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Urban Development in the Western Part of Tamil Nadu (Kongu Nadu Region), India: A Temporal Study Using Land use Land Cover Change Detection Analysis

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Abstract: Urbanization is a significant driver of environmental transformation, with profound implications for socio-economic development and ecological balance. This study examines the spatiotemporal dynamics of urban development in the Kongu Nadu region of Tamil Nadu, India, from 1985 to 2024, leveraging advanced Land Use Land Cover (LULC) change detection methodologies. Utilizing multi-source satellite imagery and geospatial techniques, the study identifies patterns of urban expansion and their cascading impacts on agriculture, forest cover, water bodies, and barren lands. Results indicate a sharp increase in urbanized areas from 1.2% in 1985 to 14.4% in 2024, paralleled by a significant reduction in croplands and water bodies, highlighting the pressures of population growth, industrialization, and infrastructural development.

Keywords: *Urbanization - Land Use Land Cover - Change Detection - Remote Sensing - GIS Analysis - Sustainable Urban Planning - Environmental Impact - Kongu Nadu - Temporal Analysis - Resource Management.*

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I. INTRODUCTION

Urban development is a dynamic process driven by factors such as population growth, economic expansion, and infrastructural advancements. Over recent decades, rapid urbanization has significantly transformed land use and land cover (LULC) patterns, leading to various environmental and socio-economic impacts. Understanding these changes is crucial for sustainable urban planning, resource management, and environmental conservation (Mehra. N et al., 2024). LULC change detection analysis is a vital tool for assessing the spatial and temporal evolution of urban areas. By employing remote sensing and geospatial technologies, researchers can monitor urban sprawl, land conversion, and associated environmental impacts. This approach enables policymakers and urban planners to make informed decisions regarding land resource allocation, infrastructure development, and ecological sustainability. This study aims to analyze urban development trends over a specific temporal scale using LULC change detection techniques. The research focuses on identifying key drivers of land transformation, evaluating their environmental implications, and providing insights into sustainable urban growth. By leveraging multi-temporal satellite data and geospatial analysis, this study seeks to contribute valuable knowledge to the field of urban development and land management (Das. S et al., 2022).

- *Study Area*

The Kongu region, also known as Kongu Nadu, is located in the western and north-western part of Tamil Nadu, India, between 10° and 12°30′ north latitude and 76° to 79° east longitude, covering a total area of **45,552 km²** across 10 districts (Coimbatore, Erode, Tiruppur, Nilgiris, Salem, Namakkal, Karur, Dindigul, Dharmapuri, Krishnagiri) Map - 1. This diverse physiographic landscape includes the Western and Eastern Ghats traversing the Deccan Plateau, with varied elevations comprising hills, plains, and river valleys. Major hill ranges like the Nilgiri and Anamalai Hills dominate the western margins while undulating plains with rocky outcrops characterize the interior. The region is drained by important rivers such as the Kaveri, Bhavani, Noyyal, and Amaravathi, which support agriculture and irrigation despite being non-perennial. The soils range from red loamy to black cotton, fostering diverse crops, while the semi-arid climate with moderate rainfall during the northeast monsoon influences the vegetation, which includes dry deciduous forests and scrublands. Urban centers like Coimbatore, Tiruppur, and Salem play a pivotal role in the region's industrial and economic growth, though disparities persist among districts.

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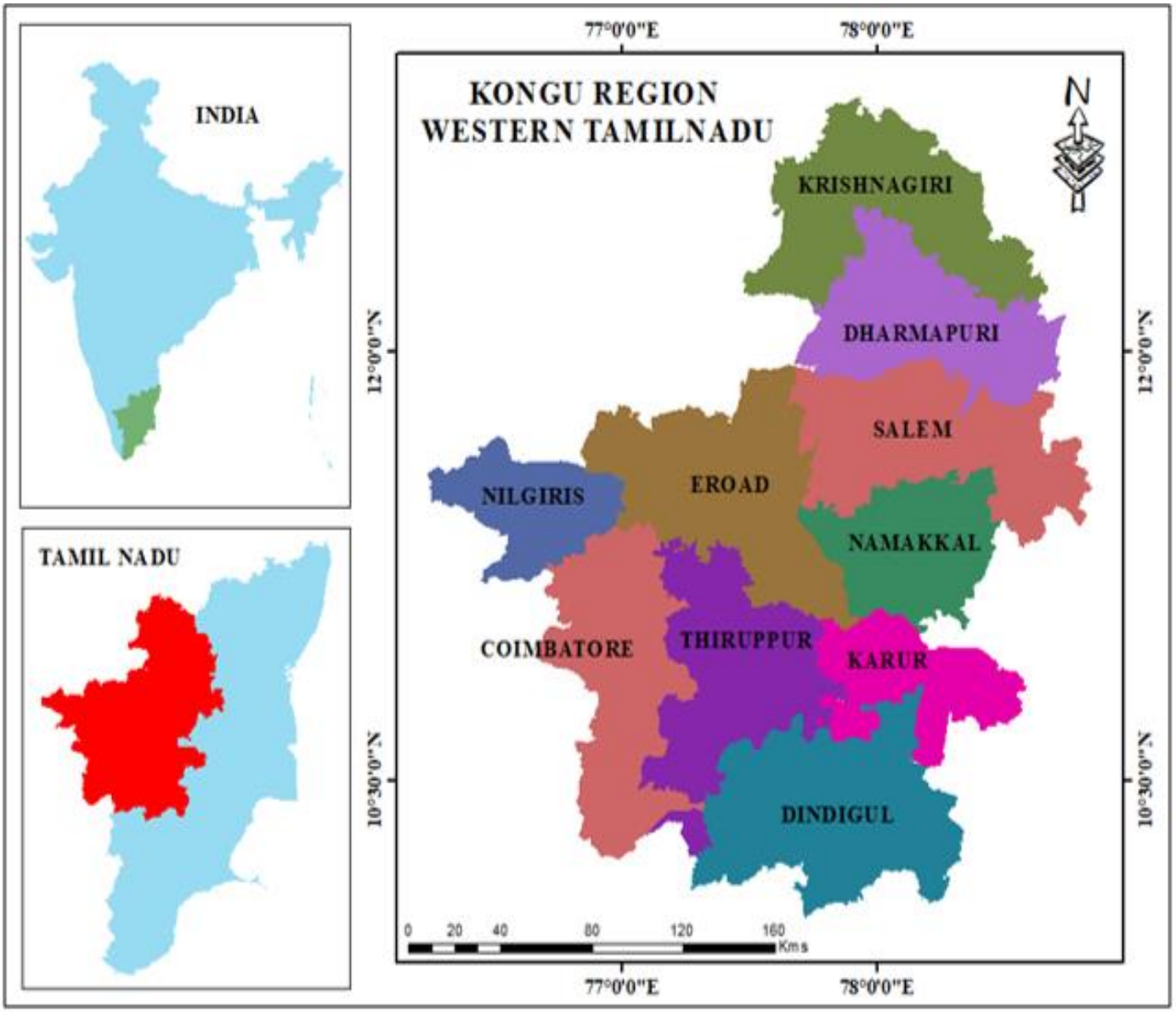
The unique physiographic and geographic attributes of the Kongu region are vital to its agricultural and industrial development but also present challenges in water resource management and environmental conservation (Rajendran et al., 2023).



Map 1 Study Area

➢ *Objective*

This study aims to analyze the patterns and dynamics of urban development in the western part of Tamil Nadu, specifically the Kongu Nadu region, using Land Use Land Cover (LULC) change detection analysis. The research focuses on identifying urban expansion's spatial and temporal trends over a specified period and understanding its impact on the region's natural landscape. Particular attention is given to how urbanization has transformed agricultural lands, forested areas, and water bodies, reflecting the pressures of population growth, industrialization, and infrastructure development.

II. MATERIALS AND METHOD

Land Use Land Cover (LULC) analysis relies on diverse satellite data sources, evolving with technological advancements. Landsat series (Landsat-4 MSS, Landsat-5 TM, ETM+) have been pivotal since 1985 for moderate-resolution data. Resourcesat LISS III (23.5 m) enhanced regional-scale studies (Roy et al., 2015). Sentinel-2 MSI, with its 10 m resolution, has been transformative since 2017, offering high-precision data for detailed LULC mapping (Drusch et al., 2012; ESA-2023). The integration of these datasets enables multi-temporal and spatial analyses crucial for understanding land dynamics and informing sustainable development.

➢ *Data Sources*

This study analyzes changes in land use and land cover (LULC) in Kongu Nadu. The research was conducted using spatial datasets obtained from the various datasets collected from the following sources (Table -1). All spatial datasets were projected into the same coordinate system (WGS-1984), in Meters.

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Table 1 Satellite Remote Sensing Data used for LULC Mapping

Period	Satellite	Sensor	Spatial Resolution
1985	Landsat - 4	MSS	80 (resampled to 60 m)
1995	Landsat - 5 and IRS 1B	Thematic Mapper (TM), Enhanced Thematic Mapper (ETM +), Linear Imaging Self-Scanning Sensor – 1 (LISS I)	30 and 72 m (resampled to 56 m) respectively
2005	Landsat - 5 and Resourcesat	ETM+, LISS III	30 and 23.5 m respectively
2017	Sentinel-2	Multispectral Instrument (MSI)	10 m spatial resolution.
2024	Sentinel-2	Multispectral Instrument (MSI)	10 m spatial resolution.

➢ *LULC Maps*

Land Use and Land Cover (LULC) change detection plays a crucial role in urban development analysis by providing insights into the dynamics of urban expansion and its environmental impacts. Utilizing remote sensing and GIS technologies enables the monitoring of urban growth, environmental assessments, and informed urban planning. For instance, studies have revealed significant urban expansion and its impact on land use patterns, such as in Pabna Municipality, Bangladesh, where urban areas increased substantially over two decades (Rahman et al., 2021). LULC analysis is also vital for assessing the reduction of green spaces and agricultural lands, as evidenced in peri-urban Greater Cairo (Mansour et al., 2020). Additionally, accurate LULC maps aid urban planners in formulating sustainable development policies (Zhang et al., 2023). Techniques like machine learning and deep learning, such as Convolutional Neural Networks (CNNs), have further enhanced the accuracy of LULC classification, as demonstrated in the mapping of complex urban forms in Mumbai (Patel et al., 2019). These applications highlight the significance of LULC in sustainable urban development and environmental conservation.

The second part of the methodology is preparing land use and land cover maps for the study area. This involves classifying the study area into LULC using GIS software like QGIS, ArcGIS, and satellite data sets. It is an image-handling software platform that permits users to process geospatial imagery, vector data, and other images. It is also used for LULC mapping and change detection analysis of the study area (S. Ravichandran et al., 2021).

III. RESULT AND DISCUSSION

This section presents a detailed analysis of the Land Use Land Cover (LULC) changes observed over the study period. The temporal variations in LULC classes, including croplands, forests, barren lands, water bodies, and built-up areas, are evaluated to understand the patterns of landscape transformation. The results highlight significant shifts in land use driven by factors such as urbanization, deforestation, agricultural decline, and environmental restoration efforts (Table -2; Chart - 1).

The discussion focuses on the implications of these changes, particularly the rapid expansion of urban areas, the decline in croplands, and the fluctuations in forest cover and water bodies. These trends are analyzed to identify the key drivers influencing land cover changes and their broader socio-economic and environmental impacts. The findings emphasize the critical need for sustainable land management and planning to address the challenges posed by LULC transformations.

➢ *LULC - 1985*

In 1985, croplands dominated the region, covering 63% (28,715.01 km²), highlighting the area's strong agricultural base. Forests occupied 24.7% (11,285.36 km²), while barren lands accounted for 9.3% (4,225.89 km²). Water bodies covered 1.8% (847.71 km²), and built-up areas were minimal, at 1.2% (478.03 km²), reflecting limited urban development (Map - 2).

➢ *LULC - 1995*

By 1995, cropland increased slightly to 64.3% (29,188.19 km²), maintaining its dominance. Forest cover remained stable at 24.6% (11,246.22 km²). Barren land decreased to 7.7% (3,540.70 km²), possibly due to land reclamation efforts. Water bodies expanded marginally to 1.9% (880.78 km²), and built-up areas grew to 1.5% (696.11 km²), indicating early signs of urbanization (Map - 3).

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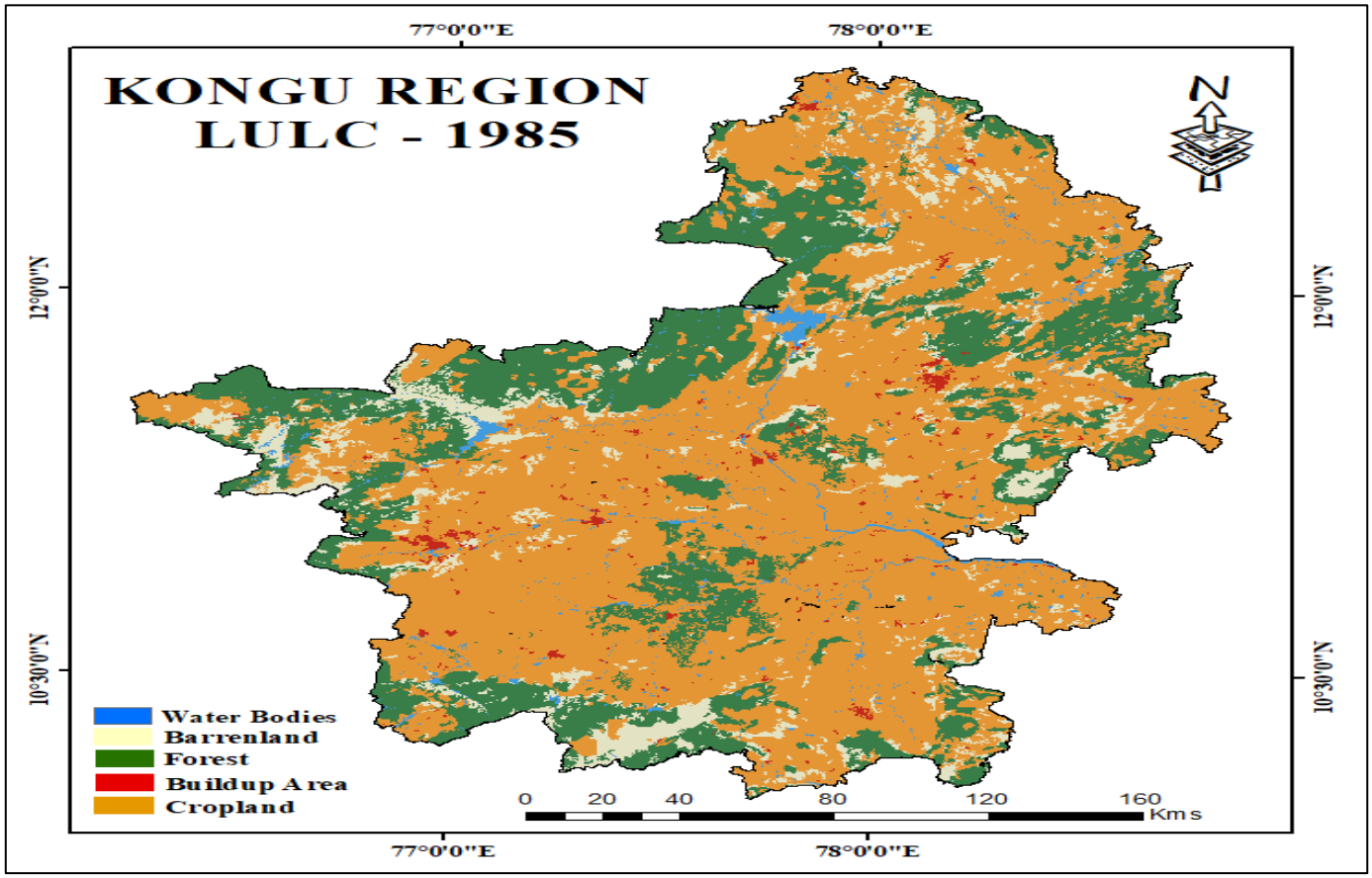
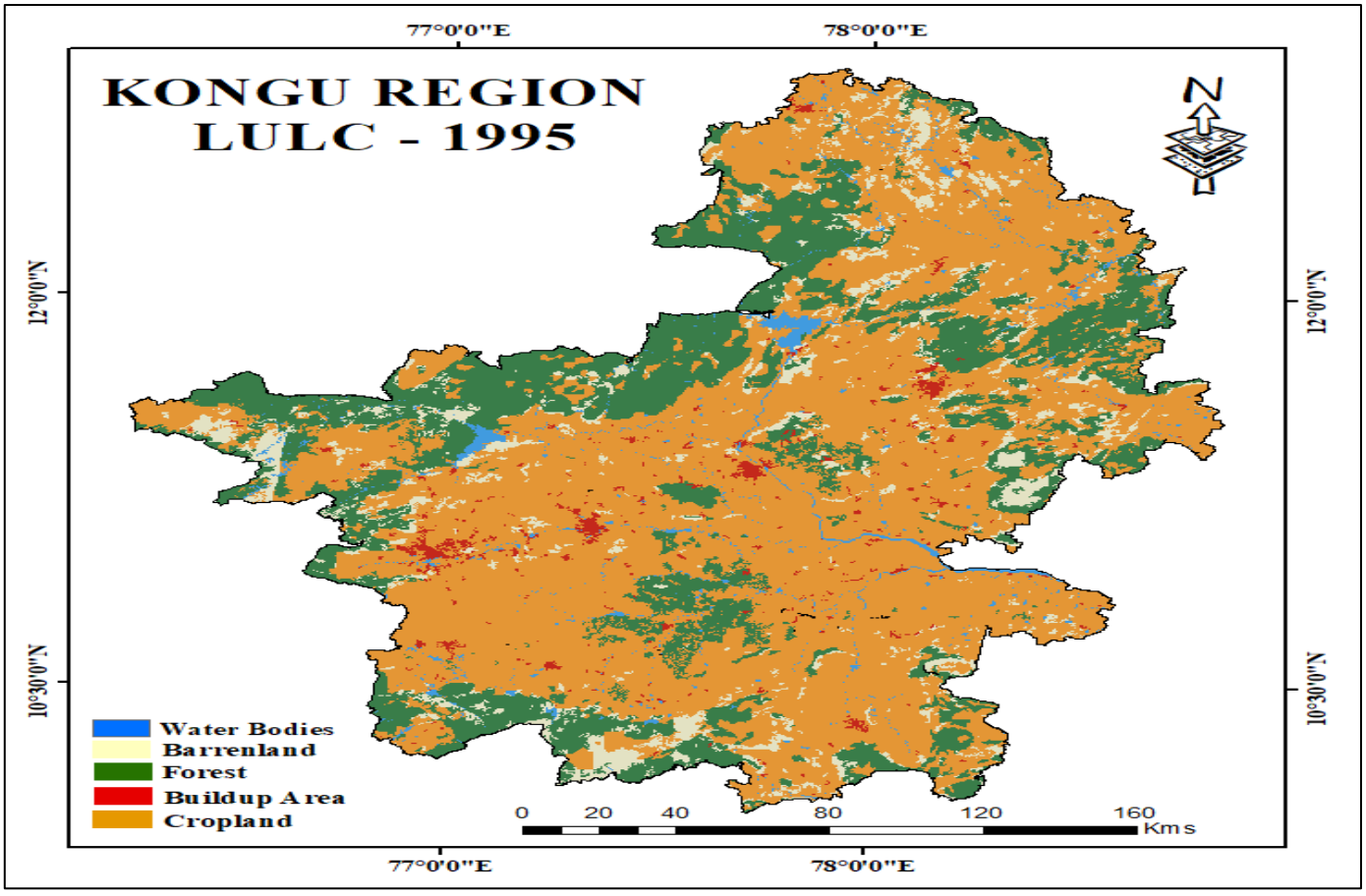


Map 2 LULC - 1985



Map 3 LULC - 1995

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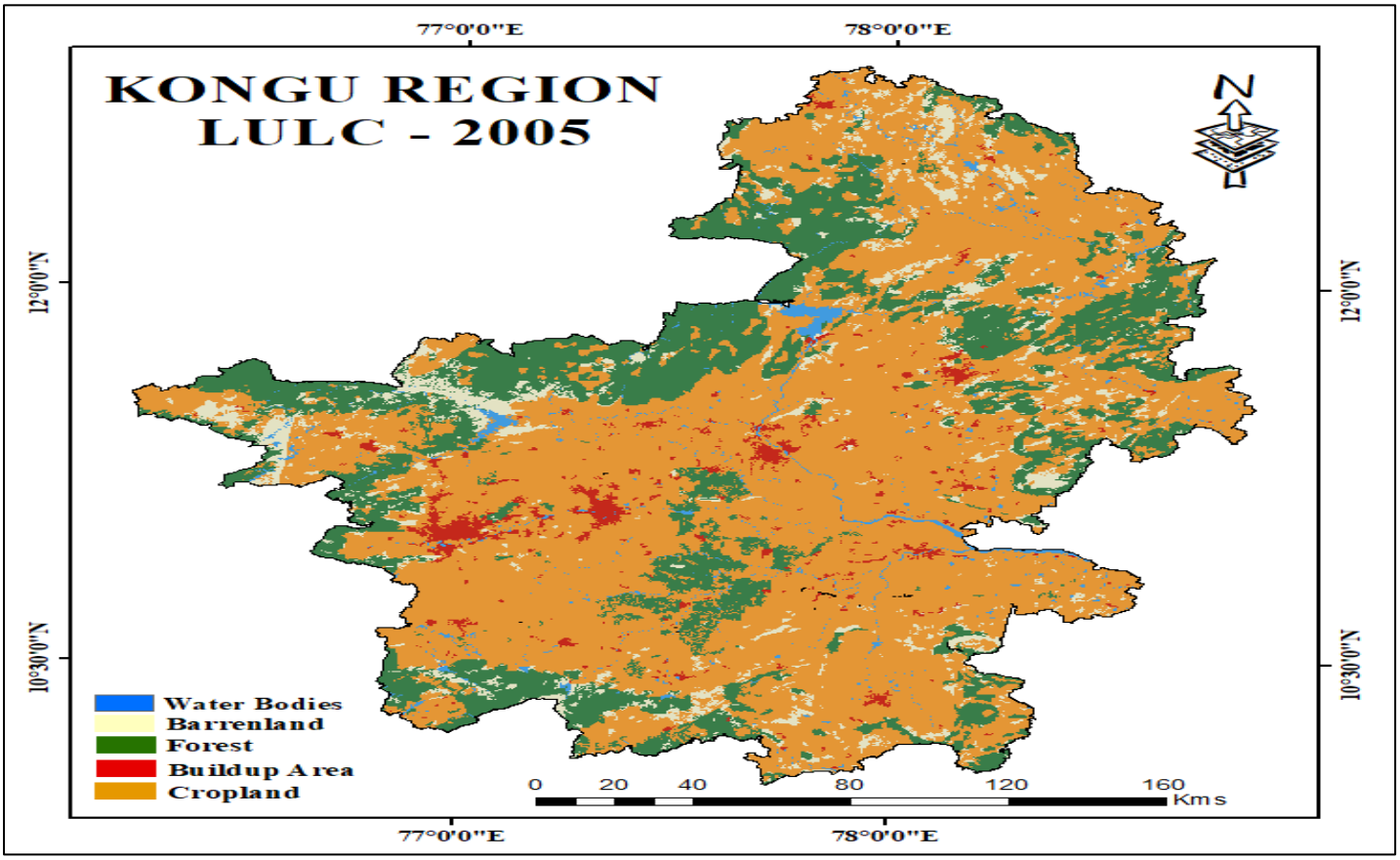
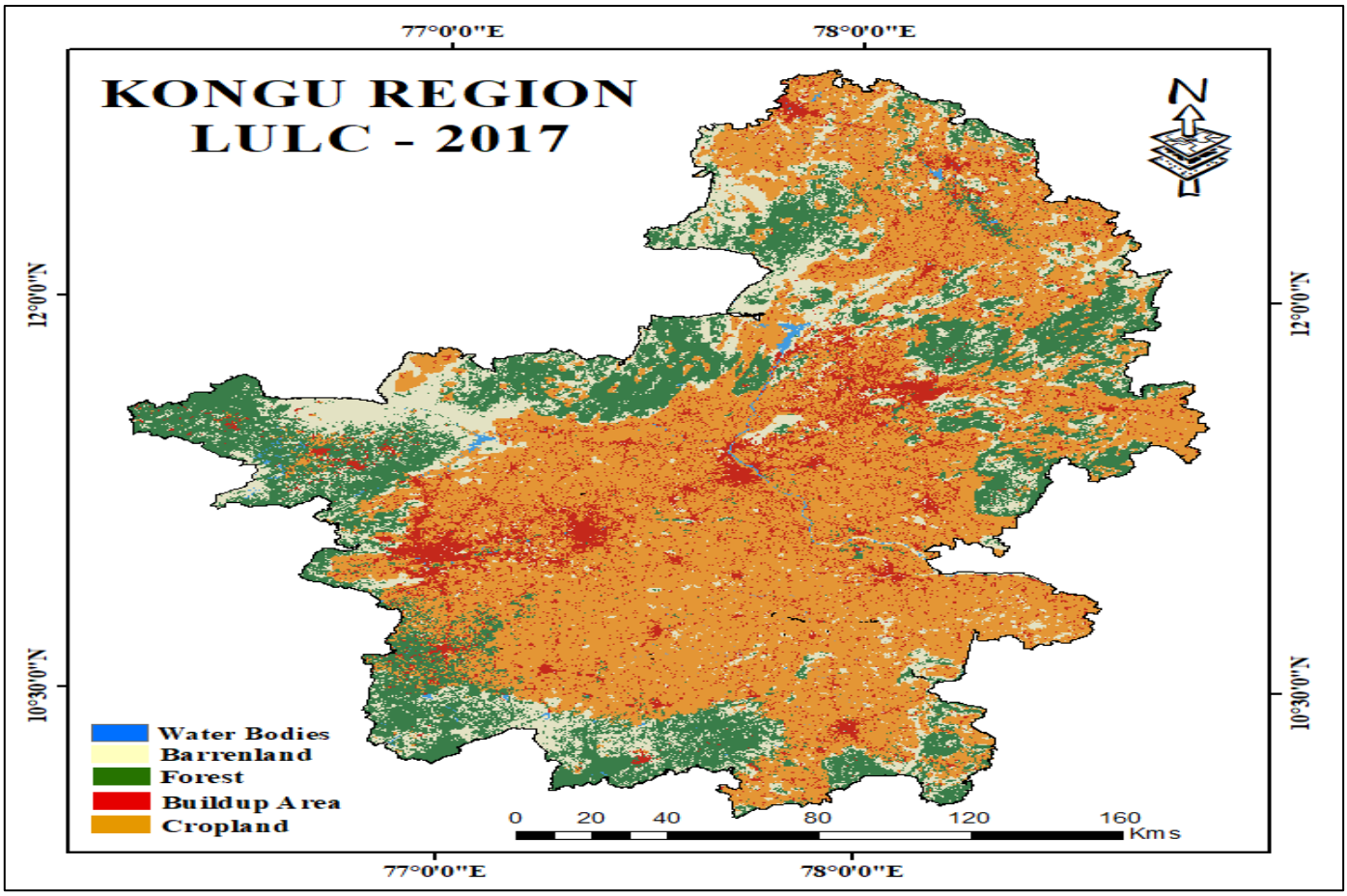


Map 4 LULC – 2005



Map 5 LULC – 2017

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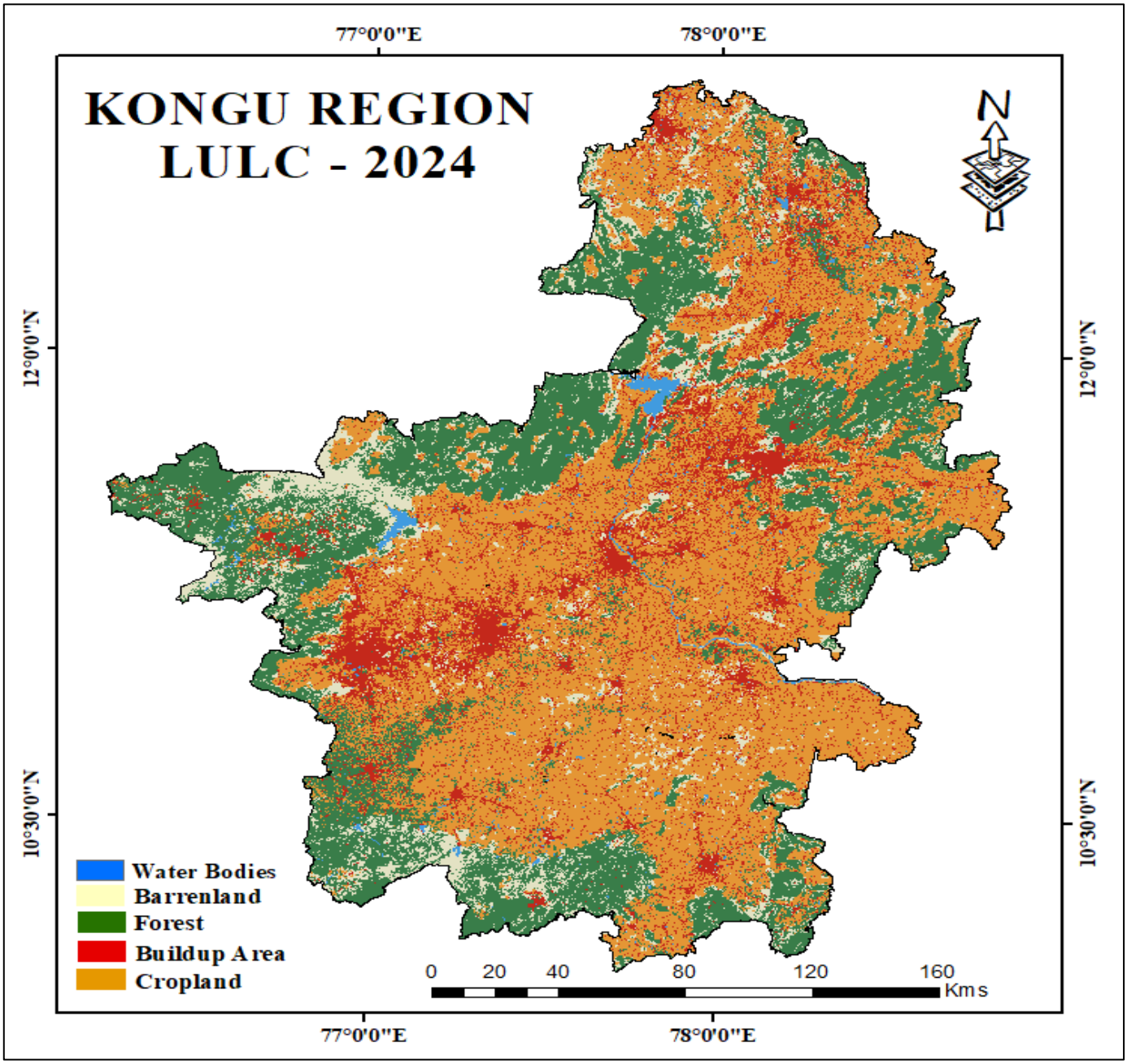

Map 6 LULC – 2024

Maps 2, 3, 4, 5, and 6 show the Land Use Land Cover (LULC) of the Kongunadu Region for the years 1985, 1995, 2005, 2017, and 2024.

➢ *LULC - 2005*

Cropland continued to increase slightly, reaching 65% (29,763.01 km²). Forest cover began to decline, falling to 23.3% (10,629.06 km²), likely due to deforestation. Barren land further decreased to 7.4% (3,257.81 km²), while water bodies shrank to 1.7% (797.34 km²). Built-up areas more than doubled compared to 1995, reaching 2.6% (1,104.78 km²), reflecting growing urban expansion (Map - 4).

➢ *LULC - 2017*

By 2017, a significant shift occurred. Cropland decreased sharply to 51.7% (23,576.18 km²), likely due to urbanization. Forest cover also reduced to 21.7% (9,913.24 km²). Barren land saw a dramatic increase to 15.6% (7,116.81 km²), possibly due to land degradation. Water bodies drastically declined to 0.4% (204.16 km²), indicating severe water resource depletion. Built-up areas surged to 10.6% (4,741.61km²), highlighting rapid urbanization (Map - 5).

➢ *LULC - 2024*

In 2024, cropland further reduced to 46% (20,985.16 km²), reflecting ongoing urban expansion. Forest cover increased to 27.9% (12,737.41 km²), possibly due to afforestation programs. Barren land decreased to 10.5% (4,782.17 km²), suggesting land reclamation efforts. Water bodies recovered to 1.2% (549.47 km²), likely due to conservation measures. Built-up areas continued to grow, reaching 14.4% (6,497.79 km²), driven by industrialization and population growth (Map - 6).

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Table 2 Area of Land Use Land Cover Area of Kongu Nadu.

CLASSES	1985	%	1995	%	2005	%	2017	%	2024	%
Water Bodies	847.71	1.8	880.78	1.9	797.34	1.7	204.16	0.4	549.47	1.2
Barren Land	4225.89	9.3	3,540.70	7.7	3,257.81	7.4	7116.81	15.6	4782.17	10.5
Forest	11285.36	24.7	11,246.22	24.6	10,629.06	23.3	9913.24	21.7	12737.41	27.9
Build Up Area	478.03	1.2	696.11	1.5	1104.78	2.6	4741.61	10.6	6497.79	14.4
Cropland	28715.01	63	29,188.19	64.3	29,763.01	65	23576.18	51.7	20985.16	46

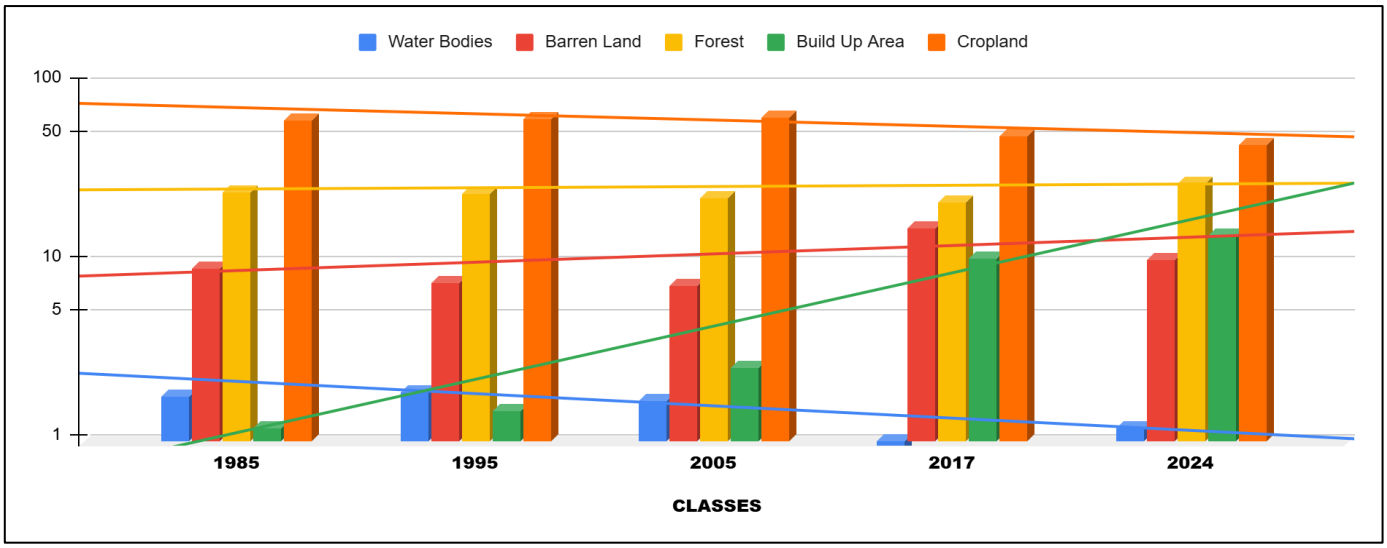

Chart 1 Trend of Landuse Landcover Classes Over the Period

➢ *Accuracy Assessment*

The Land Use Land Cover (LULC) classification for the Kongu Nadu region was evaluated for accuracy using ground verification and reference data within Google Earth Engine Pro. This cloud-based platform facilitated precise assessment by leveraging high-resolution satellite imagery. The accuracy assessment ensures that the classification results are reliable for environmental planning and resource management in the region.

➢ *Confusion Matrix Summary*

A confusion matrix was generated to compare the classified LULC map with reference data. The assessment included four LULC classes: C_2, C_5, C_7, and C_{11}, with a total of 20 samples distributed across the classes. The results are summarized below (Table - 3):

Table 3 Classification Accuracy Results

Class	Reference Samples	Correctly Classified Samples	Producer's Accuracy	User's Accuracy
C_2	3	3	100 %	100 %
C_5	13	13	100 %	100 %
C_7	2	2	100 %	100 %
C_{11}	2	2	100 %	100 %

- *Accuracy Metrics* –

The following metrics were derived from the confusion matrix to assess the performance of the LULC classification:

- *Overall Accuracy* –

Overall accuracy was calculated as the ratio of correctly classified samples to the total samples:

$$\textbf{Overall Accuracy} = \frac{\textbf{Total Correct Classifications}}{\textbf{Total Samples}}$$

$$= \frac{20}{20} = \mathbf{100}\ \%$$

- *Producer's Accuracy* –

Producer's accuracy evaluates the likelihood of correctly classifying reference samples for each class. All four LULC classes (C_2, C_5, C_7, and C_{11}) achieved 100% producer's accuracy.

- *User's Accuracy* –

The user's accuracy assesses the reliability of each class in the classified map. All classes recorded 100% user accuracy, indicating that there were no misclassifications.

- *Kappa Coefficient* –

The kappa coefficient measures the agreement between the classification and the reference data while accounting for chance. The kappa value for the Kongu Nadu LULC classification is **1**, indicating perfect agreement.

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➢ *Role of Google Earth Engine Pro*

The ground verification process was performed using Google Earth Engine Pro. This platform enabled efficient access to historical and current imagery, ensuring the accuracy of reference data and validation points across the region. The combination of robust geospatial algorithms and accurate reference data contributed significantly to the high accuracy metrics.

➢ *Urban Sprawl in Kongu Nadu*

Urban sprawl in the Kongu Nadu region has experienced remarkable growth over the years, as evident from the data spanning from 1985 to 2024. The table and graph highlight the significant transformation in urban area coverage, showcasing the rapid expansion of urbanization within the region. This surge in urban sprawl can be attributed to a combination of factors that have collectively contributed to the region's development and growth, marking a significant shift in the landscape of the Kongu Nadu region in recent decades (Map - 7, 8, 9, 10, and 11).

➢ *Trends in Urban Area Growth*

In **1985**, the urban area covered **478.03 km²**, which constituted only **4%** of the region's total area. This marked the baseline for urbanization in the study period.

By **1995**, urban expansion increased slightly to **696.11 km²**, accounting for **5%** of the total area. Although the growth was marginal, it set the stage for accelerated development in subsequent years.

A significant shift occurred in **2005**, where urban coverage rose to **1104.78 km²**, representing **8.6%** of the region. This phase indicated the early stages of rapid urbanization due to industrialization and population growth.

In **2017**, urban sprawl witnessed a dramatic rise to **4741.61 km²**, covering **34.9%** of the region. This sharp increase reflects the impact of infrastructural development, urban planning policies, and economic activities in the region.

By **2024**, urban sprawl reached its peak, with **6497.79 km²** of urban area, accounting for **47.5%** of the region's total area. This indicates almost half the region's land is now urbanized, signaling substantial environmental and socioeconomic changes (Table - 4).

➢ *Graphical Analysis*

- The graph portrays a steep upward trend in urban sprawl over the study period (Chart - 2):
- The **1985–1995** phase shows a gradual slope, indicating urban expansion during this period.
- The **1995–2005** phase depicts a slightly steeper slope, representing moderate growth.
- The sharp rise between **2005 and 2017** demonstrates an era of rapid urbanization and significant land use changes in the region.
- The continued upward trend from **2017 to 2024** signifies further expansion, with urban area growth stabilizing at a high rate.

➢ *Strategic Location* –

Kongu Nadu's strategic location plays a pivotal role in its urban development. The region is well connected to major cities within Tamil Nadu and neighboring states through an extensive network of roads, railways, and airways (Subramanian, 2018). This connectivity facilitates trade, transportation, and the movement of people, enhancing urbanization. Additionally, its proximity to the Western Ghats provides access to natural resources and trade routes, further boosting its economizing prospects.

➢ *Industrial Growth* –

Kongu Nadu is a recognized industrial hub, particularly for textiles, engineering, and manufacturing industries. Cities like Coimbatore, Erode, and Tiruppur are major centers for these industries (Ramesh & Kumar, 2020). The industrial growth in these areas not only generates employment but also attracts workers from rural and other regions, fueling urban expansion.

➢ *Agricultural and Economic Base* –

Historically, fertile soils and efficient irrigation systems supported by rivers such as the Kaveri, Bhavani, and Amaravathi have established agriculture as a strong economic foundation in the region (Gopalakrishnan, 2019). Over time, the transition from traditional agriculture to agro-industries has spurred economic diversification. The rise of agro-industrial complexes has been instrumental in supporting urban economic activities and infrastructure development.

➢ *Educational and Healthcare Infrastructure* –

The presence of reputed educational institutions and advanced healthcare facilities has made Kongu Nadu a preferred destination for education and medical services (Anand et al., 2021). This has led to migration from rural areas and other states, contributing to urban sprawl.

➢ *Climate and Geography* –

The semi-arid climate and relatively flat terrain of Kongu Nadu make it conducive for urban expansion. These geographic factors ease the development of infrastructure, including housing, transportation networks, and industrial zones (Nair & Devi, 2020).

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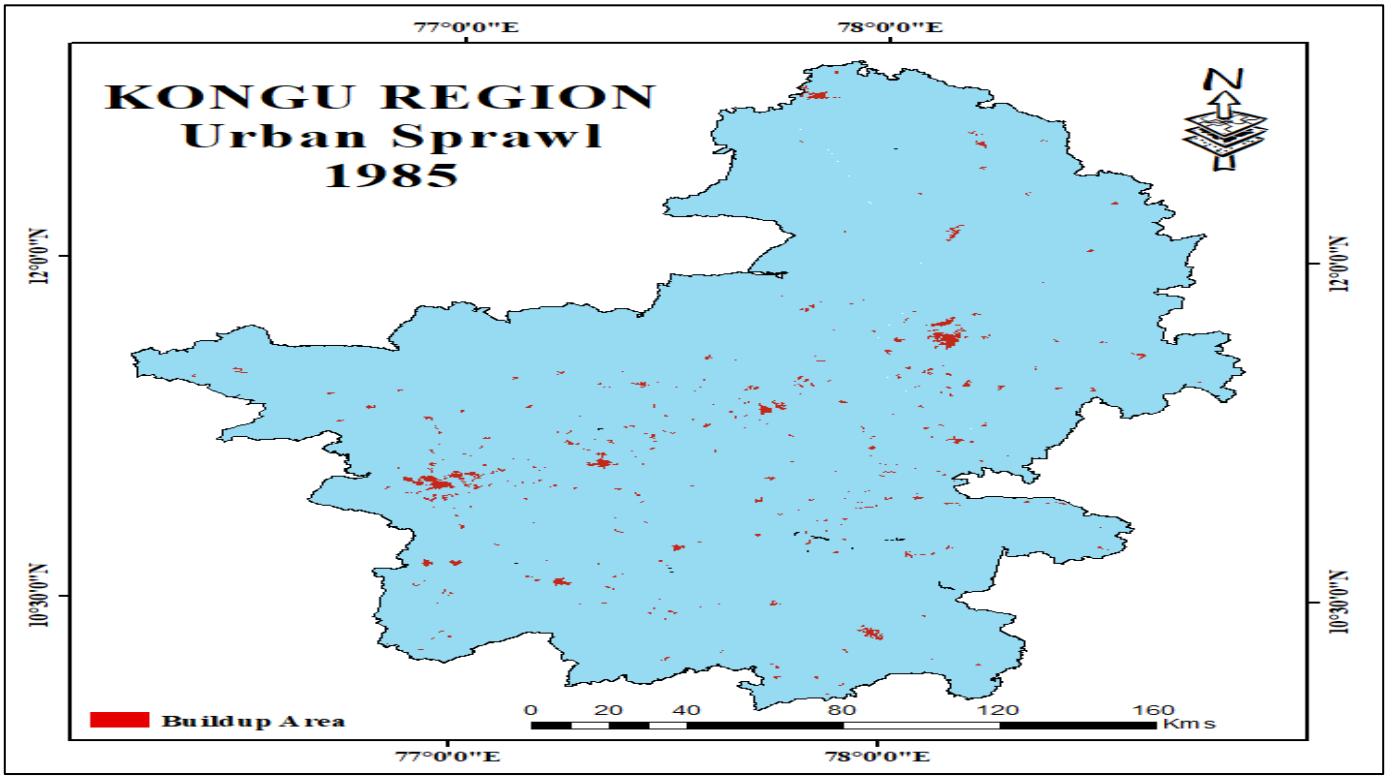
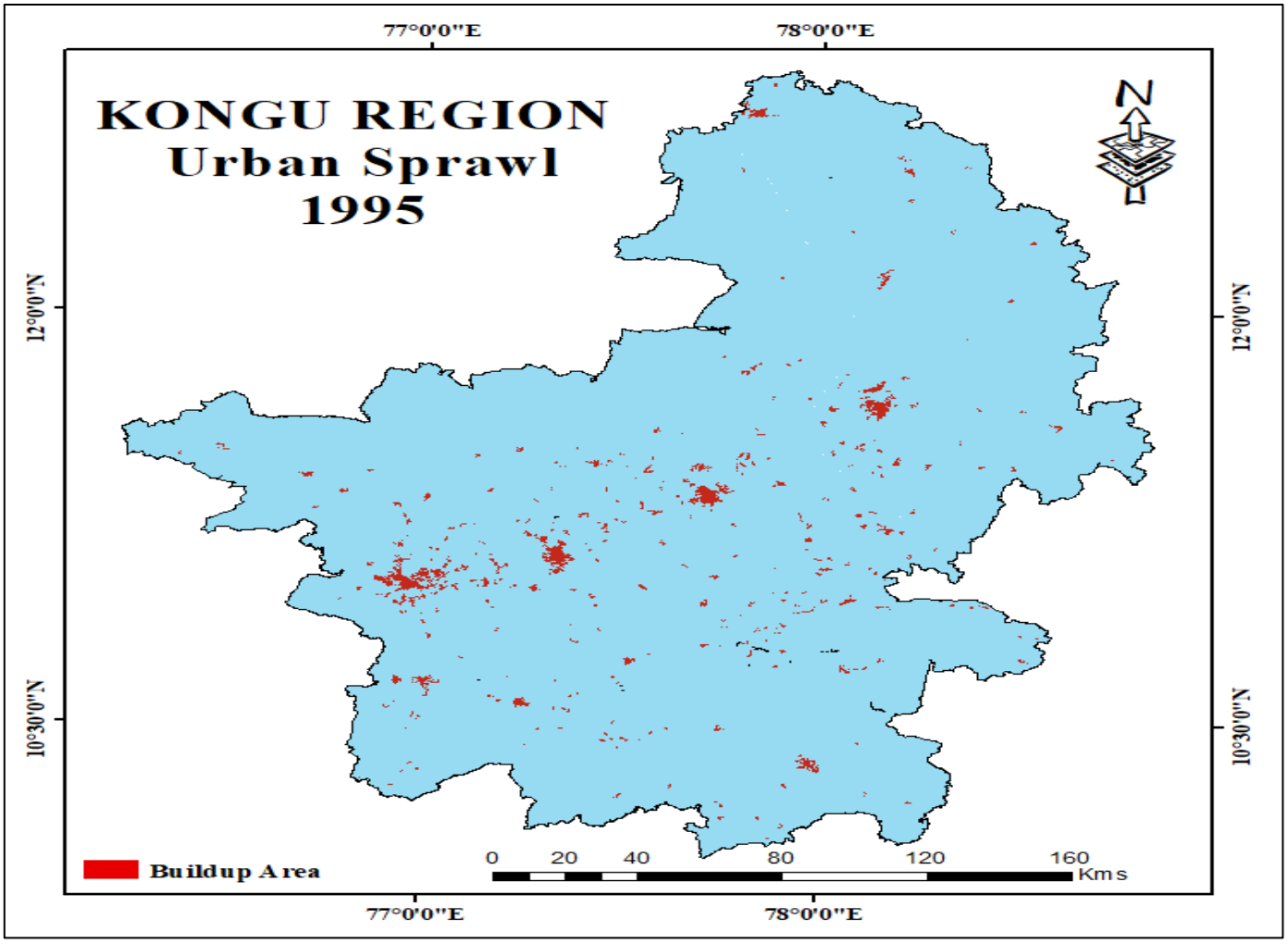


Map 7 Urban Sprawl – 1985



Map 8 Urban Sprawl – 1995

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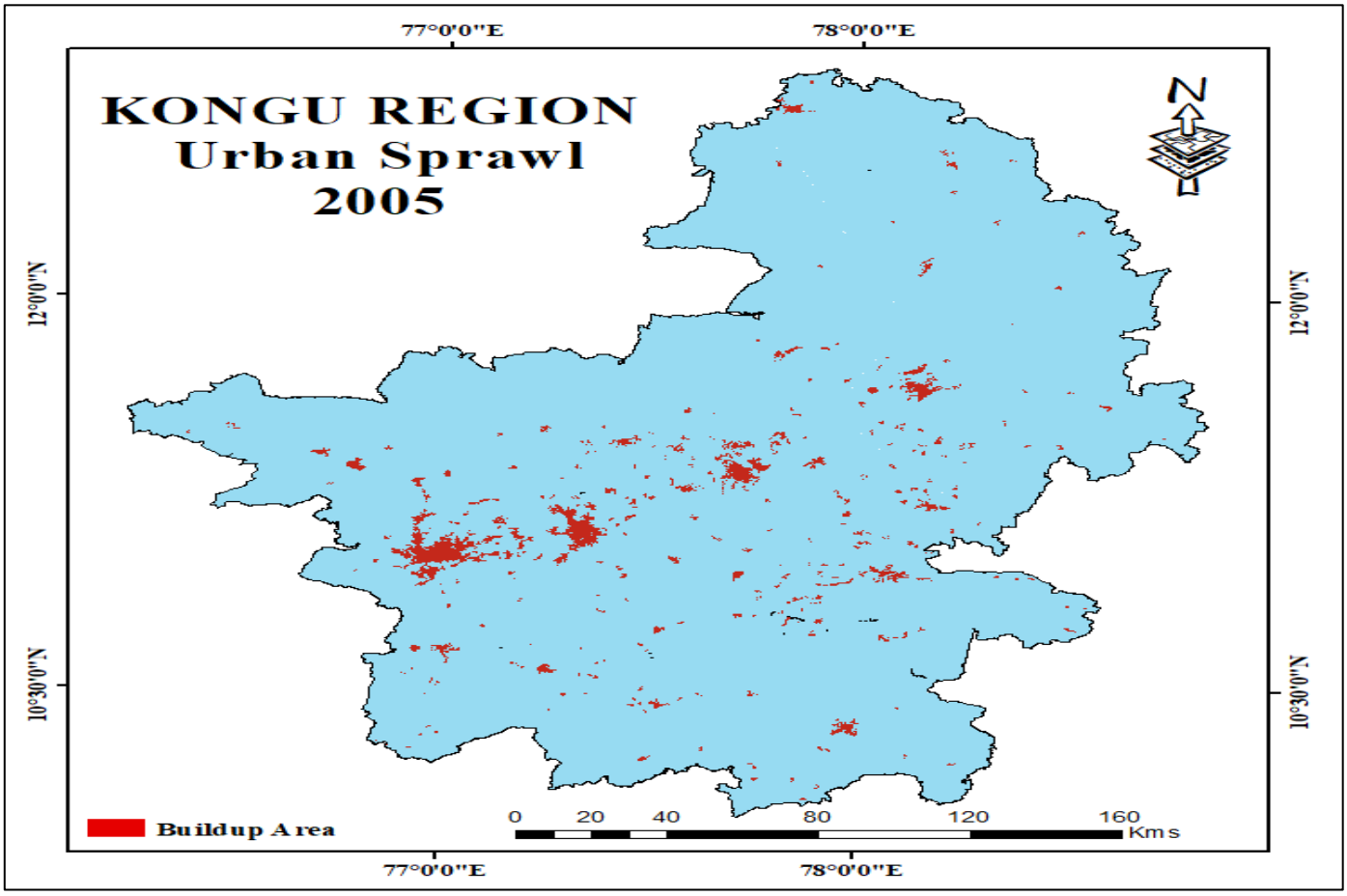
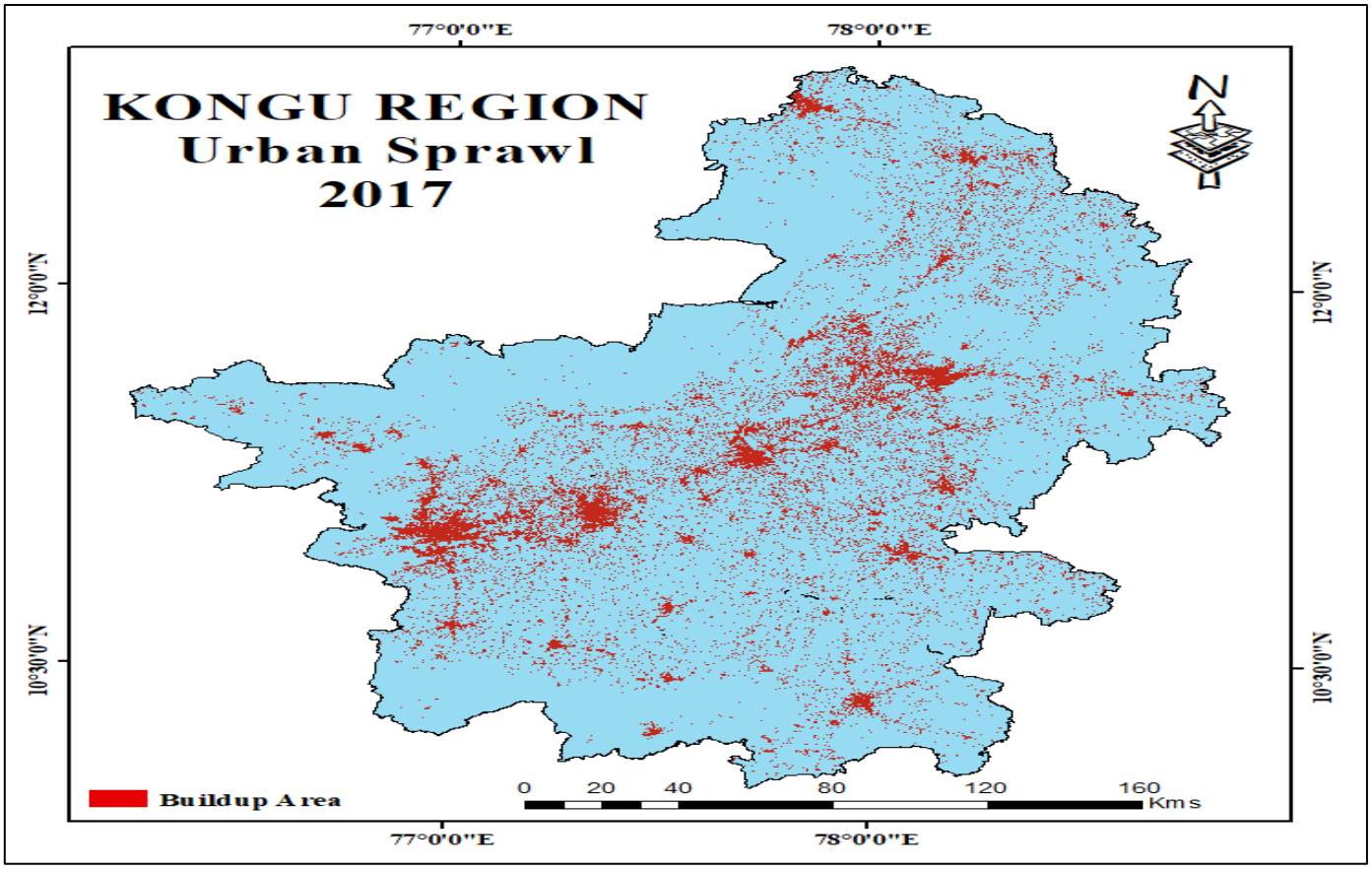


Map 9 Urban Sprawl – 2005



Map 10 Urban Sprawl – 2017

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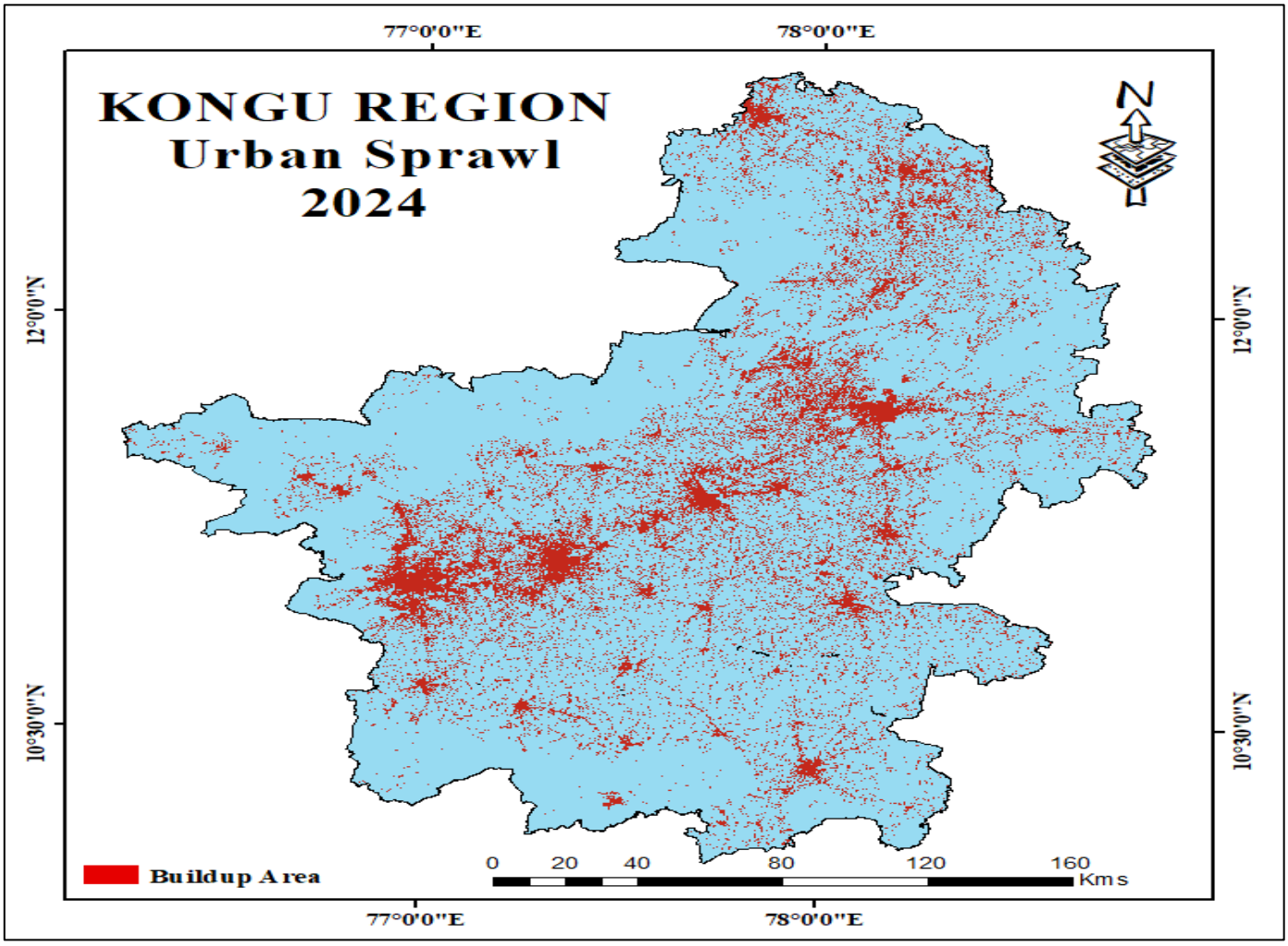

Map 11 Urban Sprawl – 2024

Maps 7, 8, 9, 10, and 11 show the Urban Sprawl of the Kongunadu Region for the years 1985, 1995, 2005, 2017, and 2024.

➢ *Entrepreneurial Culture* –

Kongu Nadu is renowned for its entrepreneurial spirit, which has driven the establishment of numerous small and medium-scale enterprises. These enterprises act as catalysts for urbanization by creating jobs and encouraging ancillary industries (Rajendran, 2018).

➢ *Government Policies and Initiatives* –

Government-led urban infrastructure projects, smart city initiatives, and the development of special economic zones (SEZs) in Kongu Nadu have accelerated urbanization. Policies aimed at improving transportation, housing, and industrial infrastructure have supported sustainable urban growth (Tamil Nadu Government Policy Report, 2023).

➢ *Migration and Population Growth* –

Migration from rural areas to urban centers such as Coimbatore and Tiruppur is a significant driver of urban development. The search for better livelihoods, education, and healthcare services motivates people to move to these cities, contributing to population growth and urban sprawl (Sundar & Velmurugan, 2022).

The urban sprawl in Kongu Nadu is a multi-faceted phenomenon driven by strategic location, industrial growth, agricultural and economic transitions, robust infrastructure, and government policies. The combination of these factors creates a dynamic environment conducive to rapid urbanization. Further studies and sustainable planning are essential to balance growth with environmental and social considerations.

Table 4 Urban Sprawl

YEAR	Urban Area in Km^2	%
1985	478.03	4
1995	696.11	5
2005	1104.78	8.6
2017	4741.61	34.9
2024	6497.79	47.5

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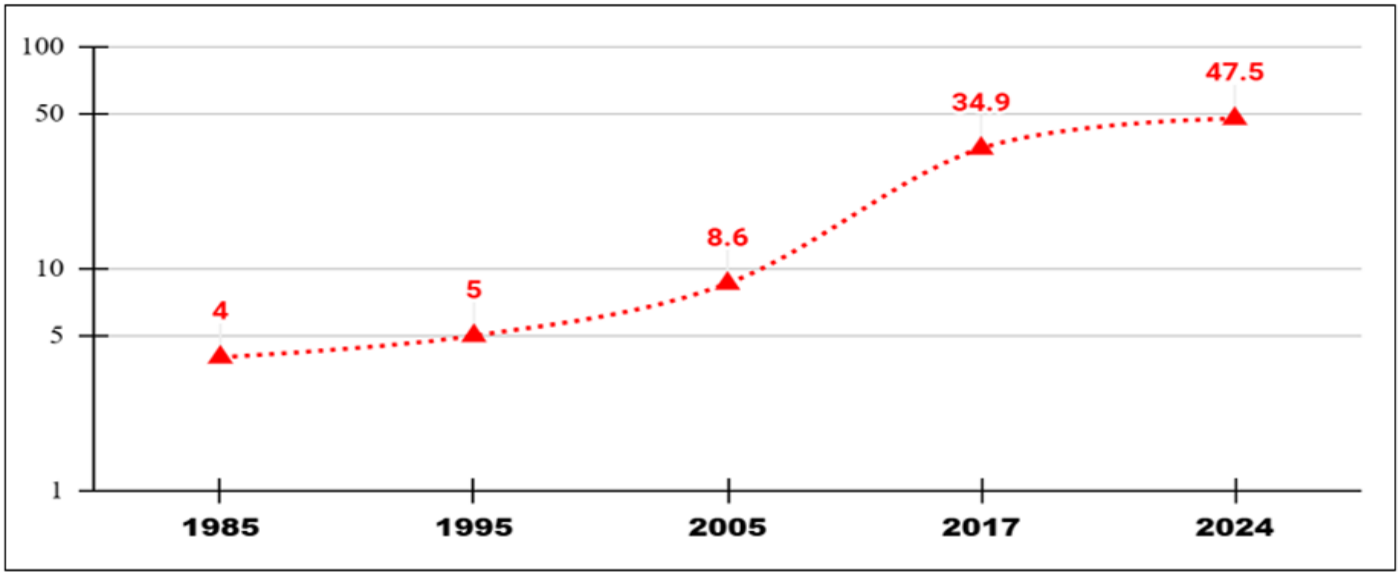

Chart 2 Direction or Trend of Urban Sprawl

Urban sprawl in the Kongu Nadu region has shown a remarkable increase over the years, as reflected in the data from 1985 to 2024. The table and graph illustrate the transformation in urban area coverage, highlighting the rapid growth and expansion of urbanization within the region.

IV. CONCLUSION

The Kongu Nadu region has experienced significant urban expansion from 1985 to 2024, profoundly transforming its land use and land cover dynamics. Urbanized areas grew dramatically, from a mere 1.2% of the total area in 1985 to 14.4% in 2024, driven by industrialization, population growth, and infrastructure development. This urbanization has come at the expense of cropland, forest cover, and water bodies, highlighting a critical trade-off between development and environmental sustainability.

The study's findings underscore the urgent need for sustainable urban planning and resource management. Proactive measures, such as afforestation programs, water body conservation, and policies promoting balanced land use, are vital to mitigating the adverse impacts of rapid urbanization. Furthermore, leveraging advanced remote sensing and GIS tools for continuous monitoring and informed decision-making can play a pivotal role in achieving sustainable growth.

In conclusion, while urbanization in Kongu Nadu has catalyzed economic and social development, it also presents significant challenges to the region's ecological balance. A collaborative approach involving policymakers, urban planners, and local communities is essential to ensure that development aligns with environmental conservation goals, securing a sustainable future for the region.

➢ *Declaration*

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