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A Systematic Review of Land Use Plan Effectiveness and GIS-Based Compatibility in Cox's Bazar, Bangladesh

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ABSTRACT

Guided by the PRISMA framework, a systematic literature review provides a precise, reliable, and structured way to synthesize existing research. Using this method, this study evaluates the effectiveness of land-use planning and GIS-based compatibility in Cox's Bazar, Bangladesh, a coastal region facing rapid urbanization and ecological vulnerability. Despite existing master plans, intense development pressure has led to significant incompatibility between designated zones and realized uses. Using the PRISMA framework, this study analysed 33 peer-reviewed articles sourced from Scopus and Google Scholar. Moving beyond simplistic conformance measures in advanced GIS and remote sensing methods, this review advocates adopting more innovative tools to quantify spatial development compatibility, using multi-criteria evaluation frameworks that have emerged internationally. The findings indicate that such innovative tools have not been used in spatial analysis in Cox's Bazar and also show that land-use plan effectiveness is driven by political and institutional rigidity, weak legal enforcement, and economic pressures, rather than purely technical flaws. The study identifies two critical gaps: the lack of spatially explicit models linking actual land-use deviations to functional planning goals in Cox's Bazar, and the weak institutional integration of drivers into spatial disparity analysis. To improve compliance, this study suggests integrating non-compensatory geospatial evaluation tools with adaptive management frameworks focused on governance analysis, converging both theory and practice towards sustainable urban management in Cox's Bazar.

Keywords: Spatial analysis, integration of geospatial tools into governance frameworks, Cox's Bazar spatial planning, land-use planning, quantifying spatial development compatibility, and spatial planning and management.

1. INTRODUCTION

Rapid urbanization in Bangladesh is driving land-use changes, particularly in major economic hubs and the ecologically sensitive southeast coastal region, including Cox's Bazar. [1,2] Moreover, such urbanization, characterized by high population density and uncontrolled urban expansion, including the conversion of agricultural land, encroachment on wetlands, and haphazard development, challenges environmental sustainability and social life. [3,4] Historical analysis also confirmed that diverse socioeconomic conditions and political influences are

significantly responsible for this rapidly unplanned transformation, which limits the achievement of planned objectives at the local level. [1,2,5,6]

Cox's Bazar, as a fast-growing tourist and administrative centre, presents a critical case where intense development pressure directly conflicts with sensitive coastal and hilly ecosystems. Despite a legal master plan, the outcomes of land-use development are likely marked by significant incompatibility between designated zones and realized uses, necessitating a rigorous evaluation of the plan's effectiveness.

However, current plan evaluations often rely on simplistic conformance measures in GIS and Remote Sensing methods. However, a quantitative assessment for Cox's Bazar is critical to inform local governance and address non-compliance [7]. This situation calls for bridging the performance-conformance divide by employing sophisticated, spatially explicit, multi-criteria methodologies (MCE/AHP) to quantify development compatibility rather than merely measuring spatial differences. [8]

This review emphasized the urgent need to move beyond merely measuring change to quantitatively assessing the quality of spatial development against explicit policy goals. Therefore, the objectives in this review focused on evaluating the extent of deviation between planned designations and realised land use in Cox's Bazar. It also concerns advanced geospatial multi-criteria evaluation tools assessing functional compatibility, as well as the key institutional, political, and socioeconomic challenges that influence deviations and mismatches during plan implementation in Cox's Bazar. To achieve these specific objectives, this review focused on a systematic literature review that synthesized 33 peer-reviewed articles and identified future research opportunities. The analysis period is defined as 1985–2024, aligning with the lifespan of recent master planning efforts in Bangladesh. By focusing on Cox's Bazar, the review contributes evidence-based insights into how spatial planning can be made more effective in ecologically sensitive, rapidly urbanizing regions of the Global South.

2. MATERIALS & METHODS

This review adheres to the PRISMA 2020 guidelines, which stand for Preferred Reporting Items for Systematic Reviews and Meta-Analyses. PRISMA is a widely recognized tool that promotes transparency in reporting and facilitates replication by other researchers. By following its step-by-step checklist, this review effectively collects and presents all available evidence related to the specific research question. [9,10]

2.1. Search Strategy and Identification

The identification stage involved a comprehensive search across major academic databases. Scopus and Google Scholar were selected for their robust coverage of peer-reviewed journals in the fields of Urban Planning, Land Use Policy, Remote Sensing, and Environmental Management. The core search terms were developed around the key concepts of the research:

- Concept/Outcome: Land Use Plan/Spatial Plan, Land Use Compatibility, Evaluation methods, Effectiveness, Challenges in Decision-making and Implementation.
- Methodology/Tool: GIS, Remote Sensing, AHP, Multi-criteria Evaluation (MCE).
- Context: Cox's Bazar, Bangladesh, Developing Countries, Third World, Global South, South Asian Countries.

This search was limited to articles published between 1985 and 2024 to capture both foundational planning concepts (mid-80s onwards) and the current state-of-the-art methodology, yielding an initial pool of records.

Initially, 87 articles were selected through this process. Then, some exclusion criteria were applied in the identification stage:

- Language: It should be published in English.
- Publication Type: Publication must be peer-reviewed journal articles and book series (excluding conference proceedings).

After doing that, 66 articles were found for screening.

2.2. Screening and Eligibility

The eligibility of the identified records was determined through a rigorous three-step screening process:

First step: Initial Screening:

Records were screened based on the following criteria:

- Relevance (Title & Abstract): Article should directly address a topic related to land use planning evaluation, implementation effectiveness, GIS/RS tool to determine LULCC (land use/land cover change), or compatibility assessment.

Through applying this, 41 articles were found among 66 articles.

Second step: Inclusion Criteria:

Full-text articles passing the initial screen were retrieved and assessed against detailed inclusion criteria:

- Article must focus on the study of Bangladesh or a country facing similar institutional/socioeconomic constraints (e.g., China-comparative, Iran, Global South case studies).
- Article must present a methodology for quantitative assessment (e.g., RS time-series, LULC modeling, multi-criteria Evaluation) to evaluate the effectiveness of the spatial plan.
- Article must provide in-depth analysis of planning implementation challenges (e.g., political interference, data deficiency, conformance/performance divide).

Third step: Exclusion Criteria:

Articles were excluded if they met any of the following:

- Articles that focus exclusively on technical ecological models (e.g., hydrological modeling) without linking results to land use policy/planning decisions.
- Articles provide purely descriptive LULC change without analyzing drivers, policy effectiveness, or suitability/compatibility.

Finally, 33 articles were selected after applying the exclusion criteria; 22 were from Scopus and 11 from Google Scholar.

2.3 Data Extraction

A total of 33 articles were selected for final inclusion. Data was systematically extracted and coded into a structured matrix using the following fields, directly aligning the review with the research objectives:

Table 1: Data fields for extraction

Data Field	Description & Alignment with Research Objectives
Title	Includes the title of the research article
Author (Year)	Standard bibliographical information (APA 6th style).
Sources / DOI	Journal name/Publisher and digital object identifier.
Abstract	Background, objective, key findings, and conclusion
Study Characteristics	Geographical area studied (to establish relevance to Cox's Bazar).
Eligibility Criteria	Specific justification for inclusion criteria based on relevant objectives, methods, or context to the Cox's Bazar study's aims.
Data Collection Process	Specific methods, models, and data sources used

2.4 PRISMA Flow Diagram

The flow of articles through the review process is detailed in the PRISMA diagram below, illustrating the number of records identified, screened, assessed for eligibility,

and finally included in the quantitative synthesis.

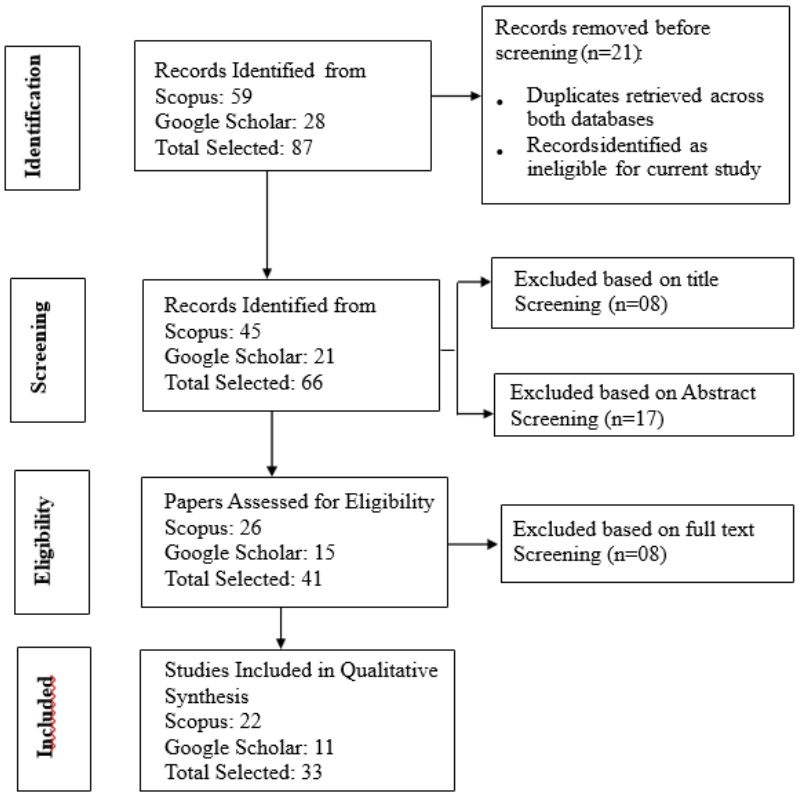

Figure 1: PRISMA Flow Diagram

2.5 Reviewing process

This study used a review method guided by [11] to analyze the selected articles. The process involved constant back-and-forth. The data was reviewed to spot emerging patterns, and then the articles were revisited to refine those ideas. This repeated comparison helped build a much richer, more accurate understanding of the land-use planning literature.

The following codebook has been developed to systematically analyze and synthesize the 33 articles selected for the Systematic Literature Review (SLR) on land use planning, with a specific focus on challenges and methodologies relevant to the Cox's Bazar region in Bangladesh.

The primary goal of this coding exercise is to move beyond mere summarization and establish a structured framework for comparative analysis. This framework ensures consistency in data extraction, facilitates the identification of patterns and research gaps, and ultimately enhances the credibility and reproducibility of the final review.

The articles, drawn from various reputable sources including Scopus-Indexed journals (e.g., Science of The Total Environment, Land Use Policy, Sustainability) and key Google Scholar publications, are categorized into two hierarchical levels:

- **First Level Codes (Descriptive):** These are precise, subject-specific codes that capture the explicit content or methodology of each paper (e.g., "LULCC Monitoring & Projection," "Land Use Conflict & Compatibility," "Planning Implementation & Governance").
- **Second Level Codes (Analytical):** These are broader, thematic codes that group the first-level codes into core analytical themes (e.g., "LULCC Dynamics & Trends," "Planning Methods & Models," "Policy & Plan Effectiveness"). These themes will serve

as the major sections for synthesizing the literature review findings.

2.5.1 1st Level Code:

Table 2: 1st level code

Code	Explanation	Articles Covered (listed in the references)
LULCC Monitoring & Projection	Studies focused on detecting and forecasting land-use/land-cover changes using Remote Sensing (RS) and GIS.	(1, 2, 3, 4, 6, 12, 13, 14, 18, 22, 34)
Land Suitability Assessment	Articles that determine the appropriateness of land for a specific use (e.g., residential, urban) using spatial models.	(15, 16, 30)
Land Use Policy/Plan Evaluation	Research that assesses the effectiveness, consistency, or compatibility of existing land use policies, systems, or master plans.	(7, 8, 19, 26, 27, 29, 31, 33, 36)
Land Use Conflict & Compatibility	Studies that identify, measure, or optimize the spatial relationship between different land uses (e.g., urban vs. agriculture).	(17, 20, 21, 25)
Multi-Criteria Evaluation (MCE) / Optimization	Methodologies that use multiple criteria (e.g., AHP, ELECTRE, MOLA) to support spatial decision-making and plan optimization.	(15, 16, 17, 20, 23, 30, 31, 32, 35)
Planning Implementation & Governance	Analyses of the political, socioeconomic, and institutional factors that drive or hinder the execution of land use plans.	(5, 8, 24, 25, 26, 29, 34)
Drivers of LULCC	Studies that quantify the socioeconomic, environmental, or climate-related drivers of land-use change.	(2, 14, 18)
Classification System Inconsistency	Research focused on problems with the definition and standardization of land use classification across institutions/regions.	(28)

2.5.2 2nd Level Code:

Code	Explanation	Grouped First-Level Codes
LULCC Dynamics & Trends	Focuses on the spatial and temporal analysis of land-use change, its drivers, and its impact on the region. This provides the context for the planning problem.	LULCC Monitoring & Projection, Drivers of LULCC, Classification System Inconsistency
Planning Methods & Models	Focuses on quantitative and innovative approaches to land-use planning, optimization, and spatial allocation. This covers the tools for better planning.	Multi-Criteria Evaluation (MCE) / Optimization, Land Suitability Assessment, Land Use Conflict & Compatibility
Policy & Plan Effectiveness	Focuses on how existing policies and plans are assessed, including their successes and failures, and the conceptual frameworks used for evaluation. This addresses the 'why' and 'what' of policy outcomes.	Land Use Policy/Plan Evaluation
Implementation & Governance	Focuses on the non-technical, political, and socio-economic factors that affect the adoption and implementation of land-use plans in developing-country contexts. This covers the how and who of plan execution.	Planning Implementation & Governance

3. RESULT

The result section provides a comprehensive overview of 33 articles in a structured manner, starting with year-wise article distribution, followed by geographic coverage, article focus areas, thematic focus, methodological trends, and research design focus.

3.1 Year-wise article distribution

The analysis of the 33 selected articles revealed a noticeable increase in scholarly attention over time. The number of studies has risen significantly in recent years. The most recent period, from 2015 to 2024, saw the highest number of articles, indicating that this topic is receiving considerably more attention currently. It also showed that, before 2010, most articles focused on governance critiques and early GIS/RS monitoring. Articles from 2010 to 2014 studied Land Use Land Cover Change, while recent articles have shown the rise of multi-criteria evaluation methods, advanced compatibility indices, and institutional analyses.

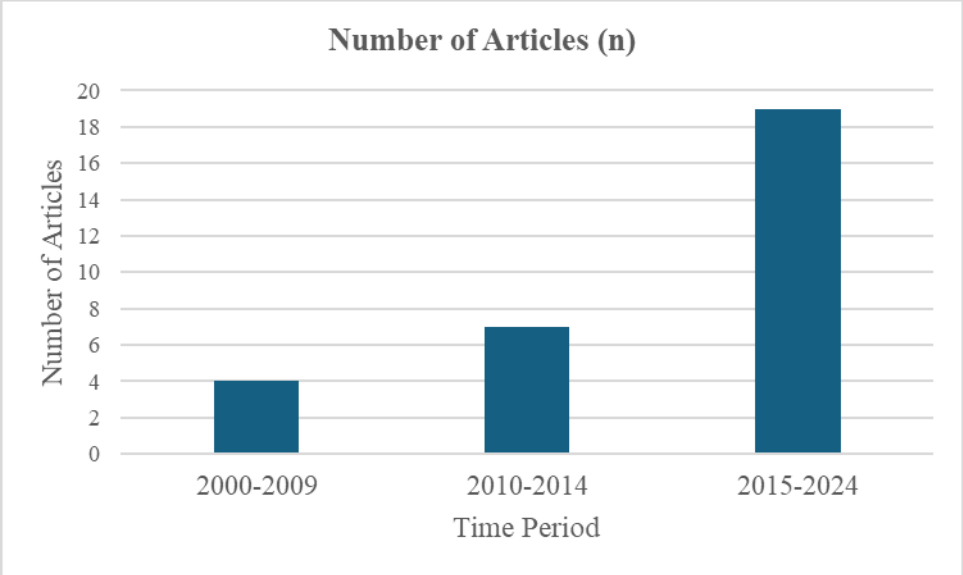

Figure 2: Number of year-wise article distribution

3.2 Continent-wise article distribution

Research is heavily focused on a few areas. Asia is the focus, accounting for a massive 70% of all articles. This is because land-use changes, rapid urbanization, and challenges in implementing planning are particularly acute in the Global South, including Bangladesh, China, and Iran. Europe is the next most significant area of study, with 12%.

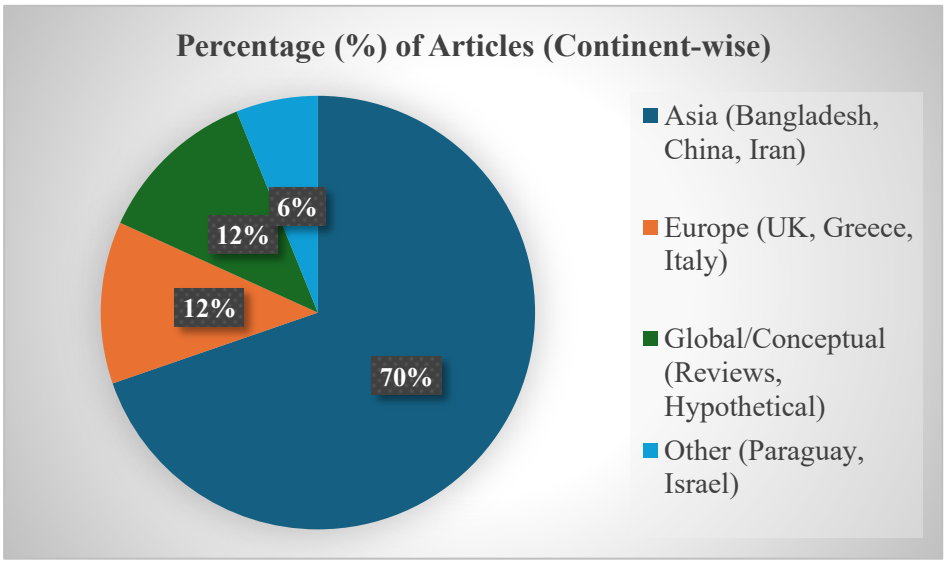

Figure 3: Percentage of Continent-wise articles

3.3 Articles Based on Spatial Scale of Analysis

The analysis of spatial scale reveals a relatively balanced distribution across the literature. Most studies operate at the macro-level (national, regional, or global reviews; 13 articles) and the meso-level (city-wide and municipal studies; 12 articles). Slightly fewer studies examine the micro-level, focusing strictly on site-specific, local, or small-town spatial dynamics (8 articles).

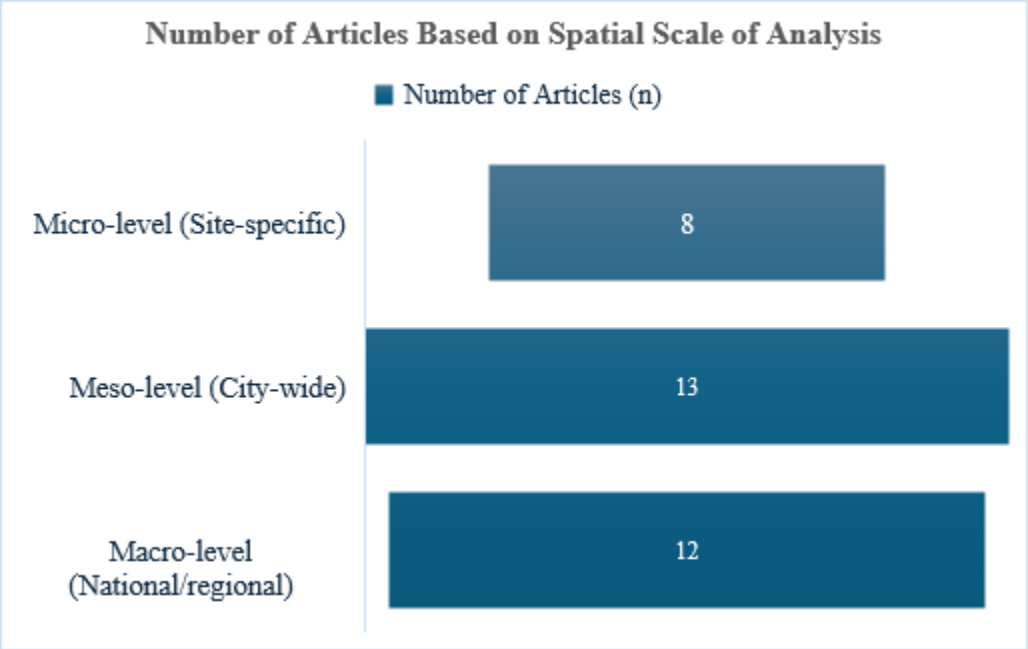

Figure 4: Number of Articles' study focus area

3.4 Thematic Focus area of articles

The most dominant focus areas are 'LULC Change/Monitoring/Prediction (using RS/GIS)' and 'Policy/Plan Evaluation & Implementation Effectiveness,' each featuring in 11 articles.

Table 3: Number of articles based on focus area

Focus Area	Number of Articles
LULC Change/Monitoring/Prediction (using RS/GIS)	11
Policy/Plan Evaluation & Implementation Effectiveness	11
Land Suitability & Zoning (GIS/AHP/MCE)	5
Land Use Compatibility/Mix (Measuring & Assessing)	4
Classification System Inconsistencies	1
Methodological/Conceptual Framework (Primary Focus)	1
Total	33

3.5 Methodologies Used in Different Articles

The studies mainly use primary data (new information collected by the researchers) and descriptive analysis (simple reporting of facts). Researchers prefer to gather fresh data for their studies.

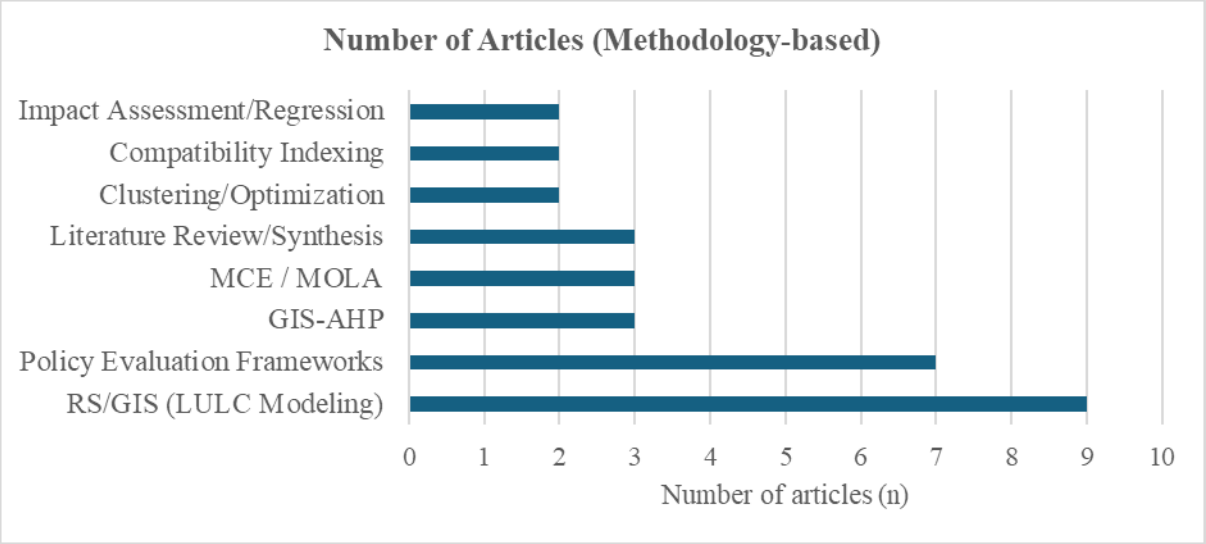

Figure 5: Number of articles using different methodologies

3.6 Articles Based on Research Design Method

Most researchers chose to use the Applied Case Study method, which involves examining a specific, real-world example to understand the issue at hand. This was the most common way to do research. The next most popular approach was Conceptual/Methodological work, in which researchers focus on developing new theories or research tools.

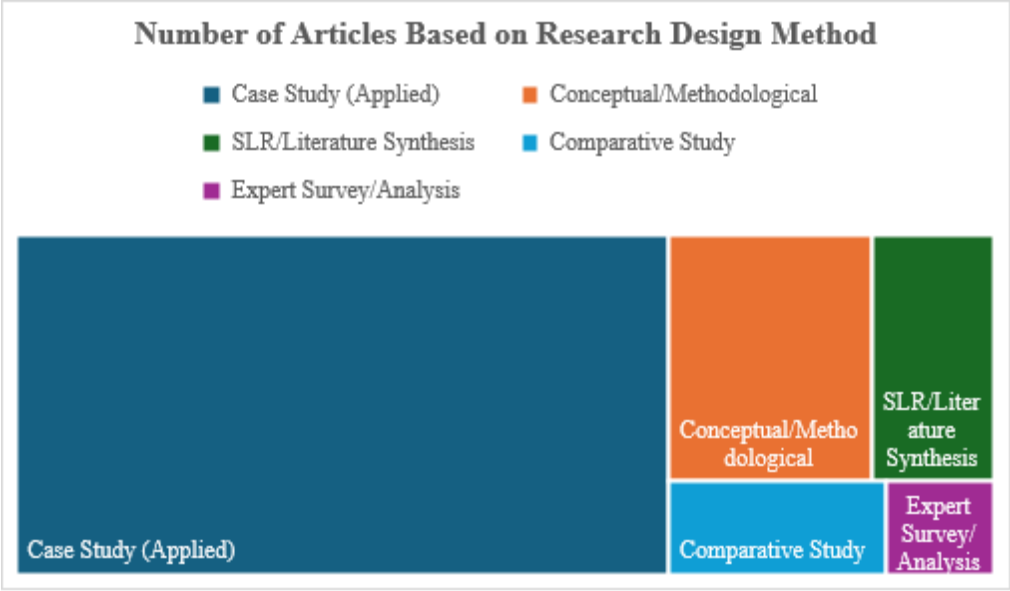

Figure 1: Number of Articles Based on Research Design Method

The structured results indicated that while many studies have concentrated on well-developed monitoring and evaluation methods across various domains, this study lacks a compatible model that links spatial mismatch to institutional drivers, which is particularly necessary in Cox's Bazar, Bangladesh.

4. DISCUSSION

The systematic literature review yielded 33 highly relevant articles, which were coded and synthesized to address the core objectives. The key findings are categorized based on thematic convergence, detailing methodological approaches, empirical observations of LULC dynamics, and

primary implementation challenges in developing countries.

4.1. Thematic Convergence in LULC Dynamics and Assessment Methodologies

The review confirms that the dominant LULCC trend in Bangladesh is rapid, unplanned urbanization. [4,12] This expansion has primarily consumed ecologically sensitive lands and intensified spatial planning challenges. Three thematic elements emerge:

- **Resource Consumption:** Studies across Dhaka, Chittagong, and Jashore show explosive built-up area expansion, achieved through sand-filling lowlands, wetland consumption, and encroachment on agricultural land. [4,13] A historical synthesis highlights that this land-hungry development is a national phenomenon dating back decades. [6]
- **Geospatial Modelling:** Quantitative LULC analysis relies heavily on advanced GIS/Remote Sensing (RS) techniques. High-accuracy models such as the Random Forest classifier, MLP Markov, and Cellular Automata (CA) are indispensable for capturing LULC changes and forecasting future growth trajectories. [1,13] Another study based on geospatial analyses confirms that Bangladesh's coastal regions, including Cox's Bazar, are undergoing severe spatial transformations, characterized by the rapid expansion of built-up areas. [14]
- **Compatibility Quantification:** There is a growing methodological shift toward quantifying functional compatibility and conflict. Key multi-criteria evaluation (MCE) tools include the Analytical Hierarchy Process (AHP) for land suitability mapping [15,16] and advanced metrics, such as the Functional Compatibility Degree Index (FCDI), to objectively measure spatial quality [17]. Beyond monitoring past changes, researchers are now forecasting future land-use scenarios—such as ecological protection versus economic growth—to guide sustainable policy [18]. Evaluating these futures requires understanding how different regions value land-use functions. [19] Moreover, identifying potential spatial conflicts using multi-objective models. [20] Measuring this functional compatibility is crucial, especially as urban development pushes into suburban and ecologically sensitive areas. [21] Satisfying the core objective of this review, the compatibility assessment, this review establishes a clear pathway.

Cox's Bazar, located in the dynamic southeast coastal region [2], requires a geospatial compatibility model integrating LULC change detection [1,22] with MCE/AHP suitability criteria. [15] The conceptual frameworks of FCDI and Dual Evaluation [17,23] are essential for objectively quantifying conflict between urban development and ecological protection in this coastal environment.

4.2. Thematic Convergence in Implementation Challenges

The most consistent finding across the studies is that political and institutional friction systematically undermines the effectiveness of a plan. This confirms that the real challenge for urban planning in Bangladesh lies in execution.

- **Political and Institutional Rigidity:** Across Bangladesh and the wider Global South, failure to achieve planned land uses is consistently linked to political interference, the power of land-owning interests, weak legal enforcement, and a critical lack of political will. [5,24] This suggests that plans are often compromised during execution.
- **Economic Drivers of Mismatch:** Quantitative analyses demonstrate that socioeconomic drivers such as rising GDP and fixed assets investment significantly increase the probability of plan mismatch. [27] This highlights a fundamental rigidity in the planning system where rigid spatial controls cannot adapt to rapid market-driven

development, leading to non-conformance.

- **Conformance-Performance Divide:** Conceptual evaluations confirm that measuring plan success must move beyond conformance (adherence to the map) to performance (the plan's actual impact versus a business-as-usual scenario). Studies emphasize that political influence and the behaviour of key actors determine regulatory effectiveness and the likelihood of plan amendments. [8, 26] Evaluating plan effectiveness requires reliable data and strong tracking indicators. [27] However, in contexts like Bangladesh, structural inconsistencies in land-use classification systems across different institutions severely hinder accurate evaluation. [28] Furthermore, national policies often fail to translate to local realities; for example, policies designed to protect agricultural land from rural housing sprawl frequently fail due to a lack of detailed zoning and local awareness. [29]

When looking at the evidence as a whole, it becomes clear that plan failure is deeply institutional. The classic argument that politics and economics derail planning in Bangladesh [5] is no longer just a theory; it is reinforced by contemporary quantitative studies showing that economic forces and inflexible zoning rules are the true culprits behind non-compliance. [25] Therefore, the process analysis in Cox's Bazar must focus on the behavior of key actors and the likelihood of plan amendments, as theorized by the conformance-performance debate. [8]

4.3. Thematic Convergence in Pathways for Compliance

The literature offers clear strategic and methodological guidance to improve plan effectiveness and compliance.

- **Advanced MCE and MOLA:** Recent methodological advancements focus heavily on removing human bias and handling complex spatial data. Studies suggest that integrating Multi-Objective Land Allocation (MOLA) directly into GIS can automate conflict resolution, while non-compensatory MCE methods (like the LUPEI/ELECTRE III approach) can fairly balance competing environmental and economic goals without arbitrary weighting. [30,31] Furthermore, broad literature reviews are pushing for a paradigm shift: rather than constantly expanding city borders, planners should optimize the spatial structures that already exist. [32] This approach is urgently needed to manage rapid, localized growth in small urban centres. [33] and in major regional hubs like Chittagong, where unchecked expansion is threatening local hillsides. [34] Solving these multi-layered urban issues requires innovative, multicriteria methodologies capable of accurately weighing new development against ecological protection. [36]
- **Policy and Governance:** Governance recommendations stress adopting adaptive management frameworks for planning under uncertainty, using scenario-based evaluation to test planning futures proactively. [36] Policy suggestions include promoting vertical expansion over horizontal sprawl and improving legal instruments and local zoning guidelines to enhance the enforceability of the plan. [12,13]

Beyond general governance improvements, the study must recommend integrating sophisticated non-compensatory evaluation tools [31] to ensure fair and transparent decision-making regarding competing land uses (e.g., tourism vs. agriculture). In high-risk areas like Cox's Bazar, adopting adaptive planning strategies [36] is critical, providing flexibility amid market uncertainty and climate change.

5. CONCLUSION

This systematic review reveals critical methodological gaps that limit our understanding of spatial planning in Cox's Bazar. While existing studies have successfully tracked fundamental land-use changes in the region [1, 22], they have not

used spatially explicit, quantitative models (such as FCDI or MCE-MOLA) to assess how these real-world deviations conflict with the functional goals of the 2015-2025 master plan. We know what changed, but we still lack a clear picture of the resulting conflicts or exactly why they happened. Furthermore, current research tends to treat spatial mismatch [25] and broad implementation failures [5] as isolated issues. To create truly effective, evidence-based policy, we need to bridge this gap by connecting measurable spatial incompatibility directly to the micro-level socioeconomic drivers unique to Bangladesh's fragile coastal zone. Finally, rather than relying on vague, generic recommendations like "enforce the law," future research must offer targeted, technically grounded solutions, such as non-compensatory evaluation and adaptive management, that actively solve these deep-rooted institutional and market deficiencies.

Declaration by Authors
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