Mapping and analysis land-use and land-cover changes during 1996-2016 in Lubuk Kertang mangrove forest, North Sumatra, Indonesia

M Basyuni[1], A Fitri[2] and Z A Harahap[2]

[1] Department of Forestry, Faculty of Forestry, Universitas Sumatera Utara, Jl. Tri Dharma Ujung No. 1 Medan, North Sumatera 20155, Indonesia
[2] Department of Aquatic Resource Management, Faculty of Agriculture, Universitas Sumatera Utara, Medan, North Sumatera 20155, Indonesia

E-mail: m.basyuni@usu.ac.id

Abstract. Mangrove forest plays a significant role for biogeochemical carbon cycle in the context of climate change along the tropical coastal area. The present study analyzed the land-use and land-cover changes from 1996, 2006 and 2016 in Lubuk Kertang mangrove forest, Langkat, North Sumatra, Indonesia. Mangrove diversity in Lubuk Kertang consists of fifteen species, *Acanthus ilicifolius, Avicennia marina, A. lanata, A. officinalis, Bruguiera gymnorrhiza, B. sexangula, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, L. littorea, R. apiculata, R. mucronata, Scyphiphora hydrophyllacea, Sonneratia caseolaris*, and *Xylocarpus granatum*. The land use/land cover consists of seven classes namely, mangrove forest, river, residential, paddy field, oil palm plantation, aquaculture, and open space area. A land use change matrix showed that the decrease of mangrove forest 109.4 ha from 1996-2006 converted to aquaculture 51.5 ha (47.1%). By contrast, mangrove lost 291.2 ha during 2006-2016, with main driver deforestation was oil palm plantation 128.1 ha (44%). During twenty years mangrove forest has been lost more than 400.4 ha, which is equal to 20.02 ha/year. On the other hand, oil palm plantation and aquaculture have been increased 155.3 ha and 114.1 ha during 1996-2016, respectively, suggested that both land-uses are mainly responsible for mangrove deforestation. These data are likely to contribute towards coastal management planning and practice and mitigating actions for emission reduction scenario.

1. Introduction

Mangrove forests are distributed in the inter-tidal zone of tropical and sub-tropical regions and play a significant role for biogeochemical carbon cycle in the context of climate change along the area. The important environmental and economic of mangroves are well documented, mangroves are currently among the most threatened ecosystems especially in Southeast Asia including Indonesia due to anthropogenic activities [1] and climate change [2]. Mangrove conversion to aquaculture and oil palm plantation has been mainly responsible for mangrove loss in Indonesia [3-4]. Mangrove deforestation reduced mangrove diversity, carbon storage of forest biomass, fish and crustacean habitat, and primary resources for human communities that depend on mangrove products and services [1-2,5].

Mangrove forests in North Sumatera, Indonesia covered approximately 50,369.8 ha and existed in the eastern coastal of Sumatra Island and widespread in Langkat, Deli Serdang, Batubara, Tanjung

Balai, Asahan, Labuhanbatu until Serdang Bedagai [6-7]. Despite mangrove deforestation globally or regionally was well studied [3,8], deforestation from land-use and land-cover changes are rarely reported especially at Regency or district level in Indonesia. Mangrove in Langkat regency has been degraded from 34,742.12 ha in 1990 to only 16,765.96 ha in 2015 [6-7]. To get more insight into a better understanding of spatial and temporal variation in the land uses that replace mangrove forests, the present study aimed to analyze the drivers of mangrove loss from land-use and land-cover changes from 1996, 2006, and 2016 in Lubuk Kertang mangrove forest, Langkat, North Sumatra, Indonesia.

2. Materials and Method

2.1. Study area and dataset

The study was carried out in Lubuk Kertang mangrove forest, North Sumatra, Indonesia, covering an area about 1200 ha. The Lubuk Kertang village is situated at 04º 02' 34.25" - 04º 05' 27.11" North latitudes, and between at 98º 14' 57.92" - 98º 18' 37.87" - East longitudes (Figure 1). Regionally, it is Regency (Kabupaten), Langkat and district (Kecamatan) of Brandan Barat. Land-use and land-cover changes data period 1996-2016 was obtained from Ministry of Forestry, Government of Indonesia. Landsat 5 Enhanced Thematic Mapper (ETM) satellite image year 1996 and 2006 and Landsat 8 OLI/TIRS year 2016 was acquired from USGS (http://govis.usgs.gov/).

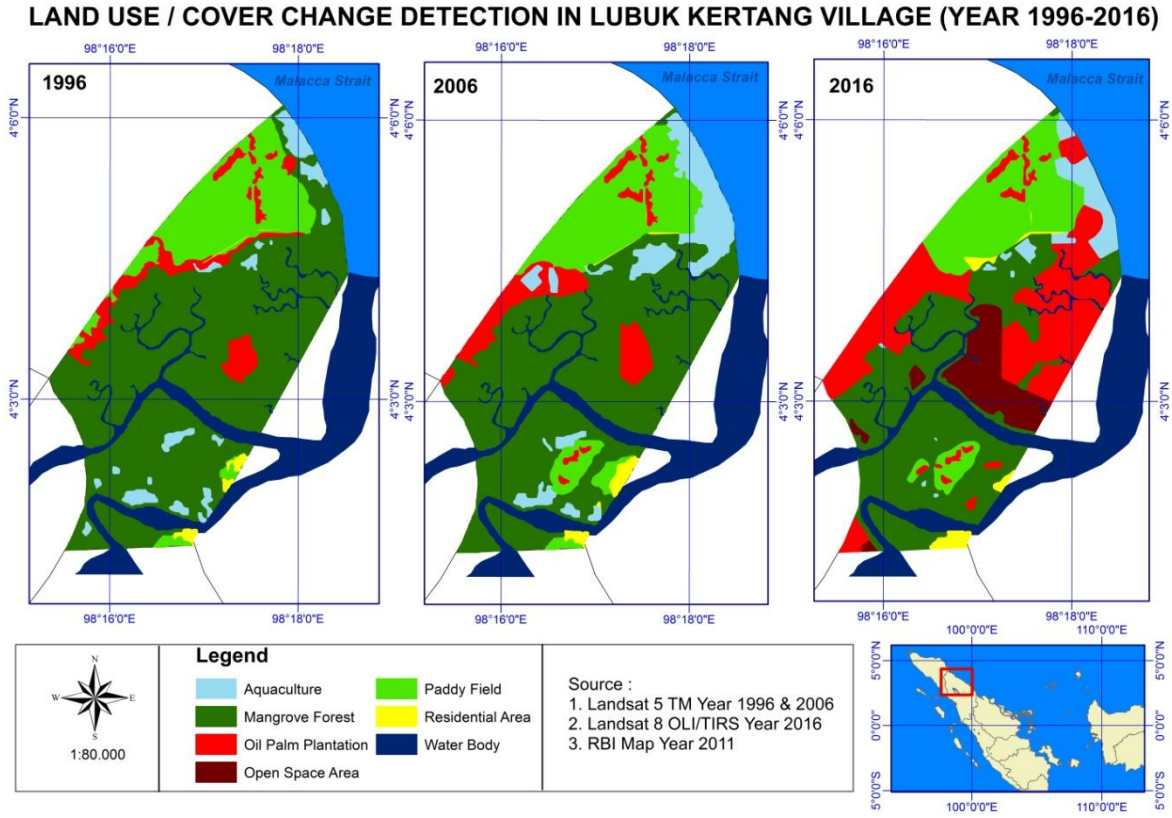

Figure 1. Land-use/land-cover changes of Lubuk Kertang mangrove forest, Langkat, Indonesia from 1996, 2006, and 2016.

2.2. Analysis of land-use and land-cover changes

Analysis of the Landsat images was carried out by applying supervised classification with maximum likelihood as previously reported [4,6]. Image pre-processing, the process of image interpretation, image classification and change detections were done by ERDAS Imagine 8.7 (ERDAS, Atlanta). The ground check conducted by employing Global Positioning System (GPS) to collect information of

recent land-use/land-cover. The information was used as supervision for image geometric correction and image improvement. Analysis of vegetation was carried out using the combination between transect and line compartment method [4].

3. Results and Discussion

The results and discussion divided into three subsections; they are vegetation analysis, land-use/land-cover changes over period 1996, 2006, and 2016 and deforestation analysis and its implication to conservation.

3.1. Flora study in Lubuk Kertang mangrove forest

Plant analysis in Lubuk Kertang mangrove forest found 15 species. Four species belongs to Acanthaceae, namely *Acanthus ilicifolius, Avicennia marina, A. lanata,* and *A. officinalis*. *Five* species includes in Rhizophoraceea*: Bruguiera gymnorrhiza, B. sexangula*(Rhizophoraceae)*, Ceriops tagal,* R. apiculata, and R. mucronata. Furthermore*, Excoecaria agallocha* (Euphorbiaceae)*, Lumnitzera racemosa* (Combretaceae)*, L. littorea* (Combretaceae)*, Scyphiphora hydrophyllacea* (Rubiaceae), *Sonneratia caseolaris* (Sonneratiaceae)*,* and *Xylocarpus granatum* (Meliaceae) exist. Ten mangrove species found at Karang Gading and Langkat Timur Laut Wildlife Reserve [4], which *R. apiculata* and *E. agallocha* were dominating species. Moreover, there were 11 species reported from Jaring Halus mangrove forest, Langkat [6], in addition to 14 species was thrived naturally in Pulau Sembilan, Langkat, Indonesia [7]. The high biodiversity of mangrove forest in Langkat suggested the importance of mangrove resource for future.

Table 1. Mangrove forest 1996-2006 converted to different land uses

Land-use (1996)	Land-use (2006)	Area (ha)	Proportion (%)
Mangrove forest	Aquaculture	51.5	47.1
	Oil palm plantation	27.2	24.9
	Paddy field	29.0	26.5
	Residential	1.2	1.1
	Water body	0.5	0.5
Total		109.4	100.0

Table 2. Mangrove from 2006-2016 converted to other land uses

Land-use (2006)	Land-use (2016)	Area (ha)	Proportion (%)
Mangrove forest	Aquaculture	62.6	21.5
	Oil palm plantation	128.1	44.0
	Paddy field	6.2	2.1
	Residential	2.9	1.0
	Water body	0.3	0.1
	Open space area	91.1	31.3
Total		291.2	

3.2. Land-use/land-cover changes over period 1996, 2006, and 2016

Mangrove deforestation remains enormous in Langkat Regency, North Sumatra with more than 17,976.2 ha mangrove lost between 1996 and 2016, decreasing 51.7% (Figure 1). The land use/land cover in Lubuk Kertang consists of seven classes namely, mangrove forest, river, residential, paddy field, oil palm plantation, aquaculture, and open space area (Tables 1-2).

Table 1 shows a land-use change matrix that the decrease of mangrove forest 109.4 ha from 1996-2006 converted to non-forest land uses. These are aquaculture 51.5 ha (47.1%), oil palm plantation 27.2 ha (44%), paddy field 29.0 ha (26.5%), residential 1.2 ha (1.1%), and water body 0.5 ha (0.5%). By contrast, mangrove lost 291.2 ha, increasing more than 100% during 2006-2016, with main driver deforestation was oil palm plantation 128.1 ha (44%), followed by aquaculture 62.6 ha (21.5), and open space or barren land 91.1% (31.3%). Table 2 depicts an interesting note illustrating a significant amount of barren land, converted from mangrove. During twenty years mangrove forest has been lost more than 400.4 ha, which is equal to 20.02 ha/year. On the other hand, oil palm plantation and aquaculture have been increased 155.3 ha and 114.1 ha during 1996-2016, respectively.

The previous reports on land-use changes in Karang Gading and Langkat Timur Laut Wildlife Reserve supported this results showing primary sources deforestation was aquaculture and oil palm plantation [4]. A study reported high rate deforestation (75%) in Indonesia during 2000-2005, due to aquaculture expansion (63%), agriculture (32%), and urban development (5%) confirmed these findings [8]. It has been shown that mangrove in replacing to aquaculture has been stimulated by governmental support, private investment, and multilateral development agency [5].

3.3. Deforestation analysis and its implication to conservation

Mangrove deforestation large in Langkat Regency 719.05 ha/year also implied to Lubuk Kertang mangrove forest (20.02 ha/year). The threat of oil palm to mangrove has been predicted to increase in the future in Indonesia including North Sumatra [3]. Extensive clearing mangrove results in increasing greenhouse gas [4]. It has been reported that to protect mangrove forest may be avoided at less than \$10 per ton of CO_2 [9]. Local wisdom to maintain the existence mangrove forest in Jaring Halus village has been reported to play a significant role in decreasing net carbon emission and increasing carbon sequestration until the year 2030 [6].

The importance of mangrove conservation not only to protect the coastal areas and human communities from seawater instruction, coastal hazard, sea-level rise changes but also to ensure the availability of mangrove resources for future use in the course of adaptation to changing environment [2,8]. Mitigation action also was proposed to increase carbon sequestration through rehabilitation of degraded mangroves and education awareness to communities adjacent to mangroves.

4. Conclusions

The conversion of mangrove forests to aquaculture and oil palm plantation in Lubuk Kertang are mainly responsible for deforestation. These data are likely to contribute towards coastal management planning and practice and mitigating actions for emission reduction scenario in mangroves.

Acknowledgments

We are grateful to the Directorate for Research and Community Service, Ministry of Research, Technology, and Higher Education, the Republic of Indonesia for Science and Technology for Villages Partner Grant 2017 (003/SP2H/PPM/DRPM/IV/2017). A Grant-in-Aid for a Community Service Research-Based (No. 453C/UN5.2.3.2.1/PPM/2016 to MB) from the Non-PNBP University of Sumatera Utara 2016 supported this study partly.

References

[1] DasGupta R, Shaw R 2013 Cumulative impacts of human interventions and climate change on mangrove ecosystems of South and Southeast Asia: an overview *J. Ecosyst.* **2013**, http://dx.doi.org/10.1155/2013/379429.

[2] Gilman EL, Ellison J, Duke NC, Field C 2008 Threats to mangrove from climate change and adaptation options: A review *Aquat. Bot.* **89**: 237–250.

[3] Richards DR, Friess DA 2012 Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012 *Proc. Natl. Acad. Sci. USA* **113**: 344–3349.

[4] Basyuni M, Putri LAP, Murni MB 2015 Implication of land-use and land-cover changes into carbon dioxide emission in Karang Gading and Langkat Timur Laut Wildlife Reserve, North Sumatra, Indonesia *J. Man. Hut. Trop.* **21**: 25–35.

[5] Friess DA, Thompson BS, Brown B, Amir AA, Cameron C, Koldewey HJ, Sasmito SD, Sidik F 2016 Policy challenges and approaches for the conservation of mangrove forests in Southeast Asia *Conserv. Biol*. **30**: 933–949.

[6] Basyuni M, Rouf RA, Saragih M, Asbi AM, Yuriswan W 2017 Local wisdom and mitigation action to maintain secondary mangrove forest: a case study of Jaring Halus village in Langkat, North Sumatra, Indonesia *Adv. Soc. Sci. Educ. Hum. Res*. **81**: 551–555.

[7] Basyuni M, Sagami H, Baba S, Oku H 2017 Distribution, occurrence, and cluster analysis of new polyprenyl acetones and other polyisoprenoids from North Sumatran mangroves *Dendrobiology* **78**: 18–31.

[8] Thomas N, Lucas R, Bunting P, Hardy A, Rosenqvist A, Simard M 2017 Distribution and drivers of global mangrove forest change, 1996–2010 *PLoS ONE* 1**2**: e0179302. https://doi.org/10.1371/journal.pone.0179302.

[9] Siikamaki J, Sanchirico N, Jardine SJ. 2011. Global economic potential for reducing carbon dioxide emissions from mangrove loss. *Proc. Natl. Acad. Sci. USA* **109**: 14369–14374.