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RESEARCH ARTICLE

SPATIO-TEMPORAL ANALYSIS OF URBAN GROWTH IN AIZAWL CITY, MIZORAM

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Abstract

Urban growth and land use land cover changes have been increasing recently due to growing population and infrastructure development. The study examined the urban growth in Aizawl city from 1991 to 2021 using remote sensing and GIS. Land use land cover of Aizawl city has been examined using supervised classification, and acquired data has been utilized to analyse urban growth within the study area. The study reveals that the land use and land cover of Aizawl city has been changing rapidly due to urban growth. The declining forest cover (-19.92 km^2) with increasing urban land (16.42km^2) and agricultural land (3.74 km^2), clearly define transformation of land use classes due to urbanization. The total increased of urban area with 16.01 per cent highlights a clear expansion and directional trend of the urban area indicating considerable changes in the distribution of urban growth. This research contributes to a deeper understanding of the relationship between land use and land cover, and urban growth providing a foundation for future studies and practical applications in monitoring and planning sustainable cities.

Introduction: -

Urbanization has become a main issue all over the world, transforming natural land into man-made surfaces.Despite urban regions occupying merely 3% of the Earth's surface, the rapid urbanization resulting from increasing population leads to significant ecological and socio-economic challenges within urban areas (Liu and Lathrop, 2002). Urban growth has become the most determining factor in changes to population, socio-economic and environment over the past few years (Kafy etal., 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 is expected to continue in the future as long as urban areas in developing countries continues to expand. Urban development marksthe conversion of land from open fields and green spaces to built-up areas to satisfy the desires of urban habitants (Liong etal.,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 transformation of vegetation cover into

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built-up areas and various others land uses, along with the increase in population and related economic ventures (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 the vegetation cover of an area (Kafy etal., 2021). The change of land features from one class to another has a significant impact on the local and regional environment (Rousta etal., 2018). Increase in size and quantity of urban clusters determines the relative significance of urban environment throughout the world (Yue etal., 2005). As people choose to settle in urban areas, this rapid urbanization poses significant challenges to the urban environment, resulting in a risk to environmental sustainability (Li etal., 2010). Aizawlcity, 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, but the city has also lost its green spaces, leading to depletion of vegetation within the city and surrounding areas, which has had an 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 Systems (GIS) has enabled spatial scientists to investigate urban growthanalysis from spatial and temporal perspectives. Satellite images obtained from the Landsat series are used to observe changes in land use and land cover as well as urbangrowth. The main objective ofthe study is to assess the land and 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). Given the continuousrising in both population and size, more reflection in the approach of sustainable approaches to urban and peripheral land development will gradually become more significant (Vitousek etal., 1997).

Materials and Methods: -

Study area: -

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 areas 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 state,covering an area of 102.25 sq. km. The topography of Aizawl city is generally undulant, with broken hilly ranges and steep slopes. According to the 2011 census, the population of Aizawl is 293,416 persons,comprising 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.

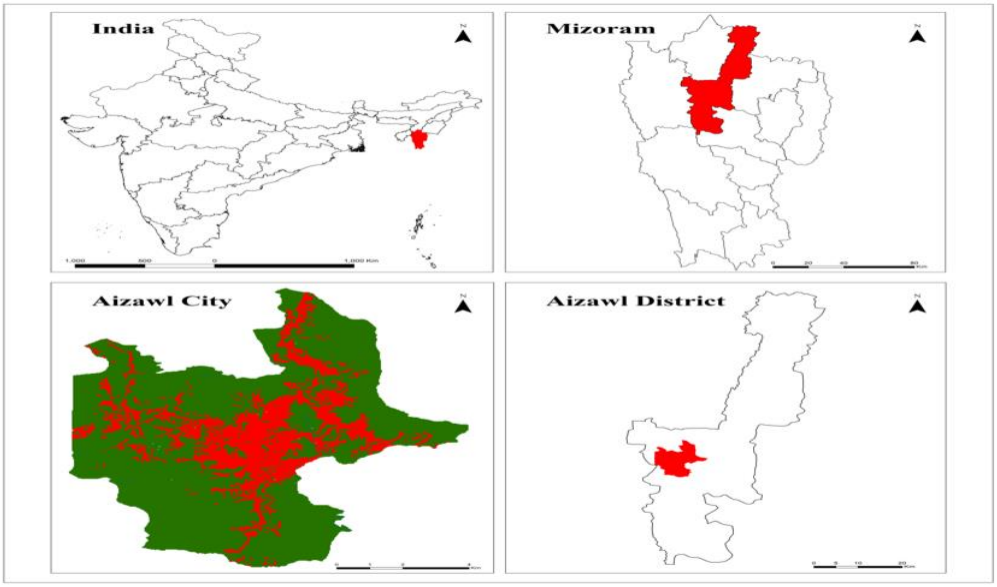

Figure 1 Location map of study area

Data Source: -

The study used 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 imageriesthat 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 includingErdas 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	43
Landsat 5 TM	19 - 11 - 1991	136	44
Landsat 5 TM	30 - 01 - 2001	136	43
Landsat 5 TM	30 - 01 - 2001	136	44
Landsat 5 TM	10 - 11 - 2011	136	43
Landsat 5 TM	10 - 11 - 2011	136	44
Landsat 8 OLI/TIRS	05 - 01 - 2021	136	43
Landsat 8 OLI/TIRS	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 imagery for the year 1991, 2001, 2011, and 2021, were classified using Erdas Imagine 9.1 software by a supervised classification algorithm. The imageryhas been classified into five LULC classes, such asforest, urban land, barren land, agricultural land, andwaterbodies. A total number of 1150areas of interest (AOIs) were selected as training samples for forest (420 AOIs), urban land (310 AOIs), barren land (180 AOIs), agricultural land (140 AOIs), and waterbodies (100 AOIs). Accuracy assessment was also conducted to determine the precision of the classified image. The changes of LULC for each class have shown in Table 2.

Urban growth analysis: -

To analyse the urban growth of Aizawl city from 1991 to 2021, the study utilized the land use land cover map of the study area. The observed data has been classified into urban, denoting land covered by urban development, and non-urban areas, which includes forest, barren land, agricultural and waterbodies. The urban growth map has been divided into four zones - 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 and land cover changes in Aizawl city from 1991 to 2021 shows significant transformation due to urban growth (Figure 2). Table 2 highlights the changes in LULC between 1991 and 2021. Forest area reduces from 82.73 km² in 1991 to 62.81 km² in 2021 indicating a steady and significant decline. Urban land has increased from 15.10km² in 1991 to31.52km² in 2021, which shows rapid urbanization during this period. The year between 2011 and 2021 demonstrates the most accelerated urban growth with an increase of 8.11 km² during the study period. The area occupied by barren land fluctuate between 1991 and 2021 by expanding significantly from 2.75 km^2 in 1991 to 6.24 km^2in2001, however, it reduces 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 by a total loss of 0.42 km²which may be due to the decline inforest land from urbanization.

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			

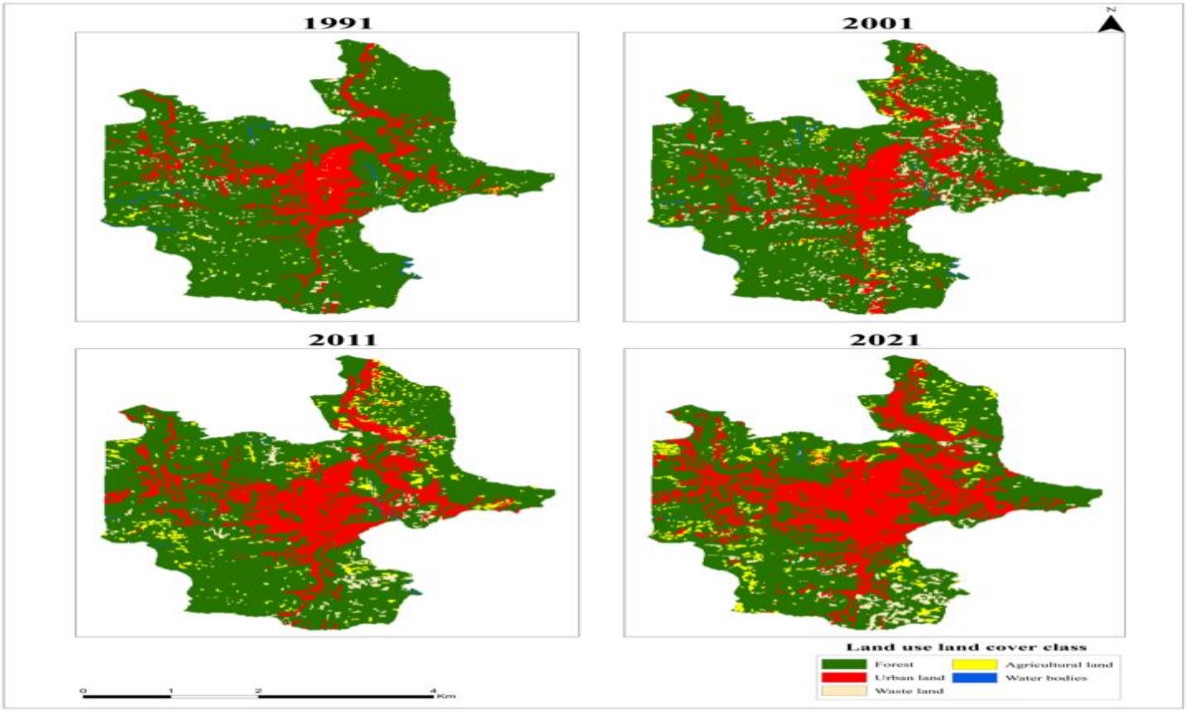

Figure 2 Land use land cover change map of Aizawl city during

Urban growth analysis during 1991 to 2021: -

The spatio-temporal analysis of urban growth in Aizawl indicates a distinct and ongoing expansion in urban areas, with a gradual decrease in non-urban areas. Table 3 highlights the area covered by urban and non-urban areasin different regionsover the last three decades within the study area. The percentage and changes in 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 the non-urban area reduced from 87.41 km² in 1991 to 71.00 km² in 2021, reflecting a considerable conversion of land into urban areas.

The urban expansion map of Aizawl city (Figure 3) shows that the growth of urban areas expands like a radial-like 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 wasdeliberate between 1991 and 2001, followed by rapid growth from 2001 to 2011 with a continuous high growth up to 2021. The decreasing rate in non-urban areas from 87.41 km² in 1991 to 71.00 km² in 2021 highlights that there has been 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. Between 1991 and2001, isolated urban areas were observed and

gradually merged 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 areas is maximumin north-eastern zone of the study area during 1991 and 2021. The total percentage of urban areas increased gradually from 5.02% in 1991 to 9.20% in 2021, indicating that urban areas spread continuously along the eastern ridges as a result of improved accessibility and developed areas 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 compared to other zones; however, it still reflects substantial change in urban areas, which 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 the highest among all zones. The proportion of urban land increased from 2.83% to 7.21%, with notable transformations occurring between 2001 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 was 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, however reveals sensible growth as compared to other zones, the zone 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 noticeable 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 km²				**Non-Urban Area in km²**			
	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
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 spatio-temporal analysisof urban growth in Aizawl city from 1991 to 2021 clearly reveals that the increasing urban expansion is the resultant outcome of land use and land cover changes. The area lost by forest (-19.92 km²) indicates an extensive decline over the past three decades due to the increasing urban land, which ismostly in the central and southern parts of the study area where urban growth is most pronounced, signifying increased deforestation for settlement due to urbanization. Urban land experienced the most substantial transformation, with a net increase of 16.21 km², more than double within three decades.

The total area of barren land fluctuates during the study period, indicating 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 increase of 3.74 km² focusing mostly around the peri-urban zones. The area covered by water bodies declined continuously, with a total loss of 0.42 km² which can be linked to deforestation for urban development. The urban growth pattern in Aizawl city demonstrates a distinct spatial expansion in every direction emerging from the core towards the periphery. The spatial distribution of urban land indicates a radial-like expansion from the core of the study area, extending towards the north, southwest, and southeast periphery. A recent study reveals that Aizawlcity has experienced remarkable growth since India's independence, fueled by demographic changes, political shifts, and economic centralization (Malsawmkimi, 2025). The 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, increasing rental prices, and aggravates overcrowding (Lallawmchullova et al.,2025).

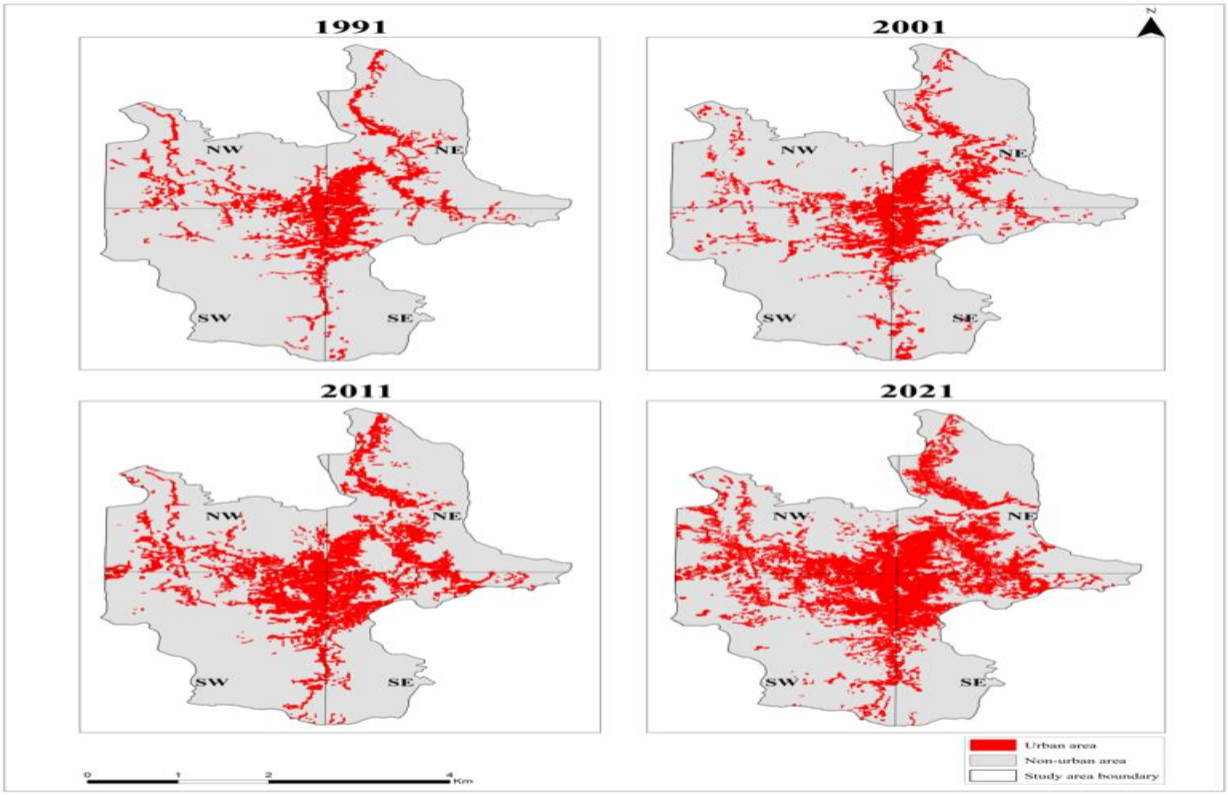

Figure 3 Urban growth map of Aizawl city from 1991 to 2021

Conclusion: -

The studyreveals substantial evidence that urban growth has occurred at a significant rate within the city.The analysis indicate that land use land cover experiences a significant change throughout the study period, with large area of forestconverted into urban and agricultural land as a result of increasing urbanization.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.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.The findings 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. However, the study has been inadequate due to limitations of high-resolution satellite imagery,which hampers a more in-depth analysis of urban growth since its inception.

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. The rise in urbanization brings numerous benefits; however, it adversely effects the urban environment by reducing green spaces and degrading ecological quality. This deterioration subsequently results in increasing land surface temperatures, which contributes to the phenomenon referred to as the urban heat island effect. Unplanned urbanization frequently causes traffic congestion and a scarcity of open spaces, thereby impacting the quality of life and overall well-being. Additionally, it creates regions susceptible to disasters, particularly in hilly terrains, due to unrestrained construction.These conclusion highlights the significance of urban growth analysis and land use and land cover changes, illustrating that continuous assessment in this area can produce beneficial insights for both researchers and experts.Future research should be focus 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 areaby employing predictive modelling for strategic and sustainable urban planning.

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