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WELCOME SPEECH FROM THE CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

بسم الله الرحمن الرحيم السلام

عليكم ورحمة الله وبركاته

Greetings to all,

It is with great pleasure that I welcome you to the 17th RISM International Surveying Conference for Undergraduates (ISCU 2025), themed *"Embracing Construction Revolution 4.0: Transforming Malaysia's Built Environment."* On behalf of the Royal Institution of Surveyors Malaysia (RISM), I also wish to express our sincere appreciation to Universiti Teknologi MARA (UiTM), Perak Campus, for graciously hosting this significant event.

As we navigate the era of the Fourth Industrial Revolution (IR4.0)—or in our context, Construction Revolution 4.0 (CR4.0)—we are witnessing transformative advancements across the global construction sector. Technologies such as Building Information Modelling (BIM), the Internet of Things (IoT), artificial intelligence (AI), robotics, big data analytics, and cloud computing are redefining the way we build, manage, and interact with our built environment. For Malaysia, embracing CR4.0 is a strategic imperative to achieve our socio-economic and environmental goals.

This conference serves as a vital platform to unite surveying undergraduates from various disciplines, fostering critical dialogue on industry challenges, enhancing professional networking, and preparing a new generation of talent for the rapidly evolving construction landscape. It is also an opportunity for employers to engage with and inspire our future professionals.

I would like to extend my heartfelt thanks to all industry speakers, paper presenters, judges, and participants for their time, contributions, and support in making ISCU 2025 a success. I also commend the organising committee for curating a meaningful and dynamic conference experience.

May the knowledge gained, connections formed, and ideas exchanged during this event inspire all participants to lead and innovate in their future endeavours.

Wishing everyone a productive and memorable conference.

Prof. Ts Sr Dr. Adi Irfan Bin Che Ani'
Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM CO-CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

Bismillahirrahmanirrahim.

السلام عليكم ورحمة الله وبركاته and greetings to all.

It is my great pleasure to welcome everyone to the 17th International Surveyor Conference for Undergraduates (ISCU 2025), proudly hosted by Universiti Teknologi MARA (UiTM) Perak Branch in collaboration with the Royal Institution of Surveyors Malaysia (RISM). This event is a meaningful platform for students in the built environment to share ideas, showcase innovations, and build professional networks. We are honoured by your presence and enthusiastic participation, with 135 accepted papers and 78 poster presentations this year.

UiTM Perak, home to the College of Built Environment, has long been a hub for academic excellence in architecture, planning, and surveying. Our commitment remains strong in nurturing competent graduates who meet industry demands and contribute to nation-building.

While you're here, we invite you to experience the heritage and culture of Perak Tengah from the architectural richness of Rumah Kutai to the historical towns of Pasir Salak, Bota, and Kampung Gajah.

To all presenters and winners, congratulations on your achievements. Let your work today be a catalyst for future success and academic growth. We hope this conference will inspire you to explore new ideas, foster collaboration, and make lasting memories.

My deepest thanks to the Royal Institution of Surveyors Malaysia (RISM) and the organising committee for making this event a success.

We hope your experience here will be rewarding and unforgettable.

Thank you. Selamat datang dan selamat berjaya.

Associates Professor Dr. Nur Hisham Ibrahim, *PMP*
Co-Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM THE PROJECT DIRECTOR

RISM 17th International Surveying Conference for Undergraduates 2025

Alhamdulillah, all praise to Allah S.W.T. for His guidance and blessings in making the RISM 17th International Surveying Conference for Undergraduates (ISCU) 2025 a reality.

It is with great honour and gratitude that I welcome all participants, guests, academicians, and industry professionals to this prestigious event, proudly organized under the Royal Institution of Surveyors Malaysia (RISM). This 17th edition of ISCU stands as a proud testament to our collective dedication toward academic excellence, professional collaboration, and youth empowerment in the field of surveying.

I extend my heartfelt appreciation to RISM for its unwavering support, to the hardworking ISCU 2025 Organising Committee, and to all 16 partnering universities across Malaysia for their commitment and contributions. Your efforts have shaped this conference into a dynamic platform for knowledge exchange, innovation, and professional growth.

To the academicians and practitioners present, your insights are invaluable in bridging the gap between academic theory and real-world practice. To our undergraduate participants, your passion, curiosity, and commitment are the very foundation of our future. May this conference not only deepen your academic journey but also ignite a spirit of leadership, integrity, and sustainable thinking.

Let this gathering serve as more than an academic milestone. May it foster lifelong networks, inspire transformative ideas, and chart new directions in our shared professional journey.

Wishing everyone a rewarding and inspiring conference experience.

Sr Dr. Nurul Fadzila Zahari
Project Director
RISM 17th ISCU 2025

ASSESSING THE IMPACT OF SEA LEVEL RISE TO THE COASTAL AIRPORT: A SYSTEMATIC REVIEW AND META-ANALYSES

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ABSTRACT

Sea level rise poses a significant threat to coastal airports as it endangers infrastructure, puts the economy at risk, and interferes with aviation operations. Despite the advancements in geospatial techniques for assessing sea level rise impacts, the relationships between airport infrastructure and rising sea levels remain sparse. This systematic review provides a comprehensive analysis of assessing the impacts of sea level rise on coastal airports. This study adopted PRISMA approach and VosViewer to show research trends and relationships among key studies from the year 2020 to 2025. The survey includes 397 papers, highlighting a growing research focus on GIS-based modelling, remote sensing applications, and hydrodynamic simulations to assess airport inundation risks. Key findings indicate an upward trend from 2020 to 2024, indicates increased awareness of the concerns associated with sea level rise as well as developments in GIS and remote sensing regarding coastal vulnerability, but a steep drop in 2025 as the year is ongoing and more articles could still be indexed. This review demonstrates how geospatial technologies can aid in evaluating airport vulnerability to sea level rise and thus in improving risk assessments. The research is bound to English published articles and uses open-source materials to guarantee credibility and confirm the absence of bias on selection criteria. The results show a heightened increase towards published works for sea level rise and coastal studies. Nevertheless, there is still a considerable deficit in research targeting the coastal infrastructure, and especially the airports as the elements of the coastal transportation system. A conceptual framework is developed in this study to address research gaps and guide support further research. This systematic literature review identifies key findings on the role of geospatial technology in assessing coastal airport vulnerability to sea level rise, highlighting existing research gaps and opportunities for future studies.

Keywords: Sea Level Rise; Coastal Airports; Geospatial Techniques; Inundation; Systematic Review

I. INTRODUCTION

Coastal regions act as key areas of economic and transport activity, housing critical infrastructure such as airports that support global connectivity and trade. However, the risk of climate change-driven sea level rise is becoming increasingly susceptible to these regions because it poses risks to the vital airport facilities and activities (Voskaki et al., 2023). Increased flooding, coastal erosion, and storm surges add to these risks and make coastal airports more vulnerable to disruptions in airport activities as well as the infrastructural damage (Yesudian & Dawson, 2021). Certain factors such as an airport's geographical location, distance to shoreline, and climate impact the susceptibility of coastal airports. Runways, terminals, and access roads are particularly at risk, with rising sea levels leading to inundation, corrosion of infrastructure, and reduced operational capabilities. Considering the importance of these areas, it is critical to estimate accurately the sea level rise impacts on coastal airports for effective adaptation response and risk management approaches development strategies (Griggs & Reguero, 2021). Remote sensing and GIS are examples of geospatial technologies that provide better analysis for spatial and temporal patterns of the impact of rising sea level. Remote sensing enables observations of wider areas while GIS combines information from different sources to map out potential flooding zones along with the rest of the infrastructure. Geospatial analysis has been used extensively and successfully for coastal monitoring, identifying high risk zones and predicting future inundation scenarios. The study area is located at Sabah, Malaysia and it focuses on the impact of sea level rise on the coastal airport of Kota Kinabalu International Airport (KKIA). KKIA is a significant transportation hub for both regional and international, which is located near the coastline. Despite its economic significance, limited research specifically addressing its susceptibility remains sparse.

Thus, this paper aims:

i. To review the application of geospatial technologies in assessing sea level rise impacts on coastal airports.
ii. To identify trends and research gaps in literature.
iii. To analyze the strengths and limitations of current research methodologies in this field.

This study intends to provide essential insights into the vulnerability of coastal airports to rising sea levels by integrating geospatial analysis which contributes to ongoing efforts in climate adaptation and infrastructure resilience planning.

XXIX. MATERIALS AND METHODS

The aim purpose of conducting a systematic literature review in this matter was to identify, select, and assess relevant research on the impact of sea level rise to the coastal airport. This method follows a structured framework to organize, analyze, interpret, and synthesize findings from various sources within the field. By adhering to established review protocols, the purpose of these studies is to synthesize all existing research while taking into account the vulnerabilities, risks, and analytical approaches related to SLR and airport infrastructure (Dong et al., 2024).

Scopus database is used for in depth search strategy of relevant literature. Focused sea level rise keywords like coastal airport vulnerability, geospatial analysis, GIS modelling, and remote sensing filter relevant literature between the years 2020 until 2025. The inclusion criteria focused on peer-reviewed journal articles and conference papers written in English, with apparent connection of the impact of sea level rise on airport infrastructure.

The studies adopted PRISMA method to screen and select where this process involved four key stages such as identification, screening, eligibility assessment, and inclusion. A total of 397 papers were initially retrieved, which were then filtered based on relevance and quality assessment.

VosViewer 1.6.20 was used for bibliometric analysis to analyze trends, relationships and thematic clusters within the selected literature. Network visualization was utilized to identify research patterns and keyword co-occurrences, whereas density visualization was used to indicate principal areas of concentration. This analytical approach provided a better understanding of the development of research in this area and the integration of geospatial tools in evaluation of airports' vulnerability to SLR impacts.

Figure 1.0 presents the systematic review workflow, detailing the methodology employed to ensure a structured research process.

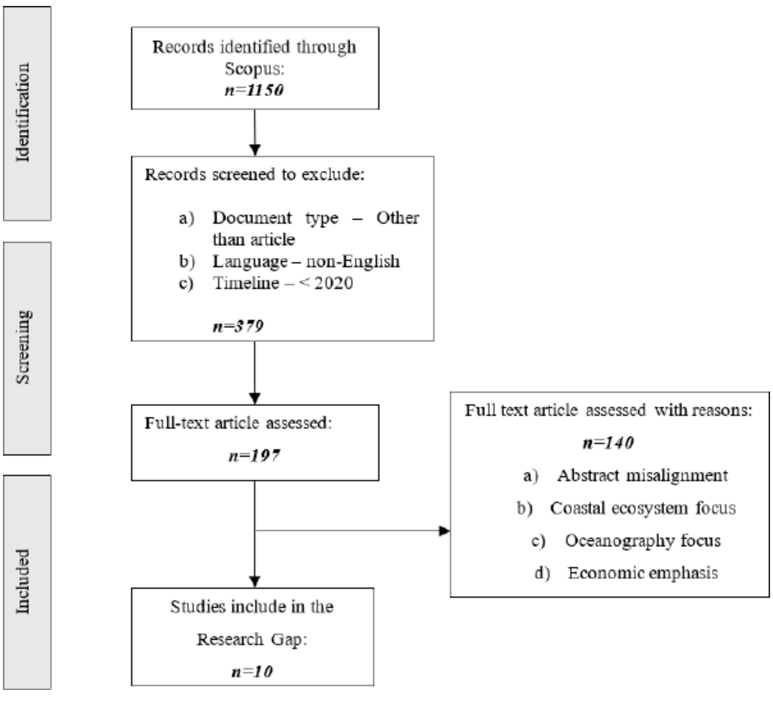


Figure 15.0 Flowchart of the Systematic Review.

A. *Scopus Database Search*

A systematic literature search using the Scopus search engine for studies published between 2020 and 2025 has been conducted. The following search term combinations have been utilized: TITLE-ABS-KEY ("sea level rise") AND TITLE-ABS-KEY ("coastal") AND TITLE-ABS-KEY ("GIS" OR "Remote Sensing"). Table 1.0 shows English search queries that use Boolean operators like "AND" and "OR" to differentiate synonyms and refine the search scope.

Table 1.0 Scopus Search Engine Queries

Keywords
TITLE-ABS-KEY ("sea level rise") AND TITLE-ABS-KEY ("coastal") AND TITLE-ABS-KEY ("GIS" OR "Remote Sensing")) AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (EXCLUDE (LANGUAGE , "Chinese") OR EXCLUDE (LANGUAGE , "French") OR EXCLUDE (LANGUAGE , "Italian") OR EXCLUDE (LANGUAGE , "Spanish") OR EXCLUDE (LANGUAGE , "Russian") OR EXCLUDE (LANGUAGE , "Portuguese") OR EXCLUDE (LANGUAGE , "Turkish") OR EXCLUDE (LANGUAGE , "Korean") OR EXCLUDE (LANGUAGE , "Japanese") OR EXCLUDE (LANGUAGE , "Croatian") OR EXCLUDE (LANGUAGE , "Arabic")) AND (EXCLUDE (DOCTYPE , "cp") OR EXCLUDE (DOCTYPE , "ch") OR EXCLUDE (DOCTYPE , "re") OR EXCLUDE (DOCTYPE , "cr") OR EXCLUDE (DOCTYPE , "bk") OR EXCLUDE (DOCTYPE , "no") OR EXCLUDE (DOCTYPE , "ed") OR EXCLUDE (DOCTYPE , "dp")) AND (EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "ENER") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "DECI") OR EXCLUDE (SUBJAREA , "BUSI") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "SOCI"))

B. *Inclusion and Exclusion Criteria*

The reviews define their scope using distinct inclusion and exclusion criteria. It mainly focuses on articles, dismissing other types of literature such as conference paper, book chapter, review, conference review, book, note, and others. This approach assures high class accuracy and relevance. Furthermore, the study only considered materials published in English. This decision is intended to increase the accessibility and understanding of research data by making it available to a wider audience. Furthermore, English is chosen for this because it is widely understood in the global research community. Likewise, the next analysis covers 5 years, specifically from 2020 to 2025, to assess the significance of the research. Furthermore, limiting the analysis to this specific period allows for the inclusion of the latest developments and publications in the field, thereby enhancing the reliability of the results and they can be used extensively. The systematic inclusion and exclusion criteria for the literature review are presented in Table 2.0

Table 2.0 Criteria for the systematic literature review.

Criteria	Inclusion	Exclusion
Document Type	Article	Conference paper, Book chapter, Review, Conference Review, Book, Note, Editorial, Data paper
Language	English	Chinese, French, Italian, Spanish, Russian, Portuguese, Turkish, Korean, Japanese, Croatian, Arabic
Timeline	2020-2025	<2020

XXX. RESULTS

A. *Literature Development Trends*

Between 2020 and 2024, the number of publications on the topic showed a steady increase, indicating a growing interest in assessing the impact of sea level rise on coastal infrastructure. In 2020, there were 31 published documents, which gradually increased to 34 in 2021, 38 in 2022, 41 in 2023, and reached a peak of 43 in 2024. The increasing number of publications suggests a sudden rise in awareness of the impacts of sea level rise, combined with improved technology around geographical information systems and remote sensing. The increasing number of publications could also be the result of political policies, a shift in funding for research, and an overall increased urgency in climate adaptation for essential infrastructure such as coastal airports. In 2025 however, there seems to be a drop off where only 10 published articles are available. The first reason could be a lack of finished data collection as the year is still ongoing. Despite this decline, it is highly important to keep research in rising sea levels, as this data analyzed from 2020 to 2024 showcases the importance of this subject. The increase in published articles suggests that there is a growing need for the analysis of the vulnerability of coastal airports to the rising sea levels.

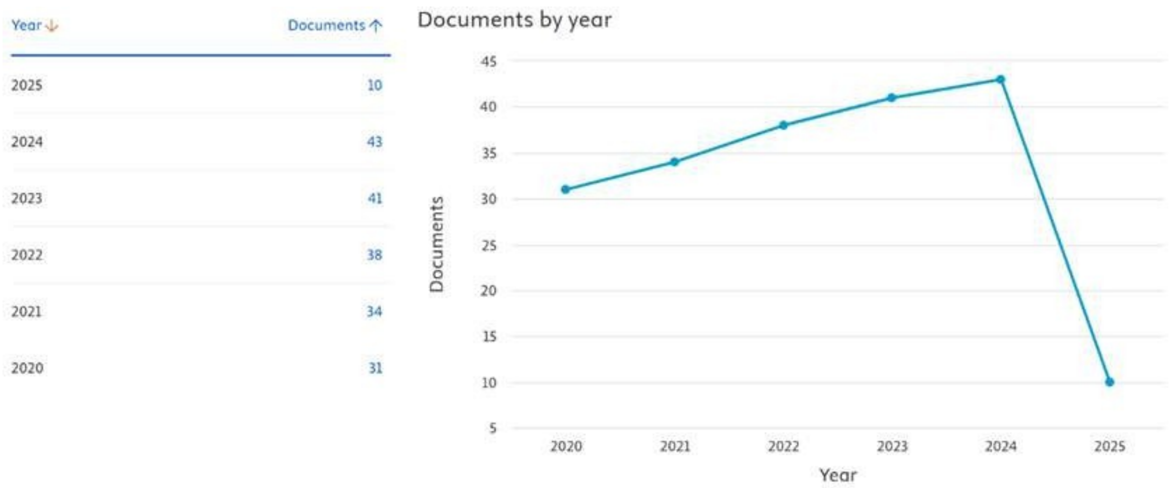


Figure 2.0 Articles from Scopus Database.

The number of published documents for the years 2020 through 2025 are illustrated in Figure 2.0. The data indicates a continuous increase in publications from 2020 until 2024, preceding an abrupt drop in 2025. In 2020, there were 31 published documents. This number steadily increased over the next four years, to 34 in 2021, 38 in 2022, 41 in 2023, and 43 in 2024. This growth is slow but indicates that there is growing interest or output in the field, however, documents published sharply decreased to 10 in 2025. This is a notable decline from the previous year. The line graph provided complements this information as it demonstrates a pathway that increases from 2020 to 2024 and sharply declines in 2025. This decline could be due to the year is still ongoing. Furthermore, Figure 3.0 illustrates the annual distribution of documents by their respective sources. Findings from the Scopus database reveal the involvement of five distinct source categories which include Journal of Coastal Conservation, Journal of Marine Science and Engineering, Remote Sensing, Journal of Environmental Management and Science of The Total Environment.

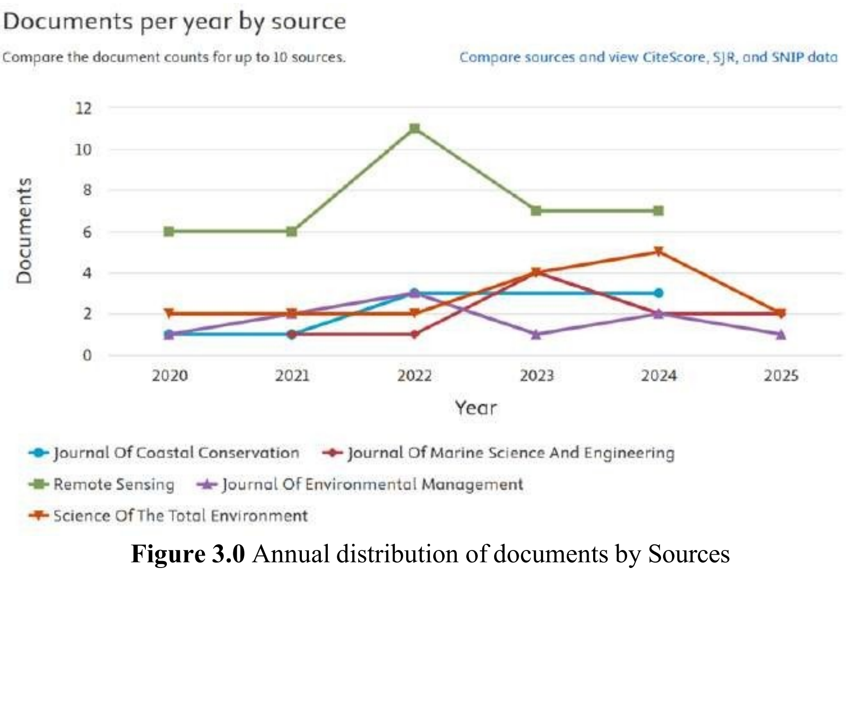


Figure 3.0 Annual distribution of documents by Sources

B. *Geographic Distributions*

Figure 4.0 contains the bar charts representing the academic work published about evaluating the impacts of the rise of the sea level to the coastal airport. This figure outlines the development of contributions to research in the area over five years from 2020 up to 2025. The data highlights specific countries that have made significant contributions to literature on the impact of sea level rise to the coastal airport, providing useful insights into the global distribution of academic activities in this field of study.

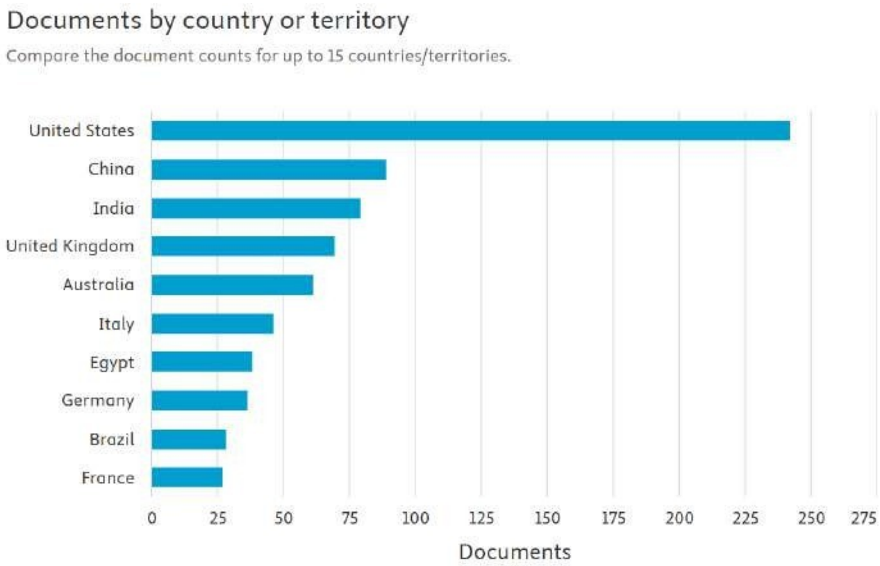


Figure 4.0 Distribution of Publication Articles Across Top 10 Countries (2020 – 2025).

Table 3.0 shows significant contributions from the United States, China and India which show differences in levels of funding, priorities, and in the availability of academic capital. Different continents have varying ways of conducting research; the United States, for example, invests in high-technology innovations, while China has directed its resources towards large scale environmental monitoring. In contrast, research in India tends to be more localized. The output of research is impacted by the state of the economy, policy, and how available the technologies are, which strongly suggests the need for accurate scientific methods to deal with global and regional issues.

Table 3.0 Distribution of Scholarly Articles

No	*Country*	*Frequency*
1	United States	242
2	China	89
3	India	79
4	United Kingdom	69
5	Australia	61
6	Italy	46
7	Egypt	38
8	Germany	36
9	Brazil	28
10	France	27

C. *Network Visualization and Analyzing Bibliometric Networks*

Network visualization offers a potent way to conduct bibliometric analysis, as it employs graphical depictions to illustrate the relationships existing among authors, citations, publications, and other vital components of a bibliometric dataset. This allows the researcher to discover patterns, thematic clusters, and trends in scholarly discourse and helps comprehend the dynamics of research fields. Figure 5.0 shows the network visualization maps, and the obtained map structural information related to the assessing the impact of sea level rise to the costal airport for the keywords or terms used in the literature review.

The network visualization showcases research themes about sea level rise and vulnerable coastal airports, illustrating how different topics are interconnected. In the network, nodes represent individual keywords, while edges (lines connecting the nodes) indicate their co-occurrence in the academic articles. The size of a node is proportional to its frequency as a keyword, while the width of an edge is indicative of the strength of relationship between the terms. The colour-coded clusters group related keywords into distinct thematic areas, illustrating the diverse research dimensions in this field. The co-occurrence keyword analysis reveals 383 items organized into 4 clusters, each with a unique colour scheme.

The terms “sensing,” “vulnerability,” and “risk” capture substantial weight within the network visualizations, which accentuates the examined keywords in the context of conducting research on the impact of sea level rise to the airports. These keywords are interlinked with a wide spectrum of relevant terms, demonstrating the multidisciplinary nature of the topic. For example, the term "sensing" is closely correlated to “monitoring”, “observation” as well as “spatial resolution”, which indicates that modern geospatial technologies are applied in the assessment of coastal areas and possible effects of the rise in sea level.

To sum up, the assessment of the network visualization analysis has incorporated research trends and thematic gaps and is currently centered on geospatial methods for assessing the vulnerability of coastal airports to the sea level rise. Developed nations lead in publications due to greater funding and satellite accessibility, highlighting the need for low-cost geospatial tools in underrepresented regions. Key terms such as "sensing," "vulnerability," and "risk" dominate the literature, emphasizing their relevance. The network structure reveals strong links between "sensing" and "satellite imagery", as well as "vulnerability" and "storm surge", confirming the threats of sea level rise to airport infrastructure. Additionally, "flood risk" and "hazard assessment" highlight the vulnerability of airport infrastructure over time. The network also shows how airport risk management connects with broader climate adaptation strategies, including urbanization and policy frameworks. Thus, this literature review functions primarily as a useful compass, guiding our current research. Therefore, change detection and land use analysis are crucial in assessing vulnerability trends. This review reinforces the importance of remote sensing, risk assessment, and adaptation planning in safeguarding coastal aviation infrastructure.

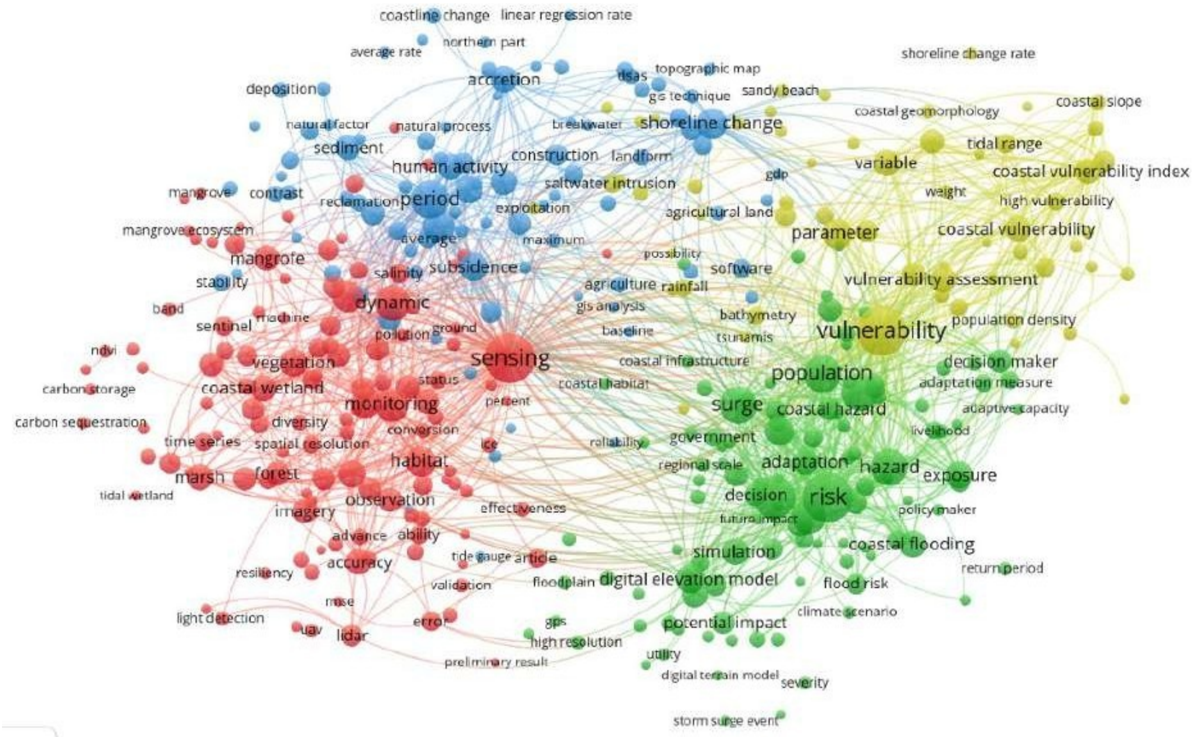


Figure 5.0 Worldwide Network Visualization.

D. *Network Visualization and Analyzing Bibliometric Networks*

Density visualization aims to illustrate the level of interrelation within the bibliometric network. This technique allows researchers to visually denote the intensity and display of links between different nodes in the network, leading to a reflective comprehension of the fundamental patterns and connections within the datasets.

Keywords related to coastal vulnerability and risk assessment using geospatial methods were analyzed through co-occurrence analysis in VOSviewer. This aimed to explore associations between key terms in coastal hazard assessment and environmental monitoring. The graphical representation revealed relationships based on keyword size and proximity. Using the Viridis colour scale, lighter shades indicate lower term frequency, while darker shades, especially yellow, denote higher density. This visualization helps identify research trends, emphasizing the most studied concepts in geospatial analysis for coastal risk management and highlighting critical thematic connections.

This visualization places the words on a horizontal background, indicating the intensity or frequency of occurrence at the same time. Darker or more crowded parts of the background indicate more words or stronger relationships between them. This allows visitors to quickly identify the most covered topics or key areas of focus in the dataset. The terms "sensing," "vulnerability," and "risk" are included prominently in the text, indicating the importance of these terms in context.

As a result, it is apparent that the phrase "sensing" is frequently associated with research using geospatial techniques for coastal vulnerability and risk assessment. This indicates that remote sensing plays a crucial role in evaluating coastal hazards and infrastructure risks. Additionally, the term "hazard" was another word that emerged, suggesting its significance in analyzing threats to coastal areas. In addition, the terms such as "population," "monitoring," and "period" were also present. Thus, by using geospatial technologies, these metrics can be used to study the impact of sea level rise to the coastal airport. Additionally, the terms "digital elevation model" and "simulation" were found to be associated with "coastal flooding", emphasizing the role of topographic modelling in flood risk assessments. To conclude, this density map shows key research themes and their frequency within the dataset. This type of visualization facilitates a better understanding of the data and makes it easier to locate key areas of interest or to guide future research by allowing viewing to immediately identify key issues in dispute.

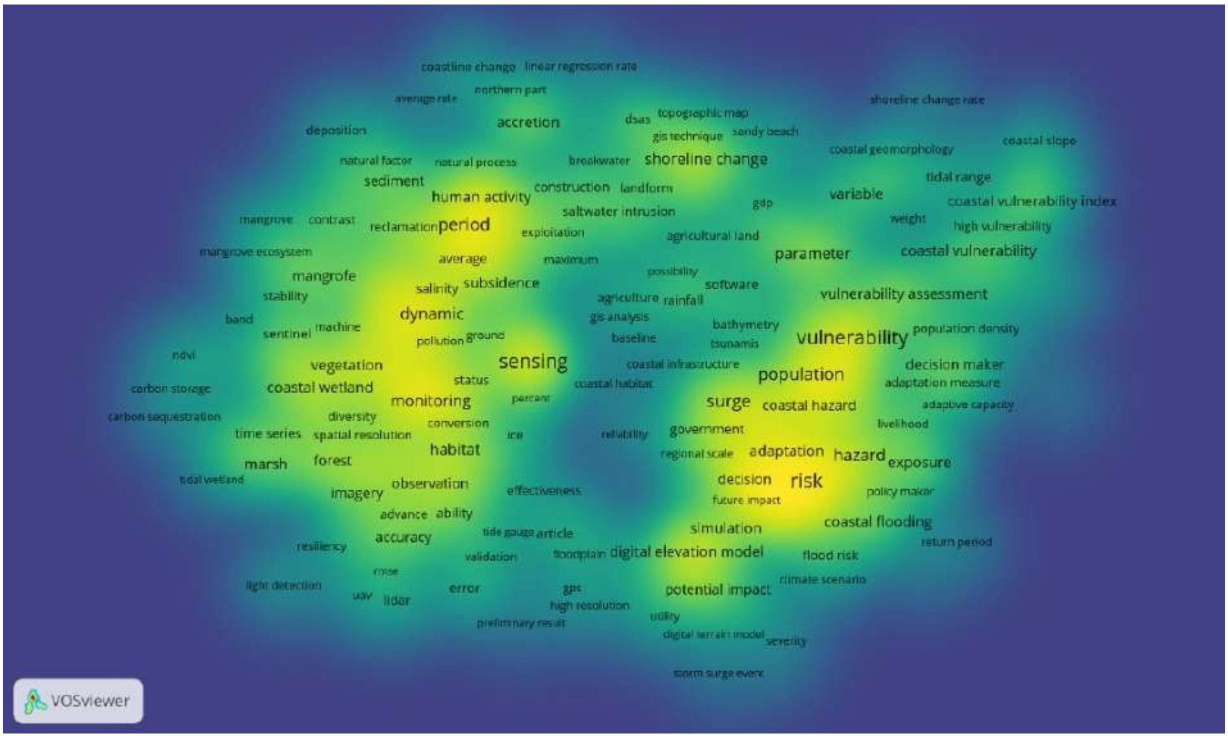


Figure 6.0 Worldwide Density Visualization.

E. *Gap Analysis for Systematic Review*

Table 4.0 presents a review of studies on sea level rise impacts on coastal infrastructure, highlighting a significant gap in research focused on coastal airports. In recent years, quite a number of studies have been conducted focusing on the impact of sea level rise related to infrastructure. However, there remains a significant lack of research focusing specifically on coastal airports. Many of the existing literature focuses on flooding and residential housing units, alongside urban infrastructure without considering aviation infrastructure, that is, airports, which are particularly prone to coastal hazards.

A further gap exists where airports have not been scarcely integrated for parametric geographical spatial defined risk evaluation. It appears that airports are treated within broader coastal models regardless of the airport's spatial layout and sensitivity in operations such as runway elevations, access roads, and drainage infrastructure. Therefore, existing models do not consider adequately discern functional risks and exposure to an airport's operations.

Thirdly, airports are hardly the focus of studies that apply geospatial tools like GIS, remote sensing, and hydrodynamic models to analyze coastal inundation. Relatively few focus on the combination of high resolution or airport specific datasets with these tools. There is a distinct absence of default, documented frameworks designed to evaluate the resilience of airports to SLR which diminishes the precision and consistency of regional evaluations. Lastly, there is minimal research addressing future-oriented, multi-hazard scenarios such as compound flooding from SLR, extreme precipitation, and storm surge within airport contexts. This limits the ability of planners and policymakers to develop adaptive strategies grounded in realistic threat modelling.

F. *Limitations*

While this review brings together a wide range of geospatial analysis relating to sea level rise impacts on coastal infrastructure, there are glaring limitations in current research regarding airport vulnerability. One of the most urgent issues is the absence of models that specialize in identifying airport-specific vulnerabilities. Various studies examining coastal infrastructure consider these as aggregates, treating airports collectively with maritime ports, roads, and urban areas. This approach fails to distinguish distinct spatial layouts, essential functions, and interconnected systems that define an airport. Important elements such as the runway, control tower, fuel depot, radar, and navigation systems are seldom and rudimentarily captured in models designed to depict varying levels of operational importance and exposure, which leads to inaccurate assumptions about their individual modelling. Thus, many existing models underestimate the risk profiles of these facilities which may not reflect the true vulnerability of airport facilities.

Another limitation lies in the scarcity of real-world incident data to support model calibration and validation. Only emulated records and little actual data depicting incidents of flooding or disruptive failure and emergency shutdowns exist. The unavailability of high-resolution data like damage assessment or downtime records severely weakens the existing frameworks and their real-time application. Besides, the climate hazard compounding effects are not fully incorporated into the existing models because they tend to rely on static datasets and predefined scenarios.

Additionally, solitary assessment and co-occurring stressful factors, such as storm surge, extreme rainfall, and groundwater rise, are disintegrated or disregarded entirely. This disjointed methodology does not consider the dynamic risk exposure, particularly for airports situated within the coastal zones. The lack of uncertainty modelling combined with sensitivity analysis creates even less confidence in scenario projections, particularly for high-emission scenarios towards the end of the century.

Ultimately, monitoring systems that enhance temporal resolution and real-time awareness of the situation, such as UAVs, LiDAR, or IoT, are lacking. Furthermore, the socio-economic factors, which include disruption of passenger flow, limitation to the emergency response, and economic knock-on effects, are largely simplified. This exposes the need for an interdisciplinary approach that integrates geospatial science, airport systems engineering, climatology, and operational resilience planning.

G. *Future Studies*

Future research can capitalize on the considerable gap that exists regarding the development and sharing of airport specific open-access geospatial datasets. Some of the airport specific datasets that could be included are elevation profiles, historical flooding data, drainage systems, and recovery policies from previous disruptions. Establishing collaborative frameworks with researchers, airport administrators, and climate agencies would enhance the replicability and comparability of research.

Next, research should take into consideration operational, financial, and sociological aspects which is not limited to physical ramifications only. For instance, analyzing the impact of widening delays and blocked supply chains on passenger relocation, tourism, and long-term trade will tailor-shape economic impacts. Incorporating these factors within spatial dimensions can vastly improve risk assessments made available to airport authorities, urban developers, and government decision-makers.

Moreover, it is essential to explore geospatial science within airport operations, transportation, logistics, policy research, and climatology to derive cross-disciplinary approaches that combine them with adaptation economics. This would enable policymakers to develop comprehensive models that incorporate spatial interrelations between airport infrastructure with the surrounding region, the supply chain, and emergency response.

Table 4.0 Identified Research Gaps in Assessing the Impact of Sea Level Rise to The Coastal Airport Using Geospatial Techniques

ID	Author	Study Area	Methodology	Data Used	Key Findings	Limitations
1.	(Tsegaye et al., 2024)	Bonita Bay, Florida	i. Integrated GIS-hydrologic-hydraulic modelling ii. Simulation of multiple flood drivers (storm events, land use changes, sea-level rise, groundwater rise)	i. Design storm rainfall depths ii. Stormwater collection/conveyance inventory iii. Topographic data LiDAR DEM iv. Land use/Land cover v. Soil vi. Tidal data/SLR projections vii. Confining layer	i. Rising sea and groundwater levels increase initial water storage ii. Land use changes amplify storm runoff iii. Flooded areas projected to increase by 2% (stronger storms) and 5% by 2100	i. Does not assess airport vulnerability ii. Uncertainty in hurricane impacts (storm surges and high winds not fully considered) iii. Lacks uncertainty modelling and sensitivity analysis iv. Heavily reliant on regional climate models, limiting robustness in predicting future scenarios
2.	(A. Becker et al., 2021)	Caribbean region	i. Developed a standardized, replicable method using satellite imagery and a mapping procedure to inventory critical coastal infrastructure. ii. Focused on airports, seaports, power plants, and water treatment facilities in the Caribbean.	High-resolution satellite imagery and geospatial data	i. Identified 386 critical infrastructure facilities across 28 Caribbean nations. ii. Mapped 19,000+ hectares of coastal infrastructure. iii. Established a new geospatial standard for assessing risk at regional and local scales.	i. Data quality varies across countries. ii. Manual mapping process may introduce errors. iii. Future development and climate change impacts not considered.
3.	(Murali et al., 2020)	Mumbai, India	i. Geospatial analysis of SLR, flooding, and erosion ii. Vulnerability mapping using historical data	i. Satellite imagery ii. Historical flood records iii. Land use and land cover (LULC) data	i. 24% of Mumbai is highly vulnerable, mainly coastal areas ii. 44 sq.km of built-up land at high risk iii. 30% of vulnerable zones overlap with past flood areas	i. Limited data resolution restricts analysis to city scale ii. Uncertainty due to lack of ground subsidence data iii. No high-accuracy elevation data (e.g., LIDAR)
4.	(Lyn Williams & Lück-Vogel, 2020)	Cape Town, Africa	Bathtub Model (eBTM) to improve upon the simple Bathtub Model (sBTM) for storm surge-related coastal inundation.	i. Topographic elevation data ii. Digital Terrain Models (DTMs) and Digital Surface Models (DSMs) iii. Sea level rise projections	i. The eBTM produced more conservative and realistic inundation results compared to the sBTM. ii. It reduced the occurrence of disconnected unrealistic inundation areas in the results. iii. Using Digital Surface Models (DSM) instead of Digital Terrain Models (DTM) provided more accurate water movement trajectories.	i. Does not focus on airport vulnerability. ii. Limited consideration of airport-specific parameters iii. The accuracy of results depends on the quality of elevation data (DTM vs DSM) and local hydrological conditions.

					iv. eBTM can help quantify coastal inundation risk to infrastructure.	
5.	(Eliawa et al., 2023)	Karasu Coastal Area, Turkey	i. GIS-based analysis using Digital Elevation Model (DEM) ii. ArcMap software with high-resolution DEM data from eleven 1:5000 scale topographic maps iii. Eight-side rule algorithm applied for inundation modelling	i. High-resolution DEM data from topographic maps ii. GIS-based spatial analysis iii. Population and GDP data for risk assessment	i. Inundation projections: ii. 1.40% (1m SLR), 6.02% (2m SLR), 29.27% (3m SLR) iii. High-risk areas: Sakarya River, Maden Stream mouths, western and eastern coastal regions iv. Impacted zones: urban areas, roads, agricultural land, forests, beaches v. 11,132 people at risk of displacement vi. Estimated GDP loss: $162.5 million	i. Assumes a fixed shoreline (excludes shoreline erosion/accretion) ii. Storm surge effects not considered iii. Does not focus on airport vulnerability iv. Lacks uncertainty analysis in projections v. Simplified economic impact evaluation
6.	(El-Quilish et al., 2023)	Northern Coastal Zone, Nile Delta, Egypt	i. GIS-based inundation model using high-accuracy Local Digital Elevation Model (LDEM) ii. Tide gauge measurements for Sea Level Rise (SLR) data iii. Hazard Index Map (HIM) integrating SLR and land subsidence effects	i. High-accuracy LDEM data ii. Tide gauge measurements for SLR trends iii. GIS spatial analysis	i. 50 km² of land projected to be inundated by 2050 ii. Impacted land use: - Urban: 38.4 km² - Agricultural: 3.8 km² - Fishing farms: 5.2 km² - Bare land: 2.6 km² iii. Northern coastal zone highly vulnerable iv. Recommends seawalls and breakwaters for mitigation	i. GIS techniques tend to overestimate inundation by merging low-lying areas ii. Does not focus on airport vulnerability iii. Requires more detailed spatial analysis of sea level rise iv. Lacks uncertainty analysis in predictions
7.	(Schuldt et al., 2020)	Northern Germany	i. GIS-based simulation using TanDEM-X DEM ii. IDW interpolation of sea level and land movement iii. IPCC climate scenarios (RCP4.5 & RCP8.5) iv. Static maps created for journalistic use	i. TanDEM-X DEM ii. Sea level and land movement data iii. IPCC projections iv. GIS spatial analysis	i. Inundation between 1,061 and 9,004 km² ii. Affected population: 5,477 to 626,880 people iii. North Sea coast vulnerable, severe impact if dikes fail iv. Baltic Sea coast naturally protected by cliffs	i. Does not assess infrastructures ii. Simulation accuracy depends on the quality of elevation transformations iii. Effectiveness of media maps needs further evaluation regarding readability and usability
8.	(Tumawu et al., 2024)	Keta Municipality, Ghana	i. GIS-based analysis ii. Uses topographic data, administrative shapefiles, field surveys, and infrastructure data iii. Two flood scenarios: 2.5m and 5m sea level rise	i. Topographic maps ii. GIS shapefiles iii. Field survey points iv. Infrastructure data	i. 2.5m scenario: 3.3 km² (9%) of land, 3.9 km of roads, 69 structures at risk ii. 5m scenario: 7.1 km² (19.4%) of land, 13.6 km of roads, 667 structures at risk iii. Increased flood risk threatens socio-economic development	i. Focuses on general infrastructure rather than airports. ii. Infrastructure data may lack recent developments or informal structures

9.	(Santos et al., 2024)	Conde County, Brazil	i. Shoreline change analysis using DSAS ii. Future shoreline projections for 2032 and 2042 iii. SLR impact assessment on urban and agricultural areas	i. Satellite Imagery: Landsat (for shoreline detection) ii. Land Use/Land Cover Data: MapBiomas Project (2000, 2010, 2020) iii. Shoreline Analysis Tool: Digital Shoreline Analysis System (DSAS) iv. Cloud Removal: Kalman filter algorithm v. SLR Scenarios: 1, 2, 5, and 10 meters	i. Coastline change rate: 0.27 m/year (1985–2022) ii. Future projections (2032, 2042): Continued erosion, particularly in highly vulnerable zones iii. SLR impacts: - 1–2m SLR: Limited immediate effects - 5m SLR: Significant inundation of urban and agricultural areas - 10m SLR: Severe flooding	i. Focuses on general coastal dynamics rather than infrastructure. ii. Does not include airport vulnerability. iii. Inundation factors does not focus on SLR only but considered from a variety of factors, including significant rainfall, storm surges, and sea-level elevation.
10.	(Papagiannakis & Ntafos, 2020)	Thessaloniki, Greece	i. Assessing sea level rise (SLR) impacts on transport infrastructure in Greater Thessaloniki ii. GIS-based simulation of 0.5m and 1m SLR scenarios	i. SLR Data ii. Land Use Data iii. Population Data	i. 0.5m SLR Scenario (by 2100): 1.87% of the coastal road network submerged ii. 1m SLR Scenario: 3.07% of roads inundated iii. Key Vulnerabilitie: - Road access to airport disrupted - - Parts of Thessaloniki's port at risk of inoperability	i. Focuses on general transport rather than airports. ii. Lacks GIS-based flood modelling specific to airports. iii. Does not provide direct sea-level rise impact projections for airport facilities.

Assessing The Impact of Sea Level Rise to The Coastal Airport

Impacts: infrastructure flooding, transportation disruption, operational downtime

Software: ArcGIS, HEC-RAS, ERDAS Imagine

Data: Satellite Imagery

What causes sea level rise?

-Thermal expansion
-Land subsidence
-Extreme weather events

Methodology:

- DEM Analysis
- Inundation Modelling
- Vulnerability Mapping

Other studies

Hydraulic modelling

Flood drivers

Building shapefiles

DEM

Digital Shoreline Analysis System (DSAS)

SLR projections

LULC changes

Assessing the impact of sea level rise to Kota Kinabalu International Airport

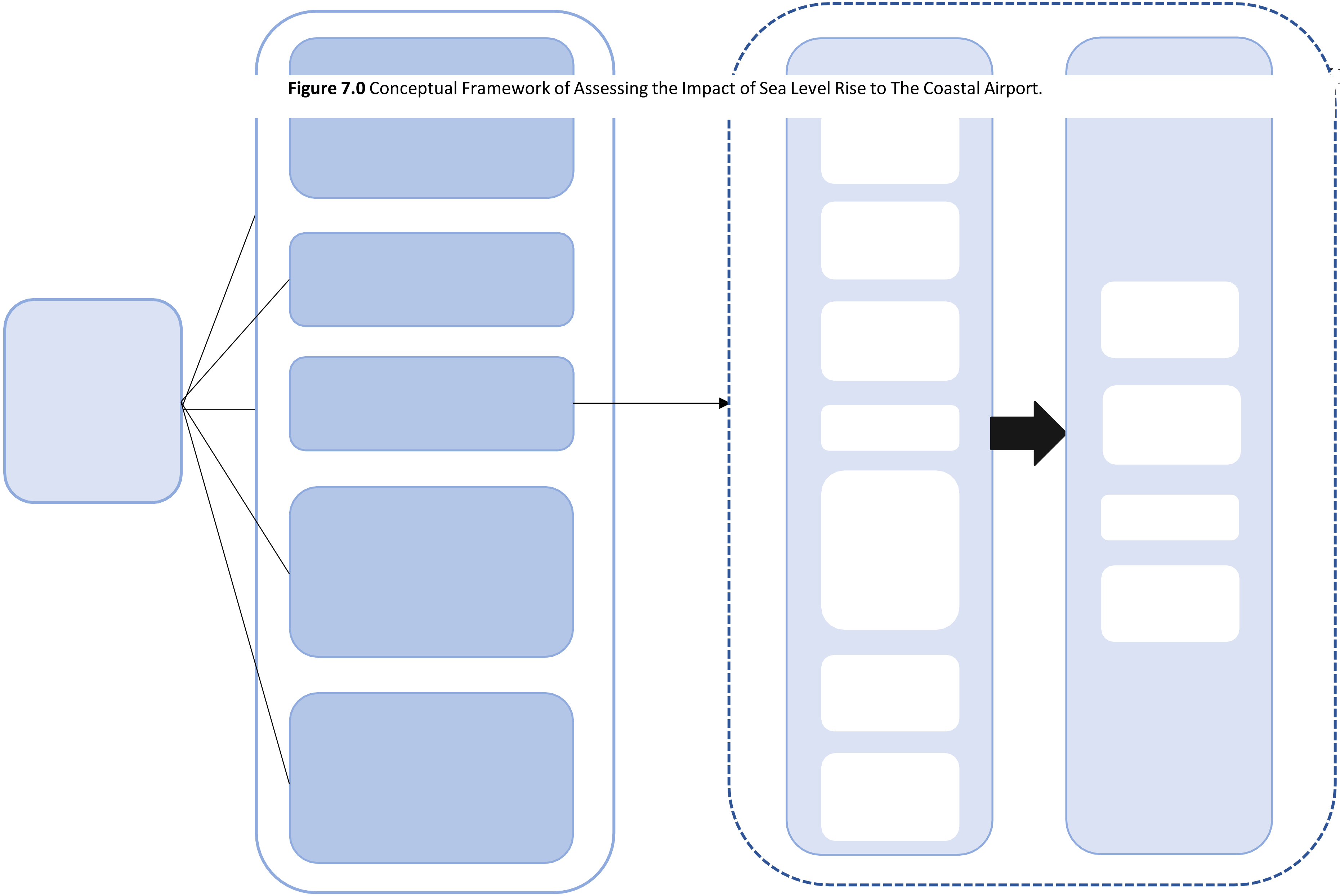
Hydraulic modelling

Building shapefiles

DEM

SLR projections

Figure 7.0 Conceptual Framework of Assessing the Impact of Sea Level Rise to The Coastal Airport.



CONCLUSION

This systematic review examines the impact of sea level rise on coastal airports, highlighting key vulnerabilities, assessment methodologies, and research gaps. The study uncovered processes which impact the sea level rise for a given coastal area Through examination of various research approaches and literature from different regions. Coastal airports face significant threats due to rising sea levels, which include inundation of runways, endangers infrastructure, and disruption to airport operations (Das & Swain, 2024). These issues alone can have profound impacts from an economic and safety perspective. Research focusing on the problems associated with sea level rise continues to grow, however, there are very limited studies that have been done regarding the resilience and adaptation of airports (M. Becker et al., 2023).

Furthermore, this study reveals substantial rise in publications from the year 2020 until 2024 which proves the growing interest and effort in research on coastal vulnerability and infrastructure risk. The upward trend also indicates increasing acknowledgement of the importance of using geospatial methods to assess how sea level rise impacts the coastal area. The simultaneous keywords analysis reflects the importance of primary themes, emphasizing the importance of flood risk, vulnerability assessment, and geospatial methods in assessing sea level rise impacts on coastal airports. While existing models based on GIS, remote sensing, and hydrodynamic modelling are effective, there is a need for airport-specific risk models to improve accuracy. The refinement of model techniques will yield better solutions when it comes to making these decisions on the resilience of airports, infrastructure changes, and long-term risk mitigation policies for the support of coastal aviation (Steven et al., 2023).

This review emphasizes more concerned studies using bibliometric analysis and geospatial technology to study the impacts of sea level rise on coastal airports, which is lacking in this case. This review consolidates numerous studies' insights to improve coastal area resilience. It explains the relationship between infrastructure and sea level rise using diverse research methodologies. These findings also corroborate previous studies on the importance of geospatial tools in assessing coastal vulnerabilities. However, this review has identified a substantial void which is the absence of airports' specific risk models that are crucial for tailored adaptation strategies. These models along with geospatial analysis and risk modelling need further attention in the infrastructure planning and policy formulation research (Almaliki et al., 2023).

Further research should aim at addressing the issues of spatial discrepancies and improve the geospatial model to predict sea level rise impacts on coastal airports with greater accuracy. Airport vulnerability assessment in the future will undoubtedly be transformed by upcoming technological development. More precise adaptation risk evaluations can be achieved with the use of GIS-based flood modelling and high-resolution remote sensing (Sarrau et al., 2024). Forecasting based on the data retrieved from satellite altimetry and tide gauges can be improved by long-term monitoring integrated with real-time data. These developments emphasize the need for interdisciplinary approaches to strengthen airport resilience against rising sea levels (Hsiao et al., 2024).

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