

# Using Geographic Information System (GIS) for Analysis and Mapping of Coral Reef Conditions: A Review of Research

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## ABSTRACT

Indonesia has abundant fisheries and marine resources, one of them is coral reefs. Coral reefs can be used by humans for medicinal, food raw materials, decoration and marine tourism. To maintain the sustainability of coral reef resources, management is carried out using technology. Remote sensing technology through the Geographic Information System (GIS) is considered capable of being used as a tool for mapping, especially the area of coral reef land. Geographic Information Systems technology integrates common database operations, such as query and statistical analysis, with mapping's unique visualization and analysis capabilities. The use of Geographic Information Systems in processing spatial data for coral reef mapping provides several reported advantages, one of which is describing coral reef data in the form of layers, thematic or spatial cover.

**Keyword :** coral reefs, geographic information system, resources

## 1. INTRODUCTION

Indonesia is an archipelagic country because it has several islands and has vast oceans, even two-thirds of them are the sea. Indonesia has 17,500 islands with a coastline of about 95,181 km [1]. This causes Indonesia to have abundant fishery and marine resources. Along the coastline and around the islands there are coral reef ecosystems that have many roles but are vulnerable to change. Based on satellite imagery, it is estimated that the area of coral reefs in Indonesia is 2.5 million hectares [2]. In coral reef areas there are associated organisms, namely algae, crustaceans, molluscs, echinoderms and fish [3]. The area of coral reefs in Indonesia is 51% of coral reefs in Southeast Asia or 18% of the world's coral reefs, high diversity of coral reef species, in this area more than 500 species of hard coral (*Scleractinia*) can be found [4].

The existence of coral reefs has experienced a decline from year to year, that is, there is an alarming damage which causes a decrease in quantity and quality [5]. The variety of organisms that live on coral reefs is also a biological source that can be used for human benefits, such as medicinal ingredients, foodstuffs, and ornamental fish. In addition, coral reefs also contribute to marine fisheries and tourism. Coral reef ecosystems provide services to support the marine tourism industry for foreign exchange earnings and provide significant employment and business fields [6]. In utilizing the provided ecosystem and resources that can function optimally and sustainably, it is necessary to have a variety of efforts to protect against various kinds of degradation that can be caused by various utilization activities, either directly or indirectly.

Coral reefs are one of the potential marine resources in Indonesia that should be taken into account, so mapping the distribution and extent of coral reefs is needed in developing the potential for marine and coastal resources [7]. The development of remote sensing technology and Geographic Information System (GIS) computerization has provided insight for the ease of planning and development of marine areas in Indonesia [8]. The use of remote sensing data

and GIS has been widely used in relation to coastal areas and oceans, especially the fisheries sector and management of coastal areas and oceans, such as remote sensing applications to provide information on potential fishing zones, identification of potential coastal areas (such as mangroves, coral reefs, seagrass and sand fields), zoning of marine conservation areas etc [9].

Remote sensing technology is considered capable of being used as a tool for mapping, especially the area of coral reef land. The remote sensing process is a science that studies how to get an image of the earth's surface from space or from satellites which then studies and analyzes it using Geographic Information System. Geographic information system is an application developed to solve problems related to the earth's surface [10]. Geographic information system can make it easier and faster to provide information quickly, precisely, accurately and facilitate the compilation of databases [11].

## 2. LITERATURE REVIEW

### 2.1 Geographical Information System

Geographical Information System was originally developed by the Canadian Geographic Information System (CGIS) in 1960 with the aim of streamlining natural resource mapping work. The emergence of the term Geographical Information System as it is today after being coined by the General Assembly of the International Geographical Union in Ottawa Canada in 1967 [12]. This system was first introduced in Indonesia in 1972 under the name Data Banks for Development [13]. The digital data support required by Geographic Information System which is available automatically via satellite, LANDSAT, SPOT, NASA, NOAA makes GIS grow faster.

Geographic Information System is a computer-based information system designed to work using data that has spatial information (spatial reference). This system captures, checks, integrates, manipulates, analyzes, and displays data that spatially refers to earth conditions [14]. Geographic Information System technology integrates common database operations, such as query and statistical analysis, with mapping's unique visualization and analysis capabilities [15]. This ability distinguishes geographic information system from other information systems that makes it useful for various groups to explain events, plan strategies, and predict what happens [16].

Geographic Information System components include hardware, software, data, and geographic and management information [17]. According to Pratomo [18] Geographical information systems store all descriptive information along with its elements as attributes in the database, furthermore Geographic Information System will form and store them in tables (Relational). Geographic Information System connects these elements with the relevant tables, therefore, these attributes can be accessed through the location of map elements. Otherwise, map elements can be accessed through their attributes that so these elements can be searched and found based on their attributes.

ArcGIS 9.x is a collection of GIS software products that can be used to build a complete GIS application. ArcGIS 9.x consists of four main frameworks according to Hartoyo *et al.* [19], namely:

1. Mobile GIS is an ArcGIS application focused on mobile device needs, including: ArcPad, ArcGIS Mobile.



**Fig-1 : ArcGIS mobile**

- ArcGIS Desktop is a collection of server-based ArcGIS applications that are used to build an integrated cross-departmental system for the collection, organization, visualization, management, and distribution of geographic information. The server-based ArcGIS application consists of three products: ArcIMS, ArcGIS Server, and ArcGIS Image Server.

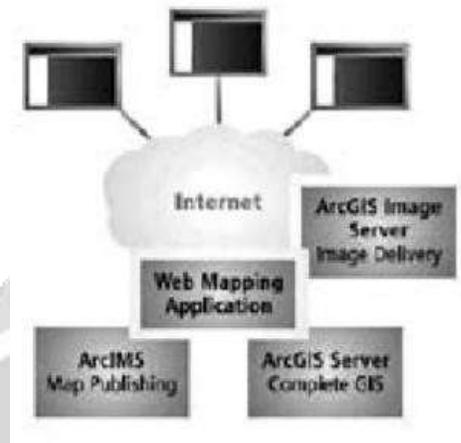


Fig-2 : Main Map Server ArcGIS

- GIS server is an integration of a series of Geographic Information System applications consisting of three main software products differentiated by their level of capability: ArcView<sup>®</sup>, ArcEditor<sup>™</sup>, and ArcInfo<sup>®</sup>.
- ESRI Developer Network (EDN<sup>SM</sup>), which is a software that provides a complete system for building applications using ArcGIS. The core of the EDN Developer Kit is ArcObjects, which is a library of various software components that can be used to build an application.

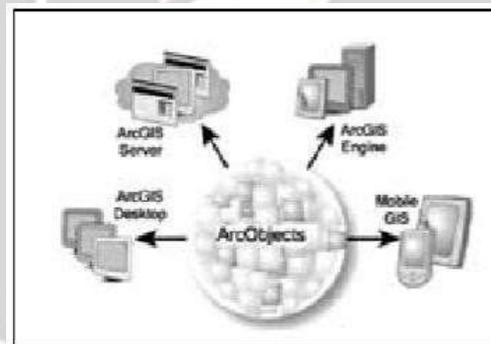


Fig-3 : ArcObjects

## 2.2 Coral reefs

Coral reef ecosystems have a high diversity of biota and productivity. Coral reefs also serve as a place to provide food, breeding ground, and shelter for populations [20] and the organisms that live there. Coral reef ecosystems have a good ability to repair damaged parts if the habitat characteristics of various coral reef formations and environmental factors that influence them are well maintained. Like other ecosystems, coral reefs do not require direct human intervention or manipulation for their survival [21]. Coral reefs have functions, including recreation (marine tourism), production (food and ornamental sources), conservation value as support for ecological processes and a buffer for coastal life, sources of coastal sediment, and protecting beaches from the threat of abrasion [22].

Coral reef ecosystems exist in rather shallow aquatic environments such as continental shelves and clusters of islands in tropical waters [23]. To achieve maximum growth, coral reefs need clear waters with warm water temperatures, large wave movements, and smooth water circulation and avoid the sedimentation process [24]. The distribution of coral reefs in Indonesia is mostly found around the island of Sulawesi, Flores, and Banda Seas. The distribution of corals on the east coast of Sumatra, along the North Coast of Java, West Kalimantan, and South Kalimantan is limited by high sedimentation. It grows and develops well in the Sulawesi region, especially North

Sulawesi due to the presence of trans-Indonesian flows that flow throughout the year from the Pacific and Indian Seas [25].

Increased tourism activities provide economic benefits but also have a negative impact on coral reef ecosystems [26]. Tourism activities such as snorkeling and diving contribute to changes in the condition of coral reef ecosystems [27]. Some tourist behavior has the potential to damage coral reefs such as kicking corals, holding corals, walking on corals, and anchoring on corals (Pohael & Inglis 1997 in Muhidin *et al.* [28]. The impact caused by each tourist's behavior on coral reefs is very small, but cumulatively this behavior can exert pressure on coral reefs and affect the percentage of coral cover [20]. To prevent further damage to coral reefs, coral reef management is needed. Management is essentially a process of controlling human actions so that the use of coral reefs can be carried out wisely by taking into account environmental sustainability. One of them is the concept of determining Marine Protected Areas (KKL) [24].

### 2.3 Mapping of Coral Reef Conditions

Mapping of Coral Reef Conditions Utilization of coastal and marine resources has not been optimal due to disregard for the potential of each island that Indonesia has, with the presence of remote sensing and geographic information system it is expected to be able to help identify existing potentials. Remote sensing is a science and art to obtain information about an object, area or phenomenon through data analysis obtained with a tool without direct contact with the object, area or phenomenon being studied [29]. Examples of using remote sensing data in coastal management identify various objects in coastal areas such as seaweed, coral reefs, sand conditions, seagrass beds, the presence of mangroves, land use, and the distribution of other vegetation which is a coastal ecosystem.

Remote sensing technology is considered capable of being used as a tool for mapping the area of coral reef land. The mapping obtained is expected to be a zone quality standard for tourists who will dive or snorkel in certain zones [7]. The advantage of geographic information system is its ability to handle geographic reference spatial data that integrates with attribute data so that the spatial form of the data can be analyzed. The results of the analysis include length, area, volume, linkages, classification, and estimates in the form of a spatial view. This situation is obtained from spatial data analysis and manipulation which is another advantage of geographic information system, while examples of spatial data analysis and manipulation carried out in geographic information system such as overlay, interpolation, buffering, and classification.

In research conducted by Adhilmah [30] on remote sensing technology and geographic information systems in coral reef management, there are the following conclusions:

1. The use of remote sensing technology and geographic information systems can identify the presence and extent of coral reefs
2. The use of remote sensing technology and geographic information systems can determine the condition of the waters of coral reefs
3. Mapping of coral reef density that is carried out using images that have been transformed by PCA and images that have not been transformed by PCA have the same mapping results..

According to Kennedy [16], the use of GIS in processing spatial data for mapping coral reefs provides several advantages, including:

1. Geographic information system is effective in data processing due to the various techniques provided, such as overlay, buffer, cropping, and other analysis techniques.
2. Geographic information system can provide a complete and comprehensive picture of the real problem of coral reefs.
3. Geographic information system can visualize spatial data along with coral reef attribute data in a modified color, shape, and size as a symbol
4. GIS has the ability to describe coral reef data in the form of layers, thematic or spatial cover.

### 3. CONCLUSIONS

Mapping of coral reefs can be done using Geographic Information Systems technology. Geographic Information System (GIS) can provide information on coral reefs automatically without the need to interpret data manually.

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