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# ASSESSING RATE OF DEFORESTATION AND CHANGES OF CARBON STOCK ON MANGROVES IN PAHANG, MALAYSIA

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**Abstract:** Mangrove forests play an important role as a substantial coastal carbon (C) sink. It is interesting to note that although plant biomass in the ocean and coastal areas comprises only 0.05% of the total plant biomass on land, it cycles a comparable amount of carbon each year. However, despite being a crucial component in the global carbon cycle and having potentially profound influence on climate change, the areal extent of mangrove forests has declined significantly as a result of coastal development, aquaculture expansion and over-harvesting. Pahang, which is the largest state in Peninsular Malaysia was selected as the study area. –in spite of being the largest state, currently Pahang has only about 9,000 ha of mangrove forest out of which about 2,416 ha is under reserve. Although having a small extent of mangrove forest, it is also inevitable from being threatened by these landuse activities. This study was carried out to assess the loss of carbon stock on mangroves forest caused by the changes of landuse. Landsat satellite images over the years 1995, 2005 and 2014 were used to determine the mangrove forest covers and changes. The images were classified and the information on landuse classes has been extracted. Post-classification changes detection has been conducted to assess the rate of deforestation based on permanent changes of landuse occurred within the periods. In the meantime, the total carbon stocks of existed mangroves were determined by using allometry specified for mangroves in Malaysia. From this study, the magnitude of mangroves changes has been quantified and the changes of carbon stocks were determined over the entire state of Pahang.

**Key words***:* Mangroves, carbon stock, satellite, Pahang

## INTRODUCTION

Mangrove forest play an important role as a substantial coastal carbon sink. It is interesting to note that although plant biomass in the ocean and coastal areas comprises only 0.05% of the total plant biomass on land, it cycles a comparable amount of carbon each year. A recent study revealed that mangroves have higher levels of primary productivity than most other forests. Their standing biomass is considered high as such mangroves are among the most carbon-rich forests in the tropics. It was reported that a hectare of mangrove forest stores up to four times more carbon (C) than most other tropical forests around the world (Daniel et al. 2011).

Daniel et al. (2011) also found that the C storage of dense mangrove has a typical mean of 1,023 Mg C $ha^{-1}$, which is exceptionally high compared to the mean C storage values of the world's major forest domains. Above-ground C pools were sizeable (mean 159 Mg C $ha^{-1}$, maximum 435 Mg C $ha^{-1}$), but below-ground storage in soils dominated, accounting for about 50–98% of total storages. Mangroves can absorb carbon dioxide and store carbon by as much as 40% more than the dry land forest ecosystem. Total carbon deposits per square kilometer in the coastal systems may be up to five times the carbon stored in tropical forests, due to their ability to absorb or sequester carbon at rates up to 50 times those of the same area of tropical forest. $CO_2$ stored in these ecosystems is found not only in the plants, but in layer upon layer of soil underneath (IUCN 2011). Hence, mangroves may have an important role to play in global carbon budgets and in mitigating climate change.

However, despite being a crucial component in the global carbon cycle and having potentially profound influence on climate change, the areal extent of mangrove forests has declined significantly as a result of coastal development, aquaculture expansion and over-harvesting. Pahang, which is the largest state in Peninsular Malaysia, was selected as the study area. Despite the largest state, currently Pahang has only about 9,000 ha of mangrove forest out of which about 2,416 ha is under Forest Reserve. Despite a small extent of mangrove forest, it is also inevitable from being threatened by these land use activities. This study was carried out to assess the loss of C stock on mangroves forest caused by the changes of landuse. This study was conducted to provide the information on deforestation of mangroves and to assess the changes of C stock that have occurred in recent decades in the ecosystem. From this study, the magnitude of mangroves changes has been quantified and the changes of carbon stocks were determined on the mangroves over the entire state of Pahang.

## MATERIALS AND METHODS

Ten-year interval of Landsat satellite imageries over the years 1995, 2005 and 2014 were used to determine the mangrove forest covers and changes. The images were classified and the information on land use classes has been extracted. Post-classification changes detection has been conducted to assess the rate of deforestation based on permanent changes of land use occurred within the periods. In the meantime, the total carbon stocks of existed mangroves were determined by using field inventory data that was collected recently.

### Satellite data analysis

Three series of temporal satellite images were acquired in years 1995, 2005 and 2014 to complete the exercise. Landsat-5 TM, Landsat-7 ETM+, and Landsat-8 OLI satellite images for the respective years were utilized in this study. All images were georeferenced to the Malaysia Rectified Skew Orthomophic (MRSO) projection system so that the series of images are registered in the same coordinate system and all were then processed to classify mangroves areas and separate them with the other land covers. The classification results were exported into vector format (shape file) to be refined and edited in GIS. The GIS platform was employed to execute post-classification processes. Changes were identified from post-classification change detection technique (Jensen 2005). Changes were categorized into several 'from-to' classes according to factors, which are i) land-use/land-development activities, ii) agricultural conversion, iii) aquaculture activities iv) erosion and v) others.

### Field sampling inventory

Field inventory data was collected in three Forest Reserves, namely Balok, Cherating and Kuantan. Mangrove trees measuring diameter of >10 cm in a square subplot measuring 20 × 20 m were measured and 4 subplots were established for each forest reserve. Biomass of each tree was calculated by using allometric equation that was developed by Komiyama et al. (2007) for common species in the mangroves of Peninsular Malaysia. The allometry can be expressed as

$$W_t = 0.251\rho D^{2.46} \quad (1)$$

$$W_r = 0.199\rho^{0.899} D^{2.22} \quad (2)$$

where $W_t$ is the dry weight of aboveground component and $W_r$ is the root biomass, which can be referred to as belowground biomass. ρ and D are wood density and diameter at breast height (dbh), respectively. The calculated biomass was converted into C by using a constant factor of 0.47.

## RESULTS AND DISCUSSION

The mangroves in Pahang are mostly found in the districts of Kuantan which is near to the surrounding areas of its capital town, Kuantan. This kind of situation has led the mangroves vulnerable to all kinds of human threats. The reason for the drop in mangrove acreage was predominantly from urban development. About 31% of the change resulted from urban expansion either for industrial parks or settlements. The agricultural sector also played a significant role in contributing to the declining extent of mangroves in Pahang. About 26% of the total change was caused by agriculture, and oil palm is one of the typical crops that have replaced the mangroves. Figure 1 shows the changes that occurred between years 1995 and 2014. The boundaries of mangroves have been shrinking from year 1995 but these changes affected only the state land i.e. outside the Forest Reserve.

Extents of mangroves of each year were multiplied by the average carbon stocks that were measured on the ground. Table 1 summarizes the sampling plots information that was collected from field inventory. The average value was used as a single factor that was multiplied by the mangroves acreage. Table 2 shows the extents of mangroves that were obtained from the images classifications. In additional to the 10-year interval satellite data, secondary information was used, which has made the observation period reduced to 5-year intervals. Deforestation of mangroves in Pahang was about 2,900 ha since 1990 with the rate of deforestation of about 123 ha $yr^{-1}$.

Analysis has shown that the average C stock in mangroves in Pahang was about 181 Mg C $ha^{-1}$. Therefore the current total carbon stock available was about 1.5 million Mg C. The estimated loss of C stock was about 0.5 million Mg C since 1990 with an average of 22,249 Mg C $yr^{-1}$ (Figure 2). The rate of C loss was estimated about 7.5 Mg C $ha^{-1}$ $yr^{-1}$.

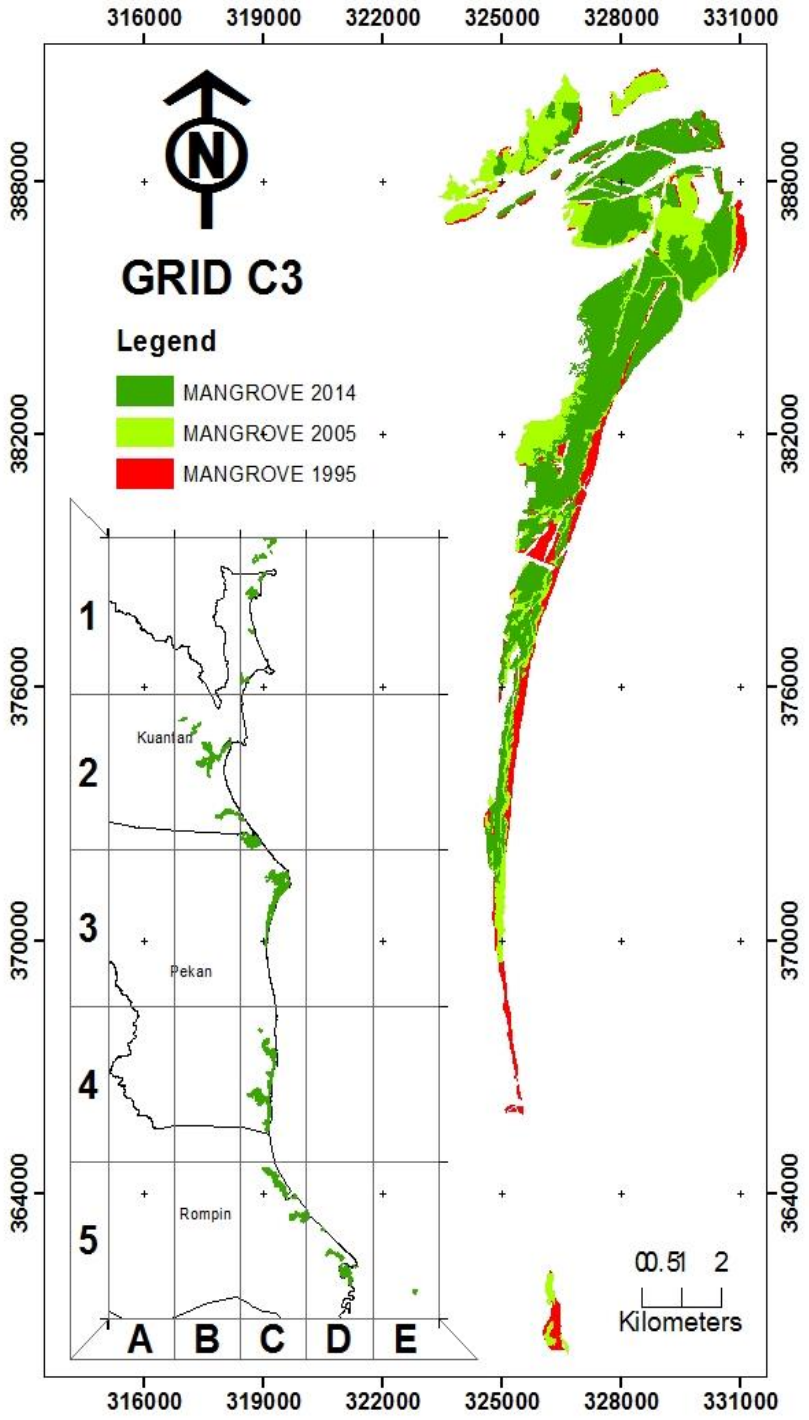


**Figure 1**. Map showing spatially distributed changes of mangroves in some parts of Pekan, Pahang.

**Table 1.** Summary of the measured carbon in sampling plots

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| Forest Reserve | Plot ID | Mg C $ha^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | | Above ground | Below ground | Total | Average | Std. Dev. |
| Balok | 170614-001 | 132.41 | 48.82 | 181.23 | 165.51 | ±29.66 |
| | 170614-002 | 141.82 | 52.85 | 194.67 | | |
| | 170614-003 | 91.03 | 35.71 | 126.73 | | |
| | 170614-004 | 116.16 | 43.26 | 159.42 | | |
| Cherating | 180614-001 | 103.47 | 40.79 | 144.26 | 161.40 | ±36.31 |
| | 180614-002 | 105.52 | 40.84 | 146.36 | | |
| | 180614-003 | 100.75 | 38.55 | 139.31 | | |
| | 180614-004 | 156.72 | 58.97 | 215.69 | | |
| Kuantan | 190614-001 | 181.63 | 63.39 | 245.02 | 215.47 | ±41.83 |
| | 190614-002 | 114.72 | 41.83 | 156.56 | | |
| | 190614-003 | 161.31 | 53.45 | 214.76 | | |
| | 190614-004 | 181.18 | 64.36 | 245.54 | | |
| Average | | | | | 180.80 | ±41.66 |

**Table 2.** Summary of mangroves deforestation and changes of carbon stock.

| Year | Area (ha) | Carbon stock (Mg C) |
|---|---|---|
| 1990* | 11,467.03 | 2,073,239.02 |
| 1995 | 11,129.23 | 2,012,163.88 |
| 2000* | 10,791.42 | 1,951,088.74 |
| 2005 | 9,915.34 | 1,792,693.47 |
| 2010* | 9,039.26 | 1,634,298.21 |
| 2014 | 8,513.61 | 1,539,261.05 |
| Total loss | 2,953.42 | 533,977.97 |
| Average | 123.06 ha $yr^{-1}$ | 22,249.08 Mg C $yr^{-1}$ |

* Source: Hamdan et al. (2012)

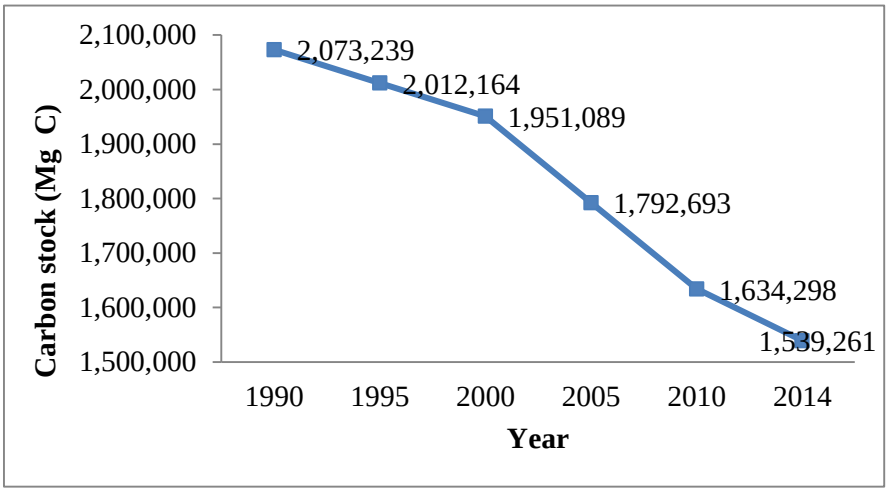


**Figure 2.** Changes in carbon stock between years 1990 and 2014.

## CONCLUSION

Overall the study has successfully determined the rate of deforestation of mangroves in Pahang. The study also quantified the changes C stock in this ecosystem in Pahang since 1990 until 2014. The study found that the combination of field inventory and remote sensing data can produce a reliable estimate of C stock in mangroves and can be used to monitor changes over times. The study suggests that action should be taken by the State Government to protect the priceless mangrove ecosystem in Pahang. One way to conserve the mangrove in the state is to gazette the remaining state land forest as Forest Reserve. This Forest Reserve should be maintained intact for amenity for current and future generations. Any development on this area should be implemented with caution or prohibited totally.

## REFERENCES

Daniel, C.D., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M. & Kanninen, M. 2011. Mangroves among the most carbon-rich forests in the tropics. Nature Geoscience Letters: NGEO1123. 5pp.

Hamdan, O, Khali Aziz, H., Shamsudin, I. & Raja Barizan, R.S. 2012. Status of mangroves in Peninsular Malaysia. Forest Research Institute Malaysia. ISBN 978-967-5221-76-7. 153 pp.

IUCN. 2011. IUCN Red List of Threatened Species™. Version 2011.1. Available at: www.iucnredlist.org

Jensen, J.R. 2005. Introductory Digital Image Processing, 3rd edition. Upper Saddle River: Prentice Hall. 526 pp.

Komiyama, A, Ong, J.E. & Poungparn, S. 2007. Allometry, biomass, and productivity of mangrove forests: A review. Aquatic Botany 89: 128–137.