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The Threats of Deforestation, Forest Fire, and CO_2 Emission toward Giam Siak Kecil Bukit Batu Biosphere Reserve in Riau, Indonesia

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***Abstract*—**A biosphere reserve is developed to create harmony amongst economic development, community development, and environmental protection, through partnership between human and nature. Giam Siak Kecil Bukit Batu Biosphere Reserve (GSKBB BR) in Riau Province, Indonesia, is unique in that it has peat soil dominating the area, many springs essential for human livelihood, high biodiversity. Furthermore, it is the only biosphere reserve covering privately managed production forest areas.

In this research, we aimed at analyzing the threat of deforestation and forest fire, and the potential of CO_2 emission at GSKBB BR. We used Landsat image, *arcView software*, and *ERDAS IMAGINE 8.5 Software* to conduct spatial analysis of land cover and land use changes, calculated CO_2 emission based on emission potential from each land cover and land use type, and exercised simple linear regression to demonstrate the relation between CO_2 emission potential and deforestation.

The result showed that, beside in the buffer zone and transition area, deforestation also occurred in the core area. Spatial analysis of land cover and land use changes from years 2010, 2012, and 2014 revealed that there were changes of land cover and land use from natural forest and industrial plantation forest to other land use types, such as garden, mixed garden, settlement, paddy fields, burnt areas, and dry agricultural land. Deforestation in core area, particularly at the Giam Siak Kecil Wildlife Reserve and Bukit Batu Wildlife Reserve, occurred in the form of changes from natural forest in to garden, mixed garden, shrubs, swamp shrubs, dry agricultural land, open area, and burnt area. In the buffer zone and transition area, changes also happened, what once swamp forest changed into garden, mixed garden, open area, shrubs, swamp shrubs, and dry agricultural land. Spatial analysis on land cover and land use changes indicated that deforestation rate in the biosphere reserve from 2010 to 2014 had reached 16 119 ha/year. Beside deforestation, threat toward the biosphere reserve area also came from forest fire.

The occurrence of forest fire in 2014 had burned 101 723 ha of the area, in which 9 355 ha of core area, and 92 368 ha of buffer zone and transition area. Deforestation and forest fire had increased CO_2 emission as much as 24 903 855 ton/year.

***Keywords*—**Biosphere reserve, CO_2 emission, deforestation, forest fire.

I. Introduction

THE loss of forest area is one of environmental problems occurred around the world. Among the causes are deforestation, land degradation, and air pollution by greenhouse gasses, particularly CO_2, resulted from human activities such as forest fire. The decrease of forest area and increase of CO_2 emission due to forest fire cause the decline of CO_2 absorbance by forest and escalation of greenhouse effect. This condition results in local air temperature rise, which in turn affects global air temperature. In addition, forest fire produced smokes that along with mass airflow reached neighboring countries, particularly Singapore and Malaysia [1].

The rising of global air temperature pose various threats, such as loss of biodiversity, decline of human comfort, increase frequency of climate disturbance, and reduction of terrestrial area due to water level rise. Indonesia, which consists of thousands of islands, high number of human population, and high biodiversity, is vulnerable to global warming and climate change. Therefore, Indonesian government had ratified the Convention of Climate Change [2]. Indonesian government had issued Act No.6 year 1994 to regulate national implementation of the convention.

Forest had major role in controlling earth's climate, particularly for its role as carbon sink [3]. Carbon is stored in leaves, wood tissues, and roots. The world's forest can absorbed up to 2.4 billion ton of CO_2 each year, equal to 1/3 of CO_2 emission from fossil fuel combustion. Forest also stores 77% of carbon stock of all vegetation and store twice as much carbon compare to carbon in the atmosphere. Therefore, the existence of forest is crucial in controlling the earth's climate. The increase of open area in a forest would increase solar radiation and air temperature [4]. The average difference of minimum and maximum air temperature in the clear-cut forest reached 17.1ºC.

Carbon stock on various land cover classes of natural forest ranged between 7.5–264.70 ton C/ha [5]. Forest fire, timber extraction, land use for agricultural activities, and other events or activities in forest area had caused reduction of biomass potentials, which in turn would cause a decline of forest ability to store carbon. Research in peat forest of Kalimantan showed that the C stock of the primary peat forest, repeated-burnt forest, three years after burning peat forest, and eight years after burning peat forest were consecutively 88.69 ton C/ha, 7.85 ton C/ha, 22.15 ton C/ha, 33.71 ton C/ha [6]. The research suggested that burnt forest would experience significant decrease of carbon stock. Another research also showed similar result in that burnt peat forest would result in reduction of carbon stock potential up to 93.13% [7].

Forest damage, forest fire, and greenhouse gasses emission, particularly CO_2, had caused the decline of forest function.

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Drastic rise of air temperature resulting from forest clearing and burning would disturb the balance of ecosystem, as the growth and development of less adaptive plant species would be disturbed and eventually died and extinct. Forest damage and fire causes local warming. Local warming which occur evenly around the world would result in global warming. Global warming poses severe threat toward biodiversity [8]. The increase of CO_2 would affect climate condition, which in turn would affect habitat condition and could cause extinctions of endemic plant and vertebrate species in biodiversity hotspots. Population size of rainforest birds were decreasing with the increasing temperature [9]. Apparently, bird would not be the only species affected by global warming. Forest clearing would cause air temperature increase and influence reptile's nest location; in order to survive the changes, reptile would tend to find nesting place in a higher place [10].

Deforestation, forest fire, and CO_2 emission due to land cover and land use changes, and CO_2 emission from burnt forest and land were among the threats toward the existence of an area that currently known as Giam Siak Kecil Bukit Batu (GSKBB) Biosphere Reserve, Riau. The condition presented threat toward the sustainability of biodiversity and ecosystem in the area. In order to maintain the balance of the ecosystem in this area, Sinarmas Forestry and the Indonesian Institute of Science (LIPI) initiated the establishment of the area as a biosphere reserve managed collaboratively by its stakeholders, the BBKSDA Riau of Ministry of Forestry, Riau Province local government, and the surrounding community. The area was assigned as Giam Siak Kecil Bukit Batu Biosphere Reserve in 2009. The biosphere area covered two wildlife sanctuaries, i.e. Giam Siak Kecil Wildlife Sanctuary and Bukit Batu Wildlife Sanctuary. Industrial plantation forest under the management of Sinarmas Forestry was located between the two sanctuaries. The biosphere reserve was established under the UNESCO Man and the Biosphere Program in order to promote a balance relationship between human and the nature. There are three basic function of biosphere reserve: a) a conservation function - to contribute to the conservation of landscapes ecosystems, species and genetic variation, b) a development function - to foster economic and human development which is socio-culturally and ecologically sustainable, c) a logistic function - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

Despite its establishment as biosphere reserve, the management of GSKBB Biosphere Reserve had not reached what was expected. Various problems threatening the balance between human and nature are still taking place. Complex problems related to socio-economic aspect that resulted in deforestation, forest fire, and CO_2 emission are still occurring. We aimed this research at studying the extent of threat from deforestation, forest fire, and CO_2 emission at Giam Siak Kecil Bukit Batu Biosphere Reserve, Riau, Indonesia. The result were expected to provide a description on the urgency to seriously address the environmental problems in GSKBB Biosphere Reserve in order to avoid loss and extinction of biodiversity, and to maintain the biosphere reserve's function as human life support, both in local and global level.

II. Study Area

The research was carried out in Giam Siak Kecil Bukit Batu Biosphere Reserve, which located in Riau Province, Indonesia. Geographically, the area was positioned between 101º 11' – 102º 10' East Longitude and 00º 44' - 01º 11' North Latitude. The biosphere reserve covered areas that administratively belong to Bengkalis District and Siak District, Riau Province. Based on [11], the biosphere reserve covered an area of 705 271 ha, in which 70% belong to Bengkalis District, and the remaining (30%) belong to Siak District. The area consisted of 72 255 ha production forest under Sinarmas Forestry, which was allocated as permanent conservation forest, and Giam Siak Kecil Wildlife Sanctuary and Bukit Batu Wildlife Sanctuary. The Giam Siak Kecil Bukit Batu Biosphere Reserve was the only biosphere reserve in Indonesia, and even in the world, that had a core area consisted of conservation area and non-conservation area (Industrial Plantation Forest of Sinarmas Forestry), and was initiated by private sector in cooperation with the Indonesian Institute of Science (LIPI).

The biosphere reserve was divided into three management zones, i.e. a) Core Area, b) Buffer Zone, and c) Transition Area. Each zone, consecutively covered an area of 198 722 ha (25%), 222 425 ha (32%), and 304 123 ha (43%). Fig. 1 presented the zonation map of GSKBB Biosphere Reserve. Giam Siak Kecil Wildlife Sanctuary, Bukit Batu Wildlife Sanctuary, and industrial plantation forest constituted the core area. Plantation forest dominated the buffer zone, whereas plantation dominated the transition area.

III. Materials and Methods

A. Materials

Global Positioning System (GPS) were used to record Ground Control Point (GCP). Landsat image from year 2010, 2012, and 2014 were processed to obtain Ground Control Point. E-cognition, Erdas, ArcGis and Google Earth software were used for spatial analyses of land cover and land use. The research was carried out in June to November 2014 in Giam Siak Kecil Bukit Batu Biosphere Reserve, Riau, Indonesia.

B. Method

The phases of land cover and land use change analyses included the following: preprocessing, visual interpretation of satellite image, ground check, preprocessing of image, digital image processing, test of accuracy, and land cover and land use change analyses. The phases are briefly presented in Fig. 2.

1. Preprocessing

The activity was conducted to obtain general description of the condition and number of land cover classes in Giam Siak Kecil Bukit Batu Biosphere Reserve. Data used for this

activity was Landsat 7 ETM+ image from year 2010, 2012, and 2014.

2. Visual Interpretation of Satellite Image

Visual interpretation of satellite image is an activity to study satellite image in order to identify land cover captured in the image. Land cover characteristics could be identified through interpretation elements, such as color, shape, size pattern, location, and association of objects appearance. The image used for visual interpretation was 543 composite images on guns RGB (*Red Green Blue*), which resulted in composite color. The result of visual interpretation of land cover was used in determining the points of ground check.

3. Ground Check

Ground check is an activity of measuring, observing, and recording important information from predetermined ground checkpoints. Data being measured was record data of ground checkpoints coordinates obtained from GPS. Information observed in the field was the type and physical characteristics of land cover.

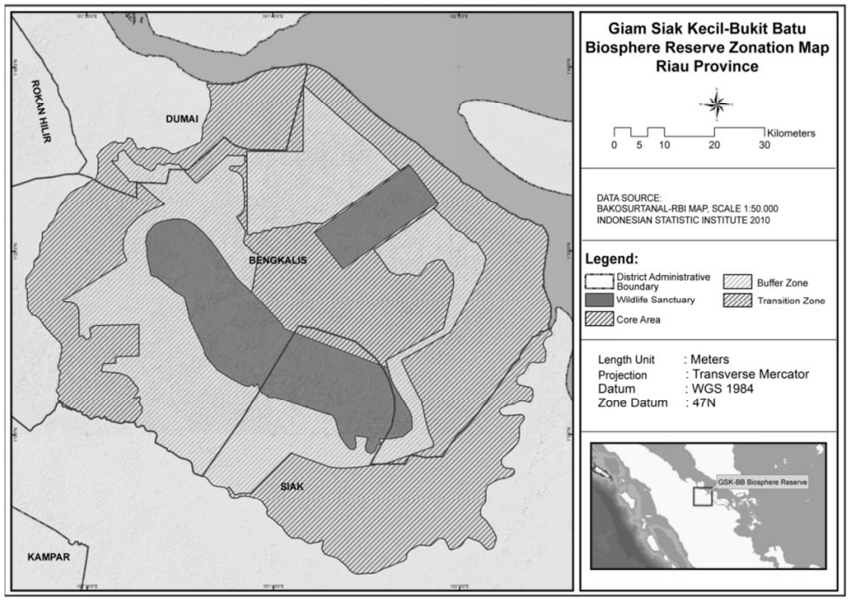

Fig. 1 Zonation of Giam Siak Kecil Bukit Batu Biosphere Reserve, Riau

4. Image Preprocessing

Image preprocessing is an initial processing before further processing of image. The phase included restoration or correction of raw data from disturbances occurred during the recording of data. The following steps were carried out to complete this phase:

a. Image Restoration

Landsat image acquired in 2010, 2012 and 2014 were restored from stripping caused by the damage of Landsat 7 Scan Line Corrector (SLC-OFF) before further processing. Image restoration was carried out using *Frame and Fill Win 32* software.

b. Image Cropping

Image cropping of the 2010, 2012, and 2014 Landsat image was conducted to separate research area from other area.

c. Geometric Correction

Geometric correction was conducted toward geometrical error occurred during image acquisition. Geometric correction was aimed at rectifying or correcting image coordinate in accordance with geographic coordinate. Slave image from 2010, 2012 and 2014 used as materials in this research should first be geometrically corrected.

5. Digital Image Processing

The analysis is a process of composing, organizing or grouping multispectral digital image pixels into several classes based on the category of the objects.

6. Analysis on Land Cover, Land Use, and Forest Fire

Analysis on changes of land cover, land use, and forest fire area was conducted based on the result of Landsat ETM+ image classification through maximum probability method. Analysis was carried out by overlaying separately pre-classified images and comparing the images to identify the changes of the area and types of land cover and land use.

IV. Results and Discussion

A. Land Cover and Land Use Changes

The results of spatial analysis on land cover and land use changes in Giam Siak Kecil Bukit Batu Biosphere Reserve Riau from 2010 to 2014 showed that mangrove forest and secondary swamp forest were keep declining. In 2010, mangrove forest covered an area of 1 547.71 ha, which

declined to 1 401.11 ha in the next two years, and further declined to 1 181.83 ha in 2014. Similar condition happened to swamp that experienced a decline from 17 045.94 ha in 2010to 10 870.10 ha in 2014.

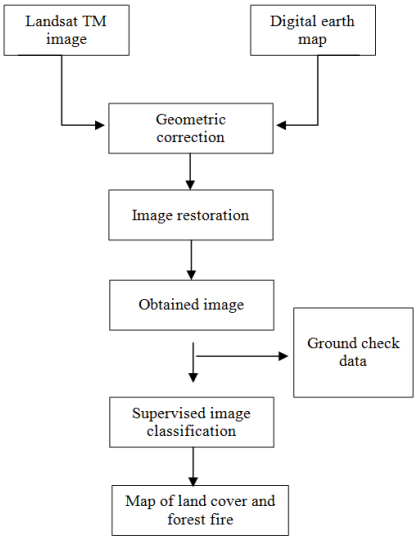

Fig. 2 Analyses on changes of land cover, land use, and forest fire

Secondary swamp forest in GSKBB Biosphere Reserve also experienced a decline, from 220 227.32 ha in 2010, to 193 867.76 ha in 2012, and kept declining to 170 994.22 ha in 2014. In contrast to mangrove forest and secondary swamp forest, the coverage of plantation forest, plantation, settlement, barren land, and cropland were increasing. These changes were presented in Table I, Figs. 3-5.

B. Forest Fire

Changes of land cover and land use were apparently happened through burning. Burnt area in 2014 reached up to 101 723 ha. The largest area indicated as burnt area was located in transition area, which covered 58 678 ha, subsequently followed a coverage of 33 690 ha in buffer zone, 6 452 ha in Giam Siak Kecil Wildlife Sanctuary, 2 580 ha in non-Wildlife Sanctuary area in core area, and 319 ha in Bukit Batu Wildlife Sanctuaries. Area indicated as burnt in each zone of biosphere reserve is presented in Table II and Fig. 6.

Based on the map of forest fire distribution and the figures presented in Table II, a conclusion could be drawn that the threat of forest fire in the biosphere reserve was still high, since the fire reached into the wildlife sanctuaries, protected areas in the biosphere reserve. Forest fire caused deforestation, degradation, and CO_2 emission, which could lead to the loss of biosphere reserve's function in maintaining ecosystem balance and biodiversity.

Dealing with forest fire problems would require preventive efforts, such as maintaining the level of peat water surface, and providing extension and training programs on alternative environmental-friendly cultivation techniques for the surrounding community to prevent them from using burning method [12]. In addition, the management of biosphere reserve should also consider strengthening of legislation, supervising land management and use, and providing incentives in peat land management as the measures to be taken in managing forest fire problems.

TABLE I
LAND COVER AND LAND USE CHANGES COVERAGE IN GIAM SIAK KECIL BUKIT BATU BIOSPHERE RESERVE

No.	Land cover and land use	Land Cover and Land Use Coverage (ha)		
		2010	2012	2014
1	Mangrove forest	1 548	1401	1182
2	Secondary swamp forest	220 227	193868	170994
3	Plantation forest	126 251	155990	125439
4	Plantation	89 789	108720	137 805
5	Mixed garden	75 748	110743	65273
6	Mining area	279	279	279
7	Barren land	85 718	58 088	129 190
8	Settlement/Built area	8 895	9383	9669
9	Crop land	12 559	7020	13322
10	Swamp	17 046	17506	10870
11	Rice field	4 962	5990	4954
12	Shrub	34 095	17305	17926
13	Peat swamp shrub	26 936	17722	17124
14	Water body	1 217	1255	1244

TABLE II
BURNT AREA OF GIAM SIAK KECIL BUKIT BATU BIOSPHERE RESERVE IN 2014

Zone of Biosphere Reserve	Coverage of Indicated Burnt Area (ha)
Non-Wildlife Sanctuary Core area	2 584
Bukit Batu Wildlife Sanctuary	319
Giam Siak Kecil Wildlife Sanctuary	6 452
Buffer zone	33 690
Transition Area	58 678
TOTAL	101 723

C. Deforestation

Spatial analysis on land cover and land use from 2010 to 2014 showed that changes of land cover and land use occurred in GSKBB Biosphere Reserve. People had converted what was once natural forest and industrial plantation forest into other uses, such as plantation, mixed garden, settlement, rice field, burnt area, and dry agricultural land (cropland). Deforestation, particularly in wildlife sanctuary, took from in land cover changes from natural forest to other land cover and uses, i.e. plantation, mixed garden, shrub, peat swamp shrub, cropland, barren land, and burnt area. Result of the analysis suggested that the rate of deforestation in GSKBB Biosphere Reserve from 2010 to 2014 had reached 16 119 ha/year. The combination effect of twofold increase of deforestation and CO_2 concentration would raise the average temperature as much as 3.58ºC [13]. The increase of average air temperature caused by local deforestation could affect global environment. Deforestation occurred in tropical region would start impact on a global scale through global biogeochemical cycles, hydrological flows, and soil degradation [14]. Deforestation also triggered climate change, both at local and global level. A research in Madagascar showed that among the consequences of population growth and unsustainable agricultural processes

were habitat loss, death of several species, negative impact of carbon cycle, and the raise of global warming [15].

We need strategy to deal with deforestation, considering the large amount of negative impact it create. Forest management strategy for climate change mitigation was reduction of greenhouse gasses emission (including CO_2) by cutting back deforestation and forest degradation [16]. Strategy to enhance forest carbon stock by increasing sequestration through forest restoration and reforestation was also necessary.

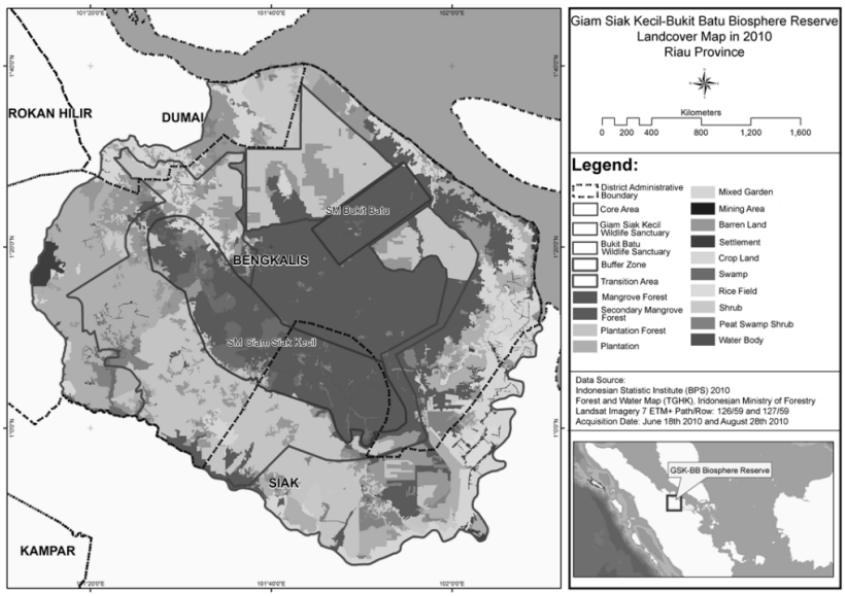

Fig. 3 Land cover and land use of Giam Siak Kecil Bukit Batu Biosphere Reserve in 2010

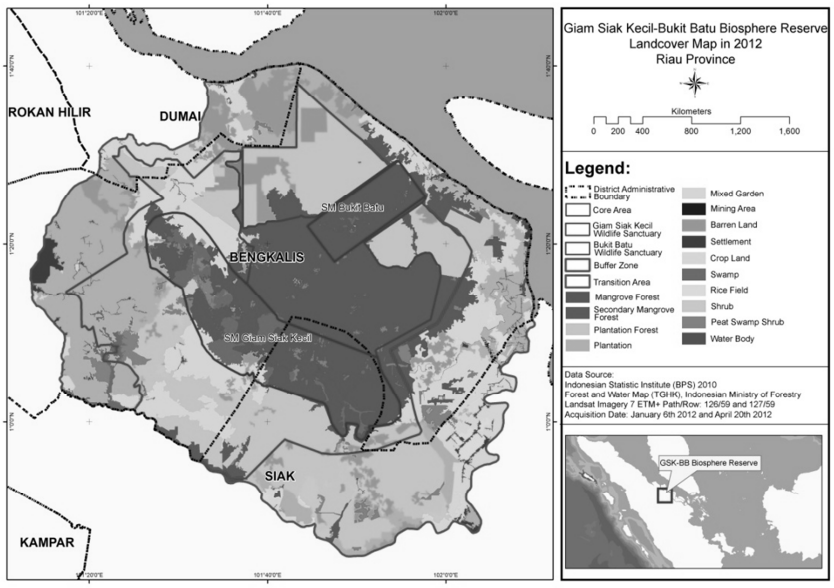

Fig. 4 Land cover and land use of Giam Siak Kecil Bukit Batu Biosphere Reserve in 2012

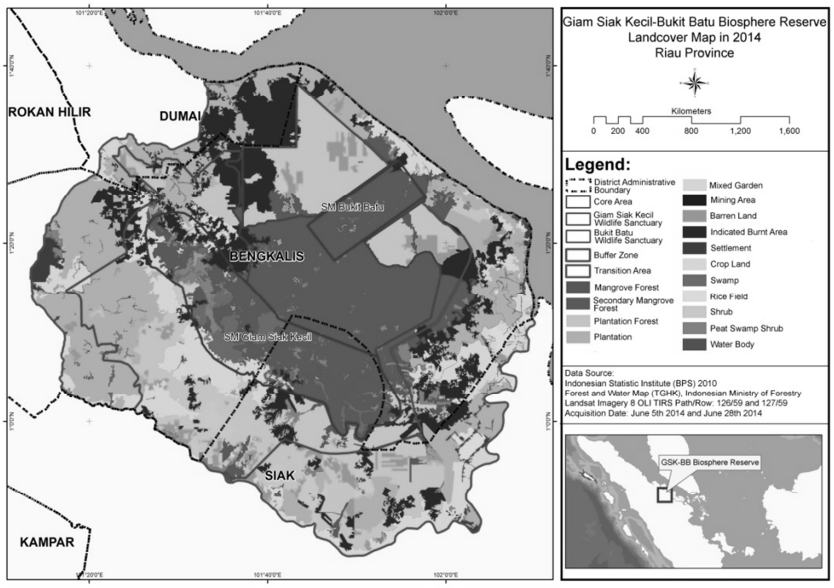

Fig. 5 Land cover and land use of Giam Siak Kecil Bukit Batu Biosphere Reserve in 2014

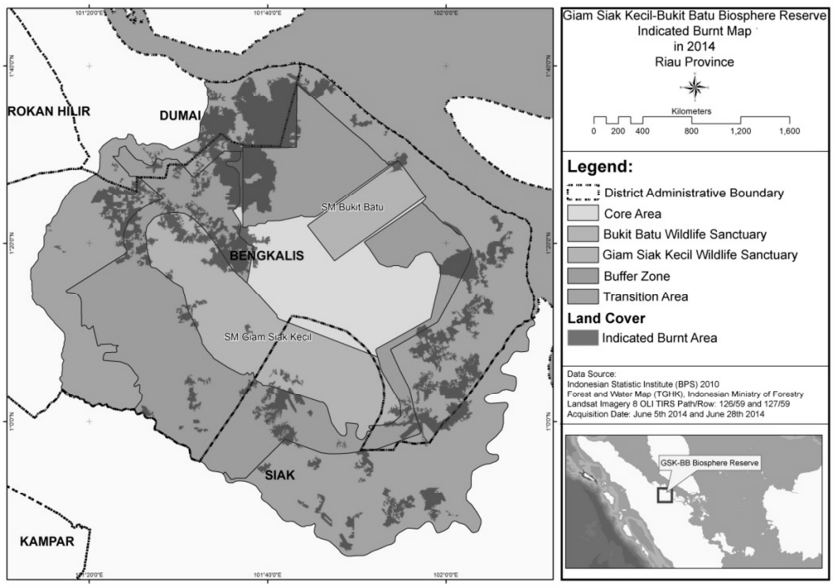

Fig. 6 Burnt area of Giam Siak Kecil Bukit Batu Biosphere Reserve in 2014

D. CO_2 Emission

Converting forest ecosystem into cultivated land or plantation forest would emit CO_2 through burning, decomposition of organic carbon stored in plant biomass, and decomposition of timber, litter, and wood products [17]. Based on spatial analysis of land cover and land use change, particularly deforestation, and analyses on CO_2 emission potential resulted from the changes, we generate a linear regression equation of deforestation and CO_2 emission, as:

$$Y = 54\,323\,232 + 1545\,X \quad (1)$$

Y = CO_2 emission (ton)

X = Deforestation (ha)

Refer to (1), the equation suggested that each 1 ha increase of deforestation would increase CO_2 emission as much as 1 545 ton. The average number of deforestation occurred in GSKBB Biosphere Reserve was 16 119 ha/year. Based on the number, we can calculate that CO_2 emission from deforestation was as much as 79 227 087 ton/year. The relation between deforestation and CO_2 emission was presented in Fig. 7.

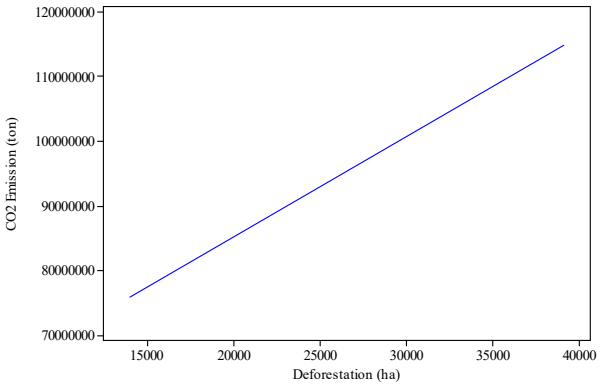

Fig. 7 Relation of deforestation and CO_2 emission

As a comparison, a research conducted in Portugal on the contribution of CO_2 emission to global warming suggested that burnt area which exceeds 100 000 ha contributed as much as 7% of CO_2 emission to the total CO_2 emission in Portugal [18]. CO_2 emission determined greenhouse gasses emission at local and global level. Forest and land fire caused a decrease of air quality. Greenhouse gasses, particularly CO_2, resulted from forest fire would influence the global concentration of greenhouse gasses. CO_2 gas was feared to increased greenhouse effect and global warming and climate change. Global warming would cause systematic changes toward species distribution and would increase extinction [19]. Beside its threat toward various species, global warming also threatened human livelihood. A research in London provided evidence that heat increased above 19°C, which occurred during 1976 to 1996, had caused the death of human [20]. There was a linear relation between mortality and temperature above 19°C [20]. Another research, conducted in Bologna, Milano and Roma, also showed a relation between high temperature and mortality [21]. Minimum temperature of the three cities in 2003 was higher than in 2004, and the mortality number was higher in 2003 compared to 2004 [21].

CO_2 emission would result in air temperature increase, both in local and global level. A report estimated that given the current condition, by the year 2050 and 2100 consecutively, sea level would rise of about 0.3–0.5 m and 1 m, accompanied with a rise between 0.2°C and 2.5°C in the temperature of surface ocean layer. The rise of air temperature would adversely influence biodiversity, threat human survival, and decrease environmental quality. Therefore, mitigation and adaptation of global warming and climate change, including prevention and management of CO_2 emission threat in GSKBB Biosphere Reserve was a necessity. All stakeholder, including private sector, central and local government, higher education institution, nongovernmental organization, and the community, should join forces in managing the biosphere reserve.

V. Conclusion

Despite its establishment as biosphere reserve, threat of deforestation was still exist in Giam Siak Kecil Bukit Batu Biosphere Reserve, Riau. Spatial analysis on land cover and land use changes of 2010, 2012, and 2014 showed that the rate of deforestation was about 16 119 ha/year. In addition, forest and land fire were frequent threat to the area. Spatial analysis showed that burnt area in 2014 was about 101 723 ha, with the largest area of 58 678 ha in transition area, followed by 33 690 ha in buffer zone, and 9 355 ha in core area. Burnt area which occurred in core area covered an area of 6 452 ha in Giam Siak Kecil Wildlife Reserve, 319 ha in Bukit Batu Wildlife Reserve, and 2 584 ha in industrial plantation forest area. Deforestation, from land cover and land use changes as well as forest fire, that occurred every year had caused an increase of CO_2 gas emission as much as 24 903 855 ton/year.

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