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A SYSTEMATIC LITERATURE REVIEW OF HYDRODYNAMIC AND SEDIMENTATION MODELLING: RESEARCH TRENDS AND METHODS

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Abstract

This study aims to identify and analyse the trends and patterns of hydrodynamic and sedimentation modeling research from 2013 to 2022. A systematic literature review was conducted on publications from various databases, resulting in 39 relevant papers. The results show that the topic of hydrodynamic and sedimentation modeling has been increasing in popularity, with geomorphology as the most frequently published journal. Most studies focus on natural environmental interactions with current and sediment patterns using the Delft3D modeling software. The validation of the model is performed by comparing the observed current velocity results. Coupled models were used in only 44% of the reviewed literature. Overall, the findings suggest a significant gap in hydrodynamic and sedimentation modeling research, and more research is needed to address this issue.

Keywords: Systematic Literature Review, Hydrodynamic Modeling, Sedimentation Modeling, Research Trends

INTRODUCTION

One problem that often occurs in the coastal area is the continuous sedimentation process, causing siltation. The movement of sediment material in the sedimentation process is influenced by the movement of water flows such as tides, wind, currents, and waves (Ondara and Husrin, 2017). In structural planning, especially in ports, sedimentation is a crucial matter to review, because dredging activities can have quite a significant impact (Wurjanto and Ajiwibowo, 2019). Sedimentation also causes environmental degradation, such as increased turbidity, water pollution, and mangrove degradation, threatening aquatic ecosystems and siltation in harbour areas (Suciaty et al, 2019).

Numerical modelling is a method for determining hydrodynamic processes which are the main cause of the movement of pollutants in waters such as waste, sediment, and others (Maharta et al, 2018). Before doing modelling, data collection is first conducted with both primary data and secondary data. The field measurement includes data such as bathymetry, tidal elevation, and current velocity to complete the model. (Wurjanto and Ajiwibowo, 2019).

Some numerical model tools are widely used recently, such as MIKE21, SMS, Delft3D, HEC-RAS, CMS. The available model dimensions are 1D, 2D, or 3D. Due to

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the importance of sedimentation modeling to investigate the causes and effects of sediment or pollutant transport in water and the numerous modeling methods that can be used, this study will further explain the trend of using methods in hydrodynamic and sedimentation modelling.

METHODOLOGY

Review Method

The approach that can be taken to review the literature on hydrodynamics and sedimentation modelling problems is to use a systematic approach. According to Kitchenham and Charters (2007) in Wahono (2015), SLR is defined as the process of identifying, assessing, and interpreting all available research evidence to provide a specific answer to research questions.

This study's SLR process encompasses three distinct stages: planning, conducting, and reporting on the literature review. The SLR process utilized in this study follows the steps outlined by Wahono (2015) for steps 1 to 6 and 9, as demonstrated in Figure 1.

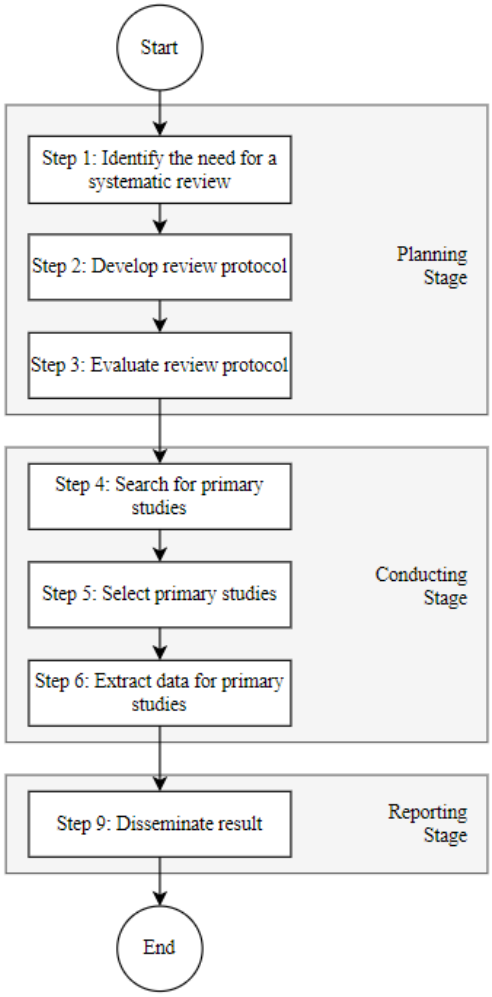

Figure 1 Systematic Literature Review Steps

Research Question

The primary focus of any review is determined by the research question (RQ) that guides the study. To facilitate the formulation of a well-defined research question, it is recommended to utilize the PICOC (Population, Intervention, Comparison, Outcomes, and Context) framework, as suggested by Kitchenham and Charters (2007 in Wahono, 2015). Table 1 provides a summary of the PICOC elements utilized in this study.

Table 1 Summary of PICOC

Population	Hydrodynamic modelling, sedimentation modelling, hydrodynamic and sedimentation modelling
Intervention	Model identification: model dimension, modelling software used, material of sediment, model validation
Comparison	N/A
Outcomes	Modelling effectiveness and accuracy
Context	Studies in academic or project area using numerical modelling

The RQ and motivation of this literature review are shown in Table 2.

Table 2 Research Questions on Literature Review

ID	Research Question	Motivation
RQ1	Which journal is the most significant hydrodynamic and sedimentation modelling?	Identification of the most significant journals in hydrodynamic and sedimentation modelling
RQ2	Who are the most active and influential researchers in the hydrodynamic and	Identify the most active and influential researchers who have contributed so much to the

ID	Research Question	Motivation
	sedimentation modelling?	hydrodynamics and sedimentation modelling research area
RQ3	What kind of research topics are selected by researchers in the hydrodynamic and sedimentation modelling?	Identify research topics and trends in hydrodynamic and sedimentation modelling
RQ4	What software will be used for modelling?	Identify the modelling software of hydrodynamic interactions and sedimentation
RQ5	What are the dimensions of the model?	Identify the dimension of hydrodynamic interactions and sedimentation modelling
RQ6	Are the hydrodynamic model and sedimentation model coupled?	Identify the modelling is done by coupled
RQ7	How is the model validated?	Identify how to validate the model

The primary research questions that guide this study are RQ4 to RQ8, while the remaining questions (RQ1 to RQ3) serve to contextualize the main investigation. Specifically, RQ1 and RQ3 seek to provide a summary and synopsis of the existing research related to hydrodynamic and sedimentation modelling. To address RQ4 to RQ8, a preliminary study was conducted to identify relevant hydrodynamic and sedimentation models. Subsequently, the collected data was analysed and classified according to the research questions.

The fundamental aim of the systematic literature review on hydrodynamic and sedimentation modelling was to identify the various applications for hydrodynamic and

sedimentation models. The underlying methodology for this review is represented in Figure 2.

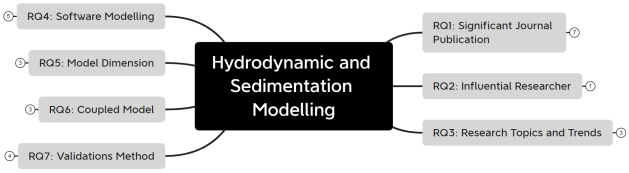

Figure 2 Basic Mind Map of the SLR on Hydrodynamic and Sedimentation Modelling

Search Strategy

The process of conducting a search encompasses a number of activities, including the selection of digital libraries, the formulation of the search query, the execution of a preliminary search, the refinement of the search query, and the retrieval of an initial list of primary studies from digital libraries that correspond to the search criteria. In order to optimize the search process, it is necessary to identify and select an appropriate set of databases that can enhance the likelihood of locating highly relevant articles. As such, the most widely utilized literature databases within the relevant field are queried in order to attain the most comprehensive set of studies possible (Wahono, 2015).

The digital library used for this study is Mendeley. The search strings employed in this study were formulated in accordance with the process outlined by Wahono (2015) in steps 1-3. The steps are as follows:

1. The search terms were identified based on the PICOC framework, with a particular emphasis on the Population and Intervention elements.
2. The search terms were further refined based on the research question.
3. Relevant titles, abstracts, and keywords were examined to identify additional search terms to be included in the query.

Subsequently, the search string utilized in this study is presented below:

hydrodynamic AND sedimentation modelling

The search was conducted by querying the selected databases based on the title, keyword, and abstract fields (Wahono, 2015). The search was restricted to publications from the years 2014 to 2023, and included two types of publications, namely journal papers and conference proceedings. Only articles published in the English and Indonesia language were considered in this search.

Study Selection

To select the primary studies, a set of inclusion and exclusion criteria were applied. The specific details of these criteria can be found in Table 3.

Table 3 Inclusion and Exclusion Criteria

Inclusion Criteria	Studies in academic or project area using numerical modelling
	Studies discussing modeling performance of hydrodynamic and sedimentation modelling in ocean engineering field
	In cases where a study has been published in both conference proceedings and a journal, only the journal version will be considered for inclusion in this review. (Wahono, 2015)
	If multiple publications of the same study are found, only the most comprehensive and up-to-date version will be selected for inclusion in this review. Any duplicates will be excluded. (Wahono, 2015)
	The publication year is 2014 to 2023
Exclusion Criteria	Studies discussing modeling performance of hydrodynamic and sedimentation modelling not in ocean engineering field
	Non open journal

As illustrated in Figure 3, the study selection process is conducted in two stages: exclusion of primary studies based on their titles and abstracts, and exclusion of primary

studies based on full-text analysis. Literature reviews and other non-experimental studies are excluded from the final selection.

For the first stage, a total of 39 primary studies were included in the final list of selected primary studies. The full texts of these 39 primary studies were thoroughly analysed, considering their quality, relevance to the research questions, and similarity to other studies. In addition, any similar studies published by the same authors in different journals were removed. After the full text selection process, only the 14 primary studies that met the inclusion and exclusion criteria remained. The complete list of selected studies can be found in the last section of this paper (Table 6).

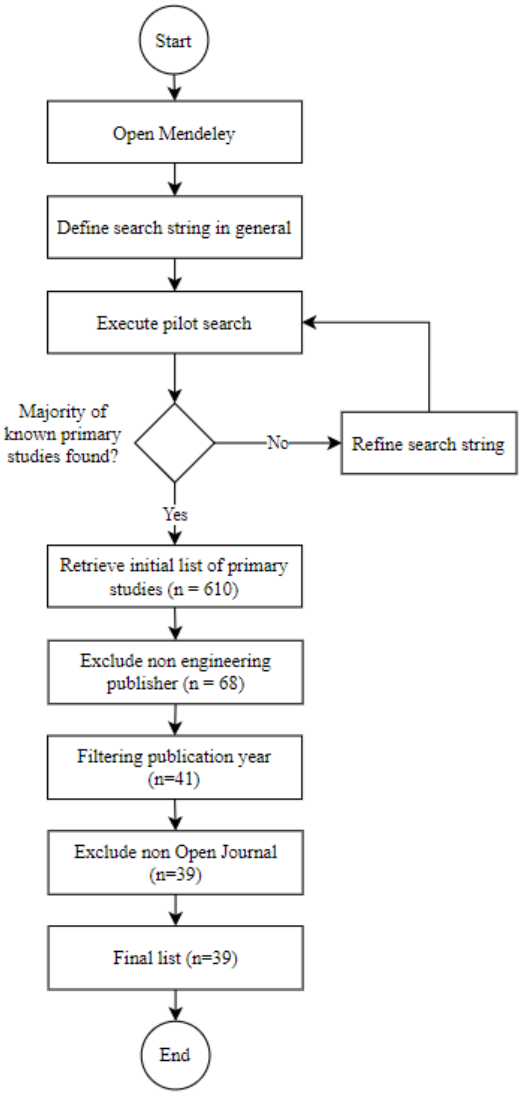

Figure 3 Search and Selection of Primary Studies

Data Extraction

The primary studies that were selected are used to gather data that can help address the research questions in this review. A data extraction form was completed for each of

the 39 selected primary studies. The data extraction form was designed to collect the data from the primary studies that are necessary to answer the research questions. Six properties were identified based on the research questions and analysis that was intended to be introduced. These properties are shown in Table 4. The data extraction process is done in an iterative manner.

Table 4 Data Extraction Properties Mapped to Research Questions

Property	Research Question
Researcher and publication	RQ1, RQ2
Research trend and topic	RQ3
Software modelling	RQ4
Model identification	RQ5, RQ6, RQ7

RESEARCH RESULT

Significant Journal Publication

This literature review includes 39 primary studies that analyse the hydrodynamic and sedimentation modelling. The distribution of these studies over the years is presented in Figure 4 to illustrate the change in interest in hydrodynamic and sedimentation modelling over time. Additionally, Figure 4 indicates that the research field of hydrodynamic and sedimentation modelling remains relevant today.

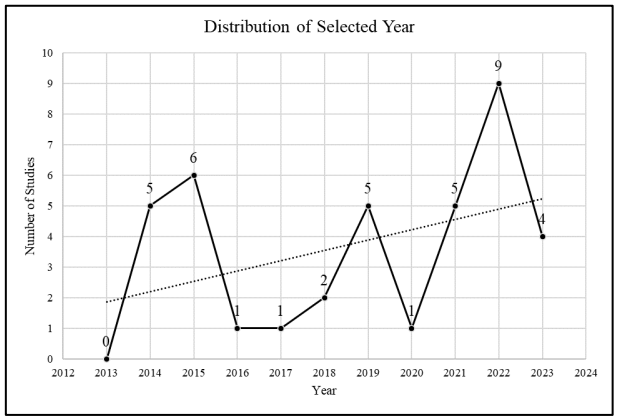

Figure 4 Distribution of Selected Studies over the Years

Based on the selected primary studies, Figure 5 presents the most significant journals related to hydrodynamic and sedimentation modelling .

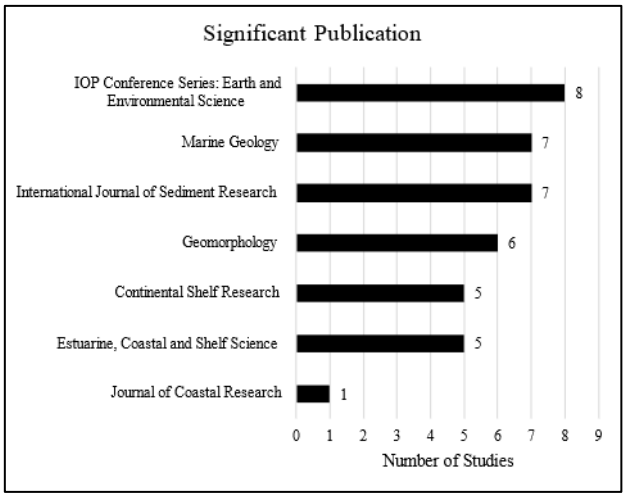

Figure 5 Journal Publications and Distribution of Selected Studies

Table 5 presents the Scimago Journal Rank (SJR) values and Q categories (Q1-Q4) of the primary hydrodynamic and sedimentation modelling journals and proceedings, with publications arranged in descending order based on their SJR value.

Table 5 Scimago Journal Rank (SJR) of Selected Journals

No	Journal Publications	SJR	Q Category
1	Geomorphology	1.21	Q1
2	Marine Geology	1.00	Q1
3	Continental Shelf Research	0.80	Q1
4	International Journal of Sediment Research	0.79	Q1
5	Estuarine, Coastal and Shelf Science	0.77	Q1
6	Journal of Coastal Research	0.28	Q3
7	IOP Conference Series: Earth and Environmental Science	0.20	Un-quartiled

Most Active and Influential Researchers

The selected primary studies were used to identify the researchers who made significant contributions and are active in the hydrodynamic and sedimentation modelling research field. Figure 6 displays the most active and influential researchers in this field, listed according to the number of studies included in the primary studies.

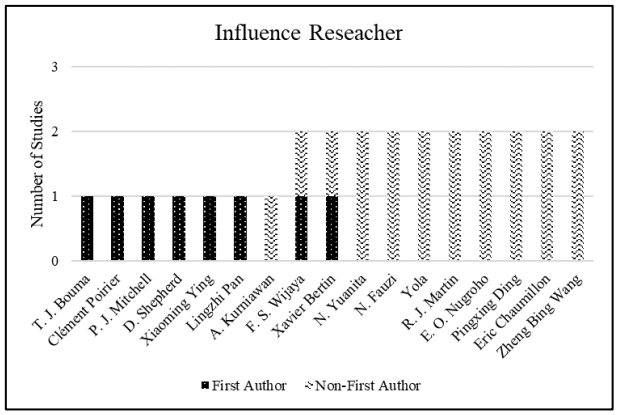

Figure 6 Influential Researchers and Number of Studies

Research Topic in Hydrodynamic and Sedimentation Modelling

The analysis of the selected primary studies revealed that the current research on hydrodynamic and sedimentation modelling focuses on three main topics:

1. Predicting the influence of human activities on changes in current patterns and sedimentation patterns (**human activities**)
2. Determining the interaction between natural events and changes in current patterns and sedimentation patterns (**natural environmental interactions**)
3. Determining the influence of the presence of structural buildings on changes in current patterns and sedimentation patterns (**structural interactions**).

Figure 7 shows the total distribution of research topics in hydrodynamic and sedimentation modelling from 2014 to 2023. Most of the topics, about 66%, focus on natural environmental interactions, followed by about 25% on structural interactions, and the remaining 9% on human activities that affect changes in current and sediment patterns. The natural environmental interaction topic is widely discussed to determine the extent of the influence of environmental factors such as wind, waves, storms, tsunamis, etc. on sedimentation patterns in a location. Meanwhile, structural interactions such as reclamation, breakwater, dikes, or port are discussed to determine the impact of the presence or absence of a building in a location on sedimentation patterns.

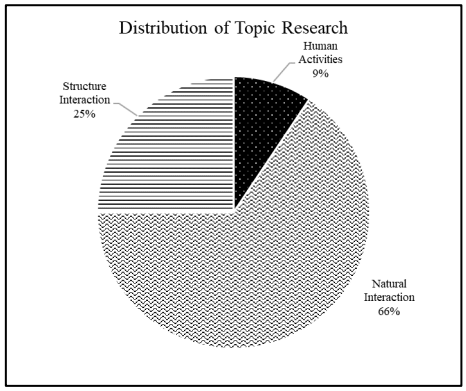

Figure 7 Journal Publications and Distribution of Selected Studies

Model Identification in Hydrodynamic and Sedimentation Modelling

Based on the selected primary studies, hydrodynamic and sedimentation models can be identified based on the type of software used, model dimensions, sediment type, validation method, and the use of coupled models. There are at least 5 popular software used for hydrodynamic and sedimentation modelling, as shown in Figure 8, which include Delft3D, MIKE21, Marsh3D, HEC-RAS, and CSTMS Software (Community Sediment-Transport Modeling System). These software programs offer various modeling capabilities, from 1D to 3D dimensions, and can be used to simulate sediment transport, erosion, and deposition in different types of environments such as rivers, estuaries, and coastal zones. The choice of software depends on the specific research questions, data availability, and modeling requirements of each study.

Delft3D is a software that is widely used in hydrodynamic and sedimentation modeling (52%). The Delft3D model demonstrated the capability to replicate hydrodynamic and sedimentological variables observed in natural settings, thereby enabling the exploration of hypothetical scenarios (Rivera, 2023). The software Delft3D has demonstrated its capacity to effectively model intricate coastal systems with precision (Elias et al, 2012 in J.J. van der Werf et al, 2020).

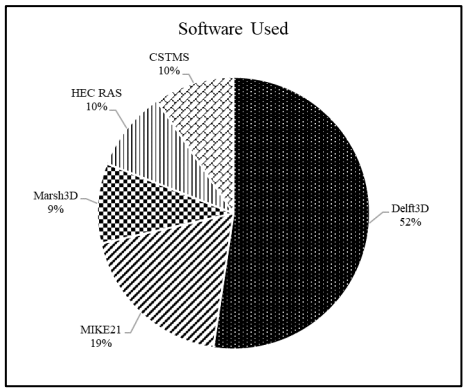

Figure 8 Hydrodynamic and Sedimentation Modelling Software Used

Based on the identification of model dimensions, the use of 3D models is around 51%, 2D models 33%, and 1D models 16%. The successful implementation of settling particles characteristics in a 3D hydrodynamic and sediment transport model allowed for the accurate reproduction of observed deposition of polluted particles in the coastal zone. The model also revealed a significant offshore export of the finest particles and their accompanying pollutants (Oursel, 2014). The identification of model dimensions is shown in Figure 9.

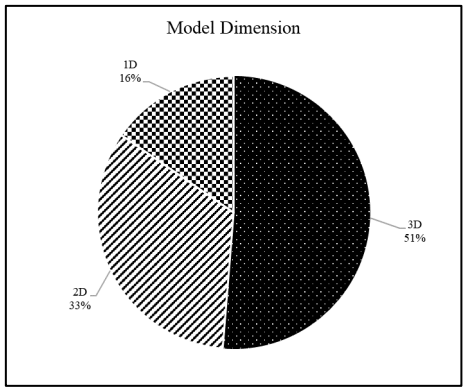

Figure 9 Model Dimension

Sediment material is one of the most important parameters in modeling. This is because some software, such as MIKE21, presents different modules for cohesive (mud) and non-cohesive (sand) sediment types. In general, the modeling trend for cohesive and non-cohesive sediment materials from the 39 primary studies is similar, as shown in Figure 10.

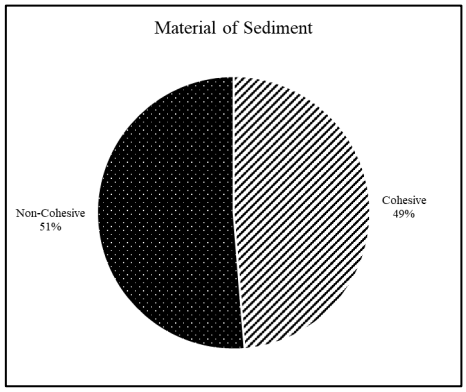

Figure 10 Sediment Material under Consideration

A coupled model is a combination of two or more models, either within the same software but different modules, or across different software programs. Based on the analysis results, it was found that 56% of the models were not coupled, meaning they did not combine two or more models either within the same software with different modules or across different software. This could be since the computational cost of the non-coupled algorithm is significantly lower (about 97%) than the conventional semi-coupled approach, and the developed algorithm had errors (Root Mean Square Error, Average Relative Error, and Maximum Relative Error of bed level) that were approximately 15% higher than those of the semi-coupled algorithm for the average value (Khorrami et al., 2019).

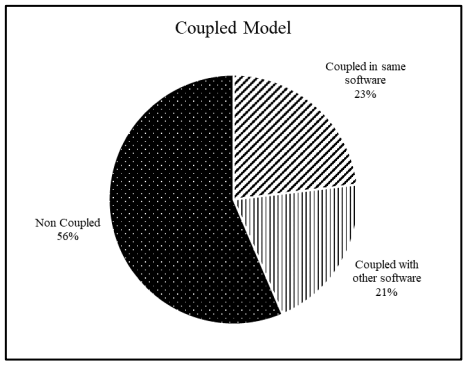

Figure 11 Distribution of Coupled Model

After the model is executed, the next step is validation. Before applying the calibrated and validated model to the proposed case, it is necessary to verify the model using observed data (Tadesse and Dai, 2019). There are at least several validation methods that can be used, depending on the modeling objectives. About 47% of the studies validate the model's current velocity against observed current velocity. Meanwhile, 14% validate against existing bathymetry and 18% against tidal range. However, 21% of the modeling was not validated. Identification of model validation methods is shown in Figure 11.

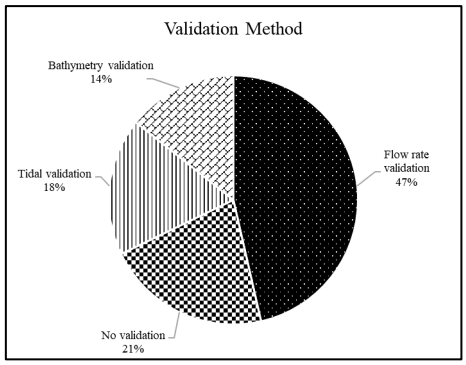

Figure 12 Model Validation Method

CONCLUSION

In general, hydrodynamic and sedimentation modelling topics are still widely studied. From 2013 to 2022, there has been a trend of increase, although there are fluctuations each year. The publisher that produces the most proceedings is IOP Conference Series: Earth and Environmental Science, with 8 proceedings, while the publishers that produce the most journals are Marine Geology and International Journal of Sediment Research, with 7 journals each.

The hydrodynamic and sedimentation modelling topic has been widely studied and has shown an increasing trend from 2013 to 2022, although there have been fluctuations each year. The publisher that produced the most proceedings is the IOP Conference Series: Earth and Environmental Science, with 8 proceedings, while the publishers that

produced the most journals are Marine Geology and the International Journal of Sediment Research, with 7 journals each.

Researchers in the hydrodynamic and sedimentation modelling field have not yet shown a significant impact in terms of the number of studies. However, at least Wijaya and Bertin have published 2 journals, although one of them is not the main author.

Based on model identification, the most researched topic is the interaction of natural environmental factors with changes in current and sediment patterns, accounting for 66%. Approximately 52% of the research uses Delft3D as the modelling software. The 3D dimension model is frequently used (51%). There is no significant difference in the number of studies between cohesive and non-cohesive materials. For model validation, the most performed validation is the validation of current velocity results against observations (47%). The use of coupled models is not dominant, accounting for only about 44% of the 39 reviewed literature.

The complete mind map depicting the findings of the systematic literature review on hydrodynamic and sedimentation modelling is presented in Figure 12. Mind maps are commonly utilized to examine relationships between concepts and components of an argument, as well as to generate solutions to problems. They also facilitate the logical organization of information and integration of new knowledge. In this study, the mind map serves to highlight the outcomes of the systematic literature review on hydrodynamic and sedimentation modelling (Wahono, 2015).

Some recommendations resulting from the SLR analysis for hydrodynamic and sedimentation modeling are as follows:

1. Modeling can use the commonly used method today: 3D un-coupled modeling using Delft3D to examine natural interactions and validated against seawater velocity and tidal elevation.
2. Conduct sensitivity analysis on the modeling parameters used, such as comparing 2D models to 3D models within the same software or comparing models from Delft3D software to Mike21 (a relevant similar software).
3. Model using topics and model parameters that have not been widely used.

Since this Hydrodynamic and Sedimentation Modelling SLR only used the digital library from Mendeley, to complement the trend and method analysis for future SLRs, other digital libraries such as Scopus, Web of Science, SINTA, Google Scholar, and others should be utilized.

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