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Bathymetry Mapping Using Landsat 8 Multyspectral Data of Bangsring Coastal Area

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ABSTRACT

The bathymetry map provides information of the seafloor's profile that has diverse in structures, shapes, and topography. Nowadays remote sensing technology becomes more prevalent because it is one of the most effective and efficient methods for bathymetric mapping. This research is aims to analyze the depth estimation from image processing of Landsat 8 satellite, and measured the water depth using an echosounder. The results showed that the depth of the water in Bangsring was between 0.39 meter and 96.05 meter, and the bathymetric profile continued to decrease with increasing distance. The coefficient determination (R2) and the coefficient correlation (R) were 0.81 and 0.90 respectively with error mean was 19.05%. Based on results, Landsat 8 satellite is suitable and recommended to be used to extract for bathymetric information in Bangsring coastal area.

Keywords: *Bathymetry, Mapping, Landsat 8, Multyspectral, Bangsring Coastal Area.*

1. Introduction

The bathymetry map provides information of the seafloor's profile that has diverse in structures, shapes, and topography. Bathymetry mapping in shallow water has important roles for fisheries and marine activities directly or indirectly (Setiawan et al., 2014; Wahyuningrum et al., 2008). Bathymetry detection was usually using echosounder (Arief, 2012; Setiawan et al., 2014; Wahyuningrum et al., 2008) or Conductivity Temperature Depth (CTD) (Arief, 2012). This method produces accurate bathymetry information for deep waters. However, this method was quite difficult to applied in shallow waters (Wahyuningrum et al., 2008), took a long time, the cost was expensive and not suitable for shallow areas. Many shallow water areas are not accessible by hydrographic ships due rocks, coral reef or simply the shallowness of the water (Gholamalifard et al., 2013; Liu et al., 2003).

Remote sensing technology becomes more prevalent because it was one of the most effective and efficient methods for bathymetric mapping (Arief et al., 2013; Setiawan et al., 2014; Wahyuningrum et al., 2008). Advantages of this method were low cost, has wide coverage area, suitable for shallow areas, and can be updated within a certain period (Arief, 2012; Arief et al., 2013). Landsat 8 is one of the remote sensing technology which could use for bathymetry detection. Landsat was the first satellite used for bathymetric applications followed by IKONOS and Quick Bird. Recently a new version of high resolution satellite images were used for detecting water depths as instance Spot images and Worldview-2 (Mohamed et al., 2016). Landsat 8 measures different ranges of frequencies along the electromagnetic spectrum and has 11 bands. From band 1 until band 4 has wavelength between 0.43 and 0.67 µm (Andana, 2015). Bands that can use for bathymetry detection has wavelength between 0.40 and 0.69 µm (Arief et al., 2013).

Remote sensing technology need clear waters for get good results (Setiawan et al., 2014). One of the waters in East Java which has clear waters is Bangsring. Bangsring, Banyuwangi located between Bali Strait and Bali Sea (Fuad et al., 2016). Bangsring has marine ecosystem conservation area such as coral reef and reef fish. Bathymetric data can use to increase marine habitat, marine resources and as a consideration to look for an alternative location for fish apartment (FA) (Fuad et al., 2016). This research was aimed to analyze the depth estimation from image processing of Landsat 8 satellite, and measured the water depth using an echosounder at Bangsring, Banyuwangi.

2. Materilas and Methods

Bathymetric data collected from Bangsring waters were taken from 17 until 18 March 2016 and 25 March 2017 used a set of single beam echosounder with frequency 50Hz, track that passed by boat in **Figure 1**. The satellite data that used was Landsat 8 image of Bangsring region (Path 117 dan Row 66) with the band combinations used were bands 4.3 and 2. Bands used were bands that has the best spectral response for aquatic objects, the combination of red, green and blue bands is the best combination of image processing with Van Hengel and Spitzer algorithms (Wahyuningrum et al., 2008). Data processing was conducted during April and May using ArcMap 10.3.

Radiometric calibration

Radiometric calibration was performed to improve image satellite based on visual quality and pixel values by considering atmospheric disturbance factors as the main source of error. The lowest pixel value in the image must be 0 (zero), this was corresponds with bit-coding which contained in the sensor. If the lowest value was not 0 (zero) then the offset was seen as a result of atmospheric scattering (Danoedoro, 2012). The reflection TOA (Top of Atmosphere) correction with the sun angle based on USGS (2017) (Algorithm 1).

$$\rho\lambda = \frac{M\rho \times Qcal + A\rho}{\sin(\theta SE)} \text{............Algorithm (1)}$$

where:

$M\rho$: Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_*BAND*_x, where x is the band number)

$Qcal$: Quantized and calibrated standard product pixel values (DN)

Aρ : Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_*BAND*_x, where x is the band number)

θSE : Local sun elevation angle

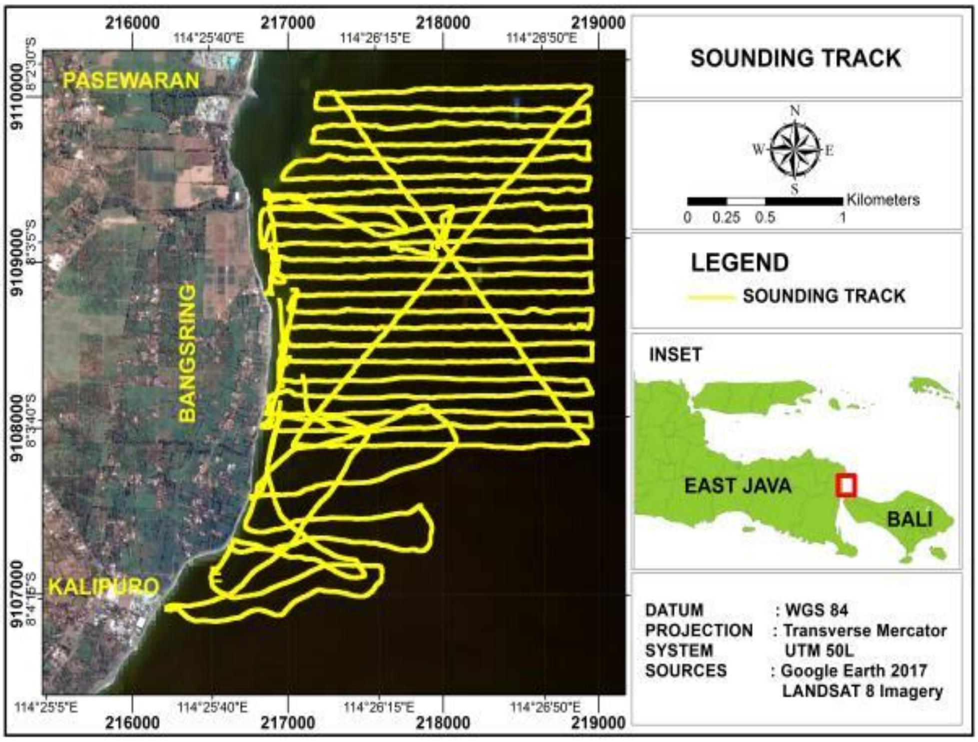

Figure 1. Sounding track in study area

Masking object

Masking aims to remove objects that are not marine area by giving a value of 0 on land area. This was done so that the ground object does not contribute in the data analysis (Wahyuningrum et al., 2008). Masking object used band ratio (Setiawan et al., 2014; Setiawan et al., 2016; Wahyuningrum et al., 2008), band ratio that used was pair of band 5 and band 3, if the value of pixels more than one then classified as marine object and if less than one then classified as land object (Algorithm 2). Band 5 (NIR band) which has high absorption in water and can distinguish colors between open ground and other objects, while band 3 (green band) which has high reflectivity in water object and can distinguish between vegetation and non-vegetation (Setiawan et al., 2016; Wahyuningrum et al., 2008).

Algorithm (2)

if (i1/i2<1) then i1 else null for *band* 5
if (i1/i2<1) then i2 else null for *band* 3
if (i1/i2<1) then i3 else null for *band* 2 and 4

Van Hengel and Spitzer Algorithm Application

Van Hengel and Spitzer (VHS) algorithm is transformation algorithm of satellite image values to produce the depth index of seawater (Wahyuningrum et al., 2008) from optical satellite images depending on the relationship between image pixel values (reflectance value) and water depths samples. This algorithm need 3 band values (Algorithm 3) to determine the depth index. The depth index will be used to determine the absolute depth using a regression analysis.

Algorithm (3)

$$Y1=X1\cos(r)\cos(s)+X2\sin(r)\cos(s)+X3\sin(s)$$

where:
X1 : 1st Reflectance Value of Band
X2 : 2nd Reflectance Value of Band
X3 : 3rd Reflectance Value of Band
Y1 : Depth Index
r dan s : Angel of Rotation

Algorithm 4, 5 and 6 is to determine the value of the angel rotation (r and s),

$$r(s)=\arctan(u+\sqrt{u^2+1}) \quad \text{………….Algorithm (4)}$$

$$Ur=\frac{var\ x2+var\ x1}{2\ cov\ x1x2} \quad \text{………………Algorithm (5)}$$

$$Ur=\frac{var\ x3+var\ x1}{2\ cov\ x3x1} \quad \text{………………Algorithm (6)}$$

where:
var xi : Variance *band* i
cov xi,xi : Covarian *band* I and *band* i

3. Results and Discussion

Comparison between in-situ bathymetric data and landsat 8 image data

Landsat image processing using VHS algorithm only produce the depth estimation form image pixel values, while to get the actual depth required regression process to determine a model equation. Regression between corrected image reflectance values (dependent variable) and water depths (independent variable) can be used for detecting bathymetric information in certain area **(Figure 2)**. The Bathymetric data was processed use kriging interpolation and Triangulated Irregular Network (TIN) in ArcMap 10.3. Kriging interpolation method was used because this method was considered flexible for process various types of data (Fuad et al., 2016).

In the regression analysis, separations of less than 30 m depth, more than 30 m and overall depth of waters were performed. At the depth <30 m **(Figure 2A)**, coefficient correlation was 0.84. At the depth <5 m, reflectance value was high, that was because the errors of image pixel values at depth <5 meters were influenced by high concentration of Total Suspended Solid (TSS) which was near to the beach. The problem of shallow water mapping using remote sensing is contrast effect caused by water depth which sometimes makes blurring to the image and distortion caused by the nature of each water layer (Arief, 2012). At a depth from 5 m to 15 m there were different reflectance values and tend to be high, because bottom subtracts was not homogenous, bottom substrate affect the reflectance value (Setyawan, 2015). At the depth of the water substrate is dominated by coral ecosystems and there are fish apartments. The reflection received by the remote sensing sensor most likely the reflectance was reflected by the objects and not from the bottom of the water, this can cause a high reflectance value.

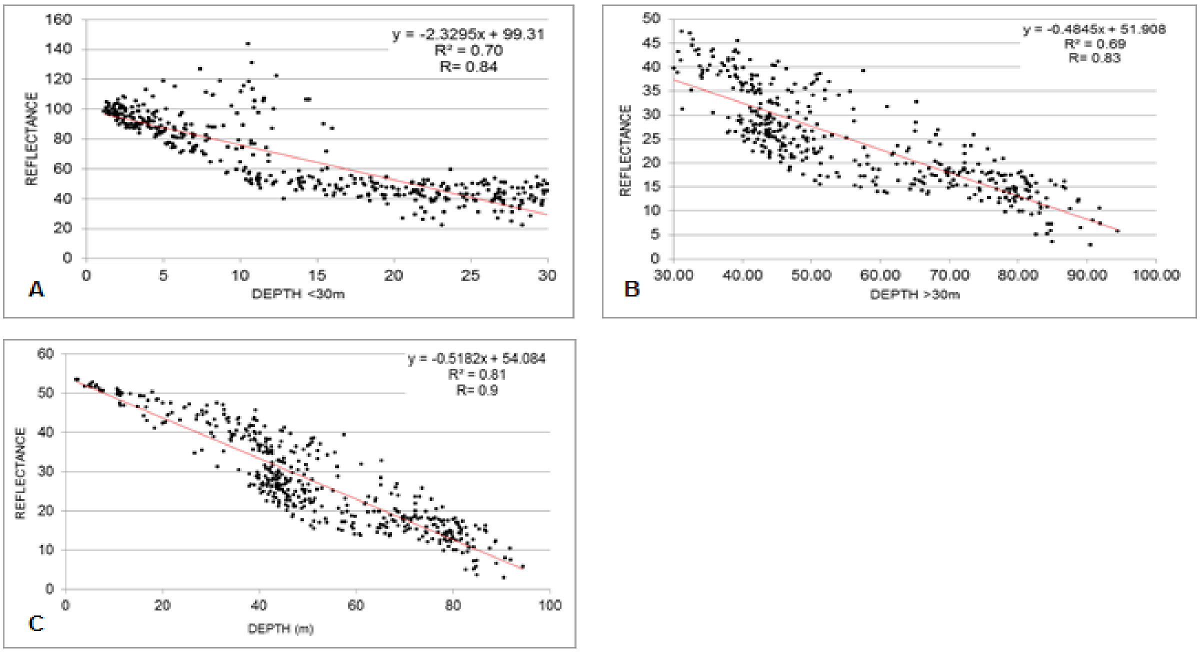

Figure 2. The Result of Regression (A) <30 m, (B) >30 m, (C) All Categories

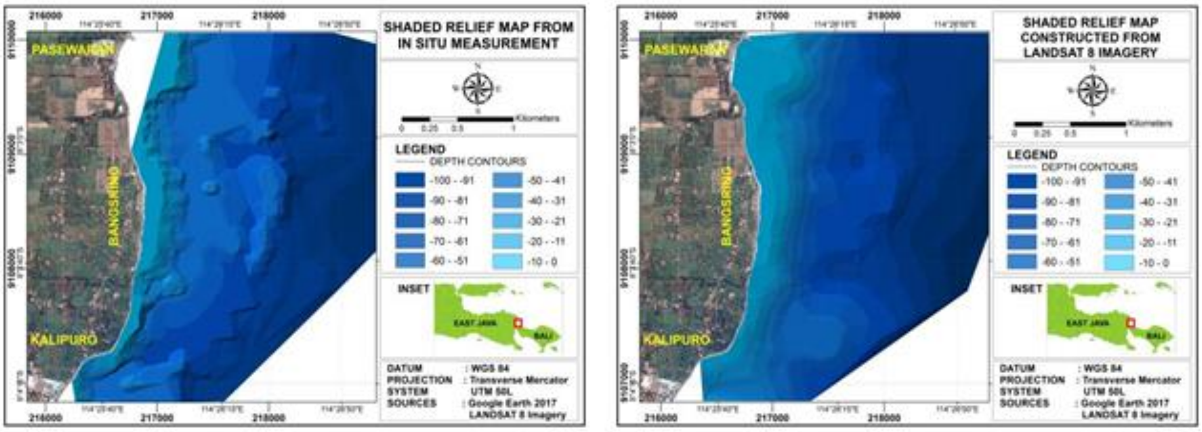

Figure 3. (Left) In-situ Measurement, (Right) Landsat 8 Imagery

While the depth > 30 m **(Figure 2B)**, the value of coefficient correlation was 0.83. Reflectance values at this depth tend to be scattered and constant, caused by the sunlight can not penetrate into the waters thus affect the value of reflectance and affect the image pixel value (Arief, 2012; Maulana et al., 2015). At depths >30 m the pixel value of the image will tend to be constant this was because the reflectance value captured by the sensor does not reach the bottom of the water and only comes from the surface. Remote sensing is capable of detecting depths of up to 30 m based on light penetration ability (Mumby et al., 2003).

The coefficient correlation of all categories was 0.9 **(Figure 2C)**. Based on Sugiono (2010), the value of correlation coefficient from analysis regression has very strong relationship level between reflectance value and bathymetric data. Regression results showed that the reflectance value and depth value has an inverse relationship. The reflectance value is inversely proportional to the depth of the waters, the reflectance value increases when the waters become shallow and otherwise the reflectance decreases when the waters increase in (Arief et al., 2013).

The result of regression model (y) will be used to determine the depth of the waters resulting from Landsat 8 image by utilizing the reflectance value. The result of reflectance value will influence how strong the model to estimate the depth come from the Landsat image 8. The higher the regression value and the result of correlation will minimize the error or different depth between the in-situ depth and the result of Landsat 8 image. Based on the results in-situ depth measurements of bathymetry were acquired by echosounder, Bangsring waters has the depth from 0.39 to 95.05 m. While the result of image processing of Landsat 8 was from 0,03 to 98,70 m. Then the value of the depth was grouped into 10 classes that from 0 meters to 100 meters to be used as depth map **(Figure 3)**.

The topography of the waters can be seen vertically by doing a cross section that used 3D Analyst in ArcMap 10.3. In the process of making cross section of Bangsring waters will be divided into 3 areas that perpendicular to the beach **(Figure 4)**. First region will be marked with points A and B, the second region was C and D, and the third region was E and F, while the results of the cross section in **Figure 5**.

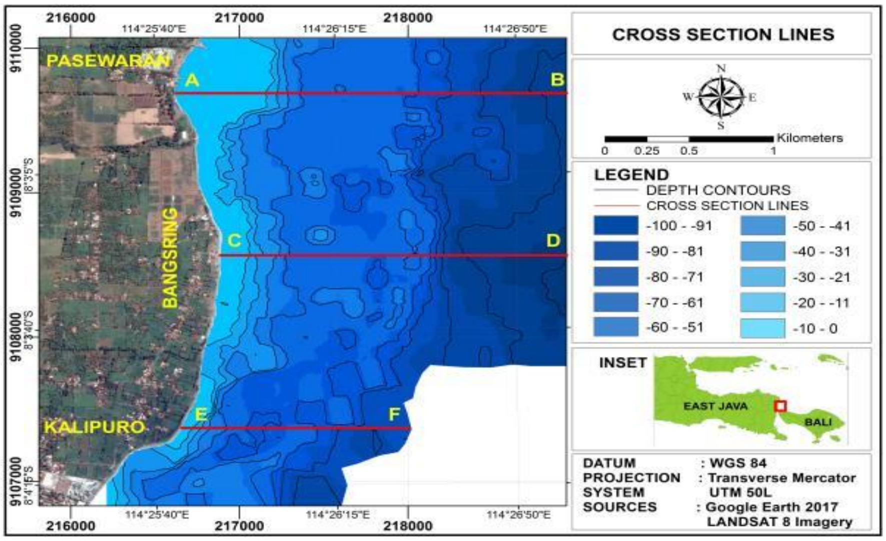

Figure 4. Cross section areas

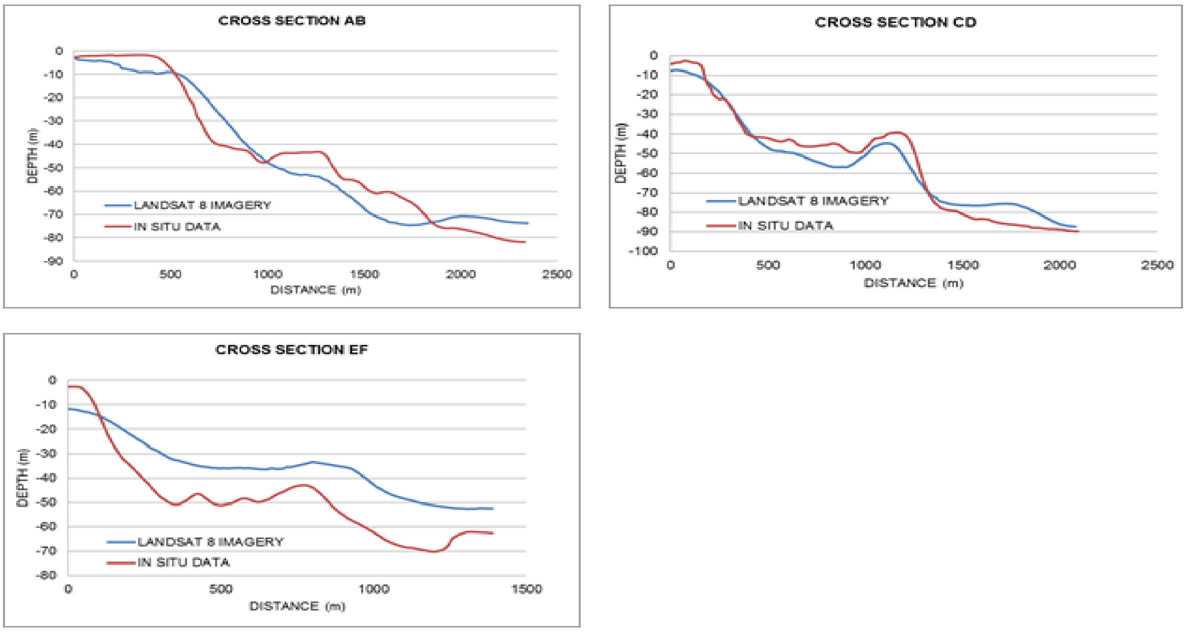

Figure 5. Cross Section Result

The cross section results from in-situ depth (red line) and Landsat 8 imagery (blue line) showed that both of the line has same line pattern and the bathymetric profile continued to decrease with increasing distance. At a depth <30 m there was a slight difference in altitude on the red line and blue line. While at a depth >30 m there was high difference in altitude on the red line and blue line. In the EF cross section there was a very high depth difference between the red line and blue line, because in the EF area the data retrieval point was less irregular when compared to the area of AB and CD.

Bathymetry detection using remote sensing was depends on image data quality and satellite capabilities (Setiawan et al., 2014). Detailed bathymetric mapping or require better detail Landsat image was less appropriate to use, because a single pixel in the image may not necessarily indicate the same depth in the field. Size 30x30 meters in the field can show very varied numbers, especially in areas of waters that are dominated by coral reefs or in waters that have a sharply decreased depth. This spatial resolution is more suitable for mapping areas that has a sloping topography (Wahyuningrum et al., 2008).

Error and residual value of in-situ bathymetric data and landsat 8 image data

Residuals with negative values indicate that the depth value of the image processing has a smaller value than the actual depth value.

The positive value of the residual indicates if the depth value of the image processing has a greater value than the actual depth value. The smaller the value of error and residual, indicate that depth was closer to the actual depth value. A comparison table of error and residual values for each depth category can be seen in Figure 6 and Table 1.

In Figure 6 there was residual value between the depth <30 m and >30 m. At a depth >30 m has a residual value higher than a depth <30 m. However, the error value at a depth <30 m was higher than the depth >30 m. That was influenced by the reflectance value at each depth. At a depth <30 m, the reflectance values at some depths tend to be too high, thus affecting the value of depth estimation in subsequent processes. While the depth >30 m, the result of reflectance value was not derived from the bottom of the water but the reflectance value comes from the surface and influenced by the color of the waters. Although at this depth the reflectance value tends to be constant, but the result of the reflectance was not from the bottom of the waters. So the residual value at this depth tends to be high but has smaller errors. The mean error value generated by the overall depth waters was 19.05% with residual values from -28.99 to 23.17.

Table 1. Error and residual values

Depth	Range(%)	Error (%)	Residual (m)
<30 meter	0,10-99,68	36,30	-11,80 until 12,63
>30 meter	0,04-70,49	18,73	-31,49 until 23,86
Overall	0,11-58,97	19,05	-28,99 until 23,17

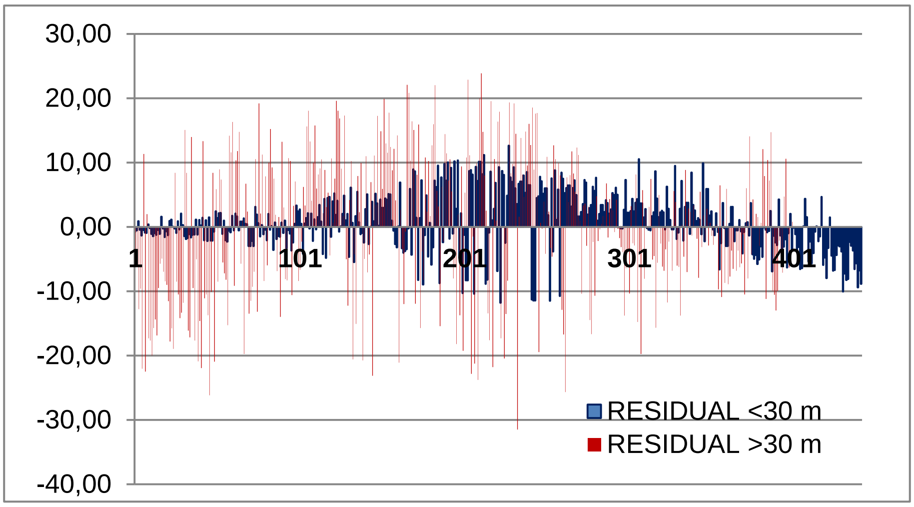

Figure 6. Residual values

4. Conclusion and Suggestion

The depth of the water in Bangsring was between 0.39 meter and 96.05 meter, and the bathymetric profile continued to decrease with increasing distance. The coefficient determination (R2) and the coefficient correlation (R) were 0.81 and 0.90 respectively with error mean was 19.05%. Based on results, Landsat 8 satellite is suitable and recommended to be used to extract for bathymetric information. The shallow water depth has a higher error value of 36.30% when compared with deeper waters with an error rate of 18.73%.

Suggestions from this research are the need for further research on the estimation of bathymetry using remote sensing for different types of waters, especially the comparison of coral ecosystem with sand-based waters by using a combination of diverse bands in order to produce an estimated value a depth close to the true depth value.

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