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Research Article

Spatial Expansion of Urban Land Use in the Eastern Economic Corridor Area: Case Study in Si Racha District, Chonburi Province, Thailand

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ABSTRACT

This study examines the spatial expansion of urban land use in Si Racha District, Chonburi Province, a strategic area within Thailand's Eastern Economic Corridor (EEC). Land use and land cover (LULC) changes for the years 2016, 2019, and 2023 were analysed using Sentinel-2 satellite imagery and Geographic Information System (GIS) techniques. A supervised classification method was applied to categorize land use into five types: urban and built-up areas, agricultural areas, forest areas, water bodies, and miscellaneous areas. The classification yielded high accuracy, with Kappa coefficients exceeding 0.80. The results revealed a significant and continuous increase in urban and built-up areas, expanding from 161.48 km² (26.53%) in 2016 to 190.01 km² (31.11%) in 2023, primarily at the expense of agricultural and forested lands. Urban expansion followed two dominant patterns: linear development along major transportation routes—such as Sukhumvit Road and Motorway No. 7—and clustered growth around key centres, including Si Racha Municipality, the Thai Oil industrial complex, Laem Chabang Industrial Estate and Port, and the Sahaphat Group Industrial Park. To predict future urban development, the Cellular Automata–Markov (CA–Markov) model was applied. The model projected a 39.81% increase in urban areas by 2027, accompanied by a notable decline in forest and agricultural zones. The anticipated growth is expected to radiate outward from existing developed areas and along major infrastructure networks. These findings provide valuable insights for urban planning and policy formulation within the EEC, supporting efforts to balance urban growth with the sustainable conservation of natural and agricultural resources.

Keywords: urban expansion, land use change, CA-Markov, Si Racha, EEC, Thailand

INTRODUCTION

Urban expansion represents a complex and dynamic phenomenon influenced by factors such as population growth, economic development, migration, and evolving land use patterns. This phenomenon is particularly evident in developing countries, where cities face increasing pressure from rapid socio-economic changes. The resulting urban growth often leads to significant transformations in ecosystems, natural resource consumption, and overall quality of life.

Within the framework of sustainable development, managing urban expansion necessitates strategic and well-informed planning to mitigate its long-term impacts, particularly those that may hinder progress toward Sustainable Development Goal (SDG) 11, which promotes inclusive, safe, resilient, and sustainable cities. However, in many regions, urban growth remains largely unplanned, resulting in challenges such as overcrowded slums, environmental degradation, inefficient land use, and unequal infrastructure distribution (Angel, 2023; Li, 2020).

Urban expansion can be analysed through various interrelated drivers, including demographic shifts, economic activities, infrastructure development, planning policies, and environmental factors. Advances in geospatial

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Research Article

technologies—such as Geographic Information Systems (GIS), Remote Sensing, and satellite imagery—have enabled researchers to monitor and interpret land use changes with increasing accuracy (Zeng et al., 2018; Pan et al., 2022; Zhang et al., 2020). Notably, remote sensing tools like Sentinel-2 satellites offer high-resolution data essential for tracking urban sprawl over space and time. When integrated with GNSS and GIS-based spatial analysis, these technologies provide valuable insights for strategic urban planning (Tonsiri et al., 2018).

Case studies from China have demonstrated the importance of location-specific drivers of urban expansion. For example, population density has been a key factor in the growth of the Xiamen-Zhangzhou-Quanzhou region (Liu, 2024), while economic indicators such as GDP and industrial investment have shaped land use patterns in eastern coastal region of China (Chen et al.,2018). Infrastructure, particularly road network density, has also played a critical role in accelerating urban development in the Jing-Jin-Ji cluster and eastern coastal areas (Wu et al., 2019).

In Thailand, Chonburi Province—particularly Si Racha District—has experienced rapid urban expansion due to structural economic transformation driven by national development policies. A key mechanism behind this transformation is the Eastern Economic Corridor (EEC), a strategic initiative designed to stimulate macroeconomic growth while inducing dynamic changes at the local level. The EEC encompasses three provinces: Chonburi, Chachoengsao, and Rayong, and follows a multidimensional development agenda focusing on economic advancement, infrastructure, technology, education, and human resource development. This initiative aims to prepare the country for the emerging economic paradigm known as the "New S-Curve Industries" (Eastern Economic Corridor Office of Thailand, 2021).

Si Racha District, in particular, has witnessed continuous population growth alongside industrial expansion, notably through the development of large-scale industrial estates such as Laem Chabang and Pinthong. This growth has led to significant land use changes, with agricultural and mangrove areas being transformed into commercial, industrial, and residential zones (Eastern Economic Corridor Office of Thailand, 2021; Chonburi Provincial Statistical Office, 2024). According to population statistics, the number of residents increased from 1,483,049 in 2016 to 1,618,066 in 2023, reflecting a growth rate of 9.1% (Chonburi Provincial Statistical Office, 2024). Concurrently, the Gross Provincial Product (GPP) rose from 897,452 million baht in 2016 to 1,173,449 million baht in 2022. Data from the Chonburi Provincial Development Plan (2023–2027) indicate that, as of 2020, the province's economy was predominantly industrial (56.2% of GPP), followed by services (41.8%), while the agricultural sector contributed only 2% (Chonburi Provincial Office, 2024).

This study aims to analyse land use changes in Si Racha District during the years 2016, 2019, and 2023 by utilizing Sentinel-2 satellite imagery integrated with GIS analysis. The research focuses on examining the spatial patterns of urban expansion and forecasting future urban growth using the CA-Markov model. The findings are expected to contribute to sustainable urban development planning at the local level, in alignment with the Sustainable Development Goals (SDGs), and serve as a model for similar studies in other areas.

METHODS

Study Area

This study was conducted in the administrative district of Si Racha, located in Chonburi Province within the Eastern Economic Corridor (EEC) development zone. The geographic coordinates of the study area range approximately from 13°10′ North latitude to 100°55′ East longitude, covering a total area of 612.76 km². Si Racha District consists of eight sub-districts: Si Racha, Surasak, Thung Sukhla, Boeng, Nong Kham, Khao Khansong, Bang Phra, and Bo Win.

Data Collection

The primary dataset used in this research comprises Sentinel-2 satellite imagery obtained from the United States Geological Survey (USGS, 2023) for three time points: 2016, 2019, and 2023. The imagery provides a spatial resolution of 10 meters and sufficient positional accuracy for land use change analysis. Additional secondary data were collected from relevant government agencies and are summarized in Table 1.

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Research Article

Table 1. Summary of secondary data sources used in this study

	Scale	Source
Administrative boundary data	1:50,000	Royal Thai Survey Department
Transportation network data	1:50,000	Royal Thai Survey Department
Land use data	1:25,000	Land Development Department

Satellite Image Analysis

All satellite imagery was geometrically corrected to ensure positional accuracy using the Universal Transverse Mercator (UTM) coordinate system with the WGS 1984 reference datum. Root Mean Square Error (RMSE) was controlled within one pixel to enhance the reliability of subsequent analyses.

Land use and land cover classification were performed using supervised classification techniques. The classification followed land use type definitions established by the Land Development Department (2024), which categorized land use into five classes: (1) Urban and built-up areas, (2) Agricultural areas, (3) Forest areas, (4) Water bodies, and (5) Miscellaneous areas.

Classification accuracy was evaluated using random sampling within each land use class. These samples were compared against ground truth data to construct an error matrix and calculate the Kappa Index, which measures the level of agreement between classification results and reference data. The interpretation criteria for the Kappa Index are as follows: Kappa > 0.80: High accuracy, 0.40 ≤ Kappa ≤ 0.80: Moderate accuracy, and Kappa < 0.40: Low accuracy. The Kappa Index was calculated using the formula:

$$Kappa = \frac{(P_o - P_e)}{(1 - P_e)} \quad (1)$$

Where: P_o is the observed accuracy

P_e is the expected accuracy by chance

Urban Expansion Pattern Analysis and Forecasting

Land use and land cover (LULC) maps for the years 2016, 2019, and 2023 were analysed within a GIS to identify spatial patterns of urban growth. Transition matrices were generated for the periods 2016–2019 and 2019–2023 to assess land use transitions over time.

This study adopts the Cellular Automata–Markov (CA-Markov) model to simulate and forecast urban expansion in Si Racha District. This hybrid model integrates temporal transition probabilities from Markov Chain analysis with the spatial dynamics of Cellular Automata, enabling estimation of future land use proportions and their spatial distribution. The model has proven effective in similar contexts worldwide, including Surat, India (Sheladiya & Patel, 2023), Wuhan, China (Yi et al., 2022), and Fortaleza, Brazil (Oliveira et al., 2022).

Given the significant land use transitions in Si Racha—driven by infrastructure investments, industrial expansion, and population growth—the CA-Markov model is well-suited for projecting urban growth trajectories. Land use data from 2016 and 2019 were used to generate a transition probability matrix, while 2023 data were used to calibrate and validate the model. The simulation outputs provide spatial projections of urban expansion for the year 2027. These results are expected to support planners and policymakers in anticipating land demands, minimizing conflicts, and promoting sustainable development (Douandji et al., 2025).

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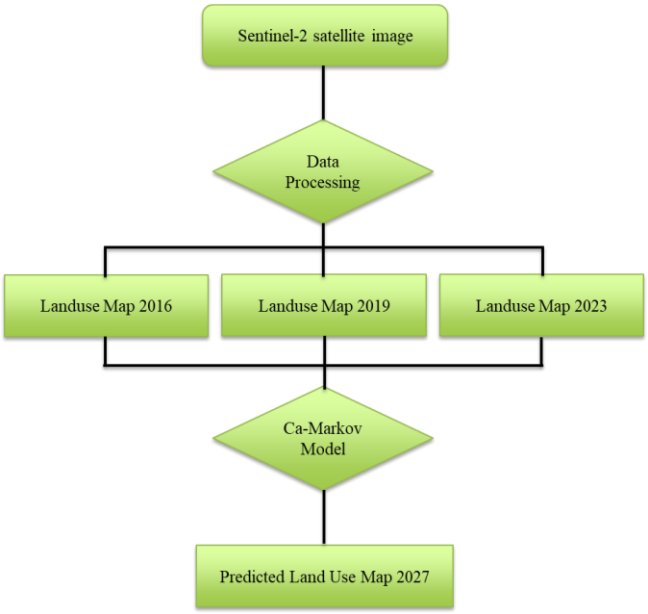

Figure 1. Conceptual Framework

RESULTS AND DISCUSSION

Land Use and Land Cover Classification (2016–2023)

The analysis of land use and land cover (LULC) changes in Si Racha District between 2016, 2019, and 2023 reveals a consistent pattern of urban expansion at the expense of agricultural and forested areas. The supervised classification yielded high overall accuracy with Kappa Index values exceeding 0.80 for each year, indicating reliable classification performance.

The supervised classification of Sentinel-2 satellite imagery revealed significant spatiotemporal changes in land use and land cover patterns across the Sriracha district from 2016 to 2023 (Table 2). Urban and built-up areas revealed a steady and continuous increase throughout the study period, increasing from 161.48 km² (26.35% of total area) in 2016 to 174.91 km² (28.54%) in 2019, and further to 190.63 km² (31.11%) in 2023—representing a cumulative increase of 29.15 km² (4.76% of total land area) over seven years.

Concurrently, agricultural and forest areas experienced substantial contraction. Agricultural land decreased from 146.76 km² (23.95%) in 2016 to 140.88 km² (22.99%) in 2019, and further to 132.27 km² (21.59%) in 2023, reflecting a total loss of 14.49 km² (2.36%). Forest areas declined even more markedly, from 261.89 km² (42.74%) in 2016 to 252.18 km² (41.15%) in 2019, and to 236.57 km² (38.61%) by 2023—representing a reduction of 25.32 km² (4.13%).

Conversely, water bodies exhibited a slight increase from 19.98 km² (3.26%) in 2016 to 21.28 km² (3.47%) in 2023. Miscellaneous areas recorded the second-highest rate of increase after urban areas, expanding from 22.65 km² (3.70%) in 2016 to 32.01 km² (5.22%) in 2023, a net increase of 9.36 km² (1.52%).

The reliability of the classification results was validated through accuracy assessment, with overall accuracy values ranging from 83.42% to 86.80% across the three datasets. The Kappa coefficient ranged from 85.07% to 85.63%, which, according to Landis and Koch (1977), indicates "almost perfect" agreement between the classification results and ground reference data, thereby providing a robust foundation for subsequent change analysis.

Journal of Information Systems Engineering and Management
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Research Article

Table 2. Land Use and Land Cover (LULC) in 2016, 2019, 2023 and Changes Over Time

Land Use / Land Cover Type	Area						Change (2016–2019)		Change (2019–2023)	
	2016		2019		2023					
	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)
Urban and Built-up Area	161.48	26.35	174.91	28.54	190.63	31.11	+13.43	43.07	+15.72	32.45
Agricultural Area	146.76	23.95	140.88	22.99	132.27	21.59	−5.88	-18.86	−8.61	-17.77
Forest Area	261.89	42.74	252.18	41.15	236.57	38.61	−9.71	-31.14	−15.61	-32.23
Water Bodies	19.98	3.26	20.44	3.34	21.28	3.47	+0.46	1.48	+0.84	1.73
Miscellaneous Area	22.65	3.70	24.35	3.98	32.01	5.22	+1.70	5.45	+7.66	15.82
Total	612.76	100.0	612.76	100.0	612.76	100.0	+31.18	100.0	+48.44	100.0
Overall Accuracy	86.80		83.42		86.45					
Kappa Coefficient	85.63		85.07		85.60					

* (+) indicates an increase in area, (–) indicates a decrease in area

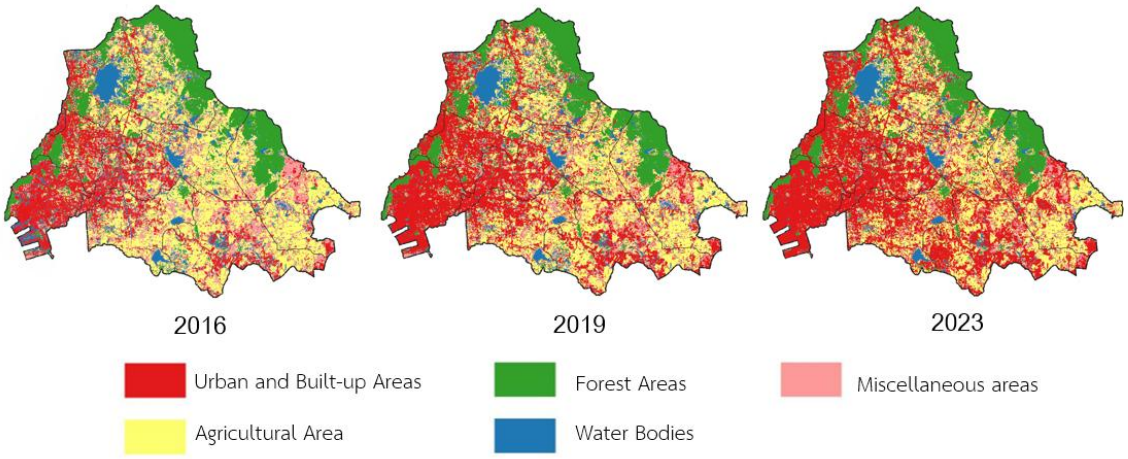

Figure 2. Land Use and Land Cover Map in Si Racha District (2016–2023)

Urban Expansion Patterns in Si Racha District

The spatial analysis of urban expansion in Si Racha District, based on land use and land cover (LULC) data from 2016, 2019, and 2023, reveals a dynamic transformation in both settlement morphology and spatial configuration.

In 2016, two predominant settlement patterns were identified: first, linear development following major transportation corridors, including Sukhumvit Road (Highway No. 3), Motorway No. 7, and Highways 331 and 3241; and second, clustered urbanization within four strategic zones—Si Racha Municipality, the surrounding petrochemical industrial clusters, Laem Chabang Industrial Estate and Port, and the Saha Group Industrial Park.

By 2019, while the overarching pattern of linear and clustered development remained, significant spatial shifts emerged. Infill development became increasingly evident within the existing transportation grid, particularly in Surasak Subdistrict, where a proliferation of new housing estates illustrated intensified land use. Urban growth extended further along both primary and secondary roads, most notably along Motorway No. 7 and Highway No. 331, indicating a growing functional integration between transportation infrastructure and land development—an observation consistent with polycentric urban expansion theory, which emphasizes decentralization and infrastructure-driven growth (Zhao & Liu, 2023).

Journal of Information Systems Engineering and Management
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Research Article

By 2023, industrial development remained a key catalyst for urban expansion, especially in the subdistricts of Nong Kham, Bo Win, Bueng, and Khao Khansong. These areas witnessed a substantial increase in secondary road construction and early signs of vertical expansion, as evidenced by the emergence of condominiums and multi-storey apartment buildings. The built environment became increasingly dense, with new residential developments constructed to accommodate the expanding labour force—a trend that aligns with global findings on employment-driven urban growth in peri-urban zones (Li et al., 2023) (Figure 3).

The observed spatiotemporal patterns in Si Racha mirror broader global urban expansion trends, wherein cities evolve in response to economic restructuring, industrial agglomeration, and transportation investment. This process supports the notion of wave-like urban development patterns and spatial diffusion models proposed in recent urban growth literature (Zhang et al., 2022; Seto et al., 2023). Overall, these findings illustrate how the interplay between infrastructure and industrial development continues to reshape urban morphology within the Eastern Economic Corridor (EEC), contributing to a complex yet traceable urban transformation trajectory.

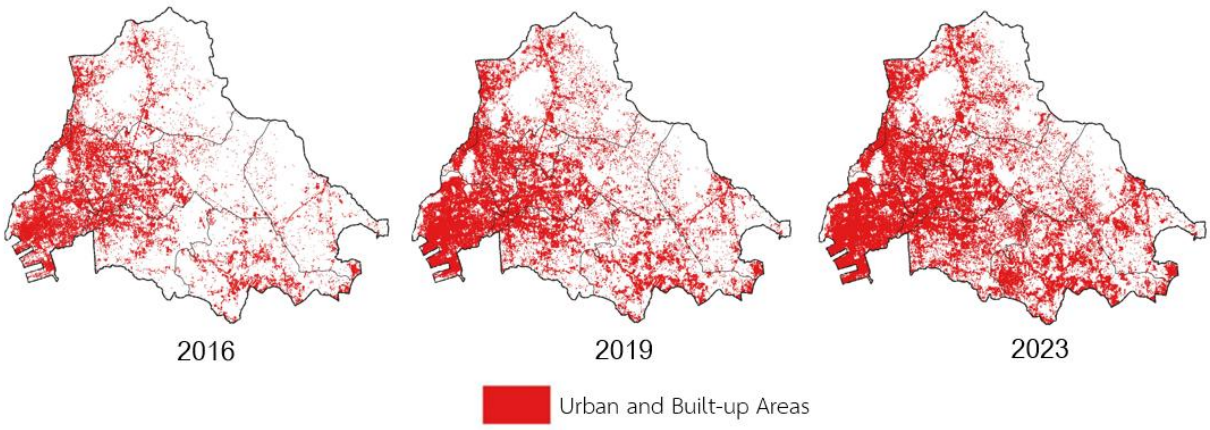

Figure 3. Urban Expansion Patterns in Si Racha District from 2016 to 2023

Urban Expansion Forecast in Si Racha District

Based on the CA-Markov model's projection of land use and land cover (LULC) in Si Racha District for the year 2027, the study indicates a significant increase in urban and built-up areas. These are expected to expand from 190.63 km² (31.11%) in 2023 to 248.78 km² (40.60%) in 2027—an increase of 58.15 km², or 39.81%. This trend underscores the accelerating pace of urbanization and the growing demand for industrial development, infrastructure, and built environments.

Conversely, forested areas are projected to decline substantially, decreasing from 236.57 km² (38.61%) to 173.38 km² (28.30%), representing a reduction of 63.19 km² or 43.26%. Similarly, agricultural land is expected to decline from 132.27 km² (21.59%) to 122.42 km² (19.98%), a decrease of 9.85 km² or 6.74%. These reductions are largely attributed to land conversion driven by urban and industrial expansion.

Water bodies, on the other hand, are projected to increase slightly from 21.28 km² (3.47%) to 22.39 km² (3.65%), an increase of 1.11 km² or 0.76%. This slight growth may reflect ongoing efforts in water resource management and the development of water infrastructure to meet the needs of a growing urban population. Additionally, miscellaneous land uses are expected to increase from 32.01 km² (5.22%) to 45.78 km² (7.47%), an increase of 13.77 km² or 9.43%, suggesting continued diversification in land development activities.

These projected changes underscore the urgency for sustainable urban planning and land management policies, especially in rapidly transforming regions such as the Eastern Economic Corridor (EEC). The findings align with recent studies that have applied CA-Markov models in similar contexts, demonstrating their utility in urban growth forecasting and land use scenario analysis (Tahir et al., 2025; Chey et al., 2023).

Journal of Information Systems Engineering and Management
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Research Article

Table 3. Urban Expansion Forecast in Si Racha District for the Year 2027 Based on the CA-Markov Model

Land Use/Land Cover Types	Area					
	2023		2027		changes	
	km²	(%)	km²	(%)	km²	(%)
Urban and Built-up Area	190.63	31.11	248.78	40.6	58.15	39.81
Agricultural Area	132.27	21.59	122.42	19.98	-9.85	-6.74
Forest Area	236.57	38.61	173.38	28.30	-63.19	-43.26
Water Bodies	21.28	3.47	22.39	3.65	1.11	0.76
Miscellaneous Area	32.01	5.22	45.78	7.47	13.77	9.43
Tota	612.76	100.0	612.76	100.00	146.07	100.00

* (+) indicates an increase in area, (–) indicates a decrease in area

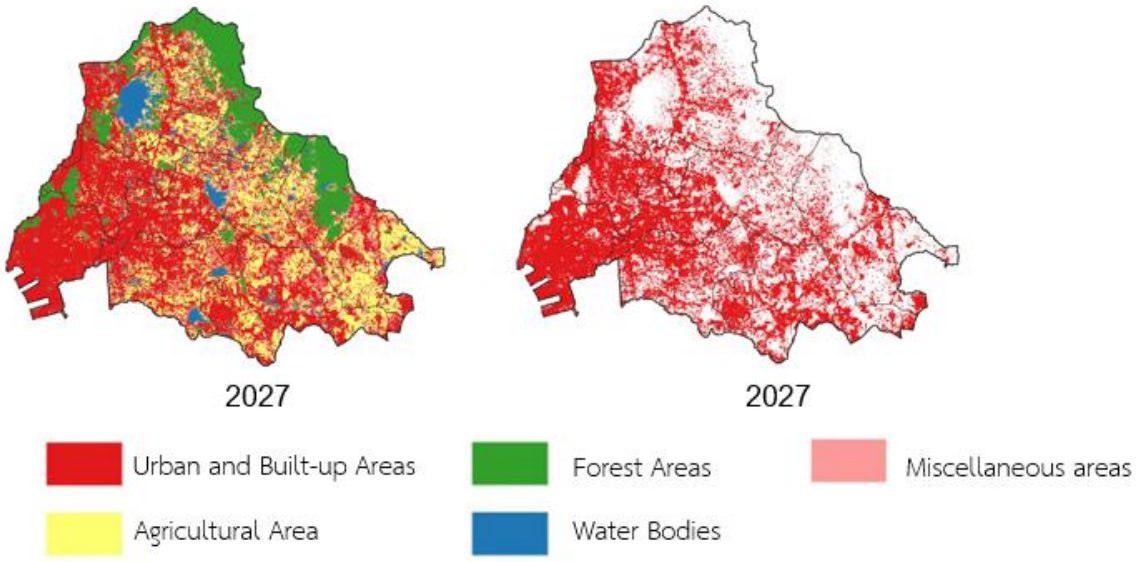

Figure 4. CA-Markov-Based Land Use and Urban Expansion Projection in 2027

CONCLUSION

This study aimed to analyse land use changes and urban expansion patterns in Si Racha District, Chonburi Province, within the context of Thailand's Eastern Economic Corridor (EEC), utilizing Sentinel-2 satellite imagery and Geographic Information System (GIS) analysis from 2016 to 2023. A supervised classification method was employed to categorize five land use types: urban and built-up areas, agricultural areas, forest areas, water bodies, and miscellaneous areas.

The results indicate that between 2016 and 2023, urban and built-up areas increased by approximately 29.15 km², reflecting a continuous transformation driven by industrial growth, infrastructure development, and demographic changes. Concurrently, a notable reduction in agricultural and forested areas was observed, highlighting the trade-offs associated with rapid urbanization.

Urban expansion exhibited two primary patterns: linear development along major transportation corridors, such as Sukhumvit Road and Motorway No. 7, and clustered development around four key urban centres—Si Racha Municipality, the Thai Oil industrial zone, Laem Chabang Industrial Estate and Port, and the Sahapat Industrial Park.

Projections generated through the CA-Markov model forecast a further increase in urban land to approximately 39.81% by 2027. This growth is expected to follow a pattern of urban sprawl radiating from existing developed zones into surrounding rural areas, especially those in close proximity to key infrastructure such as highways and industrial estates. In contrast, a continued decline in agricultural and forest land is anticipated, reflecting the pressures of rapid urbanization on natural and semi-natural landscapes.

The findings underscore the critical necessity for proactive land use planning and policy intervention to mitigate environmental degradation and ensure sustainable urban development. In alignment with Sustainable Development Goal 11, which promotes inclusive, safe, resilient, and sustainable cities, this study emphasizes the need for proactive urban governance to balance economic growth with environmental conservation. The Si Racha case exemplifies the spatial consequences of policy-driven development and offers insights for managing urbanization in similar rapidly developing regions.

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