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The vulnerability of Small Islands from Coastlines Change in Indonesia

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The vulnerability of Small Islands from Coastlines Change in Indonesia

M M Rahmadi[1,4], E Liviawaty[3], I Faizal[2.41], N P Purba[2.4], R A Ramadhan[1.4], R Amrullah[1.4], I E Dianti[1.4]

[1] Marine Science Program, Faculty of Fisheries and Marine Sciences, Padjadjaran University

[2] Marine Department, Faculty of Fisheries and Marine Sciences, Padjadjaran University

[3] Department of Fisheries, Faculty of Fisheries and Marine Sciences, Padjadjaran University

[4] Marine Instrumentation and Survey Study Group, Padjadjaran University

Email correspondent: noir.purba@unpad.ac.id

Abstract. Indonesia has 16.100 islands and 92 is outermost islands. These small islands are currently experiencing the impact of climate change from sea level rise and global warming. This study aims to determine vulnerability of small island through changes in coastline and dynamic change of area due to climate change especially from coastline changes. Nineteen islands selected as representation of Indonesia seas regions. The data were collected from satellite images range from 2000 to 2020. To analyze, this research method uses Coastsat method to detect coastlines and QGIS to process coastline data and change of the island areas. The results of this study indicate that the average reduction in the area of small islands in Indonesia reaches 5.084% for approximately 20 years. Overall, the change in the area shows that most of the small outermost islands in Indonesia have Medium vulnerability

Keywords: Small Island, Coastline changes, Ocean Currents, Coastal Vulnerability, Climate Change

1. Introduction

Indonesia is a country that has 16,100 islands and has potential to support social welfare, defense and politics, and economic values [1]. The term of small island is an island that has an area of less than or equal to 2000 km^2. Along with its ecosystem unit, a tiny island has an area of less than 100 km^2 and less than 3 km in width [2]. In the era of climate changes, small islands are one of the area which changes due to human activities and natural phenomena [3].

Contrary to their potential, these small islands have threats caused by climate change and other external force. One of the stressors to small island is sea level rise. On a global scale, sea-level rise will reach 0.5 m in 2100. about 60 cm from the recent sea level. It will sink about 34,000 km^2 of Indonesian territory including small islands which has plateau areas [4], [5]. In addition, there are still many impacts of climate change that affect coastal areas such as abrasion and degradation of shallow ecosystem [6]. Furthermore, several publications stated that changes in coastline will affect the coastal dynamics[7]. Furthermore, the sea-level rise in Indonesia from 1993 to 2003 ranges from 10-50 cm **Figure 1** [8], [9].

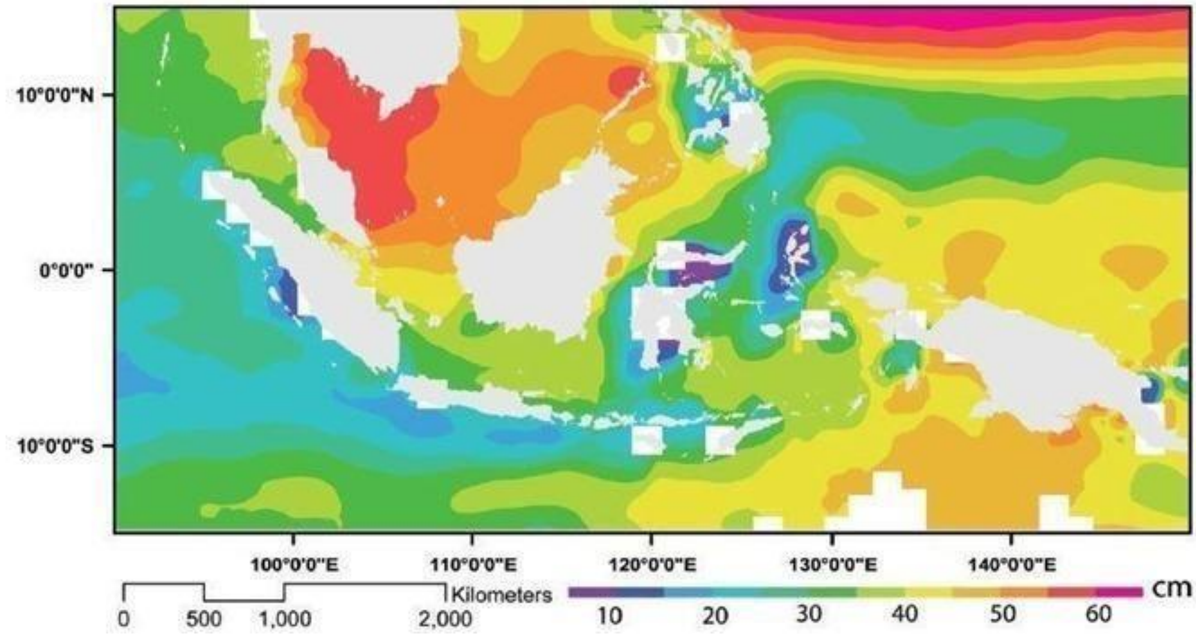

Figure 1. Average sea-level rise for 15 years from January 1993 to December 2008 in Indonesia seas and surrounding

Sea level rise can affect many aspects of the coastal environment, for example, abrasion and coastal erosion that cause coastline reduction [10]. A coastline is one coastal area defined as a line that interacts between land, atmosphere, and sea. The phenomenon of shoreline change is very closely related to coastal areas. Coastal areas are one of the primary locations that will response to environmental change activities and processes. For that, monitoring shoreline changes is essential for coastal areas due to its function to conservation system, marine and coastal management, and decision-making to policy makers[3], [6].

Previous research mentioned that aerial photography and satellite remote sensing data have become essential for environmental monitoring. Therefore, analyzing digital photography and satellite imagery has become necessary [11]. Several researchers have mentioned that shoreline changes, such as shoreline changes in Cirebon, Indonesia and regarding a coastal vulnerability in Java Island, Indonesia [9], [10].

This study aims to provide information on the vulnerability index of islands in Indonesia through changes in island areas. Research on the vulnerability of coastal areas, one of which is the coastline, supports informed decision-making in the management of coastal areas [6]. Many studies revealed the importance of geospatial technologies in estimating shoreline changes by providing researchers with multi-temporal satellite images covering the entire coastal area. Moreover, these technologies can deliver information within a short period while covering large areas [12].

2. Methodology

The locations of this research were chosen based on sea level rise conditions, with 19 islands representing the 92 outermost small islands of Indonesia [2, 12]. The study was conducted for 20 years, starting from 2000 to 2020 **Figure 1, Table 1**. The small island covered ranges from 0.027 to 7.974 Ha.

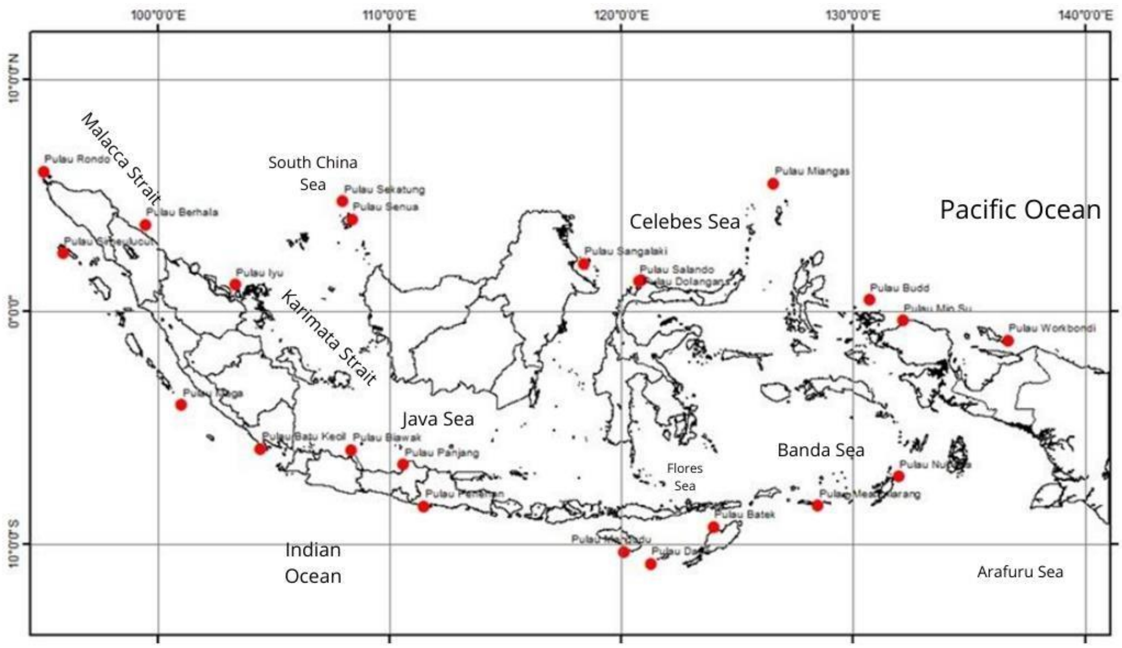

Figure 2. Geographic distribution of the 19 islands in Indonesia

Table 1. Location of the 19 small islands. Areas are defined by a polygon processed by raster calculation in QGIS.

No	Latitude	Longitude	Island Name	Area (km2)	Province	Sea-Level Rise (cm)
1	1.190698	103.3522	Iyu Kecil	0.027	Riau Islands	40 - 50
2	-5.89226	104.4427	Batu Kecil	0.622	Lampung	30
3	-6.57556	110.6283	Panjang	0.217	Central Java	30 - 40
4	-9.25659	123.9931	Batek	0.179	East Nusa Tenggara	20 - 30
5	6.073852	95.11658	Rondo	0.422	Aceh	20
6	1.365927	120.8871	Dolangan	0.156	Central Sulawesi	30 - 40
7	-0.3472	132.1683	Mio Su	0.905	West Papua	40
8	-7.07635	131.9889	Nukaha	0.425	Maluku	40
9	4.006961	108.4174	Senua	0.356	Riau Islands	50
10	0.529925	130.7336	Budd	0.203	West Papua	40
11	-10.3296	120.1173	Mangudu	1.401	East Nusa Tenggara	20 - 30
12	-8.33517	128.5008	Meatimiarang	1.292	Maluku	40
13	2.533352	95.94436	Simeulucut	7.974	Aceh	20 -30
14	-5.92956	108.38	Biawak	1.429	West Java	30 - 40
15	3.774663	99.49991	Berhala	0.403	North Sumatera	30
16	-1.21607	136.702	Workbondi	1.674	Papua	40 - 50
17	-10.8255	121.2787	Dana	0.808	East Nusa Tenggara	30 - 40
18	4.791054	108.0109	Sekatung	1.389	Riau Islands	50 - 60
19	5.557406	126.5797	Miangas	2.008	North Sulawesi	30

In this study, the area of interest is used to retrieve data via Google Earth Engine in the form of time-series images obtained through Landsat7, Landsat 8, and Sentinel 2. Annual coastline data from 19 islands is obtained through Coastsat software using the method [13], which can be viewed at https://github.com/kvos/CoastSat. At this stage, annual shoreline changes are obtained. The coastline data per year from 19 islands is converted into polygons to calculate the area using QGIS software. Moreover, the data is presented as a percentage, and the vulnerability index is calculated based on the 1992 IPCC CZMS [6].

3. Results and Discussion

Coastline changes in the area of 19 islands over 20 years were varied. In general, the average reduction in island area are 5.084 %, with an average reduction of 0.443% per year **Figure 3**. The highest reduction located in Iyu Kecil and lowest located in Batek Island.

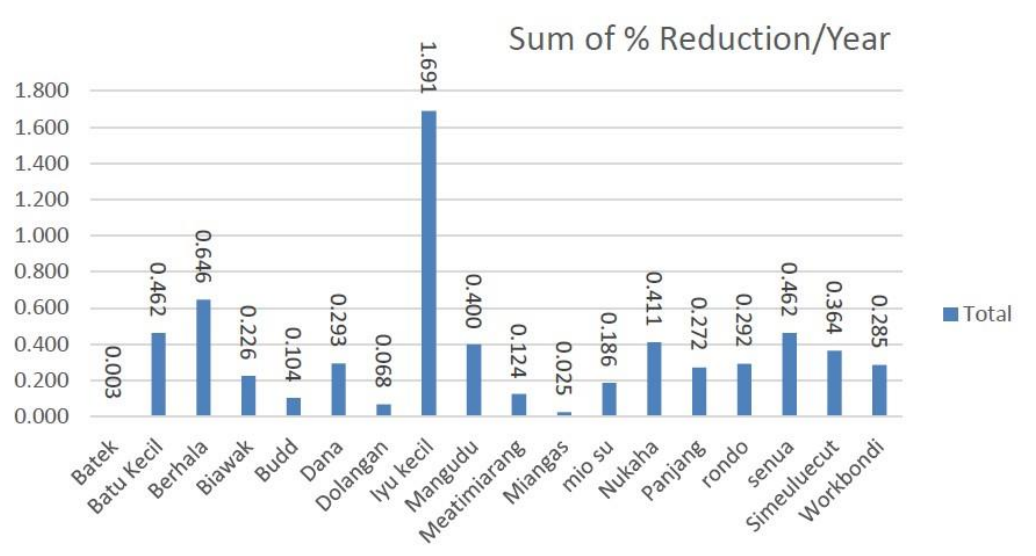

Figure 3. Sum of percentage reduction/year of the 19 islands

In **Figure 1** and **Figure 3**, a sea level rise of 50 cm caused IyuKecil Island, Senua Island, and Workbondi Island to experience a reduction in island area of 1.6%, 0.462%, and 0.285%, respectively. Sea level rise as high as 30 cm causes BatuKecil Island, Batek Island, Mangudu Island, idol Island, and Miangas Island to experience a reduction in area of 0.462%, 0.03%, 0.4%, 0.646, and 0.025% each year, respectively, and sea level rise as high as 40 cm caused Panjang Island, Dolangan Island, Mio Su Island, Nukaha Island, Budd Island, Meatimiarang Island, Biawak Island, and Ndana Island to decrease in area by 0.272%, 0.068%, 0.186%, 0.411%, 0.124%, 0.226%, and 0.293%.

It can be seen from **Figure 3, Figure 4, and Figure 1**. The reduction in island area and sea level rise affect each other. However, the percentage reduction in the area of the islands is also affected by other factors such as the position of the island against natural disturbances or because of its remote position, besides that the reduction also depends on the natural adaptive capacity of the islands. Management of coastal ecosystems such as mangroves, coral reefs, and seagrasses greatly affects the percentage of small islands [14].

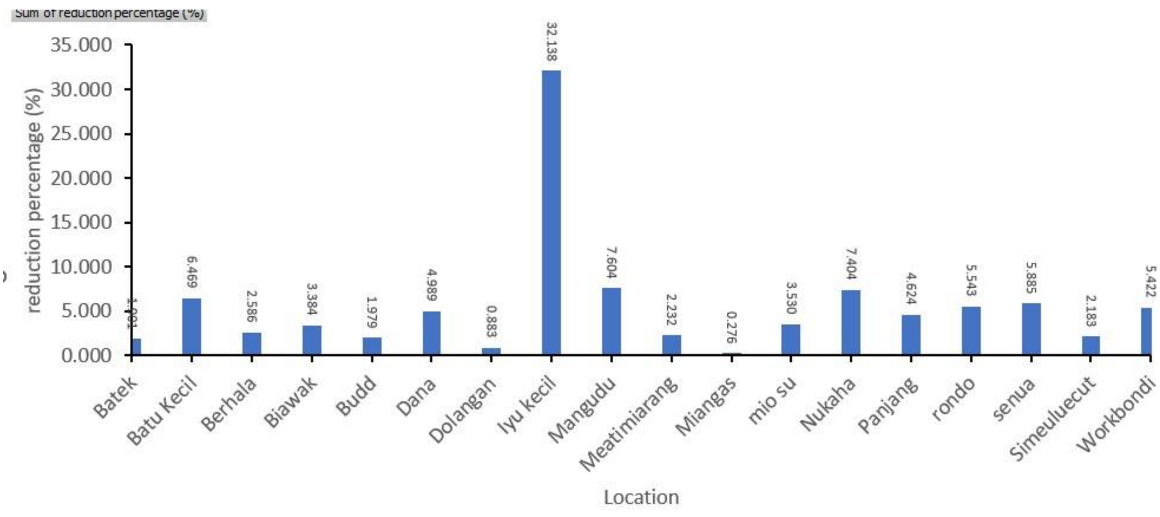

Figure 4. Sum of % reduction/inside 20 years (2000 – 2020) of the 19 islands

The change in the area shows that most of the small outermost islands in Indonesia have Medium vulnerability based on the IPCC CZMS 1992 criteria. All the vulnerabilities of the small outermost islands are shown in **Table 2**.

Table 2. Vulnerability of 19 Islands according to IPCC CZMS 1992

Island Name	Vulnerability	Island Name	Vulnerability
Iyu Kecil	Critical	Mangudu	Medium
Batu Kecil	Medium	Meatimiarang	Low
Panjang	Medium	Simeulucut	Low
Batek	Low	Biawak	Medium
Rondo	Medium	Berhala	Low
Dolangan	Low	Workbondi	Medium
Mio Su	Medium	Dana	Medium
Nukaha	Medium	Sekatung	Low
Senua	Low	Miangas	Low
Budd	Low		

Results of the vulnerability index indicate that Iyu Kecil Island has had the highest vulnerability index over the last 19 years. From the data obtained through Coastsat, the Pulau Iyu Kecil area decreased by 0.008 km^2 from the total area of 0.027 km^2. This Island has the highest level of vulnerability because it has an island slope of between 20% to 55%, with an island height of 3-5 meters. The coral reefs on Iyu Kecil Island are very poor, where the percentage of coral cover is only about 10% according to Ministry of Marine Affairs and Fisheries (MMAF) in 2015. In addition, the Iyu Island area has had a sea-level rise of 50 cm from 1993 – 2008 [15]. Assuming a constant sea-level rise of around 3 cm/year, the Island will sink by 60 years. The island has problems with coastal abrasion by sea waves, and the research mentioned that Iyu Kecil needs to construct a coastal abrasion protection building (sea wall) and planting mangroves.

Sekatung Island also mentioned in [16] that the Island has raw water crisis and beach abrasion by sea waves. The Island has a coastline composed of rocks in the southern part. According to [2], [17] Sekatung Island is an island with a stable coastline. High resistance rocks characterize the area's coast with rocky and steep coastal morphology, but during the east monsoon, the rocks are exploited as building materials. Based on the data collected, Sekatung island's area decreased by 0.037 km^2 in 2 years or 2,66% in 2 years since 2016. Skating Island has low vulnerability based on IPCC CZMS 1992 criteria.

Workbondi Island is located in the east of Indonesia. This island has experienced a 5% reduction area for 19 years and a decrease of 0.2% / year from the initial area in 2001 (1.67 km^2). In 2020, the results showed the remaining is 1.58 km^2. Monsoon significantly affects activity on Workbondi Island. Workbondi Island has a flat land configuration and a slope between 0 – 5%, sandy and coral beach types, the topography of the coast towards the sea is flat and steep, and the tides are narrow and steep [18]. Workbondi Island also acts as a protector of the Upper Palaido waters against the Pacific Ocean.

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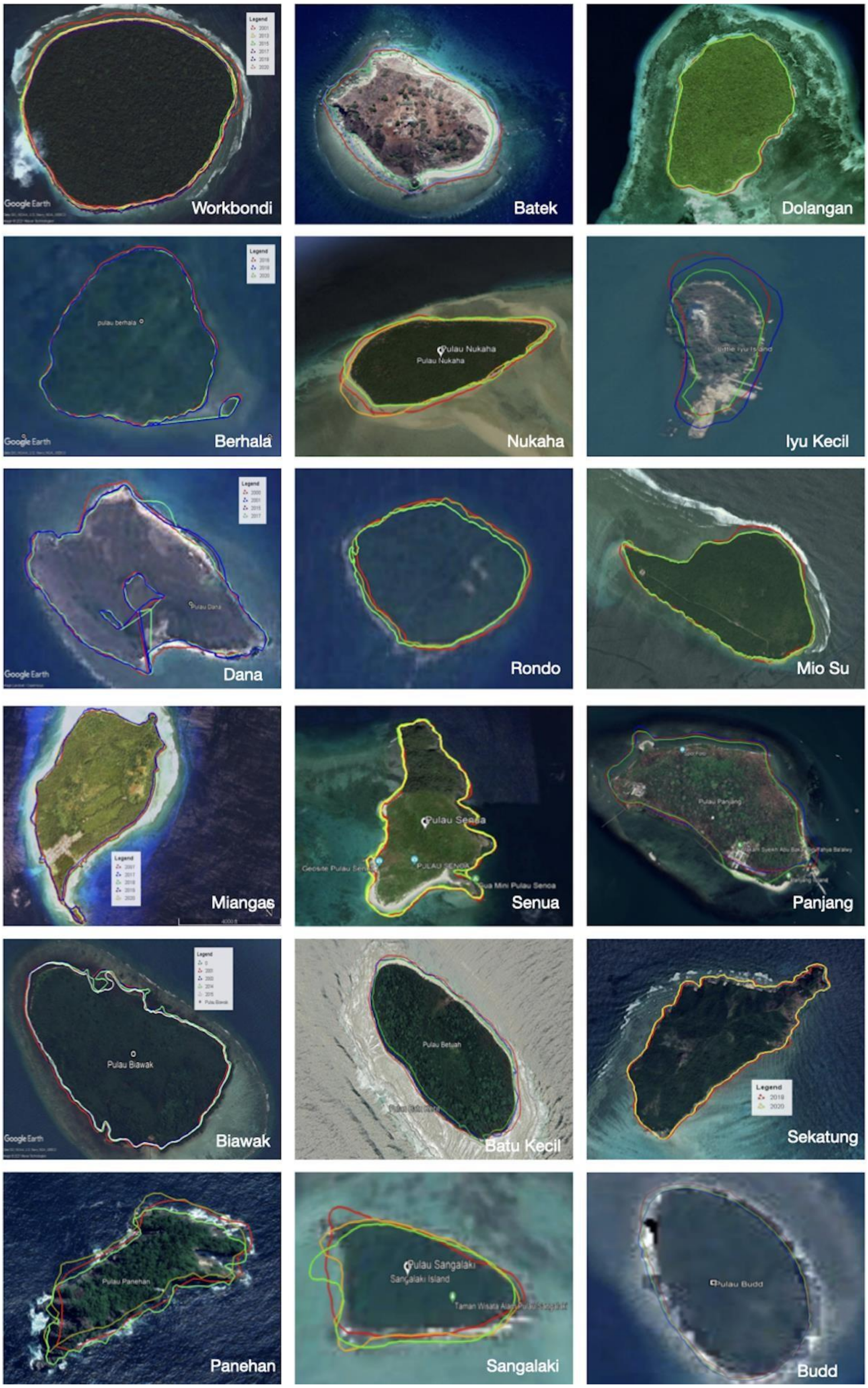

Figure 5. Coastline changes of 19 Islands processed by Coastsat (Coastline Overlaid with Google Earth Imagery).

The results of shoreline changes show that Workbondi Island experienced coastline reduction by 60 cm, Biawak Island by 30 cm, and Meatimiarang Island by 20cm, for changes to other islands, can be seen in **Figure 5**. Shoreline change data are expected to provide information for local governments to manufacture coastal defence or further sustainable development. The management of the small outermost islands in Indonesia still faces many obstacles. Various reasons related to the coastline are there is no certainty of some sea boundaries with neighboring countries and the size of the islands in Borders are generally tiny islands, so they are very vulnerable to damage by nature and humans [19]. The research also mentioned that sea level during the period 1961 to 2003 recorded an average increase of 1.8 mm per year. Furthermore, until 2080, it is estimated that sea-level rise will increase to about 4.2 mm per year. This condition means that the area reduction can increase by 233% from the estimated data obtained.

4. Conclusion

Most of Indonesia's outermost small islands get a medium vulnerability index. The most significant reduction in island area occurred in Iyu Kecil with a percentage reduction of 32.137% for 19 years, and the most minor reduction occurred on Miangas Island of 0.275% or 0.005 km^2 from 2.008 km^2 for 11 years. In reducing the area per year, the area of Iyu Island is reduced by 1.691% or about 0.0004 km^2.

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