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The Change of Land Cover and Biocapacity of CO_2 Gas Emission Absorption in Gresik Urban Area

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Abstract:
Gresik urban area is dominated by industrial, housing, trade and services activities. The growth of activities contributes to the land use change from green open spaces into built-up areas. The impact of land use change influence the level of air pollution and CO2 gas emission in Gresik urban area. The previous study briefly shows that this urban area produces 50.37% of the total CO2 gas emissions. The production of CO2 gas emissions should be controlled to reduce the impact of climate change in urban areas such as increasing urban temperature, hydrological cycle anomaly, drought, land degradation and other social and environmental issues. The green open space can recycle the CO2 gas emissions and can increase the absorption capacity of the CO2 gas emissions (bio-capacity). The land cover change for built-up area potentially reduces the absorption of CO2 gas emissions in Gresik urban area. Therefore the identification of the land cover change on CO2 emission absorption becomes an objective of this study. The preliminary study can formulate the strategic steps in the development of Gresik urban area that supports urban greenery and adaptive effort to respond the climate change. The study is conducted in two steps. The first step is to analysis the land cover change based on the Landsat satellite imagery analysis. The second step is to measure the dynamic change of the region's ability (bio-capacity) to absorb CO2 emissions by using ecological footprint analysis. The results show that Gresik urban area has a high development of developed land to the North area, Manyar Sub District. The growth of the developed land is more converting the fishpond land. The green areas in this region tend to be influenced by farming activities which also convert into fishpond land. Bio-capacity of CO_2 gas emission absorption increases from 2003 of 3.548 gha to 5.656 gha but the comparison between bio-capacity of CO_2 gas emission absorption and developed land shows the declining tendency in each year. In 2003, the comparison score is 1.59 gha/ha of developed land. In 2014, the score is declining into 1.48 gha/ha or developed land.

Keywords: CO2 Emission, Land Cover Change, Bio-capacity, Ecological Footprint.

1. Introduction

One of global issues recently concerned by the world is climate change. Climate change is believed resulting from the increase of greenhouse gas emission in atmosphere. The impact of the climate change are abnormal climate condition, the increase of sea level and global temperature, economic sector and other systems changes (environment, human, and nature) (Wilson and Piper, 2010). One of greenhouse gas element being concerned by the world is the increase of CO_2 gas emission. CO_2 gas is an important component in greenhouse gas and if there is an excessive concentration, it can cause climate change. CO_2 gas in the atmosphere is estimated 76.7% of the total greenhouse gas in the atmosphere (IPCC, 2007). Although CO_2 gas is easily dissolved in water and absorbed by plants, in 100 molecules of CO_2 released to the atmosphere, it is only 30% of it dissolved in water for one decade and 60% needs more than 6 decades (Godish and Fu, 2003). Moreover, there was a significant increase of CO_2 gas concentration on earth of 354.17 ppm in 1970 which turned to 385 ppm in 2008 (IPCC, 2007).

The increase of CO_2 gas emission can occur due to land use, which have changed from green area to developed area, and the use of fossil fuels (Franchetti and Apul, 2013). The production of CO_2 gas exceeds environment capacity such as vegetation, water, and land to absorb the gas (Wilson and Piper, 2010). The accumulation of CO_2 gas becomes one unavoidable part of the climate change issues.

Therefore, the high increase of CO_2 gas concentration in the atmosphere resulting from fuel use becomes an important issue in global warming (Houghton, 2011).

Gresik urban area, consisting of Gresik Sub District, Manyar Sub District, Kebomas Sub District and Duduksampeyan Sub District, has drastic land use change, especially in undeveloped land change which turned into housing and industrial land. In 2011-2012 period, in Gresik urban area has occurred a declining width of green areas such as paddy field, fishing ground, and dry land of 1.106,73 ha (Central Statistics of Gresik Regency, 2012).

The growth of developed land causes air pollution and CO_2 emission level in Gresik urban area is more than other sub district areas (Ghozali, et al, 2013). CO_2 gas is a kind of the most influential greenhouse gas toward the acceleration of heat increase in atmosphere (Houghton, 2011). The research result conducted one by Ghozali (2013) shows that Gresik urban area produces CO_2 gas from domestic, industrial, and transportation activities of 454.267 tons/year (Manyar Sub District), and 104.536 tons/year (Duduksampeyan Sub District), respectively. The condition is 50.37% or around 1.34 million ton/year of the total of 2.657.660 tons/year CO_2 gas produced in all Gresik Regency areas. The number has not been estimated from CO_2 emission resulting from farming activities which can reach 3.89 million tons/year (Environmental Agency, 2012). The intensity of CO_2 emission that is more than CH_4 emission which is based on the data of Environmental Agency of Gresik Regency (2012) up to 1.1 million ton/year from the farming and stockbreeding activities in urban areas is declining. Therefore, this Gresik urban area has a highly big role in producing CO_2 emission in the throughout Gresik Regency.

The condition as the result of unbalanced use of industrial and housing land which is increasing beside the green areas is decreasing. Industrial and transportation activities are the biggest CO_2 gas emission producer (IPCC, 2007). In 2007-2012 period, the growth of the number of medium and big scales industries recorded increasing from 242 units to 260 units (Central Statistics of Gresik Regency, 2008-2012). The number is 49% of the total industries exist in Gresik regency (Central Statistics of Gresik Regency, 2012).

To equalize CO_2 gas emission level in the atmosphere, it needs vegetation. Plants can reduce carbon dioxide level in the atmosphere by using carbon dioxide in any growing process (Novresiandi, 2012). Thus, it needs monitoring of vegetation in an area so that the absorption ability toward CO_2 gas emission can be identified. Each city has a very broad area if it only relies on field data inventory. Hence, to be able to monitor the vegetation scope in a broad area, remote sensing technology can be employed (Myeong, et al., 2006). By using remote sensing technology can calculate the width of green areas in Gresik urban area

2. Methodology

This research is conducted in Gresik urban area, which consists of 4 Sub Districts such as Gresik Sub District, Duduksampeyan Sub District, Manyar Sub District, and Kebomas Sub District. This research is conducted to measure the absorption ability of CO_2 gas emission in Gresik urban area in 4 different years which are in 2003, 2009, 2013, and 2014. The data being used in this research is Landsat satellite imagery data in 2003, 2009, and 2013. The first measure in the data analysis is to analyze land cover change by utilizing Landsat image analysis. The second measure is by calculating the bio-capacity of CO_2 gas emission absorption in each sub district area by using mathematical calculation of ecological footprint.

2.1. Classification of Land Cover Using Landsat Images Analysis

2.1.2. Preprocessing (Radiometric Calibration)

Before using Landsat imagery to analysis land cover change in the region, preprocessing imagery is required. There's important to do calibration in time series imagery analysis. In several time, some image has a different condition in time, such as sun, time acquisition, Earth-sun distance, Sun elevation, etc. (Myeong, et al., 2006). Removing the influence of the atmosphere condition is a critical pre-processing step in analyzing images of surface reflectance. Properties such as the amount of water vapor, distribution of aerosols, and scene visibility must be known. Due to direct measurements of these atmospheric properties are rarely available, they must be inferred from the image pixels. Hyperspectral images in particular provide enough spectral information within a pixel to independently measure atmospheric water vapor absorption bands. Atmospheric properties are then used to constrain highly accurate models of atmospheric radiation transfer to produce an estimate of the true surface reflectance.

Because of this atmospheric condition, Landsat need to be calibrated. In this research there's 2 type of step to do atmospheric calibration with using FLAASH model in Software Envy:

A. Change DN (digital number) from Landsat RAW Data to spectral radiance (Huang, et al., 2000).
B. Change DN (digital number) from Landsat RAW Data to reflectance as compensation from the difference of sensor calibration and time acquisition difference from the satellite.

2.1.2. Image Classification

In this research, the method being used for image classification is unsupervised classification-ISO cluster method *(ISODATA unsupervised)*. ISODATA unsupervised classification calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. Each iteration recalculates means and reclassifies pixels with respect to the new means. Iterative class splitting, merging, and deleting is done based on input threshold parameters. All pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, in which case some pixels may be unclassified if they do not meet the selected criteria. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached. This kind of classification is a classification which does not rely on data sampling (training data). In this research, land cover classification is clarified as follows:

1. Shrubs : paddy field and shrub land
2. Water body : fishing ground, river, and lake
3. Developed land : industrial, housing, and road
4. Trees cover : plantation, road reforestation

2.2 *The Calculation of CO_2 Gas Emission Absorption (Bio-capacity) Based on Ecological Footprint*

The concept of ecological footprint is an approach of environmental supporting power calculation in an area though the calculation of total population consumption and the waste produced by the citizens' activities with the availability of natural resources, (Wackernagel and Ress, 1996). There are two kinds of important aspects in this aspect, which are ecological footprint and bio-capacity. Ecological footprint is the measurement of human dependency level toward nature through the calculation of how wide the land needed in world land unit (global hectare (gha)). Thus, ecological footprint measures the total ecological cost (in land area). The second aspect is bio-capacity which is the available productive land and it absorbs the people' waste. Ecological footprint and bio-capacity can be measured by using 6 human main consumption lands which are (1) farming land, (2) grazing land, (3) forest, (4) fishing ground, (5) developed land and (6) Energy land (Bala and Hossain, 2012).

This research does not discuss ecological footprint calculation but is only focused in the calculation of CO_2 has emission absorption bio-capacity. This becomes the part of waste in form of CO_2 gas emission produced by people economical activities. The waste is released to atmosphere and it should be absorbed and recycled by opened green space or carbon absorption land (Pandey et al, 2011). Thus, CO_2 gas emission resulted from human activities as ecological footprint, whereas the green area is the bio-capacity.

The calculation of CO2 gas emission absorption bio-capacity score is adopted by a method developed by Global Footprint Network (GFN) (2012). There are two kinds of calculation conversions, they are:

1. Equivalent factor (EQF)

Equivalent factor is a factor converting a local unit into universal unit, which is global hectare (gha). Equivalent factor has been defined by Global Footprint Network for 6 (six) categories of land. One category of the land is CO_2 gas emission absorption land with the equivalency score of 1.26 gha/ha.

2. Yield factor (YF)
   Yield factor describes the comparison between the widths of CO_2 gas emission absorption land in an area with the same width as other areas. This factor also describes the ability of a population to enclose technology mastery and is calculated per year. According to Borucke, et al (2012), yield factor is ration between the land category productivity in an area with the average productivity of the same land category in the world and in the same year. In this research context is CO_2 gas emission absorption land as follows:

$$\mathrm{YFi} = \frac{YNi}{YWi} \qquad (1)$$

Beside those two conversion factor, in ecological footprint calculation method there are also several assumption of yield factor (YF) calculation. CO_2 gas emission absorption land has the same yield factor with the forest land due to the data limitation and global information about the absorption ability of CO_2 gas emission (Borucke et al, 2012). In this research, YF of carbon absorption land is assumed the same with 1 which is based on insufficient information to calculate and estimate the absorption ability of the world carbon absorption land. With the YF same as one, bio-capacity score is not the comparison score to bio-capacity of the world land but only in the area of study.

The calculation of bio-capacity score in this research is the productivity of CO_2 gas emission absorption in the area of study in global hectare unit (gha). This calculation method of bio-capacity is based on the method developed by GFN (2012) by using the following equation:

$$\mathrm{BC} = \mathrm{Lbc \times YF \times EQF} \qquad (2)$$

In this calculation, L_{BK} should be overall width of green areas. The width of green areas in the classification of land cover will be only distinguished into shrubs and tree covers. According to Prasetyo (2002) in Rini (2014), bush and tree cover has absorption ability difference of CO_2 gas emission as seen in the following Table.

Table 4. Absorption Capacity

Type of Vegetation	Absorption Capacity (kg/ha/month)	Absorption Capacity (kg/ha/year)
Trees	46771.2	561.25
Shrubs	4521.6	54.25

The calculation of CO_2 gas emission absorption ability is estimated based on the type of vegetation cover. Therefore, to obtain the width of bio-capacity land in the area of study, the width of shrubs cover is changed into the width of trees cover. The width of CO_2 gas emission absorption land is calculated by using following formula:

$$Lbc = L\ trees + \frac{L\ shrubs\ x\ AC\ shrubs}{AC\ trees} \qquad (3)$$

3. Results and Discussion

3.1 The Development of Land Cover in Gresik Urban Area in 2003-2014

Based on the analysis, The land cover in Gresik urban area is significantly increasing. The different condition occurs in fishpond and farm. Those lands are significantly decreasing. The number of fishpond identified is 12.033 ha in 2003, whereas in 2014 it turns into 9.979 ha. Land cover identified as farming and shrubs land also undergo the same condition. The number of land cover in farming land category and shrubs reach 1.753 ha in 2003, whereas in 2014 it decreases into 1.603 ha. This condition is inversely proportional to the developed land cover which is significantly increasing. In 2003, the number if developed land is estimated of 2.184 ha and reaches 3.393 ha in 2014. As seen in the following Figure 1.

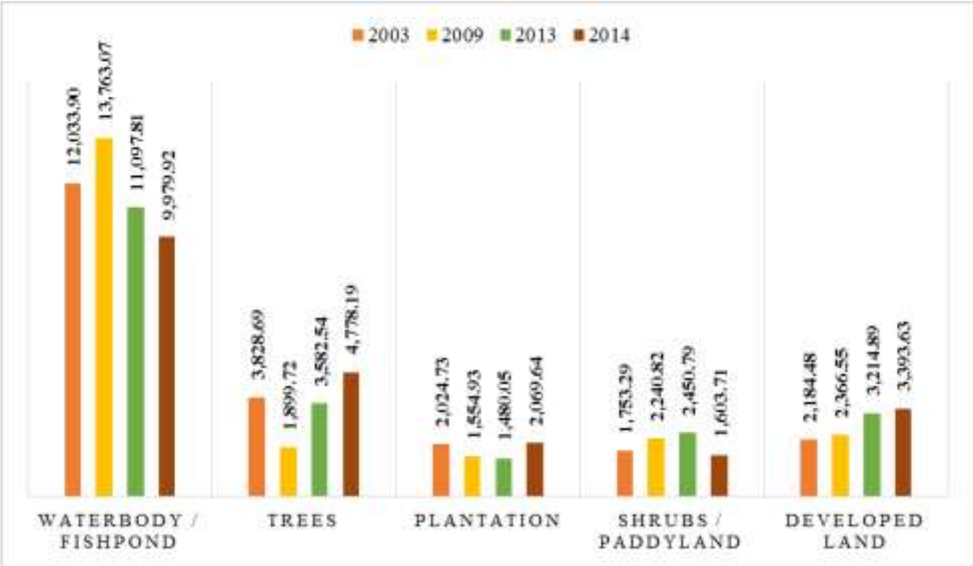


Figure 1. The width change of land cover per category of land in Gresik urban area

As coastal town, Gresik urban area has a big fishpond land. This fishpond land is a type of land which is the most susceptible converted into developed land. The massive development of industrial activities makes fishpond turns into developed land. Industrial activities is developing to the North, Manyar Sub District area, as seen in Figure 2.

Based on the data from Licensing and Investment Department of Gresik Regency, Gresik urban area is dominated by fertilizer, wood processing, metal, and chemical industry. Those four kinds of industry are potential industry type to release CO_2 gas emission from two sources which are raw material processing and the use of fossil fuels (IPCC, 2007). The statistical data shows that 4 types of industry can significantly develop as seen in Figure 3. Geographically, Gresik regency is an area with the limestone which becomes the raw material of fertilizer industry. Meanwhile, the concentration of chemical and metal industries resulting from agglomeration of big industry which is supported by big ports around this area such as Gresik port, Manyar port (still in developing stage) and Tanjung Perak and Lamong Bay port in Surabaya.

Result analysis of Landsat imagery also shows that green areas in Gresik area is influenced by farming, shrubs, and plantation area cover. The analysis of Landsat imagery classifies the shrubs and farming land as one part for the field check shows the same color tendency. As seen in figure 1, in the range of 2003-2014 land cover in category of shrubs, farming area tends to increase. This condition is caused by the fishpond land conversion into farming area other than the fishpond land changes into developed land. Trees area cover in Gresik urban area is road and plantation reforestation as seen in Figure 4. Manyar Sub District and Duduksampeyan Sub District areas have the wider green area cover. As a central government area, Gresik and Kebomas Sub District, have the smaller green area cover each year due to a massive developed land. Thus, farming activity give a big influence toward the development of green area in Gresik urban area. The fishpond land can be changed into developed land or is converted into farming land even neglected areas which there are a lot of shrub.

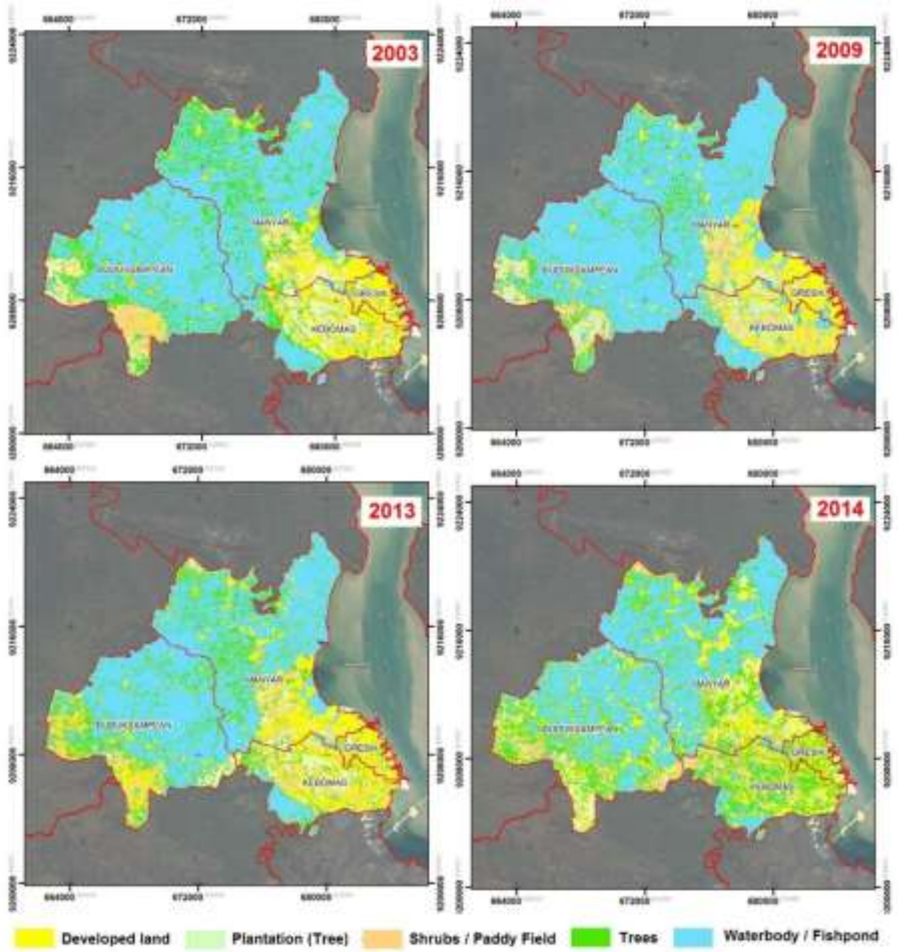


Figure 2. The change of land cover in Gresik area in 2003-2014

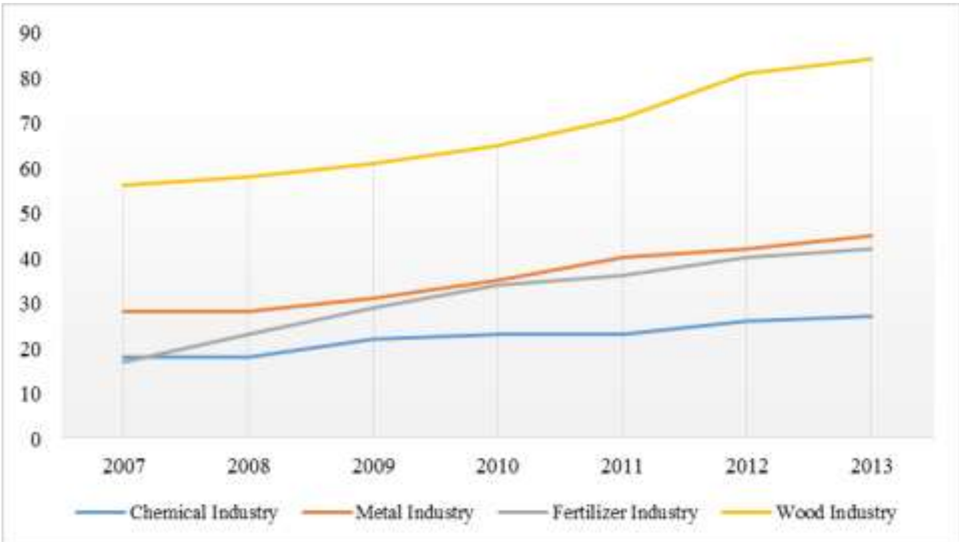


Figure 3. The Growth of the Number of Fertilizer, Wood Processing, Metal, and Chemical Industry in Gresik Urban Area

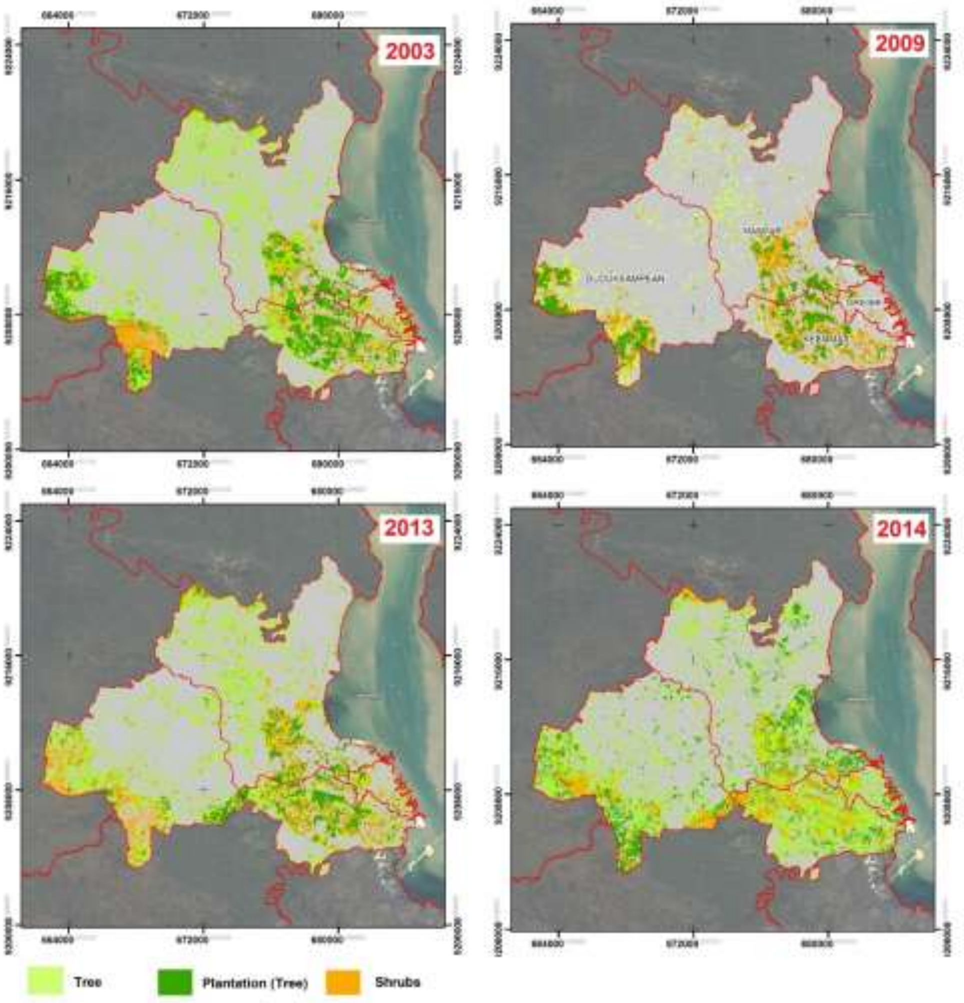


Figure 4. Map Distribution of Green Areas in Gresik Urban Area

3.2. Bio-capacity of CO_2 Gas Emission Absorption in Gresik Urban Area

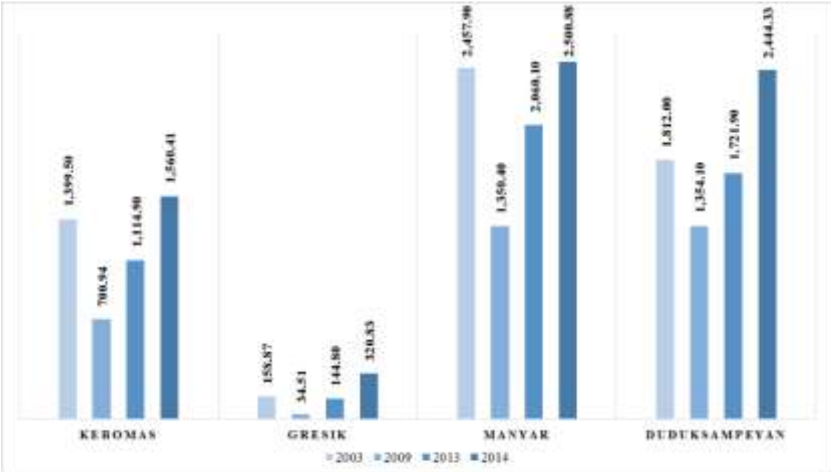
The change of land cover in Gresik urban area shows that the development of developed land is highly dominant occurring in this area. As a city developed from industrial activities, Gresik must have adequate green areas to recycle CO_2 gas emission produced in this area. Industry is one of the biggest CO_2 gas emission producers other than transportation (Franchetti and Apul, 2011). Particularly, if the developing industries are the types of industry producing CO_2 gas emission directly from raw material processing outside the fuels being used (IPCC, 2007). Those industries are fertilizer industry, wood industry, chemical industry, and metal industry.

To equalize CO_2 gas emission produced in Gresik urban area, it needs green areas, vegetation covers. The sufficient availability of green areas implies at the bigger absorption ability of CO_2 gas emission. Based on the preceding analysis result, it shows that the width of green areas in each sub district has the same width as seen in the following Graphic.

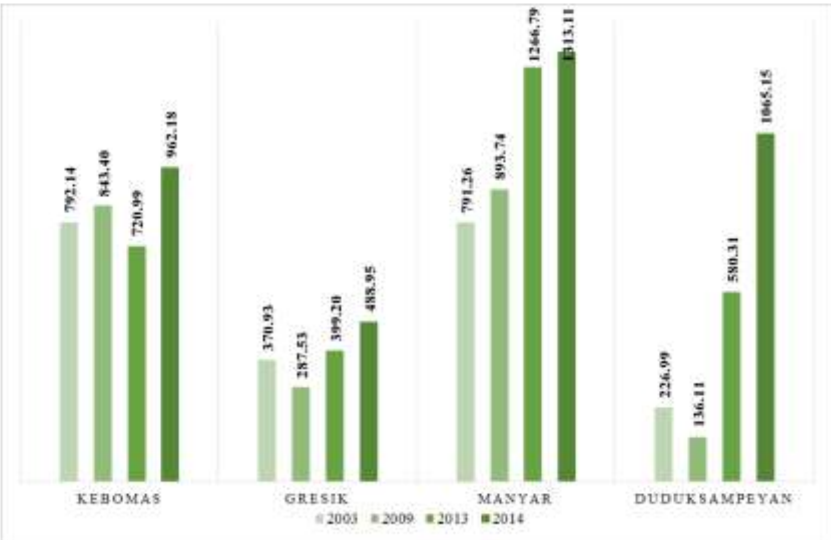
Based on the Graphic above, it can be seen that Gresik and Kebomas Sub District have small green areas. This condition is inversely proportional to the width of their big developed land. The width of big developed land indicates that the greater CO_2 gas emission production due to higher human activities in consuming transportation sector, industrial, and domestic sectors (Ghozali, et al, 2014).

The width of green areas in each sub district can be classified into shrubs and trees cover. Shrubs cover in Gresik urban area can be identified as farming land and shrubs. Trees land cover is identified as plantation land, park and reforestation for road and buildings. Manyar and Duduksampeyan Sub

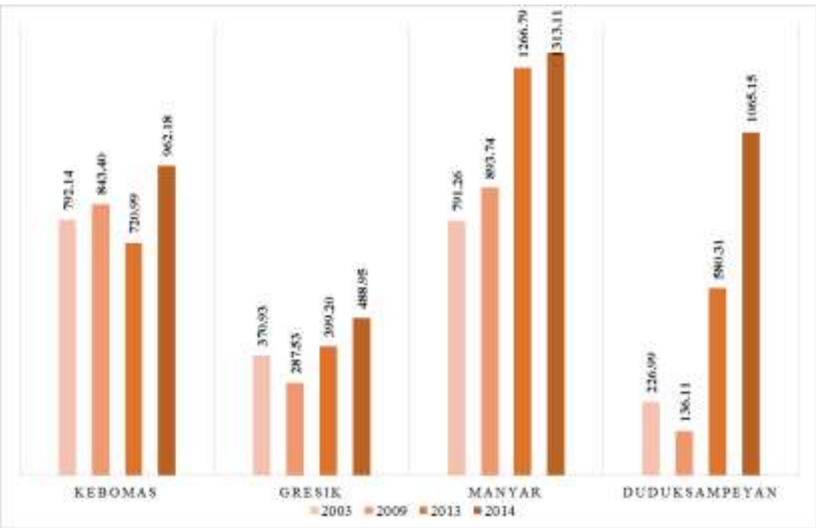
Districts have the width of green areas both in shrubs and trees category. The width of shrubs in both sub districts in 2003 are 2.457 ha and 1.812 ha, respectively, whereas in 2014 increases of 2.500 ha and 2.444 ha, respectively. This is influenced by farming activities and the fishpond land changes into farming land and neglected land in these both areas. Central government area, Gresik and Kebomas Sub Districts have small green areas but tend to increase. This condition results from city reforestation conducted by Gresik Regency government since 2009 both road and road median reforestation, expansion and addition of city parks, and allocation of green areas in the building site.



(a)



(b)



(c)

Figure 5. Annual Graphic of Green Areas (a) Width of Shrubs Land Cover (b) Width of Trees Cover and (c) Width of Developed Land

The width of green land influences the absorption ability of CO_2 gas emission in each year. Graphic 6 shows the development of CO_2 gas emission absorption ability in each sub district in Gresik urban areas. From this Graphic, it can be seen that Manyar Sub District has the biggest CO_2 gas emission absorption ability among other sub districts. In 214, absorption ability in these both areas is of 872.655 tons CO_2/year and 730.419 tons CO_2/year.

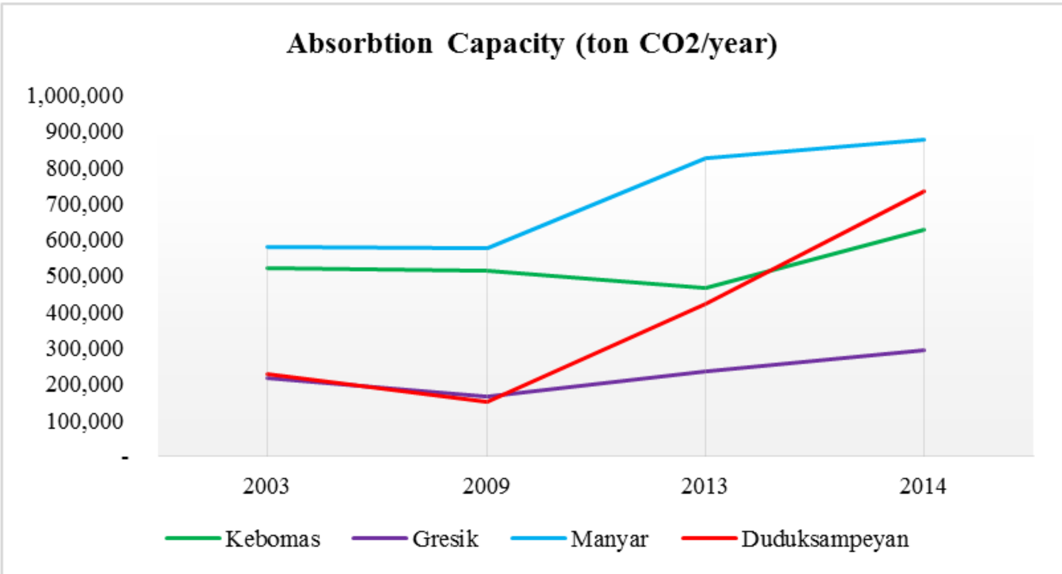


Figure 6. Graphic of the Growth of CO_2 Gas Emission Absorption Ability in Gresik Urban Area

Based on the calculation of green land width in each sub district, bio-capacity of CO_2 gas emission absorption can be calculated. Table 2 shows the comparison of bio capacities in each sub district in 2003 and in 2014. Based on the calculation result, it can be seen that bio-capacity in 2003 to 2009 tends to be stable. In 2003, bio-capacity of CO_2 gas emission absorption in Gresik urban area is 3.458 gha, whereas in 2009 is 3.299 gha. The presence of city reforestation act program conducted by Gresik Regency Government since 2009 makes an influence on the significant increase of the bio-capacity. In 2014, bio-capacity of CO_2 gas emission absorption increases to 5.656 gha. Even so, the high development of developed land makes the comparison of bio-capacity of CO_2 gas emission absorption per width of developed land gets bigger. The developed land in Gresik Urban area is dominated by big industrial activities, so that the bio-capacity increase in this area will not be proportional to emission production. The calculation of CO_2 gas emission production is not conducted in this research. If comparing between bio-capacity per width of developed land, the area.

Table 2. Bio-capacity Land (ha) in Gresik Urban Area

Sub-District	Year 2003		Year 2009		Year 2014	
	Lbk	Bio-Capacity	Lbk	Bio-Capacity	Lbk	Bio-Capacity
Kebomas	927.41	1,168.54	978.68	788.74	1,113.01	1,402.40
Gresik	386.29	486.72	302.89	402.53	519.96	655.15
Manyar	1,028.84	1,296.34	1,131.32	1,397.32	1,554.84	1,959.10
Duduksampeyan	402.14	506.69	311.26	711.20	1,301.42	1,639.78
Total	2,744.68	3,458.29	2,724.15	3,299.79	4,489.23	5,656.43

Thus, this discussion will focus on the comparison of bio-capacity of CO_2 gas emission absorption per width of developed land. Table 3 shows the comparison of bio-capacity score of developed land per ha. Table 3 shows that although bio-capacity of CO_2 gas emission absorption increases in 2003-2014, the comparison score of developed land width tends to decrease. In 2003, the comparison of bio-capacity of CO_2 gas emission absorption with the developed land in Gresik urban area is 1.59 gha/ha, whereas in 2014 it decreases into 1.48 gha/ha. Ghozali, et al (2014) shows that strong factor of CO_2 gas emission balance in Gresik urban area is influenced by the number of industries and transportation activities. Hence, it is necessary to anticipate the development of Gresik urban areas which concerns CO_2 gas emission balance. Broad fishpond land which should be used as alternative for city green spaces allocation and should not be constantly used as developed land.

Table 3. The comparison between bio-capacity of CO_2 gas emission absorption and developed land

Tahun	Kebomas	Gresik	Manyar	Duduksampeyan	Total
2003	1.48	1.31	1.64	2.23	1.59
2009	0.94	1.40	1.56	5.23	1.53
2014	1.46	1.34	1.49	1.54	1.48

5. Conclusion

Based on the analysis result, it can be concluded as follows:

1. Gresik urban area has a high development of developed land to the North area, Manyar Sub District. The growth of the developed land is found more on converting fishpond. The green areas in this region tend to be influenced by farming activities which also convert into fishpond. Green areas have been decreasing during 2003-2009 period but increasing in 2009-2014 which is influenced by city reforestation program.
2. Bio-capacity of CO_2 gas emission absorption increases from 2003 of 3.548 gha to 5.656 gha. Even so, the high development of developed land with the industrial activities dominance is potential to cause deficit for Gresik urban area to absorb CO_2 gas emission produced by activities on developed land. The comparison between bio-capacity of CO_2 gas emission absorption and developed land shows the declining tendency in each year. In 2003, the comparison score is 1.59 gha/ha of developed land. In 2014, the score is declining into 1.48 gha/ha or developed land.

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