followed by rapid growth during 2001 to 2011 with a continuous high growth till 2021. The decreasing rate in non-urban area from 87.41 km² in 1991 to 71.00 km² in 2021 highlights that there is a rapid transformation of non-urban areas into urban areas. The north-east and south-west zones reveals the maximum loss of non-urban land, at the cost of urban growth.During 1991 to 2001, isolated urban areas were observed and merged gradually creating more continuous urban patches by the year 2011 with a large and compact urban areas observable in 2021.

North-East Zone

During 1991 and 2021, the north-east zone experienced the most substantial growth in Aizawl city with a total growth of 4.28 km². The total land covered by urban area is maximum in in north-eastern zone of the study area during 1991 to 2021. The total percentage of urban areas increase gradually from 5.02 % in 1991 to 9.20% in 2021 indicating that the urban areas spread continuously along the eastern ridges as a result of improved accessibility and developed regions for urban areas.

South-East Zone

The area covered by urban areas in the southeastern zone expanded from 2.97 km² in 1991 to 6.14 km² in 2021, leading to an overall increase of 3.17 km². The growth rate of urban areas is lowest during this period as compared to other zones however still reflects substantial

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change in urban areawhich may be due to the steep topography limiting urban expansion for settlement.

South-West Zone

The south-western zone exhibits one of the most significant rates of urban growth, where the urban area has increased from 4.08 km² to 8.55 km², resulting in a net gain of 4.47 km² which is 4.36 % of the total area indicating substantial conversion of non-urban areas into urban areas between 1991 and 2021. This expansion is particularly occurred along the western slopes and transportation corridors, which reflects the growing pressure for settlement and changes in land use.

North-West Zone

The north-western zone exhibits significant urban growth, expanding from 2.90 km² in 1991 to 7.39 km² in 2021 with a total increase of 4.49 km², which is highest among all zones. The proportion of urban land increased from 2.83% to 7.21%, with notable transformations occurring between 2001 and 2011, as well as between 2011 and 2021. The increasing trend is marked by the conversion of non-urban areas into densely built-up areas, driven by enhanced connectivity and the availability of land suitable for development.

During the last three decades, the most significant growth in urban areas were observed in south-west, north-west and north-east zones, suggesting that urban growth is most concentrated in the northern and western parts of the study area. The south-eastern zone, though reveals sensible growth as compared to other zones, still demonstrates considerable change with a total increase of 3.09% in urban areas. The spatio-temporal analysis of Aizawl's urban growth reveals that the growth is multi-directional but mostly obvious toward the north-western and south-western fringes highlighting compacted and significant transformation of land use with initialstage of urban sprawl.

Table 3 Urban and non-urban area during 1991 to 2021

	Urban Area in km^2				**Non-Urban Area in km^2**			
	1991	**2001**	**2011**	**2021**	**1991**	**2001**	**2011**	**2021**
North-East	5.15	5.53	7.00	9.43	22.80	22.11	20.84	18.41
South-East	2.97	3.60	4.77	6.14	16.01	15.08	13.61	12.64
South-West	4.08	4.42	5.18	8.55	29.25	28.41	26.36	24.27

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North-West	2.90	3.01	6.47	7.39	19.36	20.35	18.30	15.67
	15.10	16.56	23.41	31.52	87.41	85.96	79.11	71.00

Table 4 Percentage of urban area and difference changes during 1991 to 2021

	Urban Area in %				**Difference changes in %**			
	1991	**2001**	**2011**	**2021**	**1991-2001**	**2001-2011**	**2011-2021**	**1991-2021**
North-East	5.02	5.40	6.82	9.20	0.38	1.43	2.37	4.18
South-East	2.90	3.51	4.65	5.99	0.61	1.14	1.34	3.09
South-West	3.98	4.31	5.05	8.34	0.33	0.74	3.30	4.36
North-West	2.83	2.94	6.31	7.21	0.11	3.37	0.90	4.38
	14.73	16.16	22.83	30.74	1.42	6.68	7.91	16.01

Discussion

The study examined the spatio-temporal changes in land use land cover to analyse the growth of urban area in Aizawl city during 1991 to 2021. The findings shows that the increasing urban growth is the resultant outcome of land use land cover changes. Land use land cover map (Figure 2) highlights that the study area has been dominated by forest and consistently decreases while urban and agricultural areas have expanded overtime as a result of urbanization. The loss of forest area reduced from 73 km² in 1991 to 62.81 km² in 2021 indicates an extensive decline over the past three decades due to the increasing urban land which is concentrated in the central and southern parts of the study area where urban growth is most pronounced signifying increased deforestation for settlement and infrastructure development due to urbanization. Urban land experienced the most significant transformation among all land use land cover categories, with a net increase of 16.21 km², which is more than double within three decades. The spatial distribution of urban land indicates a radial expansion from the core of the study area extending towards the north, south-west, and south-east periphery. The increasing agricultural land along with urban land signifies the conversion of forest and barren land for settlement and cultivation of crops as a result of increasing urbanization due to population growth pressure. The fluctuating trend of barren land during the study period indicates a transformation of open areas into urban and agricultural land and a recovery land from agricultural land to barren land in the form of fallow land. The area covered by agricultural land experienced consistent growth, with an

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195 increase of 3.74 km² focusing mostly around the peri-urban zones. The area covered by water
196 bodies decline continuously, diminishing from 1991 to 2021 with a total loss of 0.42 km² which
197 can be linked to the increased runoff resulting from deforestation, and encroachment for urban
198 development.

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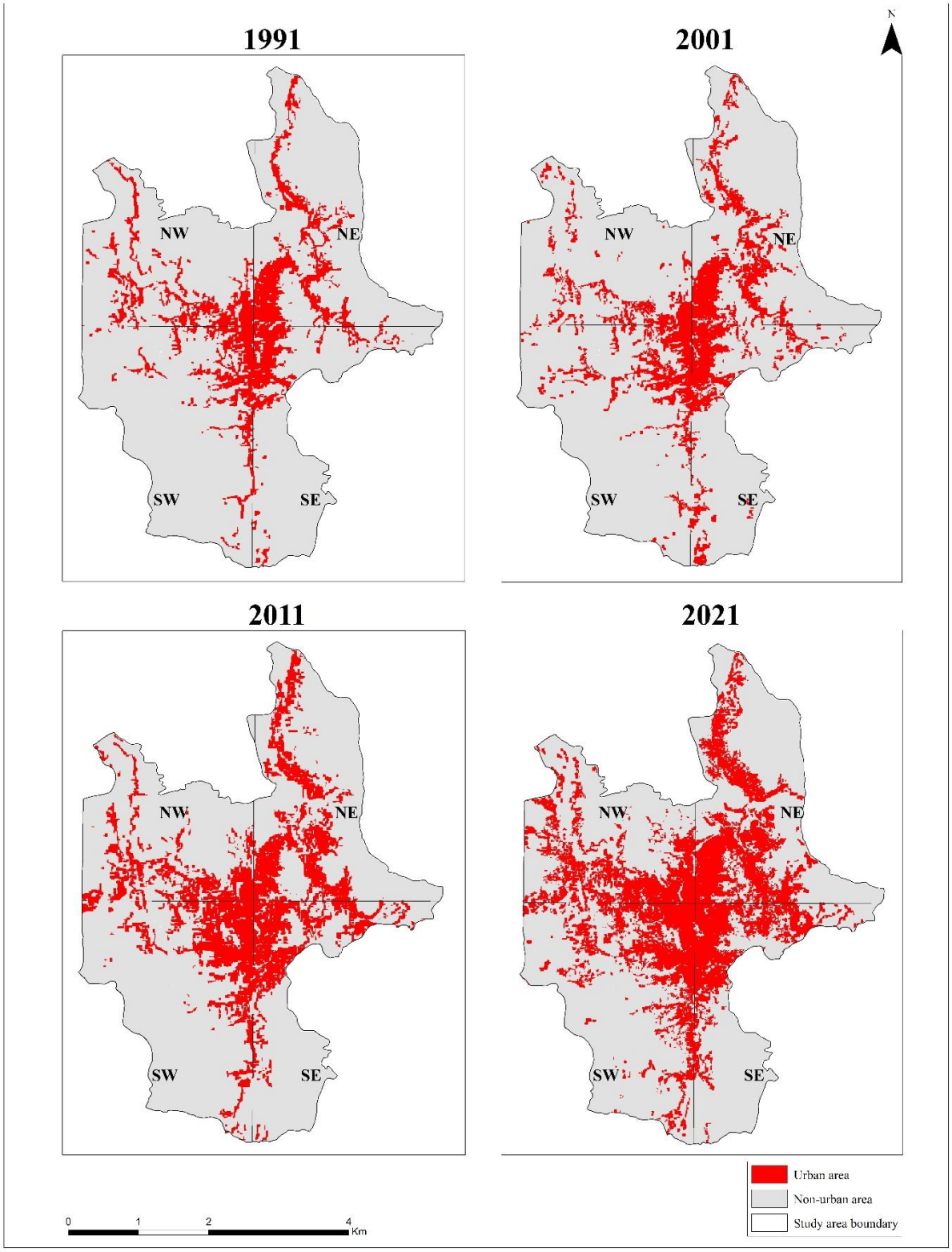

Figure 3 Urban growth map of Aizawl city

Conclusion

The present study analyses the spatio and temporal urban growth in Aizawl city during 1991 to 2021, revealing substantial evidence that urban growth has occurred at a significant rate within the city.Urban growth observed in Aizawl city shows a distinct spatial expansion in every direction emerging from the core towards the periphery. The city has experienced remarkable growth since India's independence, fuelled by demographic changes, political shifts, and economic centralization (Malsawmkimi, 2025). The growth of urban areas is particularly evident in the northeast and southeast directions, characterized by favourable topography and transport corridors that facilitate urban development, as compared to the western regions where urban expansion is constrained by steep slopes and uneven terrain.Uncontrolled urban growth negatively impacts the landscape, influences residents' behaviours, contributes to the formation of urban slums, deteriorates ecological quality, increases susceptibility to both natural and man-made hazards, increase rental prices, and aggravates overcrowding (Lallawmchullova, et al.,2025). Future research should be focused more on well-planned urban planning to avoid dispersed urban growth considering the topography of the landscape to avoid uncontrolled sprawling and hazards within the study area. The key findings of the analysis indicate that land use land cover experienced a significant change throughout the study period, with large area of forest being converted into urban and agricultural land as a result of increasing urbanization.

The findings of the present study enhanced a deeper understanding of the relationship between urban growth and changes in land use land cover, supporting previous studies while presenting new insights that may enlighten future investigations. The urban area has been increasing every decade, expanding from the city’s core towards the periphery suggesting a dense urban core accompanied by a sprawling pattern of urbanization. These conclusions highlight the significance of urban growth analysis and land use land cover changes, illustrating that continuous assessment in this area can produce beneficial insights for both researchers and experts. Future research should be enlarged on these findings by employing predictive modelling for strategic and sustainable urban planning. In summary, the study advances current knowledge in the field of urban growth analysis and provides a clear direction for future research aimed at strengthening remote sensing and GIS applications.

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