

SATELLITE-BASED MAPPING OF CORAL REEFS IN EAST ASIA, MICRONESIA AND MELANESIA REGIONS

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ABSTRACT:

Coral reefs are declining worldwide because of various factors. The necessity of marine biodiversity conservation through establishment and management of marine protected areas (MPAs) is being recognized globally. Japan has a policy to cooperate to develop an important MPAs network in the Asia and Oceania region. In this study, as part of the work of the Japanese Ministry of the Environment, the latest coral reef maps of East Asia, Micronesia and Melanesia regions have been developed by mainly using ALOS AVNIR-2 imagery.

About 1,500 scenes of less cloudy satellite imagery were used to detect coral reefs. As pre-processing, the map projections of all scenes were transformed to the geographical latitude and longitude coordinate system and also the land areas, deep sea areas, and cloudy areas were masked to prevent degradation of classification accuracy. The shallow sea areas where coral reefs are expected were clustered to 10 classes by the ISODATA algorithm and aggregated to the six categories: coral cover 5 to 50%, coral cover 50 to 100%, seaweed/seagrass, sand bottom, mud bottom, and rock. After verification, the maps were transformed from raster to vector data format for easy handling on GIS software.

1. INTRODUCTION

1.1 Objective

Coral reefs are characteristic topographical features of tropical and sub-tropical sea areas, and coral reefs play many roles, such as protecting coast lines, diversifying the ecosystems of the reefs, fishing grounds, landscape elements, and tourist resources. However it is considered that coral reefs are being affected by changes in the environment, etc., and are declining worldwide due to various causes such as the rise in water temperature, the flow of soil sediment, and damage due to crown-of-thorns starfish. The awareness of the necessity of protecting the biodiversity of the seas through the establishment of marine protected areas (MPAs) and effective management is increasing worldwide.

Japan has been cooperating in the development of a representative MPA network mainly in East Asia to protect coral reefs, and as part of the work, map information on coral reef areas including habitat data, etc., is being enhanced in the Asia and Oceania region.

The objective of this study was to provide up-to-date coral reef distribution maps for East Asia (excluding a part of the area), Micronesia, and Melanesia, by classification of satellite images using remote sensing data from ALOS AVNIR2, etc.

1.2 Outline of the Coral Reef Distribution Maps

Figure 1 shows the extent of the coral reef distribution maps prepared under this study. ALOS AVNIR2 images photographed up to the end of 2009 were mainly used, supplemented with LANDSAT images when good images could

not be obtained due to cloud, etc. There were 7 classification items: coral cover 5 to 50%, coral cover 50 to 100%, seaweed/seagrass, sand bottom, mud bottom, rock, and deep coral or sand. The data was prepared in the vector (polygon) format, which is capable of having multiple attribute information such as classification item, satellite data used, etc., when combined with other geographical information data. Figure 2 shows an example of coral reef distribution map.

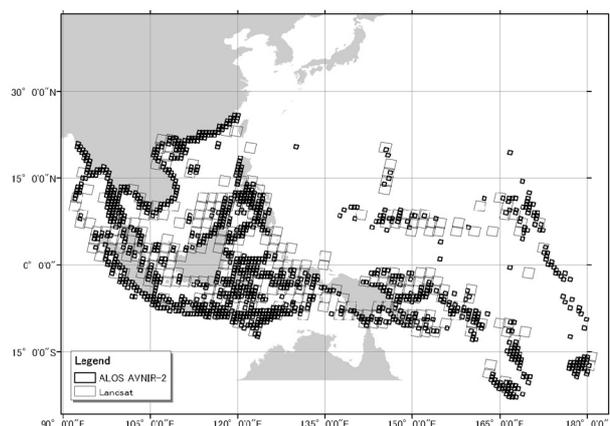


Figure 1. Extent of the coral reef distribution maps

2. PREPARATION OF CORAL REEF DISTRIBUTION MAPS

2.1 Collection of Satellite Data

AVNIR2 images which include coastlines and existing coral reef data (WorldFish Center / ReefBase) were searched. For areas where there are no coastlines such as Micronesia, and for areas where the coral reef data is only partially provided, Google Earth high resolution images were checked, and AVNIR2 images with reefs were searched. Also, if good AVNIR2 images could not be obtained due to cloud, etc., LANDSAT (TM, ETM+) images and ASTER images were searched. As a result it was found that the whole area could not be covered by just adding ASTER images, and that it was easier to ensure classification accuracy during classification with LANDSAT images, as the observation width is large, and the effect of difference in water depth due to the measurement date being different was small. Therefore it was decided that all the additional satellite images should be LANDSAT images. Ultimately in this study 1261 AVNIR2 image scenes and 302 LANDSAT image scenes, or a total of 1563 scenes, were collected.

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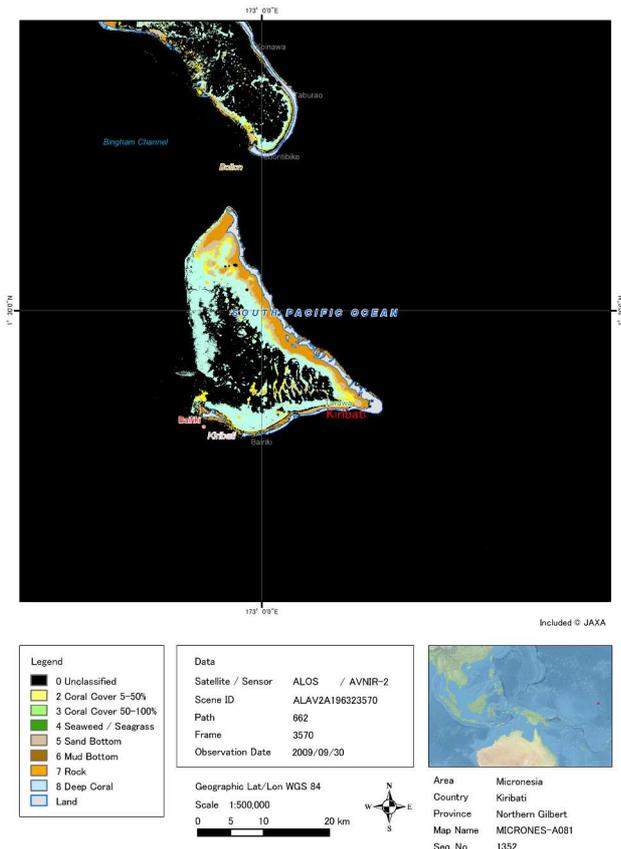


Figure 2. Example of coral reef distribution map

2.2 Analysis method

Figure 3 shows the analysis flow diagram. The analysis consisted of 3 processes: pre-processing such as geometric correction of satellite images and masking land and cloud areas, image classification including classification by the ISODATA method and image classification of coral areas by binarizing band ratio images, etc., and vectorization. The details of the

analysis are described below.

2.3 Pre-processing

The data used in the analysis was ALOS AVNIR-2 level 1B2 geocoded product (distributed by RESTEC) and LANDSAT ETM+ and TM GLCF orthorectified product (distributed by Maryland University). This data was converted to the latitude and longitude coordinate system based on the world standard geodetic system (WGS84), while maintaining the original spatial resolution of the data. Geometric correction of each scene was carried out by movement relative to the coastline data. For this purpose the coastline data used was SRTM-3 ver.2 SWBD (distributed by NASA JPL).

Next, land areas and cloud were masked, as these can cause errors during classification. For the mask images of land, images of the ratio of near infrared bands and green bands (NIR-Green)/(NIR+Green) were created by automatic binarization. Mask images of cloud were produced manually for all scenes.

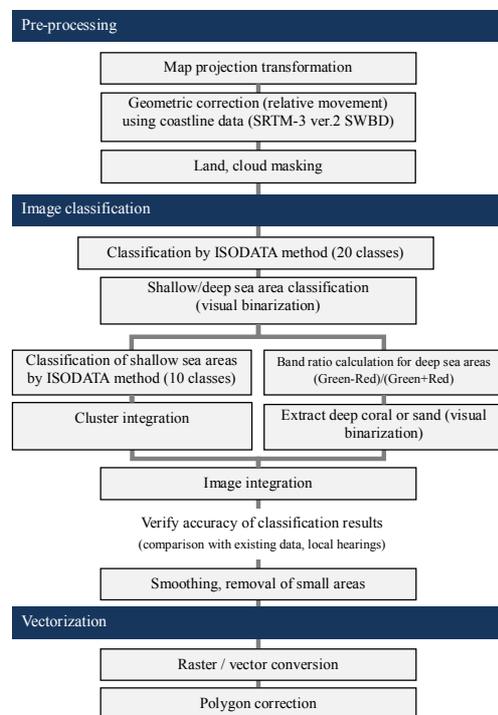


Figure 3. Analysis flow diagram

2.4 Image classification

To avoid large variations in classification accuracy from area to area, unsupervised classification (the ISODATA method) was adopted, and the distribution maps were produced by interpreting the classification results obtained in this way and integrating clusters.

To enable detailed classification of the coral reef areas, the classification process was carried out by processing twice: classification of shallow sea areas and deep sea areas, and classification within the shallow sea areas. Also, to extract the coral reef areas from the deep sea areas, ratio images of (Green-Red)/(Green+Red) were calculated for the red bands and the green bands of the deep sea areas, and these images were binarized visually.

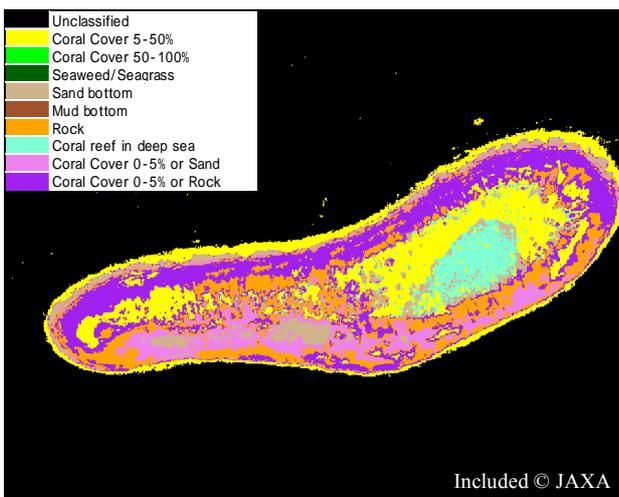
Determination of classification categories within the shallow sea areas was carried out by interpreting the brightness value

information from the satellite data in each cluster and the distribution location within the coral reef. Classification into the following 9 categories was carried out: coral cover less than 5% or sand bottom, coral cover less than 5% or rock, coral cover 5 to 50%, coral cover 50 to 100%, seaweed/seagrass, sand bottom, mud bottom, rock, and deep coral or sand. Also, to remove noise such as waves and halation from the classification results images, smoothing and removal of areas smaller than 1 pixel was carried out by majority filtering. Figure 4 shows a coral reef distribution result obtained using the ALOS AVNIR-2 images.

As in the example in Figure 4, when the water depth is comparatively shallow and there is no effect from the atmosphere, etc., it is possible to clearly distinguish rock, coral cover less than 5%, and coral cover 5-50% areas, which can be comparatively difficult to classify. On the other hand when the water is deep or when there are effects such as noise, halation, or sediment flows, it is difficult to clearly distinguish these items, and the effects vary with location within a scene, so the classification results also differ. Therefore, to reduce these effects, scenes were broken down into small areas in advance, and the classification was carried out on each small area, and finally they were integrated again.



(a) ALOS AVNIR2 true color image



(b) Coral reef distribution results

Figure 4. Coral reef distribution results (example from Spratly Islands)

2.5 Verification of Accuracy

The coral reef distribution maps obtained from the classification results were comprehensively and efficiently verified using existing coral reef data, and detailed verification of important points were carried out by holding hearings with local research institutes, etc.

Two types of comparison were carried out using the existing coral reef data: quantitative comparison using the ReefBase coral reef data (line, polygon data) which is controlled and managed by the WorldFish Center, and qualitative comparison with Millennium Coral Reef Mapping project data. The ReefBase coral reef data is available over a wide area, so it is suitable for comprehensive verification, but the scale varies greatly from 1:50,000 to 1:2,500,000 depending on the area. Therefore, taking the positional accuracy into consideration, the whole area was rasterized to a 5km mesh, before carrying out the comparison. Also, the object of verification was not the detailed items within the coral reefs, but whether or not an area was a coral reef area in accordance with the ReefBase data. The classification items included in coral reef areas were taken to be coral other than mud bottom, seaweed/seagrass, sand bottom, rock, and deep coral or sand. Table 1 shows the verification results. The result indicated that the coral reef extraction accuracy was 71.3%.

		Existing coral reef data (ReefBase)	
		Non-coral reef area	Coral reef area (Type attribute=coral reef)
Classification result	Non-coral reef areas		
	mud bottom	90.5%	28.7%
	Coral reef areas		
	Coral cover 5-50%	9.5%	71.3%
	Coral cover 50-100%		
	Seaweed/seagrass		
	Sand bottom		
	Rock		
Coral cover less than 5% or sand bottom			
Coral cover less than 5% or rock			
	Deep coral or sand		
Total		100.0%	100.0%

Coral reef area correct percentage 71.3%

Table 1. Coral reef distribution map accuracy verification results

Next, qualitative verification was carried out using the Millennium Coral Reef Mapping project data. Although this data does not include South-East Asia, it includes most of Micronesia and Melanesia, so it was possible to verify a part of Melanesia that could not be verified using ReefBase. As a result of superimposing and comparing the two, it was found that there was agreement for almost all areas, apart from some deep coral areas. Also, the coral reef areas of the Solomon Islands and Fiji, which are not included in ReefBase or the Millennium Coral Reef Mapping data, were also extracted. Finally hearings were held with researchers from the various countries mainly in East Asia, to discuss the correctness of each item in the classification results. From the responses obtained from Brunei, Cambodia, and Thailand, it was found that classification results generally agreed with the local situation, although there was a tendency for misinterpretation between coral cover less than 5% and rock, which were difficult to classify.

- The classification results for coral cover 5-50% were in full agreement in 9 examples.

- The classification results for rock were in agreement in 4 cases out of 9 examples. In the cases that did not agree, coral cover less than 5% was misinterpreted as rock.
- There was agreement in 7 cases out of 9 examples of coral cover less than 5% or rock. In the cases that did not agree, coral cover less than 5% or sand bottom were misinterpreted.
- There was one example each for seaweed/seagrass and sand bottom, and they both agreed.

2.6 Vectorization

The coral reef distribution maps produced were vectorized so that they could be superimposed on existing geographical information databases. In doing so the coral cover less than 5% or sand bottom and the coral cover less than 5% or rock classification items were integrated into the sand bottom and rock classification items respectively, and the original interpretation results information was stored as attribute values. When carrying out vectorization, the low quality boundary lines were smoothed by applying a majority filter to the raster data, so that the distribution of the coral, etc., was consolidated to a certain extent. Also, visual checking was carried out, and where necessary corrections were made by removal of polygons with wrong classification, etc., to improve the accuracy. An example of coral reef distribution map is shown in Figure 2. The data was formatted as shapefiles in polygon format, having the classification items as attribute information, and the geodetic system was the latitude and longitude coordinate system based on the world standard geodetic system (WGS84), the same as for satellite images.

3. CONCLUSIONS

In this study ALOS AVNIR-2 images were comprehensively used over the wide area of East Asia, Micronesia, and Melanesia, to produce up-to-date coral reef distribution maps. Also, overall quantitative and qualitative verification of the coral reef distribution maps obtained was carried out using existing coral reef data, and detailed verification of important points was achieved by hearings with local researchers. The results indicated that the extraction accuracy of coral reef areas was higher than 70%, and each classification item generally agreed with the local situation.

In the future, it is necessary to study the following in order that the coral reef distribution maps can be effectively utilized.

- The classification accuracy from satellite images is about 70%, so a certain amount of error is unavoidable. Also, in this study responses were obtained in local hearings for only some areas, so it is important to continuously obtain the opinions of specialists for the other areas, so that the accuracy can be increased.
- It is necessary to have specific examples of use, etc., in order to present this data for projects for the preservation of international coral reef ecosystems, and to encourage the effective use of the coral reef distribution maps in the various countries.

4. ACKNOWLEDGEMENTS

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