SUITABILITY ANALYSIS OF MULTISPECTRAL SATELLITE SENSORS FOR MAPPING CORAL REEFS IN INDONESIA CASE STUDY: WAKATOBI MARINE NATIONAL PARK

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ABSTRACT

Providing accurate information on suitable multispectral satellite sensors for mapping coral reefs in Indonesia is a challenge for coastal remote-sensing experts. As coral reefs vary in spatial extent, shape, length, perimeter and/or distance to shore, the mapping of coral reefs will need different satellite sensors depending on the objectives and the kind of information required. This work compares the suitability of two kinds of multispectral satellite sensors for mapping coral reefs in Indonesia, high and moderate spatial resolution. This was done through a case study of Wakatobi Marine National Park since that represents many types of coral reef in Indonesia (fringing, barrier, atoll, and patch). Indonesian coral reef shapefile data 2010 was downloaded from UNEP (United Nations Environment Programme) website, and Landsat 7 ETM + images, path/row 112/064 was used to determine the terrestrial area of Wakatobi Islands. Both high and moderate spatial resolution sensors are suitable for mapping the benthic communities and geomorphic zones on coral reefs. The former are more accurate but they are also much less cost-effective, especially over large areas.

Keywords: suitability, multispectral satellite sensors, mapping coral reefs

INTRODUCTION

Indonesia is an archipelago country with more than 17,000 islands and has some 75,000 km^2 of coral, approximately one-eighth of world's coral reefs (Cesar et al., 1997). Yet despite the high potential economic value of coral reefs, the percentage of healthy coral reefs in Indonesia decreases significantly year by year (Suharsono, 2004). Monitoring and managing coral reef ecosystem is the responsibility of many stakeholders and, this necessitates research studies and good management in order to provide accurate biophysical properties in the form of spatial information to support management decisions (Mumby et al., 2004).

The coral reefs of Indonesia are characterized by a variety of reef types (e.g. fringing, barrier, atoll, and patch), geomorphic zones (e.g. reef crest, reef flat) and benthic community compositions (e.g. coral, algae, sand) (Suharsono, 2004). From the literature it is known which type of sensor is more suitable for mapping the specific spatial scales and extent. Satellite imagery data is particularly useful for mapping coral reef habitat (Green et al., 2000; Roelfsema and Phinn, 2010). Remote sensing technology is an important tool for assessing coral reef environments due to its ability to provide a synoptic view of the earth that would be impossible from the ground, except with exhaustive field surveys (Green et al., 1996).

Even though benthic habitat mapping projects using multispectral satellite sensors have been undertaken Indonesian waters, including coral reef environments, there is still lack of information about which type of satellite sensors are most suitable for mapping the coral reef habitat in Indonesia. This depends on not only the ability of the sensor to map a specific scale, but also the shape and size of the reefs covered by the image scene, since each reef will vary in spatial extent,

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shape, length, perimeter and/or distance to shore. This research study aims to conduct a suitability analysis of two types of satellite sensors for mapping the coral reef habitat in Indonesia, taking into consideration the reef extent, length shape, reef density and distance from other reefs. The research focused on two types of multi spectral sensors, high spatial resolution multi spectral (0.6 – 4 m) and moderate resolution multi spectral (4 – 30 m).

MATERIALS AND METHODS

Wakatobi Marine National Park is located in the Province of Southeast Sulawesi, Indonesia and established by Forestry Ministerial Decree No. 7651/Kpts/II/2002, 19 August 2002, with an area covering 1,390,000 ha. Wakatobi District consists of 4 major islands, Wangi Wangi Island, Kaledupa Island, Tomia Island and Binongko Island. The coral reef environment in Wakatobi Marine National Park is representative of many coral reef types in Indonesia and includes fringing, barrier and atoll reef types (Suyarso and Budiyanto, 2008).

Data for this research study includes Indonesian coral reef shapefile data 2010 which was downloaded from UNEP (United Nations Environment Programme) website and Landsat 7 ETM + images, path/row 112/064, acquisition on 25 October 2002 level 1G which covers Wakatobi Marine National Park. Literature studies were undertaken to determine which type of satellite sensor is most commonly used for mapping the geomorphic zone and the benthic community on coral reefs in a specific spatial scale or extent. Spatial analysis of reef types, reef extent, length shape, reef density and distance to other reefs was undertaken using eCognition and ArcGIS 10.1 software. The analysis focused on assessing the type of sensors that are the most suitable for mapping coral reef habitats in Indonesia using satellite imagery data.

Multispectral Sensors Characteristic

Table 1 provides information on the various multispectral sensors which are commonly used in marine remote sensing. These sensors are divided into two spatial resolution types:

1. High spatial resolution

These have a minimum 3 meters of spatial resolution (e.g. Quick bird, Ikonos and Worldview).

2. Medium spatial resolution

These have a range between 15 and 30 meters of spatial resolution (e.g. Landsat and Alos).

Table 2 describes the spatial scale of high and moderate multi spectral sensors for mapping coral reef.

Pre-processing

eCognition will only process raster data formats, while this research study explores coral reef data from Wakatobi Islands which is vector data, so Landsat 7 EMT + is used as an image layer to be joined with vector data (coral reef and land of Wakatobi). Landsat level 1G images are geometrically correct, so geometric correction is no longer needed. Radiometric and atmospheric correction are also unnecessary as this ETM+ image is used as an image layer alias, so that further classification in eCognition can be done.

Table 1. Various sensors commonly used in marine science (based on Stuart Phinn and Chris Roelfsema, 2010)

Platform	Sensor	Spatial Scales - Extent - Pixel size
High spatial resolution multi spectral	QuickBird 2 IKONOS GeoEye-1	Extremely fine (local) Extent : 25sqkm+, 49sqkm+ GRE: 0.5-1m (pan) or 1.64-4m (multi)
	WorldView-1	Extremely fine (local) Extent : 25sqkm+ GRE : 0.5m (pan)
Moderate spatial resolution multi spectral	Landsat 7 EMT+ Landsat TM	Medium: (province, region) Extent : 625sqkm – 185km x 185km GRE : 15m (pan) or 30m (multi)
	ALOS (Daichi)	High to medium: (local, province, region) Extent: 35km x 35km – 70km x 70km GRE: 2.5m (pan) or 10 (multi)

GRE: ground resolution element or pixel size

Table 2. Spatial Scale of high and moderate multispectral sensors for mapping coral reefs

	High spatial resolution multi spectral		Moderate spatial resolution multi spectral	
	Geomorphic Zones	Benthic Habitat	Geomorphic Zones	Benthic Habitat
Minimum Extent (km^2)	200	100	1000	500
Minimum Spatial Resolution (m)	5	5	30	30

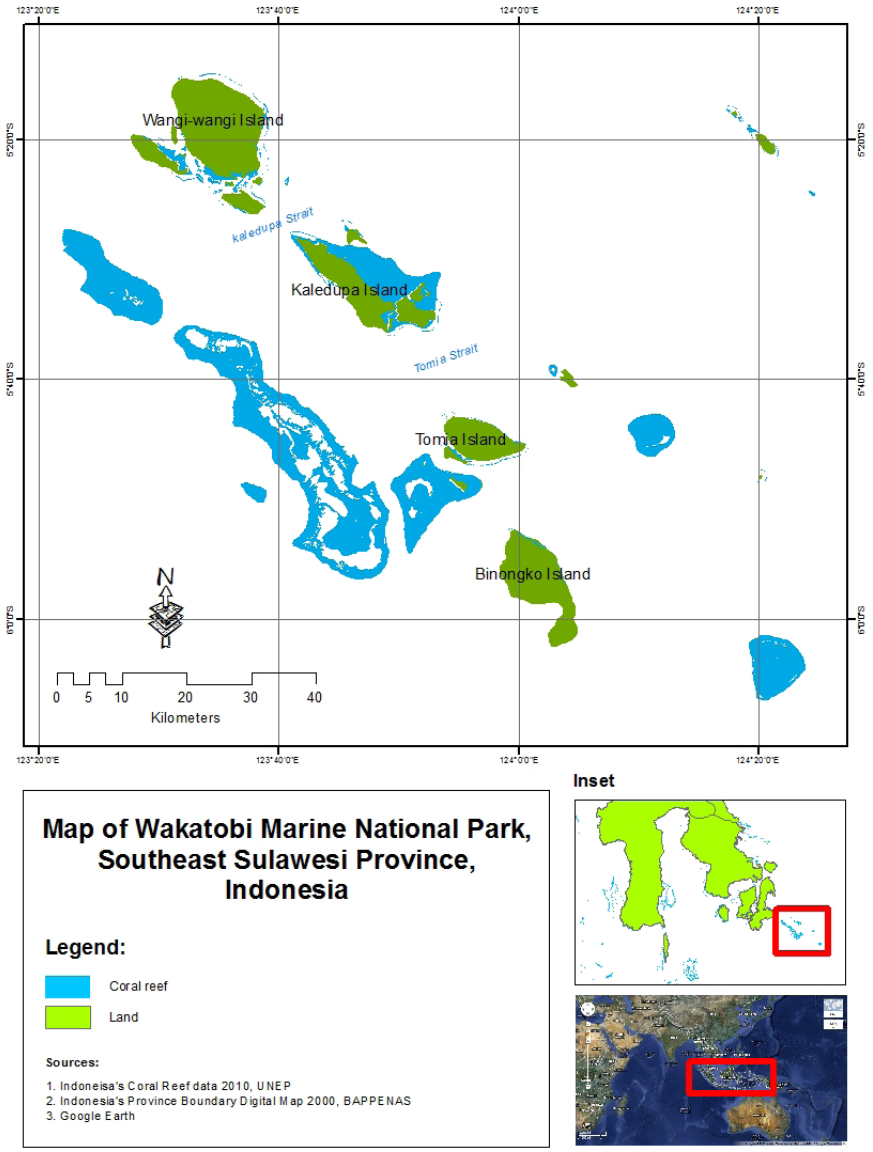

Figure 1. Map of Study Area

RESULTS

Figure 2 shows the coral reefs around Wakatobi Islands, with those classified as small reefs shown in red. A small reef is defined as having an area of less than 7100 pixels or equal to less than 6.39 km^2. The calculation of the area is based on Landsat pixel size because this project used the Landsat image as an image layer, 1 pixel of Landsat images equal to 30 m x 30 m. Therefore, the area of small reefs is 900 m x 7100 m. High spatial resolution sensors are essential to produce a high quality map of the benthic community and geomorphic zone on these small reefs. It is nearly impossible to derive more accurate classification of benthic communities with moderate spatial resolution sensors in these small reefs area.

Figure 3 shows the big reefs round the Wakatobi Islands. Big reefs, shown in yellow, are defined as those that are larger than 6.39 km^2. Both moderate and high spatial resolution sensors are suitable for mapping the benthic community and geomorphic zone on these coral reefs. In terms of a wide range area of the coral reef habitat, moderate spatial resolution sensors are capable to cover a large area at a low cost price. However, these sensors will only generate a small number of benthic classes and a moderate level of accuracy. On the other hand, high spatial resolution sensors are able to provide more details about habitat types and promise a better level of accuracy but are much more expensive, especially when used to map large areas.

It is feasible to use moderate spatial resolution sensors for mapping small reefs which are close to each other or close to big reefs as long as these small reefs are less than 10 km away from the other reefs. Figure 4 illustrates a small reef area where it is still feasible to map the geomorphic zone using moderate spatial resolution sensors. The area of this small reef is 7074 pixels, equal to 637 ha. It is also the largest reef within a group of small reefs.

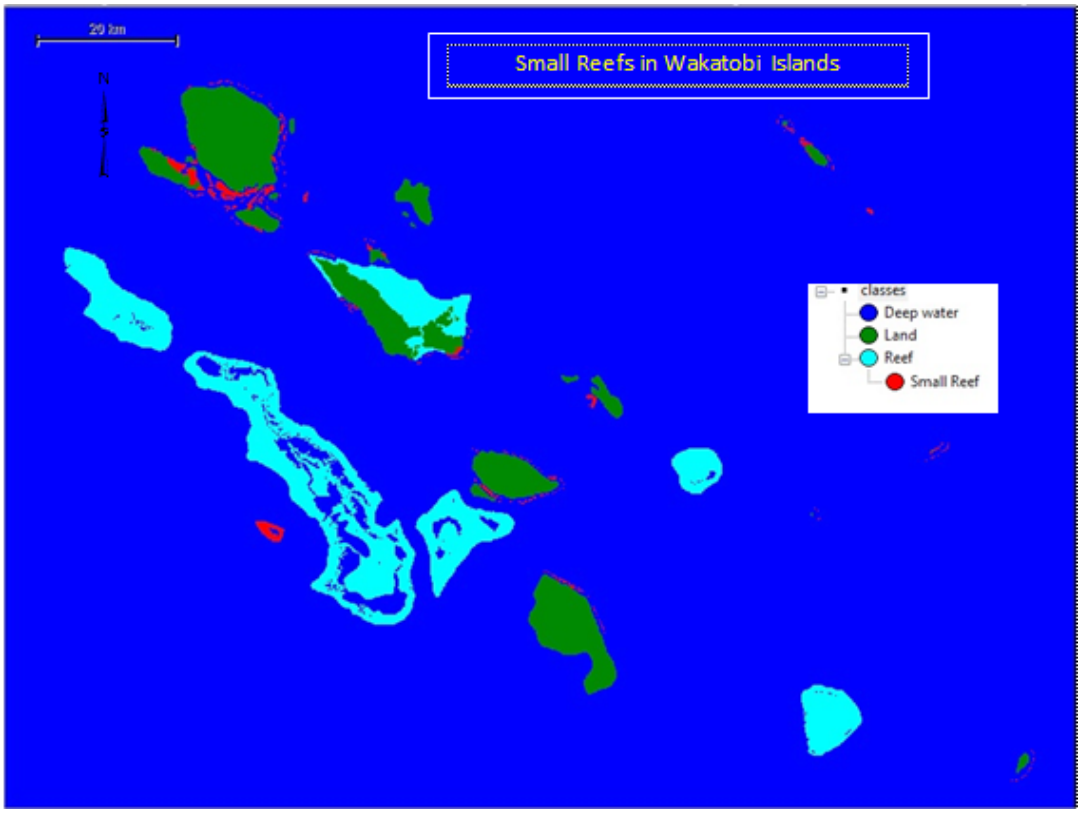

Figure 2. Small reefs in Wakatobi Islands

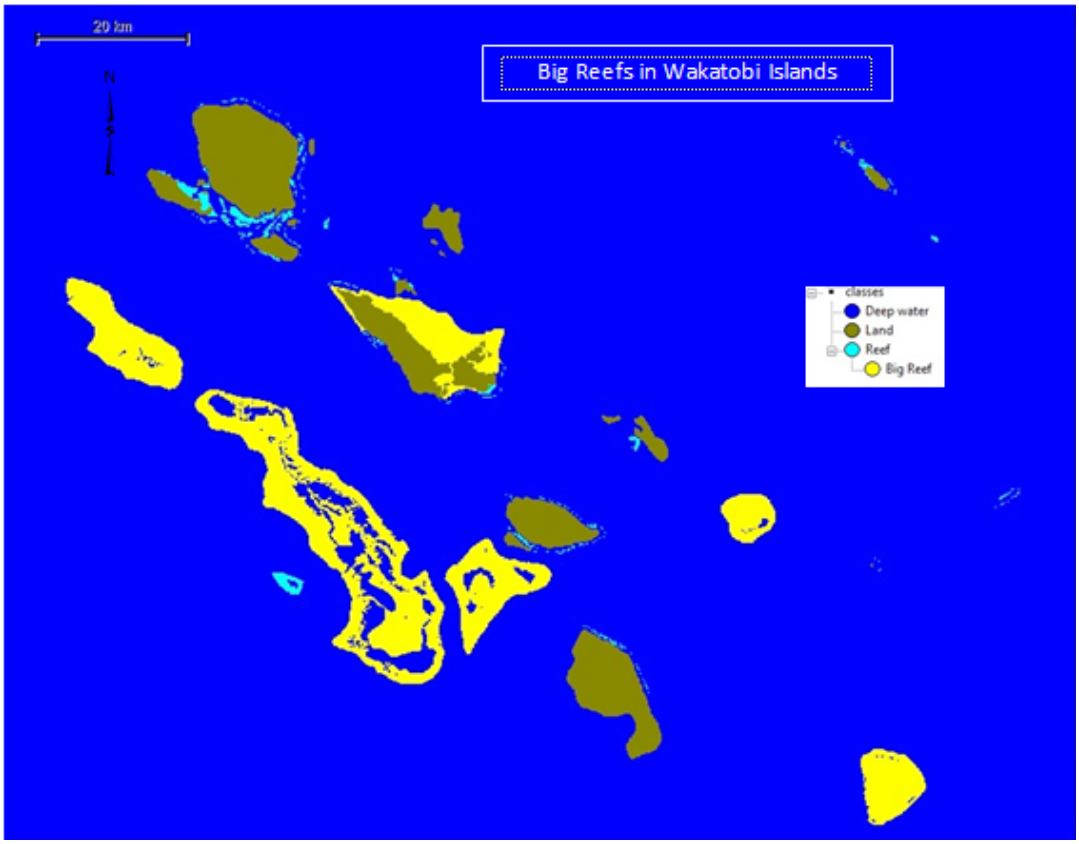

Figure 3. Big reefs in the Wakatobi Islands

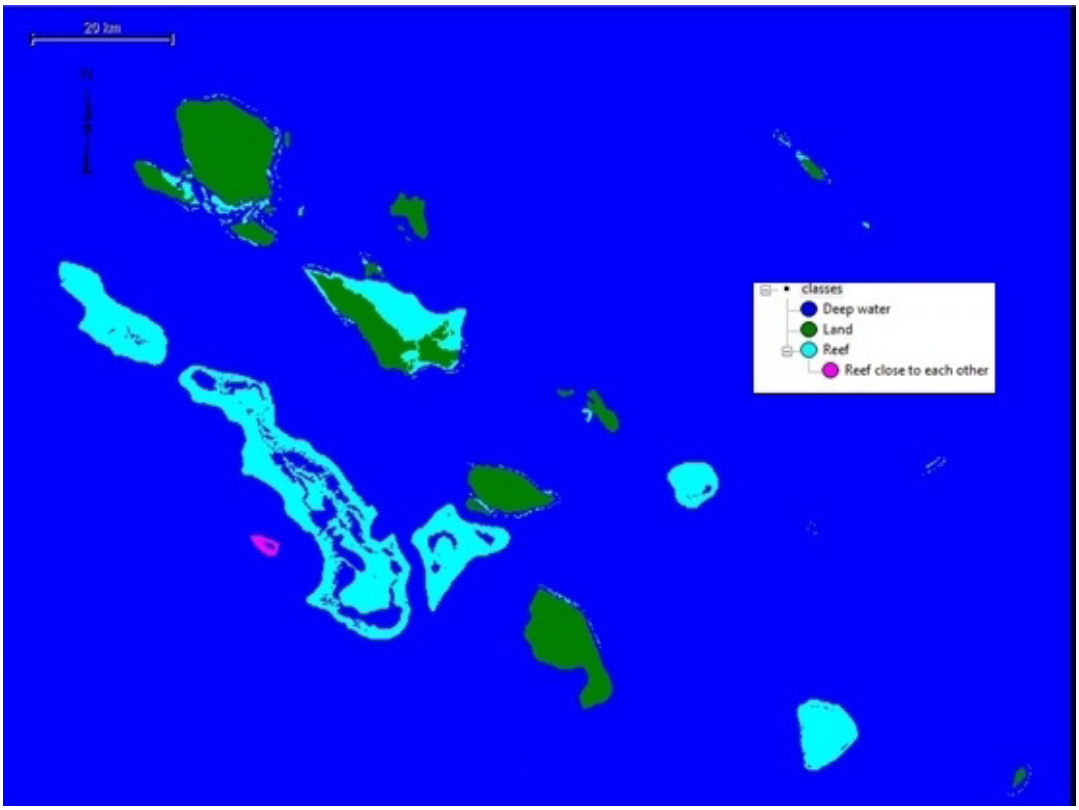

Figure 4. Small reef where it is possible to map the geomorphic zone using moderate spatial resolution multispectral sensors

DISCUSSION

Only high spatial resolution sensors should be used to map the benthic community and geomorphic zone on coral reefs with an area of less than 6.39 km^2. However, moderate high spatial resolution sensors still can be used to map geomorphic zone on reefs with an area of less than 6.39 km^2 if they are adjacent to other ones (less than 10 km away).

It is evident that both moderate and high spatial sensors are suitable for mapping the benthic community and geomorphic zone of reefs with an area of more than 6.39 km^2. High spatial resolution sensors are able to provide more complex mapping of benthic habitat types and a high level of accuracy, but are very expensive, especially if the project covers a large area. Moderate spatial resolution sensors are suitable for mapping the benthic community and geomorphic zone of coral reefs over a large area and are low cost, since satellite imagery data can be freely downloaded (e.g. Landsat 8), but they map fewer benthic habitat types and are not as accurate.

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