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UAV's Remote Sensing for Observation of Microatolls in Shallow Waters of Small Islands, Spermode Archipelago, Indonesia

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ABSTRACT

Microatolls are massive corals on flat reefs with the colony dying in the center or there is a hole in the middle due to erosion by algae or other micro-borers. This study aims to measure the ability of UAV RGB imagery to identify micro atolls located on reef flats and objects associated with them on small islands. High resolution satellite images were also used to compare their accuracy in estimating the size of micro atolls. Some of the important steps carried out are field surveys, aerial and google earth photo acquisitions as well as mosaics, classification with segmentation based on, shape and color, texture, and shape of object proximity. RGB UAV is used to collect data and it is processed by object-based image analysis (OBIA) classification algorithm and supervised classification. This paper represents the result of UAV data analysis is more accurate and precise than high resolution satellite image data analysis. The diameter of the micro atoll can be calculated and the associated community around it. This technology allows it to be used for monitoring shallow water ecosystems bordering community activities on the mainland of small islands and producing a higher scale.

Keywords: UAV, microatolls, OBIA, reef flat, small island.

1. INTRODUCTION

The existence of massive corals can provide great benefits as a habitat for various types of biota that inhabit coral reef areas, and at the same time function as a place for spawning, rearing, sheltering, and as a place to find food. Rock coral as a producer of calcium carbonate (CaCO3) provides benefits in the form of global warming absorption of 7-15% [18]. Coral growth is a linear increase in length, weight, volume, or area of the limestone skeleton over a certain period. In general, coral skeleton formation is interpreted as an increase in the weight of the coral skeleton composed of calcium carbonate in the form of crystalline aragonite and calcite [3].

Microatolls are a form of adaptation carried out by coral colonies that live in areas with extreme environmental conditions. Microatolls have a hemispherical shape, like a dome whose top is flat because of death. This was caused by the lowest tide and sedimentation conditions which stopped the vertical growth of the colony [9]. Corals that form a lot of microatolls are corals of the genus Porites, Goniastrea, and Platygyra. Microatolls are recorded on several islands in the Spermonde Archipelago, namely Panambungan Island, Sanane Island, Bone Batang Island, Kodingareng Keke Island, Sanrobengi Island, Suranti Island, Tambakulu Island, and Barrang Lompo Island [8]. Research related to the use of remote sensing technology for providing spatial information on shallow water benthic habitats using the object-based images (OBIA) method has been widely carried out [12]; [17]; [4]. The acquisition of remote sensing data from satellite

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recordings can provide quantitative information for various purposes, including assessment of shallow water habitat conditions [7]; [11],[13]; [14]. However, along with technological developments, in this decade the use of unmanned aerial vehicle (UAV) technology for mapping is growing not only in land areas [15] but also in the marine sector. UAV technology in the marine sector has been used to map and monitor the coastal environment. The utilization of satellite image data and aerial photography (UAV) can be used as an alternative to providing spatial data effectively and efficiently.

The high level of shallow water bottom heterogeneity requires high image resolution and requires a fairly high cost. The use of UAVs can produce data with a higher temporal resolution, be more economical, avoid cloud cover, and have more flexible data acquisition while maintaining a high potential for accuracy [20]. Aerial photography using an Unmanned Aerial Vehicle (UAV) is an alternative technology to obtain images with high spatial resolution but at a relatively low cost. UAVs or drones can collect coral reef data with centimeter spatial resolution and allow researchers to focus coral data collection efforts on optimal weather conditions. This study aims to map the growth of microatolls in shallow waters by calculating the diameter of microatolls using UAV imagery in 2020 and 2022 with object-based classification methods/OBIA and in situ measurements.

2. MATERIALS AND METHODS

2.1 Study area and data collection

Barrang Lompo Island is included in a group of small islands located in Spermonde Islands, South Sulawesi. Indonesia. Geographically, the island is located at $119^0$19'48" East and $05^0$2'48" South with an area of 48 hectares and a population of about 4,547 inhabitants. This island is the island that has the highest population of hundreds of small islands in the Spermonde archipelago. Barrang Lompo has coral reefs that can be found on almost all sides of the island. Most of the people of Barrang Lompo Village work as fishermen. The sampling location for this research is on the south side of the island (Figure 1).

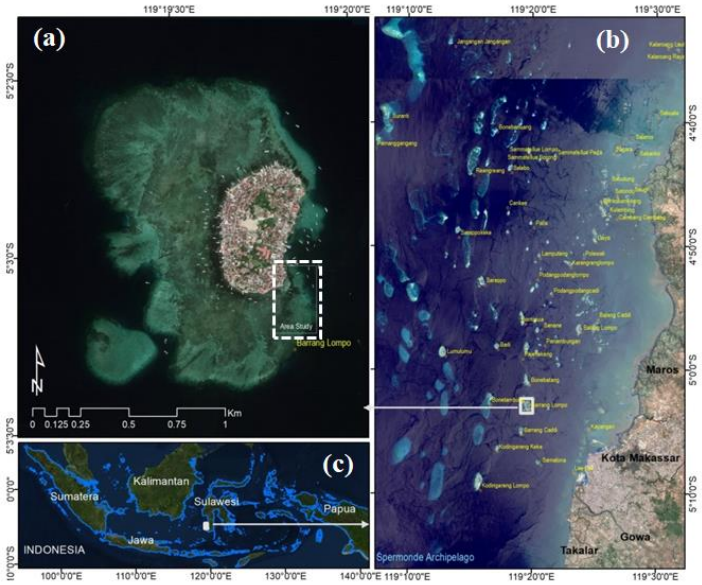


Figure 1. The Geographical location of the research area, (a) Shallow waters of Barrang Lompo Island, white dotted lines indicate the sampling area of 9 microatolls, (b) a group of small islands located in the Spermonde Archipelago, (c) the Republic of Indonesia.

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Aerial photographs are used to visually identify microatolls in shallow water and are integrated with field data. Aerial photos were taken using a DJI Phantom 4 Professional which has a drone specification with a quadcopter type (4 motors). DJI Phantom 4 is equipped with a sensor with effective pixels of ½.3" CMOS (12.4 MP) and weighs 1,380 grams. The DJI Phantom 4 has a Micro SD slot up to 64 GB with a 6,000 mAh battery and can air for about 28 minutes at a maximum altitude of 19,685 feet.

2.2 Methods

2.2.1 Insitu measurement

The field survey was conducted to collect data and information on the presence of microatolls in the waters of Barrang Lompo Island. Determination of the location of the microatoll using the manta tow method. The manta tow method is a technique for observing coral reefs as a whole in a short time with the observer behind the boat being pulled using ropes and boards. The ship moves slowly, steadily, and passes over the coral surface [2]. In this study, the determination of the location of the UAV flight was determined directly above the location of nine (9) microatolls that tend to congregate on the southern side of the island's mainland.

Direct visual observations and diameter measurements were carried out on each of these microatolls combined using underwater photos. Furthermore, the coordinates were taken using GPS at each data collection location. The coordinates taken will be used as a reference for the RoI (region of interest) in the image classification process and part of it will be used as data for testing the accuracy of the image classification results.



Figure 2. Underwater pictures of microatoll in Barrang Lompo Island. In situ measurement of microatoll diameter in the southern part of Barrang Lompo island on 9 June 2022.

2.2.2 Flight Planning and UAV Data Acquisition

Image acquisition is made by aerial photography technology using a vehicle, namely a UAV, commonly known as a drone. The aerial photo acquisition in this study used a DJI Phantom 4 quadcopter model UAV by utilizing a mobile phone application, namely Pix4d Capture. This application provides convenience in the process of planning the flight path and setting the mapping parameters needed in the aerial photo acquisition process. In the acquisition process, everything is done automatically based on pre-set parameters by utilizing the automatic mode on the drone which is integrated with the Pix4d Capture application.

Several factors need to be considered before taking aerial photos, namely first, the water and weather conditions at the research location. Water conditions and weather will greatly affect the quality of the resulting aerial photos. Waves, currents, and turbidity will affect or interfere with the penetration of light entering the waters so that objects on the

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bottom of the waters will be difficult to detect by sensors/cameras. Cloudy will reduce the light intensity. Second, the high intensity of the sunlight can cause sun glints (flashes of light on the water surface). Third, windy weather conditions will affect the balance of the UAV. The conditions mentioned above will greatly determine whether the quality of the resulting aerial photos is good. Flight planning using DroneDeploy over the microatoll area can be seen in Figure 3.

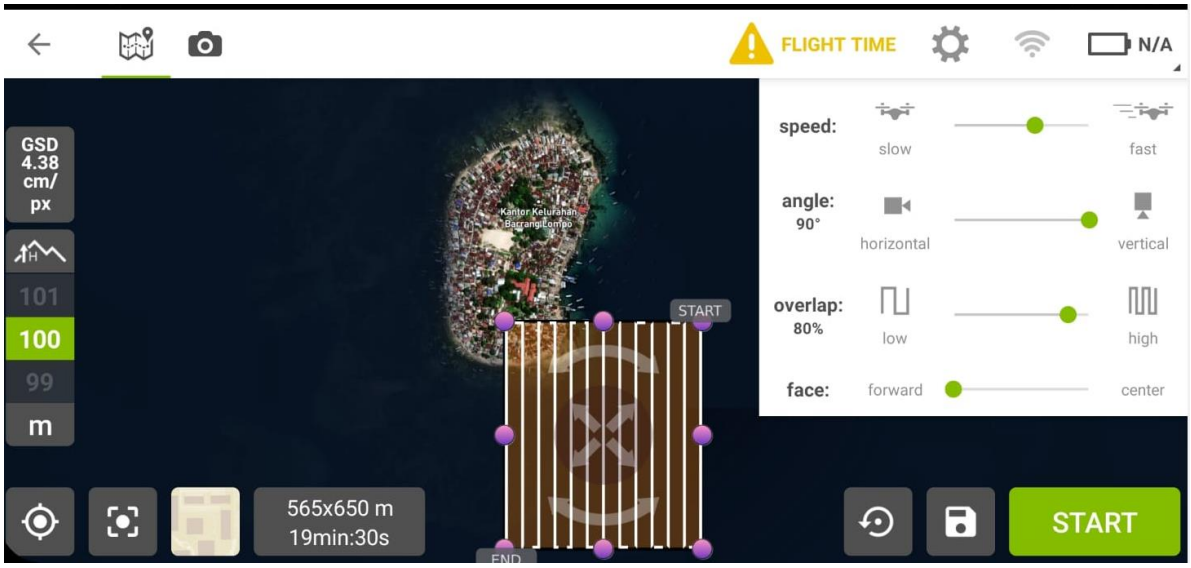


Figure 3. Flight planning using pix4d mapper, setting flight parameters and flight path.

2.2.3 Orthophoto

At this stage, all aerial photos resulting from UAV acquisition are orthomosaic or combine several photos using agisoft photo scene software and produce a single photo/orthophoto image or UAV image. The aerial photo orthomosaic process is carried out with several processing stages, namely: (1) Add photo, namely inputting photos into the agisoft application; (2) Align photo is adjusting the position and orientation of the camera for each photo and building a point cloud model; (3) Build dense cloud, which is the merging of each photo into a single dense point cloud based on the approximate position of the camera; (5) Build mesh is to connect the surface of each photo based on a dense point cloud; (6) Building orthomosaic is the formation of orthophoto images; and (7) Export orthomosaic. This process is carried out sequentially to produce orthophoto images or UAV images.

The resulting UAV image is an image that has been equipped with geographic information or georeferenced images. All aerial photos obtained from the acquisition have been equipped with geographic information in the form of coordinate points and the geographic information is inputted in the orthomosaic process. The resulting UAV image is used in the image classification process to classify between microatolls and non-microatolls.

2.2.4 Data analysis

Geometric correction is the process of correcting errors and marking map properties in an image. Image geometry must be corrected to match the map used with the selected coordinate system, so that the image can be identified properly or the points observed in the field can be found easily on the image [5]. Geometric correction uses GCP (ground control point) to adjust the image position to the actual position in the field. GCP points were taken using GPS during a field survey spread over the study site. Furthermore, rectification is carried out to correct geometric errors in the image. Geometric correction of UAV RGB images to increase the accuracy of detail in the aerial photo image.

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OBIA Method

The OBIA (Object-based classification) method is a method of segmenting orthomosaic aerial photographs based on the color, texture, and shape of object proximity. It works on the basis of individual pixels and then into groups of pixels (segments) that have similar spectral properties. This segment is usually a polygon associated with statistical information about the average spectral characteristics of an area. These objects can then be classified using unsupervised or supervised techniques. This study mapped microatolls using the SAGA GIS application by combining the Object-Based method with supervised techniques to classify objects. The neighboring analysis approach uses pixels in the image, so it is easy to group pixels based on their similarity in spectral brightness of their neighbors (that is, other pixels surrounding the target one). This neighboring analysis method is a well-known technique used for pixel analysis in cell automata of object-based image segmentation [16].

Microatoll diameter and Growth Rate

Microatoll diameter and growth rate In this study, a spatial analysis was carried out to calculate the diameter of the microatol on the UAV aerial photo of the mosaic result. The next step is to calculate the diameter of 9 samples of microatolls on UAV aerial photos that have been classified and compare the diameter sizes between 2020 and 2022. Calculation of each sample in the classification results uses UAV acquisitions in 2020 and 2022. The diameter calculation results are then compared with the survey results. Field to see the level of accuracy of the UAV image. Coral growth rate was calculated using the formula referred to in [6].

$$P = (Lt - L0)/(t)$$

P=Increase in length/height after the t-th observation, Lt= Average length/height after the t observation, L0= Average length/height at the start of the study and t= Observation time (months).
Changes in the size and rate of coral growth were calculated using the following formula:

$$\beta = \mathrm{Lt} - \mathrm{Lo}$$

β = Change in length/width of transplanted coral fragments (cm), Lt = Average length/width of the fragment at the t-th observation time (cm), Lo= Average initial length/width of fragment (cm)

3. RESULTS & DISCUSSION

3.1 UAV Data

Aerial Photo Acquisition was carried out on June 14, 2020, and June 9, 2022. Aerial photos during the flight were 380 photos and resulted in one (1) image of the southern part of the island. Each flight is able to cover an area of ± 18.87 ha with a flight time of 10 - 12 minutes. The average photo-taking height is 100 m in accordance with the Regulation of the Minister of Transportation of the Republic of Indonesia Number 47 of 2016 which states that unmanned aircraft systems may not be operated in airspace with an altitude of more than 150 m. The resulting image has a spatial resolution of ±4.38 cm/pixel. The total area taken is ±36.72 ha with a flying speed of 10-12 m/s and 80% overlap. The greater the value of the overlap in taking photos, the less the possibility of errors in the process of identifying the points in each photo. Figure 4 is the result of orthomosaic using Agisoft Photoscan Pro software producing one (1) area.

3.2 Orthophoto

A total of 380 aerial photos were processed orthomosaic or combined into one. The orthophoto images produced by orthomosaic in this study are presented in Figure 4. The orthophoto images produced based on the acquisition of aerial photos using the DJI Phantom 4 Professional produced a very high GSD or image spatial resolution of 4.38 cm2/pixel

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with a wide coverage area adjusted to the research location, namely 18.87 ha. The resulting orthophoto image is a georeferenced two-dimensional image. In general, orthophoto images only produce two-dimensional display images that have been equipped with X and Y coordinate information. Orthophoto images are produced through an improvement process related to photo tilt, lens distortion, and relief displacement which are then eliminated or adjusted. Figure 4 shows that the shallow waters of the southern part of Barrang Lompo Island have a distribution of microatolls that vary in size. Several research results related to the use of UAV technology show that the orthophoto images produced on average have very high spatial resolution values.

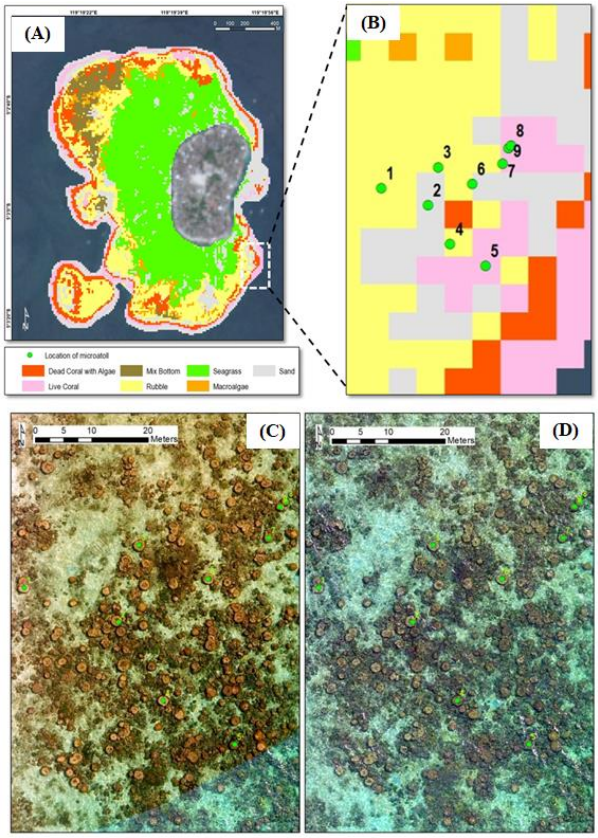


Figure 4. Shallow water classification results of Barrang Lompo Island, (A) Sentinel 2A satellite image, (B) Microatoll location based on in situ survey (sample 1-9) superimposed on top of Sentinel 2A image classification, (C) Orthomozaic aerial photography using UAV Year 2020 and (D) Results of orthomozaic aerial photography using UAV 2022

3.3 OBIA Classification

The image classification used in this study is object-based classification (OBIA) and supervised from UAV images. The segmentation process produces a set of image object layers in a hierarchical network [1]. Based on the results of segmentation on Barrang Lompo Island, it produces a number of different segments in 2020 and 2022. In the research area, the 2020 UAV imagery produces 33,735 segmentation and 52,396 UAV images in 2022. The number of segmentation for the microatol class is 969, and the non-microatol class is 32,766 (UAV in 2020), while in 2022, the segmentation for the microatol class is 1,120, and the non-microatol class is 51,276. The difference in the number of segmentation is influenced by differences in water conditions (sunlight and waves) at the time of taking aerial photos. The scale/bandwidth value of 10 used in the segmentation shows segments that focus on shallow sea water areas so that the identified objects are more detailed.

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Overall, the segmentation results show the same level of detail in UAV images in different years. Segmentation is focused on shallow water as area boundaries. In this segment, the object of the benthic habitat is classified, namely microatol and non-microatol (Figure 5). The segmentation process uses a smaller scale to form more segments. The results of segmentation in the microatol class become a reference in calculating the outer diameter. This study also uses the unsupervised classification method, where the segmentation results are used as input from the results of the field survey. This method is used to simplify or determine the spatial distribution of microatoll objects in the shallow waters of Barrang Lompo Island.

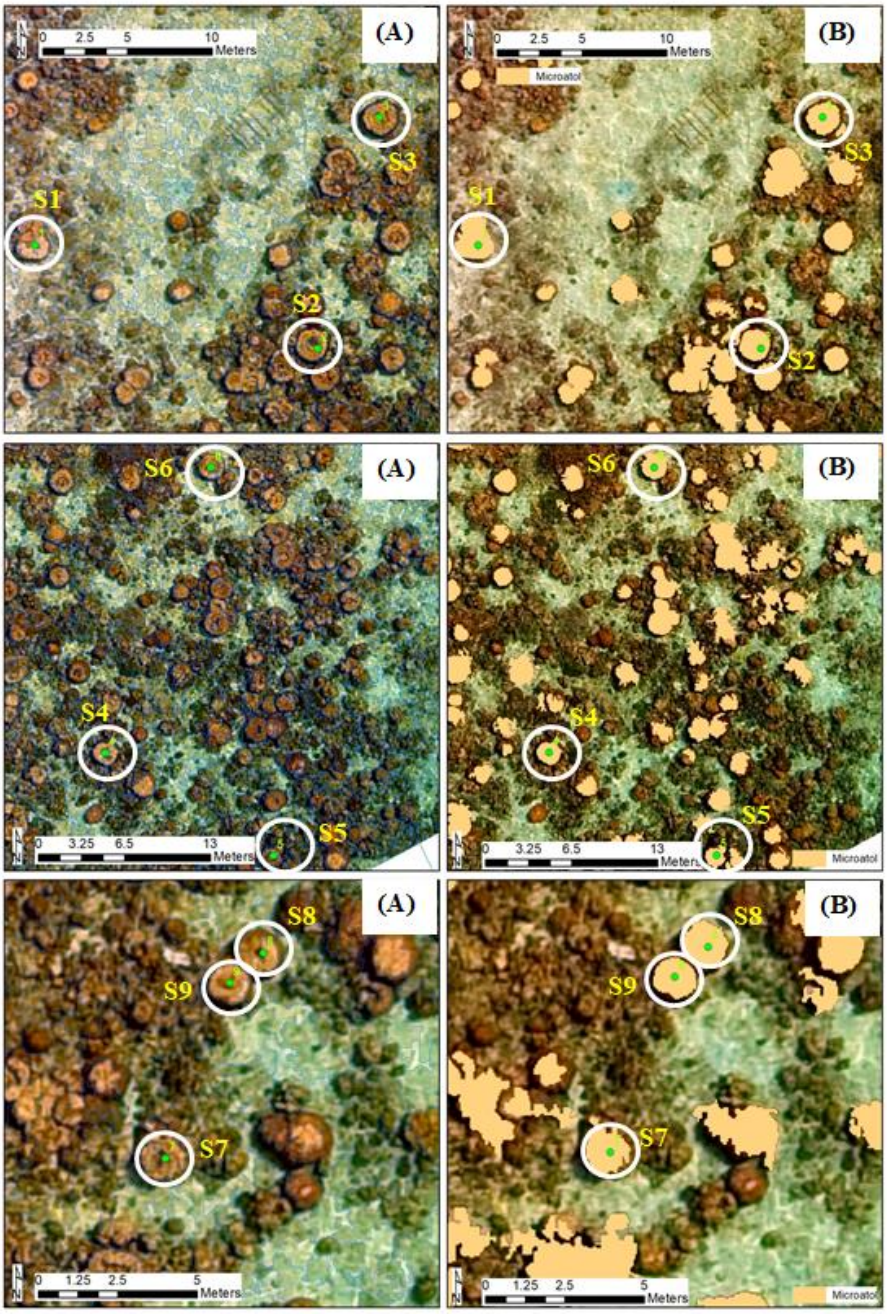


Figure 5. (A) OBIA Results, (B) OBIA Results + Supervised

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3.4 Diameter In situ Measurement

Corals have various growth rates, especially corals. Hard corals such as Porites, this is because Porites corals can survive in extreme environmental conditions. Changes in environmental conditions causes corals to experience changes in growth forms that are different from previous growth. The average growth rate of microatolls with UAV images in 2020 and 2022 in 9 samples is 6.4 cm per year. Research [19] in the waters of Kalasey, Minahasa Regency, Indonesia with one year observation obtained the value of coral growth rate in the range between 0.81 – 0.94 cm/month and [10] in Kareko waters for four months of 0.96 cm/month. The growth pattern of microatolls is strongly influenced by the characteristics of the surrounding aquatic environment. There are differences in the diameter of the microatolls using the results of UAV aerial photography, OBIA method, and In situ (Table 1). Variation of environmental parameters will have different impacts on the growth patterns of each type of coral, both in terms of morphology and physiology.

Table 1. The Diameter of Nine (9) microatolls based on aerial photo mosaics, OBIA method in 2020 and 2022, and in situ measurements in 2022

Sample	Diameter (cm)				
	Areal Foto		OBIA		Insitu (2022)
	2020	2022	2020	2022	
1	280.67	303.18	267.74	310.13	308
2	189.2	209.66	190.11	210.49	223
3	183.8	195.14	185.87	185.39	208
4	183.14	186.29	185.94	178.31	141
5	141.94	150.24	149.9	156.11	167
6	187.29	197.9	193.5	199.94	208
7	136.24	154.39	138.8	149	122
8	142.04	152.43	145.99	173.96	172
9	128.62	139.6	131.22	134.2	162

Microatol diameter based on ArcGIS on-screen measurements on UAV aerial photo mosaics compared with on-screen measurements on ArcGIS on OBIA results shows that OBIA diameter measurements are closer to field measurements on nine (9) samples of microatol diameter measurements, the smallest difference between microatolls from UAV mosaics and in situ measurements. Is 4 cm and the highest difference is 45.29 cm. while the difference between the minimum and maximum diameters of OBIA and in situ microatol diameters was 1.96 cm and 37.31 cm (Table 1).

Microatolls from the genus Porites are the most frequently found. This is because Porites coral microatolls are corals that are able to live in various environmental conditions such as waters with low or high sedimentation, waters with low or high salinity, waters with very low tides, and with various substrates [9]. The dead part of the microatoll can become a microhabitat for another marine biota. Like other types of coral, bivalves, gastropods, various types of worms, sponges, echinoderms, and others. Microatolls have large sizes ranging from 1 m to several meters, microatolls can also be used as natural wave energy breakers and as beach protectors from abrasion [9]

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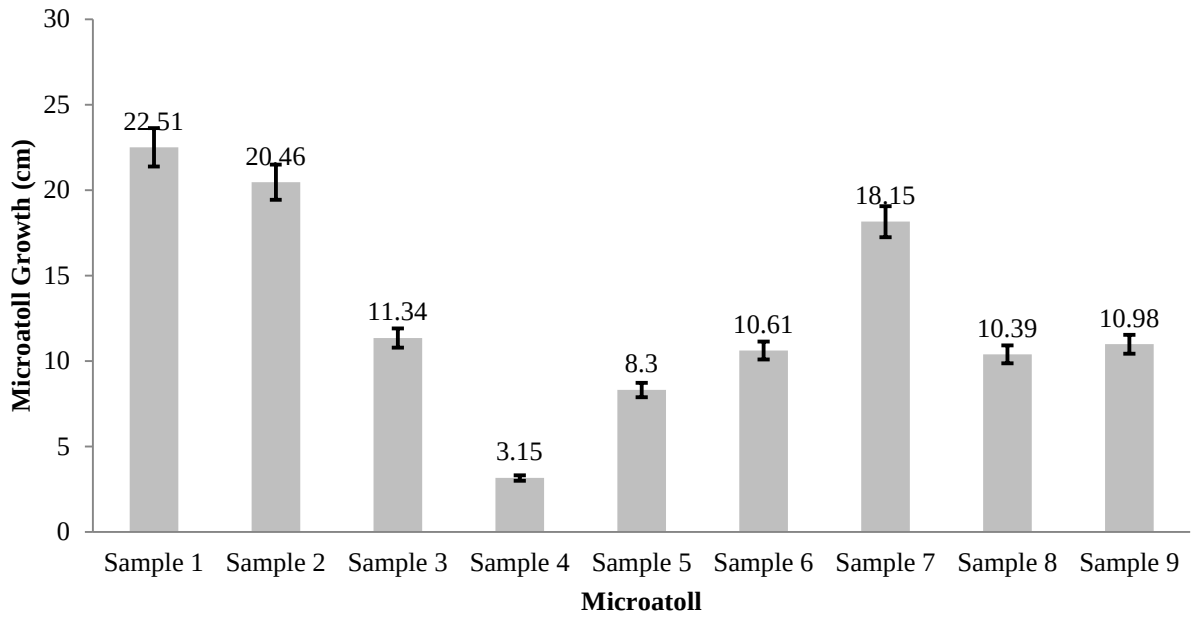


Figure 6. Graph of growth rate of microatolls in 9 (nine) samples using UAV aerial photography in 2020 and 2022

The growth dimension measured was the diameter of the microatol. The difference in growth in corals caused the occurrence of different morphological forms. Sample 1 has the largest growth rate, which is 22.51 cm and the smallest growth is found in sample 4, which is 3.15 cm (Figure 7). Different species of corals of the same genus can have different growth forms. The same species occupying different areas will have different morphological forms. The influence of various environmental factors will give different responses to the behavior of colony growth.

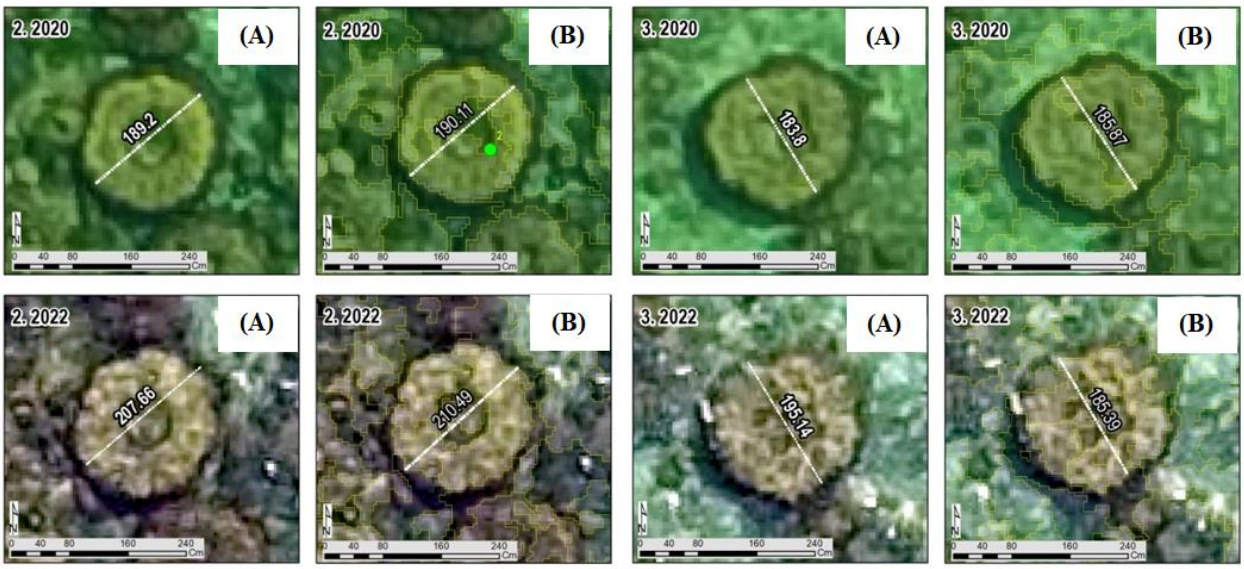


Figure 7. Two representative microatol samples from 9 UAV aerial photographic microatolls, (A) Microatol diameter based on mosaic results in samples 2 and 3, and (B) Microatol diameter based on OBIA results in samples 2 and 3 through on-screen measurements in ArcGIS.

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4. CONCLUSION

The diameter of microatolls based on screen measurements in ArcGIS from UAV aerial photo mosaics compared to ArcGIS on-screen measurements on OBIA shows that OBIA analysis are closer to the diameters of in situ measurements of nine (9) samples of microatolls. The difference between the minimum and maximum diameters of UAV mosaics with in situ microatolls was 4 cm and 45.29 cm, while the minimum and maximum differences between the diameters of OBIA and in situ microatolls were 1.96 cm and 37.31 cm, respectively. The average growth rate of microatolls with UAV images for two years (2020-2022) in nine (9) samples was 6.4 cm per year. The method used in this research makes it easy to know the dynamics of conditions and growth of spatially oriented microatolls with precision in shallow water

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REFERENCES

[1] Anggoro, A., Siregar, V. P. and Agus, S. B., "Geomorphic zones mapping of coral reef ecosystem with OBIA method, case study in Pari Island," Jurnal Penginderaan Jauh. 12(1):1-12 (2015).

[2] Asep, S., Audrie, J. S. and Christovel, R., Proyek pesisir –CRMP Indoneia. Proyek pesisir, CRC/URI CRMP (2001).

[3] Carricart-Ganivet, P J. and Barnes, J.D., "Densitometry from digitized images of x-radiographs: methodology for measurement of coral skeletal density," *Exp. Mar. Biol. Ecol.* 344:67-72 (2007).

[4] Fallati, L., Saponari, L., Savini, A., Marchese, F., Corselli, C. and Galli, P., "Multi-Temporal UAV Data and Object-Based Image Analysis (OBIA) for Estimation of Substrate Changes in a Post-Bleaching Scenario on a Maldivian Reef," *Remote Sensing* 12(13):2093 (2020).

[5] Green, E. P., Mumby, P. J., Edwards, A. J. and Clark, C. D., [Remote sensing handbook for tropical coastal management]. UNESCO, Paris (2000).

[6] Joni., Pratomo, A. and Irwan, H., "Laju pertumbuhan dan tingkat kelangsungan hidup karang *Acropora formosa* hasil transplantasi pada kedalaman berbeda," Jurnal FPIK UMRAH (2015).

[7] Kutser, T., Hedley, J., Giardino, C., Roelfsema, C. and Brando, V. E., "Remote sensing of shallow waters – A 50 year retrospective and future directions," Remote Sensing of Environment. Volume 240 (2020).

[8] Mann, T., Schöne, T., Rovere, A., Klicpera, A., Satari, D. Y. and Westphal, H., "Reconstructing past sea level in the Spermonde Archipelago, SW Sulawesi, Indonesia," Internasional Sedimentology Congress (ISC) (2014).

[9] Meltzner, A. J., and Woodroffe, C. D., [Chapter 8: Coral Microatolls. (I. Shennan, A. J. Long, & B. P. Horton, Penyunt], Handbook of Sea-Level Research (First Edition), 125-144 (2015).

[10] Mompala, K., Rondonuwu, A.B. and Rembet, U. N. W. J., "Laju pertumbuhan karang batu *Acropora sp.* yang ditransplantasi pada terumbu buatan di Perairan Kareko Kecamatan Lembeh Utara Kota Bitung," Jurnal Ilmiah Platax. Vol 5(2). Hal 234-242 (2015).

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[11] Muslim, A. M, Chong, W. S, Safuan, C. D. M., Khalil, I. and Hossain, M. S. “Coral Reef Mapping of UAV: A Comparison of Sun Glint Correction Methods,” Remote Sens. 11, 2422 (2019).

[12] Nababan, B., Mastu, L. O. K., Idris, N. H. and Panjaitan, J. P., “Shallow-Water Benthic Habitat Mapping Using Drone with Object Based Image Analyses,” Remote Sens, 13, 4452 (2021).

[13] Nurdin, N., Komatsu, T., Agus., Akbar, A. S. M., Djalil, A.R. and Amri, K., “Multisensor and multitemporal data from Landsat images to detect damage to coral reefs, small islands in the Spermonde Archipelago, Indonesia,” Ocean Science Journal 50(2): 1-9 (2015).

[14] Nurdin, N., Komatsu, T., Rani, C., Supriadi., Fakhriyyah, S. and Agus., “Coral reef destruction of small island in 44 years and destructive fishing in Spermonde Archipelago, Indonesia,” IOP Conference Series: Earth and Environmental Science 47(1): 012011 (2016).

[15] Nurdin, N., Inaku, D. F., Rasyid, A. R., Agus., Akbar, M. A. S., Al Azizi, S.Q., Alimuddin, A. and Jalil, A. R., “Spatial Technology Based Participatory Digital Database for Village Potentials,” IOP Conf. Series: Earth Environ,” Sci. 750 012053 (2021).

[16] Lemenkova, P., “Object Based Image Segmentation Algoritm SAGA GIS for Detection Urban Spaces in Younde, Cameroon,” Central European Journal of Geography and Sustainable Development (2020).

[17] Siregar, V. P., Agus, S.B., Subarno, T. and Prabowo, N. W., “Mapping shallow waters habitats using OBIA by applying several approaches of depth invariant index in North Kepulauan Seribu,” IOP Conf. Ser.: Earth Environ. Sci. 149 012052 (2018).

[18] Suzuki, A. H., Kawahata, H., Shiyomi, M., Koizumi, H., Tsuda, A. and Awaya, Y., [Characterization of ocean productivity using a new physical biological coupled ocean model], Global Environmental Change in the Ocean and on Land. 1-44 (2004).

[19] Tioho, H., Paruntu, C.P. and Patrich, H., “Ketahanan Hidup Dan Laju Pertumbuhan Karang Scleractinia Yang Ditransplantasi Pada Rataan Terumbu Perairan Kalasei, Kabupaten Minahasa, Sulawesi Utara,” Aquatic Science & Management, Vol. 1, No. 2, 111-116 (2013).

[20] Ventura, D., Bonifazi, A., Gravina, M. F. and Belluscio, A., Ardizzone, G., “Mapping and classification of ecologically sensitive marine habitats using unmanned aerial vehicle (UAV) imagery and Object-Based Image Analysis (OBIA),” Remote Sens,10, 1331 (2018).

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