Obtaining low water line contour value for enclave claim regime 12 nautical miles on Hatohobei Island Republic of Palau against the Republic of Indonesia in according with UNCLOS 1982 using satellite-derived bathymetry

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Abstract. UNCLOS (United Nations Convention on the Law of The Sea) 1982 gives the authority to coastal state to make claims on their sea regime. An island that is more than 125 nautical miles from the mainland where the baseline to draw a territorial line is drawn is given the right to claim the maritime regime by enclave method 12 nautical miles maximum. In determining enclave claims, Low water line contour points are needed through satellite-derived bathymetry using the Lyzenga bathymetry algorithm. The data used in this study is a multispectral planet scope imagery with 3 meters resolution, where the imagery was acquired at the ⁰⁷th April 2019 and depth sample from NGA nautical chart of the Hatohobei Island and Hellen reef region. To normalize the depth value, tidal correction is done by extrapolating from BIG tides data during 29 days of tides data prediction. The Lyzenga bathymetry is applied using intercept (24.422094) and the coefficient for each band result by Ordinary Least Square regression, where the R² value obtained is 0.194075. That variable is applied in Lyzenga Bathymetry Formula. The results of the Lyzenga bathymetry algorithm are converted into contour lines to obtain low water line contour, and buffer 12 nautical miles is carried out. The result of this study shows the areas which can be claimed by Hatohobei Island (Republic of Palau). The claim of the maritime space that can be given to Tobi Island is 1634.39 km².

1. Introduction
The Republic of Palau and the Republic of Indonesia are archipelagic countries, where a coastal state means a country which consists of one or more islands and can include other islands, and the islands here means a group of islands, including parts of the island, water and various natural forms that are related to each other so closely that the islands, water and other natural forms constitute an intrinsic geographical, economic and political unity, or historically [1]. As stated in UNCLOS 1982, the island nation has the same rights as other coastal states to make maritime regime claims as well as the Republic of Palau and the Republic of Indonesia.

The Republic of Palau has a separate island away from its main land, namely Hatohobei Island (Tobi). According to UNCLOS 1982 article 47, Hatohobei Island (Tobi) cannot be made an island with
a base point for claiming archipelagic baselines because the distance exceeds 100 nautical miles, those
the maritime regime does not apply fully in that region, but is still given the right to do so maritime
regime claims using the enclave method [2]. The enclave method is given to independent islands located
within the territory of other countries, by setting boundaries based on circular arcs taken from the cape
of the base point (lowest water line) located. In practice, the area of the circle is 3 or 12 nautical miles
representing the territorial sea [3], the term boundary based on the arc in GIS (Geographic Information
System) is known as a buffer, which provides sea space claims based on agreed area.

Claims of Territorial that’s 3 or 12 nautical miles against Hatohobei Island (Tobi) must be based on
the acquisition of a base point as a reference to draw enclave lines, through a contour point with low
water line contour depth, or have been sequenced using tidal correction, on depth extraction data using
satellite derived bathymetry (SDB) [4]. The concept of reducing the depth contour low water line can
be obtained through measuring hydrographic surveys or using the help of remote sensing data via
satellite-derived bathymetry (SDB). SDB is based on the assumption the deeper water has darker color
than shallower water. The complexity of this concept can be explained through a simple analogy that
shallow black rocks can appear darker than surrounds the deeper seabed. Complex mathematical
analysis of imaging tries to distinguish these differences and removes many other sources of 'noise' in
satellite images and produces the best estimate for the average depth in each pixel. Satellite imagery that
is used must have a resolution higher than 30m, because SDB produces an average depth per pixel [5].

Spectral value (Digital Number) on pixel of remote sensing raster data especially in shallow water
areas is used to predict depth in these shallow water [6]. Theoretically, the bathymetry model is built
based on a physical model that describes optical penetration in the water, including its inhibiting
parameters which are simulated with a regression statistical model [7]. The correlation between the
depth value to the spectral value in remotely-sensed images is an assumption for modeling [6]. Based
on the calculation of depth of penetration zones (DOP), interpolation of depths within penetration zones,
and calibration of depths within the zones, so this method is based on the principle that radians can be
attenuated at different rates when they penetrate a body of water [8]. These assumptions are represented
in the equation as follows:

\[ R_z = R_{z\text{deepmean}} + (R_{z\text{surface}} - R_{z\text{deepmean}}) e^{-2kz} \]  \hspace{1cm} (1)

Other perspectives in the bathymetry model are the spectral reflection recorded by the sensor (water-leaving radiance, \( R_w \)) which is a function of the bottom reflection of the water (\( A_d \)), the magnitude of
the coefficient [6]. Obtaining the value of \( k \) (attenuation coefficient) is quite difficult to do, so there are
other alternatives using the equation, as follows [6]:

\[ R_w = (A_d - R_{pw})e^{(-g_z)} + R_{pw} \]  \hspace{1cm} (2)

A water depth estimation algorithm based on a simplified model for reflections in shallow water
areas [4]. This model represents an estimation for a radiative transfer solution in the water and is
therefore not entirely accurate, but errors can be minimized. The results of obtaining depth information
via satellite-derived bathymetry are used to obtain depth contours with a low water line contour. This
low water line depth contour will later be used as a basis for withdrawing buffer 12 nautical miles of the
territorial sea regime based on UNCLOS 1982.

2. Methods and material
The data used in the form of Planet Scope multispectral satellite imagery with a resolution of 3 meters,
which has a processing level up to 3B. To make corrections to the depth value by sitting in the middle
of the sea level, it is necessary to have tide prediction data in the Hatohobei Island region for 29 days,
the data will be obtained from tides.big.go.id. Depth samples are obtained through secondary data,
namely international navigation chart / Nautical chart.
2.1. Data collection

Planet Scope Multispectral Imagery has a resolution of three meters in which there are 4 channels namely red channel, green channel, blue channel and infrared. The processing level used in this study is Planet Scope with 3B Ortho Scene: Analytics processing level. Level 3 in question is systematic orthorectification, and correction has been carried out until the Reflectant TOA process. Level 3B products have been adjusted to cartographic projections [9]. The imagery recording time used in this study was acquired dated 7th April, 2019, at 01:08:22 UTC.

Other data prepared are 29 days tides data prediction for April 2019. Tidal data is used to obtain mean sea level (MSL) and reflux values that are used to correct the bathymetry data extracted through the Lyzenga method.

2.1.1. Research location

This research was conducted in two regions of the Republic of Palau within the scope of the exclusive economic zone (EEZ) claim. The two regions are Hatohobei Island and Hellen Reef, can legally claim the marine regime in an enclave manner [3], due to the distance being too far from the main land of the state of Palau, or exceeding 125 nautical miles from the nearest base point [10].

![Figure 1. Research sites, Hatohobei (Tobi) Island (Left) and Hellen Reef (Right)](image)

2.2. Image preparation and processing

This study uses remote sensing imagery that have been corrected to the level of TOA (Top of Atmospheric) Reflectants, then shallow-water reflectance model is corrected. The water depth estimation algorithm is based on a simplified model for reflection of shallow water areas. This model represents an estimation for a radiative transfer solution in water and is therefore not entirely accurate, but errors can be minimized [4]. According to this model, subsurface reflectance for water depth can be written as follows:

\[ R(h) = \frac{\pi L^-}{E_1^-} = r_v + r^*_b e^{-\alpha h} \]  \hspace{1cm} (3)

Where \( E_1^- \) is irradiance downwelling and \( L^- \) is light up-welling just below the surface, \( r_v \) is reflectance because the volume of scattering in the water column for effective water depth, \( r^*_b = r_b - r_v \), where \( r_b \) is the base reflectance and \( \alpha \) is the sum of the diffuse attenuation coefficients for light upwelling and downwelling. The relationship between Radiance and depth is correlated linearly to obtain the reflectance transformation (\( Xi \)). The reflectance transformation (\( Xi \)) is a linear value between the value of Reflectance and Depth, as follows [4]:
\[ X_i = \log(\rho_{si} - \rho_{s\infty i}) \]  

Where \( \rho_{si} \) is the value of the reflectance transformation and \( \rho_{s\infty i} \) is the mean value of the sea surface reflectance in each channel \( i \) [11]. The results of \( X_i \) are used to formulate the model using the predicted value of the Ordinary Least Square Regression.

2.3. Ordinary Least Square Regression

Ordinary Least Square (OLS) regression is a general linear modelling technique that can be used to model a single response variable that has been recorded on at least an interval scale. This technique can be applied to a single or multiple explanatory variables and also categorical explanatory variables that have been properly coded. Ordinary Least Square (OLS) is often used to estimate the parameters of different functional relationships. Through the calculation of the OLS statistical process, the following values are obtained:

| Variable | Coefficient (a) |
|----------|-----------------|
| 1        | Intercept       |
| 2        | \( X_1 \)       |
| 3        | \( X_2 \)       |
| 4        | \( X_3 \)       |
| 5        | Rasio           |
|          | 24.422094       |
|          | -1.516789       |
|          | -0.405923       |
|          | 0.000252        |
|          | 0.148064        |

Table 1. Result of Ordinary Least Square (OLS) regression.

![Histogram](image1)

**Figure 2.** Ordinary Least Square (OLS) regression results show that the reflectance transformation value on channel 1 and channel 2 is the best combination when compared to the reflectance transformation of channel 3 and the ratio. The value of \( R^2 \) obtained is: 0.194075

2.4. Application of Lyzenga Algorithm

Ordinary Least Square regression results are used as a fundamental formula to be included in the equation. The method was developed by entering the \( k \) (coefficient) and intercept values, in the following equation [4]:

\[ h = (X_1 \times k_1) + (X_2 \times k_2) \ldots + (X_n \times k_n) + \text{Intercept} \]  

(5)
The depth obtained is the initial depth or temporary depth, the depth value indicates the type of the island when the imagery was recorded. Temporary depth values obtained through this extraction will later be corrected using tides.

Figure 3. SDB results on Hellen reefs. Color gradation display (left), Hillshade display (right) [4].

Figure 4. SDB results on Hatohobei Island. Color gradation display (left), Hillshade display (right) [4].
2.5. Tidal data processing and depth correction

Tidal data used is tidal data for April 2019, with the total of 29 pals. This data is used to eliminate the effects of tides when the imagery is recorded. Corrections are made using high references or vertical datum that have been approved by the international law. Bathymetry maps use the lowest water level so that the depth figures on the map cannot be smaller than the actual depth. From the tidal data obtained DT / middle sitting with a value of 140 cm, and 9 tidal harmonics as follows:

Table 2. Harmonic tides constant in the waters of Hatohobei Island

| Harmonic | Final Result |
|----------|--------------|
| S0       | 141          |
| M2       | 46           |
| N2       | 19           |
| K1       | 18           |
| O1       | 12           |
| M4       | 0            |
| MS4      | 0            |
| K2       | 5            |
| P1       | 6            |

Calculation of tidal properties shows that the waters around Hatohobei Island are mixed inclined to double (0.466) (see graph 1). From the results of the harmonic constant, the value of Z0 is obtained by the formula AM2 + AS2 + AN2 + AK1 + AO1 + AM4 + AMS4 + AK2 + AP1, then Z0 is obtained with a value is 112 cm. DT and Z0 values are used to obtain the tidal face with equation = DT - Z0. The subsidence value obtained is 28 cm, which then be calculated with the height of the water when the imagery was recorded to obtain a reflux, where the height of the water during the recording of the imagery is 190 cm, then the retrograde value obtained is 162 cm.

Figure 5. Tidal graphs in the waters of Hatohobei Island showing the nature of the mixture leaning to double.

The calculated reflux value (162 cm) is used to make corrections to the imagery, which in turn will produce a bathymetry depth value, and reduced to low water line contour on the Hatohobei Island basepoint.

2.5 Model validation

Validation is performed to obtain accuracy and error value (RMSE) using the following mathematical equation:

\[ RMSE = \left( \sum_{i=1}^{n} (h_i - h_n)^2 \right)^{0.5} \]  \hspace{1cm} (6)

3. Results and discussion

Satellite-Derived Bathymetry succeeded in obtaining depth information with a range of depth values ranging from 4.32 meters to 45.7 meters [4]. This value is generated from the extraction of depth
information using three planet scope imagery channels, namely red, green and blue and using the ratio between the red band and the green band. The bathymetry derived results are then corrected with the results of the calculation (Chart Datum) to obtain a low water line contour. SDB extraction using the development shows that the accuracy is still low, RMSE value of the result of SDB is 5.81 meters [4]. The resulting low accuracy is due to several factors, including the lack of evenness of sample depth on the sea map used, the 'noise' from surface reflections and the radiometric aspects of the imagery, where the spectral value (Digital Number) which at the same depth can have different value.

The SDB extraction results are then corrected to eliminate the effects of tides when the imagery is recorded. The SDB extraction results were corrected with retroactive values. The reflux value obtained is a datum chart, so the height of the water obtained is the low water line, or the water line that has been corrected from the effects of the tides. After tidal correction, the lowest depth is 2.7 meters to 44 meters. To get contour 0, extrapolation needs to be done. The results of the acquisition of low water line contour are used as a basic as a baseline for drawing the 12 nautical mile boundary towards the Indonesian archipelago water. The claim of the maritime space that can be given to Tobi Island is 1634.39 km².

Figure 6. Contour result by SDB extraction and low water line contour, then be drawed for baseline (red line).

Figure 7. Claims of maritime space enclaves based on the results of satellite-derived bathymetry processing.
The low water line produced as a basic for withdrawing claims of 12 nautical miles coincides with land, this is due to the tidal factors that exist in the area, and because of the small factor of the vast area of Tobi Island and the surrounding waters. Because Tobi Island is a small island in Indonesian EEZ, so when it is placed on a map on a smaller scale, the low water line cannot be seen clearly. The baseline delineation results are then buffered as far as 12 nautical miles to give Hatohobei Island sea space using the enclave method. Note that the results of claims obtained from this study cannot be used as a reference in negotiations or in the determination of maritime area, because there is still a lot of 'noise' in the imagery and image processing results with bad validation values. Figure 8 is an overview showing Hatohobei Island in the waters of Indonesia's exclusive economic zone regime.

Figure 8. Hatohobei island overview in EEZ Indonesian regime.

4. Conclusion
The results of depth extraction using derived bathymetry satellites can be used to obtain low water line contour value, but it is very influential with the quality of the imagery and the quality of data processing. Thus, it needs an improvement in various parameters. This research is a preliminary study that still needs a lot of improvement, and the results of this study are not recommended for consideration in negotiations since there are still many deficiencies and 'noise' in the data.

5. References
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