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Integration of the Spatial Planning of Land and Sea: Case Study on Coastal Bontang

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Abstract

Coastal management approach with a territorial approach is important for the sustainability of coastal management because at that level there is an incorporation of highly complex interaction of ecological, social and economic phenomena. Sustainable coastal utilization must look at two aspects of territoriality, namely the spatial aspects of land (terrestrial) and the spatial aspects of the Sea (coastal waters). This study attempts to build a model of the zoning plan for Bontang City's coastal areas by integrating the issues and potentials—ecological, social, and economic—on the land and in the coastal waters. The analytical tool used in this research is Geographic Information System (GIS) and a decision support tool of Marxan with Zone. Several previous studies had used Marxan with Zone, but their planning units covered only a maximum of three allocation zones of uses. This study is an effort to develop a planning unit of more than three planning zones. In addition, in this research, the input data used to run Marxan with Zone is based on the perspectives of stakeholders.

Keywords: integration; zoning; coastal; Marxan with Zones.

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1. Introduction

Coastal spatial planning is a framework which informs the spatial distribution of the marine sector activities to support current as well as future uses by maintaining the quality and the function of ecosystems to meet ecological, economic, and social purposes [1]. Coastal spatial planning has been seen as a mechanism to provide greater socio-economic benefits out of the sea and protect vulnerable marine habitats and species [2]. Coastal spatial management has been used as an effective way to minimize conflicts between human uses and biodiversity conservation [3]. Directions of coastal spatial planning are efforts to utilize coastal areas with their natural resources in an integrated and sustainable manner [4]. An effective spatial planning should consider the relationship between social-ecological system and follow a cross-sectoral approach in allocating the sustainable uses of space to reduce the threat of human activities and maintain ecological processes [5]. Sustainable coastal utilization should be concerned with two aspects of territoriality, the teristorial aspects and the spatial aspects of coastal waters [6,7,8,9]. A coastal management approach with a territorial approach is very important for the sustainability of coastal zone management, because at that level there is a combination of highly complex interaction of ecological, social, and economic phenomena [10]. The question is: Has the current coastal spatial planning reached a balance between social, economic and ecological benefits? [11,12] Some have argued that to a certain extent, in an objective process, it is impossible to maximize the balance [13,5]. In the context of coast management, the use of optimization algorithms in spatial planning has become one of the decision support tools for coastal spatial planning that integrates the ecological and socio-economic objectives [14,15,16] . The aim of this study was to see a zoning plan that integrates the land and the coastal waters with an analysis of Geographic Information Systems (GIS) and a decision support tool of Marxan with Zones. Marxan with Zones is an extension of the Marxan software developed by Ian Ball and Hugh Possingham. Marxan with Zones has the same function as Marxan, but it has the capability of allocating planning units to multiple zones (i.e. marine protected areas of various levels of protection) and to incorporate some costs into the framework of systematic planning. Marxan with Zones aims to determine each planning unit in the research site for a particular zone in order to meet a number of ecological, social, and economic objectives with a minimum total cost [17]. Some previous studies of the spatial planning analysis had employed Marxan with Zones, but the planning unit dealt with not more than three use zones [16,17,18]. This study attemps to develop planning units employing the analysis of Marxan with Zones to be more than three planning zones. In addition, in the research the input data used to run Marxan with Zones was based on the perspectives of stakeholders. Stakeholder perspectives will consider social and economic issues to maximize the ecological, social, and economic benefits as well as to minimize unnecessary conflicts concerning different uses of coastal areas [5,19].

2. Method

2.1. Research Site

The study was conducted in a coastal area of Bontang City in East Kalimantan. Geographically, Bontang lies between 001' N latitude - 0˚12' N latitude and 117˚23' E longitude - 117˚38' E longitude. Bontang City covers area of 497.57 km^2, dominated by the sea covering an area of 349.77 km^2 (70.30%) while the land is only 147.8 km^2 (29.70%). Bontang is located in the central part of the Province of East Kalimantan. There are various activities in the coastal area of Bontang such as fisheries, oil and gas industry, housing, tourism and conservation, thus putting pressure on the coastal ecosystem of Bontang. The study area was focused on the southern part of Bontang, most of which is still idle, making it easier to conduct spatial planning.

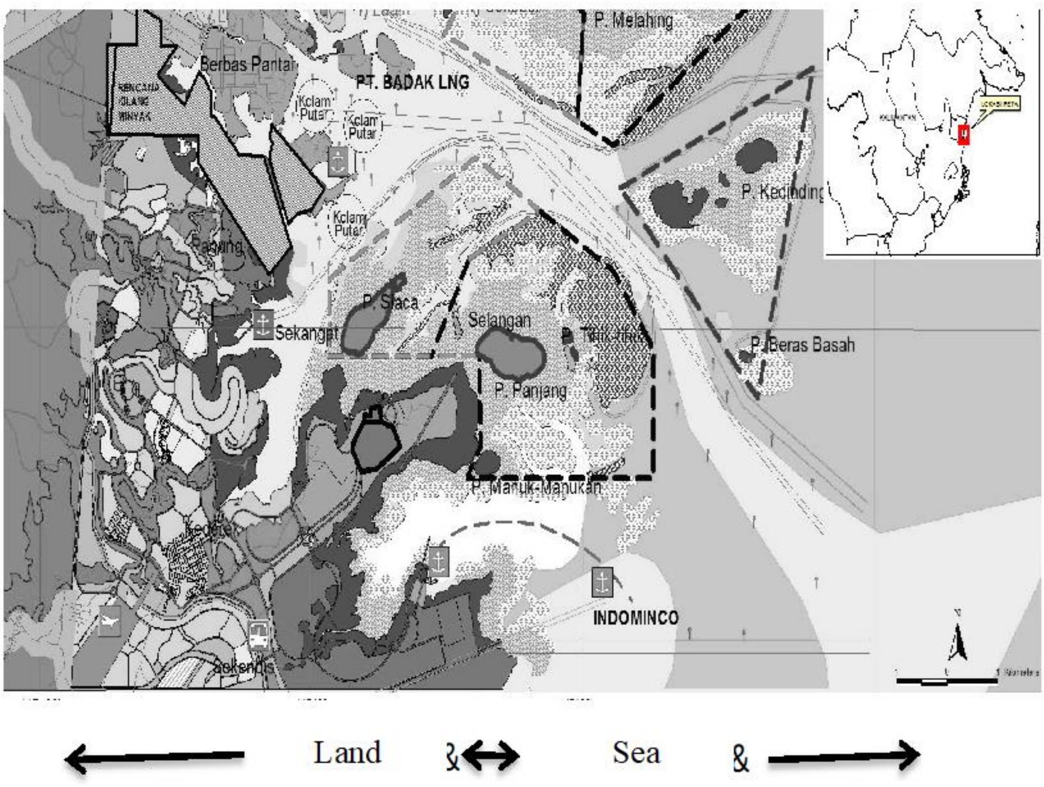


Figure 1: Research Site

2.2. Research approach

The approach to the preparation of an integrated coastal zoning plan was carried out with the involvement of stakeholder participation (Figure 2). The stakeholder involvement is an aspect inherent in the coastal spatial planning. [20,21,22]. **The first stage** was the preparation of a zoning plan starting from pre-planning, which included identifying the stakeholders who participated in the conflict resolution process and defining the desired outcome of conflict resolution in accordance with the goals and objectives [21,23]. The stakeholder involvement was very important in contributing to the conflict identification and the definition of purpose and the target allocation of space in the process of the preparation of spatial coast (Figure 2). Stakeholders are individuals, groups or organizations that are (or will be) affected by and involved or interested in (positive or negative) the use of coastal space [21]. There are three considerations to be made before involving stakeholders: Who should be involved? When should stakeholders be involved? How should stakeholders be involved? [21,23,24]. **The second stage** was the analysis of existing conditions. This stage aimed to identify spatial conflicts at the study site by overlaying the mapping of habitats and ecosystems of coastal resources with the result of human activities and policy mapping of the space utilization. The overlay data of ecology and human activities were the basis for the mapping of potential conflicts between activities in coastal areas. A spatial conflict analysis is required as a basis for determining the direction of policy in the utilization of space [25].

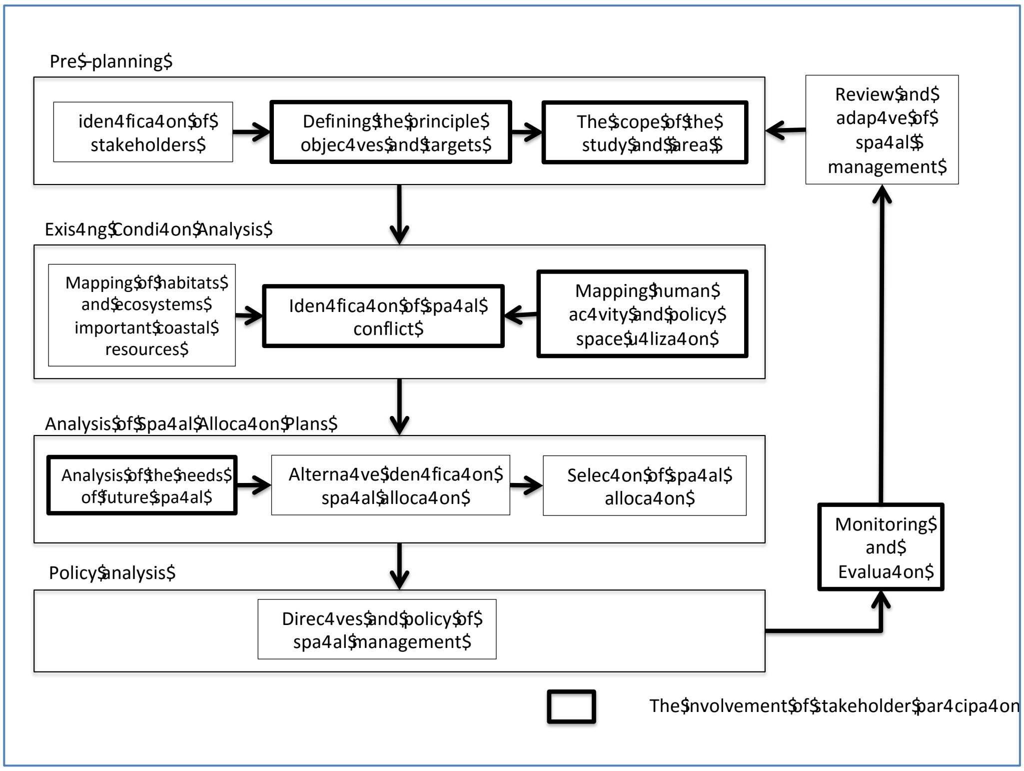


Figure 2: Process of Drafting an Integrated Zoning Plan of Coastal Zones (adoption of [21]

2.3. Data collection

Spatial planning of a coastal region is a framework which informs the spatial distribution of marine activities to support current and future uses and maintain the quality and the function of ecosystems to meet ecological, economic, and social purposes [26,27]. Therefore, the success of the formulation is determined by the existence of the ecological and socio-economic data which are comprehensive and valid [26]. The ecological data are necessary to identify the areas important for the conservation of biodiversity and ecosystem function. Meanwhile, the area identification of the existing uses was done through participatory analysis and deep interviews with stakeholders. The combination of the use of ecological data and human activities is very valuable in explicitly identifying overlapping interests between activities [16]. Spatial data are very important as inputs in the use of a decision support tool, Marxan with Zones [17]. As a decision support tool, Marxan with Zones can assist in the planning of coastal zones by identifying options for areas that require special management such as the conservation of coastal waters [28], or the area of special use such as fisheries department [29]. The data collected to support the analysis of Marxan with Zones were the primary data and secondary data. The primary data were obtained through field surveys and questionnaires, while secondary data were obtained from relevant agencies with regard to the potential of coastal resources in the study area. The thematic as well as biogeophysical data of the coastal area of the research location were collected as materials to perform the analysis of land suitability for seaweed farming, tourism, and conservation. The data on the existing uses were based on stakeholder perspectives through interviews, while the policy on the uses of coastal areas was collected through relevant agencies.

2.3.1. Technique of Data Analysis

Marxan with Zones

Geographic Information System (GIS) and a decision-making support tool of Marxan with Zones were used to produce three main products: (1) spatial allocation zoning in accordance with the use of each, (2) the conflict analysis / conformity between the contiguous zones, and (3) the analysis and identification of the optimum area in the direction of the spatial allocation of coastal zoning. Marxan with Zones 2.1.1 was used as a decision-making support tool to find an efficient solution to the problem of choosing a set of regions to meet the target of stakeholders [27]. An explanation of how Marxan works has been provided in detail elsewhere and is not repeated here (see website Marxan http://marxan.io [17]. In general, there are five principles in the analysis of Marxan with Zone: collecting data, making planning units, setting targets, performing calibrations, conducting the analysis and designing of space allocation [17,19]. The determination of these targets was based on the results of the discussion and the analysis with the agency responsible for the planning of Bontang city, namely the Regional Development Planning Agency (Bappeda) of Bontang City. The discussion referred to the document of Spatial Planning of Coastal Zones and dynamics of coastal uses of today. The discussion and analysis aimed to recommend a range of targets for each zone, which included at least the desired extent in a particular area [27]. Marxan with Zones was used to generate an optimal solution, with various scenarios used for the analysis of the allocation of space integrated coastal area. In this case, the scenario was designed to explore the use of the most optimal and most efficient and as combinations between the utilization areas [17].

Analysis of Linkage or Suitability between Zones

One of the activities carried out in this research was to identify the user conflict as one of the issues required in the context of coastal spatial planning, as a measure to manage and resolve conflicts. The conflict identification was carried out by analyzing the relationship between zones. A zone-linked analysis used a decision-making tool of Marxan with Zones by using the input data based on stakeholder perspectives. The opinions of stakeholders consisted of the public and the private sector, the government and the experts. The public and the private sector were the main actors that interacted directly with the coastal areas so that their opinions were very important to map the conflict zones. The government in this case represented by related agencies was a decision maker in the coastal zoning. According to [30], every stakeholder has a degree of influence on the decision-making on the management of land and the great interest of coastal resources, while expert opinions were used as a heuristic (i.e. used in the context of exploration) and as scientific tools (e.g. used in the context of justification) [31]. The expert is a knowledgeable person who participates in the management process, both directly and indirectly [32]. There were three conflicts that could be identified in coastal areas, namely 1) the conflict between users of the same resources (between fishermen using different gear), 2) the conflict between users of different resources (e.g. between fishermen and divers), and 3) conflicts between agencies [23]. (The purposes of conflict settlement were formulated as: 1) minimizing conflicts in coastal areas of Bontang to the lowest level; and 2) allocating space optimally for sustainable use.

3. Results and Discussion

Based on the results of mapping overlay of the habitats and ecosystems of coastal resources by mapping human activities and policies of the existing space utilization, there were four additional utilizations of space in the coast of Bontang: industrial area, sustainable utilization area, conservation area and sea lanes. In the four areas of space utilization, there were several zones of uses as can be seen in Table 1.

Table 1: Results of land suitability analysis of Bontang's coastal area

Industrial Area	Sustainable Utilization	Conservation	Sea Course
Oil and Gas	Seaweed Farming	Conservation of Coastal Waters	Shipping Lanes
Power Plant	Tourism	Coastal Border	Undewater Pipelines
Port	Capture Fisheries		

Analysis Result of Land Suitability

Table 1. shows three regions of the spatial allocation in the study area: industrial zone, sustainable utilization, conservation area and sea course. The industrial zone consists of Oil and Gas Industry, Electiric Power Plant, and Port. In the meantime, the sustainable utilization zone consists of Seaweed farming, Tourism, and capture fisheries. The consevation zone consists of Aquatic Conservation, and Coastal border, while Sea Course zone consists of Shipping lanes. The results of suitability analysis were used as inputs to conduct the mapping analysis of spatial conflicts. Coastal ecosystems are ecologically, culturally, and economically important, and hence are under pressure from diverse human activities. [40] The analysis of conflict mapping in this research with a questionnaire method was carried out by asking the opinions of each stakeholders as to the suitability / linkage between the two zones that are side by side.

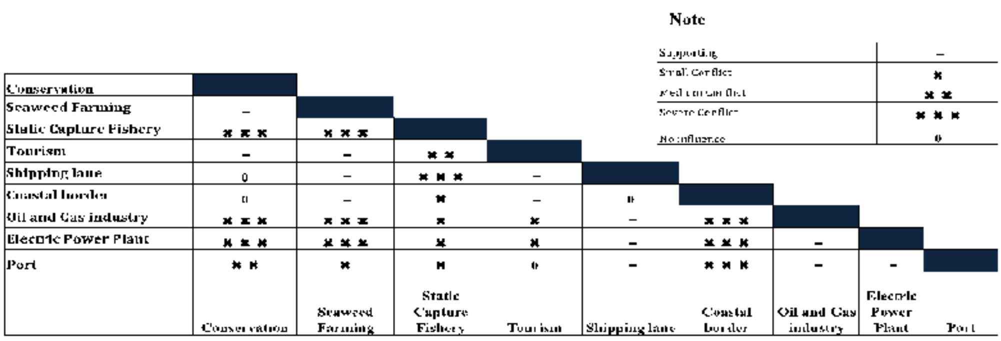


Figure 3: Matrix of Spatial Conflict Mapping in the Coastal Region of Bontang [39]

The question is: What will happen if the two zones are located side by side? The options are: (1) **they will support each other**, (2) **there will be no influence**, (3) **there will be a small conflict** (only one conflict, either ecological, social or economic), (4) **there will be a medium conflict** (only two conflicts, either ecological, social or economic) or **there will be a severe conflict** (more than three conflicts, either ecological, social or economic). [39] Based on the analysis of the aggregate rankings of 112 stakeholder respondents with different ages, educational backgrounds, job titles, and employment status, the matrix of spatial use conflicts between the zones can be described as in **Figure 3**. Figure 3. shows that the spatial conflict that occurs between the conservation zone and the seaweed farming zone when the two zones are side by side with the zone of static fisheries (splint), oil and gas zone, and electric power plant zone will potentially cause heavy conflicts (ecological, social, and economic). Meanwhile, static capture fishery zone (splint) will potentially cause a severe conflict if side by side with shipping lanes [33] suggested that the fisheries sector had the potential conflict with other sectors in land use. The coastal border zone will potentially cause a severe conflict if the zone is side by side with the zones of port, power plant, and oil and gas. Several zones are mutually supportive, among others, the conservation zone with the tourism zone, the conservation zone with the seaweed farming zone, the seaweed farming zone with the tourism zone, the seaweed farming zone with the shipping lanes, and the seaweed farming zone with with the coastal border zone. The zone of shipping lanes can be mutually supportive with the zones of port, oil and gas, and power plant. The various conflicts that arise require conflict management, namely a process that is directed at managing conflicts to create more controlled conditions through an engineering to make them better [25]. Management and control of the conflicts will facilitate decision-making in determining the allocation of space which considers the interests of the parties.

Setting up Feature Targets

Marxan is software that is complex because there are many settings in order to get a wide choice of decision-making. One of the Marxan advantages is that it is able to define different scenarios. The making of the scenarios uses a variation of the target values based on the objectives to be achieved, both based on the literature / previous study and the existing policies. The allocation of space was determined by the area that had the smallest cost in line with ecological, social, and economic parameters. These objectives were achieved using the analysis of Marxan with Zones to find and select the space allocation that met ecological, social, and economic criteria [17]. Target setting is done by setting a percentage of the features in the allocation plan of space utilization. Features can be defined as elements that will be incorporated in a specific space allocation [17,18]. For example, the elements of the area of certain space utilization consisted of the types of habitat, the gradient of elevation, soil types, and distribution of species. The features could also be in form of the existing utilization at each planning unit (e.g., conservation, agriculture, and recreation). This target setting was intended to ensure that there was at least a percentage target of some of the features which were included in the elements of the space allocation plan that would be set in accordance with their objectives. This information determines how much each feature in any plan of space allocation required for the achievement of the target.

Setting Percentage Target (Feature) of Industrial Area

The setting of targets for the space planning of the industrial area was important as one of the inputs for the analysis using Marxan with Zones. This target was a proportion of the total number of features that should be included in the industrial area. Both Scenario 1 and Scenario 2 in Table 1 show the features that should be included in the area of industry, among others, the general port area, the coal port area, industrial areas of oil and gas industry and power plant. The value of 100% for the features of public port, coal port, oil and gas industry, and the feature of power plant to the target of the industrial area, meaning that the whole features should go into the industrial area. This provision is based on the policy of space use contained in Regional Regulation [34].

Setting Percentage Target (Feature) of Sustainable Utilization Area

Based on the data obtained, the features that should be entered into sustainable utilization which included seaweed farming, capture fishery, settlement, services and trade as well as tourism. There were two scenarios for the target of any feature of the determination of the space allocation of the area for sustainable use of the region. The first scenario had a tourism target of 100% and the feature of static capture fisheries had a target of 30% getting into the sustainable use [35]. The feature of seaweed farming had a target of 70% to be included into the allocation plan of the sustainable utilization of the region [35]. Meanwhile, the features of settlement and services trade on the coastal land had a target of 80% to be included into the allocation of the plan of the sustainable utilization of the region [17]. Next was the second scenario that had a target of 100% tourism feature [35]. into sustainable utilization. The feature of static capture fishery had a target of 30%, seaweed farming feature 100%, coastal border feature 50% into sustainable utilization (FGD result with the public). Meanwhile, the features of settlement and services trade on the mainland coast had a target of 80% into the sustainable utilization of regional allocation plan [17].

Setting Percentage Target (Feature) of Conservation Area

The features that should be included in the conservation area included the ecosystems of coral reefs, mangrove, seagrass, coastal border and the features of settlement and services trade on the land. The first scenario, the target of every feature of the determination of the allocation of space conservation of the area was as follows: the features of coral reefs, mangroves, seagrass and coastal border had a target of 50% to be included in the allocation of space conservation of the area [17,36,37, 38]. The features of settlement and services trade in the coastal land had a target of 30% to be included in the allocation of space consevation of the area [34] As for the second scenario targets, the features of coral reefs and seagrass beds had a target of 75% to be included in the allocation of space conservation of the area, while the features of mangrove and coastal border areas had a target of 50% to be included in the allocation of space conservation of the area (FGD with the public). The features of settlement and services trade in the coastal area had a target of 30% to be included in the allocation of space conservation of the area [34].

Setting Percentage Target (Feature) of Sea Course

The features that should be entered into sea course, among others, were shipping lanes and underwater pipelines. Both scenario 1 and scenario 2 had a target that the features of shipping lanes and underwater pipeline belonged to the allocation target of sea course in the coastal waters of Bontang.

Table 2: Target of features for space allocation in Bontang City's coastal area.

Scenario	Feature	Area Target			
		Industrial Area	**Sustainable Utilization Area**	**Consevation Area**	**Sea Course**
I.	1. Sea course	0	0	0	100%
	2. Port	100%			0
	3. Sea tourism	0	100%	0	0
	4. Static capture fishery	0	30%	0	0
	5. Coral reef	0	0	50%	0
	6. Seagrass area	0	0	50%	0
	7. Mangrove island	0	0	50%	
	8. Seaweed farming	0	70%	0	
	9. Underwater pipeline	0	0	0	100%
	10. Coar port	100%	0	0	0
	11. Power plant	100%	0	0	0
	12. Oil and gas industry	100%	0	0	0
	13. Coastal border	0	0	50%	0
	14. Settlement and service trade	0	80%	30%	0
II	1. Sea course	0	0	0	100%
	2. Port	100%	0	0	0
	3. Sea tourism	0	100%	0	0
	4. Static capture fishery	0	20%	0	0
	5. Coral reefs	0	0	75%	0
	6. Seagrass area	0	0	75%	0
	7. Mangrove	0	0	50%	
	8. Seaweed farming	0	100%	0	
	9. Underwater pipelines	0	0	0	100%
	10. Coal port	100%	0	0	0
	11. Power plant	100%	0	0	0
	12. Oil and gas industry	100%	0	0	0
	13. Coastal border	0	50%	50%	0
	14. Settlement and service trade	0	80%	30%	0

Based on the analysis of Marxan with Zones with the number of "run" 100 times and the iteration 1,000,000, the results of frequency selection were obtained for each planning unit for scenarios 1 and 2. Figures 4 and 5 show the frequency selection for planning units as a result of Marxan with Zones analysis for scenarios 1 and 2. The difference of the colors in the Figure shows the frequency selection of space allocation. The red color frequency was between 71-100%, meaning that Marxan with Zones recommended the area as a potential allocation of space for the use of a particular region. Orange with a frequency between 51-70% indicated the frequency of the second option, namely as a backup in case the vast area that is in the red color does not meet the targets that have been determined. The areas that are not recommended being included in the direction of space allocation are yellow, light green and dark green with a selection frequency below 50%.

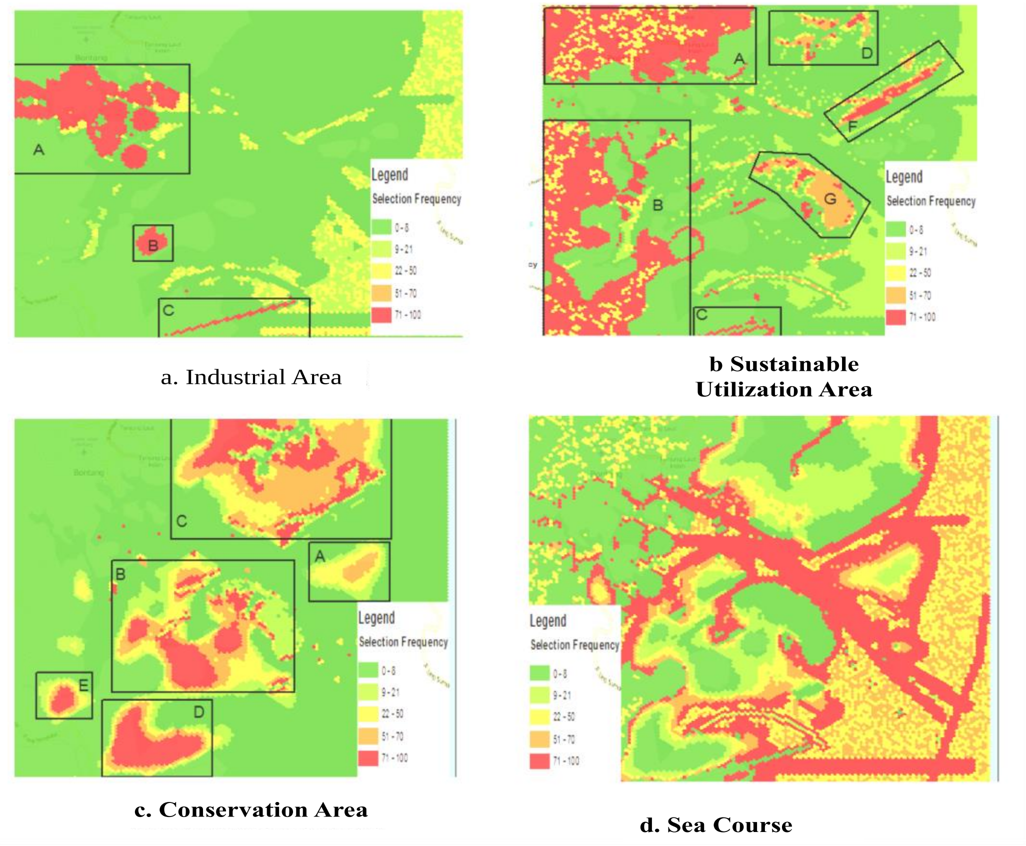
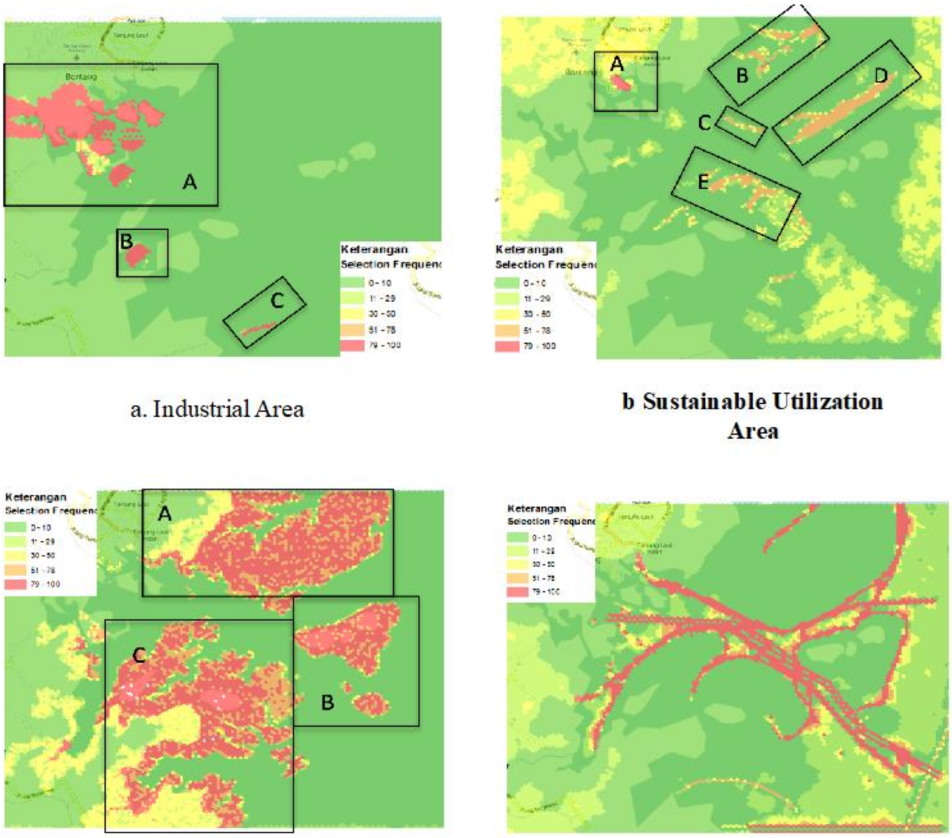


Figure 4: Frequency Selection for Planning Unit of the Analysis Results of Marxan with Zones Scenario 1.

Figure 4 is the frequency selection for planning unit based on the target of scenario 1 for each allocation of te space utilization. The frequency selection in the location of the industrial area for scenario 1 that can be seen in Figure 4a consisted of (A) the zones of oil and gas industry and port; (B) power plant zone; (C) Coal Port. The frequency selection for the planning unit of sustainable area utilization can be seen in Figure 4b consisting of settlement zone and service trade zone in the coastal land, namely in the areas (A) (B) and (C), and the planning units of seaweed farming area and static capture fisheries were in the areas (D), (E) and (F). The frequency selection for the planning unit of conservation area which is shown in Figure 4.c consisted of coastal border zone and mangrove in the areas (B), (C), (D) and (E) and coastal waters of conservation zone (A)



a. Industrial Area

b Sustainable Utilization Area

c. Conservation Area

d. Sea Course

Figure 5: Frequency Selection for the Planning Unit of Analysis Results of Marxan with Zones Scenario 2.

Figure 5 is the result of frequency selection for the planning unit of analysis results of Marxan with Zones with the target of scenario 2. The selected frequency at the location of the industrial area is shown in Figure 5a, consisting of area (A) the zones of oil and gas industry and port; area (B) the zone of power plant; area (C) Coal Port. Meanwhile, the results of the frequency selection for the planning unit for sustainable utilization area (Figure 5b) consisted of the zones of coastal settlement, area (A) and the zones of seaweed farming and static capture fisheries, area (B), area (C), area (D), and area (E). In this scenario 2, the result of frequency selection for the planning unit of the sustainable area utilization of Marxan with Zones did not select an area within the coastal mainland. Meanwhile, the result of frequency selection for the planning unit in the location of the consevation area is shown in Figure 5c, consisting of the zones of coastal border and mangrove of areas (A) and (B) and the conservation of coastal waters region (C). In Figure 5c Marxan selected two conservation areas in the coastal mainland that borders the beach and mangrove, while the coastal waters of the conservation zones, Marxan selected coral reefs and seagrass. The final analysis results of Marxan with Zones based on the inputs and the scenarios that had been established and the results of the selected frequency for each direction of the previous space allocation, the best solution was found in the allocation of space as in Fig. 6. In accordance with the scenario of space allocation, the recommendation result of Marxan with Zones was the industrial area on the orange map, the sustainable utilization area light yellow, and the conservation area green, and the sea course blue. The recommendation analysis of Marxan with zones for the industrial zone was ± 1,782 ha, general use area ± 4,605 ha, and conservation areas ± 3,280 ha. The results of Marxan with zones were tools to aid in decision-making, although a final decision on the allocation of space remained in the hand of stakeholders in this case the public, private and government[17].

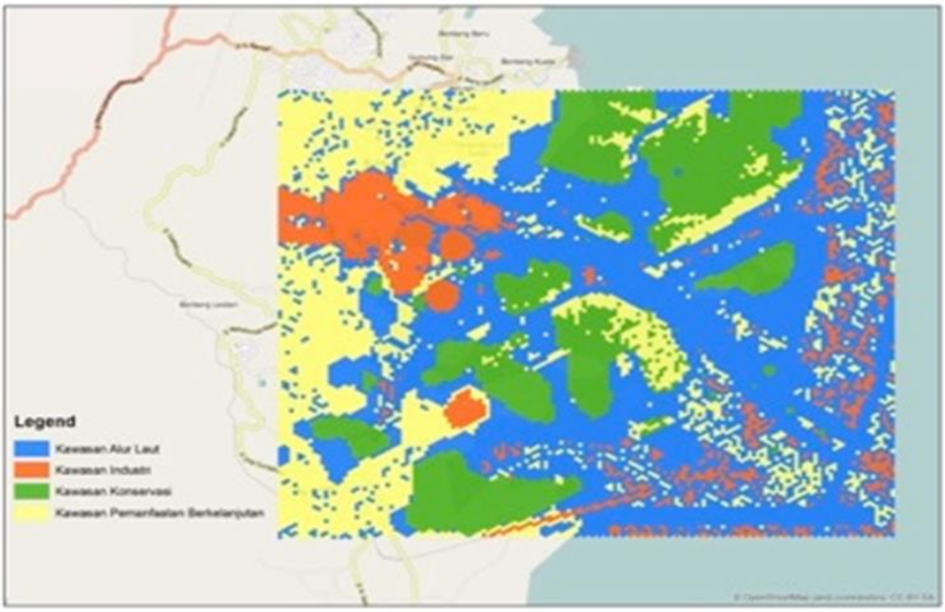


Figure 6: The best solution of the analysis result of Marxan with Zones version 2.1.1.

4. Conclusion and Recommendations

Coastal zoning planning by integrating ecological, social, and economic issues both on land and coastal waters is very important. Marxan with Zones is an alternative tool to formulate a zoning plan that integrates land and coastal waters with ecological, social and economic aspects. Marxan with Zones also allows us to set up several target scenarios for each unit of planning. However, in addition to its advantageous tools, Marxan with Zones has limitations as found in this study, namely the zoning allocation for Marxan with Zones could not carry out more than 4-5 zones at the most to make sure it will work optimally. This study is expected to be the basis for the development of Marxan with Zones and the future researches to build a model of coastal spatial planing that integrates land and sea with ecological, social and economic aspects.

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