KORESPONDENSI PAPER

Judul : Estimation of Sea Level Rise threat on the existence of the three northeastern and outermost small islands of Indonesia (i.e. Liki, Bepondi and Miossu Islands) using remote sensing method

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Estimation of Sea Level Rise threat on the existence of the three northeastern and outermost small islands of Indonesia using remote sensing method

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Abstract

The outermost small islands determine the territorial boundary of Indonesia. Liki, Bepondi and Miossu Islands are the three northeastern and outermost small islands of Indonesia located in the northern part of Papua Island. On the other hand, Sea Level Rise as an impact of global warming has threat the existence of small islands around the world. In the present study, the threat of Sea Level Rise (SLR) on the existence of those Islands is estimated from remote sensing method which is very useful for quick assessment. We use drone photography with photogrametry method to estimate the elevation of the three Islands. These elevations were corrected by tidal data to estimate the elevation above highest high water level. The linear regression assumption of 25 years sea level anomaly data obtained from altimetry satellite from 1993-2017 were calculated to analyze the rate of SLR. The elevation above highest high water level for Liki, Bepondi and Miossu Islands are 265.84 m, 103.19 m, and 26.37 m, respectively. With the the rate of Sea Level Rise of 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, the threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia is small.

1. Introduction

Indonesia is the biggest archipelagic state in the world with 16,056 islands spread within Indonesia region. As in 2017, this number of named and positioned islands has been officially registered to the United Nations by the Information and Geospatial Agency of Indonesia (http://www.big.go.id). As an archipelagic state, Indonesian region borders to 10 other countries whereas most parts of the border area consist of outermost small islands. The Presidential Decree No. 6 of 2017 has established as many as 111 islands as outermost small islands in Indonesia. The Government Regulation No. 62 of 2010 on The Use of Outermost Small Islands, stated that a small island is an island with an area smaller or equal to 2000 Km2 including its ecosystem unity. While the

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Commented [A3]: Change to superscript outer small islands are small islands which have basic geographical coordinates that connect the archipelagic sea baseline in accordance with international and national law. Furthermore, Government Regulation No. 26 of 2008 states that the sovereign territory of Indonesia is including the outermost small islands that border directly with neighboring countries and/or the high seas. Therefore, the existence of the outermost and small islands should be maintained by the development priority to the outermost and small islands in Indonesia.

On the other hand the world is now facing the common threat coming from the global warming. One of the impact of global warming which possibly threat the existence of small islands is sea level rise (SLR). Global warming causes SLR through 2 mechanisms i.e., the increase of volume and mass of sea water (Wills et al., 2010). The increase of water mass is related to the melting ice at the poles and gletser as a direct impact of increasing temperature on earth due to the increase of green house gases concentration in the atmosphere. The increase of volume is related to the sea water heating that causes thermal expansion of water molecule. International Panel on Climate Change reported that in 100 years from 2000 the global sea level increase ranges from 15cm to 95 cm. Furthermore, Based on altimetry satellite observations, from 1992 the rate of global SLR is ±3.31 mm/year (e.g., Kuo, 2006; Ablain et al., 2009; Leuliette and Scharroo, 2010; Nerem et al., 2010; Shum and Kuo, 2010). The spatial distribution of SLR is shown in Wills et al. (2010). Among the areas around the world, western equatorial Pacific is the area with the highest SLR. The rate of SLR at this area can reach 1 cm/year. Thus, northeastern Indonesia which is part of the western equatorial Pacific faces the most rapid SLR.

Liki, Bepondi and Miossu Islands are the outermost small islands in Indonesia located at the northeastern most of Indonesia at the western equatorial Pacific (Fig. 1). Liki and Bepondi Islands are located at Papua Province while Miossu Island is at West Papua Province. The position of these three islands becomes the baseline for determining Indonesia territory. Thus, the existence of these three islands should be maintained since the position of these islands is vulnerable to the threat of SLR. Furthermore, since Liki and Bepondi Islands are inhabitant islands, SLR also can be the threat for people live in these islands. In the present study we investigated the potential impact of SLR in threatening the existence of Liki, Bepondi and Miossu Islands estimated from remote sensing approach.

2. Material and Method

First, we simulated the potential loss of Indonesia territory assuming the disappearance of Liki, Bepondi and Miossu Islands. The actual baseline of Indonesia territory is obtained from Information and Geospatial Agency of Indonesia. According to the Law No. 6 of 1996 on Indonesian Waters, The Indonesia territorial line is determined by 12.5 nautical miles from the baseline which is determined by the position of the outermost islands. Assuming the disappearance of the outermost island, the baseline was retreated to the mainland. The potential loss of Indonesia territory was estimated by calculating the areal size of territorial line before and after the disappearance of the outermost island.

For investigating the threat of SLR to the existence of Liki, Bepondi and Miossu Islands, we conducted 2 main analysis depicted in Fig. 2. The first analysis is calculating the rate of SLR at these three Islands. We used re-processing daily sea level anomalies (SLA) Level 4 from multi-mission data result of altimetry satellites provided by Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu/) with the period of observation from 1993 to 2017. The spatial resolution of this data is

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0.25°×0.25°. We composed daily data into yearly data. With the basis of yearly data, we calculated the rate of SLR per year by using simple linear regression.

$$y = ax + b \quad (1)$$

Where y and x are yearly SLA (m) and year, respectively. The rate of SLR (m/year) is determined by value of constant ‘a’.

Second analysis is estimating the highest elevation at Liki, Bepondi and Miossu Island. To reach these three islands, we joined the research cruise “Baruna Jaya VIII” owned by Research Center for Oceanography, Indonesian Institute of Science in the expedition called “Nusa Manggala”. The aim of this expedition is to explore the potential resources of coastal ecosystem in the outermost small Islands at the northeastern Indonesia. We joined the second leg of the cruise from 14 November to 4 December 2018. We used aerial photography taken from drone DJI Phantom 4 Pro with photogrametry method to generate Digital Surface Model for Liki, Bepondi and Miossu Island. The plan was to fly the drone from the beach passing the highest topography until the other side of the beach for several loops with 80% overlapping images.

The images of Liki Island was taken on 22 November 2018 at 12.00 Local Time (LT). Drone was taken off from the beach side at position 1°36’9.76” S and 138°44’34.37” E to the highest part of the island. The take off altitude was 280 m. However, the drone could not reach the other side of island due to the limitation of communication signal between the drone and the controller. We collected 345 aerial images at Liki Island. At Bepondi Island, the drone took off from the highest part of the island at the position 0°24’12.45” S dan 135°16’5.96” E on 26 November 2018 at 15.00 LT. The take off altitude was 50 m. Since it flied from the highest part of the island, the drone managed to capture both side of the beach with 740 aerial images. The aerial images of Mioussu Island were taken on 1 December 2019 at 9.00 LT. The drone took off from the highest part of island at position 0°20’49.33” S dan 132°10’12.91” E with 110 m of take off altitude. We managed to collect 850 aerial images that covered both side of the beach. The aerial images of three islands are then processed to obtain high resolution orthoimagery, Digital Surface Model (DSM) and Digital Terrain Model (DTM).

The image processing to produce orthoimagery, DSM and DTM was conducted by using photogrametry method (Mouloua, Ferraro, Mouloua, Hancock, & Florida, 2018) (Polat & Murat, 2018) (Cunliffe, Brazier, & Anderson, 2016). The three dimension format of geographical location, size and capture of the object were measured by georeferencing orthoimages and Digital Terrain Model (Sammartano & Spanò, 2016). The accuracy of 3D model is depend on the distribution of Ground Control Point (GCP) (Suh & Choi, 2017). Kung et al (2011) stated that the accuracy of drone photogrametry with and without GCPs range from 0.056m to 1.25 m and from 1.97 to 7.84 m, respectively. In the present study, we did not conducted GPS survey for determining GCPs due to the limitation of survey duration. However, the sea side covered by the drone were used as GCPs since we assumed that the elevation of sea level is 0 m in both side of the sea side. The flowchart of photogrametry method is shown in Fig. 3.

The DTM generated from photogrametry method was then corrected by tidal data. UNCLOS (1982) article 121 stated that, an island is a naturally formed area of land, surrounded by water, which is above water at high tide. Thus, tidal data was used to project the datum of DTM at the position of Highest High Water Level (HHWL). We used 29 days of tidal prediction data provided by the Information and Geospatial Agency of Indonesia (http://tides.big.go.id/pasut/). To ensure the accuracy of the tidal prediction data, we compared it with tidal observation data and used the tidal observation data as reference for tidal prediction data. The tidal observation data at Liki

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Island is recorded by using tide logger RBR Duo at position 1°37’28.48” S dan 138°44’30.62” E for 1.5 days started from 20 November 2018. At Bepondi Island, we used the tidal observation Island at the Biak Island owned by Information and Geospatial Agency of Indonesia (http://ina-sealevelmonitoring.big.go.id/ipasoet/) due to the failure of RBR measurement. The position of tidal observation at Biak Island is 1.1776°S and 136.056°E. For Miossu Island, we used 2 observation data i.e., RBR duo data and visual observation. The position of the observation was 0.35135 °S dan 132.172613° E. The referenced tidal prediction data for each island then was analyzed by using admiralty method to obtain the value of HHWL and other tidal characteristics. DTM for each island was then corrected by HHWL value to obtain the elevation of the islands above highest tide. Finally, we simulated the the impact of SLR for the existence of Liki, Bepondi and Miossu Islands for the next 100 years by using the obtained value of SLR rate and the topography of each island.

3. Result And Discussion

3.1. Potential area loss due to the absence of the outermost small islands

The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands are 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha, respectively (Fig. 4). Thus, total potential area loss of Indonesia territory if these three outermost island disappear is 346,462.36 Ha. The loss of the outermost small islands in Indonesia can have juridical consequences for Indonesia's Exclusive Economic Zone (EEZ) with the EEZ of other countries at sea bordering the lost island. Overlapping of boundaries between countries can occur because of the same claim for an area affected by the loss of the island. The problem of territorial boundaries that might occur as a result of this matter will affect the economic aspects in relation to area management, administrative aspects of government, and the defense/security aspects.

Determination of continental shelf boundaries can be used as a reference in establishing EEZ. Indonesia has the characteristics of an archipelagic state based on what is stated in Article 46 of UNCLOS, and an archipelagic country has special rights or provisions in determining maritime boundaries, one of which can be seen from the way of establishing archipelagic baselines contained in Article 47 of UNCLOS. Other countries that border directly with Indonesia in general are coastal countries. Determination of the continental shelf boundary between Indonesia and other countries that border directly with Indonesia can refer to Article 76, 77 and 78 of UNCLOS wherein the article states the coastal state's right to continental shelf. The solution to the EEZ problem can refer to Article 55 of UNCLOS which states that in determining the EEZ boundaries, a coastal country must be based on the provisions of its rights as a coastal state. Based on this, the problem of the boundaries of Indonesia's EEZ with other coastal countries should be avoided because Indonesia as an archipelagic state has special features in determining maritime boundaries based on UNCLOS.

3.2. **Sea Level Rise**

The distribution of SLR in Indonesian Seas is shown in Fig 5. Most of the area within Indonesian Seas has rate of SLR by more than 4 mm/year. Especially in the Arafura Sea, Savu Sea, Southern coast of Java, and parts of Java Sea have SLR rate by more than 5 mm/s. Along the northern coast of Papua which becomes our study area, the SLR rate is about 4 mm/year. Specifically for Liki, Bepondi and Miossu, their SLR rates are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, respectively (Fig. 6). Thus, it can be concluded that SLR rate in Indonesian Seas is higher than the global average i.e., (e.g., Kuo, 2006; Ablain et al., 2009; Leuliette and Scharroo, 2010; Nerem et al., 2010;

Shum and Kuo, 2010). Furthermore, Fig. 6 also shows yearly variation of SLA from 1993 to 2017. The higher anomaly beyond the regression line are obtained in 1996, 2000, 2001, 2002, 2008, 2011, 2012, and 2013. Conversely, in 1993, 1997, 1998, 2015 and 2016, SLAs tend to be lower than their regression line. These features apply for all three islands. The lower (higher) SLA correspond to the occurrence of El Nino (La Nina) years which are mentioned in other studies (e.g., Kismawardhani et al., 2018; Handoko et al, 2019).

3.3. Tidal characteristic

The comparison between tidal prediction data and tidal observation data is shown in Fig. 7. Tidal prediction data provided by Information and Geospatial Agency of Indonesia demonstrates good agreements both in amplitude and period with the observational data for three Islands. Next, 29 days of tidal prediction data were analyzed by using admiralty method to obtain the vertical datum and tidal type of the seas at Liki, Bepondi dan Miossu Island. HHWL value for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m, and 2.66 m respectively. The list of other vertical datum for three islands is also presented in Fig. 5. It is important to noted that these vertical datums are based on the local zero reference of the depth of tidal measurement at each island. Thus, these datums are only used for correcting the elevation of three islands as explained in the next section. Tidal ranges are 2.0 m, 2.34 m and 2.44 m for Liki, Bepondi and Miossu Islands, respectively. The Formzahl values for Liki, Bepondi and Miossu Islands are 0.697, 0.507, and 0.439, respectively. These mean that all three islands have tidal type of mixed prevailing semidiurnal tide.

3.4. Topography

The result of photogrametry method are demonstrated in Fig. 8, 9, and 10 for Liki, Bepondi and Miossu Islands, respectively. Fig. 8a, 9a, and 10a show the orthophotos of each island in true color image passing the highest area of each island. Vegetation can be easily identified by the greenish color and the beach side is denoted by the white color. High resolution DSM of each island is shown in Fig. 8b, 9b, and 10b for Liki, Bepondi and Miossu Island, respectively. Since the land cover of the three islands is dominated by vegetation, ground elevation cannot be represented by DSM. In the vegetated area, DSM refers to the elevation of tree canopy. To obtain the ground elevation, DSM was converted to DTM by auto assessment of land pixels and interpolation process. DTM of each island is presented in Fig. 8c, 9c, and 10c. Fig. 11 shows the cross section of DTM and DSM passing the highest elevation of each island. The maximum elevation of Liki, Bepondi and Miossu Islands are 267 m, 106 m and 28 m, respectively. However, it is important to be noted that these highest elevation values were measured from the sea level at the time when the drone was flying. These values are then corrected HHWL value. The simulation of tidal correction is depicted in Fig. 7. The maximum elevation of Liki, Bepondi and Miossu Islands above the highest tide are 265.84 m, 103.19 m, and 26.37 m, respectively.

3.5. Simulation of SLR threat to the existence of outermost islands

Taking back the result from section 3.2, the prediction of SLR in the next 100 years in Liki, Bepondi and Miossu Islands is only 40 cm. This value is not comparable with the elevation of these three islands. Therefore, the threat of of SLR to the existence of Liki, Bepondi and Miossu Islands is small. However, it is important to be noted that since Liki and Bepondi Island are inhabitant islands and major human activities occur in the coastal plain, SLR may threat the people living in Liki and Bepondi Islands. For example, we conducted the levelling measurement by using water pass method to obtain the elevation of benchmark located in the housing area of Liki Island. The elevation of bench mark is only 29 cm from HHWL. This means that in the next 100 years, the housing area can be inundated as an impact of SLR. Furthermore, Feagin et al. (2005) stated that SLR may worsen the coastal erosion due to change of ocean wave and current pattern. However, this possibility still need to be examined further by focusing the investigation on the coastal plain where most people are living there. This work is left for future studies.

4. Conclusion

The conclusions of the SLR threat for the existence of three outermost small islands in the northeastern Indonesia are as follows :

a. The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands are 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha, respectively.
b. SLR rates for Liki, Bepondi and Miossu Islands are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, respectively.
c. HHWL value for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m, and 2.66 m respectively. The tidal type pf these three islands is mixed prevailing semidiurnal tide.
d. The highest elevation of Liki, Bepondi and Miossu islands from HHWL are 265.84 m, 103.19 m, and 26.37 m, respectively.
e. The threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia is small.

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Ackowledgement

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Reference

Ablain, M., Cazenave, A., Guinehut, S., and Valladeau, G., A new assessment of global mean sea level from altimeters highlights a reduction of global slope from 2005 to 2008 in agreement with in-situ measurements, *Ocean Sci.*, **5,**193–201 **(2009)**

Cunliffe, A. M., Brazier, R. E., and Anderson, K., Remote Sensing of Environment Ultra- fi ne grain landscape-scale quanti fi cation of dryland vegetation structure with drone-acquired structure-from-motion photogrammetry, *Remote Sensing of Environment*, **183**, 129–143 **(2016)** https://doi.org/10.1016/j.rse.2016.05.019

Feagin, R.A., Sherman, D.J., and Grant, W.E., Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. *Frontiers in Ecology and the environment*, **3(7)**: 359-364 **(2005)**, https://doi.org/10.1890/1540-9295(2005)003[0359:CEGSRA]2.0.CO;2

Handoko, E.Y., Hariyadi, H., and Wirasatriya, A, The ENSO's Influence on the Indonesian Sea Level Observed Using Satellite Altimetry, 1993 - 2016, *2018 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology (AGERS)*, **(2019)** Kismawardhani, R.A., Wirasatriya, A., Berliant, D., Sea Level Rise in The Java Sea Based on Altimetry Satellites Data Over 1993-2015, *IOP Conf. Series: Earth and Environmental Science*, **165,** 012006 (2018) doi :10.1088/1755-1315/165/1/012006

Kung, O., Strecha, C., Beyeler, A., Zufferey, J-C., Floreano, D., Fua, P., and Gervaix, F., The accuracy of automatic photogrametric techniques on Ultra-light UAV Imagery, *In IAPRS, Proceedings of the International Conference on Unmanned Aerial Vehicle in Geomatics (UAV-g), Zurich, Switzerland, 14–16 September 2011,* **38 (2011)**

Kuo, C.Y., Determination and Characterization of 20th Century Global Sea Level Rise, Ohio State University Report No. 478 **(2006)**

Leuliette, E., and Scharroo, R., Integrating Jason-2 into a multiple-altimeter climate data record, *Marine Geodesy*, **33,** 504–517 **(2010)**, doi:10.1080/01490419.2010.487795.

Li, X., Shen, H., Feng, R., Li, J., and Zhang, L., DEM generation from contours and a low-resolution DEM, *ISPRS Journal of Photogrammetry and Remote Sensing*, **134**, 135–147 **(2017)**, https://doi.org/10.1016/j.isprsjprs.2017.09.014

Mouloua, S. A., Ferraro, J., Mouloua, M., Hancock, P. A., and Florida, C., Trend analysis of Unmanned Aerial Vehicles (UAV), *The HFES Proceedings*, 1067–1071 **(2018)** https://doi.org/10.1177/1541931218621245

Nerem, R.S., Chambers, D.P, Choe, C., and Mitchum, G.T, Estimating mean sea level change from the TOPEX and Jason altimeter missions, *Marine Geodesy*, **33**, 435–446 **(2010)**, doi:10.1080/01490419.2010.491031.

Polat, N., and Murat, U., An Experimental Analysis of Digital Elevation Models Generated with Lidar Data and UAV Photogrammetry, *Journal of the Indian Society of Remote Sensing*, ***8*** **(2018),** https://doi.org/10.1007/s12524-018-0760-8

Sammartano, G., and Spanò, A., DEM Generation based on UAV Photogrammetry Data in Critical Areas, *In Proceedings of the 2nd International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2016)*, 92-98, **(2016)**, https://doi.org/10.5220/0005918400920098

Shum, C., and Kuo, C., Observation and geophysical causes of present-day sea level rise. Chapter 7 in *Climate Change and Food Security in South Asia*. R. Lal, M. Sivakumar, S.M.A. Faiz, A.H.M. Mustafizur Rahman, and K.R. Islam, eds, Springer Verlag, Holland, **(2010)**

Suh, J., and Choi, Y, Mapping hazardous mining-induced sinkhole subsidence using unmanned aerial vehicle (drone) photogrammetry. *Environmental Earth Sciences*, **(2017)**, https://doi.org/10.1007/s12665-017-6458-3

Willis, J. K., Chambers, D.P., Kuo, C-Y., and Shum, C.K., Global Sea Level Rise; Recent Progress and Challenges for The Decade to Come. *Oceanography*, **23 (4)**, 26-35 **(2010)**

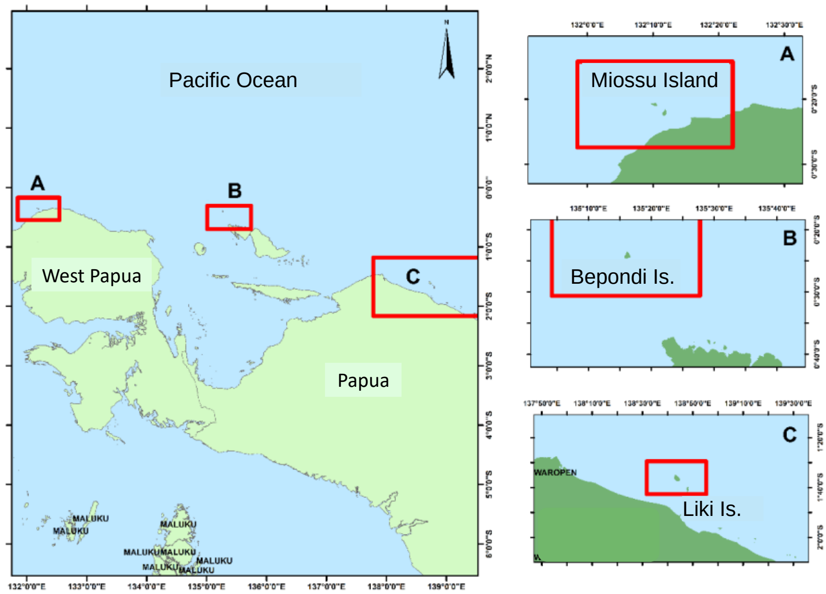


Fig. 1. The position of Liki, Bepondi and Miossu Islands

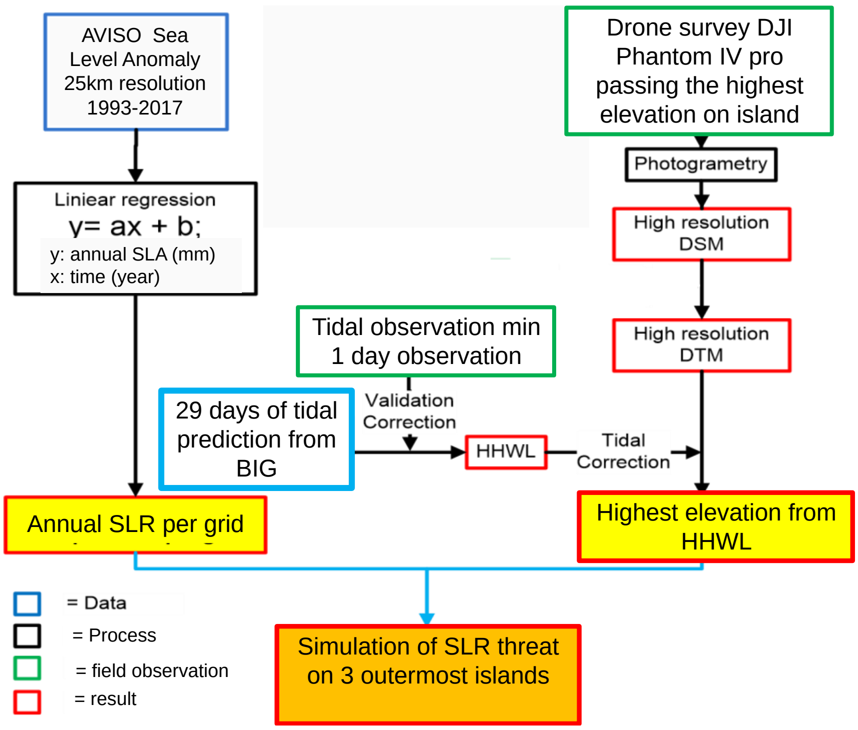


Fig. 2 Research Flowchart

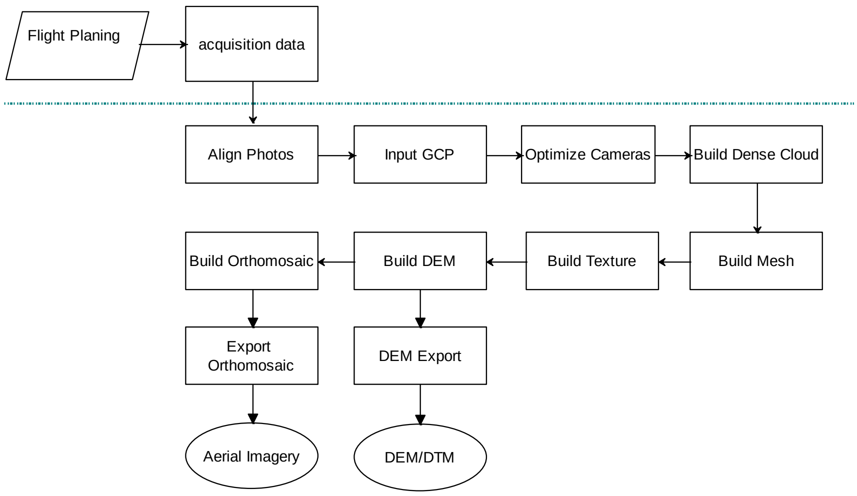


Fig. 3. Flowchart of photogramtry method

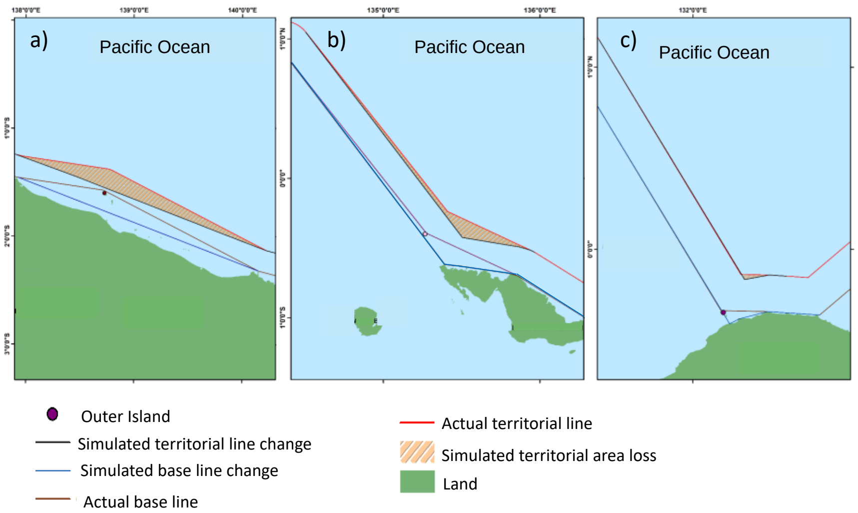


Fig. 4. Simulation of Indonesia territorial change due to the absence of a) Liki, b) Bepondi and c) Miossu Islands.

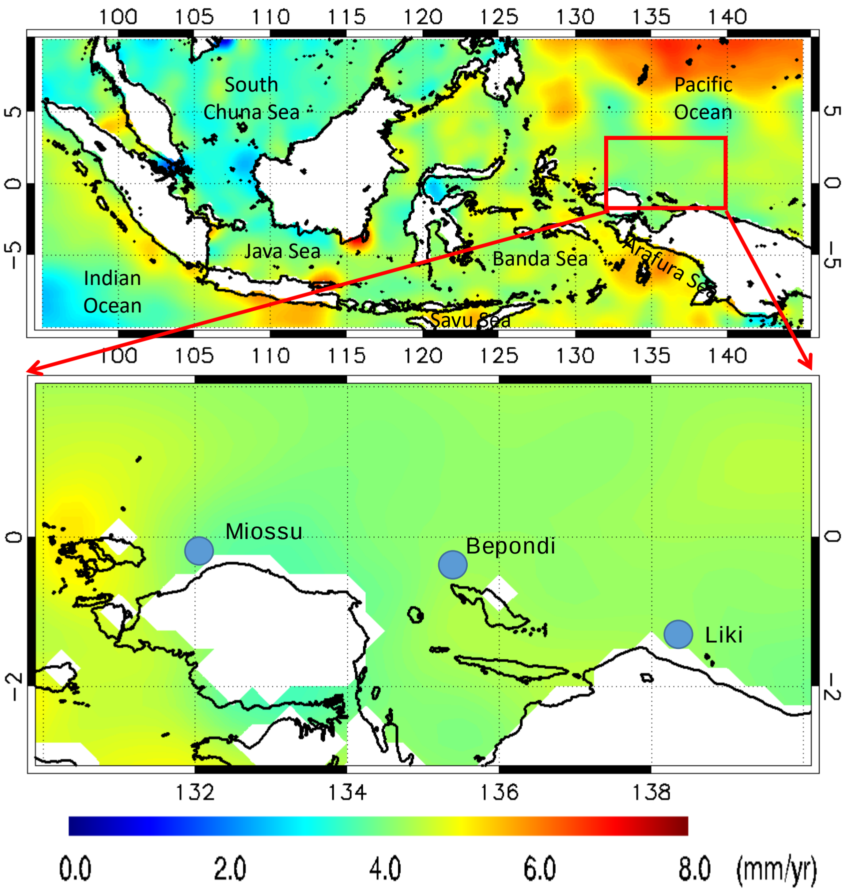


Fig. 5. Distribution of SLR rate in Indonesian Seas and the study area from 1993 to 2017

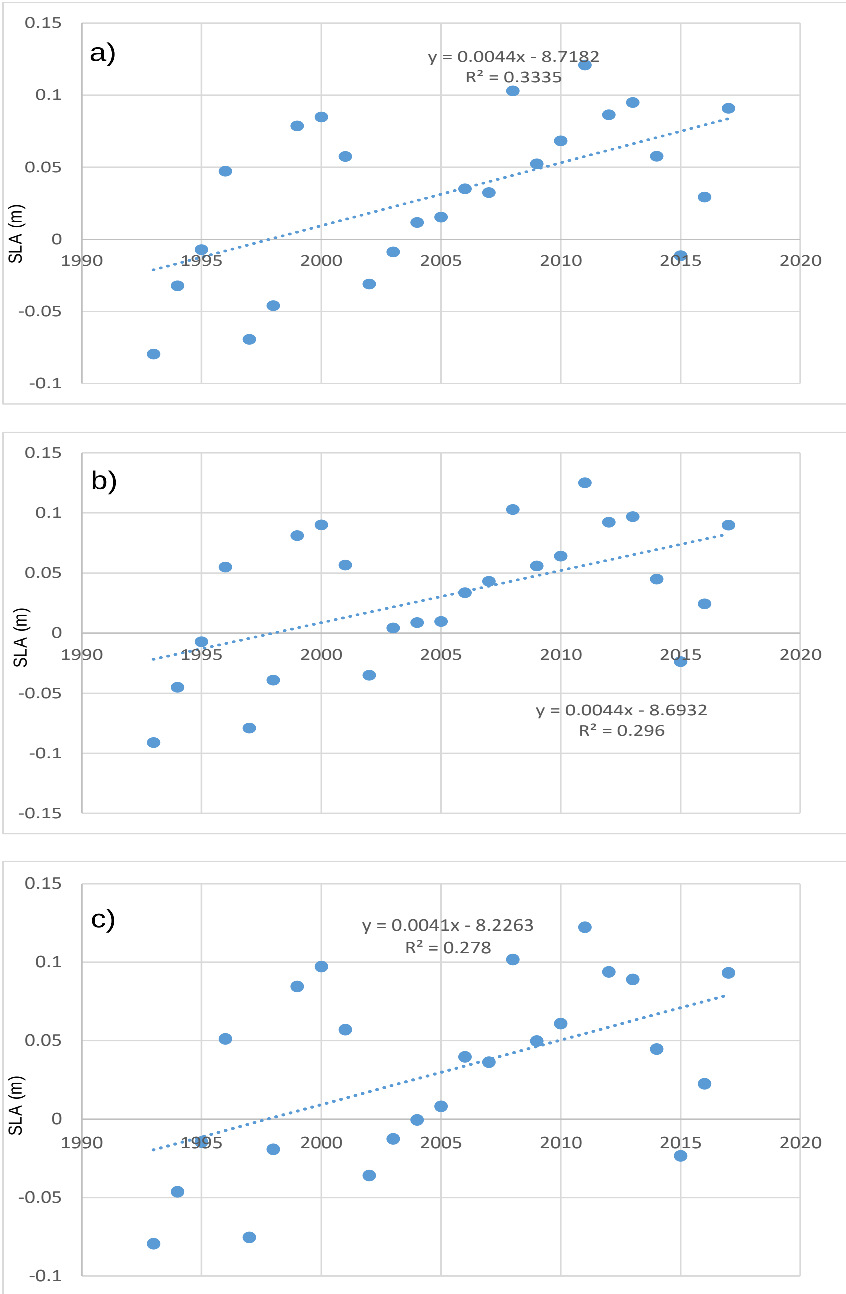
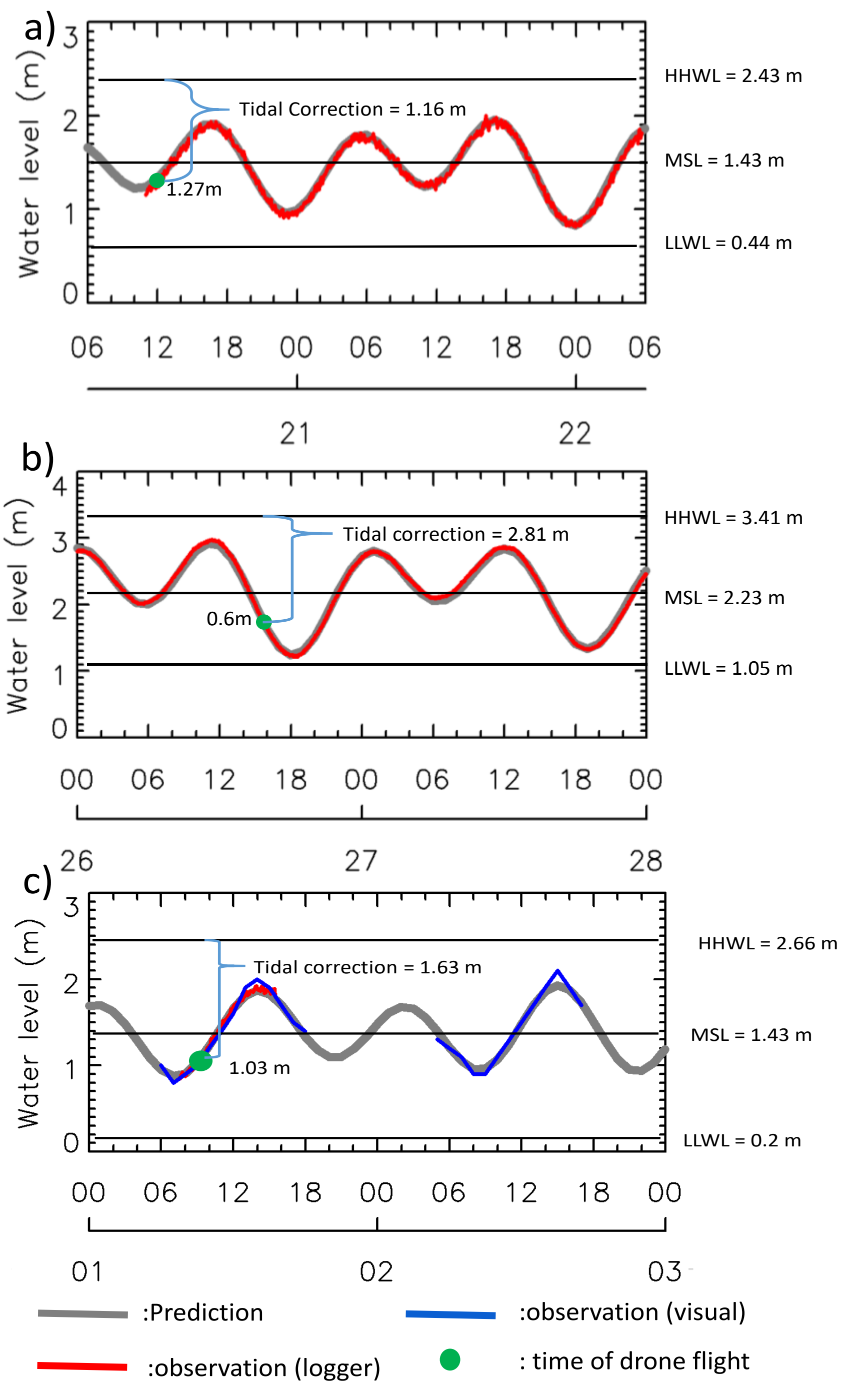


Fig. 6. Linear regression plot of SLR rate at a) Liki, b) Bepondi and c) Miossu Islands


a)
Water level (m)
HHWL = 2.43 m
Tidal Correction = 1.16 m
MSL = 1.43 m
1.27m
LLWL = 0.44 m
06 12 18 00 06 12 18 00 06
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b)
Water level (m)
HHWL = 3.41 m
Tidal correction = 2.81 m
MSL = 2.23 m
0.6m
LLWL = 1.05 m
00 06 12 18 00 06 12 18 00
26 27 28
c)
Water level (m)
HHWL = 2.66 m
Tidal correction = 1.63 m
MSL = 1.43 m
1.03 m
LLWL = 0.2 m
00 06 12 18 00 06 12 18 00
01 02 03
:Prediction
:observation (visual)
:observation (logger)
: time of drone flight

Fig. 7. Tidal data analysis at a) Liki, b) Bepondi and c) Miossu Islands

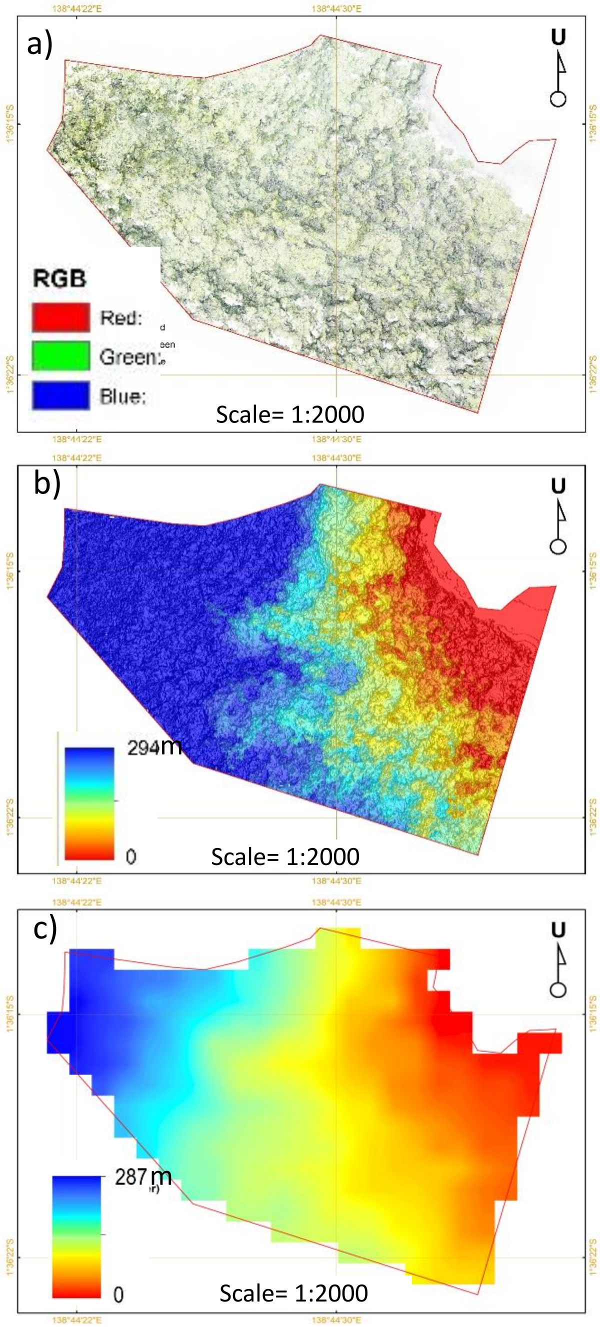

Fig. 8 a) Orthoimagery, b) DSM and c) DTM of Liki Island

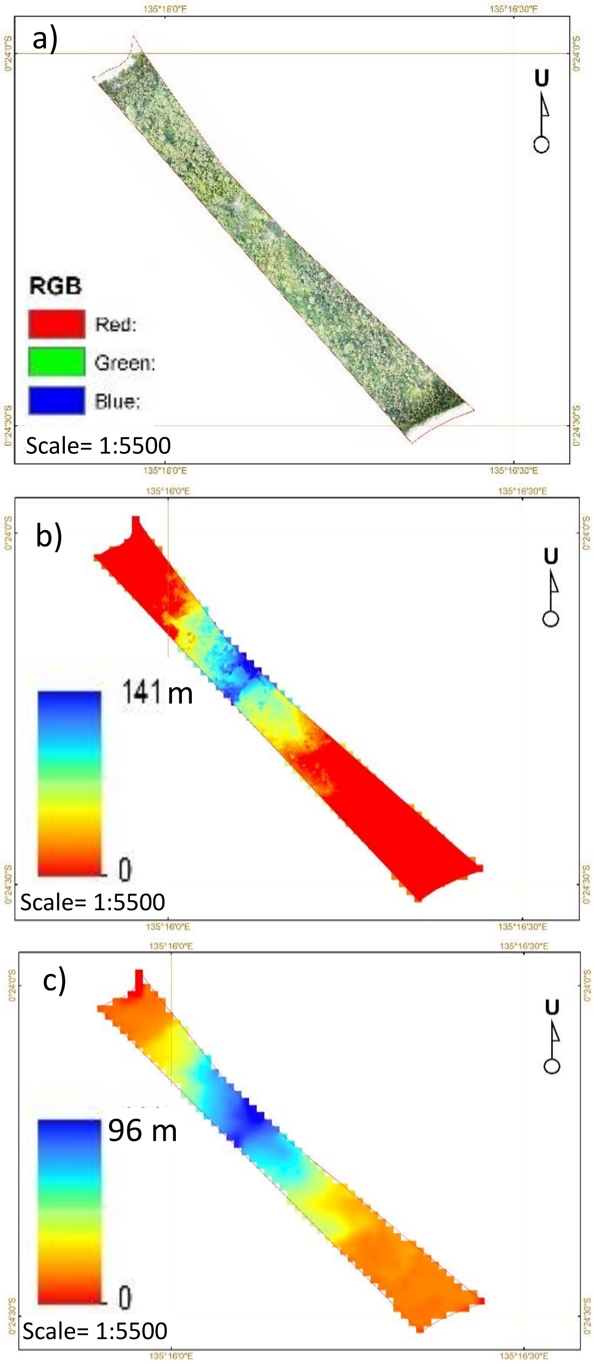

Fig. 9 a) Orthoimagery, b) DSM and c) DTM of Bepondi Island

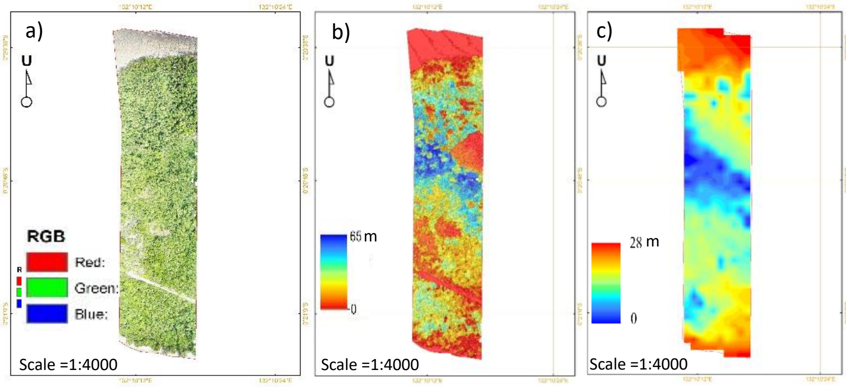

Fig. 10 a) Orthoimagery, b) DSM and c) DTM of Miossu Island

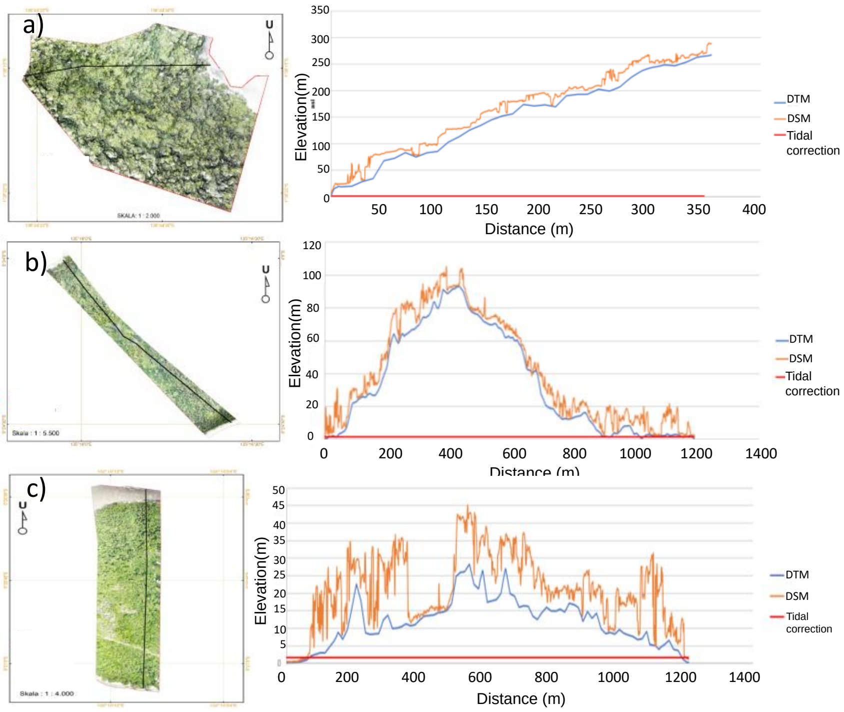

Fig. 11. Cross section of DSM and DSM of a) Liki, b) Bepondi and c) Miossu Islands with simulated tidal correction. Black lines on the left figures represent the cross section line on in the right figures.

Lampiran 3

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Estimation of Sea Level Rise threat on the existence of the three northeastern and outermost small islands of Indonesia using remote sensing method

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Abstract

The outermost small islands determine the territorial boundary of Indonesia. Liki, Bepondi and Miossu Islands are the three northeastern and outermost small islands of Indonesia located in the northern part of Papua Island. On the other hand, Sea Level Rise as an impact of global warming has threat the existence of small islands around the world. In the present study, the threat of Sea Level Rise (SLR) on the existence of those Islands is estimated from remote sensing method which is very useful for quick assessment. We use drone photography with photogrametry method to estimate the elevation of the three Islands. These elevations were corrected by tidal data to estimate the elevation above highest high water level. The linear regression assumption of 25 years sea level anomaly data obtained from altimetry satellite from 1993-2017 were calculated to analyze the rate of SLR. The elevation above highest high water level for Liki, Bepondi and Miossu Islands are 265.84 m, 103.19 m, and 26.37 m, respectively. With the the rate of Sea Level Rise of 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, the threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia is small.

1. Introduction

Indonesia is the biggest archipelagic state in the world with 16,056 islands spread within Indonesia region. As in 2017, this number of named and positioned islands has been officially registered to the United Nations by the Information and Geospatial Agency of Indonesia (http://www.big.go.id). As an archipelagic state, Indonesian region borders to 10 other countries whereas most parts of the border area consist of outermost small islands. The Presidential Decree No. 6 of 2017 has established as many as 111 islands as outermost small islands in Indonesia. The Government Regulation No. 62 of 2010 on The Use of Outermost Small Islands, stated that a small island is an island with an area smaller or equal to 2000 Km^2 including its ecosystem unity. While the outer small islands are small islands which have basic geographical coordinates that connect the archipelagic sea baseline in accordance with international and national law. Furthermore, Government Regulation No. 26 of 2008 states that the sovereign territory of Indonesia is including the outermost small islands that border directly with neighboring countries and/or the high seas. Therefore, the existence of the outermost and small islands should be maintained by the development priority to the outermost and small islands in Indonesia.

On the other hand the world is now facing the common threat coming from the global warming. One of the impact of global warming which possibly threat the existence of small islands is sea level rise (SLR). Global warming causes SLR through 2 mechanisms i.e., the increase of volume and mass of sea water (Wills et al., 2010). The increase of water mass is related to the melting ice at the poles and gletser as a direct impact of increasing temperature on earth due to the increase of green house gases concentration in the atmosphere. The increase of volume is related to the sea water heating that causes thermal expansion of water molecule. International Panel on Climate Change reported that in 100 years from 2000 the global sea level increase ranges from 15cm to 95 cm. Furthermore, Based on altimetry satellite observations, from 1992 the rate of global SLR is ±3.31 mm/year (e.g., Kuo, 2006; Ablain et al., 2009; Leuliette and Scharroo, 2010; Nerem et al., 2010; Shum and Kuo, 2010). The spatial distribution of SLR is shown in Wills et al. (2010). Among the areas around the world, western equatorial Pacific is the area with the highest SLR. The rate of SLR at this area can reach 1 cm/year. Thus, northeastern Indonesia which is part of the western equatorial Pacific faces the most rapid SLR.

Liki, Bepondi and Miossu Islands are the outermost small islands in Indonesia located at the northeastern most of Indonesia at the western equatorial Pacific (Fig. 1). Liki and Bepondi Islands are located at Papua Province while Miossu Island is at West Papua Province. The position of these three islands becomes the baseline for determining Indonesia territory. Thus, the existence of these three islands should be maintained since the position of these islands is vulnerable to the threat of SLR. Furthermore, since Liki and Bepondi Islands are inhabitant islands, SLR also can be the threat for people live in these islands. In the present study we investigated the potential impact of SLR in threatening the existence of Liki, Bepondi and Miossu Islands estimated from remote sensing approach.

2. Material and Method

First, we simulated the potential loss of Indonesia territory assuming the disappearance of Liki, Bepondi and Miossu Islands. The actual baseline of Indonesia territory is obtained from Information and Geospatial Agency of Indonesia. According to the Law No. 6 of 1996 on Indonesian Waters, The Indonesia territorial line is determined by 12.5 nautical miles from the baseline which is determined by the position of the outermost islands. Assuming the disappearance of the outermost island, the baseline was retreated to the mainland. The potential loss of Indonesia territory was estimated by calculating the areal size of territorial line before and after the disappearance of the outermost island.

For investigating the threat of SLR to the existence of Liki, Bepondi and Miossu Islands, we conducted 2 main analysis depicted in Fig. 2. The first analysis is calculating the rate of SLR at these three Islands. We used re-processing daily sea level anomalies (SLA) Level 4 from multi-mission data result of altimetry satellites provided by Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu/)

with the period of observation from 1993 to 2017. The spatial resolution of this data is 0.25°×0.25°. We composed daily data into yearly data. With the basis of yearly data, we calculated the rate of SLR per year by using simple linear regression.

$$y = ax + b \quad (1)$$

Where y and x are yearly SLA (m) and year, respectively. The rate of SLR (m/year) is determined by value of constant 'a'.

Second analysis is estimating the highest elevation at Liki, Bepondi and Miossu Island. To reach these three islands, we joined the research cruise "Baruna Jaya VIII" owned by Research Center for Oceanography, Indonesian Institute of Science in the expedition called "Nusa Manggala". The aim of this expedition is to explore the potential resources of coastal ecosystem in the outermost small Islands at the northeastern Indonesia. We joined the second leg of the cruise from 14 November to 4 December 2018. We used aerial photography taken from drone DJI Phantom 4 Pro with photogrametry method to generate Digital Surface Model for Liki, Bepondi and Miossu Island. The plan was to fly the drone from the beach passing the highest topography until the other side of the beach for several loops with 80% overlapping images.

The images of Liki Island was taken on 22 November 2018 at 12.00 Local Time (LT). Drone was taken off from the beach side at position 1°36'9.76" S and 138°44'34.37" E to the highest part of the island. The take off altitude was 280 m. However, the drone could not reach the other side of island due to the limitation of communication signal between the drone and the controller. We collected 345 aerial images at Liki Island. At Bepondi Island, the drone took off from the highest part of the island at the position 0°24'12.45" S dan 135°16'5.96" E on 26 November 2018 at 15.00 LT. The take off altitude was 50 m. Since it flied from the highest part of the island, the drone managed to capture both side of the beach with 740 aerial images. The aerial images of Mioussu Island were taken on 1 December 2019 at 9.00 LT. The drone took off from the highest part of island at position 0°20'49.33" S dan 132°10'12.91" E with 110 m of take off altitude. We managed to collect 850 aerial images that covered both side of the beach. The aerial images of three islands are then processed to obtain high resolution orthoimagery, Digital Surface Model (DSM) and Digital Terrain Model (DTM).

The image processing to produce orthoimagery, DSM and DTM was conducted by using photogrametry method (Mouloua, Ferraro, Mouloua, Hancock, & Florida, 2018) (Polat & Murat, 2018) (Cunliffe, Brazier, & Anderson, 2016). The three dimension format of geographical location, size and capture of the object were measured by georeferencing orthoimages and Digital Terrain Model (Sammartano & Spanò, 2016). The accuracy of 3D model is depend on the distribution of Ground Control Point (GCP) (Suh & Choi, 2017). Kung et al (2011) stated that the accuracy of drone photogrametry with and without GCPs range from 0.056m to 1.25 m and from 1.97 to 7.84 m, respectively. In the present study, we did not conducted GPS survey for determining GCPs due to the limitation of survey duration. However, the sea side covered by the drone were used as GCPs since we assumed that the elevation of sea level is 0 m in both side of the sea side. The flowchart of photogrametry method is shown in Fig. 3.

The DTM generated from photogrametry method was then corrected by tidal data. UNCLOS (1982) article 121 stated that, an island is a naturally formed area of land, surrounded by water, which is above water at high tide. Thus, tidal data was used to project the datum of DTM at the position of Highest High Water Level (HHWL). We used 29 days of tidal prediction data provided by the Information and Geospatial Agency of Indonesia (http://tides.big.go.id/pasut/). To ensure the accuracy of the tidal prediction data, we compared it with tidal observation data and used the tidal observation data as reference for tidal prediction data. The tidal observation data at Liki Island is recorded by using tide logger RBR Duo at position 1°37’28.48” S dan 138°44’30.62” E for 1.5 days started from 20 November 2018. At Bepondi Island, we used the tidal observation Island at the Biak Island owned by Information and Geospatial Agency of Indonesia (http://ina-sealevelmonitoring.big.go.id/ipasoet/) due to the failure of RBR measurement. The position of tidal observation at Biak Island is 1.1776°S and 136.056°E. For Miossu Island, we used 2 observation data i.e., RBR duo data and visual observation. The position of the observation was 0.35135 °S dan 132.172613° E. The referenced tidal prediction data for each island then was analyzed by using admiralty method to obtain the value of HHWL and other tidal characteristics. DTM for each island was then corrected by HHWL value to obtain the elevation of the islands above highest tide. Finally, we simulated the the impact of SLR for the existence of Liki, Bepondi and Miossu Islands for the next 100 years by using the obtained value of SLR rate and the topography of each island.

3. Result And Discussion

3.1. Potential area loss due to the absence of the outermost small islands

The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands are 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha, respectively (Fig. 4). Thus, total potential area loss of Indonesia territory if these three outermost island disappear is 346,462.36 Ha. The loss of the outermost small islands in Indonesia can have juridical consequences for Indonesia's Exclusive Economic Zone (EEZ) with the EEZ of other countries at sea bordering the lost island. Overlapping of boundaries between countries can occur because of the same claim for an area affected by the loss of the island. The problem of territorial boundaries that might occur as a result of this matter will affect the economic aspects in relation to area management, administrative aspects of government, and the defense/security aspects.

Determination of continental shelf boundaries can be used as a reference in establishing EEZ. Indonesia has the characteristics of an archipelagic state based on what is stated in Article 46 of UNCLOS, and an archipelagic country has special rights or provisions in determining maritime boundaries, one of which can be seen from the way of establishing archipelagic baselines contained in Article 47 of UNCLOS. Other countries that border directly with Indonesia in general are coastal countries. Determination of the continental shelf boundary between Indonesia and other countries that border directly with Indonesia can refer to Article 76, 77 and 78 of UNCLOS wherein the article states the coastal state's right to continental shelf. The solution to the EEZ problem can refer to Article 55 of UNCLOS which states that in determining the EEZ boundaries, a coastal country must be based on the provisions of its rights as a coastal state. Based on this, the problem of the boundaries of Indonesia's EEZ with other coastal countries should be avoided because Indonesia as an archipelagic state has special features in determining maritime boundaries based on UNCLOS.

3.2. **Sea Level Rise**

The distribution of SLR in Indonesian Seas is shown in Fig 5. Most of the area within Indonesian Seas has rate of SLR by more than 4 mm/year. Especially in the Arafura Sea, Savu Sea, Southern coast of Java, and parts of Java Sea have SLR rate by more than 5 mm/s. Along the northern coast of Papua which becomes our study area, the SLR rate is about 4 mm/year. Specifically for Liki, Bepondi and Miossu, their SLR rates are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, respectively (Fig. 6). Thus, it can be concluded that SLR rate in Indonesian Seas is higher than the global average i.e., (e.g., Kuo, 2006; Ablain et al., 2009; Leuliette and Scharroo, 2010; Nerem et al., 2010; Shum and Kuo, 2010). Furthermore, Fig. 6 also shows yearly variation of SLA from 1993 to 2017. The higher anomaly beyond the regression line are obtained in 1996, 2000, 2001, 2002, 2008, 2011, 2012, and 2013. Conversely, in 1993, 1997, 1998, 2015 and 2016, SLAs tend to be lower than their regression line. These features apply for all three islands. The lower (higher) SLA correspond to the occurrence of El Nino (La Nina) years which are mentioned in other studies (e.g., Kismawardhani et al., 2018; Handoko et al, 2019).

3.3. Tidal characteristic

The comparison between tidal prediction data and tidal observation data is shown in Fig. 7. Tidal prediction data provided by Information and Geospatial Agency of Indonesia demonstrates good agreements both in amplitude and period with the observational data for three Islands. Next, 29 days of tidal prediction data were analyzed by using admiralty method to obtain the vertical datum and tidal type of the seas at Liki, Bepondi dan Miossu Island. HHWL value for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m, and 2.66 m respectively. The list of other vertical datum for three islands is also presented in Fig. 5. It is important to noted that these vertical datums are based on the local zero reference of the depth of tidal measurement at each island. Thus, these datums are only used for correcting the elevation of three islands as explained in the next section. Tidal ranges are 2.0 m, 2.34 m and 2.44 m for Liki, Bepondi and Miossu Islands, respectively. The Formzahl values for Liki, Bepondi and Miossu Islands are 0.697, 0.507, and 0.439, respectively. These mean that all three islands have tidal type of mixed prevailing semidiurnal tide.

3.4. Topography

The result of photogrametry method are demonstrated in Fig. 8, 9, and 10 for Liki, Bepondi and Miossu Islands, respectively. Fig. 8a, 9a, and 10a show the orthophotos of each island in true color image passing the highest area of each island. Vegetation can be easily identified by the greenish color and the beach side is denoted by the white color. High resolution DSM of each island is shown in Fig. 8b, 9b, and 10b for Liki, Bepondi and Miossu Island, respectively. Since the land cover of the three islands is dominated by vegetation, ground elevation cannot be represented by DSM. In the vegetated area, DSM refers to the elevation of tree canopy. To obtain the ground elevation, DSM was converted to DTM by auto assessment of land pixels and interpolation process. DTM of each island is presented in Fig. 8c, 9c, and 10c. Fig. 11 shows the cross section of DTM and DSM passing the highest elevation of each island. The maximum elevation of Liki, Bepondi and Miossu Islands are 267 m, 106 m and 28 m, respectively. However, it is important to be noted that these highest elevation values were measured from the sea level at the time when the drone was flying. These values are then corrected HHWL value. The simulation of tidal correction is depicted in Fig. 7. The maximum elevation of Liki, Bepondi and Miossu Islands above the highest tide are 265.84 m, 103.19 m, and 26.37 m, respectively.

3.5. Simulation of SLR threat to the existence of outermost islands

Taking back the result from section 3.2, the prediction of SLR in the next 100 years in Liki, Bepondi and Miossu Islands is only 40 cm. This value is not comparable with the elevation of these three islands. Therefore, the threat of of SLR to the existence of Liki, Bepondi and Miossu Islands is small. However, it is important to be noted that since Liki and Bepondi Island are inhabitant islands and major human activities occur in the coastal plain, SLR may threat the people living in Liki and Bepondi Islands. For example, we conducted the levelling measurement by using water pass method to obtain the elevation of benchmark located in the housing area of Liki Island. The elevation of bench mark is only 29 cm from HHWL. This means that in the next 100 years, the housing area can be inundated as an impact of SLR. Furthermore, Feagin et al. (2005) stated that SLR may worsen the coastal erosion due to change of ocean wave and current pattern. However, this possibility still need to be examined further by focusing the investigation on the coastal plain where most people are living there. This work is left for future studies.

4. Conclusion

The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands are 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha, respectively. SLR rates for Liki, Bepondi and Miossu Islands are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, respectively. HHWL value for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m, and 2.66 m respectively. The tidal type pf these three islands is mixed prevailing semidiurnal tide. The highest elevation of Liki, Bepondi and Miossu islands from HHWL are 265.84 m, 103.19 m, and 26.37 m, respectively. Considering the rate of SLR and the elevation of the islands, it can be conclude that there is no threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia.

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Reference

Ablain, M., Cazenave, A., Guinehut, S., and Valladeau, G., A new assessment of global mean sea level from altimeters highlights a reduction of global slope from 2005 to 2008 in agreement with in-situ measurements, *Ocean Sci.*, **5,**193–201 **(2009)**

Cunliffe, A. M., Brazier, R. E., and Anderson, K., Remote Sensing of Environment Ultra- fi ne grain landscape-scale quanti fi cation of dryland vegetation structure with drone-acquired structure-from-motion photogrammetry, *Remote Sensing of Environment*, **183**, 129–143 **(2016)** https://doi.org/10.1016/j.rse.2016.05.019

Feagin, R.A., Sherman, D.J., and Grant, W.E., Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. *Frontiers in Ecology and the environment*, **3(7)**: 359-364 **(2005)**, https://doi.org/10.1890/1540-9295(2005)003[0359:CEGSRA]2.0.CO;2

Handoko, E.Y., Hariyadi, H., and Wirasatriya, A, The ENSO’s Influence on the Indonesian Sea Level Observed Using Satellite Altimetry, 1993 - 2016, *2018 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology (AGERS),* **(2019)**

Kismawardhani, R.A., Wirasatriya, A., Berliant, D., Sea Level Rise in The Java Sea Based on Altimetry Satellites Data Over 1993-2015, *IOP Conf. Series: Earth and Environmental Science,* **165,** 012006 (2018) doi :10.1088/1755-1315/165/1/012006

Kung, O., Strecha, C., Beyeler, A., Zufferey, J-C., Floreano, D., Fua, P., and Gervaix, F., The accuracy of automatic photogrametric techniques on Ultra-light UAV Imagery, *In IAPRS, Proceedings of the International Conference on Unmanned Aerial Vehicle in Geomatics (UAV-g), Zurich, Switzerland, 14–16 September 2011,* **38 (2011)**

Kuo, C.Y., Determination and Characterization of 20th Century Global Sea Level Rise, Ohio State University Report No. 478 **(2006)**

Leuliette, E., and Scharroo, R., Integrating Jason-2 into a multiple-altimeter climate data record, *Marine Geodesy*, **33,** 504–517 **(2010)**, doi:10.1080/01490419.2010.487795.

Li, X., Shen, H., Feng, R., Li, J., and Zhang, L., DEM generation from contours and a low-resolution DEM, *ISPRS Journal of Photogrammetry and Remote Sensing*, **134**, 135–147 **(2017)**, https://doi.org/10.1016/j.isprsjprs.2017.09.014

Mouloua, S. A., Ferraro, J., Mouloua, M., Hancock, P. A., and Florida, C., Trend analysis of Unmanned Aerial Vehicles (UAV), *The HFES Proceedings*, 1067–1071 **(2018)** https://doi.org/10.1177/1541931218621245

Nerem, R.S., Chambers, D.P, Choe, C., and Mitchum, G.T, Estimating mean sea level change from the TOPEX and Jason altimeter missions, *Marine Geodesy*, **33**, 435–446 **(2010)**, doi:10.1080/01490419.2010.491031.

Polat, N., and Murat, U., An Experimental Analysis of Digital Elevation Models Generated with Lidar Data and UAV Photogrammetry, *Journal of the Indian Society of Remote Sensing*, ***8*** **(2018),** https://doi.org/10.1007/s12524-018-0760-8

Sammartano, G., and Spanò, A., DEM Generation based on UAV Photogrammetry Data in Critical Areas, *In Proceedings of the 2nd International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2016)*, 92-98, **(2016)**, https://doi.org/10.5220/0005918400920098

Shum, C., and Kuo, C., Observation and geophysical causes of present-day sea level rise. Chapter 7 in *Climate Change and Food Security in South Asia*. R. Lal, M. Sivakumar, S.M.A. Faiz, A.H.M. Mustafizur Rahman, and K.R. Islam, eds, Springer Verlag, Holland, **(2010)**

Suh, J., and Choi, Y, Mapping hazardous mining-induced sinkhole subsidence using unmanned aerial vehicle (drone) photogrammetry. *Environmental Earth Sciences*, **(2017)**, https://doi.org/10.1007/s12665-017-6458-3

Willis, J. K., Chambers, D.P., Kuo, C-Y., and Shum, C.K., Global Sea Level Rise; Recent Progress and Challenges for The Decade to Come. *Oceanography*, **23 (4)**, 26-35 **(2010)**

http://www.big.go.id

http://tides.big.go.id/pasut/

http://ina-sealevelmonitoring.big.go.id/ipasoet/

http://marine.copernicus.eu/

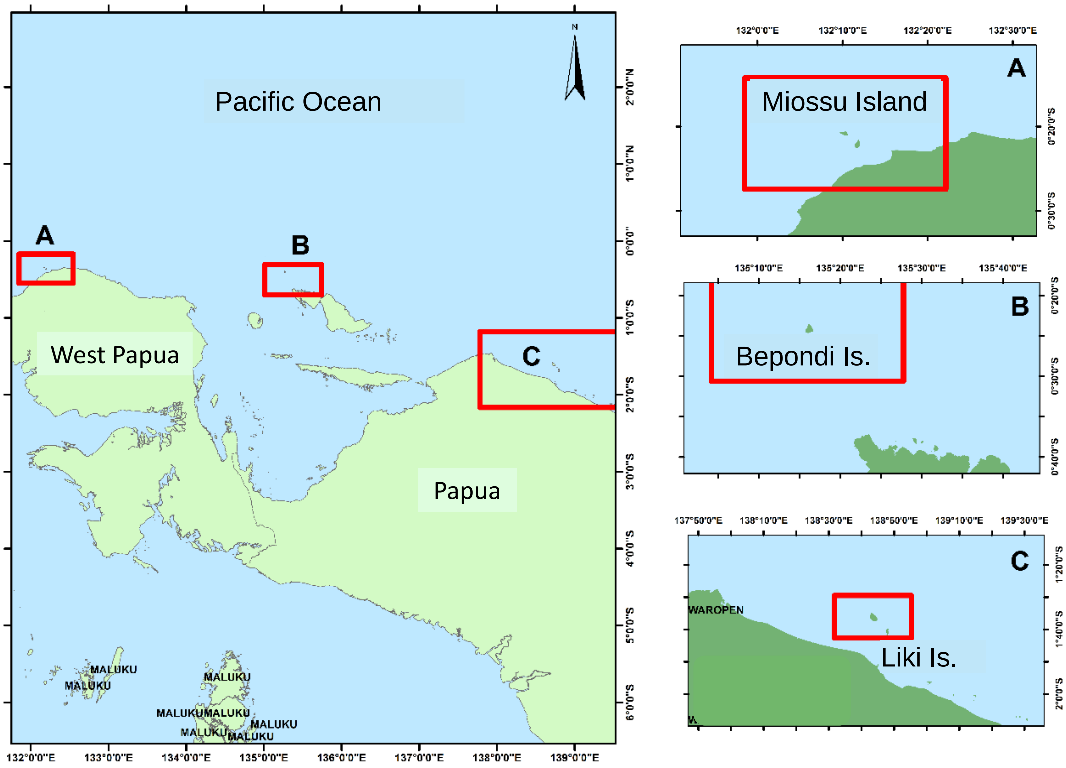


Fig. 1. The position of Liki, Bependi and Miossu Islands

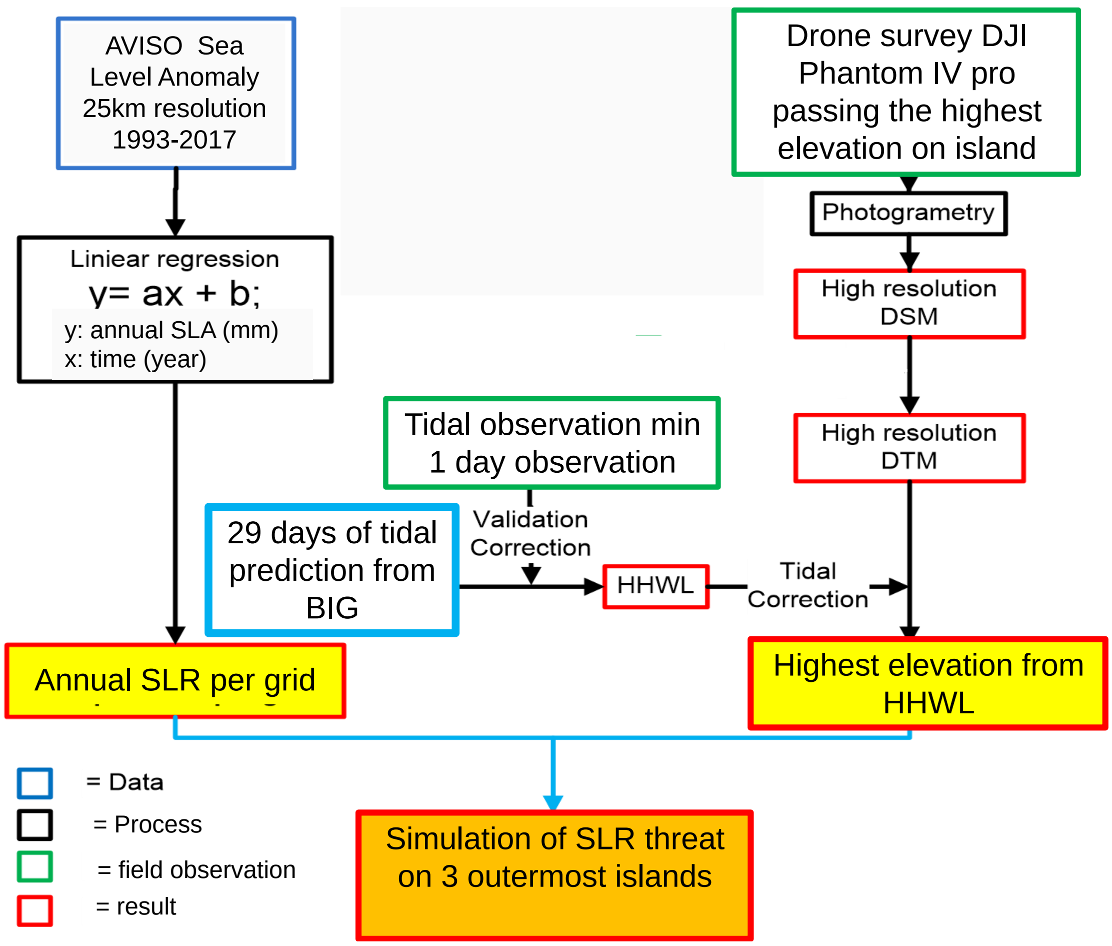


Fig. 2 Research Flowchart

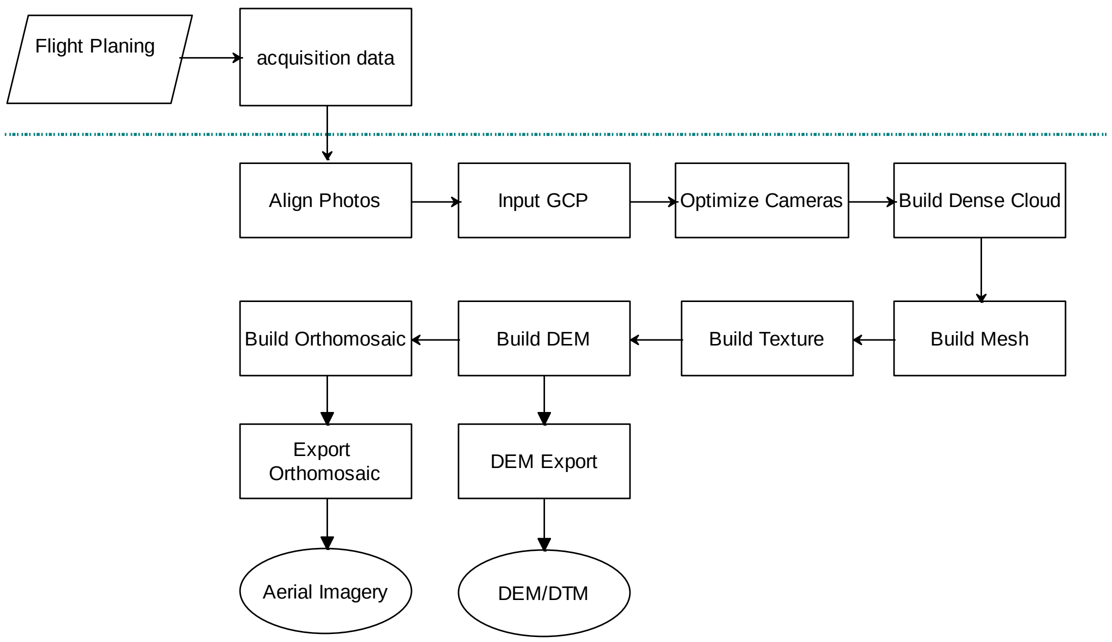


Fig. 3. Flowchart of photogramtry method

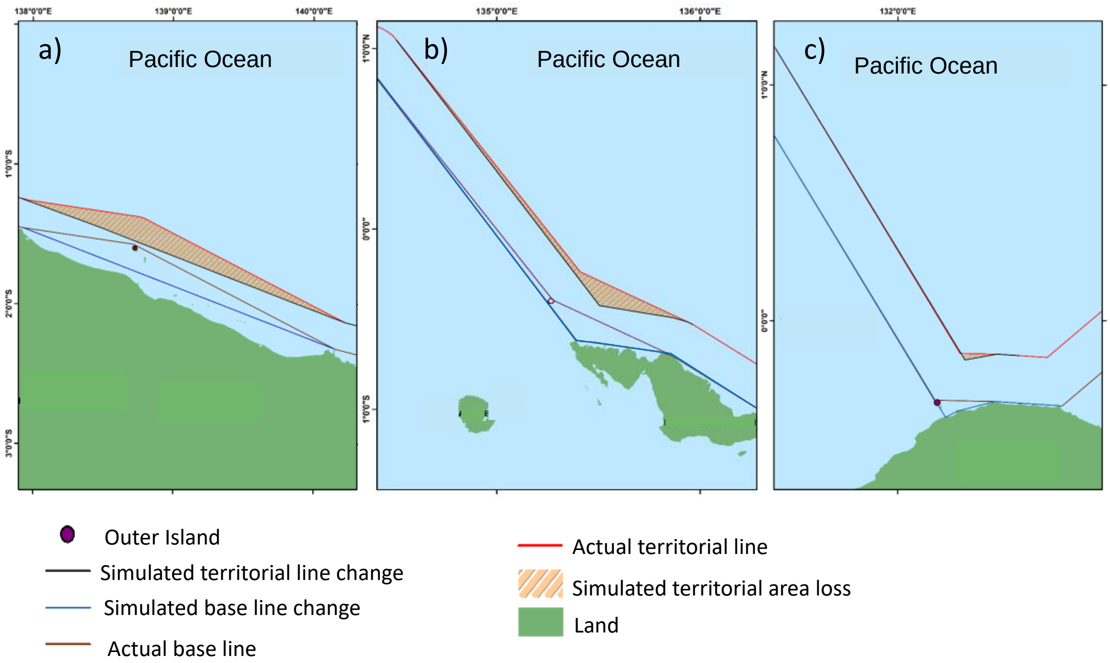


Fig. 4. Simulation of Indonesia territorial change due to the absence of a) Liki, b) Bepondi and c) Miossu Islands.

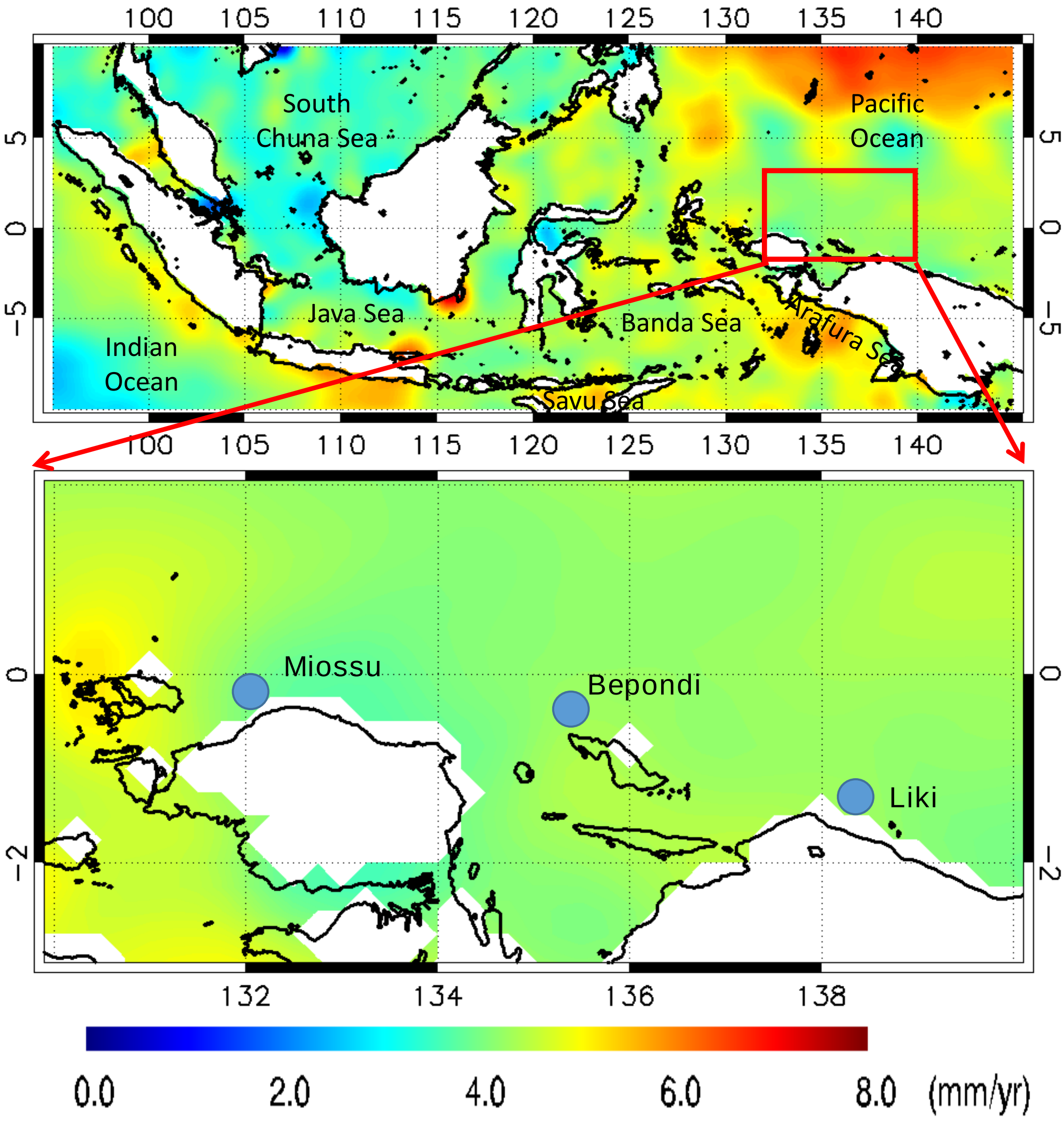


Fig. 5. Distribution of SLR rate in Indonesian Seas and the study area from 1993 to 2017

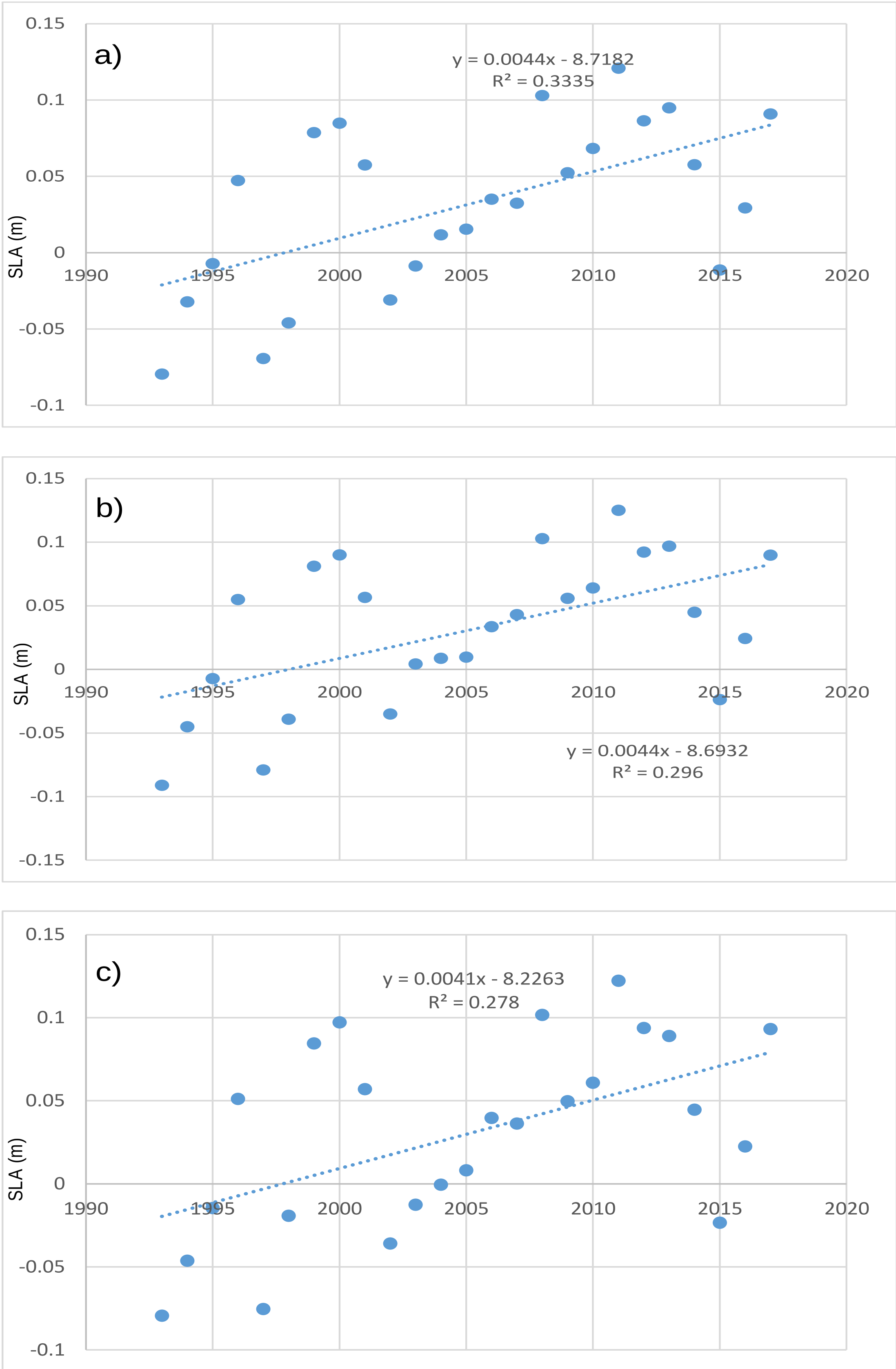
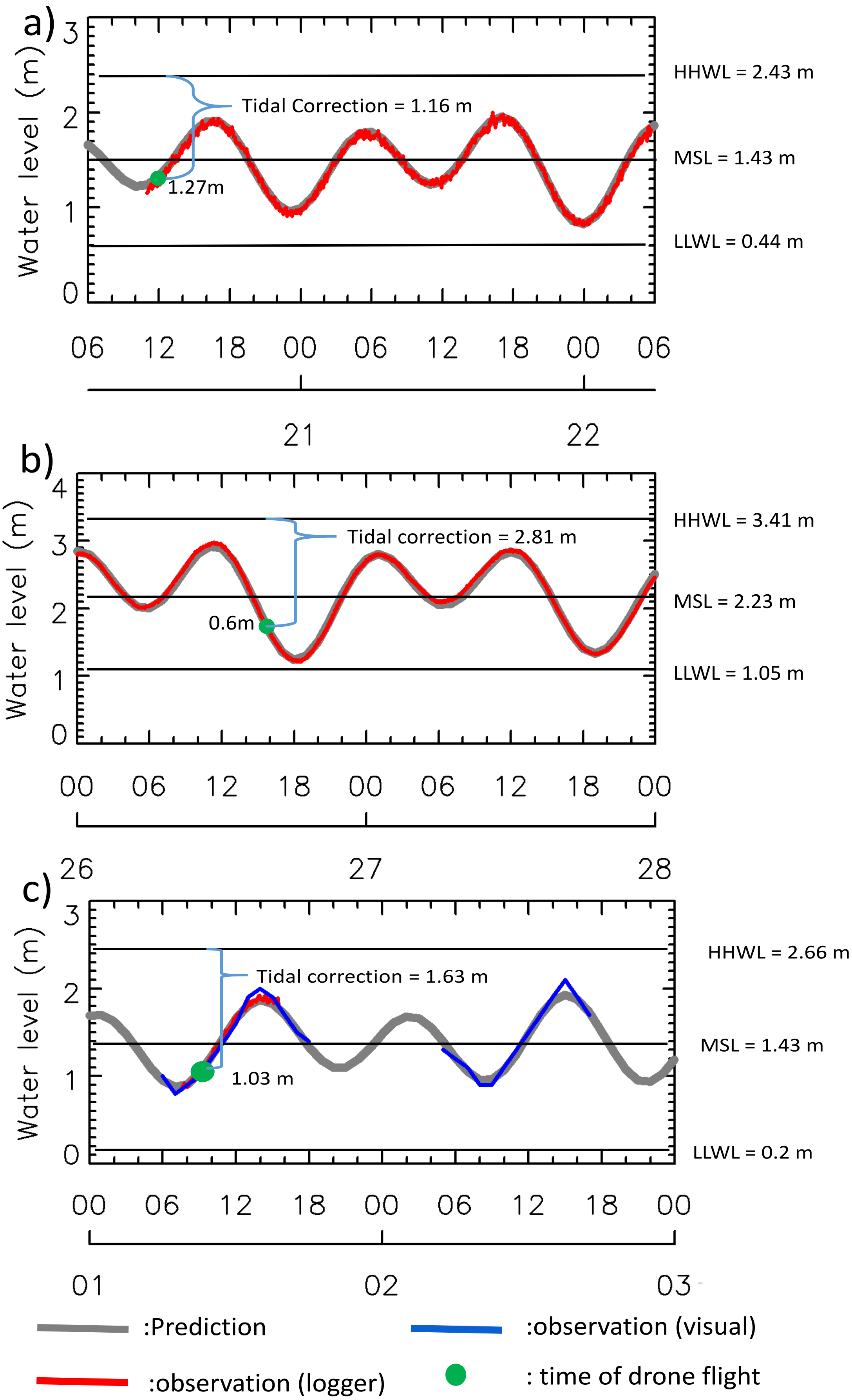


Fig. 6. Linear regression plot of SLR rate at a) Liki, b) Bepondi and c) Miossu Islands



a)
Water level (m)
3
2
1
0
HHWL = 2.43 m
MSL = 1.43 m
LLWL = 0.44 m
Tidal Correction = 1.16 m
1.27m
06 12 18 00 06 12 18 00 06
21 22
b)
Water level (m)
4
3
2
1
0
HHWL = 3.41 m
MSL = 2.23 m
LLWL = 1.05 m
Tidal correction = 2.81 m
0.6m
00 06 12 18 00 06 12 18 00
26 27 28
c)
Water level (m)
3
2
1
0
HHWL = 2.66 m
MSL = 1.43 m
LLWL = 0.2 m
Tidal correction = 1.63 m
1.03 m
00 06 12 18 00 06 12 18 00
01 02 03
:Prediction
:observation (visual)
:observation (logger)
: time of drone flight

Fig. 7. Tidal data analysis at a) Liki, b) Bepondi and c) Miossu Islands

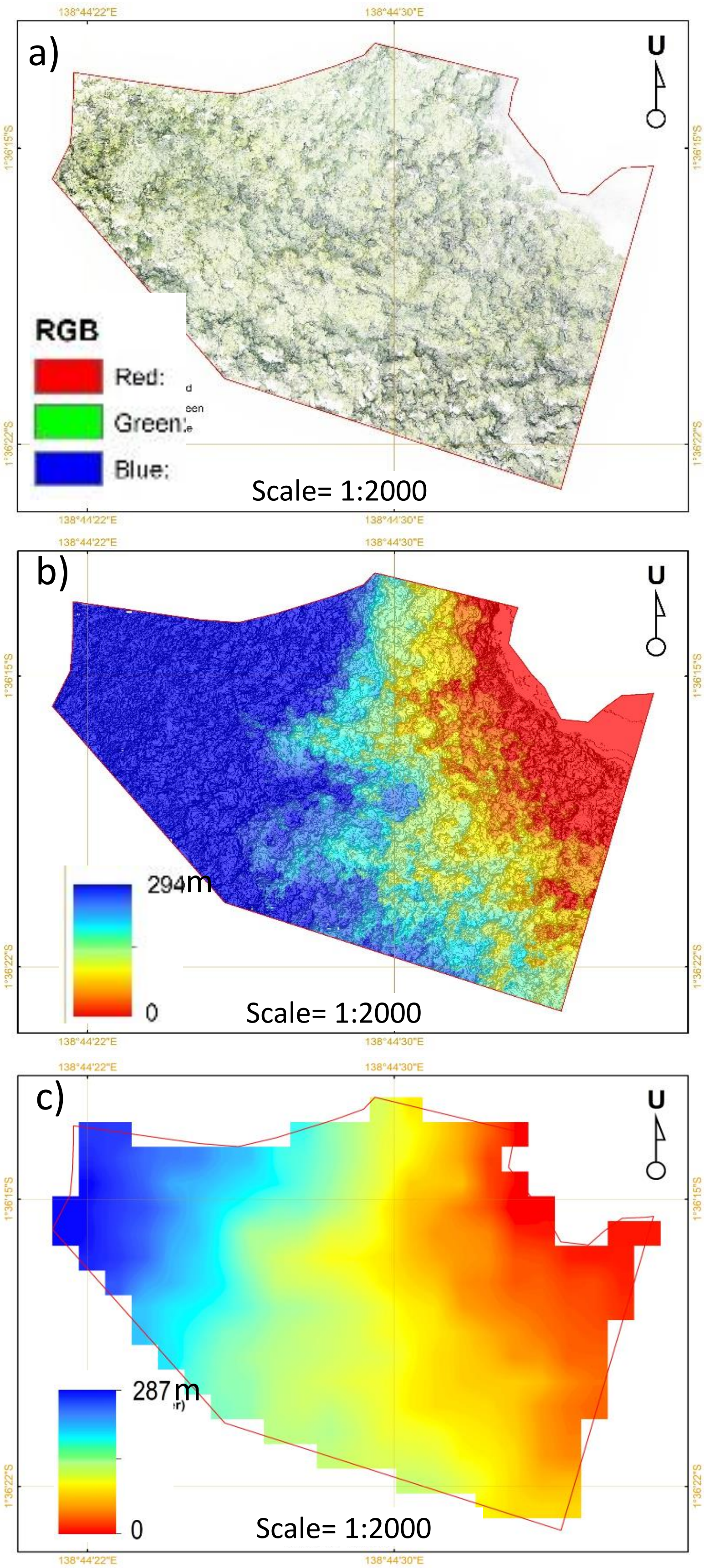


Fig. 8 a) Orthoimagery, b) DSM and c) DTM of Liki Island

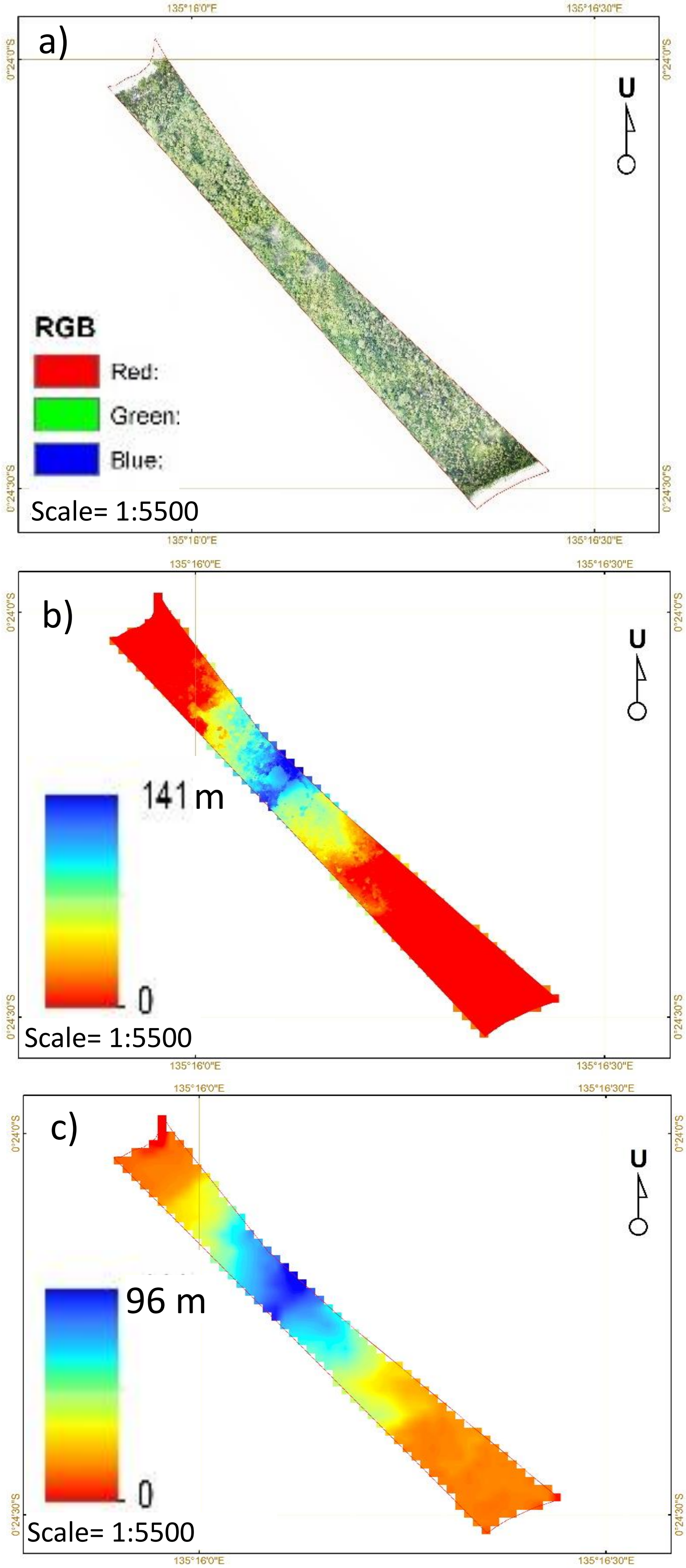


Fig. 9 a) Orthoimagery, b) DSM and c) DTM of Bepondi Island

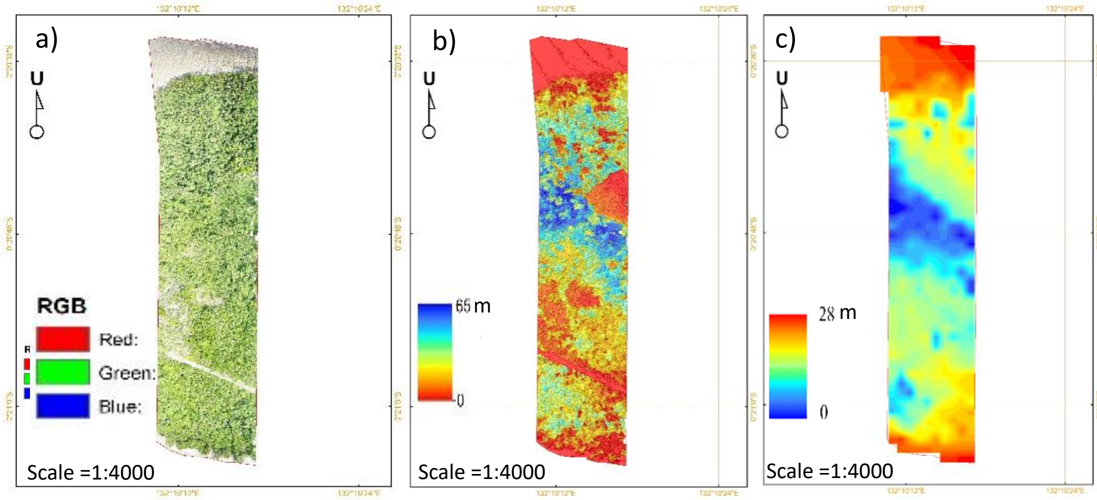


Fig. 10 a) Orthoimagery, b) DSM and c) DTM of Miossu Island

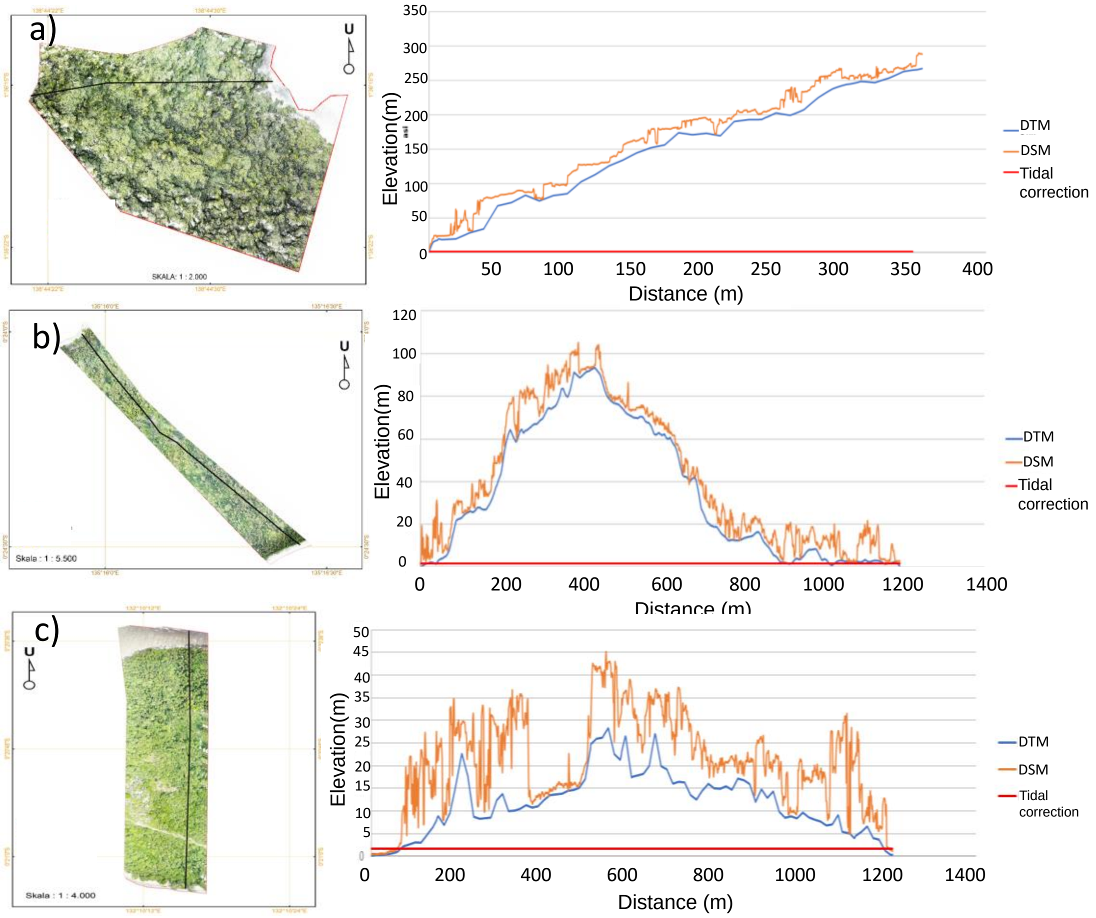


Fig. 11. Cross section of DSM and DSM of a) Liki, b) Bepondi and c) Miossu Islands with simulated tidal correction. Black lines on the left figures represent the cross section line on in the right figures.

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Estimation of Sea Level Rise threat on the existence of the three northeastern and outermost small islands of Indonesia (i.e. Liki, Bepondi and Miossu Islands) using remote sensing method

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Abstract

The outermost small islands determine the territorial boundary of Indonesia. Liki, Bepondi and Miossu Islands are the three northeastern and outermost small islands of Indonesia located in the northern part of Papua Island. On the other hand, sea level rise as an impact of global warming has threatened the existence of small islands around the world. In the present study, the threat of sea level rise (SLR) on the existence of those Islands is estimated from remote sensing method which is very useful for quick assessment. We use drone photography with photogrametry method to estimate the elevation of the three Islands. These elevations were corrected by tidal data to estimate the elevation above highest high water level.

The linear regression assumption of 25 years sea level anomaly data obtained from altimetry satellite from 1993-2017 was calculated to analyze the rate of SLR. The elevations above highest high water level for Liki, Bepondi and Miossu Islands are 265.84 m, 103.19 m, and 26.37 m respectively. With the rate of sea level rise of 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, the threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia is small.

Keywords: Sea Level Rise, Liki Island, Bepondi Island, Miossu Island.

Introduction

Indonesia is the biggest archipelagic state in the world with 16,056 islands spread within Indonesia region. As in 2017, this number of named and positioned islands has been officially registered to the United Nations by the Information and Geospatial Agency of Indonesia[17]. As an archipelagic state, Indonesian region borders to 10 other countries whereas most parts of the border area consist of outermost small islands. The Presidential Decree No. 6 of 2017 has established as many as 111 islands as outermost small islands in Indonesia. The Government Regulation No. 62 of 2010 on The Use of Outermost Small Islands stated that a small island is an island with an area smaller or equal to 2000 Km^2 including its ecosystem unity.

The outer small islands are small islands which have basic geographical coordinates that connect the archipelagic sea baseline in accordance with international and national law. Furthermore, Government Regulation No. 26 of 2008 states that the sovereign territory of Indonesia is including the outermost small islands that border directly with neighboring countries and/or the high seas. Therefore, the existence of the outermost and small islands should be maintained by the development priority to the outermost and small islands in Indonesia.

On the other hand, the world is now facing the common threat coming from the global warming. One of the impacts of global warming which possibly threat the existence of small islands is sea level rise (SLR). Global warming causes SLR through 2 mechanisms i.e. the increase of volume and mass of sea water[16]. The increase of water mass is related to the melting ice at the poles and gletser as a direct impact of increasing temperature on earth due to the increase of green house gases concentration in the atmosphere. The increase of volume is related to the sea water heating that causes thermal expansion of water molecule. International Panel on Climate Change reported that in 100 years from 2000, the global sea level increase ranges from 15cm to 95 cm. Furthermore, based on altimetry satellite observations, from 1992 the rate of global SLR is ±3.31 mm/year[1,7,8,11,14]. The spatial distribution of SLR is shown by Willis et al[16].

Among the areas around the world, western equatorial pacific is the area with the highest SLR. The rate of SLR at this area can reach 1 cm/year. Thus, northeastern Indonesia which is part of the western equatorial pacific, faces the most rapid SLR.

Liki, Bepondi and Miossu Islands are the outermost small islands in Indonesia located at the northeastern most of Indonesia at the western equatorial Pacific (Fig. 1). Liki and Bepondi Islands are located at Papua province while Miossu island is at West Papua province. The position of these three islands becomes the baseline for determining Indonesia territory. Thus, the existence of these three islands should be maintained since the position of these islands is vulnerable to the threat of SLR.

Furthermore, since Liki and Bepondi Islands are inhabitant islands, SLR also can be the threat for people living in these islands. In the present study we investigated the potential impact of SLR in threatening the existence of Liki, Bepondi and Miossu islands estimated from remote sensing approach.

Material and Methods

First, we simulated the potential loss of Indonesia territory assuming the disappearance of Liki, Bepondi and Miossu islands. The actual baseline of Indonesia territory is obtained from Information and Geospatial Agency of Indonesia. According to the Law No. 6 of 1996 on Indonesian Waters, The Indonesia territorial line is determined by 12.5 nautical miles from the baseline which is determined by the position of the outermost islands. Assuming the disappearance of the outermost island, the baseline was retreated to the mainland. The potential loss of Indonesia territory was estimated by calculating the areal size of territorial line before and after the disappearance of the outermost island.

For investigating the threat of SLR to the existence of Liki, Bepondi and Miossu islands, we conducted 2 main analysis depicted in fig. 2. The first analysis is calculating the rate of SLR at these three Islands. We used re-processing daily sea level anomalies (SLA) level 4 from multi-mission data result of altimetry satellites provided by Copernicus Marine Environment Monitoring Service[20] with the period of observation from 1993 to 2017. The spatial resolution of this data is 0.25°×0.25°. We composed daily data into yearly data. With the basis of yearly data, we calculated the rate of SLR per year by using simple linear regression:

$$y = ax + b \qquad (1)$$

where y and x are yearly SLA (m) and year respectively. The rate of SLR (m/year) is determined by value of constant ‘a’.

Second analysis is estimating the highest elevation at Liki, Bepondi and Miossu island. To reach these three islands, we joined the research cruise “Baruna Jaya VIII” owned by Research Center for Oceanography, Indonesian Institute of Science in the expedition called “Nusa Manggala”. The aim of this expedition was to explore the potential resources of coastal ecosystem in the outermost small islands at the northeastern Indonesia. We joined the second leg of the cruise from 14 November to 4 December 2018. We used aerial photography taken from drone DJI Phantom 4 Pro with photogrammetry method to generate Digital Surface Model for Liki, Bepondi and Miossu island. The plan was to fly the drone from the beach passing the highest topography until the other side of the beach for several loops with 80% overlapping images.

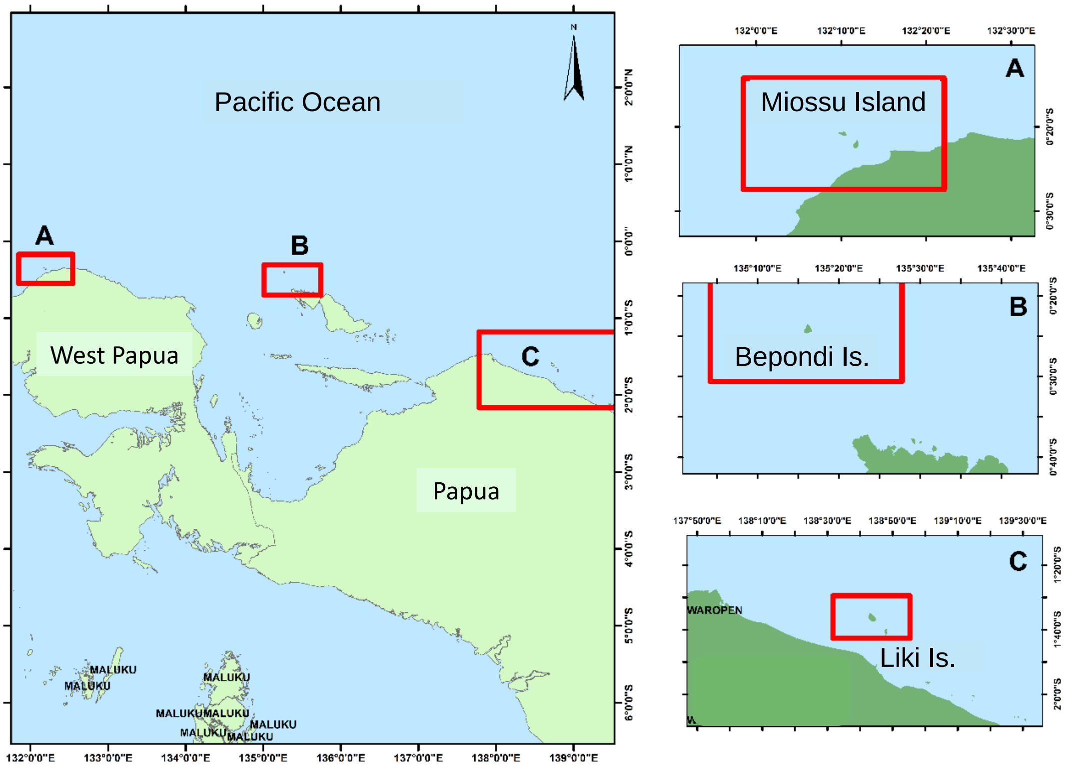

Fig. 1. The position of Liki, Bepondi and Miossu Islands

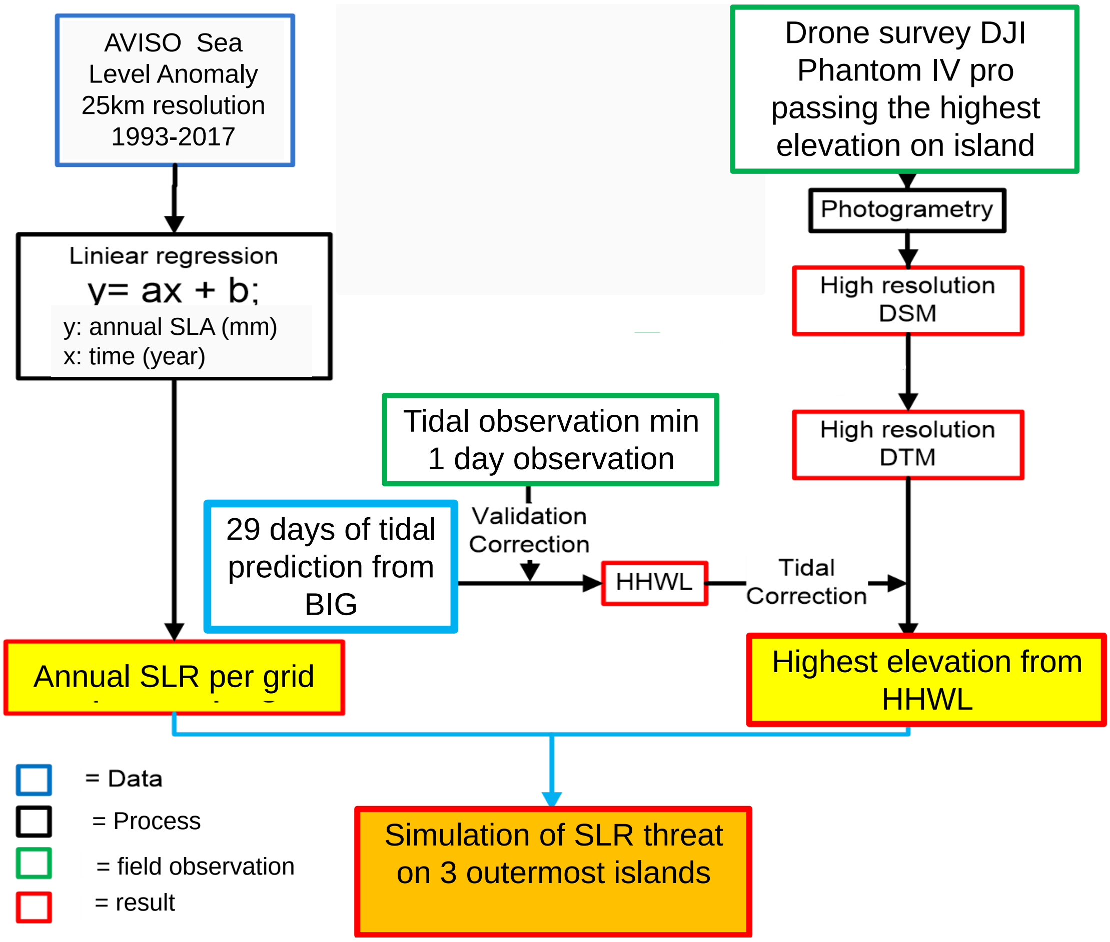

Fig. 2: Research Flowchart

The images of Liki island was taken on 22 November 2018 at 12.00 local time (LT). Drone was taken off from the beach side at position 1°36'9.76" S and 138°44'34.37" E to the highest part of the island. The take off altitude was 280 m. However, the drone could not reach the other side of island due to the limitation of communication signal between the drone and the controller. We collected 345 aerial images at Liki island. At Bepondi island, the drone took off from the highest part of the island at the position 0°24'12.45" S dan 135°16'5.96" E on 26 November 2018 at 15.00 LT. The take off altitude was 50 m. Since it flied from the highest part of the island, the drone managed to capture both side of the beach with 740 aerial images.

The aerial images of Mioussu island were taken on 1 December 2019 at 9.00 LT. The drone took off from the highest part of island at position 0°20'49.33" S dan 132°10'12.91" E with 110 m of take off altitude. We managed to collect 850 aerial images that covered both side of the beach. The aerial images of three islands are then processed to obtain High Resolution Orthoimagery, Digital Surface Model (DSM) and Digital Terrain Model (DTM).

The image processing to produce Orthoimagery, DSM and DTM was conducted by using photogrammetry method[2,10,12]. The three dimension format of geographical location, size and capture of the object were measured by georeferencing orthoimages and Digital Terrain Model[13]. The accuracy of 3D model depends on the distribution of Ground Control Point (GCP)[15]. Kung et al[6] stated that the accuracy of drone photogrammetry with and without GCPs ranges from 0.056m to 1.25 m and from 1.97 to 7.84 m respectively. In the present study, we did not conduct GPS survey for determining GCPs due to the limitation of survey duration. However, the sea side covered by the drone was used as GCP since we assumed that the elevation of sea level is 0 m on both side of the sea. The flowchart of photogrammetry method is shown in fig. 3.

The DTM generated from photogrammetry method was then corrected by tidal data. UNCLOS (1982) article 121 stated that an island is a naturally formed area of land, surrounded by water, which is above water at high tide. Thus, tidal data was used to project the datum of DTM at the position of Highest High Water Level (HHWL). We used 29 days of tidal prediction data provided by the Information and Geospatial Agency of Indonesia[18].

To ensure the accuracy of the tidal prediction data, we compared it with tidal observation data and used the tidal observation data as reference for tidal prediction data. The tidal observation data at Liki Island is recorded by using tide logger RBR Duo at position 1°37'28.48" S dan 138°44'30.62" E for 1.5 days starting from 20 November

2018. At Bepondi Island, we used the tidal observation at the Biak Island owned by Information and Geospatial Agency of Indonesia[19] due to the failure of RBR measurement.

The position of tidal observation at Biak Island is 1.1776°S and 136.056°E. For Miossu island, we used 2 observation data i.e. RBR duo data and visual observation. The position of the observation was 0.35135 °S dan 132.172613° E. The referenced tidal prediction data for each island then was analyzed by using admiralty method to obtain the value of HHWL and other tidal characteristics. DTM for each island was then corrected by HHWL value to obtain the elevation of the islands above highest tide. Finally, we simulated the the impact of SLR for the existence of Liki, Bepondi and Miossu Islands for the next 100 years by using the obtained value of SLR rate and the topography of each island.

Results and Discussion

Potential area loss due to the absence of the outermost small islands: The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands is 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha respectively (Fig. 4). Thus, total potential area loss of Indonesia territory if these three outermost island disappear is 346,462.36 Ha. The loss of the outermost small islands in Indonesia can have juridical consequences for Indonesia's Exclusive Economic Zone (EEZ) with the EEZ of other countries at sea bordering the lost island. Overlapping of boundaries between countries can occur because of the same claim for an area affected by the loss of the island.

The problem of territorial boundaries that might occur as a result of this matter will affect the economic aspects in relation to area management, administrative aspects of government, and the defense/security aspects.

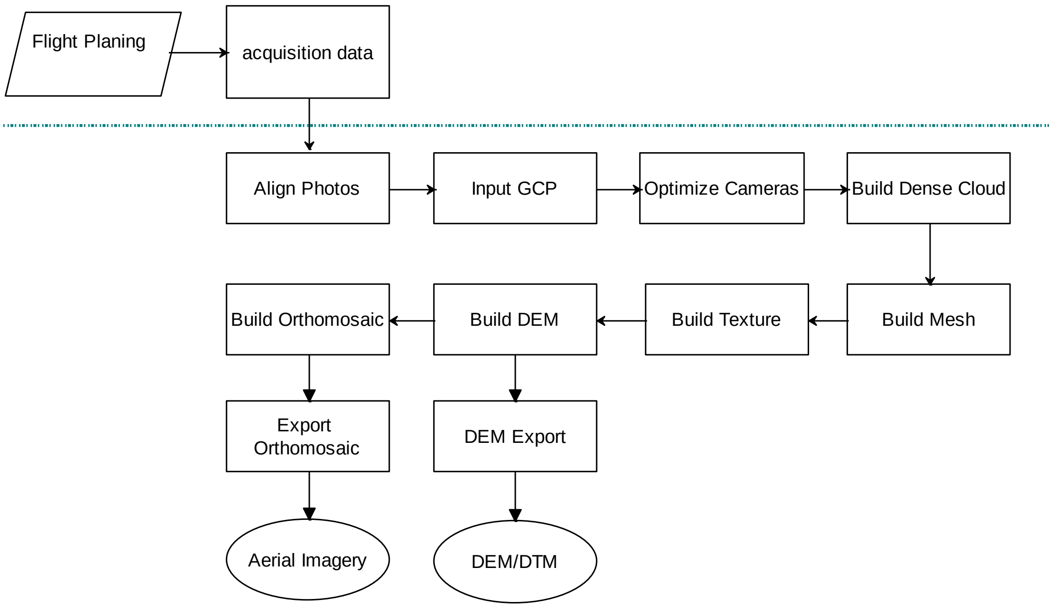

Fig. 3: Flowchart of photogrametry method

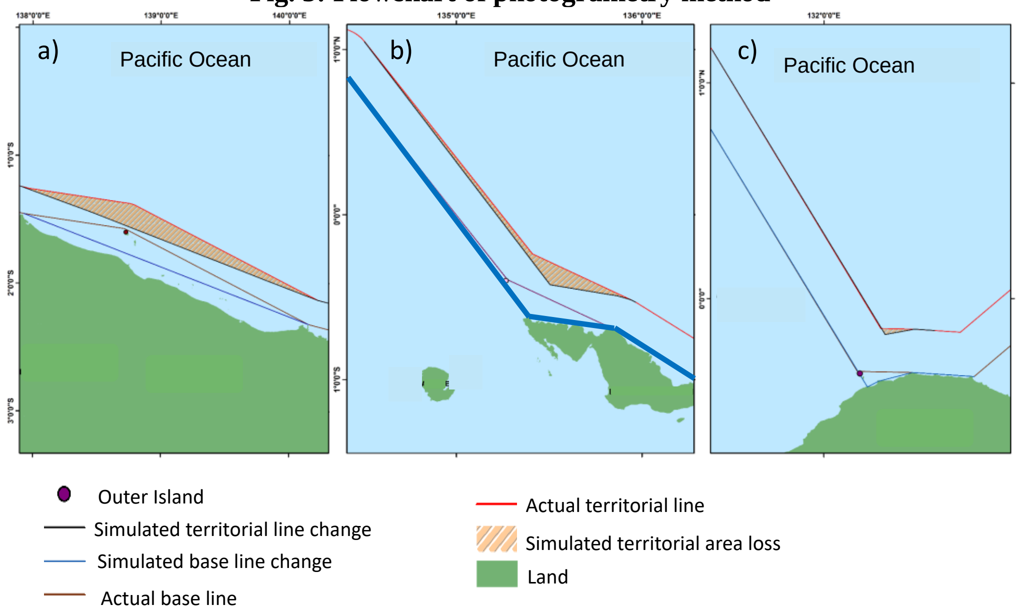

Fig. 4: Simulation of Indonesia territorial change due to the absence of a) Liki, b) Bepondi and c) Miossu Islands.

Determination of continental shelf boundaries can be used as a reference in establishing EEZ. Indonesia has the characteristics of an archipelagic state based on what is stated in Article 46 of UNCLOS, and an archipelagic country has special rights or provisions in determining maritime boundaries, one of which can be seen from the way of establishing archipelagic baselines contained in Article 47 of UNCLOS. Other countries that border directly with Indonesia in general are coastal countries. Determination of the continental shelf boundary between Indonesia and other countries that border directly with Indonesia can refer to Article 76, 77 and 78 of UNCLOS wherein the Article states the coastal state's right to continental shelf.

The solution to the EEZ problem can refer to Article 55 of UNCLOS which states that in determining the EEZ boundaries, a coastal country must be based on the provisions of its rights as a coastal state. Based on this, the problem of the boundaries of Indonesia's EEZ with other coastal countries should be avoided because Indonesia as an archipelagic state has special features in determining maritime boundaries based on UNCLOS.

Sea Level Rise: The distribution of SLR in Indonesian Seas is shown in fig. 5. Most of the area within Indonesian Seas has rate of SLR by more than 4 mm/year. Especially in the Arafura Sea, Savu Sea, Southern coast of Java, and parts of Java Sea have SLR rate by more than 5 mm/s. Along the northern coast of Papua which becomes our study area, the SLR rate is about 4 mm/year. Specifically, for Liki, Bepondi and Miossu, their SLR rates are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year respectively (Fig. 6).

Thus, it can be concluded that SLR rate in Indonesian Seas is higher than the global average i.e. around 2.8 mm/year[7]. Furthermore, fig. 6 also shows yearly variation of SLA from 1993 to 2017. The higher anomaly beyond the regression line is obtained in 1996, 2000, 2001, 2002, 2008, 2011, 2012, and 2013. Conversely, in 1993, 1997, 1998, 2015 and 2016, SLAs tend to be lower than their regression line. These features apply for all three islands. The lower (higher) SLA corresponds to the occurrence of El Nino (La Nina) years which are mentioned in other studies[4,5].

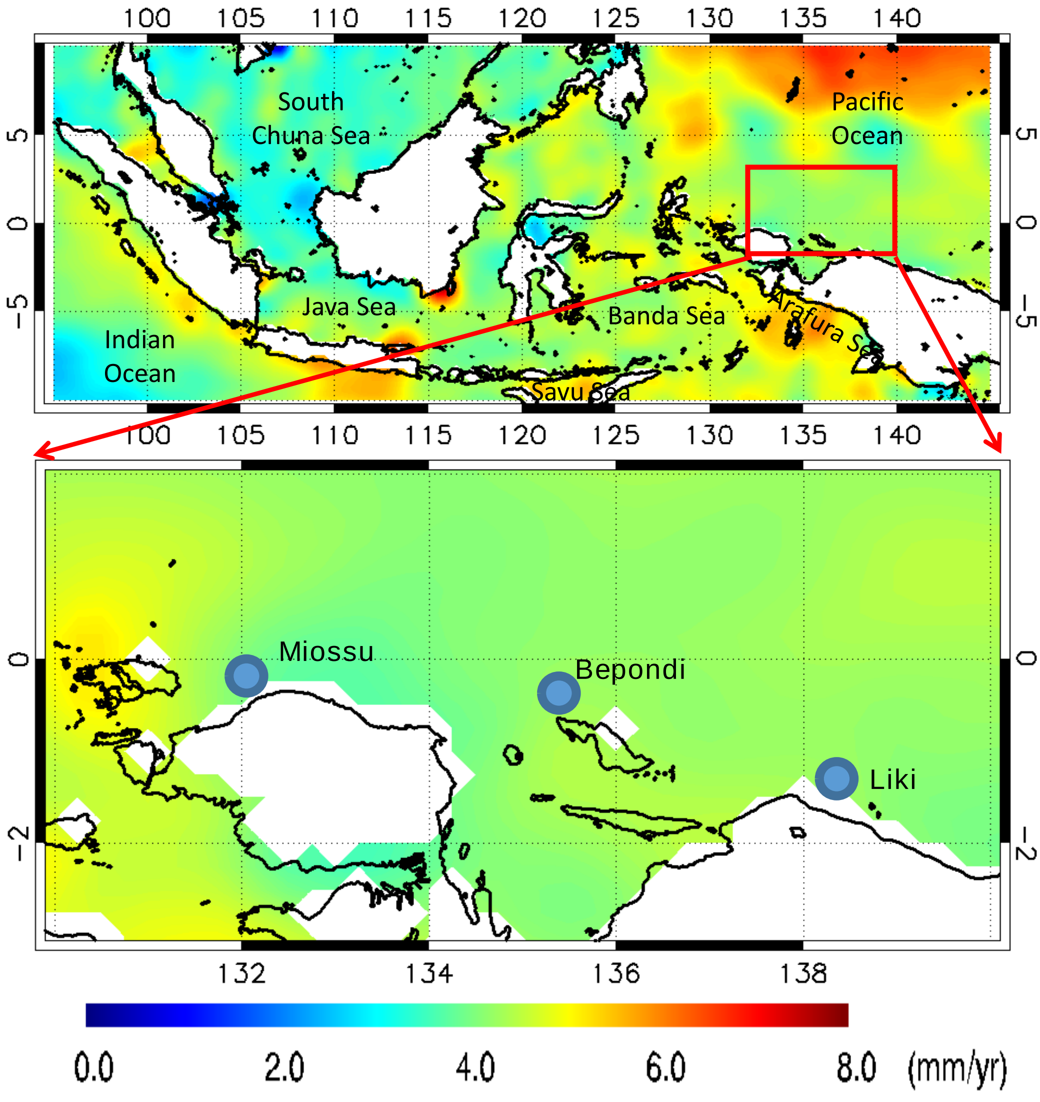

Fig. 5: Distribution of SLR rate in Indonesian Seas and the study area from 1993 to 2017

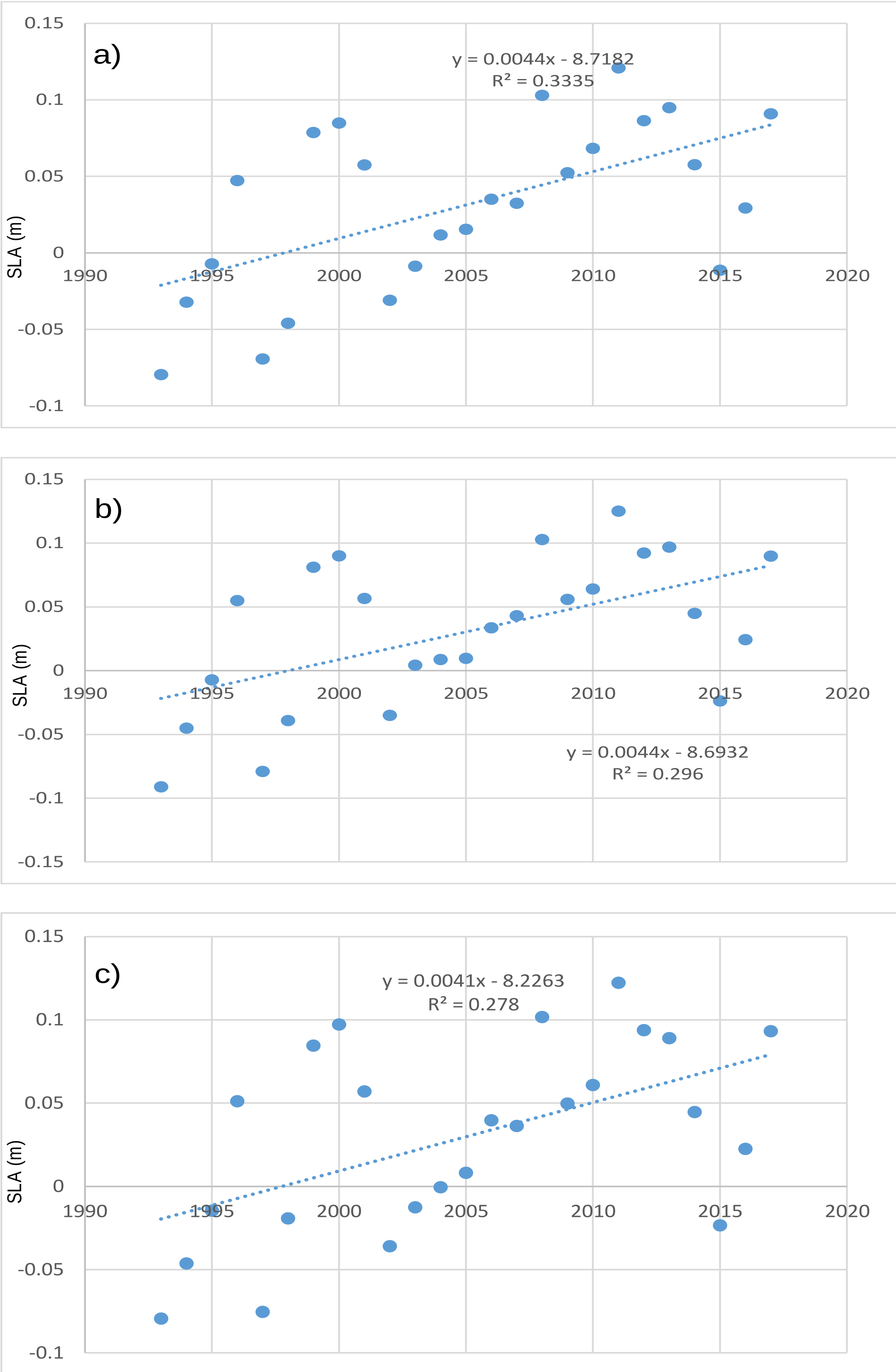

Fig. 6: Linear regression plot of SLR rate at a) Liki, b) Bepondi and c) Miossu Islands

Tidal characteristic: The comparison between tidal prediction data and tidal observation data is shown in fig. 7. Tidal prediction data provided by Information and Geospatial Agency of Indonesia demonstrates good agreements both in amplitude and period with the observational data for three Islands. Next 29 days of tidal prediction data were analyzed by using admiralty method to obtain the vertical datum and tidal type of the seas at Liki, Bepondi dan Miossu Island. HHWL values for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m and 2.66 m respectively.

The list of other vertical datum for three islands is also presented in fig. 5. It is important to note that these vertical datums are based on the local zero reference of the depth of tidal measurement at each island. Thus, these datums are only used for correcting the elevation of three islands. Tidal ranges are 2.0 m, 2.34 m and 2.44 m for Liki, Bepondi and Miossu Islands respectively. The Formzahl values for Liki, Bepondi and Miossu Islands are 0.697, 0.507 and 0.439 respectively. These mean that all three islands have tidal type of mixed prevailing semidiurnal tide.

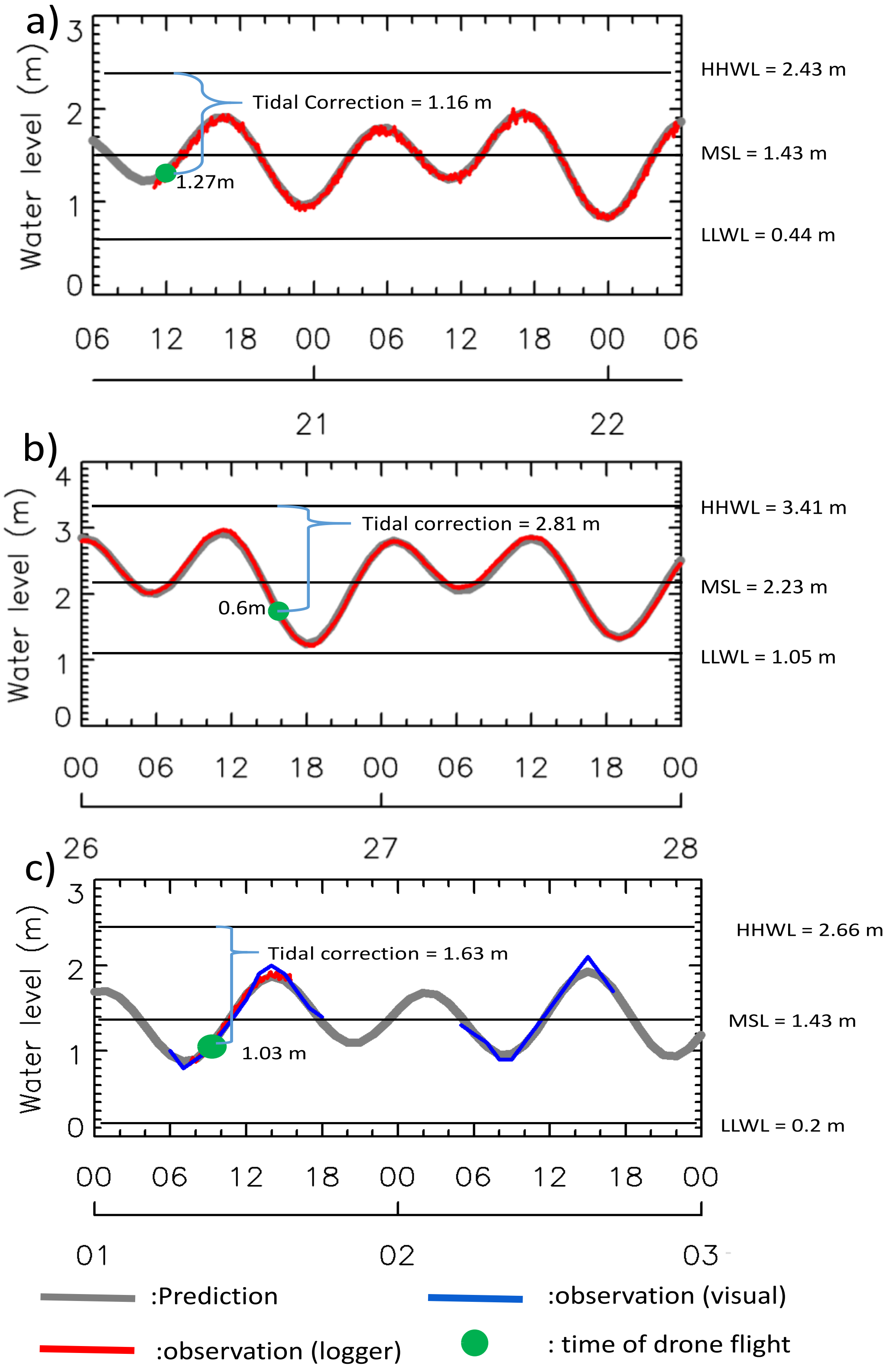

Fig. 7: Tidal data analysis at a) Liki, b) Bepondi and c) Miossu Islands

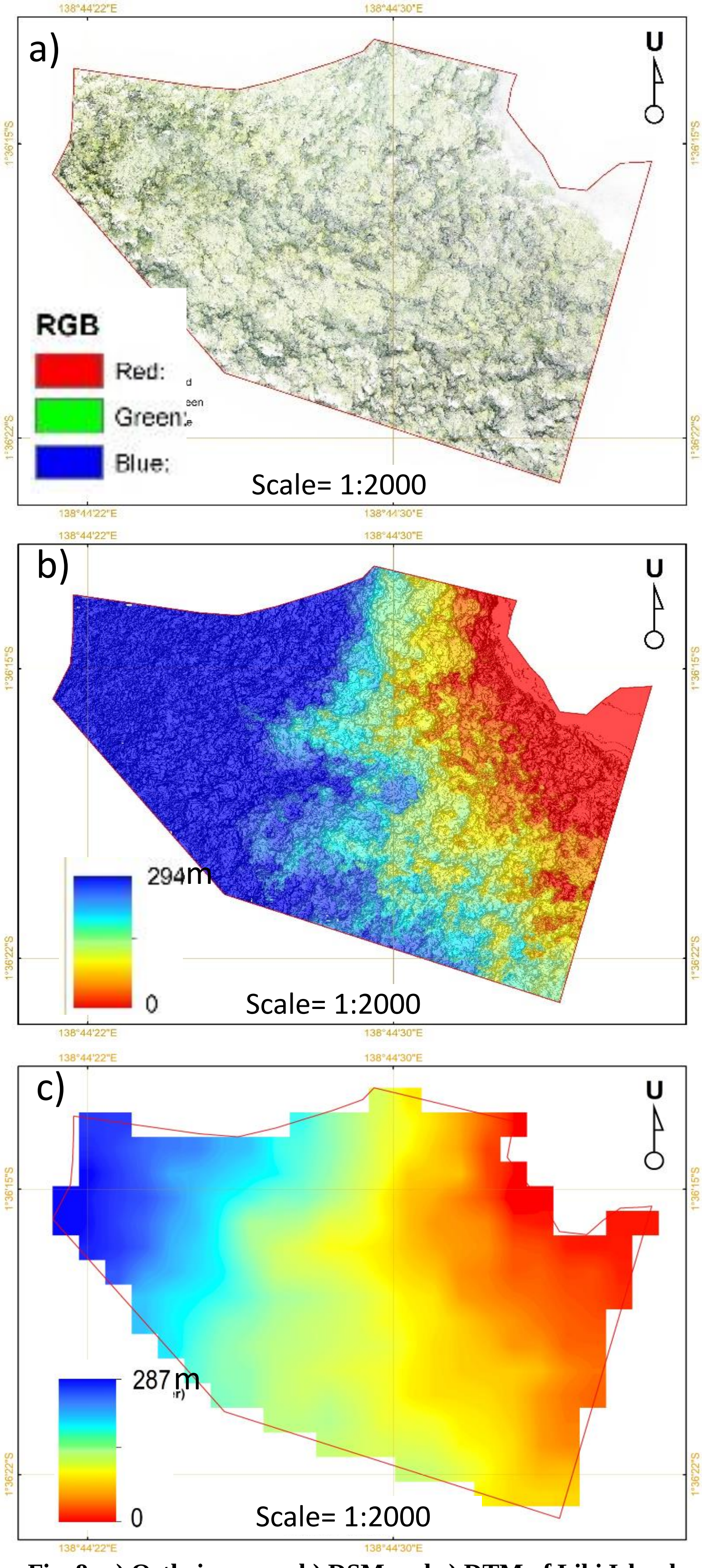

Fig. 8: a) Orthoimagery, b) DSM and c) DTM of Liki Island

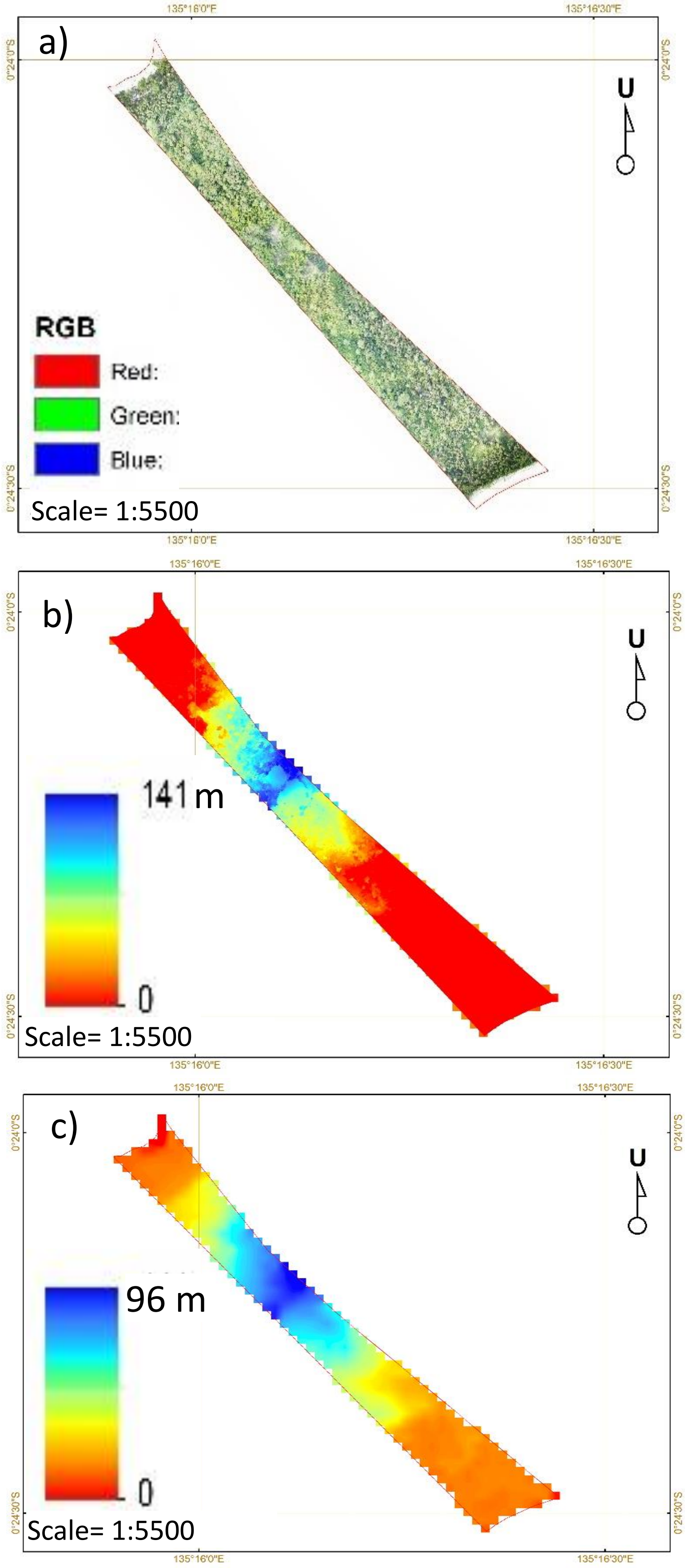

Fig. 9: a) Orthoimagery, b) DSM and c) DTM of Bepondi Island

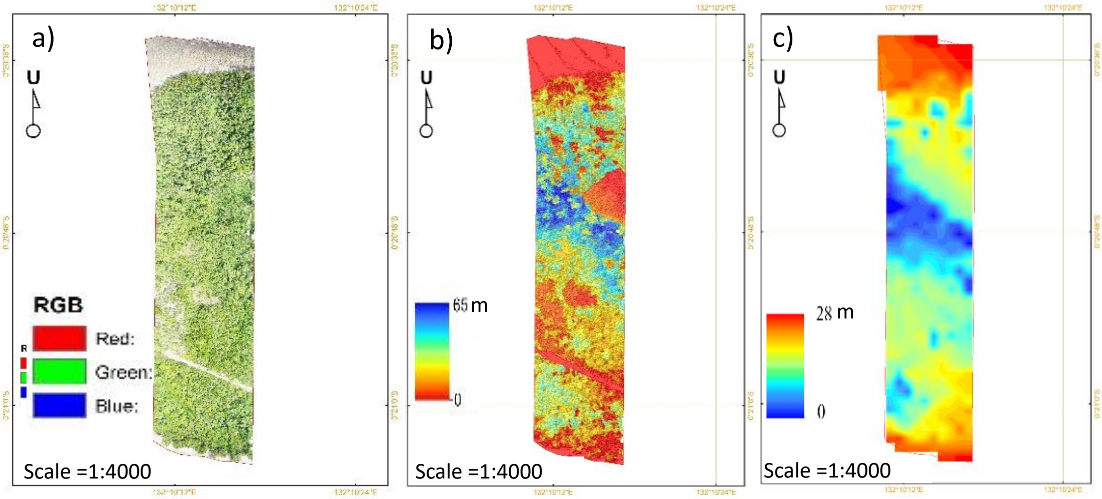

Fig. 10: a) Orthoimagery, b) DSM and c) DTM of Miossu Island

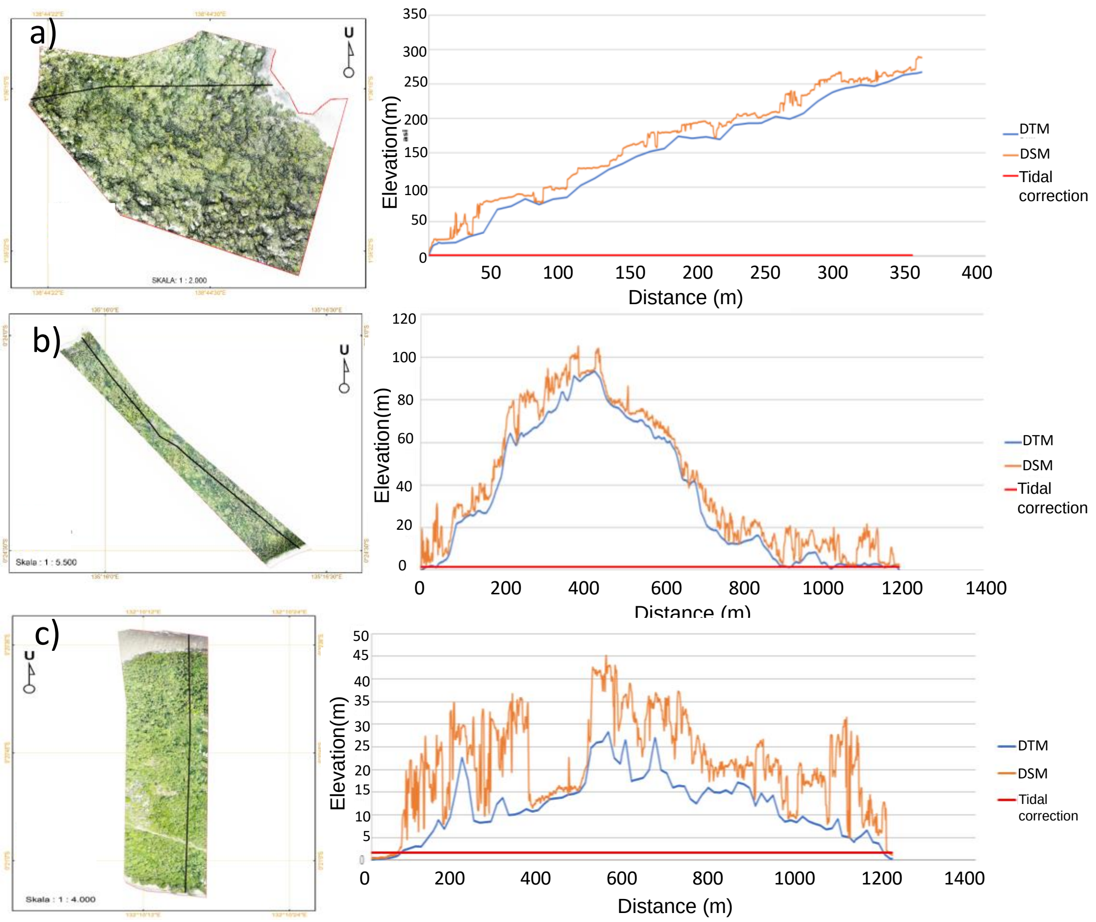

Fig. 11: Cross section of DSM and DSM of a) Liki, b) Bepondi and c) Miossu Islands with simulated tidal correction. Black lines on the left figures represent the cross section line on in the right figures

Topography: The results of photogrametry method are demonstrated in fig. 8, 9, and 10 for Liki, Bepondi and Miossu Islands respectively. Fig. 8a, 9a and 10a show the orthophotos of each island in true color image passing the highest area of each island. Vegetation can be easily identified by the greenish color and the beach side is denoted by the white color. High resolution DSM of each island is shown in fig. 8b, 9b, and 10b for Liki, Bepondi and Miossu Island respectively. Since the land cover of the three islands is dominated by vegetation, ground elevation cannot be represented by DSM. In the vegetated area, DSM refers to the elevation of tree canopy. To obtain the ground elevation, DSM was converted to DTM by auto assessment of land pixels and interpolation process.

DTM of each island is presented in fig. 8c, 9c, and 10c. Fig. 11 shows the cross section of DTM and DSM passing the highest elevation of each island. The maximum elevations of

Liki, Bepondi and Miossu Islands are 267 m, 106 m and 28 m respectively. However, it is important to be noted that these highest elevation values were measured from the sea level at the time when the drone was flying. These values are then corrected HHWL value. The simulation of tidal correction is depicted in fig. 7. The maximum elevation of Liki, Bepondi and Miossu Islands above the highest tide are 265.84 m, 103.19 m, and 26.37 m respectively.

Simulation of SLR threat to the existence of outermost islands: Taking back the earlier result, the prediction of SLR in the next 100 years in Liki, Bepondi and Miossu Islands is only 40 cm. This value is not comparable with the elevation of these three islands. Therefore, the threat of SLR to the existence of Liki, Bepondi and Miossu Islands is small.

However, it is important to be noted that since Liki and Bepondi Island are inhabitant islands and major human activities occur in the coastal plain, SLR may threat the people living in Liki and Bepondi Islands. For example, we conducted the levelling measurement by using water pass method to obtain the elevation of benchmark located in the housing area of Liki Island. The elevation of bench mark is only 29 cm from HHWL. This means that in the next 100 years, the housing area can be inundated as an impact of SLR. Furthermore, Feagin et al[3] stated that SLR may worsen the coastal erosion due to change of ocean wave and current pattern. However, this possibility still needs to be examined further by focusing the investigation on the coastal plain where most people are living there.

Conclusion

The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands are 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha respectively. SLR rates for Liki, Bepondi and Miossu Islands are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year respectively. HHWL value for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m and 2.66 m respectively. The tidal type pf these three islands is mixed prevailing semidiurnal tide.

The highest elevation of Liki, Bepondi and Miossu islands from HHWL is 265.84 m, 103.19 m, and 26.37 m respectively. Considering the rate of SLR and the elevation of the islands, it can be concluded that there is no threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia.

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References

1. Ablain M., Cazenave A., Guinehut S. and Valladeau G., A new assessment of global mean sea level from altimeters highlights a reduction of global slope from 2005 to 2008 in agreement with in-situ measurements, *Ocean Sci.*, **5,** 193–201 **(2009)**

2. Cunliffe A.M., Brazier R.E. and Anderson K., Remote Sensing of Environment Ultra- fi ne grain landscape-scale quanti fi cation of dryland vegetation structure with drone-acquired structure-from-motion photogrammetry, *Remote Sensing of Environment*, https://doi.org/10.1016/j.rse.2016.05.019, **183**, 129–143 **(2016)**

3. Feagin R.A., Sherman D.J. and Grant W.E., Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats, *Frontiers in Ecology and the Environment*, https://doi.org/10.1890/1540-9295(2005)003[0359:CEGSRA] 2.0.CO;2, **3(7)**, 359-364 **(2005)**

4. Handoko E.Y., Hariyadi H. and Wirasatriya A., The ENSO's Influence on the Indonesian Sea Level Observed Using Satellite Altimetry, 1993 - 2016, 2018 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology **(2019)**

5. Kismawardhani R.A., Wirasatriya A. and Berliant D., Sea Level Rise in The Java Sea Based on Altimetry Satellites Data Over 1993-2015, *IOP Conf. Series: Earth and Environmental Science*, doi :10.1088/1755-1315/165/1/012006, **165**, 012006 **(2018)**

6. Kung O., Strecha C., Beyeler A., Zufferey J.C., Floreano D., Fua P. and Gervaix F., The accuracy of automatic photogrametric techniques on Ultra-light UAV Imagery, In IAPRS, Proceedings of the International Conference on Unmanned Aerial Vehicle in Geomatics (UAV-g), Zurich, Switzerland, 14–16 September 2011, 38 **(2011)**

7. Kuo C.Y., Determination and Characterization of 20th Century Global Sea Level Rise, Ohio State University Report No. 478 **(2006)**

8. Leuliette E. and Scharroo R., Integrating Jason-2 into a multiple-altimeter climate data record, *Marine Geodesy*, doi:10.1080/01490419.2010.487795, **33,** 504–517 **(2010)**

9. Li X., Shen H., Feng R., Li J. and Zhang L., DEM generation from contours and a low-resolution DEM, *ISPRS Journal of Photogrammetry and Remote Sensing*, https://doi.org/10.1016/j.isprsjprs.2017.09.014, **134**, 135–147 **(2017)**

10. Mouloua S.A., Ferraro J., Mouloua M., Hancock P.A. and Florida C., Trend analysis of Unmanned Aerial Vehicles (UAV), The HFES Proceedings, https://doi.org/10.1177/1541931218621 2451067–1071 **(2018)**

11. Nerem R.S., Chambers D.P, Choe C. and Mitchum G.T., Estimating mean sea level change from the TOPEX and Jason altimeter missions, *Marine Geodesy*, doi:10.1080/01490419.2010.49103, **33**, 435–446 **(2010)**

12. Polat N. and Murat U., An Experimental Analysis of Digital Elevation Models Generated with Lidar Data and UAV Photogrammetry, *Journal of the Indian Society of Remote Sensing*, https://doi.org/10.1007/s12524-018-0760-8, **8 (2018)**

13. Sammartano G. and Spanò A., DEM Generation based on UAV

Photogrammetry Data in Critical Areas, In Proceedings of the 2nd International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2016), https://doi.org/10.5220/0005918400920098, 92-98 **(2016)**

14. Shum C. and Kuo C., Observation and geophysical causes of present-day sea level rise, Chapter 7 in Climate Change and Food Security in South Asia, Lal R., Sivakumar M., Faiz S.M.A., Mustafizur Rahman A.H.M. and Islam K.R., eds., Springer Verlag, Holland **(2010)**

15. Suh J. and Choi Y., Mapping hazardous mining-induced sinkhole subsidence using unmanned aerial vehicle (drone) photogrammetry, *Environmental Earth Sciences*, https://doi.org/ 10.1007/s12665-017-6458-3 **(2017)**

16. Willis J.K., Chambers D.P., Kuo C.Y. and Shum C.K., Global Sea Level Rise; Recent Progress and Challenges for The Decade to Come, *Oceanography*, **23(4)**, 26-35 **(2010)**

17. http://www.big.go.id (Year)

18. http://tides.big.go.id/pasut/ (Year)

19. http://ina-sealevelmonitoring.big.go.id/ipasoet/ (Year)

20. http://marine.copernicus.eu/ (Year).

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Lampiran 5

Re: Corrections

From: anindya wirasatriya (aninosi@yahoo.co.id)

To: info@worldresearchersassociations.com

Date: Tuesday, November 24, 2020, 09:09 PM GMT+7

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Estimation of Sea Level Rise threat on the existence of the three northeastern and outermost small islands of Indonesia (i.e. Liki, Bepondi and Miossu Islands) using remote sensing method

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Abstract

The outermost small islands determine the territorial boundary of Indonesia. Liki, Bepondi and Miossu Islands are the three northeastern and outermost small islands of Indonesia located in the northern part of Papua Island. On the other hand, sea level rise as an impact of global warming has threatened the existence of small islands around the world. In the present study, the threat of sea level rise (SLR) on the existence of those Islands is estimated from remote sensing method which is very useful for quick assessment. We use drone photography with photogrametry method to estimate the elevation of the three Islands. These elevations were corrected by tidal data to estimate the elevation above highest high water level.

The linear regression assumption of 25 years sea level anomaly data obtained from altimetry satellite from 1993-2017 was calculated to analyze the rate of SLR. The elevations above highest high water level for Liki, Bepondi and Miossu Islands are 265.84 m, 103.19 m, and 26.37 m respectively. With the rate of sea level rise of 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year, the threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia is small.

Keywords: Sea Level Rise, Liki Island, Bepondi Island, Miossu Island.

Introduction

Indonesia is the biggest archipelagic state in the world with 16,056 islands spread within Indonesia region. As in 2017, this number of named and positioned islands has been officially registered to the United Nations by the Information and Geospatial Agency of Indonesia[17]. As an archipelagic state, Indonesian region borders to 10 other countries whereas most parts of the border area consist of outermost small islands. The Presidential Decree No. 6 of 2017 has established as many as 111 islands as outermost small islands in Indonesia. The Government Regulation No. 62 of 2010 on The Use of Outermost Small Islands stated that a small island is an island with an area smaller or equal to 2000 Km^2 including its ecosystem unity.

The outer small islands are small islands which have basic geographical coordinates that connect the archipelagic sea baseline in accordance with international and national law. Furthermore, Government Regulation No. 26 of 2008 states that the sovereign territory of Indonesia is including the outermost small islands that border directly with neighboring countries and/or the high seas. Therefore, the existence of the outermost and small islands should be maintained by the development priority to the outermost and small islands in Indonesia.

On the other hand, the world is now facing the common threat coming from the global warming. One of the impacts of global warming which possibly threat the existence of small islands is sea level rise (SLR). Global warming causes SLR through 2 mechanisms i.e. the increase of volume and mass of sea water[16]. The increase of water mass is related to the melting ice at the poles and gletser as a direct impact of increasing temperature on earth due to the increase of green house gases concentration in the atmosphere. The increase of volume is related to the sea water heating that causes thermal expansion of water molecule. International Panel on Climate Change reported that in 100 years from 2000, the global sea level increase ranges from 15cm to 95 cm. Furthermore, based on altimetry satellite observations, from 1992 the rate of global SLR is ±3.31 mm/year[1,7,8,11,14]. The spatial distribution of SLR is shown by Willis et al[16].

Among the areas around the world, western equatorial pacific is the area with the highest SLR. The rate of SLR at this area can reach 1 cm/year. Thus, northeastern Indonesia which is part of the western equatorial pacific, faces the most rapid SLR.

Liki, Bepondi and Miossu Islands are the outermost small islands in Indonesia located at the northeastern most of Indonesia at the western equatorial Pacific (Fig. 1). Liki and Bepondi Islands are located at Papua province while Miossu island is at West Papua province. The position of these three islands becomes the baseline for determining Indonesia territory. Thus, the existence of these three islands should be maintained since the position of these islands is vulnerable to the threat of SLR.

Furthermore, since Liki and Bepondi Islands are inhabitant islands, SLR also can be the threat for people living in these islands. In the present study we investigated the potential impact of SLR in threatening the existence of Liki, Bepondi and Miossu islands estimated from remote sensing approach.

Material and Methods

First, we simulated the potential loss of Indonesia territory assuming the disappearance of Liki, Bepondi and Miossu islands. The actual baseline of Indonesia territory is obtained from Information and Geospatial Agency of Indonesia. According to the Law No. 6 of 1996 on Indonesian Waters, The Indonesia territorial line is determined by 12.5 nautical miles from the baseline which is determined by the position of the outermost islands. Assuming the disappearance of the outermost island, the baseline was retreated to the mainland. The potential loss of Indonesia territory was estimated by calculating the areal size of territorial line before and after the disappearance of the outermost island.

For investigating the threat of SLR to the existence of Liki, Bepondi and Miossu islands, we conducted 2 main analysis depicted in fig. 2. The first analysis is calculating the rate of SLR at these three Islands. We used re-processing daily sea level anomalies (SLA) level 4 from multi-mission data result of altimetry satellites provided by Copernicus Marine Environment Monitoring Service[20] with the period of observation from 1993 to 2017. The spatial resolution of this data is 0.25°×0.25°. We composed daily data into yearly data. With the basis of yearly data, we calculated the rate of SLR per year by using simple linear regression:

$$y = ax + b \qquad (1)$$

where y and x are yearly SLA (m) and year respectively. The rate of SLR (m/year) is determined by value of constant ‘a’.

Second analysis is estimating the highest elevation at Liki, Bepondi and Miossu island. To reach these three islands, we joined the research cruise “Baruna Jaya VIII” owned by Research Center for Oceanography, Indonesian Institute of Science in the expedition called “Nusa Manggala”. The aim of this expedition was to explore the potential resources of coastal ecosystem in the outermost small islands at the northeastern Indonesia. We joined the second leg of the cruise from 14 November to 4 December 2018. We used aerial photography taken from drone DJI Phantom 4 Pro with photogrammetry method to generate Digital Surface Model for Liki, Bepondi and Miossu island. The plan was to fly the drone from the beach passing the highest topography until the other side of the beach for several loops with 80% overlapping images.

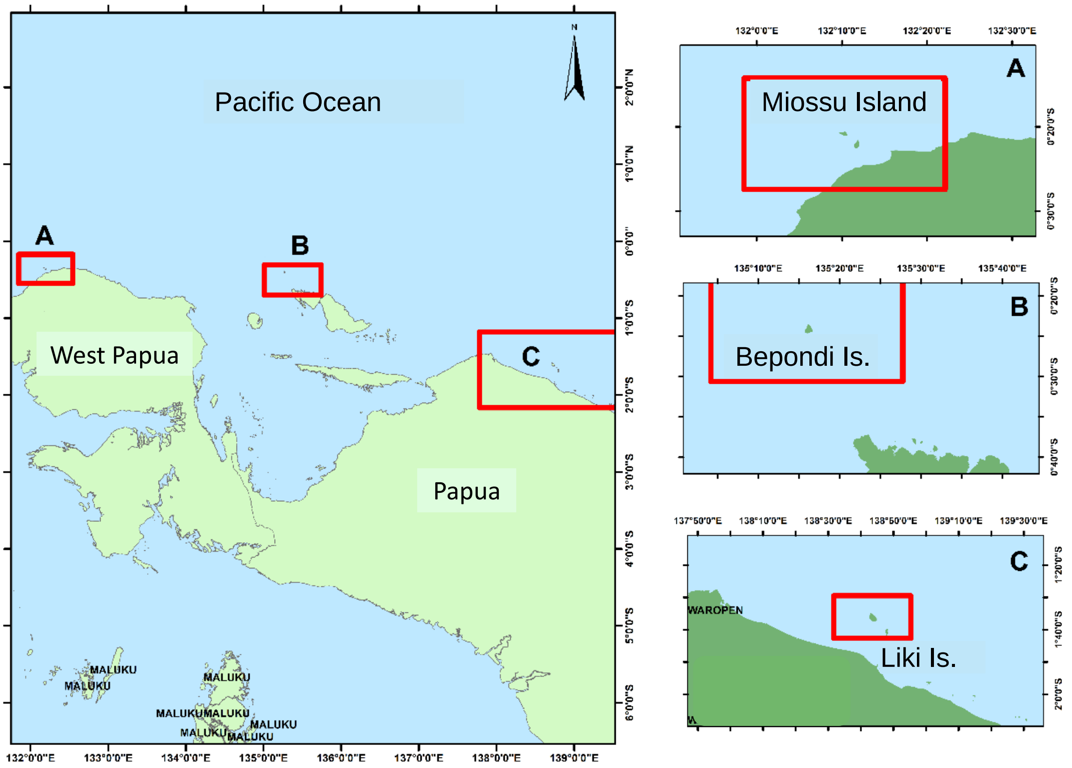

Fig. 1. The position of Liki, Bepondi and Miossu Islands

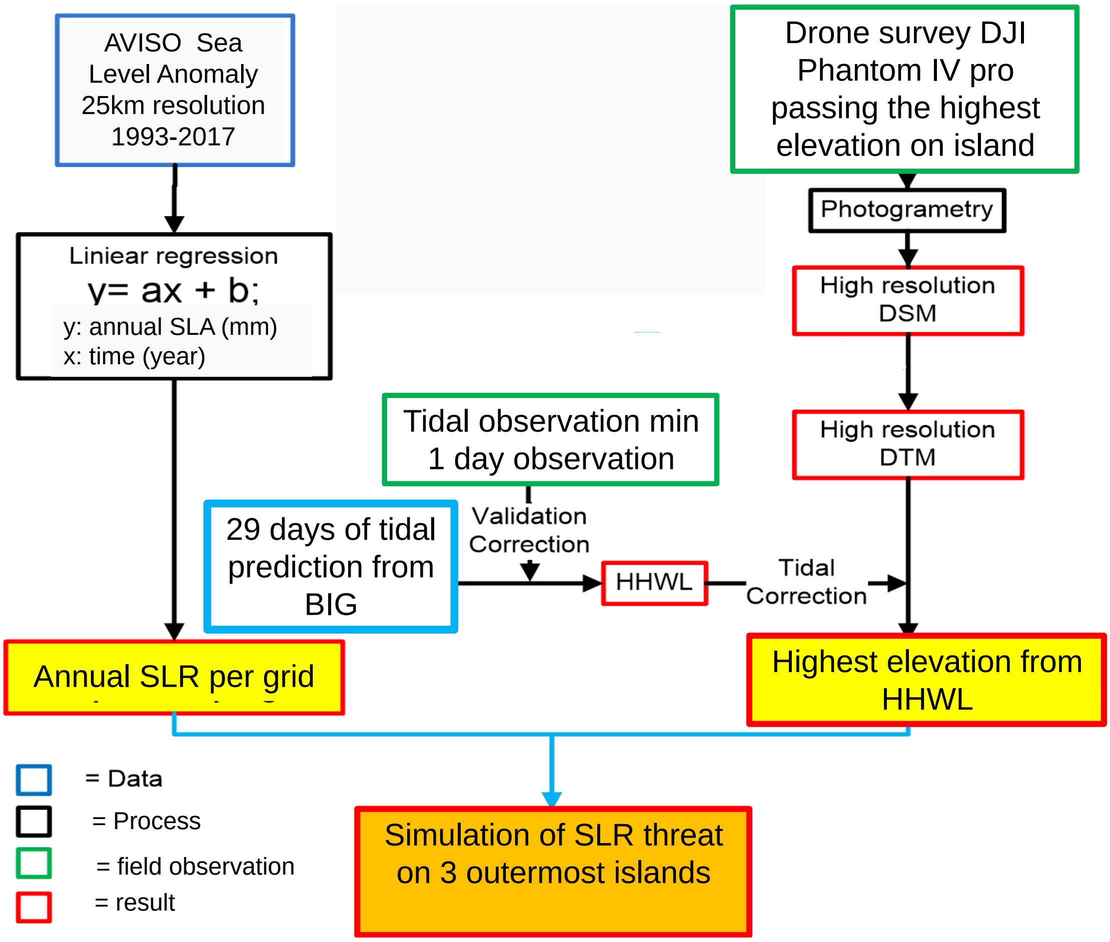

Fig. 2: Research Flowchart

The images of Liki island was taken on 22 November 2018 at 12.00 local time (LT). Drone was taken off from the beach side at position 1°36'9.76" S and 138°44'34.37" E to the highest part of the island. The take off altitude was 280 m. However, the drone could not reach the other side of island due to the limitation of communication signal between the drone and the controller. We collected 345 aerial images at Liki island. At Bepondi island, the drone took off from the highest part of the island at the position 0°24'12.45" S dan 135°16'5.96" E on 26 November 2018 at 15.00 LT. The take off altitude was 50 m. Since it flied from the highest part of the island, the drone managed to capture both side of the beach with 740 aerial images.

The aerial images of Mioussu island were taken on 1 December 2018 at 9.00 LT. The drone took off from the highest part of island at position 0°20'49.33" S dan 132°10'12.91" E with 110 m of take off altitude. We managed to collect 850 aerial images that covered both side of the beach. The aerial images of three islands are then processed to obtain High Resolution Orthoimagery, Digital Surface Model (DSM) and Digital Terrain Model (DTM).

The image processing to produce Orthoimagery, DSM and DTM was conducted by using photogrammetry method[2,10,12]. The three dimension format of geographical location, size and capture of the object were measured by georeferencing orthoimages and Digital Terrain Model[13]. The accuracy of 3D model depends on the distribution of Ground Control Point (GCP)[15]. Kung et al[6] stated that the accuracy of drone photogrammetry with and without GCPs ranges from 0.056m to 1.25 m and from 1.97 to 7.84 m respectively. In the present study, we did not conduct GPS survey for determining GCPs due to the limitation of survey duration. However, the sea side covered by the drone was used as GCP since we assumed that the elevation of sea level is 0 m on both side of the sea. The flowchart of photogrametry method is shown in fig. 3.

The DTM generated from photogrametry method was then corrected by tidal data. UNCLOS (1982) article 121 stated that an island is a naturally formed area of land, surrounded by water, which is above water at high tide. Thus, tidal data was used to project the datum of DTM at the position of Highest High Water Level (HHWL). We used 29 days of tidal prediction data provided by the Information and Geospatial Agency of Indonesia[18].

To ensure the accuracy of the tidal prediction data, we compared it with tidal observation data and used the tidal observation data as reference for tidal prediction data. The tidal observation data at Liki Island is recorded by using tide logger RBR Duo at position 1°37'28.48" S dan 138°44'30.62" E for 1.5 days starting from 20 November

2018. At Bepondi Island, we used the tidal observation at the Biak Island owned by Information and Geospatial Agency of Indonesia[19] due to the failure of RBR measurement.

The position of tidal observation at Biak Island is 1.1776°S and 136.056°E. For Miossu island, we used 2 observation data i.e. RBR duo data and visual observation. The position of the observation was 0.35135 °S dan 132.172613° E. The referenced tidal prediction data for each island then was analyzed by using admiralty method to obtain the value of HHWL and other tidal characteristics. DTM for each island was then corrected by HHWL value to obtain the elevation of the islands above highest tide. Finally, we simulated the the impact of SLR for the existence of Liki, Bepondi and Miossu Islands for the next 100 years by using the obtained value of SLR rate and the topography of each island.

Results and Discussion

Potential area loss due to the absence of the outermost small islands: The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands is 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha respectively (Fig. 4). Thus, total potential area loss of Indonesia territory if these three outermost island disappear is 346,462.36 Ha. The loss of the outermost small islands in Indonesia can have juridical consequences for Indonesia's Exclusive Economic Zone (EEZ) with the EEZ of other countries at sea bordering the lost island. Overlapping of boundaries between countries can occur because of the same claim for an area affected by the loss of the island.

The problem of territorial boundaries that might occur as a result of this matter will affect the economic aspects in relation to area management, administrative aspects of government, and the defense/security aspects.

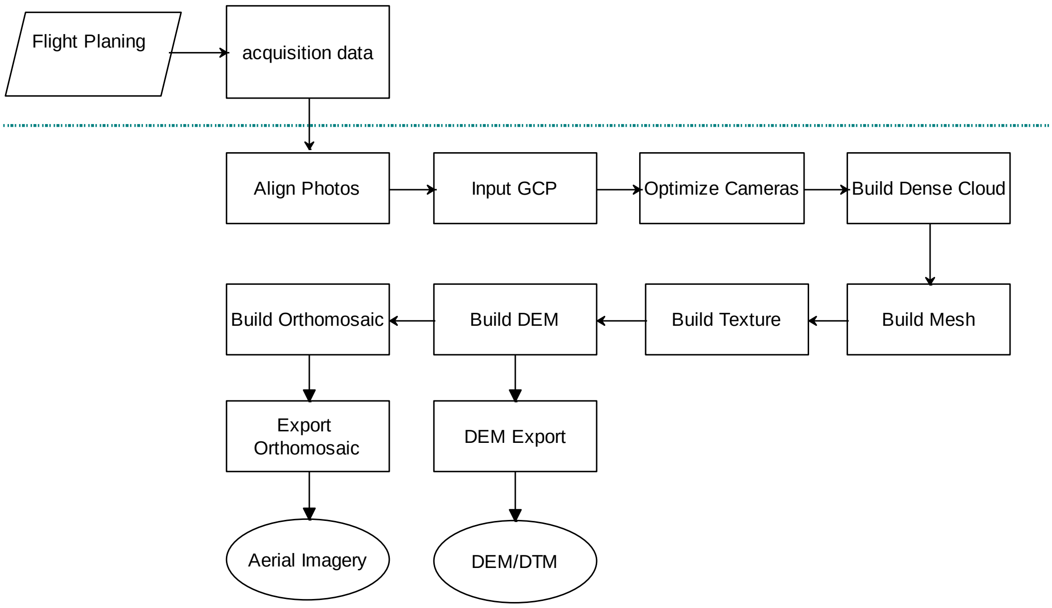

Fig. 3: Flowchart of photogrametry method

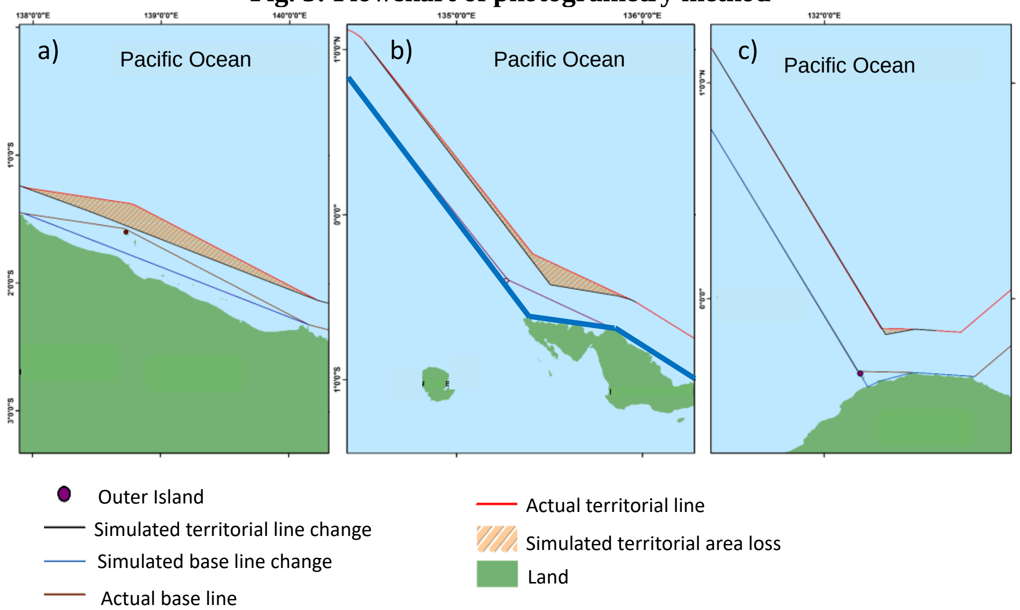

Fig. 4: Simulation of Indonesia territorial change due to the absence of a) Liki, b) Bepondi and c) Miossu Islands.

Determination of continental shelf boundaries can be used as a reference in establishing EEZ. Indonesia has the characteristics of an archipelagic state based on what is stated in Article 46 of UNCLOS, and an archipelagic country has special rights or provisions in determining maritime boundaries, one of which can be seen from the way of establishing archipelagic baselines contained in Article 47 of UNCLOS. Other countries that border directly with Indonesia in general are coastal countries. Determination of the continental shelf boundary between Indonesia and other countries that border directly with Indonesia can refer to Article 76, 77 and 78 of UNCLOS wherein the Article states the coastal state's right to continental shelf.

The solution to the EEZ problem can refer to Article 55 of UNCLOS which states that in determining the EEZ boundaries, a coastal country must be based on the provisions of its rights as a coastal state. Based on this, the problem of the boundaries of Indonesia's EEZ with other coastal countries should be avoided because Indonesia as an archipelagic state has special features in determining maritime boundaries based on UNCLOS.

Sea Level Rise: The distribution of SLR in Indonesian Seas is shown in fig. 5. Most of the area within Indonesian Seas has rate of SLR by more than 4 mm/year. Especially in the Arafura Sea, Savu Sea, Southern coast of Java, and parts of Java Sea have SLR rate by more than 5 mm/s. Along the northern coast of Papua which becomes our study area, the SLR rate is about 4 mm/year. Specifically, for Liki, Bepondi and Miossu, their SLR rates are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year respectively (Fig. 6).

Thus, it can be concluded that SLR rate in Indonesian Seas is higher than the global average i.e. around 2.8 mm/year[7]. Furthermore, fig. 6 also shows yearly variation of SLA from 1993 to 2017. The higher anomaly beyond the regression line is obtained in 1996, 2000, 2001, 2002, 2008, 2011, 2012, and 2013. Conversely, in 1993, 1997, 1998, 2015 and 2016, SLAs tend to be lower than their regression line. These features apply for all three islands. The lower (higher) SLA corresponds to the occurrence of El Nino (La Nina) years which are mentioned in other studies[4,5].

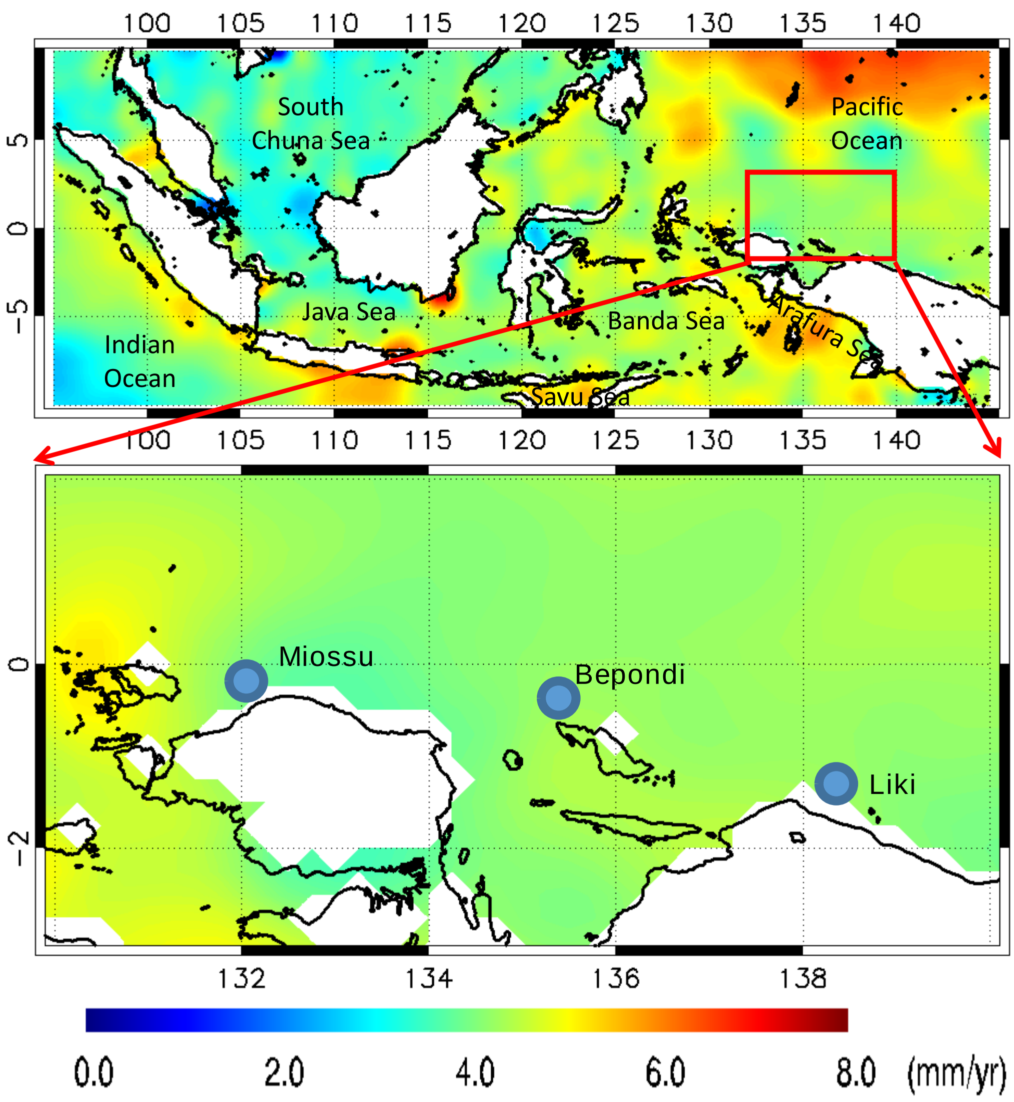

Fig. 5: Distribution of SLR rate in Indonesian Seas and the study area from 1993 to 2017

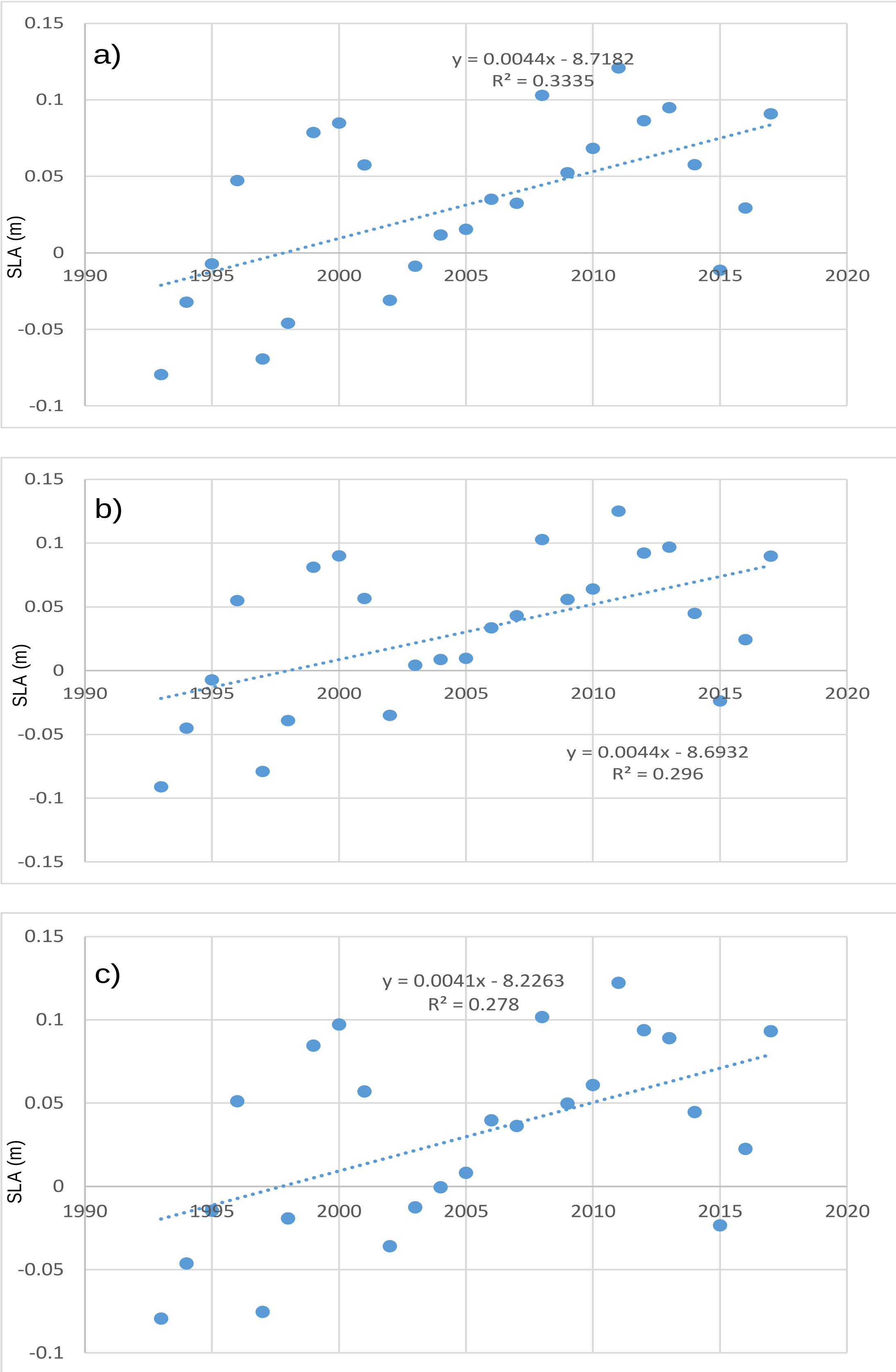

Fig. 6: Linear regression plot of SLR rate at a) Liki, b) Bepondi and c) Miossu Islands

Tidal characteristic: The comparison between tidal prediction data and tidal observation data is shown in fig. 7. Tidal prediction data provided by Information and Geospatial Agency of Indonesia demonstrates good agreements both in amplitude and period with the observational data for three Islands. Next 29 days of tidal prediction data were analyzed by using admiralty method to obtain the vertical datum and tidal type of the seas at Liki, Bepondi dan Miossu Island. HHWL values for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m and 2.66 m respectively.

The list of other vertical datum for three islands is also presented in fig. 5. It is important to note that these vertical datums are based on the local zero reference of the depth of tidal measurement at each island. Thus, these datums are only used for correcting the elevation of three islands. Tidal ranges are 2.0 m, 2.34 m and 2.44 m for Liki, Bepondi and Miossu Islands respectively. The Formzahl values for Liki, Bepondi and Miossu Islands are 0.697, 0.507 and 0.439 respectively. These mean that all three islands have tidal type of mixed prevailing semidiurnal tide.

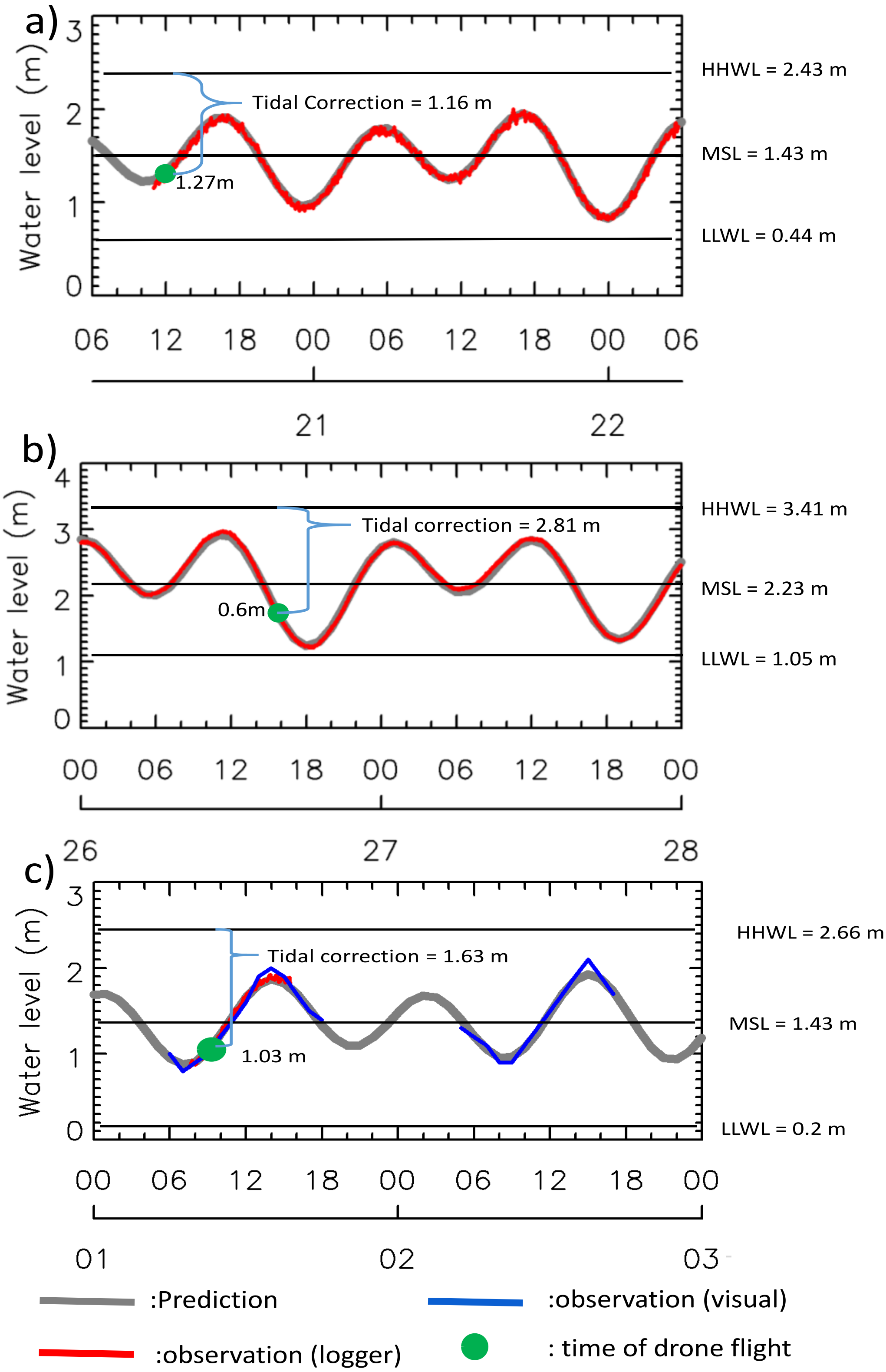

Fig. 7: Tidal data analysis at a) Liki, b) Bepondi and c) Miossu Islands

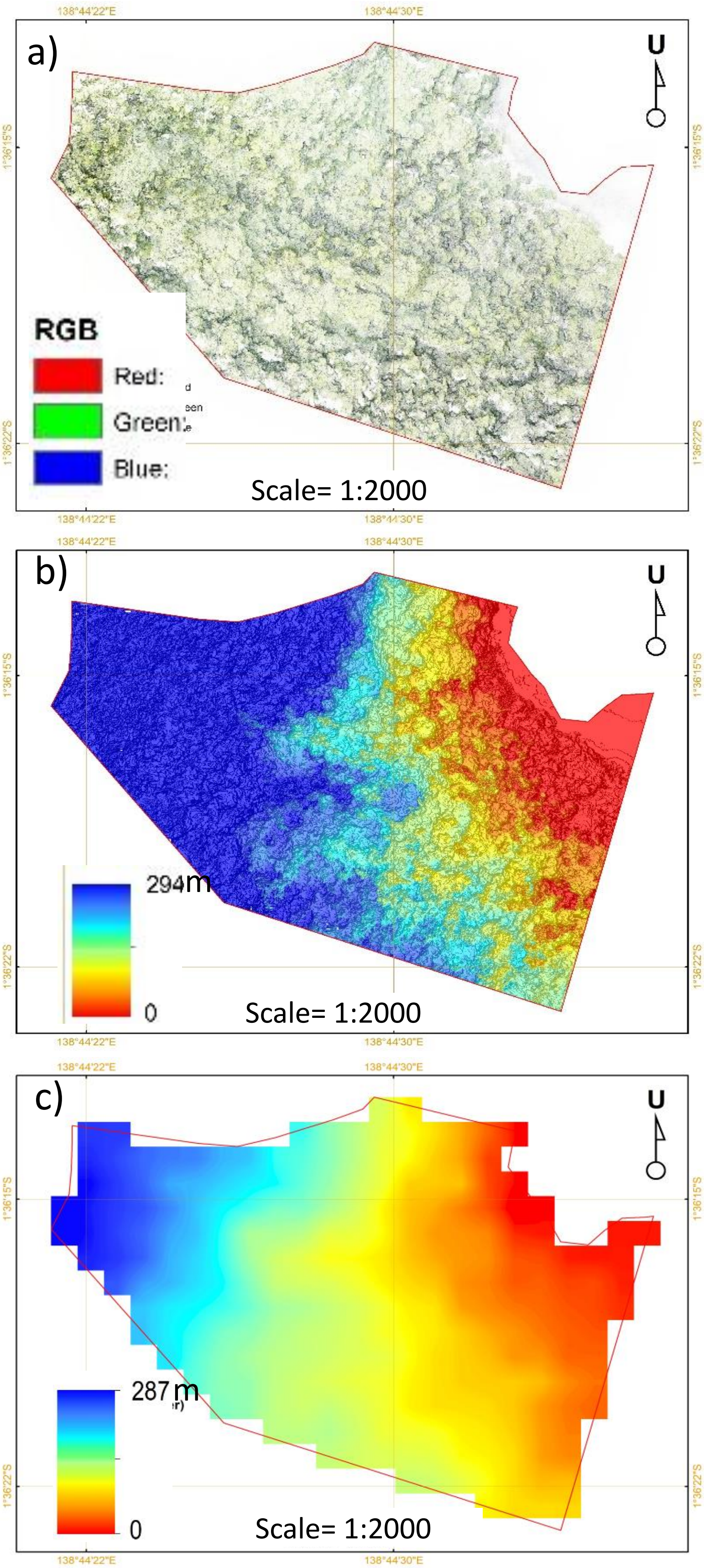

Fig. 8: a) Orthoimagery, b) DSM and c) DTM of Liki Island

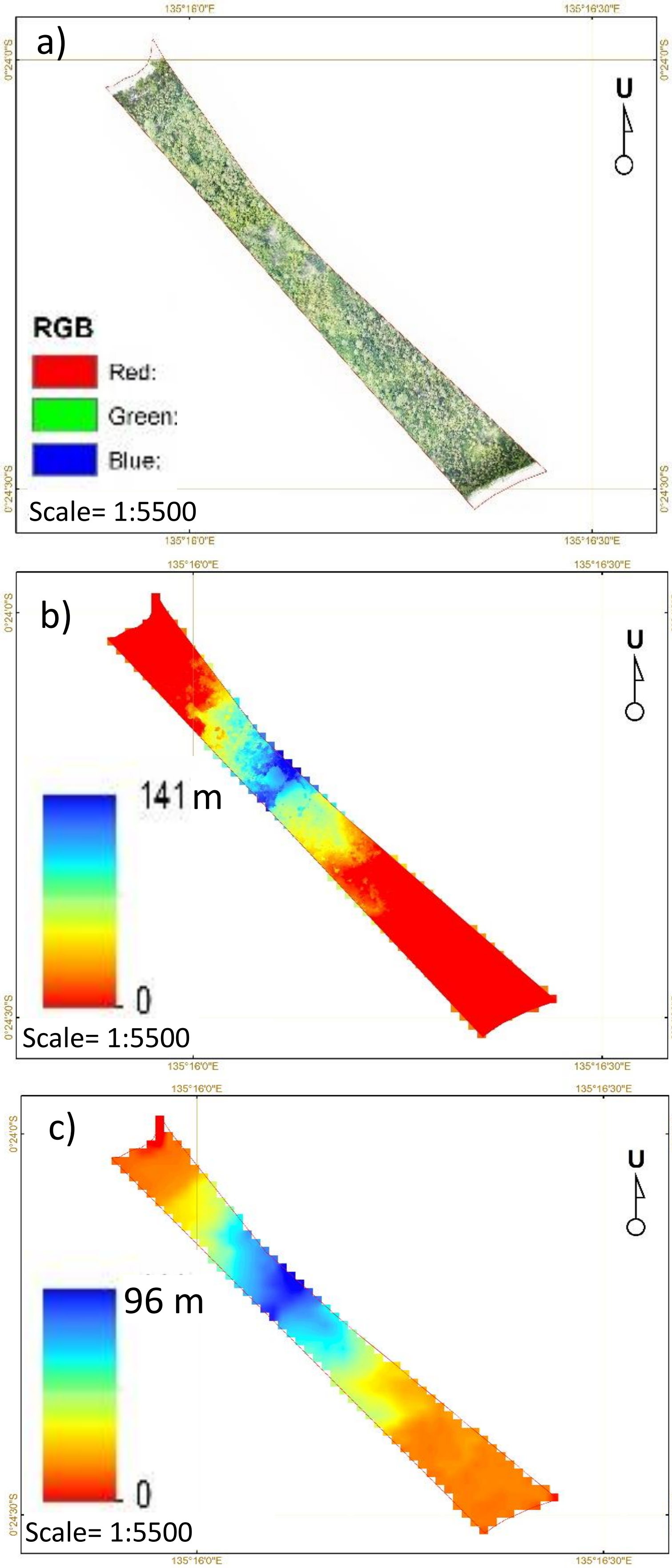

Fig. 9: a) Orthoimagery, b) DSM and c) DTM of Bepondi Island

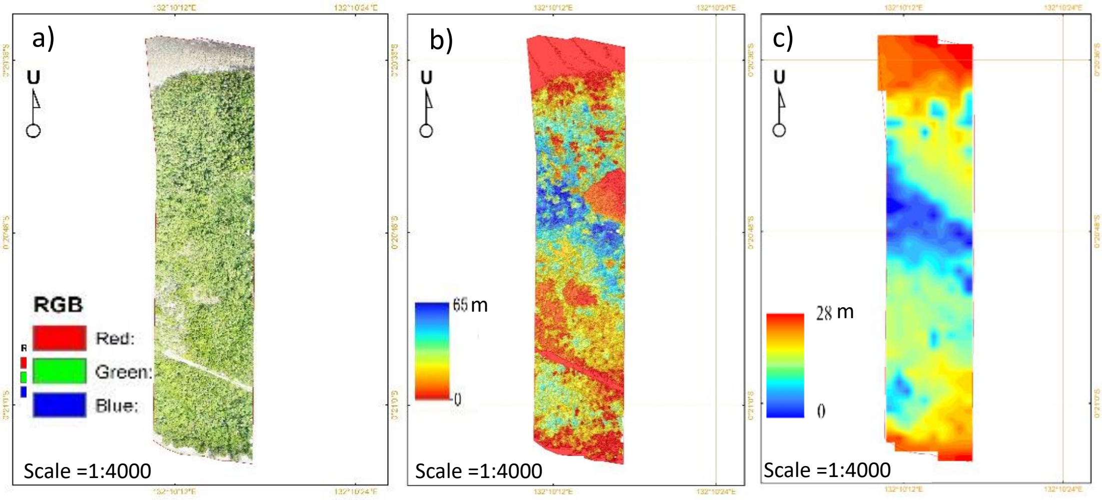

Fig. 10: a) Orthoimagery, b) DSM and c) DTM of Miossu Island

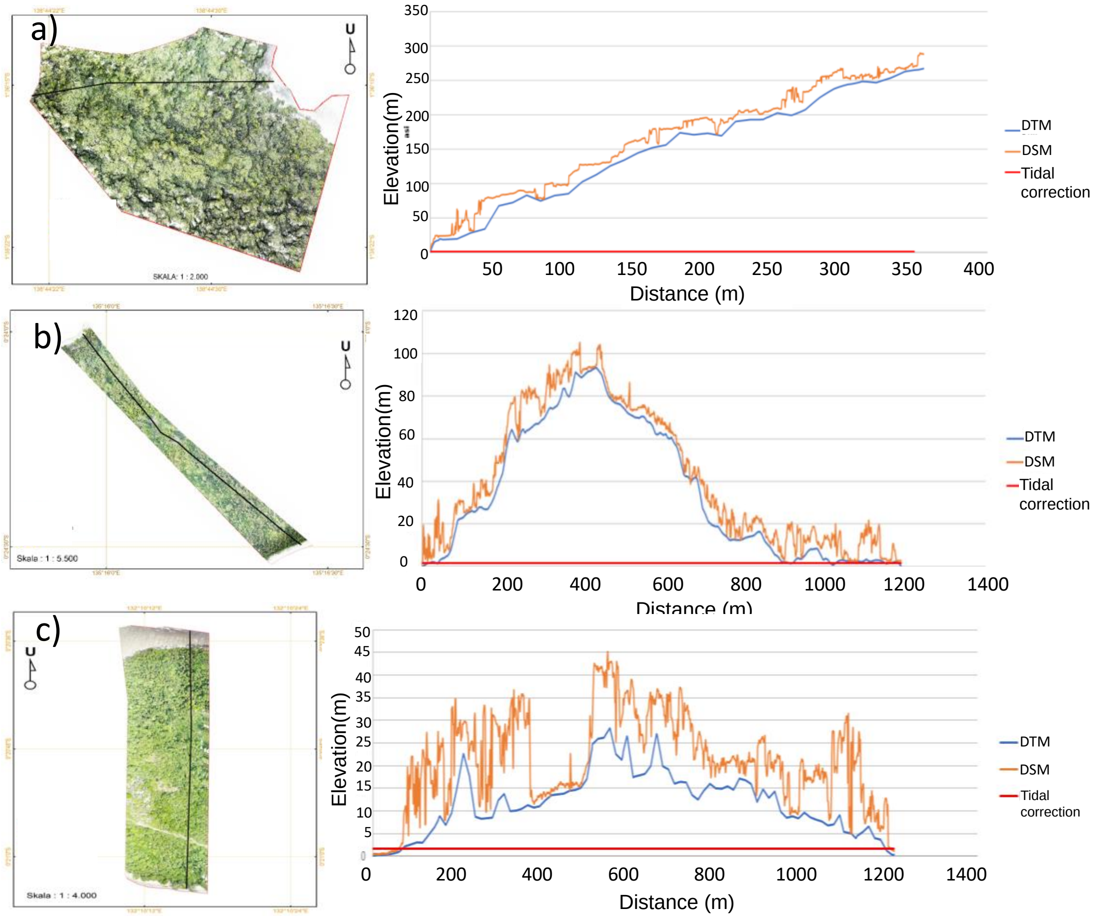

Fig. 11: Cross section of DSM and DSM of a) Liki, b) Bepondi and c) Miossu Islands with simulated tidal correction. Black lines on the left figures represent the cross section line on in the right figures

Topography: The results of photogrametry method are demonstrated in fig. 8, 9, and 10 for Liki, Bepondi and Miossu Islands respectively. Fig. 8a, 9a and 10a show the orthophotos of each island in true color image passing the highest area of each island. Vegetation can be easily identified by the greenish color and the beach side is denoted by the white color. High resolution DSM of each island is shown in fig. 8b, 9b, and 10b for Liki, Bepondi and Miossu Island respectively. Since the land cover of the three islands is dominated by vegetation, ground elevation cannot be represented by DSM. In the vegetated area, DSM refers to the elevation of tree canopy. To obtain the ground elevation, DSM was converted to DTM by auto assessment of land pixels and interpolation process.

DTM of each island is presented in fig. 8c, 9c, and 10c. Fig. 11 shows the cross section of DTM and DSM passing the highest elevation of each island. The maximum elevations of

Liki, Bepondi and Miossu Islands are 267 m, 106 m and 28 m respectively. However, it is important to be noted that these highest elevation values were measured from the sea level at the time when the drone was flying. These values are then corrected HHWL value. The simulation of tidal correction is depicted in fig. 7. The maximum elevation of Liki, Bepondi and Miossu Islands above the highest tide are 265.84 m, 103.19 m, and 26.37 m respectively.

Simulation of SLR threat to the existence of outermost islands: Taking back the earlier result, the prediction of SLR in the next 100 years in Liki, Bepondi and Miossu Islands is only 40 cm. This value is not comparable with the elevation of these three islands. Therefore, the threat of SLR to the existence of Liki, Bepondi and Miossu Islands is small.

However, it is important to be noted that since Liki and Bepondi Island are inhabitant islands and major human activities occur in the coastal plain, SLR may threat the people living in Liki and Bepondi Islands. For example, we conducted the levelling measurement by using water pass method to obtain the elevation of benchmark located in the housing area of Liki Island. The elevation of bench mark is only 29 cm from HHWL. This means that in the next 100 years, the housing area can be inundated as an impact of SLR. Furthermore, Feagin et al[3] stated that SLR may worsen the coastal erosion due to change of ocean wave and current pattern. However, this possibility still needs to be examined further by focusing the investigation on the coastal plain where most people are living there.

Conclusion

The estimated potential area loss due to the absence of Liki, Bepondi and Miossu Islands are 269,456.73 Ha, 71,007.84 Ha, and 5.997.79 Ha respectively. SLR rates for Liki, Bepondi and Miossu Islands are 4.4 mm/year, 4.4 mm/year, and 4.1 mm/year respectively. HHWL value for Liki, Bepondi and Miossu Islands are 2.43 m, 3.41 m and 2.66 m respectively. The tidal type pf these three islands is mixed prevailing semidiurnal tide.

The highest elevation of Liki, Bepondi and Miossu islands from HHWL is 265.84 m, 103.19 m, and 26.37 m respectively. Considering the rate of SLR and the elevation of the islands, it can be concluded that there is no threat of SLR on the existence of the three northeastern and outer-most small islands of Indonesia.

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We thank to Research Center for Oceanography, Indonesian Institute of Science, Jakarta, Indonesia for the opportunity in joining "Nusa Manggala" Expedition at the outermost small islands in Papua waters from 14 November to 4 December 2018 and Directorate General of research and development, the Ministry of Research, Technology and Higher Education, Republic Indonesia for the funding support under scheme Fundamental Research, Contract no. 257-16/UN7.P4.3/PP/2019.

References

1. Ablain M., Cazenave A., Guinehut S. and Valladeau G., A new assessment of global mean sea level from altimeters highlights a reduction of global slope from 2005 to 2008 in agreement with in-situ measurements, *Ocean Sci.*, **5,** 193–201 **(2009)**

2. Cunliffe A.M., Brazier R.E. and Anderson K., Remote Sensing of Environment Ultra- fi ne grain landscape-scale quanti fi cation of dryland vegetation structure with drone-acquired structure-from-motion photogrammetry, *Remote Sensing of Environment*, https://doi.org/10.1016/j.rse.2016.05.019, **183**, 129–143 **(2016)**

3. Feagin R.A., Sherman D.J. and Grant W.E., Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats, *Frontiers in Ecology and the Environment*, https://doi.org/10.1890/1540-9295(2005)003[0359:CEGSRA] 2.0.CO;2, **3(7)**, 359-364 **(2005)**

4. Handoko E.Y., Hariyadi H. and Wirasatriya A., The ENSO's Influence on the Indonesian Sea Level Observed Using Satellite Altimetry, 1993 - 2016, 2018 IEEE Asia-Pacific Conference on Geoscience, Electronics and Remote Sensing Technology **(2019)**

5. Kismawardhani R.A., Wirasatriya A. and Berliant D., Sea Level Rise in The Java Sea Based on Altimetry Satellites Data Over 1993-2015, *IOP Conf. Series: Earth and Environmental Science*, doi :10.1088/1755-1315/165/1/012006, **165**, 012006 **(2018)**

6. Kung O., Strecha C., Beyeler A., Zufferey J.C., Floreano D., Fua P. and Gervaix F., The accuracy of automatic photogrametric techniques on Ultra-light UAV Imagery, In IAPRS, Proceedings of the International Conference on Unmanned Aerial Vehicle in Geomatics (UAV-g), Zurich, Switzerland, 14–16 September 2011, 38 **(2011)**

7. Kuo C.Y., Determination and Characterization of 20th Century Global Sea Level Rise, Ohio State University Report No. 478 **(2006)**

8. Leuliette E. and Scharroo R., Integrating Jason-2 into a multiple-altimeter climate data record, *Marine Geodesy*, doi:10.1080/01490419.2010.487795, **33,** 504–517 **(2010)**

9. Li X., Shen H., Feng R., Li J. and Zhang L., DEM generation from contours and a low-resolution DEM, *ISPRS Journal of Photogrammetry and Remote Sensing*, https://doi.org/10.1016/j.isprsjprs.2017.09.014, **134**, 135–147 **(2017)**

10. Mouloua S.A., Ferraro J., Mouloua M., Hancock P.A. and Florida C., Trend analysis of Unmanned Aerial Vehicles (UAV), The HFES Proceedings, https://doi.org/10.1177/15419312186212451067–1071 **(2018)**

11. Nerem R.S., Chambers D.P, Choe C. and Mitchum G.T., Estimating mean sea level change from the TOPEX and Jason altimeter missions, *Marine Geodesy*, doi:10.1080/01490419.2010.49103, **33**, 435–446 **(2010)**

12. Polat N. and Murat U., An Experimental Analysis of Digital Elevation Models Generated with Lidar Data and UAV Photogrammetry, *Journal of the Indian Society of Remote Sensing*, https://doi.org/10.1007/s12524-018-0760-8, **8 (2018)**

13. Sammartano G. and Spanò A., DEM Generation based on UAV

Photogrammetry Data in Critical Areas, In Proceedings of the 2nd International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2016), https://doi.org/10.5220/0005918400920098, 92-98 **(2016)**

14. Shum C. and Kuo C., Observation and geophysical causes of present-day sea level rise, Chapter 7 in Climate Change and Food Security in South Asia, Lal R., Sivakumar M., Faiz S.M.A., Mustafizur Rahman A.H.M. and Islam K.R., eds., Springer Verlag, Holland **(2010)**

15. Suh J. and Choi Y., Mapping hazardous mining-induced sinkhole subsidence using unmanned aerial vehicle (drone) photogrammetry, *Environmental Earth Sciences*, https://doi.org/ 10.1007/s12665-017-6458-3 **(2017)**

16. Willis J.K., Chambers D.P., Kuo C.Y. and Shum C.K., Global Sea Level Rise; Recent Progress and Challenges for The Decade to Come, *Oceanography*, **23(4)**, 26-35 **(2010)**

17. http://www.big.go.id (2019)

18. http://tides.big.go.id/pasut/ (2018)

19. http://ina-sealevelmonitoring.big.go.id/ipasoet/ (2018)

20. http://marine.copernicus.eu/ (2019).

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