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COASTAL PEAT MASS MOVEMENT AND ITS EFFECT ON THE TERRESTRIAL CARBON DISCHARGE TO THE OCEAN IN BENGKALIS ISLAND, INDONESIA

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SUMMARY

Multi temporal high resolution satellite imagery was used to identify the peat-coastal setback of Bengkalis Island, Indonesia. Shuttle Radar Topography Mission DEM was used to estimate the geomorphology of the peatland. Multi temporal topographic survey using RTK-GPS, peat core samplings, and ground water level measurements were conducted to clarify the geomorphology change and carbon storage of the peatland. Recent coastline change and long term coastline change were analyzed with high resolution satellite images; SPOT-6 and WorldView3. The average annual setback changed from 11.93 m to 23.37 m. Over the long term, average annual setback was 14.46 m. The results reveal that total erosion extent was 478 ha between 2000 and 2015, which represents a peat volume loss of 21.7 Mm^3 which correspond to a total carbon loss of 1.27 Mt C. Bog bursts in Bengkalis Island coast was observed in the rainy season caused by extensive rainfall. Following the bog burst, the peat mass was eroded to the sea.

Keywords: *peat failure, bog burst, Sumatra, Indonesia*

INTRODUCTION

In the northern part of Bengkalis Island, the peat swamp forest has collapsed and fallen to the sea (Fig. 1). The situation is quite serious as well as strange because peat swamp forest is generally established behind the coast in the peat swamp model of the Anderson (1964). The coastal peat cliff is about 5 m higher than the mean sea level. In the 1950s, a mangrove coast was a likely feature at that time (U.S. Army Map Service, 1955). However, in recent satellite images, the mangrove has gone, and the coast been eroded till 1988. Long term coastline setback and peat mass movements were observed in Bengkalis Island, Indonesia. In Bengkalis Island, Riau Province has faced a coastal erosion problem for more than thirty years. Vast areas of the peat swamp forest have been used for palm oil production since 2002. The objective of this study was to provide an estimate of how much the land area and carbon storage in the terrestrial region have been reduced in the last 15 years.

METHODS

Our study area is Bengkalis Island, Indonesia (Fig. 2), which is located 8 kilometers off the coast of the main island Sumatra and lies along the west side of Malacca strait. The total land area is roughly 900 km^2, of which more than 70% is covered by peat soils with a thickness more than 1 m. The peat deposit on Bengkalis Island contains 3.0×10^9 m^3 of peat (Supardi *et al*., 1993). The island is almost flat and has a maximum surface elevation of approximately 10-15 m above mean sea level. Low-lying and swampy, the island has high precipitation, is sparsely populated, and is mostly unfit for cultivation. It stretches northwest-southeast for about 68 km; its width east-west is about 19 km. It consists of 4 main peat domes which are typical of tropical peatland morphology. We concentrated our study area on the western side of the island that is currently dominated by palm oil plantations. In order to cover the study area with a time series of high-resolution satellite images for the short term erosion analysis, a total of five satellite scenes from ALOS PRISM, SPOT 6, and World View 3 were used (Fig. 3). ALOS PRISM images were recorded on March 24 2010, and March 27 2011, while the SPOT 6 images were captured on January 27 2013, and September 18, 2013. For the latest image, we used World View 3 recorded on April 2 2015. We used SPOT 6 images recorded on September 18 2013 as a master image for geometric correction. In order to preserve the original pixel value, nearest neighbor was applied for resampling the pixel value following affine method that used to rectify the image. Five ground control points obtained from in-situ measurement by using static GPS were used for rectifying the master image, producing a RMSE of 1.11 m. The other four images were rectified based on the master image by employing image to image rectification, producing a RMSE of less than 1.85 m. For long term erosion, Landsat images were used to obtain the annual erosion and annual setback between 2000 and 2015. Terrestrial carbon loss was calculated by the procedure shown in Fig. 4.

Fig. 1: Erosion of the peat coast in Bengkalis Island, Indonesia. Peat swamp forest (left) and palm oil plantation (right)

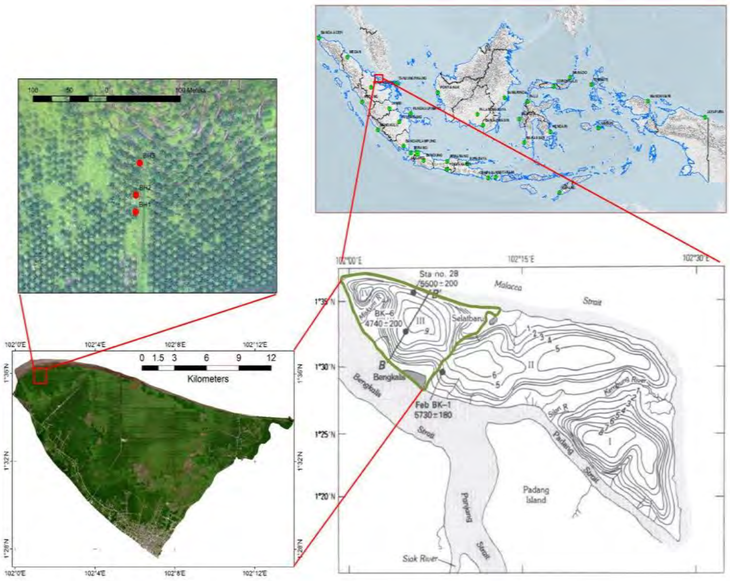

Fig. 2: Bengkalis Island, Indonesia

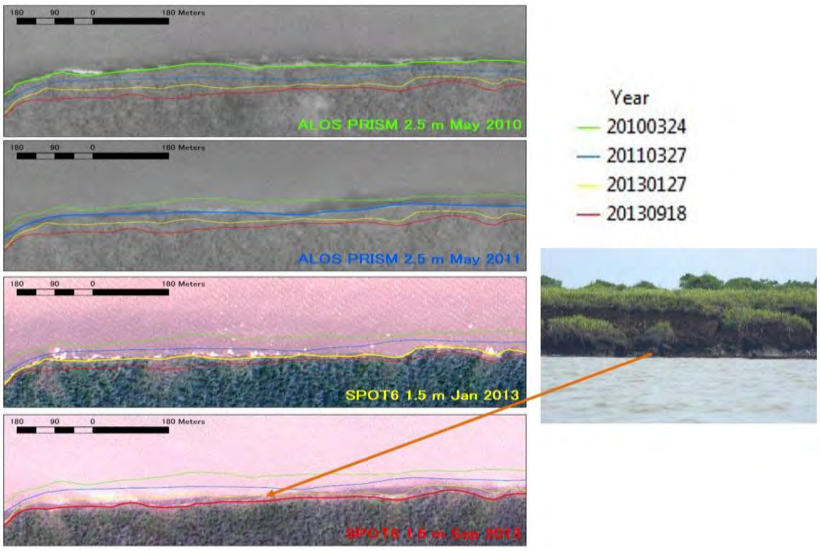

Fig. 3: Coastal erosion process of the northern part of the Bangkalis Island, Indonesia.

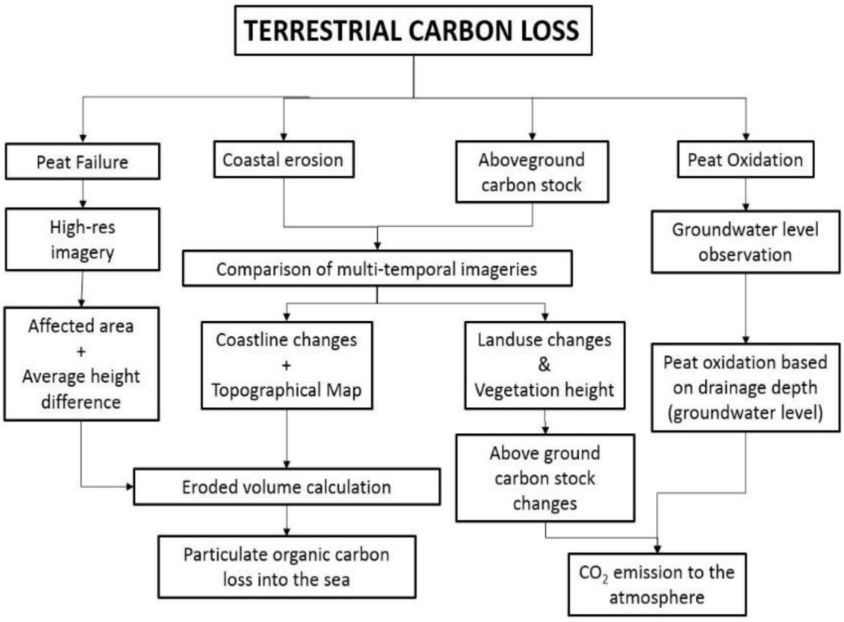

Fig. 4: Procedure to evaluate terrestrial carbon loss in the Bangkalis Island, Indonesia.

RESULTS

We collected peat soil samples from 17 locations in Bengkalis Island that represent various types of land use. Vertical distribution of organic carbon and nutrients were analyzed from sample points located in oil palm plantations and forests. The highest carbon content (57.85%) was found in the forest located on the northern side of oil palm plantation. Even though this forest was affected by a waterway constructed inside the oil palm plantation, it had the highest carbon content among the sample locations. Conversely, the lowest carbon content (40.8%) was located in the small holder oil palm plantation. This area was recently burned for land clearing. Low carbon content might be correlated with the burning activity. To analyze the coastline changes, we employed two images of ALOS prism recorded in March 2010 and March 2011, two images of SPOT 6 recorded in January and September 2013, and one image of World View 3 recorded in April 2015.

Table 1: Annual rate of coastal erosion (ha/year) and setback (m/year).

Time	Erosion		
	Annual (ha/year)	Affected coast length (m)	Average annual setback (m/year)
Mar 2010- Mar 2011	37.79	20807	18.16
Mar 2011- Jan 2013	22.58	18924	11.93
Jan 2013 -Sep 2013	23.5	9903	23.73
Sep 2013-Apr 2015	25.88	12666	20.43
May 2000-May 2015	31.88	22038	14.46

The results in Table 1 shows that the highest annual erosion rate occurred during March 2010 to March 2011, it was caused by the length of affected coastline is long (more than 20 kilometers). In other words, the coastal erosion occurred alongside the coastline. The highest rate of coastal setback occurred during January to May 2013 because the erosion process only occurred at a certain location where massive erosion was observed. This process is closely linked to the peat failure phenomena that occurred near the coastline. In the long term period, coastal erosion somehow showed the average value of the short term. In both short term (2010-2015) and long term (2000-2015). The height points were extracted on the vegetation-free area in SRTM DEM. Based on these points we interpolate by using the nearest neighbor method to derived topographic map. The topographic transect was measured using RTK GPS at 4 survey lines to validate the topographic map. The result of topographic map indicates the morphology of tropical peatland which is in the shape of peat dome. The difference between RTK GPS and topographical map is 0.95 meter in average. Since there is a time gap between the RTK measurement and SRTM observation, the difference between both elevations might be attributed to subsidence process. Another possible explanation is that it was caused by the bush or necromass that cover the open area.

CONCLUSION

Over the past 15 years, Bengkalis Island has experienced a massive loss of terrestrial carbon owing to coastal erosion, deforestation, and peat oxidation. Although peat failure only occurred in the past year on a massive scale, it is the highest contributor to the annual carbon loss. Nearly 50 % of the annual carbon loss came from peat failure. The peatland of Bengkalis islands is facing threats from the over exploitation of natural land resources. This study had revealed that the carbon loss is dominated by particulate organic carbon from coastal erosion and peat failure. This general conclusion was based on the following result: 1) Annual coastal erosion has decreased in the past four years, in contrast to the annual setback that has increased in the past two year. Furthermore, the total erosion extent is 478 ha along 22 km of coastline area in the past 15 years. This represents a peat volume loss of 21.7Mm^3 which correspond to a total carbon loss of 1.28 MtC. In the past year, the peat failure process has occurred on a massive scale and contributes significantly to the carbon loss. In fact, the peat failure contributed to 2.89 Mm^3 of total eroded volume that represents a carbon loss of 0.21 Mt C in the past year. There was no significant different between LULUCF and vegetation height aboveground carbon stock derived method. The difference is less than 3 %. The lowering of groundwater table has contributed the CO_2 emissions of 0.357 Mt per year. This phenomenon occurred due to the construction of artificial drainage in oil palm plantation.

The conservative method of carbon accounting for climate change mitigation only considers the carbon dynamics from land use change and peat oxidation. This study case has shown that other factors (coastal erosion and peat failure) also contribute significantly to terrestrial carbon loss.

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REFERENCES

i. J.A.R. Anderson (1964) The structure and development of the peat swamps of Sarawak and Brunei, Journal of Tropical Geography, 18 (1964), pp. 7–16

ii. Supardi, Subetkty, A. D., and Neuzil, S.G., 1993, General geology and peat resources of the Siak Kanan and Bengkalis ISland peat deposits, Sumatra, Indonesia, in Cobb, J. C., and Cecil, C. B., eds., Modern and Ancient Coal-Forming Environments: Boulder, Colorado, Geological Society of America Special Paper 286