Eco. Env. & Cons. 27 (4) : 2021; pp. (1645-1652)
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ISSN 0971–765X

Dynamics of Land Cover Change and Carbon stock in Pagar Alam City, South Sumatra Province

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(Received 10 February, 2021; Accepted 22 March, 2021)

ABSTRACT

The City of Pagar Alam and its protected areas have experienced degradation and decreased carbon stocks due to periodic anthropogenic activities. However, the availability of information on this matter is still very limited. This research was conducted to assist in providing the intended information through a series of analyses of land cover change and carbon stock estimation using a remote sensing approach. The dynamics of land cover change have experienced an increasing trend or a decreasing trend in each period of the observation year. Meanwhile, the estimated carbon stock shows the highest carbon emission occurred in 2000 - 2005 with emission values reaching 3,126,680.86 tons CO2-eq and the lowest carbon emission values reaching 759,508.44 tons CO2-eq occurred in 2010-2015. On the other hand, the highest sequestration value was the addition of carbon stock, which reached 2,026,747.63 tons of CO2-eq occurred in 2010-2015. The highest annual carbon emission rate in Pagar Alam city with a value of 6.54 tons CO2-eq/ha/year only occurred in the 2000-2005 period and the lowest emission rate occurred in the 2010-2015 period with a value of -3.97 tons CO2-eq/hectare/year. However, the emission rate for the 2015-2019 period is 1.52 tons CO2-eq/hectare/year. The triggers factor of land cover change that cause carbon emissions came from conversion activity of forest to shrubs. To assist and support the determination of climate change mitigation and adaptation strategies in a region, it is necessary to monitor periodically of land cover change and carbon stock in a certain area.

***Key words** : Landcover change analysis, Environmental services, Carbon stock, Carbon emission and sequestration*

Introduction

Indonesia's tropical rainforests are widely recognized for their ecological benefits at a global scale as well as for socio-economic benefits at a local scale, serving as a home for a variety of flora and fauna, serving as a buffer for the rate of rainfall, reducing soil erosion, regulating hydrology in a landscape, store carbon (C) and maintain global environmental balance due to increasing concentrations of greenhouse gases (GHG) in the atmosphere which causes global warming.

Regardless of its important function and contribution, disturbances that cause deforestation and forest degradation remain a serious significantthreat for forest sustainability (Dewi *et al.,* 2011b; Tiryana *et al*., 2016). Forest change and its trigger factors are carried out due to human intervention (Noordwijk *et al*., 2002; Margono *et al.,* 2012; Siarudin *et al*., 2014). The impact of large-scale land cover changes has led to deforestation and forest degradation (Erburg *et al*., 2011; Hansen and Loveland, 2012; Nurwanda *et al.,* 2016; Vogelmann *et al*., 2017). In addition, these changes also have an impact on the loss of biodiversity in various forest types (Surni *et al.,* 2015), as well as landscape fragmentation (Zulfikhar *et al.,* 2017). The rapid change in forest cover has spurred a number of activity initiatives aimed at supporting sustainable forest and environmental management at local, provincial and national levels. One of the efforts taken is to collect information on forest carbon stocks (Hairiah *et al.,* 2011; Nurwanda *et al.,* 2016; Tiryana *et al.,* 2016). However, data and information that shows periodic changes in land cover and carbon stock data in districts or provinces, particularly in South Sumatra Province, are still not widely available (Dewi *et al.,* 2016; Nguyen *et al.,* 2016).

PagarAlam City is an upstream area in South Sumatra Province with 40% of its area being protected areas (BPS, 2018). Protected forest areas in this city have also experienced degradation of carbon stocks due to periodic anthropogenic activities. However, information on how much land cover and carbon stock changes have occurred in this city, especially for protected forest areas is still limited.

Referring to the need for the availability of the intended information, this research was conducted to analyze the dynamics of changes in land cover and carbon stocks in PagarAlam City, South Sumatra Province. In addition, this research will take a role to help fill information gaps through the study and analysis of changes in land cover and carbon stock as well as the factors that trigger change. This information is expected to support efforts to monitor the increase and/or decrease in carbon stocks, so that it will help determine mitigation and adaptation strategy efforts to be carried out in an area.

Materials and Methods

The study area

The study area is located in the southern part of the South Sumatra Province of Indonesia with its geographic location at 04 ’00 ‘- 04 ’15 South Latitude, and 103 ’05 - 103 ’25 East Longitude, the minimum height from sea level is 694 meters and the maximum height above sea level equals 2700 meters with a typical slope ranging from 8% to 45%. Soil types are latosols, andosols and the average annual rainfall in this area is 2325 mm and the average annual temperature is around 22 ° C.

Study method

This study uses two types of data, namely secondary data and primary data. Secondary data is in the form of shapefile data consisting of city spatial planning data, forest area data, city/sub-district administrative boundary data, 2011 forestry land cover data and Pagar Alam city statistical data. This secondary data comes from government agencies, namely Bappeda Kota PagarAlam, Central Bureau of Statistics for City of PagarAlam, Bappeda for South Sumatra Province, and Forestry Services for South Sumatra Province.

Primary data is downloaded from the US National Geological Survey Center for Observation and Science of Earth Resources through the data portal (http://earthexplorer.usgs.gov/) in the form of a series of satellite image data from Landsat TM 7 Path 125 / Line 62 from the Landsat Worldwide Reference System (WRS) with a period of 2000 to 2019 with an interval of 5 years. Landsat images were chosen based on their availability and minimal cloud cover in the study area (<10% cloud cover). There are three satellite images selected for each year.

Landsat satellite image data is downloaded in a GeoTIFF format. Pre-processing satellite imagery conducted with two stages which are radiometric and geometry correction. Radiometry correction aims toimprove the visual quality of the image and, correct the pixel values and geometric corrections aims toput the position of objects in the image by theactual position in the field.

Landsat imagery has a fairly large data gap regarding cloud cover as a major problem that is often found in tropical regions such as Indonesia. Besides that, according to (Eric, 1999, Harsh et al., 2013) states that the use of Landsat 7 will also experience problems in data quality due to damaged Landsat 7 scan-line correctors. However, to overcome this gap, the tools contained in ENVI 5.1, namely software for processing satellite images and matters related to remote sensing can be used to overcome this problem (MS Hossain *et al.,* 2014; Peng Gong *et al.,* 2012).

The Landsat data analyzed was overlaid using ARCGIS 10.5 software. The Maximum Likelihood (ML) method is used for classification because of its accessibility which does not require a long process and can be done by digitizing polygons on the screen based on field knowledge obtained during fieldwork and distributed throughout the study area.

Field work carried out to determine the accuracy of the classification and data collection that cannot be obtained through image analysis. Fieldwork data are also used to test the accuracy of map interpretation of satellite imagery.

In the fieldwork, 120 locations were used to verify and confirm land cover classification classes. The determination of this class refers to the land cover classification system that has been developed by the National Standardization Agency for Indonesia (BSN, 2010). However, the determination of the classification class in this study is simplified, for example for forest classes which in BSN can consist of dry land forest, primary dry land forest, secondary dry land forest, and wetland forest. However, in this study, forest classes were only used to be one class, as well as other land cover classes which were also simplified or class merged.

The land cover classification in this study consists of six types of land cover consisting of forest (primary forest, secondary forest), plantations, open land. shrubs, settlements, and other. Further explanation and characteristics of each land cover type are as follows.

Forest: this land cover type is defined as intact forest, where the standing stand has almost reached stability. Forests are generally native tree species, there is no clear indication of human intervention, and ecological processes are not significantly disturbed. Secondary forest is a regenerating forest that has been disturbed by human activities or natural disasters. Agroforestry and community forestry are included in this forest type.

Plantation: land cover type is defined as the crop that covers the land and is the crop that is harvested consisting of tea plantations, coffee plantations and vegetable plantations.

Open land: this type of land cover is defined as an area or land that is prepared for crops and usually occurs after logging activities without cultivation, including rice fields and dry land cultivation areas.

Settlement: this type of land cover is defined as all areas or land that are used as residential areas including roads or transportation infrastructure as well as parts of areas that are water bodies.

Shrubs: this type of land cover is defined as land where the dominant woody vegetation is shrubs, young trees, generally less than 3 m tall with less than 5% canopy cover.

Others: this land cover is defined as the area outside the study area.

The method used to identify changes in land cover is a simple formula as implemented (Kafi *et al*., 2014; Meshesha *et al*., 2016). The amount of change is calculated using a simple formula, namely.

$$K=F-I \quad .. (1)$$

The percentage change is calculated using a formula, namely:

$$A=(F-I)/I \times 100 \quad .. (2)$$

Whereas:
K = Number of Changes
A = Percentage Change
F = First Year Period
I = Other Year Period

Each land use system has a different number of carbon stocks. A change in the land use system in a landscape will result in a change in the number of carbon stocks in the landscape. The reduction in carbon stock in the landscape due to changes in land use is called carbon emissions, while the increase in carbon stock in the landscape due to changes in land use is called Sequestration.

Further research was carried out to estimate the amount of carbon stock and emissions by calculating the difference in carbon stock in two different time periods (Dewi *et al.,* 2011; Hairiah *et al.,* 2011). The analysis of the calculation of the amount of carbon stock and emissions was carried out using Lumens 0.1 software. Meanwhile, the emission factor data used for calculating carbon stock uses local emission factor data that has been conducted by previous researchers (Tiryana *et al*., 2016).

Results

Land Cover Change Analysis

Analysis of land cover change aims to determine trends in land cover change and its use in an area within a certain period of time. Information on these changes is expected to provide a general picture of land use. Changes in land cover will usually describe a dynamic change that occurs as a result and consequence of development activities related to land use by interested parties. The results of the analysis of land cover changes in Pagar Alam City for each period of the year are shown in Figure 1.

In Figure 1, a dark green color indicates a forest area and the other colors are non-forest areas. In plain view, it can be seen that the forest area in each observation year has changed with a significant downward trend, this can be seen from the reduction in dark green color that changes to another color. However, Figure 1 also shows the change from another color to green. This indicates an increase in non-dense vegetation to areas with dense vegetation in several locations or it can be assumed as an increase in forested areas.

Analysis of changes that indicate an increase or decrease in other land cover types such as plantation land cover, open land, settlements and shrubs is presented in Table 1.

Table 1 shows the results of the analysis of land cover changes that occurred from 2000 to 2019 and the percentage of the area of change of each type of land cover to the area of Pagar Alam City. In 2000, the forest area was 28.18%, then in 2005 the area was reduced to 19.58%. Meanwhile, the forest area in the following years tended to increase or increase to 21.07% in 2010 and 24.02% in 2015. However, the forest area in the 2019 period tended to decline when compared to 2015 with a total area of 21.84. % of the total area of Pagar Alam City.

The area of plantation land in 2000 was 10.42%. The plantation area also experienced a fluctuating trend in the area of Pagaralam City. In 2005, the plantation area was 7.70% and then decreased again to 3.72% in 2010. Meanwhile, in 2015 and 2019 the plantation area increased to 6.78% in 2015 and 9.86% in 2019.

The same condition is also indicated by the type of land cover in the form of open land. The area of open land in 2000 was 4.28%, decreasing in area to 0.83% in 2005. Mean while in the following year the area also fluctuated to 1.73% in 2010, then decreased again to 1.12% in 2015 and in 2019 the area is 1.87%.

The residential area in 2000 was 25.61%, and its area increased to 25.88% in 2005, then the residential area decreased to 20.92% in 2010. Whereas in 2015 and 2019 the residential area became 16.52% and 17.31. % of the total area of Pagar Alam city.

The land cover in the form of shrubs tends to

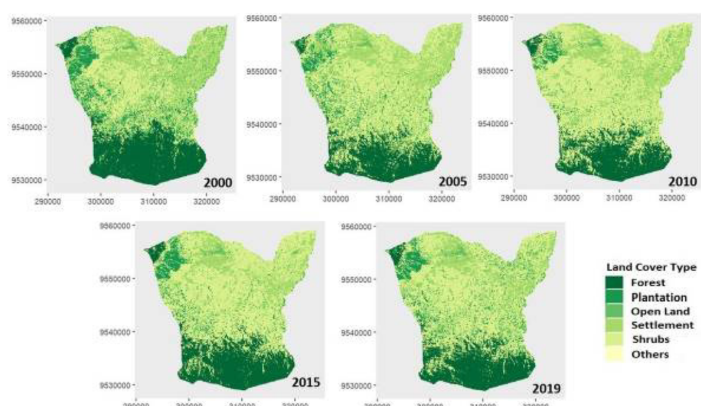

Fig. 1. Changes in land cover in Kota Pagar Alam, during 2000 - 2019.

Table 1. Landcover Analysis, 2000-2019

Tipe Tutupan Lahan	Thn. 2000 (Ha)	%	Thn. 2005 (Ha)	%	Thn. 2010 (Ha)	%	Thn. 2015 (Ha)	%	Thn. 2019 (Ha)	%
Hutan	18018	28.18	12519	19.58	13470	21.07	15356	24.02	13965	21.84
Perkebunan	6660	10.42	4923	7.70	2379	3.72	4333	6.78	6302	9.86
Lahan Terbuka	2737	4.28	529	0.83	1105	1.73	714	1.12	1193	1.87
Pemukiman	16375	25.61	16545	25.88	13378	20.92	10564	16.52	11070	17.31
Semak Belukar	19933	31.18	29207	45.68	33391	52.22	32756	51.23	31193	48.79
Lainnya	215	0.34	215	0.34	215	0.34	215	0.34	215	0.34
Total Luas Area	63938		63938		63938		63938		63938	

have a trend that is always increasing, in 2000 the area of shrubs was 31.18% and the area became 45.68% in 2005. The area of shrubs increased to 52.22% in 2010. Whereas for 2015 the area of shrubs to 51.23% and in 2019 to 48.79%.

To understand land cover changes, it is easier to identify and observe them by comparing them over time. The comparison of land cover changes over time is as presented in Table 2.

The dynamic picture of land cover change in Pagaralam City as shown in Table 2 illustrates the types of land use, utilization and management carried out by interested parties. Changes in land cover have many possibilities to change from one type to another, for example from forest to plantation, from plantation to forest, from forest to open land, from settlement to shrubs, or from shrubs to forest and so on.

However, Table 2 shows that there was a significant change in land cover (settlements) which was experiencing a downward trend, but on the other hand, land cover (shrubs) actually increased in all periods of the observation year. The description of this phenomenon shows that land management and land use arrangements are still not optimally implemented in Pagar Alam City, this is indicated by the increase in the area of shrubs which indicates abandoned areas.

The findings in this study also corroborate the report written by (Noordwijk *et al*., 2017, Wijaya, 2015, Zulfikhar *et al.,* 2017) which states that land use related to human activities will lead to competition for land use, therefore it is necessary to regulate land use so that the use of land resources can provide benefits and can improve community welfare.

Estimation of Carbon Stock

Information on land cover and analysis results per time period is used as the basis for information to conduct further studies, namely to estimate the availability of carbon stocks and emissions. Emissions are calculated as the amount of reduction in carbon stock caused by changes in land cover. Conversely, sequestration is calculated as the additional amount of carbon stock that is also caused by changes in land cover.

The results of land cover analysis from two different time periods combined with the results of local emission factor measurements (Tier 3) were analyzed using LUMENS 0.1 software. Emission factor (Tier 3) is calculating the 'time-averaged C stock' of a land use system using the results of forest (carbon) inventories in several areas in South Sumatra Province conducted by previous researchers (Tiryana *et al*., 2016). The analysis results for the estimation of carbon stock (carbon density) per time period in Pagar Alam City are as shown in Figure 2.

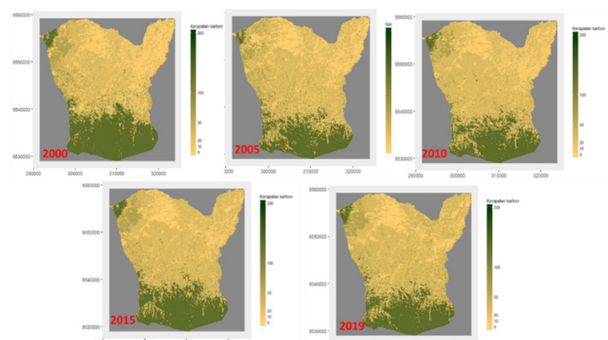

Fig. 2. Carbon density in Pagar Alam City, 2000 - 2019

Figure 2 shows a dark green color indicating the carbon density or carbon stock in Kota Pagar Alam per year period. The occurrence of color degradation from dark green to bright yellow indicates carbon emission, but on the other hand, the color degradation from bright yellow to green indicates carbon sequestration. To see the results of the calculation of carbon availability, emissions and carbon sequestration for each observation year period is as shown in Table 3.

Table 2. Comparison of land cover change over time

Tipe Tutupan Lahan	2000-2005 (ha)	2005-2010 (ha)	2010-2015 (ha)	2015-2019 (ha)
Hutan	-5499	951	1886	-1391
Perkebunan	-1737	-2544	1954	1969
Lahan Terbuka	-2208	576	-391	479
Pemukinan	170	-3167	-2814	506
Semak Belukar	9274	4184	-635	-1563
Lainnya	0	0	0	0

Table 3 shows the carbon emissions in all the observed year periods. The highest carbon emission was caused by the dynamics of land cover change occurred in 2000 - 2005 with emission values reaching 3,126,680.86 tons CO2-eq and the lowest carbon emission values reaching 759,508.44 tons CO2-eq occurred in 2010-2015. On the other hand, the highest sequestration value was the addition of carbon stock, which reached 2,026,747.63 tons of CO2-eq occurred in 2010-2015.

The net estimated value produces negative and positive values which are the sum of the comparisons between the total emission value and the total sequestration value. A negative value indicates an increase in carbon sequestration which has an impact on the size of land cover change as indicated by adding a densely vegetated area, while a positive value indicates the release of carbon which has an impact on the size of land cover change, which is indicated by a reduction in dense vegetated areas. The highest net emission occurred in the period 2010-2015 with a value reaching -1,267,239.19 tons of CO2-eq.

Some locations where emissions and sequestration are indicated which are triggered by land cover change activities in PagarAlam City are as shown in Figure 3.

Figure 3 shows that the red color indicates the location of the area where carbon emission has occurred, while the black color indicates the area where carbon sequestration has occurred. The results of the analysis of the triggers for land cover change that cause carbon emissions are as presented in Figure 4.

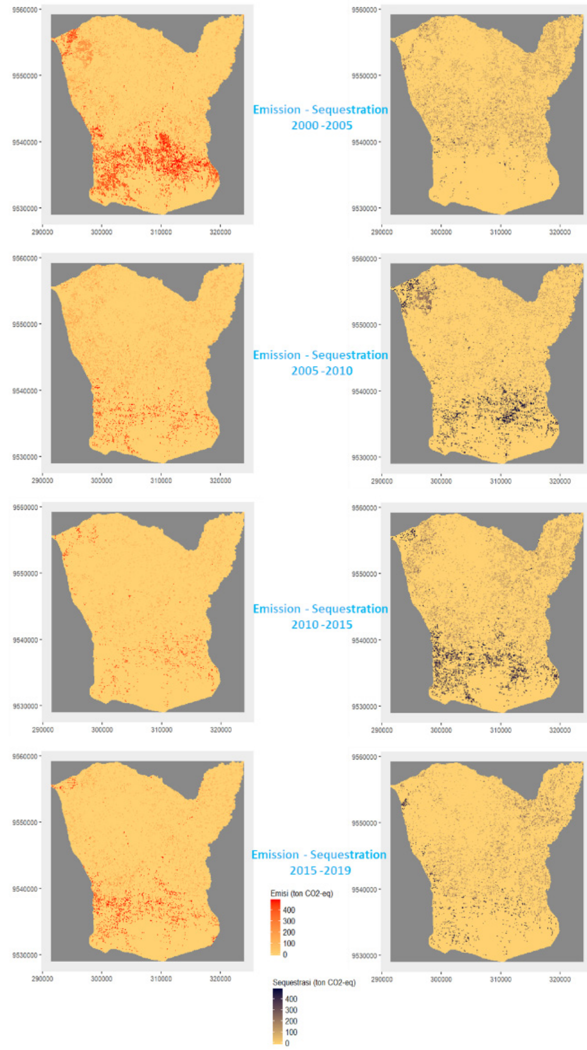

Fig. 3. Location of emission and sequestration areas in Pagar Alam City, 2000 - 2019

Table 3. Estimation results of carbon stock, emissions and sequestration of Pagar Alam City

Category	Estimation Calculation			
Period	2000-2005	2005-2010	2010-2015	2015-2019
Total area	63,881	63,881	63,881	63,881
Total Emission (Ton CO2-eq)	3,126,680.86	1,431,414,07	759,508.44	1,409,098.55
Total Sequestration (Ton CO2-eq)	1,023,114.34	1,733,080.72	2,026,747.63	1,019,952.16
Nett Emission (Ton CO2-eq)	2,103,566.52	-301,666.65	-	389,146.39
Rate Emission (Ton CO2-eq/year)	420,713.30	-60,333.33	-253,447.84	97,286.60
Rate emission per-unit area (Ton CO2-eq/ha.year)	6.59	-0.94	-3.97	1.52

Discussion

This study presents the spatial distribution of the relationship between changes in land cover that affect carbon availability. The rapid demand for land which is used for various purposes, such as for expansion of plantation land, settlements including agricultural areas over the last two decades, has directly or indirectly affected the carbon stock balance in Pagar Alam City.

Trends in land cover change over the past two decades indicate that these changes can be triggered by several factors, including;

- Population factor, rapid population growth causes an increase in the use or utilization of land to meet the economic needs of the community.
- Social factors, changes in community habits in implementing land use, for example people who usually make changes to agricultural cultivation and if the business is unsuccessful will leave the land. It can be seen that the biggest change over the last two decades is indicated by the change in land cover from settlement to land cover in the form of shrubs.
- Economic factors, there are various investments in land use that result in land conversion, for example conversion of forest and shrubs for various purposes.

The results of this study confirm the information that has been reported from previous studies (Dewi *et al*., 2011b; Erburg *et al.,* 2011; Hansen and Loveland, 2012; Margono *et al.,* 2012; Nurwanda *et al.,* 2016; Tiryana *et al*., 2016) which states that the factors that trigger land cover change are natural, physical, financial, human and social factors for various purposes in fulfilling their standard of living.

This study also provides information that the dominance of carbon emissions that occur in PagarAlam City is caused by changes in land cover from forest areas to shrubs, which are the largest contributors to carbon emissions and occur in all periods of the observation year. Meanwhile, the dominance of other carbon emissions comes from land conversion from forests to settlements, plantations into shrubs, plantations to settlements and so on.

The highest annual carbon emission rate in PagarAlam city with a value of 6.54 tons CO2-eq / hectare / year only occurred in the 2000-2005 period and the lowest emission rate occurred in the 2010-2015 period with a value of -3.97 tons CO2-eq / hectare / year. Meanwhile, the emission rate for the 2015-2019 period is 1.52 tons CO2-eq / hectare / year.

The emission rate per unit area in Kota PagarAlam at the end of the observation year period is quite low when compared to the initial observation year period, however efforts to maintain the balance of carbon stocks in this city are absolutely necessary. Efforts that can be done are also reported by (Houghton *et al.,* 2012; Kafi *et al.,* 2014) which states that carbon storage can be increased through optimization of land use structures, for example by protecting land areas with ecological value, limiting the expansion of urbanization to these areas.

The same thing was also reported by (Dewi *et al.,* 2011a; Dewi *et al.,* 2011b, Hairiah *et al.,* 2011; Tiryana *et al*., 2016) which stated that reducing carbon emissions can be done by maintaining, protecting and preserving the area. forest, applying a silvicultural system by improving the management of soil organic matter to support land intensification, and increasing carbon storage by increasing wood vegetation by replacing the use of fossil fuels with renewable energy sources.

This research is expected to provide preliminary information on the dynamics of land cover change and carbon availability in the City of Pagar Alam which is needed by decision makers, particularly to support the preparation of action plans for low carbon development. With the identification of locations that become emission sources and sequestration in Pagar Alam City, this information can be used to support determining priority programs for climate change mitigation actions or to plan future development scenarios related to land management.

Land cover change monitoring and carbon stock estimation activities need to be carried out periodically to assist in monitoring carbon stock changes in a certain area. This is necessary to assist and support the determination of climate change mitigation and adaptation strategies in a region.However, for further research, to obtain more accurate results it is highly recommended to conduct research using high-resolution satellite imagery combined with updated emission factor data.

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