

Article

Coral Reef and Shallow Water Benthic Identification Using Landsat 7 ETM+ Satellite Data in Nusa Penida District

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Abstract

This study aims to investigate the feasibility of Landsat 7 ETM+ to identify coral reefs and shallow water benthic at Nusa Penida district in 2009 and 2012, comparison with the Reef Health Monitoring (RHM) results conducted by the Coral Triangle Center (CTC) using the Point Intercept Transect (PIT) method in the same periods. This study also aims to determine the changes of coral reefs and shallow water benthic cover during this period and the distribution at Nusa Penida district. Shallow water benthic classification refers to English et al. (1997), with a modified by the addition of vegetation classes (seagrass and seaweed). The classification result using confusion matrix between the Reef Health Monitoring (RHM) with the classification of satellite image in 2009 obtained an accuracy rate of 65.85% with a kappa coefficient value of 0.525, while in 2012 the accuracy value obtained of 74.81% with kappa coefficient value of 0.650, which shows the results of that classification of satellite images of Landsat 7 ETM+ with the results of in-situ research is in a moderate level.

Keywords: coral reef; shallow water benthic; Nusa Penida district; Landsat 7 ETM+; water column correction

1. Introduction

Indonesia is a part of the “World's Coral Triangle”. In addition to Indonesia, other countries belonging to this region is Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste (Veron et al., 2009). This region also known has 30% of the world's coral reefs covers and more than 75% of the world's coral reef species and as habitat for more than 3,000 fish species (Allen and Werner, 2002; Hoegh-Guldberg et al., 2009).

Indonesia has about 51,000 km² an area of coral reefs cover, with details of the 7% estimated in very good condition, 33% in good condition, 46% broken and 14% estimated in badly damaged condition (Burke *et al.*, 2002). But until the end of 2016, according to research conducted by the Indonesian Institute of Sciences (LIPI) and Coral Reef Rehabilitation Management Program – Coral Triangle Initiative (COREMAP CTI) (Giyanto et al., 2017) in 1064 station from Aceh to Papua showed only 29.79% of Indonesia's coral reefs are in good condition, 35,06% in the medium, and the rest are in poor condition severe (35,15%). Nusa Penida District, Klungkung Regency, Bali Province-Indonesia, is one of the islands in Indonesia that managed coral reef and associated ecosystem with fairly structured. Nusa Penida district consist of three main island, that is Nusa Penida, Nusa Lembongan and Nusa Ceningan. Based on rapid survey by The Nature Conservancy

reported Nusa Penida coastal and marine area has about 1,419 hectares coral reefs cover, 230,07 hectares mangrove cover and 108 hectares sea grass cover (Darma *et al.*, 2011).

Sustainable and development research are needed in Nusa Penida islands to determine the current condition of the health of coral reef and associated ecosystem. In-situ data monitoring like Line Intercept Transect (LIT), Manta Tow, Point Intercept Transect (PIT) and other similar methods are a favourite methods for researcher so far. But, this methods are need a long time and requires a considerable cost, and relatively only cover a small area in research.

An alternatives that can be done to minimize the impact is to utilize remote sensing technology. One of satellite image that is frequently used to map marine resources and fisheries are Landsat satellite images. In general, Landsat 7 ETM+ (*Enhanced Thematic Mapper*) has the same characteristics as it is predecessor (Landsat 4, 5 and 6) which carries the sensor TM (*Thematic Mapper*) to classify the wavelength radiance and separating into 7 band channel. Landsat 7 with additional sensors ETM (*Enhanced Thematic Mapper*) to classify the wavelength radiance into 8 band channels, with additional panchromatic band (band 8).

Test accuracy result between Landsat TM, SPOT XS, merged of Landsat TM with SPOT Pan, and Landsat MSS in mapping shallow waters benthic at Caicos Bank for 4 types of habitat (sand, corals, macroalgae and seagrass) with water column correction and contextual editing for all case, Landsat TM has overall accuracy of 73%, while SPOT XS has overall accuracy of 67%, merged of Landsat TM with SPOT Pan has accuracy not significant differ with SPOT XS, and the Landsat MSS has overall accuracy <60% (Shepperd *et al.*, 1995, in UNESCO, 2013).

Reffers to Landsat TM accuracy result to mapping shallow water benthic at Caicos Bank on 1995, and with assumption the Landsat TM and Landsat 7 ETM+ satellite image has the same spectral range and spatial resolution on each bands (except band 8 that are not available on Landsat TM), it is possible to investigates the feasibility of Landsat 7 ETM+ to identified the coral reefs and shallow water benthic, and in this research will be compare with in-situ data conducted Reef Health Monitoring (RHM) result using Point Intercept Transect (PIT) methods by Coral Triangle Centre at Nusa Penida District, Klungkung Regency, Bali Province – Indonesia on 2009 and 2012. Landsat Data can be downloaded for free through the site <http://earthexplorer.usgs.gov/>.

2. Materials and Methods

2.1 Study Site

Study site is Nusa Penida district, Klungkung Regency, Bali Province – Indonesia. The figure 1 represented maps of Nusa Penida district, a white colour represented a unclassified area (lands and depth sea) and a mix colour represented a classified area (shallow waters area).

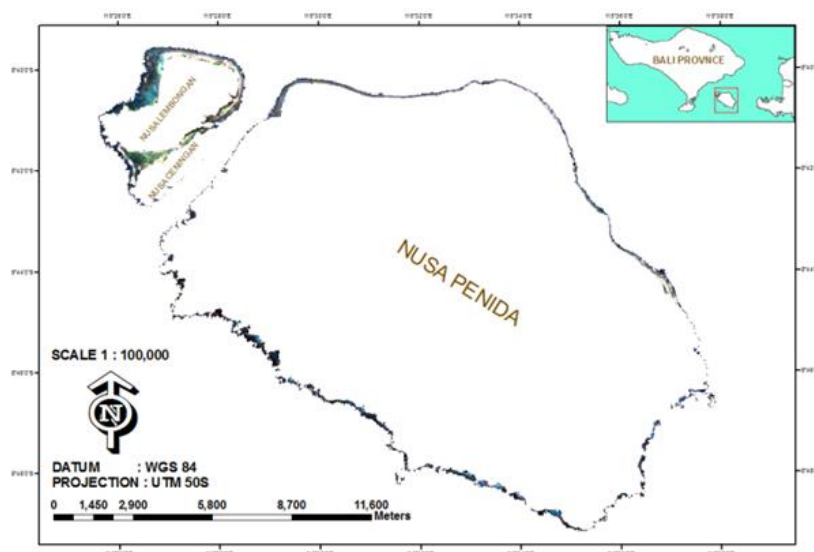


Figure 1. Study area map

2.2 Used Data

2.2.1. In-situ Data

In-situ data obtained from Reef Health Monitoring (RHM) survey conducted by Coral Triangle Centre (CTC) on 28 October - 2 November 2009 (14 stations) and on 19 - 23 September 2012 (12 stations), as shown Figure 2 and Figure 3.

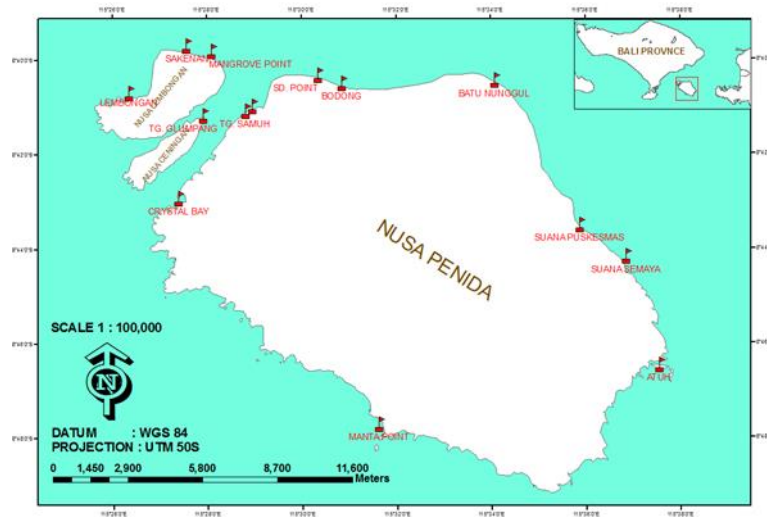


Figure 2. Nusa Penida RHM station on 2009

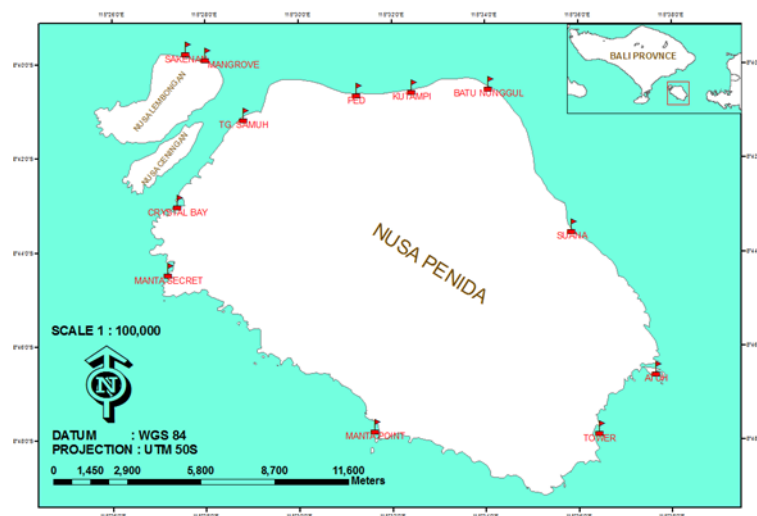


Figure 3. Nusa Penida RHM station on 2012

Refers to Kirkman *et al.*, (1998), is quite difficult to differentiate between algae with seagrass with remote sensing technology because photosynthetic pigments that are in both classes are similar, so that the spectral radiance received by satellite sensors have a similar range. In addition, algae also live in symbiosis with the coral (zooxanthellae is a photosynthetic pigment in algae found in the reef). Zooxanthellae pigment also found in others class (especially at soft coral from *xeniidae* and *clavularia sp.*). In this research, the limited of vegetation class (seaweed and seagrass) data will cause the results of supervised classification in the shallow waters will be biased and will be classified into the reef class, others class or algae class (refers to classification of basic compiler components reef ecosystem based coral life form by English *et al.* (1997).

Reef Health Monitoring (RHM) generally do not cover vegetation class data. Additional vegetation data is needed because shallow water around Nusa Lembongan and Ceningan

dominated by seaweed, seagrass, sands and rubble. Figure 4 represented addition data of seaweed and seagrass location obtained from ground truth monitoring at 7 locations in Nusa Lembongan shallow water on 2014.

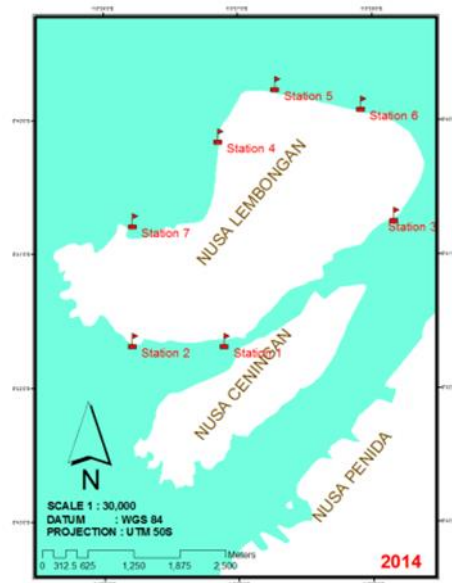


Figure 4. Nusa Lembongan vegetation ground truth location on 2014

2.2.2 Satellite Data

Landsat 7 ETM+ launched on 15 April 1999 to bring ETM+ Scanner, have an orbit aligned with the sun (sun synchronous), crossing the equator at 10:00 local time, and covered the same area (repeat coverage interval) every 16 days with a swath width of each coverage is 185 km, more details about the characteristics of Landsat 7 ETM+ can be seen in Table 1.

Table 1. Landsat 7 ETM+ characteristic

System	Landsat 7 ETM+
Swath width:	185 kilometers
Repeat coverage interval:	16 days (233 orbits)
Altitude:	705 kilometers
Quantization:	Best 8 of 9 bits
On-board data storage:	-375 Gb (solid state)
Inclination :	Sun-synchronous, 98.2 degrees
Equatorial crossing:	Descending node;10:00am +/- IS min.
Launch vehicle:	Delta II
Launch date:	Apr-99

Source: <http://geo.arc.nasa.gov/sge/landsat/17.html>

Landsat 7 ETM+ are composed of seven different bands plus one panchromatic bands, with a different ground resolution range as seen on the Table 2. Each bands representing a different portion of the spectral. Shorter range of wave length, better the ability to differentiated obyek on the earth. Base on Lillesand et al. (2004) statement, that the best light penetration in pure water are in the band channel that has a range of wavelengths from 0.48 - 0.6 μm . In the Landsat 7 ETM + satellite image, the wavelength range between 0.48 - 0.6 μm contained in the band 1 (blue) and band 2 (green).

Table 2. Band of Landsat 7 ETM+ (Chander et al., 2009)

Band Number	Spectral Range (μ)	Ground Resolution (m)
1	0.45 to 0.515	30
2	0.525 to 0.605	30
3	0.63 to 0.690	30
4	0.75 to 0.90	30
5	1.55 to 1.75	30
6	10.40 to 12.5	60
7	2.09 to 2.35	30
Pan	0.52 to 0.90	15

Source: <http://geo.arc.nasa.gov/sge/landsat/17.html>

2.3 Methodology

2.3.1. Gapfill Image

On 31 May 2003, the Scan Line Corrector (SLC) on Landsat 7 ETM+ has a damage. This is known as the SLC-off. SLC is a technology on Landsat 7 ETM+ is designed to fill the gaps in satellite images of Landsat 7 ETM+, which is caused by the forward motion of the satellite during orbit. As a result of this damage, estimated at about 22% of the image produced on a path/row losing information (Scaramuzza and Barsi, 2005).

One technique to fill the gaps information occurs, using algorithm named Localized Linear Histogram Match (LLHM) as shown at Figure 5. Pixels on the image which gapfill filled by another image that does not lose information, while minimizing the area that experienced gapfill image pixels in the same area both the primary image and the fill image. This methods using moving windows.

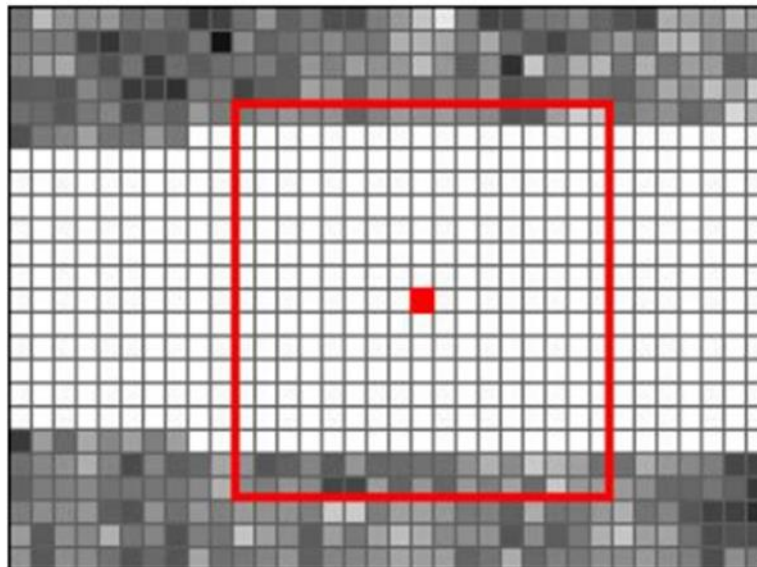


Figure 5. Moving Window illustrated for LLHM (Scaramuzza et al., 2004)

Algorithm results obtained in use to calculate the value of the missing pixels in the primary image pixel base of the fill image pixel. The equation for LLHM are (Scaramuzza et al., 2004):

$$MergedDN = Fill_{DN} \times Gain + Bias \quad (1)$$

$$Gain = \frac{\sigma_p}{\sigma_F} \quad (2)$$

$$Bias = \mu_p - \mu_F \times Gain \quad (3)$$

Where:

$$\mu_p = \frac{1}{N} \sum_{n=1}^N Primary_{DN} \quad (4)$$

$$\sigma_p = \frac{1}{N-1} \sum_{n=1}^N (Primary_{DN} - \mu_p)^2 \quad (5)$$

$$\mu_F = \frac{1}{N} \sum_{n=1}^N Fill_{DN} \quad (6)$$

$$\sigma_F = \frac{1}{N-1} \sum_{n=1}^N (Fill_{DN} - \mu_F)^2 \quad (7)$$

With the principle of *Linear Localized Histogram Match (LLHM)*, then developed software named Frame and Fill. To consider in choosing a filler image are (i) the position of the gap between the primary image and the fill image does not the same coordinates, (ii) the date of the recording between the primary image and the fill image is not too much effort, (iii) the fill image selected should have a low cloud cover or none at all (USGS, 2004).

2.3.2. Atmospheric Correction

Assuming that the entire visible band radiance will be absorbed entirely in the deep ocean will be absorbed, so that the radiance values recorded by the sensor radiance value is simply due to the influence of the atmosphere (Green *et al.*, 2000). Armstrong (1993) suggested, the value of the average radiance deep ocean should be reduced by 2 multiply the standard deviation. This methods is known as the Dark Pixel Substraction, can be written by the following equation:

$$Atmospheric\ Correction = L_i - L_{si} \quad (8)$$

Where L_i is pixel radiance in band i and L_{si} is the average pixel radiance in depth water.

2.3.3. Classification of Water Body

The states of *Beer-Lambert law*, the light of intensity decreases exponentially to the difference depth (Bukata *et al.*, 1995). Then by to transform the light of intensity using the *natural logarithm (ln)* will make the relationship with the depth becomes linear. The equation can show below:

$$X_i = Ln(L_i) \quad (9)$$

Lyzenga (1981) developed techniq to remove the influence of the depth using attenuation coefficient between band i and band j . The value attenuation coefficient did not obtained from linear regression, but obtained from calculated the smallest deviation of the linear correlation line:

$$\frac{K_i}{K_j} = a + \sqrt{a^2 + 1} \quad (10)$$

Where:

$$a = \frac{\text{variance}_{bi} - \text{variance}_{bj}}{2 \times \text{covariance}_{bandij}} \quad (11)$$

Depth Invariant Index (water column correction) algorithm then calculated using algorithm 12 below:

$$Y = In\ Band_i - \left(\frac{ki}{kj} \right) \times In\ Band_j \quad (12)$$

2.3.4 Image Classification

Supervised classification with maximum likelihood method will be used to generate the different classes for each habitat, which was trained using field data. Shallow water benthic classification refers to English *et al.* (1997), and modified with additional vegetation class (seagrass and seaweed).

2.3.5 Accuracy Test

Accuracy test is done by comparing the two map, ones derived from the analysis of remote sensing (data to be tested) and the other is a map derived from other sources (Campbell and Wynne, 2011). Standard format for reporting test results accuracy is in the form of an error matrix, or also called "confusion matrix".

3. Results

4.1 Preprocessing

4.1.1 In-situ Data

Shallow water benthic coverage on Nusa Penida district on 2009 and 2012 by Reef Health Monitoring (RHM) conducted by Coral Triangle Centre Survey on 2009 and 2012 using Point Intercept Transect (PIT) methods can be seen on figure 6 and 7.

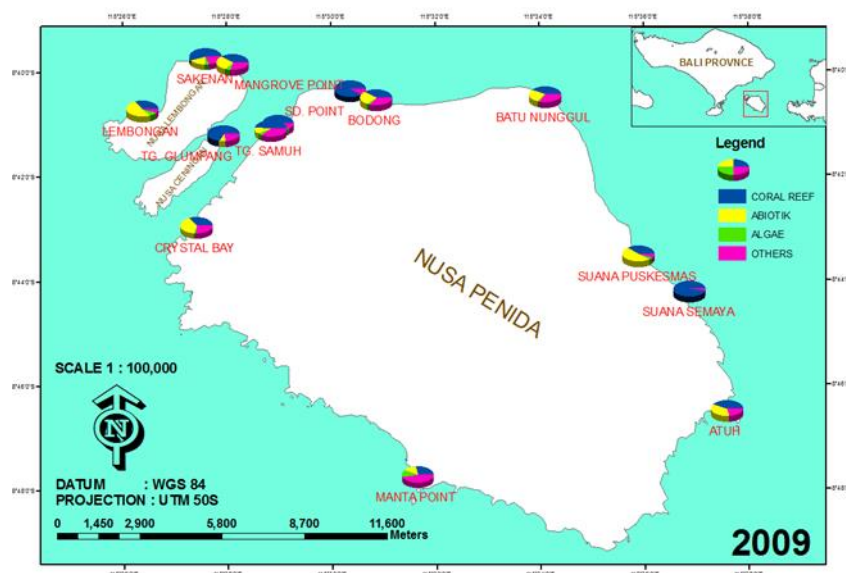


Figure 6. Shallow water benthic coverage at Nusa Penida District in 2009

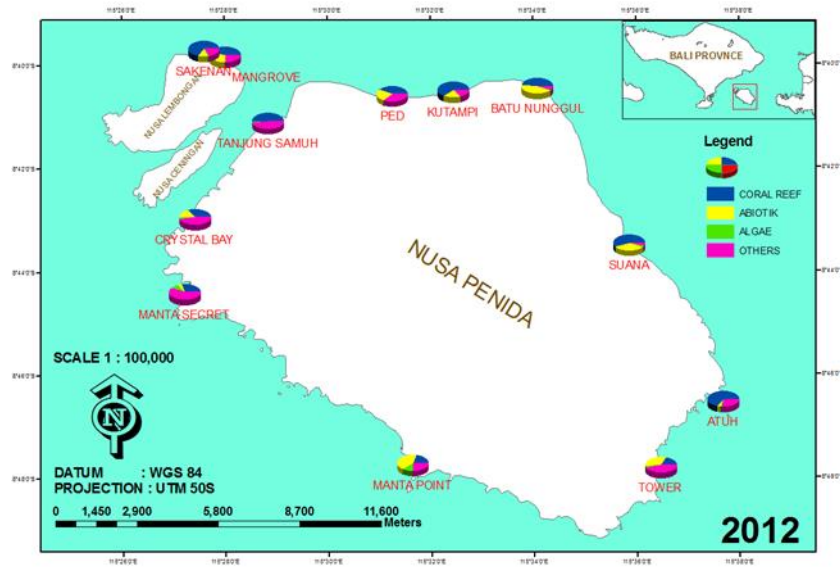


Figure 7. Shallow water benthic coverage at Nusa Penida District in 2012

Figure 8 represented ground truth monitoring location of vegetation class. Vegetation class sample is important, because, zooxanthellae photosynthetic pigments that live in symbiosis with the coral reefs, have a similar spectral characteristics of the photosynthetic pigments in seagrass or seaweed.

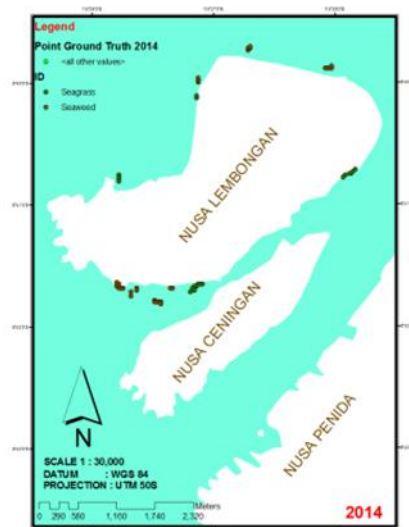


Figure 8. Seagrass and seaweed cultivation location on 2014 (base on ground truth survey)

4.1.2 Gapfill Image

Satellite data using Landsat 7 ETM+ level 1T at path/row 116/066 acquisition 15 October 2009 as primary image and 21 march 2009 as fill image. In 2012, satellite image used is Landsat 7 ETM+ acquisition 26 february 2012 as primary image and 23 october 2012 as a fill image. Figure 9 and 10 show the gapfill Landsat 7 ETM+ processing on 2009 and 2012 satellite image:



Figure 9. Gapfill processing on 2009 satellite image

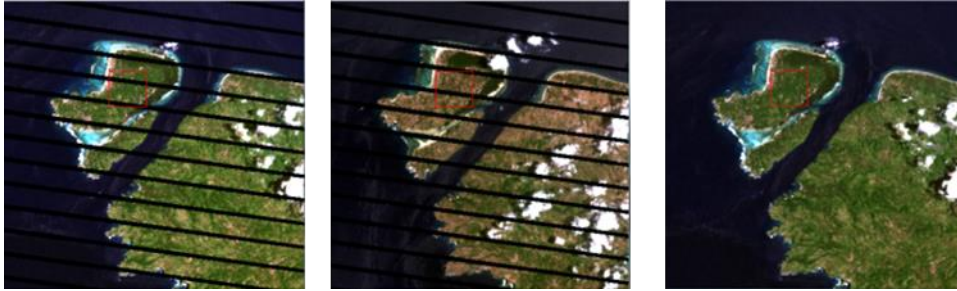


Figure 10. Gapfill process on 2012 satellite image

4.1.3. Atmospheric Correction

Atmospheric correction have be done with Dark Pixel Substraction methods.

4.1.4. Cropping Image

Crooping image intended to limited the Area of Interest (AOI) between 2009 and 2012 and make Area of interest of both image have the same extents. Table 3 represented about upper and lower coordinates using for crooping image:

Table 3. Crooping Image coordinates

UTM (meter)	Easting	Northing
Upper Right	325035	352065
Lower Right	9044065	9023395
Zone	50 South of Equator	

4.1.5 Image Masking

Image Masking mentioned to separate the areas out of the study area. In this research, first step, image masking is intended to separated between land and sea with near Infrared Band (Band 4) on Landsat 7 ETM+ imagery which has a spectral between 0.76-0.90 is used as a masking. Second step do to masking depth water and shallow water area using shape file, obtained from the digitized of Landsat 7 ETM+ satellite images on the boundary between the depth water and shallow waters. Figure 11 represented image masking processing on 2009 and 2012 on Landsat 7 ETM+ satellite image. Black colour represented unclassified area (land and depth water) mix colour represented classified area (shallow water).

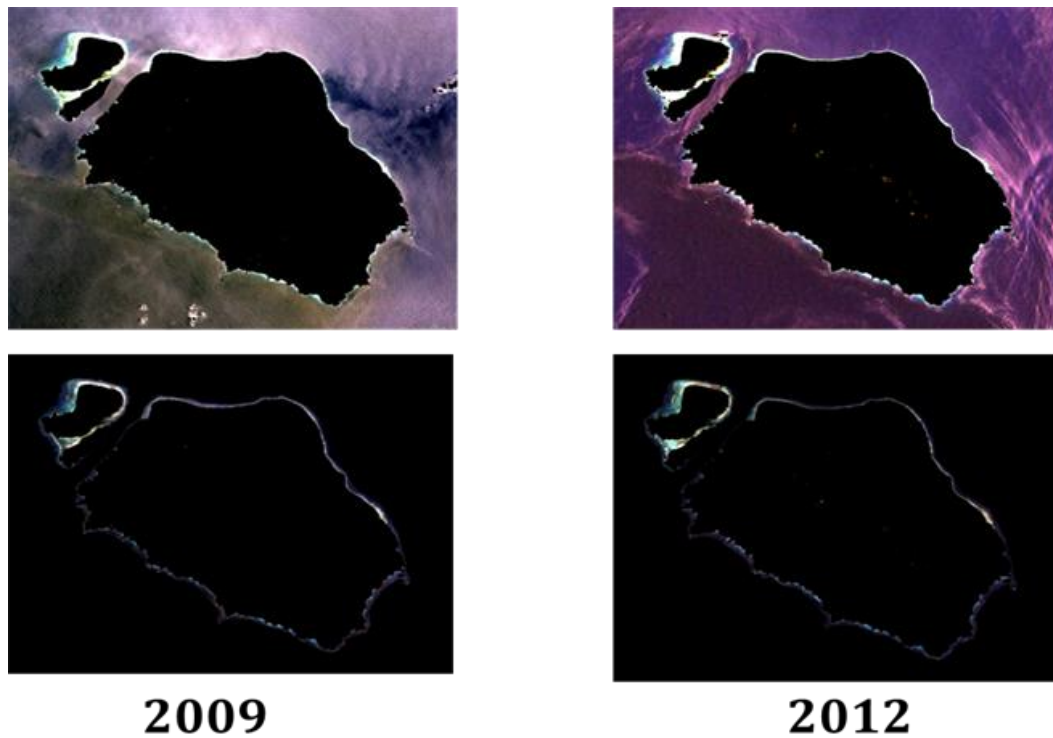


Figure 11. image Masking process

4.2 Classification of Water Body

The light of intensity decreases exponentially to the difference depth (Beer-Lambert Law). The good linear correlation between the two band channels when sampling substrate obtained on the same substrate at different depths (Lyzena, 1981). Figure 12 and 13 using the distribution of coral reefs as trained area sample. With transform the radiance using natural logarithm, the relationship between depth and radiance getting a linear correlation.

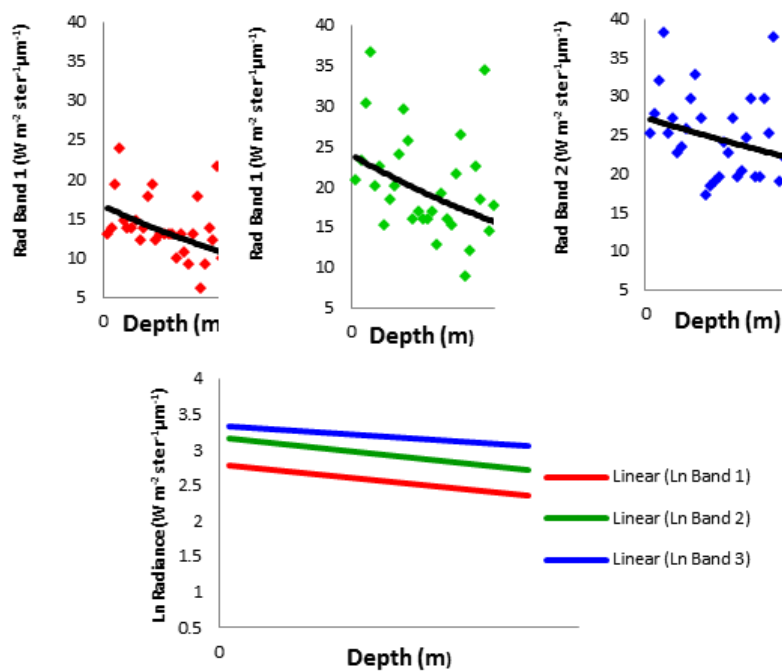


Figure 12. Linearis relationship between radiance with the depth on coral reef substrat at 2009

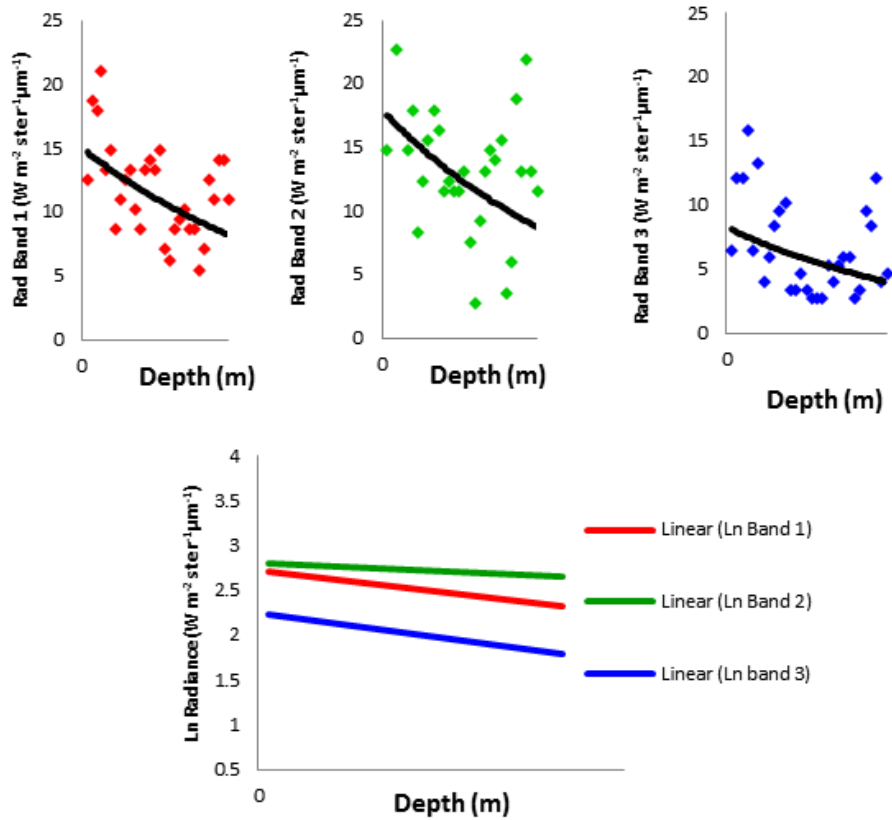


Figure 13. Linearis relationship between radiance with the depth on coral reef substrat at 2012

Figure 14 presented of linearise between differences depth and the spectral radiance in the water body on Landsat 7 ETM+ satellite image on 2009 and 2012. The difference colour represented about the difference depth, because spectral radiance from bottom water getting linear with the depth.

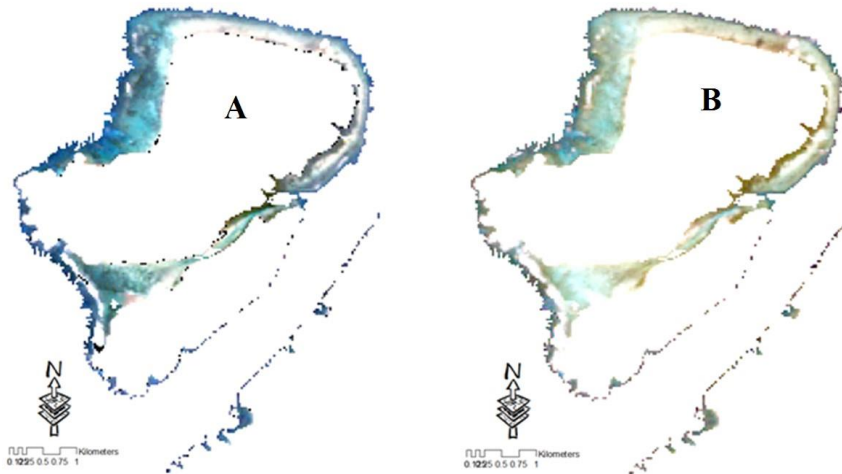


Figure 14. Transform radiance result A. 2009 B. 2012

The coefficient (k) band i obtained from a linear regression are the attenuation coefficient of band i (k_i) to the differences depth. Using linear regression to correlate between the two bands, the difference wavelength in each different bands can minimize or even removed, the coefficient correlation values between band i (k_i) with band j (k_j)

known as *attenuation coefficient* (k_i/k_j) between two band, as represents at Figure 15 and 16.

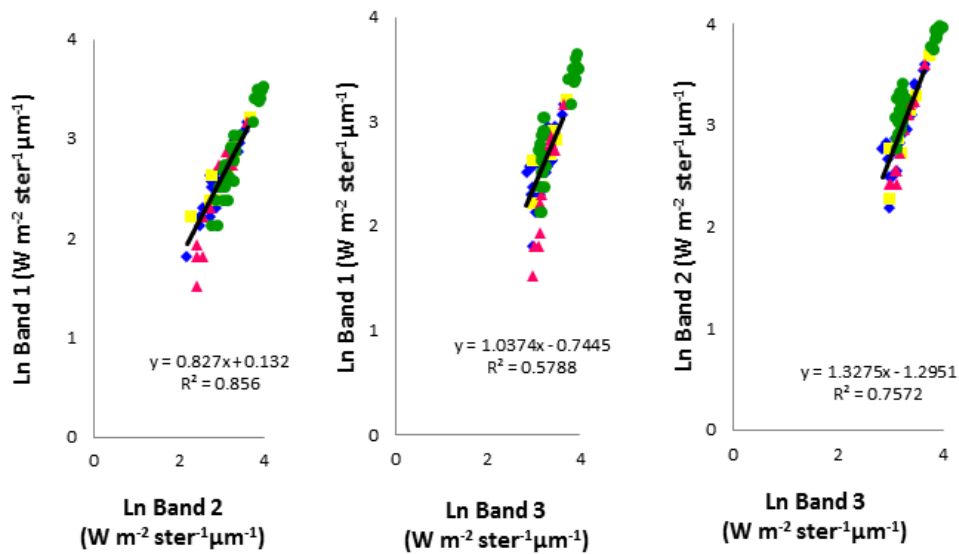


Figure 15. Transform band i against band j at various depth in 2009 (coral reef benthic)

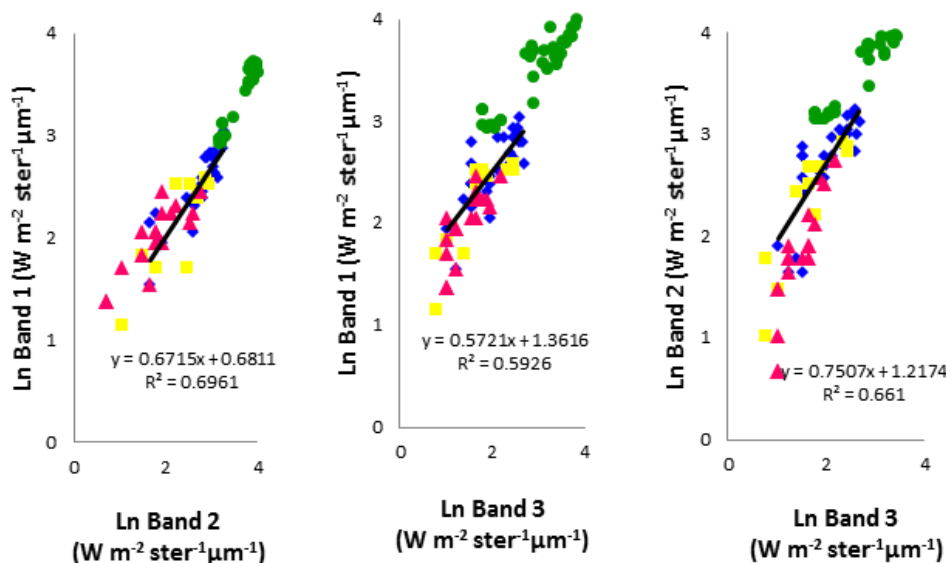


Figure 16. Transform band i against band j at various depth in 2012 (coral reef benthic)

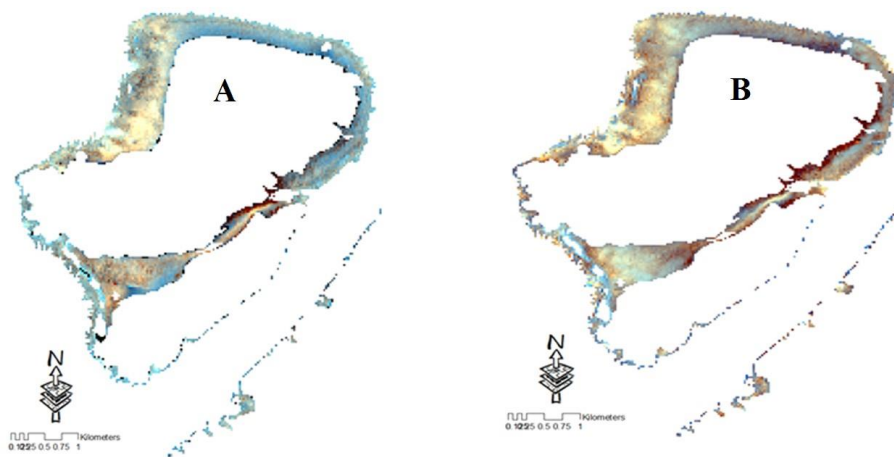
The correlation between natural logarithm (ln) band i and band j using linear regression is the basic of algorithm depth invariant index (water column correction). With the R-square value (R^2) in 2009 amounted to 0.856, 0.578, 0.757, and in 2012 amount to 0.696, 0.592, 0.661 indicate a “strong” and “very strong” level correlation between the natural logarithm (ln) band 1, band 2 and band 3.

The result of calculation *attenuation coefficient* (k_i/k_j) using the conventional linear regression analysis will produce coefficient value with dependent variable, so the equation obtained using regression linear ignored. *Attenuation coefficient* (k_i/k_j) between band i and band j will calculated from variance and covariance training data at difference depth. Base on equation 11, the calculation attenuation coefficient between natural logarithm (ln) band i and band j can see on the Table 4.

Table 4. Calculation of attenuation coefficient values

ki/kj	2009	2012
ln b1b2	0.882347	0.764596
ln b1b3	1.515810	0.673733
ln b2b3	1.642124	0.903495

Figure 17 presented the affect of the depth have been minimized using depth invariant index alghoritm (equation 12) at 3 visible band in Landsat 7 ETM+ using band math in ENVI 4.8. *Attenuation coefficient (ki/kj)* values obtained from the coefficient at Table 4. The different color on the satellite image shown a different spectral radiance (reflectance) from a different dominant benthic at the bottoms.

**Figure 17.** Water Column Correction result A.2009; B. 2010

4.3 Image Classification

Image classification is intended to provide a different color pixels for each thematic class based on their spectral properties as shown at Figure 18. Supervised classification with maximum likelihood method will be used to generate the different classes for each habitat, which was trained area using Reef Health Monitoring data.

Table 5 represented change detection on the shallow water benthic covered at Nusa Penida coastal from 2009 to 2012. Study area covers after image resize was about 560,142,000 m², then divided into two regions, 1) unclassified region (presented to land and depth sea) with an area of 538,725,600 m² (96.18%), and 2) classified region (presented coastal region) with an area of 21,416,400 m² (3.82%).

With a study area of approximately 21,416,400 m² (ignored unclassified area), live coral reefs cover area of 28.59% in 2009 and decreased to 23.34% in 2012. Referring to Gomez and Yap (1998), the condition of live coral cover at Nusa Penida decreased from *moderate* (2009) to *damage* (2012).

4.4 Accuracy Test

The classification results of the Landsat 7 ETM + satellite images will be compared with data obtained from field surveys result in 2009 and 2012. The method used is known by the confusion matrix. Accuracy test result using *confussion matrix* method can be seen in the Table 6.

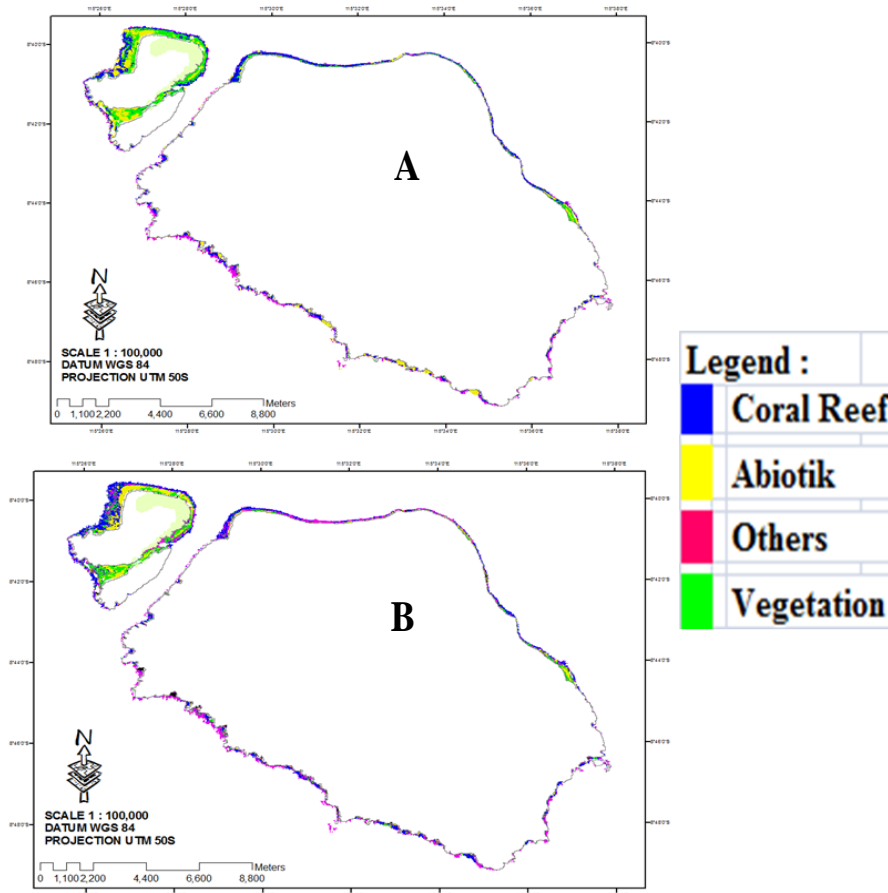


Figure 18. Shallow water benthic classification on result A. 2009 B. 2012

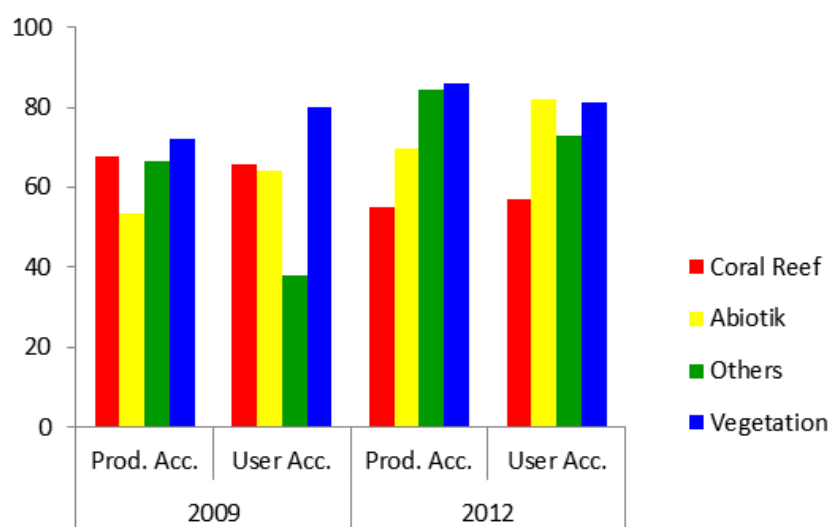
Table 5. Nusa Penida shallow water benthic change detection 2009-2012

Year	Coverage Area (m ²)				
	Unclassified	Coral Reef	Abiotik	Others	Vegetation
2009	538,725,600	6,121,800	2,329,200	10,512,000	2,453,400
2012	538,587,000	4,997,700	4,862,700	8,694,900	2,999,700
Change Detection	(138,600)	(1,124,100)	2,533,500	(1,817,100)	546,300
Percentage Change	-0.0257	-18.3622	108.7713	-17.2860	22.2671

Figure 19 presented the accuracy test by based on Table 6. Classification results show the ability of Landsat 7 ETM+ satellite images to distinguishing types of shallow water benthic covered at different depths by comparing the results of a user classification (in-situ data) with the results of the producer classification (satellite image) using statistics calculation in Ms. Excell 2007. Vegetation class has the highest degree of accuracy both producer accuracy (satellite images) and user accuracy (in-situ data). Abiotic class have a intermediate level of accuracy which producers classification generated lower than the in-situ data results.. Class coral reefs have a intermediate level of accuracy, both producer accuracy (satellite images) and user accuracy (in-situ data). Error in this class tend to be balanced between the satellite image with of in-situ data. Class others have a accuracy level that is nearly identical to the coral reefs classes, but the satellite image classification result is higher than in-situ data classification, especially in 2009. Base on Maingi *et al.* (2002), kappa coefficient on 2009 and 2012 is *moderate level*.

Table 6. Accuracy test using confusion matrix methods

Class	Habitat	2009		2012	
		Prod. Acc.	User Acc.	Prod. Acc.	User Acc.
Coral Reef		67.74	65.63	55.17	57.14
Abiotik		53.33	64.00	69.70	82.14
Others		66.67	38.10	84.21	72.73
Vegetation		72.00	80.00	86.00	81.13
Over all Acc.			65.85		74.81
Error			34.15		25.19
Kappa Coeff.			0.525		0.650

**Figure 19.** Accuracy test graph

4. Discussion

Fill and frame software successful remove a gaps on Landsat 7 ETM+ which will be used in this research. Investigation using 2 landsat image on 2009 and 2 landsat image on 2012, have been remove the gaps without change another pixel are not affect of gaps, except on band 6 and band 8 which has a resolution different from other bands, where the band 6 has a resolution of 60 meters, and band 8 has a resolution of 15 meters, this software has failed to use.

An area after crooping image is about 560,142,000 m². Unclassified area is about 538,725,600 m² (96,18%) and classification area is about 21,416,400 m² (3,82%). Landsat image 7 ETM+ classification using the maximum likelihood method in ENVI 4.8 obtained coral reefs and others class in 2012 decreased by 18.36% and 17.29% from 2009 covered, while the abiotik and vegetation increased 108.77% and 22.26% (Table 5).

Abiotic class cover change in 2012 increasing of to 108.77% percent and vegetation class increasing of to 22.26%, compare class covers at 2009. This is due to the difference acquisition time of satellite image used in this study. In 2009 the image used is a of Landsat 7 ETM+ satellite image on the acquisition of October 15, 2009 (summer), where the seaweed farmers are generally active so that the spectral radiance received by satellite sensor derived from radiance (reflectance) from seaweed cultivation areas. In 2012, using of Landsat 7 ETM+ satellite images on the acquisition of February 26, 2012 (rainy season) where the seaweed farmers are less active in farming so that the spectral radiance received by sensor satellite derived from radiance (reflectance) from bottom waters are generally in the form of sand or rubble.

Coral class cover decreased 18.36% and others class cover decreased 17.29% at the periods 2009-2012. The acquisition of Landsat 7 ETM+ satellite image in 2012 (rainy season) led to the ability of light to penetrate into the water body is limited, because of the atmospheric noisy (clouds, haze, aerosol, etc) and also increasing dissolved sediments in water bodies. It is caused a scattering and an absorption is greater than summer acquisition (2009), so that the spectral radiance (reflectance) at each class on a certain depth be lower even resembling each other. This caused a bias classification in large enough to classified of coral or others class (dominated by soft coral from *xeniidae* and *clavularia sp*), which also perform photosynthesis, then classified into a vegetation class or reverse. Good knowledge of coastal ecosystems and the location of research is very important to understand the classification results.

Reducing the light ability to penetrate into the water body in the rainy season due to increased dissolved sediment, causing the ability of zooxanthallae on coral reefs and soft coral (other class) in conducting photosynthesis capability will be reduced, so the spectral radiance received by satellite sensor from the shallow water benthic although became lower, but the spectral range value has a capability to distinguish shallow water benthic types more significantly. This can be seen in the accuracy test on each shallow water benthic class on using Landsat 7 ETM+ satellite image of acquired during the rainy season (2012) which showed an accuracy of better than satellite image acquired in the summer (2009) as presented on Table 6. Over all accuracy test results show the value in 2009 amounted to 65.85% with a kappa coefficient of to 0.525, while in 2012 obtained an accuracy value of 74.81% with a kappa coefficient of to 0.650.

5. Conclusions and Suggestion

5.1 Conclusion

Trouble SLC (SLC off) on Landsat 7 ETM+ can be improved by using the fill and frame software developed by the USGS, without affecting the pixel values are not have a impact image gaps. Landsat 7 ETM+ is good enough to identify the shallow water benthic in the district of Nusa Penida with accuracy 65.85% (2009) and 74.81% (2012), and the kappa coefficient 0.525 (2009) and 0.650 (2012). The accuracy of the classification results of Landsat 7 ETM+ image compared to in-situ data classified is in *moderate level*. This means that the Landsat 7 ETM+ reliable in shallow water benthic mapping with remote sensing technology.

Study area covers was about 560,142,000 m², consist of two regions, 1) unclassified region (presented to land and depth sea) with an area of 538,725,600 m² (96.18%), and 2) classified region (presented coastal region) with an area of 21,416,400 m² (3.82%). Change detection in this area from 2009 until 2012 obtained coral reefs classes cover decreased by 18.36% (6,121,800 m² to 4,997,700 m²), abiotic class cover increased by 108.77% (2,329,200 m² to 4,862,700 m²), others classes cover decreased by 17.27% (10,512,000 m² to 8,694,900 m²) and vegetation classes cover increased by 22.27% (2,453,400 m² to 2,999,700 m²). With a classified area about 21,416,400 m² (ignored unclassified area), live coral cover area of 28.59% in 2009 and decreased to 23.34% in 2012. The condition of live coral cover at Nusa Penida district decreased from moderate (2009) to damage (2012).

Live coral is found in nearly all Nusa Penida coastal area with the highest concentrations found in the western and southern part of Nusa Lembongan. Abiotic class is uniformly dispersed in high concentrations at western and southern part of Nusa Lembongan. Others class is a dominant class in 2009, with cover evenly across the coast of Nusa Penida. But in 2012, the concentration decreased and spread in large concentrations in the south and east of the Nusa Penida island. Vegetation classes are generally concentrated in the northern, southern and eastern part of the Nusa Lembongan.

5.2 Suggestion

Ideally, when we want to compare between satellite image data compare with in-situ data in the depth water with Point Intercept Transect (PIT) or a similar method such as Line

Intercept Transect (LIT) method, we can choose to use a high-resolution satellite image with a precision equal or close to the interval between the points on the line transect

Using a high resolution satellite image with a good geometric correction and good atmospheric correction, will give a best accuracy, because 1 pixel on satellite image can be represented by 1-2 point of the benthic sample at in-situ data. With high resolution satellite image, we can identified more of benthic class in the shallow water benthic.

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