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# Modeling the Dynamics of Coastal and Marine Ecosystems: Integration of Remote Sensing Data and Field Observations for Resource Management

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The purpose of this study is to analyze Coastal and Marine Ecosystem Dynamics Modeling Based on Integration of Remote Sensing Data and Field Observations for Resource Management. This research method uses normative law with data collection techniques through *library research,* and the data source is primary data consisting of primary legal material, secondary legal material and tertiary legal material.

The results showed that: Coastal and marine resources are very strategic ecosystems for national development, so in determining programs and policies, efforts must be made to make efficiency in the use of coastal space and resources, increase income/welfare of coastal communities, empower coastal communities, and enrich and improve the quality of natural resources. Modeling the dynamics of coastal and marine ecosystems and integrating data from remote sensing and field observations are important approaches in natural resource management. By understanding the complex interactions between living organisms and their environments, we can develop more effective strategies to protect and utilize these ecosystems sustainably. By continuously improving technology and collaboration across disciplines, we can face the challenges faced by coastal and marine ecosystems in the future.

*Keywords: Modeling, Dynamics, Ecosystem, Coastal, Remote Sensing, Resource Management*

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## INTRODUCTION

### Background

Indonesia is a Connecting Country of Two Oceans as the largest archipelagic country in the world. With a water area nearly four times larger than its land area, the country derives its tremendous economic, geopolitical, cultural and natural benefits from the sea. Located at the center of major maritime trade routes, the Indonesian sea is a gateway connecting Europe, the Middle East, Africa and South Asia. Its coastal and marine waters make Indonesia one of the most abundant fishing grounds in the world, even Indonesia is currently ranked second in the world as a fish producer after China.[1]

The Indonesian nation is blessed by God Almighty with wealth in the form of abundant natural resources, both on land, in the waters and in the air which is the basic capital of national development in all fields. Indonesia's land area ± 2,012,402 km2 and its water area ± 5,877,879 km2 5 consists of 17,508 islands with a coastline of 81,000 km which makes Indonesia the largest archipelagic country in the world, and recognized by the international world.[2] Recognition of Island States through *the United Nations Convention of the Law of the Sea* 1982, followed up through Law Number 17 of 1985. This right is followed up in Amendment IV to the 1945 Constitution article 25A.

Indonesia is a state of law, normatively the wealth of these resources is controlled by the State to be managed in such a way as to realize public welfare (Article 33 paragraph 3 of the 1945 Indonesian State Constitution[3]). The coastal *zone* is a transitional area between land and sea ecosystems that interact with each other, where towards the sea 12 miles from the coastline for the province

[1] CEA *Trends in Marine Resources and Fisheries Management in Indonesia*, *California Environmental Associates* (California: California Environmental Associates &; David and Lucile Packard Foundation, 2018), p. 1.

[2] Rokhim et. Al. Dahuri, *Integrated management of coastal and marine resources* (Jakarta: Pradnya Paramita, 1996), p. 1.

[3] Endang Sutrisno, "Implementation of Integrated Coastal Resources Management Based on Coastal Area Management for Fishermen's Welfare," *Journal of Legal Dynamics* 14, no. 1 (2014): 1–12.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
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and one-third of the sea area for the district / city, and towards land the administrative boundary of the district / city.[4] Coastal areas have strategic significance because they are transition areas (*interfaces*) between terrestrial and marine ecosystems, and have very rich potential natural resources and environmental services.

Management of coastal areas and small islands is the activity of planning, organizing, controlling and implementing all activities in coastal areas and small islands while the spatial planning element itself is included in the management section because spatial planning has the meaning of "something that includes the process of planning, utilization, and control or utilization of space that must be related to each other".[5]

Coastal and marine ecosystems are complex environments and essential for human survival and biodiversity. The dynamics of these ecosystems are influenced by a variety of factors, including interactions between living organisms, physical environmental conditions, and human activities. To understand and manage these ecosystems effectively, accurate modeling and integration of data from multiple sources is required, including remote sensing and field observations. In this study, we will explain the exploration of the concept of modeling the dynamics of coastal and marine ecosystems and the importance of data integration for resource management. [6]

**Problem Statement**

1. How is the Dynamics Modeling of Coastal and Marine Ecosystems?
2. How is Remote Sensing and Field Observation Data Integration Modeling for Resource Management?
3. How is Integrated Coastal and Marine Management Sustainable?

[4] Bambang Pramudyanto, "Control of Pollution and Damage in Coastal Areas," *Journal of Lingkar Widyaiswara*, No. 4 (2014): 21–40, www.juliwi.com.

[5] G Kartasasmita, *Development Administration (Development of Thought and Practice in Indonesia)* (Jakarta: LP3ES, 1997), p. 51.

[6] Ari Atu Dewi.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
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## THEORETICAL FRAMEWORK

The management of coastal areas is regulated in Law 27 of 2007 concerning the Management of Coastal Areas and Small Islands which has been amended by Law 1 of 2014 concerning Amendments to Law Number 27 of 2007 concerning the Management of Coastal Areas and Small Islands. Regarding community participation in managing coastal areas, it is regulated by the Regulation of the Minister of Marine Affairs and Fisheries Number 40 / PERMEN-KP / 2014 concerning Community Participation and Empowerment in the Management of Coastal Areas and Small Islands. The existence of regulations regarding coastal area management provides a basis for active participation in coastal area management.

In the protection and management of coastal areas, the role of Regional and Regency / City Governments is very large, so regional legal products are needed that regulate the protection and management of coastal areas. The basis for determining this regional legal product is to support the spirit of regional autonomy by utilizing the potential that exists in each region. However, the formation of regional legal products is inseparable from the basics stipulated in Law Number 12 of 2011 concerning the Establishment of Laws and Regulations, which in principle shows:

1) There must be authority from the makers of laws and regulations;
2) The necessity of conformity of the form or type of legislation with the regulated material;
3) Must follow certain formation procedures;
4) Necessity does not conflict with higher laws and regulations.

These principles in the process of forming legal products are very important to note, considering that a regional legal product must contain the spirit of regulation in accordance with the procedures for the formation of laws and regulations that can be obeyed by the community and provide happiness and welfare to the community. Thus, it is very appropriate in the protection and management of coastal areas, encouraging

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and supporting regional autonomy through the formation of regional legal products that are responsive and in accordance with regional potential.[7]

In this study, using the theoryof legal protection is the obligation of the state in providing legal protection to every citizen. Legal protection can also be described as a function of law both as a function of regulating and as a function of enforcing the law to achieve justice and legal expediency. Legal protection is defined as providing protection to human rights and such protection is given to the community so that they can enjoy legal rights.[8]

In examining the authority of local governments to regulate the protection and management of community-based coastal areas, it is necessary to consider the philosophical aspects, namely the purpose and direction of regulation of a regulation formed (community-based protection and management of coastal areas). Furthermore, the sociological aspect is seen from the aspect of the needs of coastal communities which do require arrangements related to the participation of coastal communities in coastal area management as regulated in higher standards.

## RESEARCH METHODOLOGY

### 1. Types of Research

This research is included in the type of collaborative research, where the approach method used is normative as well as empirical, namely normative juridical and empirical juridical collaboration. Normative legal research method, which is a study conducted by reviewing laws and regulations that apply or are applied to a particular legal problem. Normative research is often referred to as doctrinal research, which is research whose object of study is statutory documents and library materials.

[7] Muhammad Suharjono, "Establishment of Responsive Regional Regulations in Support of Regional Autonomy," *Journal of Legal Studies* 10, no. 1 (2014): 1–25.

[8] Satjipto Rahardjo, *Legal Studies* (Bandung: Citra Aditya Bakti, 2000), p. 121.

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This research uses various approaches, with the aim of obtaining information from various aspects of the issue under study. Therefore, to solve the problems that are the subject of discussion in this study, the following approaches are used:

1. Statute *approach* is an approach taken by reviewing laws and regulations related to the legal issue being raised.[9]
2. The conceptual *approach* is an approach that departs from the views and doctrines that develop in the science of law.[10] Philosophically, a concept is a mental integration of two or more units isolated according to characteristics

The case study approach is used with regard to legal cases that discuss community-based management of coastal and marine resources at the end of Morodemak Bonang Beach.

## 2. Research Data Sources

The data source of a study is primary data and secondary data. Because this research is empirical and normative legal research, the sources studied are primary data sources, secondary data, and tertiary data.[11]

Primary legal materials are data that are materials in binding legal research sorted based on the hierarchy of legislation.[12]

Secondary legal materials, namely legal materials that can provide explanations to legal materials that can provide explanations to primary legal materials, which can be in the form of draft legislation, research results, textbooks, scientific journals, newspapers (newspapers), *pamphlets*, *lefleats*, brochures, and internet news.[13]

Tertiary legal material, also is a legal material that can explain both primary legal material and secondary legal material, in the form of dictionaries, encyclopedias, lexicons and others related to the problem under study.[14]

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[9] Johnny Ibrahim, *Theory and Methodology of Normative Legal Research* (Malang: Banyumedia Publishing, 2006), p. 101.

[10] Peter Mahmud Marzuki, *Legal Research* (Jakarta: Kencana Prenada Media Group, 2008).

[11] Soekanto and Mamudji, *Normative Legal Research, A Brief Review*.

[12] Mahmud Marzuki and Peter Mahmud, "Legal Research," *Journal of Legal Research* (Jakarta: Kencana Prenada Media Group, 2011), p. 25.

[13] Satjipto Rahardjo, *The Science of Law: The Search, Liberation and Enlightenment.* (Semarang: Diponegoro University, 2003).

[14] Marzuki, *Legal Research*.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
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### 3. Data Collection Techniques

The studies conducted are field studies (*field research*) and literature studies (*library research*) which use primary data and secondary data. Perimer data through field studies, secondary data in this study were obtained through literature studies, by finding information as complete and as much as possible with journal literature, newspapers, articles, scientific papers and laws and regulations related to the research theme.

### 4. Data Analysis

The research technique in this study is descriptive analytical, where the analysis is carried out critically. The data collected in this study will be analyzed descriptively with a *qualitative approach*, namely by providing a thorough and in-depth explanation and explanation (*holistic* / *verstelen*).[15]

## RESEARCH RESULTS

### Modeling the Dynamics of Coastal and Marine Ecosystems

An ecosystem is a complex system consisting of interactions between living organisms and their environment. Ecosystem dynamics refers to the changes that occur in a community of organisms and their environment over time. A deep understanding of these dynamics is key in maintaining environmental sustainability and managing natural resources wisely. One important tool in understanding ecosystem dynamics is through modeling. In this article, we will explain the importance of modeling in understanding ecosystem dynamics

Ecosystem modeling involves creating mathematical or computer models that represent the interactions between biotic (living organisms) and abiotic (physical and chemical environment) components in an ecosystem. This model is used to simulate how a change in one variable might affect another variable in the ecosystem. In general, there are two main types of models: deterministic models, which are based

[15] Sugiyono, "Quantitative, Qualitative and R&D Research Methods," *26th* (Bandung: Cv. Alfabeta, 2018), p. 34.

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on strict mathematical rules, and stochastic models, which take into account uncertainties and natural variations in ecological processes.

Management can be interpreted as the activity of managing resources by working together with others through certain processes to achieve organizational goals effectively and efficiently.[16] According to Sulistyorini, management is a person's activities in managing organizations or institutions that are human or non-human, so that the goals of the organization, institution or organization can be achieved effectively and efficiently.[17]

Based on the explanation above, in this study management is a management process that is held, implemented or planned by an organization or institution. Meanwhile, coastal area management is carried out with the aim of improving the welfare of coastal and marine areas by integrating Remote Sensing Data and Field Observations for coastal resource management in order to achieve justice, balance, and sustainability.

From this description, it can be concluded that coastal area management can be interpreted as a process of planning, utilizing, supervising, and controlling coastal resources.

Coastal and marine ecosystems include a wide range of habitat types, from coral reefs to seagrass beds and mangroves. High biodiversity and great productivity make this ecosystem a very valuable resource. However, pressures from human activities such as pollution, climate change, and resource exploitation can threaten the sustainability of these ecosystems.

Modeling ecosystem dynamics allows scientists to understand the complex interactions between living organisms and their environment. Mathematical and computer models are used to simulate ecosystem behavior over time. The modeling takes into account factors such as population growth, predator-prey interactions, and biogeochemical cycles.

[16] Barnawi &; M. Arifin, *Management of School Facilities and Infrastructure* (Yogyakarta: Ar-Ruzz Media, 2012), p. 15

[17] Sulistyorini, *Islamic Education Management: Concepts, Strategies, and Applications* (Yogyakarta: Sukses Offset, 2009), p. 11

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
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The matters contained in the management of coastal areas are planning, utilization, supervision, and control. Planning is a programmatic and gradual effort to utilize coastal resources optimally so as to generate sustainable economic benefits for the prosperity of the community.[18]

The following are some of the benefits of Ecosystem Modeling, namely:

1. **Understanding Complex Interactions**

An ecosystem is a complex web of interactions between organisms and their environment. Ecosystem modeling makes it possible to map and understand these interactions better. For example, models can help identify predator-prey relationships or the impact of environmental changes on species distribution.

2. **Predicting the Impact of Environmental Change**

Environmental changes, such as climate change or human activities, can have significant impacts on ecosystems. Through modeling, we can predict how ecosystems will react to these changes and identify adaptation strategies that may be needed.

3. **Developing a Management Strategy**

Ecosystem modeling is also important in natural resource management. By understanding how ecosystems react to human activities, we can design more effective and sustainable management strategies. For example, models can be used to optimize fishing schedules or assess the impact of development on wildlife habitat.

However, in addition to several benefits, there are also several challenges that must be faced to realize optimal coastal resource modeling so that they can generate sustainable economic benefits for the prosperity of the community. Among some of the challenges are;

1. Ecosystem Complexity

   Ecosystems are very complex systems, and it is often difficult to account for all the variables that affect them. As a result, ecosystem models are often simple and may not fully reflect the actual state of affairs on the ground.

[18] Djohani, Chairul Saleh, Ali Abdurrahman, et al. "Indonesia's Coastal and Marine Ecosystems: Diversity, Wealth, and Management Challenges", (Jakarta: Rili Conservation International Indonesia Year Published: 2009). p 43

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 44 Issue: 05-2025
DOI: 10.5281/zenodo.10183374

2. Uncertainty

   There is inherent uncertainty in ecosystem modeling, mainly due to the large number of variables involved and uncertainty in the input data. This can make predictions from the model less reliable, especially in situations where available information is limited.

3. Data Limitations

   Ecosystem modeling requires accurate and complete data to deliver meaningful results. However, it is often difficult to collect the necessary data, especially in hard-to-access environments such as oceans or tropical rainforests.

**Integration of Remote Sensing and Field Observation Data for Coastal and Marine Resources Management**

Coastal resources are one of the most valuable natural assets for human life and biodiversity. However, the management of coastal resources is not easy given the ever-changing complexity of coastal environments and the pressures they face from human activities. In an effort to protect and sustainably manage coastal resources, the use of remote sensing technology and field observations has been key in collecting data, understanding environmental dynamics, and formulating appropriate policies.[19]

Remote sensing includes the collection of information about objects or phenomena without direct contact with the observed area. In the coastal context, this technology makes it possible to obtain data on various aspects of the environment, such as land cover, water quality, sea surface temperature, and oceanographic dynamics. Satellite imagery is one of the main tools in remote sensing that provides a broad picture of coastal conditions from a global to regional perspective.

Benefits of Remote Sensing in Coastal Resource Management:

1. Environmental Change Monitoring: Satellite imagery enables continuous monitoring of environmental changes such as coastal erosion, land cover

[19] Bagir Manan, "Local Government Law as an Independent Legal Study", in Solly Lubis, Post-Reformation Legal Policy Paradigm in the Framework of Prof. Solly Lubis' 80th Anniversary, (Jakarta: Sofmedia, 2010), pp. 80-81

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 44 Issue: 05-2025
DOI: 10.5281/zenodo.10183374

change, and river flow patterns. This information is important in assessing the impact of climate change and human activities on coastal resources.

2. Habitat Mapping: Remote sensing makes it possible to map important habitats such as coral reefs, seagrass beds, and mangrove forests. This mapping helps in the identification of areas that need to be protected and properly managed to maintain coastal biodiversity.

3. Pollution Detection: Satellite imagery can be used to detect water pollution such as industrial waste or algal bloom that can damage coastal ecosystems. This information is important in determining the mitigation and recovery measures required.

Field observations involve direct surveys in coastal areas to collect data on environmental parameters, biodiversity, and human interaction with ecosystems. This method involves sampling water, soil, or living organisms, as well as direct measurement of parameters such as salinity, pH, temperature, and population density.

The Role of Field Observations in Coastal Resource Management:

1. **Remote Sensing Data Validation:** Field observations help in validating the data obtained from remote sensing. By comparing the results of field observations with satellite imagery or other data, the accuracy and reliability of information from various sources can be ensured.
2. **Deep Understanding of Ecosystems:** Field observations provide an in-depth understanding of the actual conditions of coastal ecosystems and the complex interactions between living organisms and their environment. This information is important in designing management strategies that fit local needs.
3. **Community Involvement:** Through field observations, local communities can be directly involved in coastal resource management processes. Their participation in field surveys not only increases their understanding of their

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E-Publication: Online Open Access
Vol: 44 Issue: 05-2025
DOI: 10.5281/zenodo.10183374

environment, but also encourages a sense of belonging and responsibility towards environmental sustainability.

Data Integration for Holistic Management

The integration of data from remote sensing and field observations allows for more holistic and effective management of coastal resources. Using information from multiple sources, the weaknesses of one method of observation can be masked by the advantages of another, thus providing a more complete picture of coastal conditions.

Steps to Effective Data Integration:

1. **Data Synchronization:** Integrates data from remote sensing and field observations through a unified platform for easy data access and analysis.
2. **Cross-Validation:** Validates remote sensing results with field observations and vice versa to ensure data accuracy and reliability.
3. **Integrated Analytics:** Combines data from multiple sources for a deeper analysis of environmental dynamics and management policy impacts.
4. **Stakeholder Participation:** Involving various parties, including government, research institutions, industry, and civil society, in the process of collecting and analyzing data to support evidence-based decision making.

## Sustainable Integrated Coastal and Marine Management

An activity is said to be sustainability, if economic, ecological and socio-political development activities are sustainable. Economically sustainable means that a development activity must be able to produce economic growth, *capital maintenance,* and efficient use of resources and investment. Ecologically sustainable means that the activity must be able to maintain ecosystem integrity, maintain the carrying capacity of the environment, and conserve natural resources including biodiversity *,* so that it is expected that the use of resources can be sustainable. Meanwhile, socio-political sustainability requires that a development activity should be able to create equitable distribution of development outcomes, social mobility, social cohesion, community

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Vol: 44 Issue: 05-2025
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participation, community empowerment (decratization), social identity, and institutional development.[20]

To be able to realize the sustainable development of coastal areas, integrated *coastal zone management is needed.* This choice is based on:

(1) Coastal areas are multiple use zones where there are more than two kinds of natural resources and environmental services and there are more than two kinds of coastal area uses;
(2) characteristics and natural dynamics of the nature of coastal and marine resources that are ecologically interrelated with each other including upper land ecosystems;
(3) Coastal areas are inhabited by more than one ethnic group that has different livelihood preferences.[21]

Coastal management can be carried out by government institutions, private sector, community organizations involved in daily activities that occur in coastal areas. The entire process above must be carried out continuously and dynamically by considering all social, economic, cultural aspects and aspirations of coastal and marine area user communities as well as resource use conflicts and conflicts over the use of coastal and marine areas that may exist. The integration of coastal and marine resource management includes four aspects: (1) ecological integration; (2) sectoral cohesiveness; (3) integration of disciplines; and (4) integration of stakeholders.[22]

Ecological integration: ecologically coastal areas have a relationship between the upper land (land) and the ocean. This is because coastal areas are meeting areas between land and sea. With the interrelation of these areas, coastal area management cannot be separated from environmental management in the two regions. [23]

[20] Adi Wiyana, "Factors Affecting the Sustainability of Integrated Coastal Management (P2T)", https://www.rudyct.com/PPS702-ipb/07134/adi_wiyana.htm

[21] Efendy, Makhfud. "Integrated Coastal Area Management: Solutions for Optimal and Sustainable Spatial Utilization, Resource Utilization and Capacity Utilization for Coastal Area Assimilation." *Indonesian Journal of Marine Science and Technology* 2, no. 1 (2009): 81-86.

[22] Ibid.

[23] Rokhmin Dahuri et al., *Integrated Management of Coastal and Marine Resources,* (Jakarta : Pradnya Paramita, 2004), p. 12.

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Vol: 44 Issue: 05-2025
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Various environmental impacts that occur in coastal areas are impacts caused by development activities carried out on upper land such as the oil drilling industry, settlements, agriculture and so on. Similarly, activities carried out on the high seas such as offshore oil drilling activities, sea transportation. Mitigation of pollution and sedimentation caused by industrial waste cannot be done only in coastal areas but must be done starting from the source of impact. [24]

Therefore, the management of this area must be integrated with the management of land and sea areas. Sector integration: as a consequence of the large and diverse natural resources in coastal areas is the number of agencies or sectors of the development sector engaged in the utilization of coastal resources. As a result, there is often overlapping use of coastal resources between one sector and another. [25]

The activities of one sector are not allowed to interfere with let alone to the point of shutting down the activities of other sectors. Spatial planning and coastal area development guidelines are very necessary to avoid collisions between one activity and other development activities. Therefore, the management of this region in its planning must integrate the interests of all sectors. [26]

The integration of scientific disciplines in this case coastal areas have unique and specific properties and characteristics, both the nature and characteristics of coastal ecosystems and the nature and socio-cultural characteristics of their communities. Therefore, it requires integration of scientific disciplines in coastal area management, following the ecosystem and socio-cultural characteristics of the community.

Integration of stakeholders, all of the above integration will be successfully applied if supported by the integration of actors and managers of development in coastal areas. As is known that development actors and coastal resource managers consist of

[24] Peni Susetyorini, "Indonesian Marine Policy in the Perspective of UNCLOS 1982", Journal of Legal Issues of Diponegoro University, Vol. 48, No. 2, (Semarang, 2019), p. 167

[25] Rosmawati, "The Influence of International Law on National Law", Journal of Legal Sciences, Syah Kuala University, Vol. 15, No. 61, (Aceh, 2013), p. 461

[26] Ida Kurnia, "Application of UNCLOS 1982 in National Legislation, Especially Indonesia's Exclusive Economic Zone", Research Journal of Gajah Mada University, Vol. 2, No. 1, (Yogyakarta, 2008), p. 42

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
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the government, communities, the private sector, and also non-governmental organizations, each of which has an interest in the use of coastal resources. [27]

The preparation of integrated management planning must be able to accommodate all the interests of coastal development actors. Therefore, development management planning must use a two-pronged approach, namely a top down approach and a bottom up approach. With the background of the above thinking, a sustainable development model known as sustainable development will emerge which contains three main elements covering economic, ecological and social dimensions.[28]

A coastal development, first economically considered sustainable *(economic growth)* if the area is able to produce goods and services sustainably; second ecologically considered sustainable *(ecological sustainability)* when the basis of the availability of natural resources can be maintained stably, there is no overexploitation of renewable natural resources, there is no waste disposal beyond environmental assimilation capacity that can result in polluted conditions, as well as the use of non-renewable resources accompanied by adequate development of substitute materials, and thirdly socially considered sustainable *(social equity)* if the basic needs of the entire population are met; there is a fair distribution of income and business opportunities.

Optimal and sustainable development of coastal and marine resources is realized if it meets three ecological requirements:

(1) utilization of coastal and marine resources in accordance with their carrying capacity;
(2) harmonious utilization of coastal and marine space; and;
(3) Utilization of assimilation capacity of coastal areas in accordance with the carrying capacity of the environment.

[27] Firdaus, "The Position of International Law in Indonesia's National Legislative System", Journal of Legal Sciences, Universitas Agung Tirtayasa, Vol. 8, No. 1, (Banten, 2014), p. 37

[28] Harris, *A survey of Sustainable Development: Social and Economic Dimensions*. S9Tufts University, Island Press, Washington, et al. 2001).

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition) ISSN: 1671-5497
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## CONCLUSION

The results showed that;

Coastal and marine resources are very strategic ecosystems for national development, so in determining programs and policies, efforts must be made to make efficiency in the use of coastal space and resources, increase income/welfare of coastal communities, empower coastal communities, and enrich and improve the quality of natural resources. Modeling the dynamics of coastal and marine ecosystems and integrating data from remote sensing and field observations are important approaches in natural resource management. By understanding the complex interactions between living organisms and their environments, we can develop more effective strategies to protect and utilize these ecosystems sustainably. By continuously improving technology and collaboration across disciplines, we can face the challenges faced by coastal and marine ecosystems in the future.

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DOI: 10.5281/zenodo.10183374

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