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Distribution of Carbon Stock by Land in Banyuasin Regency, South Sumatra

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Abstract

Land use and land cover changes impact on carbon losses in terrestrial areas. The loss of carbon increase carbon dioxide (CO_2) in the atmosphere which is the major cause of global warming. Intensive land use and land cover changes took place in Banyuasin Regency from 2004-2014 led to changes in carbon stock distribution in the area. This study aimed to know how the distribution of carbon pools by land that occur in Banyuasin Regency. Research includes land use change, the amount of carbon stock changes, carbon balance and CO_2 emissions/sequestration. The study was conducted from June 2015 to February 2016. The method used was the method that calculates land use change and land cover in 2004-2009 and 2009-2014, calculation of carbon stocks using allometric equations and destructive sampling methods, and Carbon/CO_2 emissions/sequestration calculations using stock difference method. The results showed that during the period 2004-2014 the carbon balance moved toward the negative direction. Average carbon stock per hectare was 338.28 tons while average carbon loss was 0.45% per year. CO_2 sequestration amounted to 29.298.966 tons while the emission was 118,044,141 tons, of which net emission was 88,745,175 tons. The average CO_2 emitted from above ground carbon pools, necromass carbon pools, litter carbon pools and belowrground carbon pools was 7 tons ha^{-1} yr^{-1}, while CO_2 emissions from soil organic C pools was 0.61 ton ha^{-1} yr^{-1} . Emission sources were dominated by changes in land use and land cover of peat swamp forests, secondary mangrove forests, primary mangrove forests and secondary swamp forests. While the source of sequestration came from changes in Rubber monoculture on peat, palm oil plantations, rubber monoculture, and shrubs.

Key Words: Land use and land cover, carbon pool distribution, CO_2 emissions/sequestration

1. Introduction

Changes in land use and land cover are the causes of terrestrial carbon loss and have been a significant source of increasing carbon dioxide (CO_2) in the atmosphere (Waston *et al*., 2000; Jiao *et al*., 2010; Singh *et al*., 2011; Wang *et al*., 2011). Increased CO_2 concentration in atmospher is believed to have an impact on global warming. The existence of anthropogenic influences to meet the land and space demands led to changes in land use and land cover that occurred globally, one of which in Banyuasin Regency.

The impacts of land use and land cover changes can be determined by studying the dynamics of biomass changes occurring in five carbon pools, namely above ground carbon pools, necromass carbon pools, litter carbon pools, below-ground carbon pools and soil organic C pool (IPCC, 2007). Vegetation inputs determine the five carbon pools, as vegetation is the only source of carbon in terrestrial ecosystems. Therefore, land use and land cover play a major role in determining biomass and carbon stocks in terrestrial systems (Pandey *et al*., 2010).

Land use and land cover changes determine the region's carbon balance. The carbon balance provides an overview of the total carbon pool in a region over time, the amount of CO_2 emissions and sequestration as well as determine what type of land use and land cover changes leading to a positive or negative direction on the balance sheet. Globally, the carbon balance indicates an imbalance between the release of CO2 from terrestrial ecosystem to the atmosphere and the flow of CO_2 from the atmosphere to the terrestrial system. The flow of CO_2 into the atmosphere is much greater than that from the atmosphere to the terrestrial (Guo and Gifford, 2002).

Even if land use change is believed to have contributed one-third of the increasing CO_2 concentrations in atmosphere globally, but the amount of CO_2 released into the atmosphere certainly varies in each region. This is due to differences in changes of land use and land cover occurring in each region. To know the addition and subtraction of CO_2 from the atmosphere to the terrestrial and vice versa, it would be necessary to conduct a study to know the carbon balance in a region. In addition to estimating the amount of CO_2 released (emissions) and vegetation capture (sequestration), it is also important to determine the carbon status of a region in terms of total carbon stock and average carbon stock per hectare. Hence, This data could be used as the basis for an objective assessment in determining the amount of CO_2 emissions and sequestration because it could be compared with the amount of total carbon stock of a region.

The main objective of this research was to study the distribution of carbon pools by land in Banyuasin Regency of South Sumatra. Furthermore, the research stages conducted were aimed at (1) Identifying land cover/land use and analyzing land use change in 2004, 2009 and 2014; (2) Measuring carbon stocks and changes in carbon stocks on above ground carbon pools, necromasses carbon pools, litter carbon pools, below-ground carbon pools and soil organic C pools that caused by changes in land use and land cover; (3) preparing carbon balance and estimating CO_2 emission/historical sequestration in the terrestrial system of Banyuasin Regency

2. Methodology

2.1 Research Area

Banyuasin Regency is administratively located in South Sumatera Province. In terms of land use, it is quite rapid development, thereby affecting the dynamics of changes in land use and land cover. The total area of Banyuasin Regency amounted 12,815.55 km2, 92.21% (1,181,610 ha) is a land with a slope of 0-2% with the condition of tidal swamp scattered along the northern coast of South Sumatra to the hinterland while 7.8% (1.689 ha) is a land with a slope of 2-5% located in the western part of Banyuasin Regency.

According to the classification of Oldemand, Banyuasin Regency has climate type B2 (average rainfall of 2,521-2,683 mm yr-1), climate type B (average rainfall of 2,359-2,521 mm th-1), climate type B1 (average rainfall of 2197-2359 mm yr-1) and climate type C2 (average rainfall of 1872-2197 mm yr-1)There are eight types of land (ordo) in Banyuasin Regency (Dudal-Soepraptohardjo classification (PPT Bogor) (1957-1961) with the total area were, Glei 604,621 ha (46,81%), Peat 311,288 ha 24,10%), Alluvial 153,671 ha (11,90%), Hydromorf 85,804 ha (6,46%), Litosol 27,509 ha (2,13%), Latosol 18,911 ha (1,46%) and Regosol 14,790 ha (1,4%)

2.2 Tools and Materials

2.2.1 Analysis of Land Use and Land Cover Changes

Spatial data processing of land use was done by applying digital image processing method by using Spot 5 image of 2004, Spot 5 image of 2009 and Spot 6 image of 2014. After the visual image interpretation was done, the map then overlaid with the map on Balance Sheet of Banyuasin Land Use (Scale 1: 25,000 of 2014). The result of this overlay was further overlaid with the map of the land type of Banyuasin Regency (scale 1: 50.000). Ground checks were conducted at 50 points for each land use and land cover. Analysis of changes in land use and land cover in the period 2004 - 2014 in the research area was conducted with an overlay of land use and land cover in 2009 and 2004 as well as 2014 and 2009. To analyze the carbon stock changes in forest land, cropland, grasslands, Settlement, and other lands, lands were grouped based on LULUC-IPCC (2007) GPG 2003 and GL 2006.

2.2.2 Analysis of Carbon Stocks and Carbon Stocks Changes

Carbon stocks and carbon stocks changes were analyzed on 381 points of land use/land cover samples, each point was observed with 2 replications. The experimental plot used referred to the Indonesian National Standard (SNI) (7724: 2011) about the measurement and calculation of carbon stocks. Calculation of above ground biomass such as piles, poles, and trees using allometric equations. The calculation of seedling biomass is done by harvesting and weighing the yield. The necromass biomass for dead trees was calculated by allometric equations multiplied by the correction factor of the intactness of the dead tree, whereas the necromass in the form of twigs, barks, and other dead tree parts was directly weighed with 300 grams were taken for dry weight measurement. Measurement of litter biomass was conducted by collecting litter in the experimental plot, weighing the total weight of litter, and taking 300 grams of the litter for dry weight measurement. Measurement of below-ground biomass stocks used allometric equations (Brown, 1997). Measurement of soil organic C was done by soil sampling at 0-30 cm depth which then bulked and subsequently the soil organic C content set in percent by Walkley and Black methods.

The calculation of carbon content stored in each land use was performed by multiplying the weight of the biomass by 0.48 (Brown 1997). The calculation of changes in carbon stocks in 2004 - 2009 and 2009 - 2014 used the stock difference method, that was by estimating the difference in carbon stock at a time interval, which also used by Van Noordwijk *et al*. (2010). The analysis of changes in carbon stocks was also based on IPCC categories (forest land, cropland, grassland, settlement and other lands)

2.2.3 Analysis of Carbon Balance and Calculation of Emission/Historical Sequestration of CO_2

Carbon balance analysis and CO_2 emission/sequestration calculations were performed by comparing carbon stock at a time period (stock difference method). Differences in carbon stocks at different times indicated the occurrence of emissions or additional stocks (sinks) (Wibowo *et al*., 2010). In principle, the calculation of CO_2 emissions and sequestration, if land use changes into land use and land cover with less carbon use it is classified as emission (Negative score difference) if the change of land use and land cover from less carbon into more carbon use, it is classified as sequestration (Positive score difference). Meanwhile, if there is no change of land, it is considered as no emission or sequestration. The calculation of CO_2 emissions/sequestration was based on changes in carbon stocks, that was by converting the molecular weight of emitted and absorbed carbons with the CO_2.

3. Result and Discussion

3.1 Land Use/land Cover and the Change

Results of land use and land cover mapping in 2004, 2009 and 2014 indicated that the dominant land uses were monoculture rubber, secondary mangrove forest, primary mangrove forest, secondary swamp forest, paddy field cultivated once a year, swamp forest, and shrub. Figure 1 shows that the period 2004-2009, there was a reduction in the area of paddy field cultivated once a year, secondary swamp forest, secondary mangrove forest, shrubs. Besides, there was the addition area of extensive monoculture rubber peat, palm, shrub and monoculture rubber. In 2009-2014 the reduction area of swamp forest and secondary swamp forest was occured. The increase of total area occurred in peat shrubs, shrubs, and monoculture rubber on peat.

Increased area of oil palm plantation and rubber plantations was higher than other land use changes. More dominant land use changes on palm and rubber plantation might be caused by three factors. First, the land suitability of the land of Banyuasin Regency that is suitable for growing requirements of oil palm and rubber plants. Second, the influence of external factors such as the improvement of rubber and oil palm commodity markets, both domestically and internationally. Third, location license of the government that permits large-scale land use.

In total, land use and land cover changes in Banyuasin regency in 2004-2009 amounted to 75,819 ha and 32,576 ha in 2009-2014. The total land use and land cover changes in Banyuasin Regency were not linear between 2004 - 2009 and 2009-2014. This indicated that the increasing population in Banyuasin Regency is not the major cause of land use and land cover changes in the regency. The trigger was more likely to be caused by market mechanisms of palm and rubber products. This indicated that land use change in Banyuasin Regency was also influenced by external factors from regions outside Banyuasin Regency.

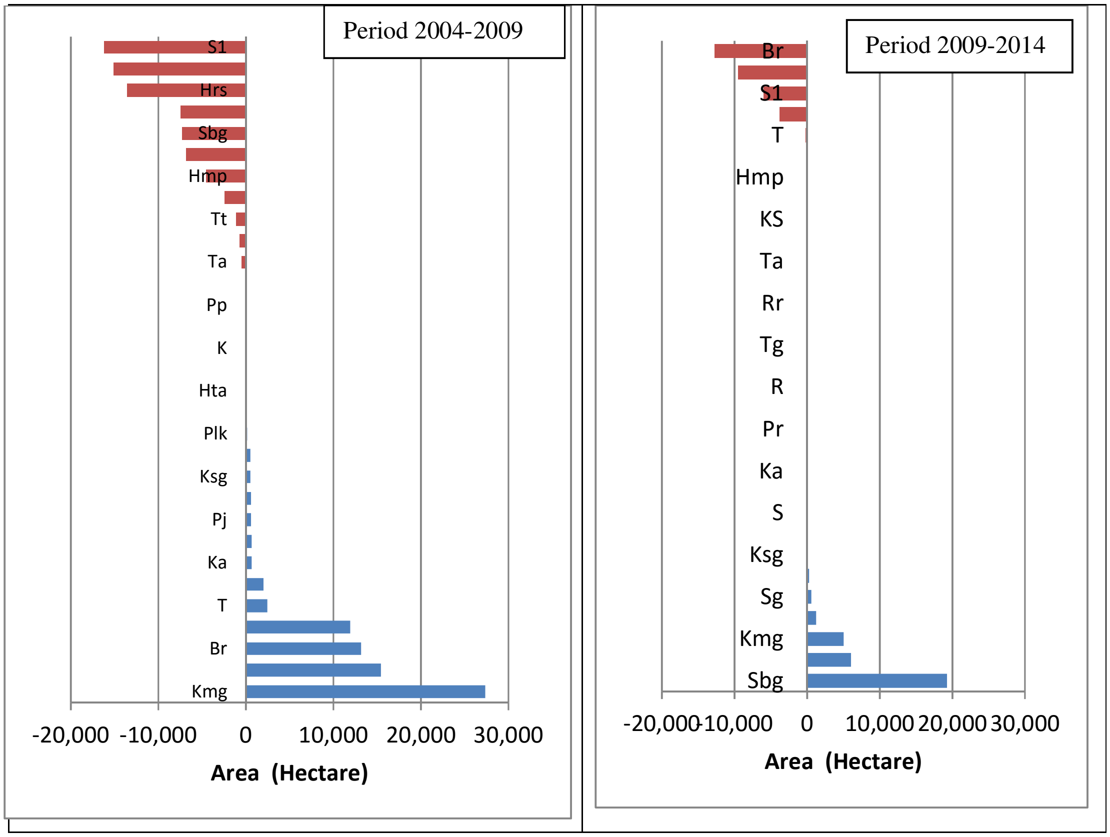
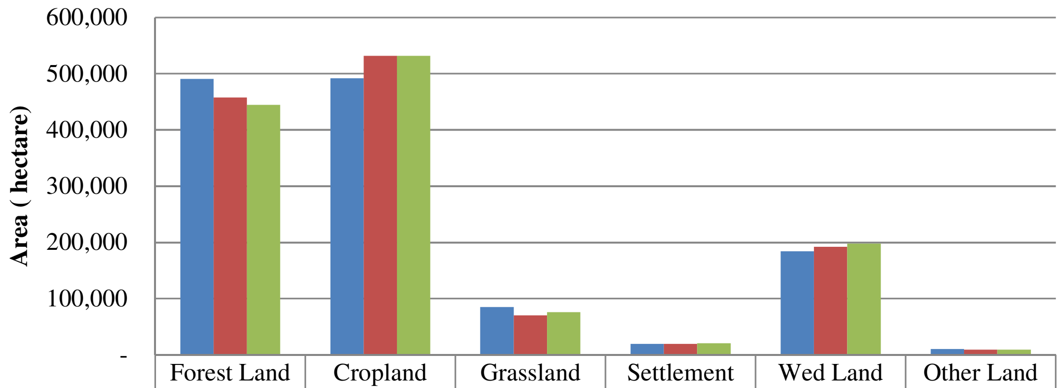


Figure 1 Total area of land use and land cover changes in Banyuasin Regency in the period 2004-2009 and 2009-2014

Information; Primary Mangrove Forest (Hmp), Secondary Mangrove Forest (Hms), Secondary Swamp Forest (Hrs), Acacia Plantation Forest (Hta), Shrubs (Sm), Swamp Grass (Rr), Swamp (Br), oil palm (S) , Ponds (T), Dryland Farming (Plk), Dryland Farm Mix (Plkc), Coconut (K), Rural Settlements (Pj), Solid Settlement (Pp), Open Mining (Pt), Swamp (R), Pasture (Pr), Open Land (Tt), paddy harvest once a year (S1) paddy harvest twice a year (S2), Rubber Monoculture (Km), Rubber Bush (KS), Rubber Agroforestry (Ka), Water Body (Ta), Peat oil palm plantations (Sg)., Rubber Monoculture Peat (Kmg), Rubber Peat Bush (ksg), Peat Agroforestry Rubber (Kag), Peat Swamp Forest (Hrsg), Peat Swamp (Sgg), Peat moss (Tg)



	Forest Land	Cropland	Grassland	Settlement	Wed Land	Other Land
Year 2004	490,648	491,536	85,392	19,304	184,328	10,346
Year 2009	458,176	531,912	70,304	19,870	192,046	9,247
Year 2014	444,714	531,762	76,329	21,117	198,383	9,249

Figure 2 Total area of land use change in Banyuasin Regency in 2004, 2009 and 2014

Figure 2 shows that the reduction of forest land area occurrs in 2004-2009, at the same time the addition of cropland area also happened. In the 2009-2014 the forest land use decreased, yet the use of cropland was also not increased. This is due to the change of cropland into shrubs peat and shrub (Figure 1). The results of Ground check indicated that croplands were re-transformed into peat shrubs and shrubs. This change probably caused by the poor of water management that led to the failure of rubber and oil palm cultivations.

Factors that cause changes in land use and land cover were not dominated by natural factors, but more likely due to anthropogenic factors. This factor related to the government policy in the allocation of land for plantation purposes. In the year 2004-2009 the changes occurred more dominated by non-cultivation use into cultivation use. Moreover, an enormous increase in the land use was obtained on rubber and oil palm plantations, which are generally made by private companies. The main factors that led to the increase of the land use were the granting of land use and land utilization permits, which impact on land use and land cover changes. Licensing is determined by the allocation of land used based on the spatial plan of the region. The existence of licensing mechanism indicated that the role of the regional spatial plan is very dominant in affecting the changes of land use and land cover in Banyuasin Regency.

3.2 Carbon Stocks and Carbon Stocks Change

Changes in land use and land cover in Banyuasin Regency resulted in carbon pool changes in five carbon pools, that were above ground carbon pools, litter carbon pools, necromass carbon pools, below-ground carbon pools, and soil organic C pools, affected total carbon stocks in Banyuasin Regency. The addition and subtraction of a type of land use and land cover formed a dynamic of carbon stocks addition on one side and carbon stocks reduction on the other.

The reduction of total carbon stocks in Banyuasin Regency was caused by the changes in land use and land cover types with high carbon stocks into the type of land use and land cover types with low carbon stocks. Meanwhile, carbon stocks increased if the opposite happened. In addition to the changes of land use and land cover types, carbon stock was also affected by the total area of land use and land cover changes. The result revealed that the high change of land use and land cover changes in a wide area had a high impact on the total carbon stocks.

Carbon stocks change in Banyuasin Regency were inseparable from the carbon cycle that occured in the three compartments of the carbon system, namely soil, plants and atmosphere. In addition, changes in land use, climate, geology and land management practices had also affected the carbon stocks.

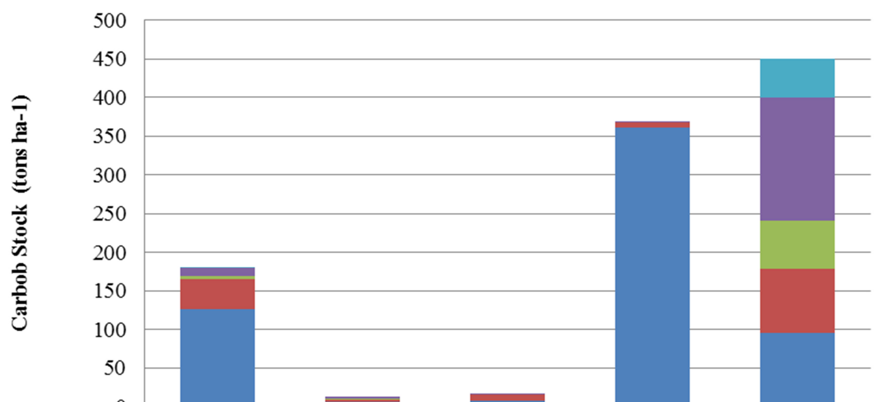
Carbon stocks in primary mangrove forest and secondary mangrove forests vegetations were the highest, this is due to the high carbon stocks was obtained in below-ground. Research conducted by Donoto *et al.* (2012) stated that below-ground carbon in land cover with mangrove forest was five times than that aboveground carbon.

Variations in carbon stocks due to land use and land cover as shown in Figure 3, showed that the different of biomass existed in each type of land use and land cover. In the land use and land cover with cropland, it is suggested that litter, seedlings, and necromass carbon pools relatively lower than that non-cropland type, this is due to the cultivation practice such as cleansing activities of litter, seedlings, and necromass.

Stocks of carbon formed were affected by vegetation numbers and the vegetation ability to capture CO_2.In addition, the formation of biomass was also affected by the presence of nitrogen, in which soils with a high nitrogen content captured higher CO_2. Nitrogen enrichment by nature and fertilization application increased the land productivity thereby resulting in greater CO_2 absorption and led to a higher biomass formed. This was in line with findings research by Evans *et al*. (2006), Reay *et al*. (2007) and Reich *et al*. (2006).

Figure 3 shows the distribution of carbon pools has varied, in which forest land has the largest carbon stocks mostly in whole pools, except in the soil organic C pool. Soil organic carbon is highest in settlement use. This is thought to be due to a better mechanism of soil organic C protection, as it is lack of decomposition or mineralization processes.

The results of carbon stock measurements in each type of land use and land cover indicated the presence of the difference between the smallest and largest amounts of carbon in some types of land use and land cover. The results of these measurements are presented in Figure 4.



	Aboveground	Litter	Necromass	Below-ground	Organic soil C
Other land	0.35	0.00	0.00	0.00	51.54
Settlement	10.11	2.34	0.33	0.59	157.50
Grassland	4.84	1.25	0.00	0.00	63.48
Crop land	38.95	2.21	7.06	5.75	83.00
Forest land	126.02	6.79	8.17	361.64	95.39

Figure 3 Carbon distribution per hectare of each pool in Banyuasin Regency

Figure 4 shows the type of land use/land cover of secondary mangrove forest, secondary swamp forest, mixed dryland farming, paddy field cultivated once a year, paddy field cultivated twice a year and monoculture rubber showed a large variation in a number of carbon stocks. This variation may be caused by the influence of various soil types, of which differences in physical, climatic and biological properties of soil impact on different responses to the growth and development of plants, including in decomposing and protecting the soil carbon.

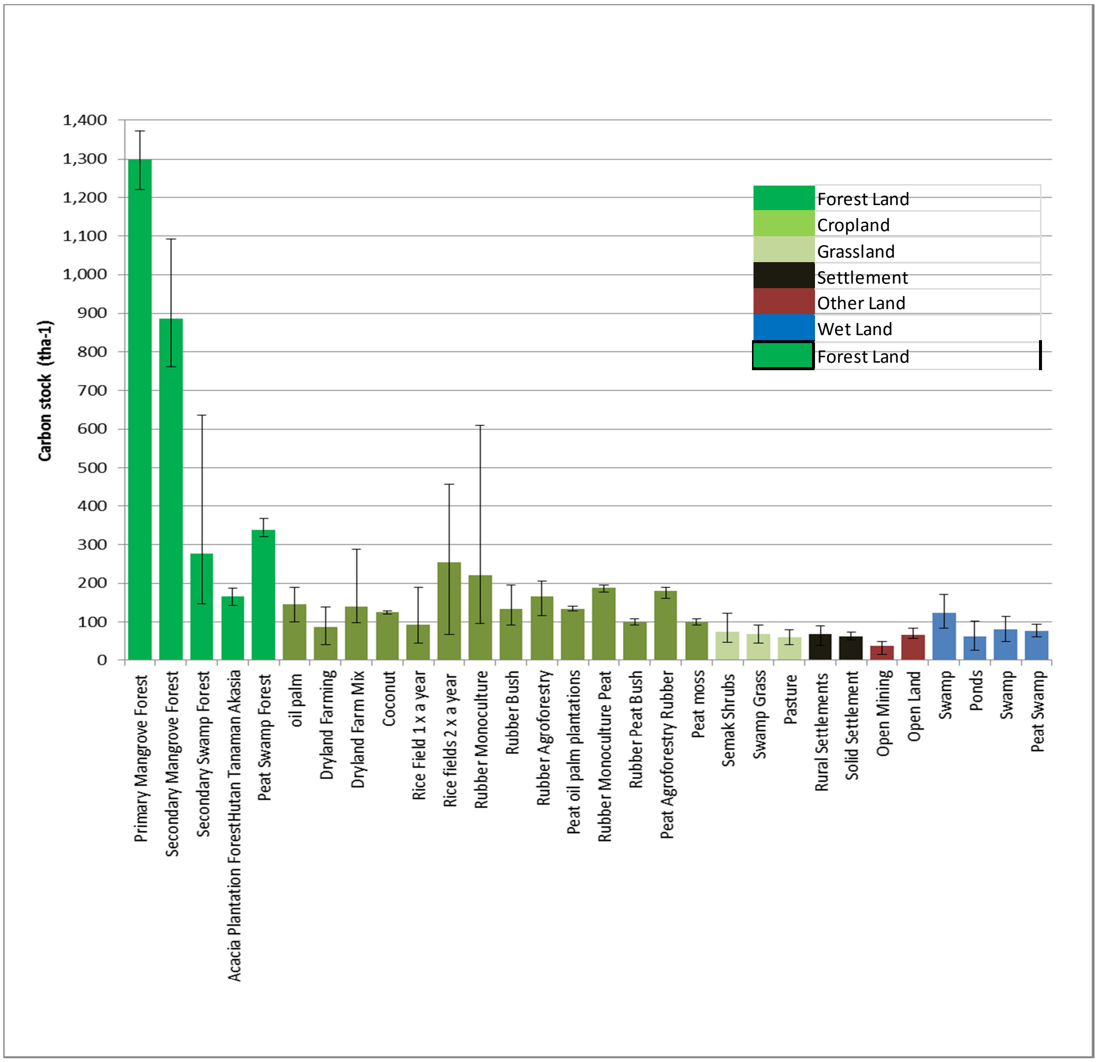
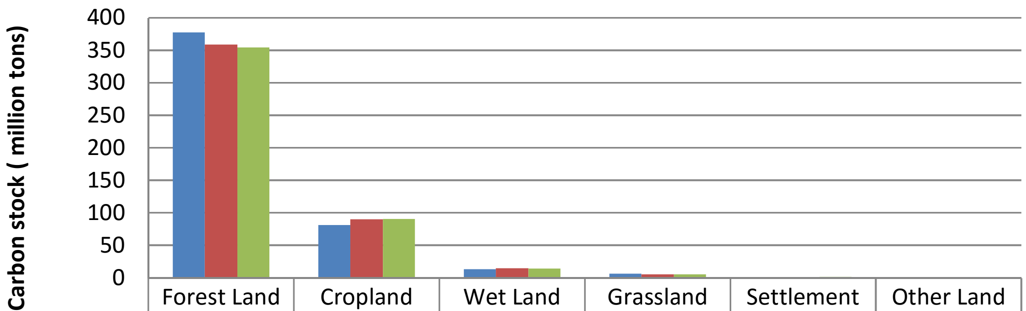


Figure 4 Carbon stocks of each land use and land cover in Banyuasin Regency in 2004, 2009 and 2014



	Forest Land	Cropland	Wet Land	Grassland	Settlement	Other Land
Year 2004	377,526,731	81,216,890	13,204,953	6,286,612	1,347,655	638,450
Year 2009	358,677,859	90,066,314	14,437,730	5,141,433	1,387,207	565,513
Year 2014	354,240,815	90,543,997	14,310,261	5,598,730	1,474,347	565,646

Figure 5. Carbon stocks change in Banyuasin regency in 2004, 2009, and 2014

The soil organic C in the terrestrial system in Banyuasin Regency play a role as the main source of essential nutrients resulting from decomposition process and mineralization of organic matter. The higher decomposition rate of organic matter or the faster the turnover of organic matter impact on the faster nutrients available to the plants. Furthermore, the nutrient availability greatly affects the meet of nutritional needs of plants to grow and develop in producing biomass.

In order to control carbon stocks at the research area on the aspects of land use and land cover changes, the main priority that need special attention is first to minimize land use changes from high carbon stocks to land use and land cover with low carbon stocks such as the conversion of primary mangrove forests into ponds or palm plantations. The second is to control the total area changes. In addition, it is also needed to give special attention to maximize the change in land use and land cover types with low carbon stocks into land use and land cover types with higher carbon stocks. In this study, for example, the conversion from shrub to oil palm plantation and conversion of rainfed rice field cultivated once a year to the rubber plantation.

3.3. Carbon Balance and Emission/Historical Sequestration of CO_2

Figure 6 shows that the carbon balance in Banyuasin regency during the period 2004-2014 moves forward to negative direction, indicate that the amount of carbon loss was greater than the amount of carbon added. The observation of the soil organic C pools showed different results, of which the soil organic C increased from 2004 to 2009, but return to decline from 2009 to 2014. This is might be caused by the biomass inputs into the organic soil is higher than decomposed biomass on land use and land cover in 2004-2009.

The carbon balance shows that the conversion of peatland, palm oil plantation, monoculture and Shrub rubbers are a positive contributor to carbon stocks. Meanwhile, the change in land use and land cover type of primary mangrove forest, secondary mangrove forest, swamp forest and peat shrub is the contributor of the carbon balance to the negative. The cause of shifting the balance toward positive or negative is required for the management plan of subsequent land use and land cover.

During the period 2004-2014, CO_2 emissions have occurred due to land use and land cover changes. However, sequestration has also obtained, although the emissions are far greater than sequestration. This data indicates that land use and land cover changes during that period are dominated by changes in the land-use with high carbon stock than land use with low-carbon type.

CO_2 emissions, in addition, was caused by the carbon pools change of aboveground, necromass, litter, below-ground, it was also caused by the loss and addition of soil organic C pool, that amounted 7,883,048 tons with an average of 788,304 tons per year. The average carbon emission from organic soil C was 0.61 tons $ha^{-1}yr^{-1}$.

The availability of CO_2 and temperature as well as its interactions directly or indirectly affected C cycle in the soil. Increased temperature directly activated the decomposition process, by accelerating enzyme activity and chemical reactions, while increased CO_2 indirectly affected the decomposition rate of organic matter. Jauhiainen and Vasander (2002) reported that on soil without vegetation, CO_2 emissions decreased with increasing soil moisture. This is related to the low activity of aerobic bacteria in producing CO_2 and slow gas diffusion in flooded conditions.

Changes in land use and land cover in the period 2004 - 2014 impacted on carbon stocks of the region and led to emissions and sequestration. The CO_2 sequestration from the atmosphere to the terrestrial region of Banyuasin regency amounted 29,298,966 tons, while emissions reached 118,044,141 tons with net emissions of 88,745,175 tons and annual emission of 8,974,517 tons per year. Based on the average annual emissions, the emissions in Banyuasin Regency were 7 ton $ha^{-1}yr^{-1}$ (Figure 7). The major causes of emissions in the study area were land use change of secondary peat swamp forest, secondary mangrove forests, primary mangrove forests, secondary swamp forests, while dominant sequestration was caused by the changes in land use and land cover of rubber plantation on peat, palm oil plantation, monoculture rubber and shrubland

In 2004-2014, there were considerable CO_2 emissions, however, sequestration of CO_2 was also obtained in a slight amount. CO_2 sequestration occurred through the mechanism of photosynthesis by vegetation which further turned into biomass and O_2. Although the CO_2 sequestration was also obtained in the terrestrial system of Banyuasin Regency the total amount was less than the total amount of CO_2 emitted.

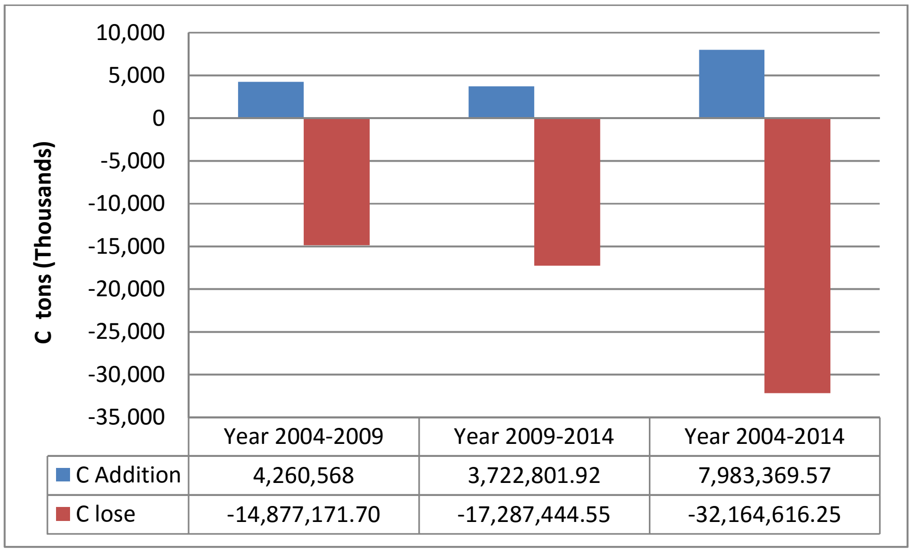


Figure 6 Carbon Balance of Banyuasin Regencyin the period 2004-2009, 2009-2014 and 2004 - 2014

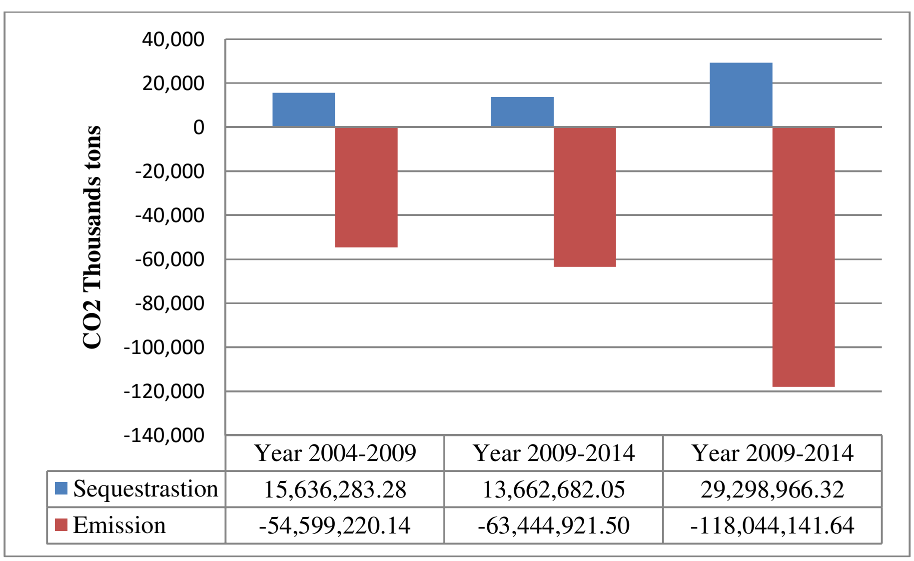


Figure 7 The amount of CO_2 sequestration/emission of Banyuasin Regency in the period 2004-2009, 2009-2014 and 2004 – 2014

4. Conclusion

There are three dynamics of land use and land cover changes in Banyuasin Regency, that are the addition and reduction of the total area, as well as no addition and reduction of the area. Land use and land cover changes are dominated by monoculture rubber plantation, secondary mangrove forest, primary mangrove forest, secondary swamp forest and rainfed rice fields cultivated once a year. The total area of land use and land cover changes in 2004-2009 was 75,819 ha and 32,576 ha in 2009-2014. The carbon stocks changes occur in all pools, namely above ground carbon pools, necromass carbon pools, litter carbon pools, below ground carbon pools and soil organic C pools. The types of land cover with the most dominant carbon stocks are primary mangrove forests, secondary mangrove forests, peat swamp forests, secondary swamp forests and rubber plantation on peat. During 2004-2014 the carbon balance in Banyuasin Regency towards negative direction. The average net CO_2 emissions of above and below grounds carbon pools were 7-tons $ha^{-1}yr^{-1}$, while emissions from organic C soil pools reached 61 tons $ha^{-1}yr^{-1}$.

References

Brown. S. (1997), " Estimating Biomass and Biomass Change of Tripocal Forest". FAO Forestry Papaer 134

Donato, C. D., Kauffman, J., Murdiyarso, B., Kurnianto, S., Stidham, M dan Kanninen, M. (2011), "Mangroves among the most carbon rich forests in the tropics". *Nature Geoscience*. 4: 293—297.

Evans CD, Caporn SJM, Carroll JA, Pilkington MG, Wilson DB, Ray N, Cresswell N.(2006), "Modelling nitrogen saturation and carbon accumulation in heathland soils under elevated nitrogen deposition". *Environmental Pollution.* 143: 468–478.

Feller C, Bernoux M. (2008), "Historical advances in the study of global terrestrial soil organic carbon sequestration". *Waste Manage* 28(4):734–740.

Guo LB, Gifford RM. (2002), "Soil carbon stocks and land use change: ameta analysis". *Global Change Biolog*y. 8: 345–360.

Indonesian National Standard. (2011), "Ground Based Forest Carbon Accounting". Indonesian National Standard Agency. 7724:2011, Jakarta.

IPCC. (2007), "Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assess-ment Report of the Intergovernmental Panel on Climate Change" [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Jauhiainen J, Heikkinen J, Martikainen PJ, Vasander H,(2001), "CO2 and CH4 fluxes in pristine peatswamp forest and peatland converted to agriculture in central Kalimantan, Indonesia", *International Peat Journal* 11: 43-49.

Janzen HH.(2004), "Carbon cycling in earth systems: a soil science perspective". *Agr Ecosyst Environ* 104:399–417.

Jiao JG, Yang LZ, Wu JX, Wang HQ, Li HX, Ellis EC. (2010), "Land use and soil organic carbon in china's village landscapes. *Pedosphere* 20(1): 1–14.

Lal R. (2004), "Soil carbon sequestration impacts on global climate change and food security". *Science* 304:1623–1627

Myrold DD.(1999), "Transformation of Nitrogen. In: Principles and Application of Soil Microbiology". Sylvia,DM; Jeffry,JF; Peter,GH and David AZ (eds.) Prentice hall, New Jersy: 259-294.

Pandey CB, GB, Singh SK, Singh RK. (2010), "Soil nitrogen and microbialbiomass carbon dynamics in native forests and derived agricultural land uses in a humid tropical climate of India". *Plant Soil* 333: 453–467.

Reay DS, Dentener F, Smith P, Grace J, Feely R. (2007), "Global nitrogen deposition and carbon sinks". *Nature Geoscience* 1: 430–437.

Reich PB, Hobbie SE, Lee T, Ellsworth DS, West JB, Tilman D, Knops JMH,Naeem S, Trost J. (2006), "Nitrogen limitation constrains sustainability of ecosystem response to CO_2". *Nature* 440: 922–925.

Sing SK, Pandey CB, Sidhu GS, Sakar D, Sagar R. (2011), "Concentration and stock of carbon in the soils affected by land uses and climates in the western Himalaya, India". *Catena* 87: 78 -89.

Van Noordwijk M, Dewi S, Khasanah N, Ekadinata A, Rahayu S, Caliman JP, Sharma M dan . Suharto R. (2010), Estimating the Carbon Foot print of Biofuel Production from Oil Palm: Methodology and Results from Two Sites in Indonesia. International Conference on Oil Palm and Environment", 23-25 Feb. 2010, Bali, Indonesia.

Wang S, Wilkes A, Zhang Z, ChangX, Lang R. (2011), "Management and land use change effects on soil carbon in northern China's grasslands: a synthesis". *Agriculture, Ecosystems and Environment* 142 ; 329 - 340.

Watson RT, Noble IR, Bolin B, Ravindranmath NH, Verardo DJ, Dokken DJ. (2000), "Use Change, and Forestry". Cambridge Univ. Press,Cambridge, UK.

Wibowo A, Ginoga K, Nurfatriani F, Indartik, Dwiprabowo H, Ekawati S, Krisnawati, H, Siregar A, (2010), "REDD+ & Forest Governance". Center for Socio-Economic Social and Policy Research Campus Research and Development Center for Forestry.