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Use of the TOPSIS-Entropy-GIS Method and Evaluation of the Sustainability of Carrying Capacity of Marine Waters to Determine Blue Economy Strategy Priorities in Indonesia

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Abstract

Management of coastal sedimentation is an important policy approach on accomplishing the Blue Economy in Indonesia. Accumulated coastal sedimentation possibly threatens ecosystems thus resulting in degradation of the carrying capacity. This conditions also plausibly harm the livelihoods of the community as well as the surrounding infrastructure. This study is designed to solve the problem of identifying areas experiencing heavy degradation of the carrying capacity as well as the priority areas using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which is integrated with the Entropy and Geographic Information System. The analysis was carried out on a national level in four major stages with 13 parameters for 32,284 spatial blocks by: (a) grading of inter-regional marine area; (b) screening of priority areas; (c) determining clusters of priority location; and (d) evaluation of Sustainability analysis. The result shows that the Java Sea and Sunda Strait, as well as the Natuna Sea and North Natuna Sea are the main priorities of Inter-Regional Marine Area to implement the management of coastal sedimentation. In detail, the priority location cluster in the Java Sea and Sunda Strait areas is located in the waters around Jakarta, West Java, Central Java, East Java, West Kalimantan, Central Kalimantan and South Kalimantan, while the priority location cluster in the Natuna and North Natuna Sea areas is located in the waters around Riau, Riau Islands, South Sumatera, and West Kalimantan. Moreover, the TOPSIS analysis is completed by doing a ground check to collect additional data and aspirations of local communities. The result of the Sustainability analysis using a qualitative approach through the BIRU method (Budget, Impact, Response, and Uncertainty) shows that there are variations in the intensity of budget variables, community response, problem intensity, and variables of the urgency of managing sedimentation problems in the priority areas.

Keywords: TOPSIS, Entropy, GIS, Sedimentation
Jel codes: Q01, Q22

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1. Introduction

Management of coastal sedimentation is a prominent emerging topic for realizing the Blue Economy policy in Indonesia as Government Regulation Number 26 of 2023 concerning Management of Sedimentation Products at Sea was released. Coastal sedimentation could threaten coastal areas, especially in terms of environmental, social and economic aspects (Adriman et al., 2013; Dwianti et al., 2017; Juliano et al., 2021; Sipahutar et al., 2020; Tarigan et al., 2020). Due to the vast territory of Indonesia and the many locations experiencing sedimentation as well as lack of finance, a reliable method is needed that can be used to determine priority locations for implementation of the Management of coastal sedimentation programme.

Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) analysis combined with the Entropy and GIS methods is an alternative method that can be used since TOPSIS has the principle of approaching positive ideal solutions and moving away from negative ideal solutions, while the entropy method avoids subjectivity bias at the weighting stage criteria (Cao et al., 2021; Ding et al., 2016). GIS analysis also provides an advantage to acquire and analyse data within a vast area and abundant of quantity accurately and undemanding on the process.

2. Literature Review

Sedimentation is the process of sediment deposition, including all activities that influence and change sediment into sedimentary rock. The sedimentation process that occurs in the environment, especially the marine environment, will change the interaction pattern between biotic and abiotic factors, and this will create natural conditions that are different from before the process took place (Rifardi, 2010). Coastal sedimentation affects environment aspect of coastal area, such as coral reef. It is known to cause: 1) coral death if it covers or covers the entire coral surface with sediment; 2) reduce coral growth directly; 3) inhibit coral planula from attaching themselves and developing on the substrate; 4) increase the adaptability of coral to sediment (Adriman et al., 2013; Fabricius, 2005). Besides, social and economic of coastal communities along coastal areas also affected by coastal sedimentation by shallowing of river estuaries and disruption of fishing boat traffic, shutting down fishing ports (Dwianti et al., 2017; Juliano et al., 2021; Rahmawan et al., 2023; Tarigan et al., 2020).

Application of The TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) analysis was first proposed by Hwang and Yoon in 1981 (Global Reporting Initiative, 2002; Mitra et al., 2023), while (Yuvaraj et al., 2024), revealed this method was first introduced earlier by (Hwang & Masud, 1979). TOPSIS grants an effective method to solve the problem of multi-attribute decision-making by sorting the solutions by evaluating the difference between each solution and the ideal solution along with the negative ideal solution. TOPSIS analysis and its combination have also been used in several studies related to coastal areas, including the suitability of marine tourism (Yuvaraj et al., 2024), evaluation of the health of coastal ecosystem (Chen et al., 2022), flood risk mapping (Nguyen et al., 2020), as well as evaluate sustainable development of islands (Zhao et al., 2022).

One of development TOPSIS approach is dynamic as it might be integrated to other approach such as hybrid of TOPSIS and Entropy analysis. Zhao et al., (2022) said that the advantages of Entropy and TOPSIS are as follows: Entropy is an objective tool for attribute evaluation, and its advantages are reflected in the calculation of Entropy weights from existing data without personal subjective factors. The index weight has strong objectivity to guarantee the scientific nature of the evaluation conclusions so that the results are consistent with decisions that are intuitive, easy to understand, and accepted by decision makers; and has advantages over other methods for determining index weights. The TOPSIS method is also an effective method for solving multi-attribute decision making problems with solutions that have ranking values. The principle of this method is to sort the solutions by calculating the difference between each solution and the ideal solution along with the negative ideal solution, so that the optimal solution can be determined. Another advantage is that the calculations are simple, easy to understand, and can be integrated with other methods. When combining the ideas of Entropy and TOPSIS, Entropy determines the weights of the indices to be evaluated, and TOPSIS estimates the ideal solution to determine the final order of objects to be evaluated. Therefore, the combination of Entropy and TOPSIS provides clear evaluation principles, robust operation, and a strong adaptation range. TOPSIS integration with Geographic Information System (GIS) makes it easier to process and interpret large, broad and multi-attribute spatial data (Jozaghi et al., 2018; Mitra et al., 2023).

3. Data Sources dan Metodology

3.1.Data Sources

Data used in this study, namely:

No	Variable	Source
a	Distribution of coral reef ecosystem 2013	Thematic Geospastial Information of coral reef ecosystem 2013
b	Distribution of mangrove ecosystem 2021	Thematic Geospastial Information of Mangrove
c	Distribution of sea grass ecosystem 2014	Thematic Geospastial Information of sea grass ecosystem 2014
d	Distribution of seafloor sediment 1991	P3GL, Ministry of Energy and Mineral Resources
e	Distribution of Coastal erosion and accretion 2023	Directorate of Utilization of Coasts and Small Islands-Ministry of Marine Affairs and Fisheries
f	Bathymetry	BATNAS of Geospastial Information Agency
g	Sea water Quality index 2021	Ministry of Environment and Forestry
h	Distribution of fishing port 2023	Masterplan of National Fishing Ports 2023
i	Distribution of Sunken Shipwrecked Objects 2020	Directorate of Marine Services-Ministry of Marine Affairs and Fisheries
j	Total Suspended Solid	Marine Copernicus
k	Distribution of estuary	Geospastial Information Agency
l	Marine Spatial Planning	Directorate of Marine Spatial Planning - Ministry of Marine Affairs and Fisheries

3.2 *Analysis Methods*

Analysis used in this study applied on four main stages, namely:

a) Grading of Inter-Regional Marine Areas

Grading of Inter-Regional Marine Areas is carried out for ranking/selection of areas at the national level where the spatial unit used is the Inter-Regional Marine Area (hereinafter called as IRMA). Boundary of IRMAS are accordance with the delineation in Government Regulation Number 32 of 2019 concerning Marine Spatial Planning. Grading of IRMAs is applied through GIS analysis using an approach to the proportion of potentially affected coastal ecosystems (coral reefs, seagrass and mangroves), water conditions and distribution of sand/mud substrates to width of the IRMA, as well as the numbers of fishing ports. In detail, the variables and criteria used are as follows.

1) Coastal ecosystem

The value of the coastal ecosystem component used is the proportion of the area of the coastal ecosystem (coral reefs, seagrass and mangroves) towards width of the IRMA.

2) Water Quality Condition

Water quality condition covers water clarity and Total Suspended Solid (TSS)

- Priority marine areas are waters with water clarity of less than 5 meters
- TSS value of more than 20 ppm for areas around coral reef and seagrass ecosystems.
- TSS value is more than 80 ppm for areas around the mangrove ecosystem

3) Distribution of seafloor sediment

Distribution of seafloor sediment covers sand mud as indication of sedimentation

4) Accretion distribution

Coastal areas experiencing accretion are an indication of a sedimentation process that has the potential to be detrimental to the environment and society. The accretion component value used is the proportion of the length of the coastline that experiences accretion to the length of the coastline of IRMA.

5) Bathymetry

The depth of the waters at the location where sediment accumulated will influence the potential negative impacts. The shallower the water, the more detrimental the presence of sedimentation will be. The depth of the waters also influences the effectiveness of implementing management of Sedimentation Results in the Sea. Taking this into account, the value of the water depth component used is the proportion of water area with a depth of <50 meters to the width of IRMA.

6) Fishing port

Fishing ports are one of the socio-economic centres for marine and fisheries sector where the more fishing ports in a region indicate the higher socio-economic activities related to marine and fisheries in that region which have the potential to be affected by sedimentation.

b) Screening of priority areas

Based on the results of the national scaling priority analysis, it is then carried out through screening using geospatial analysis with the following criteria:

1) beyond sea lane area
2) beyond marine mining zone
3) beyond marine conservation area
4) beyond port area
5) beyond submarine pipe and cable area (buffer of 500 m)
6) beyond sunken shipwreck object area (buffer of 500 m)
7) beyond safe distance of small island area
8) Within feasible depth of operational implementation of coastal sedimentation management area (max depth of 50 m)
9) Beyond coastal erosion area

c) Determining clusters of priority area.

Determining cluster of priority location is carried out through several steps, namely:

1) Geospatial analysis

In this research, a spatial unit area approach is used in the form of a grid/block with dimensions of 2,000 ha which divides the entire IRMA.

2) Data Standarization

Data standarization was carried out on criteria grouped into positive criteria and negative criteria

The standardized formula for the positive variables is as follows

$$r_{ij} = \frac{x_{ij} - \min\{x_{ij}\}}{\max\{x_{ij}\} - \min\{x_{ij}\}}$$

r*ij* represents the standard value of the *j*th evaluation object on the *i*th index, r*ij* ∈ {0, 1}

meanwhile the standardized formula for the negative variables is

$$r_{ij} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}}$$

3) Calculating criteria weight

Criteria weights are usually determined by experts in the field referred to. In this study, to eliminate subjectivity, we used the Entropy method in determining criteria weights.

4) TOPSIS analysis

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is adopted in this study on running *Multi Criteria Decision Making* (MCDM). The TOPSIS principle used is that the best alternative must have the shortest *Euclidean* distance for positive ideal conditions and must be at the farthest distance from negative ideal conditions. This method has a solid mathematical foundation and a rigorous calculation process (Yuvaraj et al., 2024)

Variables and index classification used in this TOPSIS scenario as follows:

No	Variables	Positive or negative index
a	Distance to coral reef ecosystem	-
b	Distance to sea grass ecosystem	-
c	Distance to mangrove ecosystem	+
d	Sea water Quality index	-
e	Total Suspended Solid value	-
f	Distance to river mouth	-
g	Distance to accreation area	-
h	Distance to fishing port	-
i	Bathymetry	-

The following step is clustering for all blocks through analysis of the determination and range between classes, using the proportional allocation method from the lowest value interval to the highest value through GIS approach.

5) Evaluation of Sustainability

In addition, a Qualitative Description Analysis was carried out to evaluate sustainability of indications of priority locations using four Quadrant Crunching components, namely 1) Budget, 2) Impact, 3) Response, and 4) Uncertainty, or what is called the "BIRU Component". Budget component means economic opportunities for private company to help conducting dredging, while Impact means Degree of importance of coastal sedimentation implementation by community. In addition, Response refers to community response to coastal sedimentation implementation. Lastly, Uncertainty refers to the level of uncertainty caused by the existence of coastal sedimentation for the social economy of society

Whole process of analysis is represented by following figure.

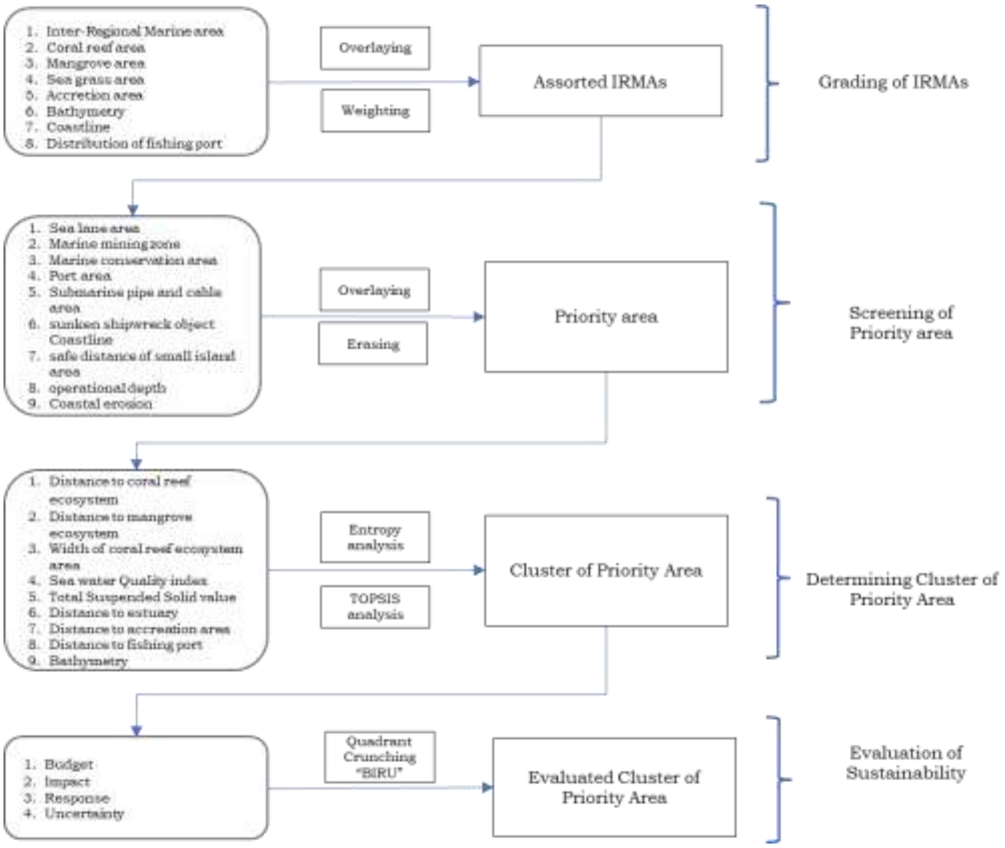

Figure 1. Flow chart of analysis

Source: Authors' analysis, 2023

4. Results and Discussion

4.1.National Scaling Priority Areas

Table 1. Rangking of National Scaling Priority Areas based on IRMA

IRMA	Width of IRMA (ha)	Prop. of width of coral reef and sea grass area to IRMA	Prop. of length of accretion to coastline	Prop. of bathy area <50m to IRMA	Total of fishing port (unit)	weight of ecosystem	weight of accretion	weight of bathy	weight of fishing port	**Total Value**	**Class of Priority**
JS	55,292,596.35	0.0000407	0.10	0.55	185	4	4	5	5	**18**	**1**
NN	62,867,913.76	0.0001222	0.03	0.46	41	5	2	5	4	**16**	**1**
SS	25,815,639.72	0.0002575	0.04	0.05	13	5	3	2	2	**12**	**2**
MS	7,178,396.89	0.0000013	0.03	0.47	15	2	2	5	2	**11**	**2**
MK	19,652,006.68	0.0000106	0.03	0.26	28	2	2	4	3	**11**	**2**
WS	99,630,907.99	0.0000055	0.02	0.04	48	2	2	2	4	**10**	**3**
AS	48,397,128.31	0.0000220	-	0.42	8	3	1	5	1	**10**	**3**
BB	3,279,632.20	-	0.09	0.24	8	1	4	4	1	**10**	**3**
BS	3,891,562.52	-	0.20	0.05	20	1	5	2	2	**10**	**3**
SJ	82,349,392.39	-	0.05	0.01	60	1	3	1	4	**9**	**4**
TB	5,650,277.88	-	0.06	0.09	16	1	3	3	2	**9**	**4**
BD	67,779,844.33	0.0000027	0.03	0.03	27	2	2	1	3	**8**	**4**
SV	10,482,912.08	-	0.04	0.03	15	1	3	1	2	**7**	**4**
FS	10,694,839.64	-	0.03	0.08	10	1	2	2	1	**6**	**5**
HS	9,790,445.96	-	-	0.09	6	1	1	3	1	**6**	**5**

IRMA	Width of IRMA (ha)	Prop. of width of coral reef and sea grass area to IRMA	Prop. of length of accretion to coastline	Prop. of bathy area <50m to IRMA	Total of fishing port (unit)	weight of ecosystem	weight of accretion	weight of bathy	weight of fishing port	**Total Value**	**Class of Priority**
CS	16,029,547.41	0.0000032	-	0.17	4	1	1	3	1	**6**	**5**
CB	6,526,256.53	-	-	0.14	4	1	1	3	1	**6**	**5**
ML	21,680,396.08	-	0.00	0.01	12	1	1	1	2	**5**	**5**
NP	77,412,948.88	-	0.00	0.01	3	1	1	1	1	**4**	**5**

Notes:

JS = Java Sea and Sunda strait	BB = Bone Bay	HS = Halmahera Sea
NN = Natuna and North Natuna Sea	BS = Bali Sea	CS = Ceram Sea
SS = Sulawesi Sea	SJ = South of Java-Bali-Nusa Tenggara Sea	CB = Cendrawasih Bay
MS = Malacca strait	TB = Tomini Bay	ML= Moluca Sea
MK = Makassar strait	BD = Banda Sea	NP = North of Papua Sea
WS = West of Sumatera Sea	SV = Savu Sea	
AS = Aru Sea	FS = Flores Sea	

Source: Authors' analysis, 2023

Table 1 shows Indonesia has a vast marine area and is divided into 19 Inter-Regional Marine Areas (IRMA) as stated by Government Regulation of Indonesia Number 32 of 2019 concerning Marine Spatial Plan. Based on Law Number 32 of 2014 concerning Maritime Affairs, Inter-Regional Marine Areas are marine areas that covers two or more provinces in the form of bays, seas, straits and bays. The West Sumatra Sea is the largest IRMA with an area of more than 99 million ha, while Bone Bay is the smallest IRMA with an area of around 3.2 million ha.

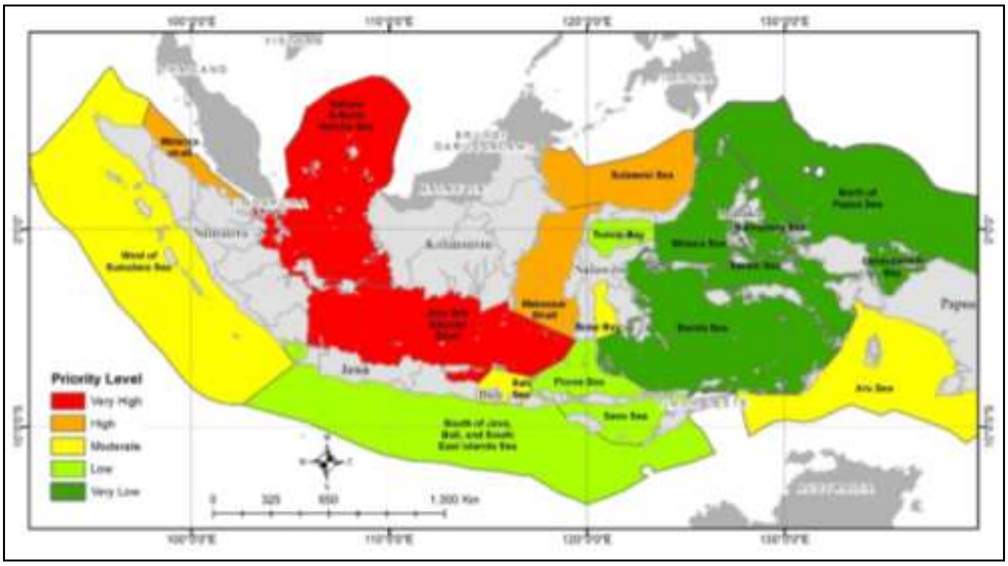

Figure 2. Ranking of IRMAs for coastal sedimentation management

Source: Authors' analysis, 2023

Based on geospatial analysis, IRMA with areas of intersecting coral reefs with TSS > 20 ppm and sand or mud substrates are the Natuna Sea and North Natuna with an area of more than 7,600 ha and followed by the Sulawesi Sea as well as the Java Sea and the Sunda Strait with an area of more than from 6,600 ha and 2,200 ha, respectively. In terms of sedimentation, the IRMAs that experienced the heaviest sedimentation or accretion were the Java Sea and Sunda Strait as well as the Natuna and North Natuna Sea, with sedimentation lengths of more than 861 km and 471 km along the coast, respectively. Apart from that, the largest number of fishing ports is spread across the Java Sea and the Sunda Strait, the Java-Bali South Sea with 185 and 60 fishing ports correspondingly. Besides, IRMAs which have a relatively shallow proportion of sea depth, namely <50 m, are the Java Sea and Sunda Strait KAW as well as the Natuna Sea and North Natuna Sea KAW correspondingly with areas of 55% and 46% of each IRMA.

Result of the rangking of all IRMAs based on several criteria shows that the Java Sea and Sunda Strait as well as the Natuna and North Natuna Sea are classified as the very high priority (1^{st} class) in which require serious intervention in term of coastal sedimentation management followed by the Sulawesi Sea, Malacca Strait and Makassar Strait are classified as the high priority class (2nd class).

4.2.*Cluster of priority location*

The following figure is produced by a combination of TOPSIS-Entropy-SIG analysis to 17,315 spatial block unit. The map demonstrates that priority location clusters in the Java Sea and Sunda Strait, which are classified by "very high priority level on the map", are spread across several regions, including in the waters around East Java, Central Java, West Java, Jakarta, West Kalimantan, Central Kalimantan, and South Kalimantan. The sedimentation priority location clusters have been detected in the coastal of cities of Surabaya, Demak, Kendal, Semarang, Indramayu, Cirebon and Jakarta are in accordance with several other studies which show the presence of sedimentation in these areas as stated by Ma'arif & Hidayah (2020), Rigitta et al. (2015), Triapriyasen et al. (2016), and Utami et al. (2018).

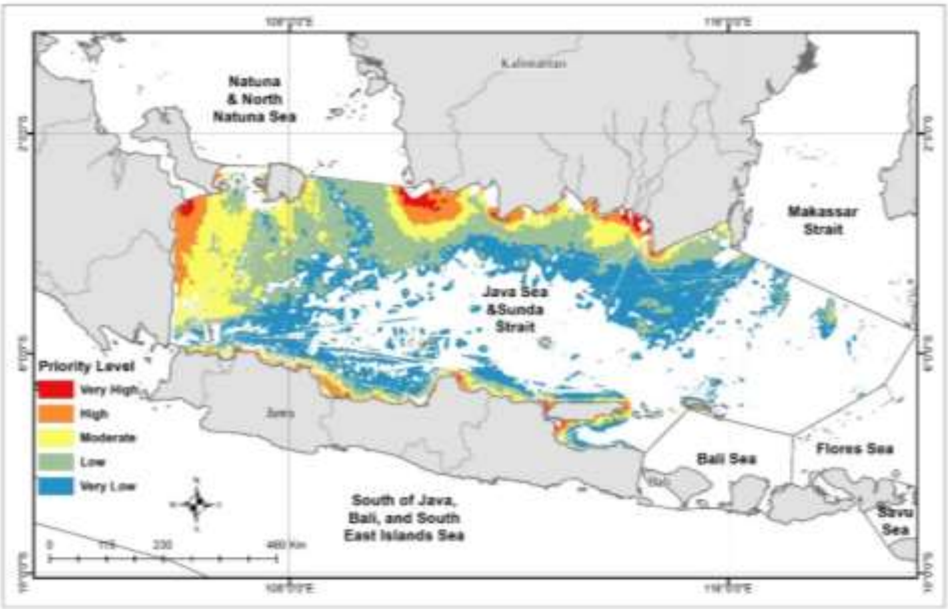

Figure 3. Clusters of priority area of coastal sedimentation at Java Sea and Sunda Strait

Source: Authors' analysis, 2023

The occurrence of coastal sedimentation in the Java Sea is linked to oceanographic conditions, including sea currents. Ocean currents with relatively slow speeds are expected to cause coastal sedimentation (Rifardi, 2010; Sipahutar et al., 2020). The Indonesian archipelago is influenced by the monsoon, which in the west monsoon winds move from the Asian Continent to the Australian Continent, while in the east monsoon the winds move from the Australian Continent to the Asian Continent. In the waters of the Java Sea, during the west monsoon the wind moves from west to east, while during the east season it moves from east to west (Wyrtki, 1961). Ocean currents around the waters of the Java Sea are flowing at a relatively slow speed. The slow speed of ocean currents is shown, for instance, by its condition of Morodemak Waters, Demak regency which has a maximum current speed of 0.0033 m/s, and a minimum current speed of 0.0003 m/s (Rigitta et al., 2015), and the current speed on the coast of Kenjeran, Surabaya City which has a range of 0.06 – 1.17 m/s (Ma'arif & Hidayah, 2020).

Coastal sedimentation that occurs in the Java Sea has disrupted fishing and fishing activities, tourism and sea transportation (Alkautsar et al., 2022; Dwianti et al., 2017; Utami et al., 2018). while these activities have great potential in implementing the blue economy in order to gain more prosperity to communities (Pane et al., 2021; Sari & Muslimah, 2020; Utami et al., 2018; Zulkifli et al., 2023). Thus, mapping priority locations for sedimentation around the Java Sea, which was carried out using a combination of TOPSIS-Entropy-SIG analysis, can be considered to support the blue economy by mapping potential threats that could occur due to coastal sedimentation.

Meanwhile, the priority location clusters in the Natuna and North Natuna Seas shown in the figure below, which are classified by "very high priority level on the map", is generated as result of an integration of TOPSIS-Entropy-SIG analysis towards 14,969 spatial blocks. The analysis spotted indication of coastal sedimentation throughout several coastal regions, including in the waters around the Riau Islands, Riau, South Sumatra and West Kalimantan. This result correspond to the sedimentation that occurred in Bintan city, Karimun regency, Banyuasin regency, as well as Sambas reported by Adriman et al. (2013), Agus et al. (2016), Rahmawan et al., (2023), and Taredja & Nugroho (2018).

The emerging of coastal sedimentation in the Natuna and North Natuna Seas possibly affected by oceanographic conditions, including sea currents. Ocean currents with relatively slow speeds are likely resulting coastal sedimentation (Rifardi, 2010; Sipahutar et al., 2020). The pattern of ocean currents in the Natuna and North Natuna Seas can be represented by the current conditions in the waters of the Riau Islands. Based on Pokja RZWP3K Riau Islands Province (2020), current patterns in the waters of Riau Islands Province are influenced by seasonal and tidal factors. The pattern of tidal currents in the waters of the Riau Islands Province during the north and south seasons or coinciding with the west and east seasons will tend to be constant both at high tide and at low tide. When approaching high tide, the water mass will move towards land. In the waters around the Batam, Bintan and Karimun areas, when approaching high tide, the water mass moves from the northwest, while in the waters of Lingga, Natuna and the Anambas Islands, the water mass moves from the north and northeast. The opposite condition is found when heading towards low tide, when heading towards low tide the water mass in the waters of the Riau Islands Province moves towards the sea away from the coast in the opposite direction when conditions approach high tide. The current speed value in the Karimun Island area in the West Monsoon has a minimum value of 0.103 m/s and a maximum value of 0.472 m/s, in Transition Monsoon 1 it has a minimum value of 0.129 m/s and a maximum value of 0.485 m/s, in the East Monsoon it has a value of the minimum value is 0.112 m/s and the maximum value is 0.266 m/s, while in Transition Monsoon 2 the minimum value reaches 0.145 m/s and the maximum value reaches 0.577 m/s.

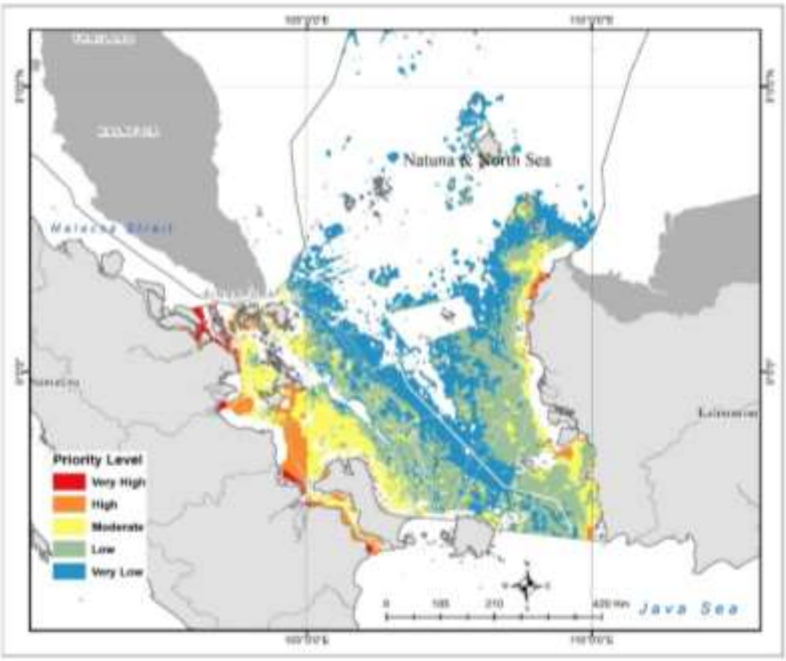

Figure 4. Clusters of priority area of Coastal sedimentation at Natuna and North Natuna Sea

Source: Authors' analysis, 2023

Coastal sedimentation that occurs in the Natuna and North Natuna Seas is also reported to disrupt coastal ecosystems (Adriman et al., 2013), fishing activities (Putra et al., 2016) as well as marine transportation (Aritonang et al., 2016; Taredja & Nugroho, 2018). This conditions reducing potency of producing value added to society as these activities related to potency of blue economy (Pane et al., 2021; Sari & Muslimah, 2020; Utami et al., 2018; Zulkifli et al., 2023). Thus, mapping priority locations for sedimentation around the Java Sea, which was carried out using a combination of TOPSIS-Entropy-SIG analysis, can be considered to support the blue economy by mapping potential threats that could occur due to coastal sedimentation.

4.3.*Evaluation of sustainability*

In order to evaluate sustainability, ground check was conducted at several areas that are considered as representative of the cluster, namely Morodemak in Demak regency, Kenjeran in Surabaya city, Setimbul bay and Paku bay in Karimun regency. Result of Quadrant Crunching analysis using BIRU method as shown above reveals the profit opportunities for private sectors to help implement coastal sedimentation management at the several locations are relatively low, especially at Kenjeran. Low profit is affected by coastal sediment characteristics containing more mud instead of sand.

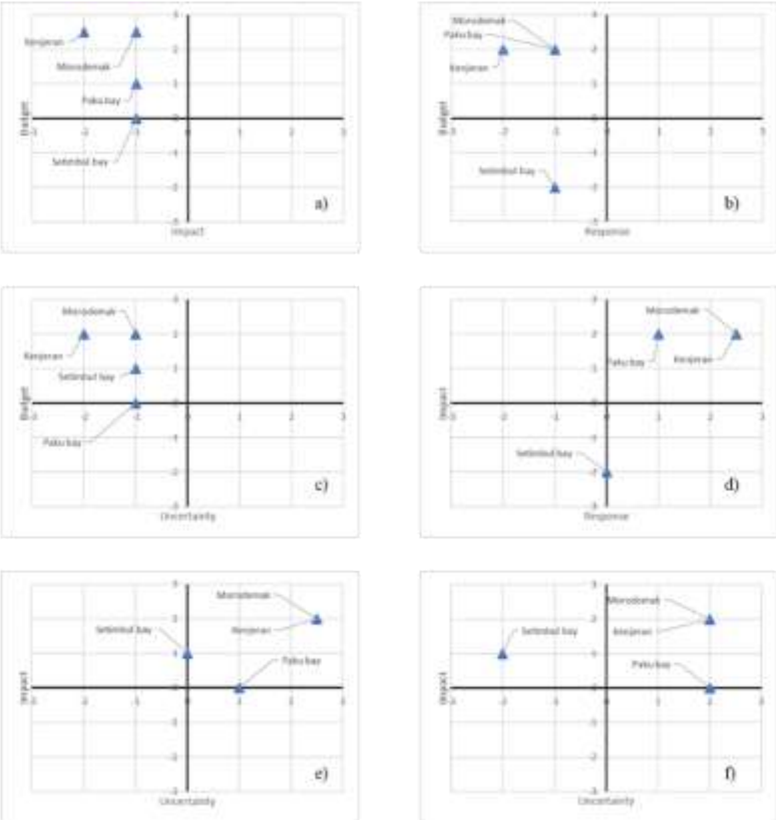

Figure 5. *Quadrant Crunching BIRU at Teluk Paku dan Teluk Setimbul, Karimun Regency a) Budget vs Impact; b) Budget vs Response; c) Budget vs Uncertainty; d) Important vs Response; e) Important vs Uncertainty; f) Response vs Uncertainty*

Source: Authors' analysis, 2023

Despite the low direct economic benefits, the degree of importance of coastal sedimentation management at these locations is assessed as high because it will have a positive impact on the socio-economic conditions of the local community. The communities mostly have high expectation that the sediment can be cleaned, except community of Setimbul bay in Karimun regency, because sediment has a very big impact on the socio-economic aspects of the community and generates uncertainty for the community. To implement coastal sedimentation management on such areas, the authority has to formulate some policies/specific intervention so that coastal sedimentation should be managed properly as well as reducing the negative impact of it to communities and ecosystem.

5. Conclusions

This paper shows several clusters of priority location in The Java Sea and Sunda Strait KAW as well as the Natuna and North Natuna Sea are considered as the main focus of IRMA on coastal sedimentation management. In spite of economic consideration, implementation of coastal sedimentation management is heavily anticipated by coastal communities. This paper also exposes an integration of TOPSIS-Entropy-GIS approach is a reliable method to assess multiple-attribute spatial data for vast study area. Quadrant Crunching "BIRU" method also has also a promising method to be incorporated to validate the result of this approach, especially in the context of sustainability evaluation. In addition, further study with extended ground truth location for Quadrant Crunching "BIRU" method coupled with benefit cost analysis feasibly encouraged to be performed to strengthen this approach.

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