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The Model of Mangrove Land Cover Change for the Estimation of Blue Carbon Stock Change in Belitung Island - Indonesia

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Abstract

The purpose of this research is to formulate the model of mangrove land cover change and to estimate blue carbon stock in Belitung Island during 1995-2015 period. The formulation of mangrove land cover change model in Belitung Island period 1995-2015 is done by using the interpretation of Landsat Imagery with the Object-Based Segmentation method. The analysis of blue carbon stock on mangrove and shrubs is done by using stratified purposive composite sampling technique through plot making (10 x 10 m) size. Blue carbon calculation on sediments is performed with ring samples of 4 cm diameter ring size and 5 cm (whole system sediment) intact diameters systematically at a depth of 35 cm for the sample area (1m x 1m x 0.7m). While the calculation of sediment carbon is done by using formula: Carbon Sediment ($MgCha^{-1}$) = BV (gr/cm^{-3}) x Depth Interval (cm) x 0.46. Total blue carbon is calculated based on the amount of blue carbon in mangrove plants, blue carbon in shrubs in a mangrove area, and blue carbon in sediment. On the year 1995 show that mangrove land cover is 16,756.34 ha. While on the year 2015 show mangrove land cover is 7,546.76 ha. The loss of blue carbon stock during the 1995-2015 period (20 years) is very large, i.e more than 50% (7,075,973.13 tons) of blue carbon stock is lost.

Keywords: Land Cover, Mangrove, Sediment, Blue Carbon.

INTRODUCTION

Mangrove land cover is generally spread over coastal areas and has a strong root system that can reduce waves, hold mud, and protect the coast from erosion. Biological aspects of mangrove ecosystems play a role in maintaining the stability of coastal biodiversity’s productivity and availability. Mangrove also serves as an absorbent of pollutants, especially organic materials and suppliers of organic materials for the aquatic environment. Mangroves can absorb carbon in the atmosphere and store it in biomass and sediment, so mangroves play a major role in global climate change mitigation (Nellemann *et al*., 2009; Hermon, 2017).

The mangrove land cover has the largest blue carbon stock in the coastal area. Mangroves are a unique type of tropical and subtropical forests, which grow along the coast or river affected by the tide (Fanckowiak and Beguin, 2001; Nellemann *et al*., 2009). With the decrease of mangrove land cover area in the coastal area hence directly also will reduce the ability of carbon absorption from the atmosphere by mangrove. Thus, the conservation and rehabilitation of mangrove ecosystems are necessary to maintain the absorption and storage of blue carbon (Twilley, *et al*., 1992; Miyajima *et al*., 2015). The potential for CO_2 absorption in the mangrove ecosystem is very large. The amount of CO_2 that can be absorbed by the mangrove ecosystem has different carbon sequestration potential. Generally, the blue carbon ecosystem is estimated to absorb 1 million-42 billion t of CO_{2eq} (Nellemann *et al*., 2009). Blue carbon stock is strongly influenced by changes in mangrove cover from year to year. Changes in mangrove land cover are a major issue in the changing coastal environment globally (Kayanne *et al*., 1995; Nellemann *et al*., 2009; Hermon, 2014; Hermon *et al*., 2018). The analysis of mangrove land cover change is more effectively done through satellite imagery analysis (Hermon, 2015).

Hermon (2016) explains that the change of land cover on Belitung Island is generally caused by illegal tin mining intervention done by UM (UM: unconventional mining) on natural lands, especially forest and mangrove land. Damage to mangrove ecosystems that occurs in Belitung Island emerged of the letting people do illegal mining activities by the government, so that the conversion of forest land and mangrove occurs on an ongoing basis. In the coastal area, in addition to illegal mining activities, damage to mangrove ecosystems is also caused by changes in mangrove land cover for settlements. In addition, the reduction of mangrove land in the coastal area of Belitung Island in 2015 when compared with the area of mangrove land cover in 1995 is also caused by the death of mangrove plants due to pollution of waste from tin mining conducted in the upstream.

Belitung Island has a large natural resource potential in terms of mineral seeds, especially tin. Hermon (2016) explains that there has been an addition of land cover change into active tin-mining since 1995 in Belitung Island covering 64,890.60 ha. As a result, there is a reduction of mangrove land cover by 9209.58 ha within 20 years. The reduced area of mangrove land cover will also directly affect the function of the mangrove itself for the sustainability and sustainability of natural resources and environment. The main functions of mangroves are the blue carbon stock and maintain a balance of coastal and marine climate, prevent abrasion and coastal damage due to extreme waves, and preserve the biodiversity of coastal areas.

MATERIALS AND METHODS

The Spatial Model of Mangrove Land Cover Change in Belitung Island

The spatial model of mangrove land cover changes in Belitung Island is formulated through Landsat Imagery Analysis 1995 and 2015 to identify and analyze the extent of mangrove land cover change (ha) within 20 years. Landsat 5+TM Analysis 1995 and Landsat Imagery 8 OLI 2015 is conducted with GIS-ENVI 5.1 analysis tool for band conversion and fusion for analysis which is corrected with ERDAS 9.1 (Dorren *et al*., 2003; Navulur, 2007; Holbling and Neubert, 2008). Connected and corrected Landsat imagery are used for mangrove land cover analysis with e_COGNITION 9.0 with the Object-Based Segmentation method, so that objects with similar spectral reflections and adjacent objects will form the same pattern or colour (Brenna and Webster, 2006; Addink *et al*., 2007; Bian, 2007; Albrecht, 2008; An *et al*., 2007; Baatz *et al*., 2008; Blaschke, 2009). Particularly in Landsat 8 OLI analysis in 2015, the patterns formed are given coordinate points for field checks with Geography Position System (GPS) to determine whether the pattern belongs to mangrove land cover or not, while pattern determination on Landsat Imagery 5+ETM in 1995 refers to Landsat 8 OLI 2015 and information from Belitung Island community about mangrove land cover in 1995 in Belitung Island. The ground check pattern is analyzed further with GIS-Arc GIS 10.3 for overlay pattern from object-based segmentation with mangrove coordinate data. The analysis of mangrove land cover changes (ha) during 1995-2015 period (20 years) is done with GIS-ENVI 5.1 converted with GIS-ERDAS 9.1 with GIS Analysis Matrix tools.

Estimated Changes in Blue Carbon Reserves on Belitung Island

The analysis of blue carbon stock on mangrove cover is divided into 2, i.e: **1) Blue Carbon in mangrove and shrubs in mangrove land**. The sampling technique to calculate carbon stock in mangrove is done by using stratified purposive composite sampling technique by making plot with 10 x 10 size (Hermon, 2015; Hermon, 2016) by prioritizing mangrove density object which is considered to represent all mangrove distribution in Belitung Island in 2015. Mangrove samples are taken compositely and analyzed by using no-destructive method (Hermon, 2015; Hermon, 2016). The biomass analysis of mangroves uses allometric equations developed by Kattering (2001); Hermon (2015); Hermon (2016), which is done by using a simple formula, where DW=0.11ρD2.62 (DW = Dry Weight/gr), (D = Diameter Breast Height/cm), and (ρ = Wood Bulk Density). The biomass analysis of shrubs under mangroves is calculated based on quadrant of total dry weight (result obtained in units of gr/m^2 and converted into ton/ha), by using formula: Total DW (gr) = DW/WW x Total WW (gr), where DW (Dry Weight in gr) and WW (Wet Weight in gr). Total carbon stocks are obtained from total biomass multiplied by 0.46 (concentration of C in organic matter is around 46%). The calculation of mangrove carbon into the whole mangrove area is done through conversion of the result (10 x 10 m) into the actual extent. The estimation of the year 1995 mangrove carbon is based on the estimation of the year 2015. **2) Blue Carbon in Sediment**. Sediment sampling is used to calculate sediment carbon stock using ring samples diameter of 4 cm and ring size of 5 cm (intact sediment samples) systematically at the depth of 35 cm for sample area (1 m x 1 m x 0.7 m) where the depth of sample taken is based on a general estimate that the depth of the average mangrove sediment is 70 cm. All intact sediment samples are put into oven with a temperature of 60^0C for 3 x 24 hours, so that the water content in the sediment sample is completely lost and the dry sediment conditions are completely dry. Sediment samples that have been perfectly dry are measured in weight (gr) and averaged. The average weight of the dry sediment sample is reduced by the average weight of sample ring (gr) for the net result of the sediment sample (gr). Ring volume counting is done by using formula $V_{ring}= IIr^2.t$ (II, constant; r, ring diameter/cm; t, ring height/cm). The calculation of sediment carbon is done first by calculating Bulk Density (BV) sediment, that is: BV (g/cm^3) = Sediment Dry Density (gr)/Volume Ring (cm^3). While the calculation of sediment carbon is done by using formula: Carbon Sediment ($MgCha^{-1}$) = BV (gr/ cm^{-3}) x Depth Interval (cm) x 0.46 (Hermon, 2017). The calculation of sediment carbon into the whole mangrove area is done through conversion of the result (1 m x 1 m x 0,7 m (0.7 m is the average depth of sediment). The number of rings required in the sample area is 11,147 ring samples. The conversion is done by the calculation of sediment carbon in the ring (gr/cm^2) to the amount of sediment carbon in ton/ha. The estimation of the year 1995 sediment carbon is based on estimation of the year 2015. **3) Total Blue Carbon.** Total Blue Carbon is calculated based on the amount of blue carbon in mangrove plants, blue carbon in shrubs in the mangrove area, and blue carbon in sediment.

RESULT AND DISCUSSION

Spatial Models of Mangrove Land Cover Change in Belitung Island

The results of object-based segmentation analysis on Landsat 5+TM 1995 and Landsat 8 OLI 2015 in Belitung Island give mangrove pattern in coastal of Belitung Island. The pattern formed has almost the same colour, uniform, and same density (Figure 1).

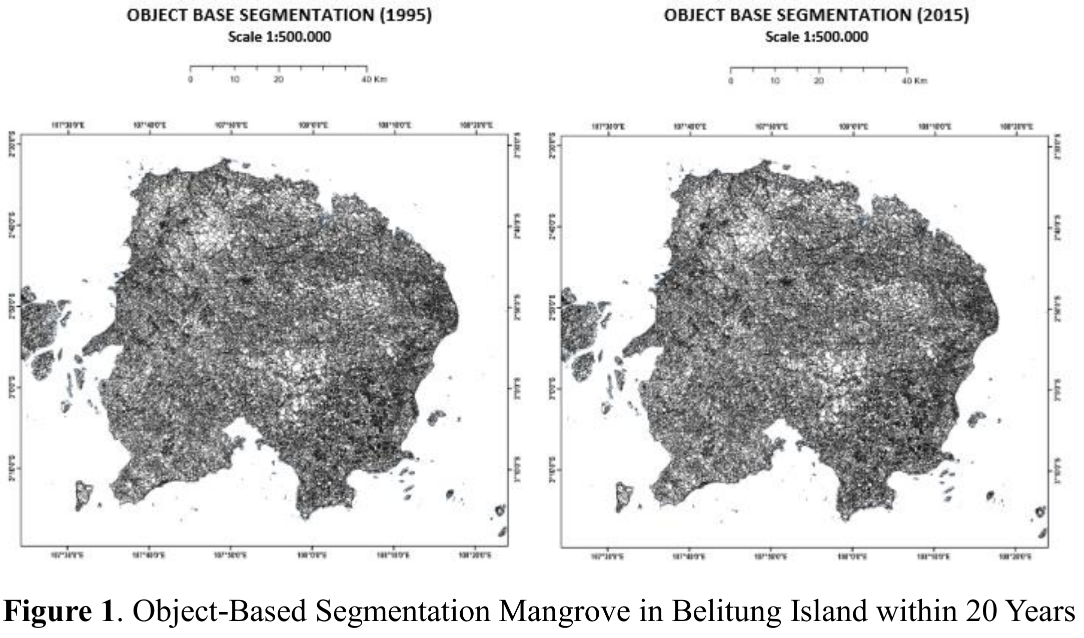

Figure 1. Object-Based Segmentation Mangrove in Belitung Island within 20 Years

(1995-2015).

Segmentation level for mangrove identification in Belitung Island has 4 levels, generally level 1-level 4 have homogeneous colour with uniformity index value of 0.7 and density index of 0.2. According to Darwish *et al*., (2006), index density of mangrove object in object-based segmentation is ranged from 0.5-0.8 and index of mangrove density is ranged between 0.2-0.4. Furthermore, Wells (2010) adds that the pattern formed through e_COGNITION Project analysis is very valid, because the identification of the object depends on the colour, uniformity, and density of the object. The uniformity of an object greatly determines the type of object being analyzed (Wang *et al*., 2004; Hay *et al*., 2005; Lang., 2005; Laliberte *et al*., 2006; Luscier *et al*., 2006; Laliberte *et al*., 2007; Lackner and Conway, 2008; Lang, 2008; Mailinis *et al*., 2008; van der Werff and Van Der Meer, 2008).

Field checks based on coordinates of homogeneous patterns and similar densities on the coastal area of Belitung Island are undertaken to analyze further from mangrove land cover in Belitung Island in 2015, while for 1995, it refers to the 2015 analysis and is corrected based on information from the community. The results of the analysis provide information that there has been a change of mangrove land cover on Belitung Island in 1995 and 2015 (Figure 2).

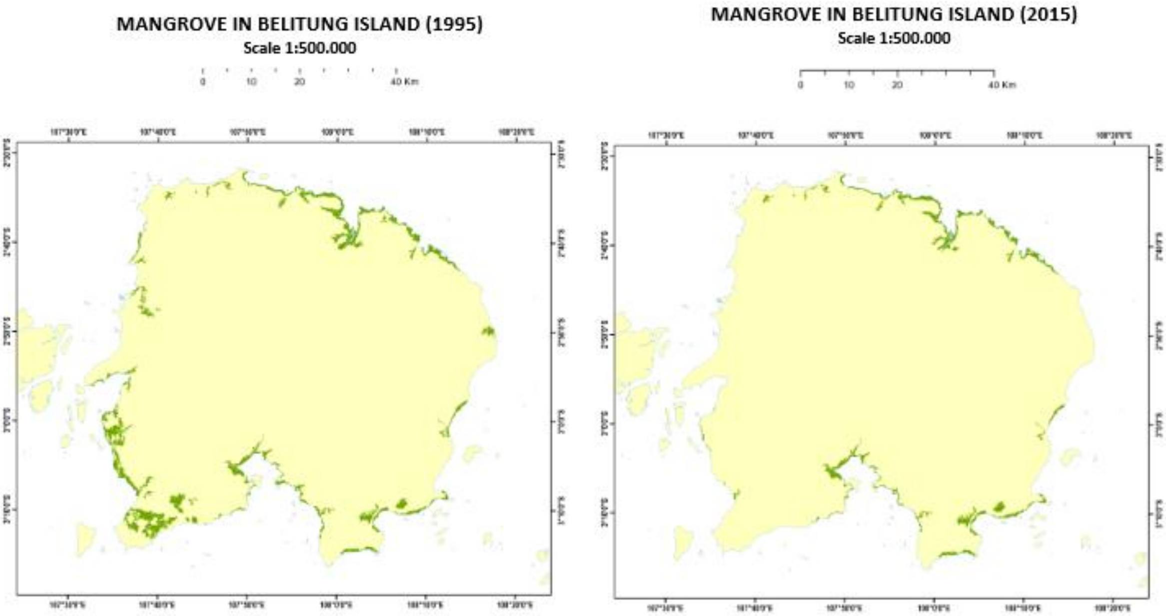

Figure 2. Spatial Models of Mangrove Land Cover Change in Belitung Island within 20 Years (1995-2015).

The result of Landsat 5+TM analysis in 1995 show that mangrove land cover in Belitung Island in 1995 is 16,756,34 ha spread in a coastal area of Belitung Island. While the results of Landsat 8 OLI analysis in 2015 show that mangrove land cover on Belitung Island is 7,546.76 ha.

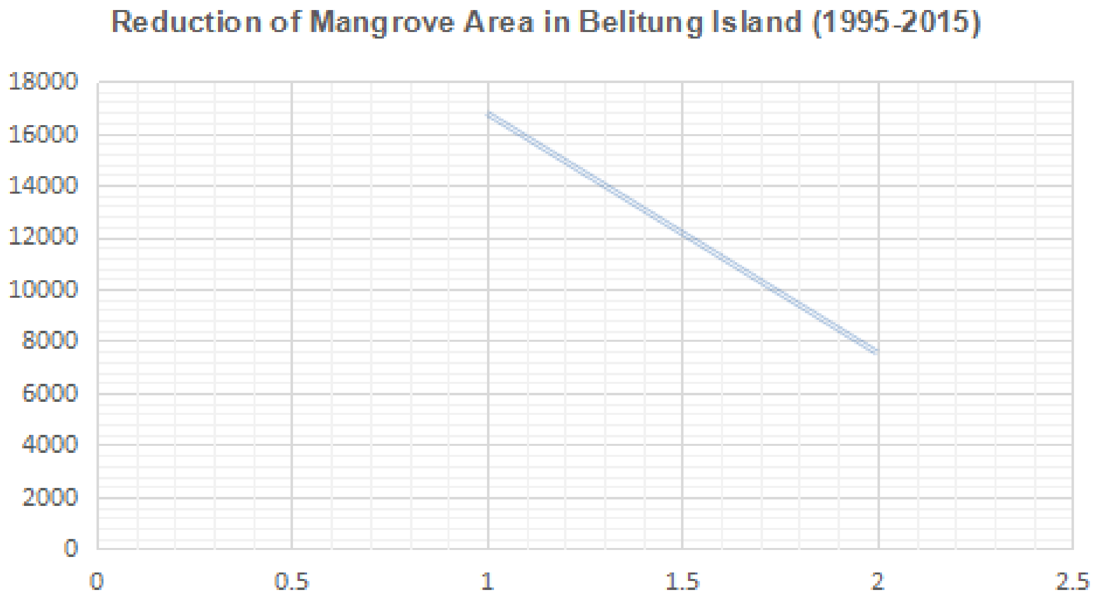

Figure 3. Reduction of Mangrove Area in Belitung Island within 20 Years (1995-2015).

The reduction of mangrove area in Belitung Island within 20 years (1995-2015) is 9,209.58 ha. The large reduction of mangrove area in Belitung Island is due to the development of coastal tourism, resulting in many conversions of mangrove land for settlements. In addition, the large number of illegal miners or Unconventional Mining (UM) that has been active since 1990 results in the conversion of mangrove for tin mining, and tin mining activities in Belitung Island in the forest area also result in damage and loss of mangrove land due to tin mining pollution (Hermon, 2016).

Estimated Changes of Blue Carbon Stock in Belitung Island

Blue carbon is a carbon stored in coastal ecosystems, especially in mangrove ecosystems, either in mangrove biomass or in mangrove sediments. Change in the area of mangrove land cover in Belitung Island within 20 years (1995-2015) directly also affect the availability of blue carbon stock in Belitung Island. The results show that in 1995 the cover of mangrove land in Belitung Island is 16,756.34 ha. While in 2015 the cover of mangrove land in Belitung Island is 7,546.76 ha. Blue carbon stock in mangroves and shrubs that grow in mangrove land cover can be seen in Table 1.

Table 1. Biomass and Blue Carbon Stock of Mangrove Land Cover in Belitung Island in 2015.

BLUE CARBON MANGROVE				TOTAL BLUE CARBON MANGROVE			
Number of Trees /ha	Biomassa		Blue Carbon (ton/ha)	1995		2015	
	(kg/m^2)	(ton/ha)		Area (ha)	Blue Carbon (ton)	Area (ha)	Blue Carbon (ton)
1.367	156,42	1564,2	719,532	16.756,34	12.056.722,84	7.546,76	5.430.135,32
BLUE CARBON LITTER/SHRUBS				**TOTAL BLUE CARBON LITTER/SHRUBS**			
	Biomassa			1995		2015	
	(kg/m^2)	(ton/ha)	Blue Carbon (ton/ha)	Area (ha)	Blue Carbon (ton)	Area (ha)	Blue Carbon (ton)
	10,56	105,6	48,576	16.756,34	813.858,82	7.546,76	366.591,41
BLUE CARBON SEDIMENT				**TOTAL BLUE CARBON SEDIMENT**			
Volume Ring (cm^3)	Bulk Density/BV (gr/cm^3)	Blue Carbon in Ring (gr/cm^2)	Number of Ring Sample Area	Blue Carbon in Sample Area (gr/m^2)		Blue Carbon Sediment (ton/ha)	Blue Carbon (ton)
62,8	0,65	20,93	11.147	20,93 x 10^{-4}		23,33 x 10^{-3}	0,23
				Blue Carbon Sediment Year 1995		Blue Carbon Sediment Year 2015	
				Area (ha)	Blue Carbon (ton)	Area (ha)	Blue Carbon (ton)
				16.756,34	3.853,96	7.546,76	1.735,76
TOTAL BLUE CARBON IN BELITUNG ISLAND						**1995 (ton)**	**2015 (ton)**
						12.874.435,62	**5.798.462,49**
TOTAL REDUCTION OF BLUE CARBON WTHININ 20 YEARS (1995-2015) IN BELITUNG ISLAND (ton)						**7.075.973,13**	

Source: Data Analysis Results (2017).

Blue carbon in Belitung Island in 2015 is much reduced when compared with blue carbon stock in 1995. Blue carbon in Belitung Island in 1995 in mangrove plants is 12,056,722.84 tons, in the shrubs in the mangrove area is 813.858,82 tons, and in sediment is 3,853.96 tons. In 2015, blue carbon on Belitung Island in mangrove plant is 5,430,135.32 tons, in litter/shrubs in mangrove area is 366,591,41 tons, and in sediment is 1,735,76 tons (Figure 4). Blue carbon is one of the natural systems to eliminate Green House Gas (GHG). Therefore, if degraded, blue carbon can increase the process of global warming (Bakker *et al*., 1996; Hartnett *et al*., 1998; Ch'ura *et al*., 2003; Hunt *et al*., 2011; Jiao *et al*., 2014). Blue carbon is stored in mangrove land, thus giving a positive influence on coastal, marine, and terrestrial environmental conservation (Kayanne *et al*., 1995; Nellemann *et al*., 2009; Miyajima *et al*., 2015; Kubo *et al*., 2015).

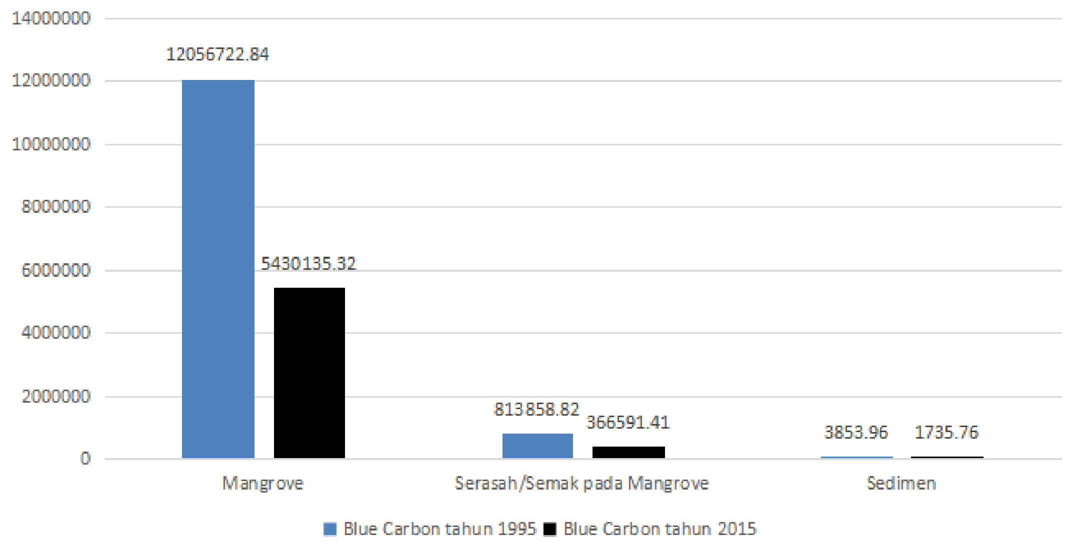

Figure 4. Blue Carbon Stock in Mangroves, Shrubs in Mangrove Area, and Sediment in Belitung Island year 1995 and 2015.

The degradation of mangrove forest in Belitung Island within 20 years (1995-2015) is due to the conversion of land for settlements and tin mining, as well as the increased mangrove land damage caused by tin mining, directly results in the change of blue carbon stock from 1995 to 2015. Change blue carbon stock on Belitung Island within 20 years (1995-2015) can be seen in Table 2.

Table 2. Changes in Blue Carbon Stock within 20 Years (1995-2015) in Belitung Island.

Stored Location	**Blue Carbon (ton)**		**Blue Carbon Stock Changes (ha)**
	1995	**2015**	
Mangrove Plant	12.056.722,84	5.430.135,32	6.626.587,52
Litter/shrubs	813.858,82	366.591,41	447.267,41
Sediment	3.853,96	1.735,76	2.123,20
Total	**12.874.435,62**	**5.798.462,49**	**7.075.973,13**

Source: Data Analysis Results (2017).

Total blue carbon stock in Belitung Island in 1995 is 12,874,435.62 tons, stored in mangrove plants, shrubs in the mangrove area, and sediment. In 2015, blue carbon stock decreased to 5,798,462.49 tons, bringing the total blue carbon loss in Belitung Island in 2015 to 7,075,973.13 tons.

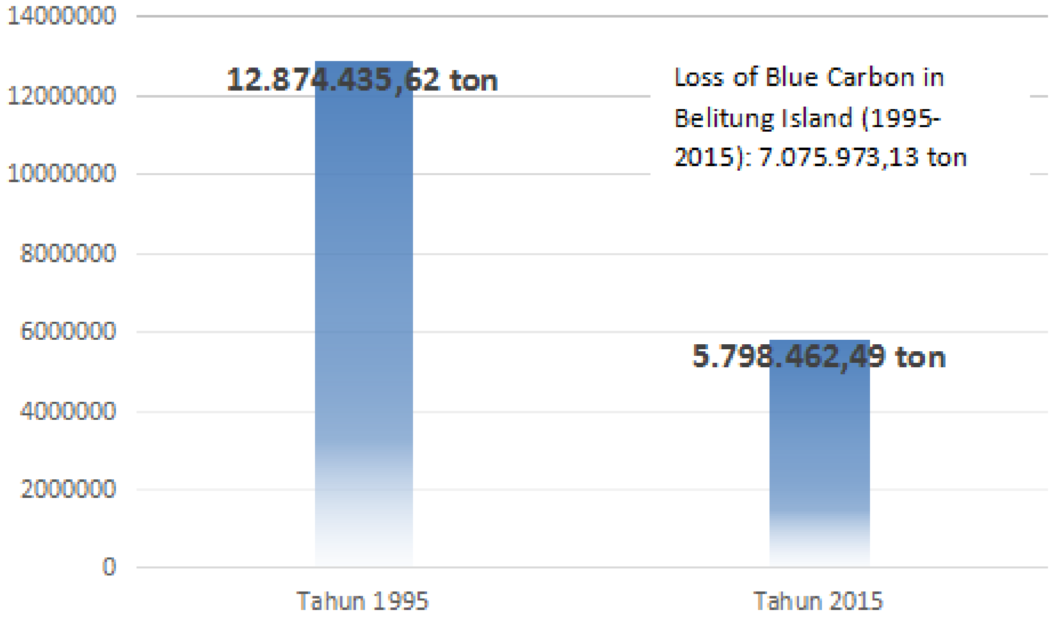

Figure 5. Total Blue Carbon in the Mangrove Land Cover Area in Belitung Island in the year 1995 and 2015.

The loss of blue carbon stock in Belitung Island during 1995-2015 period (20 years) is very large, i.e more than 50% (7,075,973.13 tons) of blue carbon stock lost. The huge loss of blue carbon stock in Belitung Island characterizes the destruction of coastal ecosystems in Belitung Island, either due to the conversion of mangrove land into settlements and tin mining, as well as to unreliable tin mining waste.

CONCLUSION

Mangrove land cover in Belitung Island during 1995-2015 period (20 years) experiences a relatively rapid change. The rapid change of mangrove land cover is due to a large number of illegal mining activities that convert mangrove land into illegal tin mining area in Belitung Island. Changes in mangrove land cover will result in changes in blue carbon stock in Belitung Island. Blue carbon reserves on Belitung Island in 1995 is 12,874,435.62 tons and in 2015 is 5,798,462.49 tons. Thus, the loss of blue carbon stock in Belitung Island during the 1995-2015 period is 7,075,973.13 tons. This, causing the coastal area of Belitung Island which is already experiencing environmental degradation and vulnerable to more severe environmental damage.

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