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Figure 01: Spatially Planned New Town

Integrated GIS-MCDA Approach for Planning Sustainable Urban Development in Trincomalee, Sri Lanka

Why Urban Planning Matters in Trincomalee

Trincomalee District, home to Sri Lanka's largest natural harbor, is undergoing rapid urban growth. While development brings economic opportunities, unplanned expansion can place heavy pressure on infrastructure, agricultural lands, and environmentally sensitive areas. Problems such as traffic congestion, loss of green spaces, flooding, and informal settlements often emerge when cities grow without clear spatial guidance.

To avoid these challenges, urban growth needs to be planned, informed, and evidence based. Identifying where development should happen is just as important as deciding how it should happen. This study focuses on supporting that decision-making process by using modern geospatial tools to identify the most suitable areas for future urban development in the Trincomalee District.

A Sri Lankan study reveals that the Analytical Hierarchy Process (AHP) and Geographic Information System (GIS) were utilized to evaluate the land suitability [1]. The Iranian study demonstrates that the Weighted Linear Combination (WLC) method with limiting factors serves as critical [2]. The Turkish study integrates Remote Sensing (RS) and Geographic Information System (GIS) techniques to analyze the data [3]. Building on these experiences, this study adapts a GIS-based suitability analysis framework specifically to the local environmental and socio-economic conditions of Trincomalee.

How Maps and Satellites Support Better Planning

Modern urban planning increasingly relies on RS and GIS techniques.

- Remote Sensing refers to satellite-based observations of the Earth, which help capture land use patterns, urban heat conditions, and environmental changes.

- Geographic Information Systems allow planners to store, analyze, and combine different types of spatial data on maps.

In this study, GIS was used to process and analyze multiple spatial factors such as land use, terrain slope, proximity to roads and services, flood-prone areas, and building density. These layers were derived from sources including satellite imagery, Digital Elevation Models (DEMs), and OpenStreetMap (OSM) data.

By integrating all these layers, GIS enables planners to see the big picture, something that is extremely difficult to achieve using traditional planning methods alone.

Study Area - Trincomalee District

The research focused on the Trincomalee district, which covers about 2,727 square kilometers and is home to more than 379,000 people. Urban growth is currently concentrated around Trincomalee town and along major transport corridors and the coastline, with new development often encroaching on vulnerable environments.

Because this expansion is already underway, the study's goal was practical: to provide a clear, map-based guide that local authorities can use to steer new housing, services, and infrastructure towards the most suitable land.

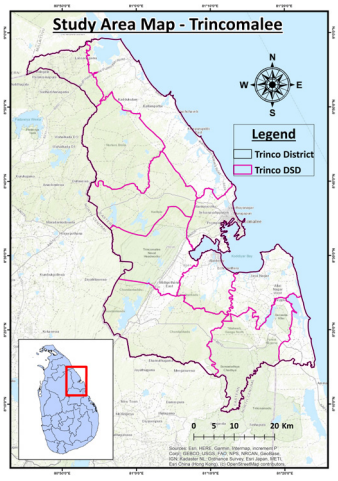

Figure 02: Study Area

Turning Many Factors into One Clear Map

Urban development suitability was assessed using ten key factors, grouped under environmental, physical, and socio-economic themes:

	1. LULC	2. DISTANCE TO FACILITIES	3. DISTANCE TO TOWNS	4. ENVI. SENSITIVE AREAS	5. SLOPE	6. DISTANCE TO ROADS	7. FLOOD FREQUENCY	8. SOIL TYPE	9. BUILDING DENSITY	10. UHI	EIGENVECTOR
1. LULC	1	1	2	4	5	6	8	9	9	9	26.98%
2. DISTANCE TO FACILITIES	1	1	1	3	4	5	7	8	8	9	22.25%
3. DISTANCE TO TOWNS	1/2	1	1	2	3	4	6	7	7	8	17.78%
4. ENVI. SENSITIVE AREAS	1/4	1/3	1/2	1	1	2	4	5	6	7	9.79%
5. SLOPE	1/5	1/4	1/3	1	1	1	3	4	5	6	7.71%
6. DISTANCE TO ROADS	1/6	1/5	1/4	1/2	1	1	2	3	4	5	5.59%
7. FLOOD FREQUENCY	1/8	1/7	1/6	1/4	1/3	1/2	1	1	3	4	3.45%
8. SOIL TYPE	1/9	1/8	1/7	1/5	1/4	1/3	1	1	1	2	2.44%
9. BUILDING DENSITY	1/9	1/8	1/7	1/6	1/5	1/4	3	1	1	1	1.94%
10. UHI	1/9	1/9	1/8	1/7	1/6	1/5	4	1/2	1	1	1.66%

Figure 03: Key factors and the respective AHP Matrix

Each factor was converted into a raster map with a 10 m spatial resolution and standardized to a common suitability scale ranging from 1 (least suitable) to 5 (most suitable).

To assign relative importance to each factor, the study applied the AHP, which is a structured decision-making technique that incorporates expert judgment. The consistency of expert judgments was tested, resulting in a Consistency Ratio (CR) of 4.3%, which indicates reliable weighting. Figure 03 illustrates the Pairwise comparison matrix developed in this study.

The final suitability map was produced using a weighted overlay analysis, where all factors were combined according to their assigned importance.

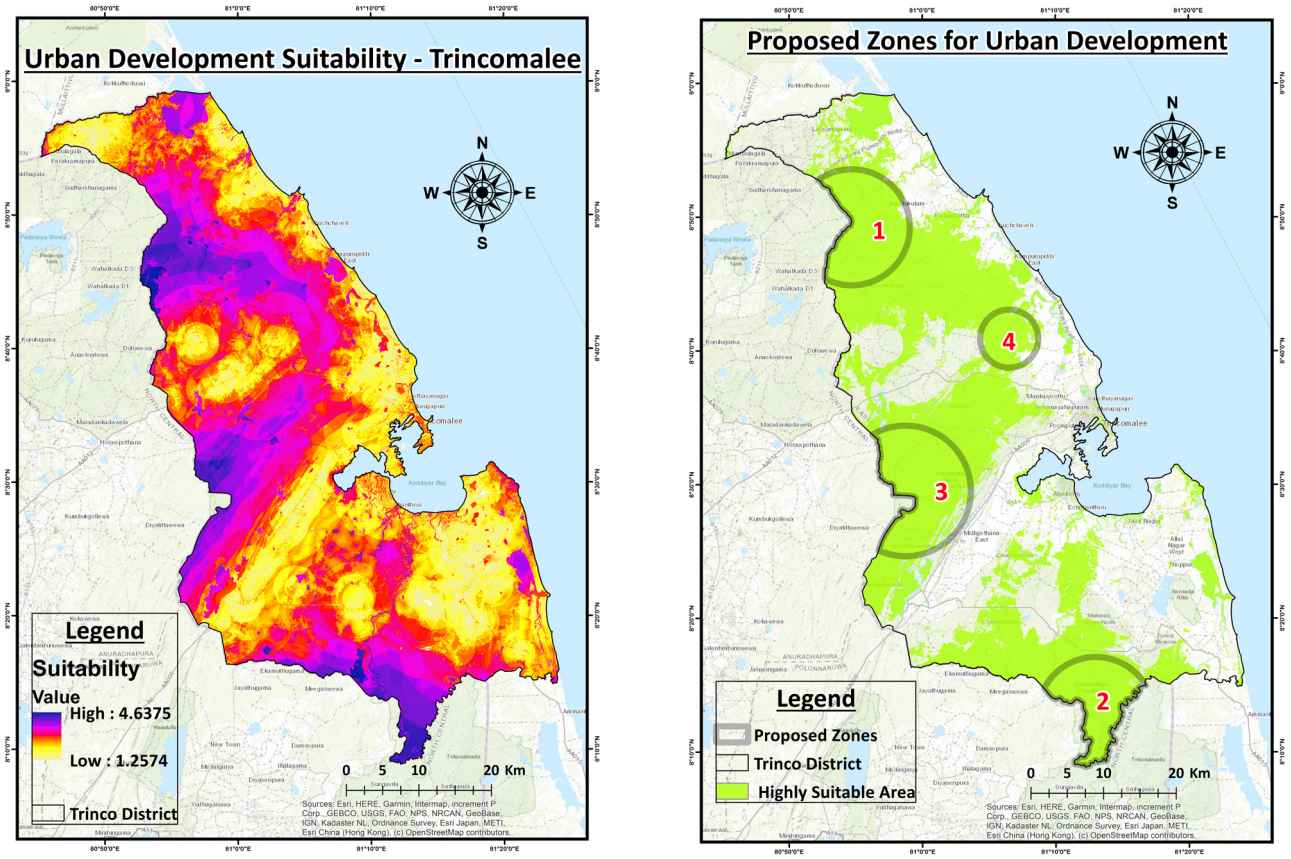

Figure 04: Suitability Map & Proposed Zones for Urban Development

What the maps reveal

The final suitability map, illustrated by Figure 04, groups the Trincomalee District into three broad planning zones: highly suitable, moderately suitable, and not suitable for urban development. Quantitative analysis shows that approximately 1,332.5 km² of the total area, representing lands with a suitability score above the mean (> 2.63), is deemed 'highly suitable' for urban development.

Many of these high-potential lands are in the Kuchchaveli and Town Gravets Divisional Secretariat Divisions, with Grama Niladhari Divisions such as Kanniya, Paalathoppur, and Kappalthurai standing out as particularly promising. Based on the spatial continuity of these highly suitable areas, the analysis further identifies four priority zones that have strong potential to accommodate future urban centres, offering planners clearly defined locations for phased development while minimizing pressure on environmentally sensitive and hazard-prone areas.

Why this matters for Sustainable Urban Development

This study demonstrates how combining multiple spatial datasets into a single, easy-to-interpret map can support smarter urban planning decisions. Instead of relying on fragmented information, planners can use the suitability map as a guidance tool to:

- Direct development toward safer and more appropriate locations
- Reduce pressure on environmentally sensitive and hazard-prone areas
- Support balanced growth across the district

By identifying over 1,300 km^2 of highly suitable land, the results provide a practical foundation for planning future residential, commercial, and infrastructure developments in Trincomalee.

Conclusion

Study successfully identified over 1,300 km^2 of appropriate land for sustainable urban development within the Kuchchaveli and Town Gravets divisions in the Trincomalee district, integrating with the Geographic Information Systems (GIS) with Analytical Hierarchy Process (AHP). Future research will be focused on the validation of the suitability map using the Kappa coefficient and the area under the curve (AUC). Further study aims to evolve future urban development predictive modeling by integrating Cellular Automata (CA) and Markov models to simulate future land use changes and make proactive decisions for the long-term development of the region.

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Article by

Hashana Senevirathne, Chamod Wijesiri, Thirilojanan Keerthi

Department of Textile and Apparel Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka.