THE MEASUREMENT OF CARBON EMISSIONS : IMPACT OF DEFORESTATION AT DONGGALA REGENCY, CENTRAL SULAWESI PROVINCE, INDONESIA BY USING ECOSYSTEM SERVICE MODELERS

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ABSTRACT: ABSTRACT: Forest is a natural resource that is very important and beneficial for the livelihood either directly or indirectly. Forest have a variety of ecological functions. One of forest functions is to maintain the amount of stored carbon. The forest area changes into non-forest area resulted in reduced forest functions as a provider of environmental services. This study aims : 1) to determine the deforestation during the period of 2000-2011, 2) to Make modelling the landcover change using logistic regression model, 3) to measure carbon emissions and valution base on impact of deforestation. The materials used in this study are : a) Indonesian Topographic Map at Scale 1: 50,000, Geospatial Information Agency (BIG) , b) landcover map (year of 2000 and 2011), scale 1 : 250,000, producted by director general of forestry planning, ministry of environment and forestry, 3) environmental variables (dependent variable) such as : distance from roads, distance from streams, elevation and slope. The spatial analysis which is done by land change modeler modul in Idrisi Terrset. Meanwhile calculations of carbon storage and economic Value which are done by ecosystem service modelers modul in Idrisi Terrset. The results shows that the rate of deforestation during the period of 2000-2011 at Donggala as high as 13,448.07 ha or about 1,222.55 ha per year. The impact of the forest cover changes resulted in the decrease of carbon storage by 3.66 million tons, equivalent to 13.42 million tons of carbon emissions. Economic losses caused carbon emission up to US$ 38,188,465 (net present value, *NPV*) .

1. INTRODUCTION

1.1 Background

Forest is natural resources that are very important and useful for life and living either directly or indirectly. Direct benefits from the existence of the forest are timber, non-timber products and wildlife. While the indirect benefits are environmental services, such as watersheds, aesthetic function, an oxygen supplier and carbon sink.

Forest destruction, climate change and global warming reduce the indirect benefit of forest because forest is the largest carbon sink and play a very important role in global carbon cycle and can hold carbon at least 10 times greater than other vegetations prairie grass, crops and tundra (Adiriono, 2009).

In 2008, the United Nations launched REDD (United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) to provide a mechanism to mitigate climate change by sequestering forest carbon. REDD also promotes the secondary ecosystem service benefits associated with this forest conservation, including protection of biodiversity and water quality (Gibson et al., 2011)

The average annual deforestation in Indonesia for the period 2000-2012 was 671,420 hectares, accounts for 525,516 ha of deforestation in mineral land and 145,904 ha of deforestation in peat land. During this period, 9 percent of deforestation occurred in Sulawesi (Government of Indonesia, 2014). Menawhile, refers to Sumargo, et.al (2011) the rate of deforestation in period 2000-2009 for Sulawesi Island was 1,667,840.59 Ha (15.58 %)

The Central Sulawesi province has forest about 4.2 million ha, so as to have a strategic role in the implementation of REDD +. The deforestation occurred central Sulawesi Province 432,111.50 Ha (10,15 %). Donggala regency is one of regency in central sulawesi province. Meanwhile Turmudi and Nahib (2015), in years 2000 that has forest 401.930 ha. The deforestation the period 2000-2011 was 14.790 ha (12,59 %)

Application of remote sensing and geographical information system was used to estimate land cover changes from multi temporally information. Integration from carbon factor was taken from secondary data (previous studies) and land cover changes data highly expected to give information about carbon stocks changes (Nahib and Widjojo, 2016)

Managing landscapes for carbon storage and sequestration requires information about how much and where carbon is stored, how much carbon is sequestered or lost over time, and how shifts in land use affect the amount of carbon stored and sequestered over time. Valuation is applied to sequestration, not storage, because market prices relate only to carbon sequestration. Discount rates are multipliers that typically reduce the value of carbon sequestration over time (Anonymous, 2016.)

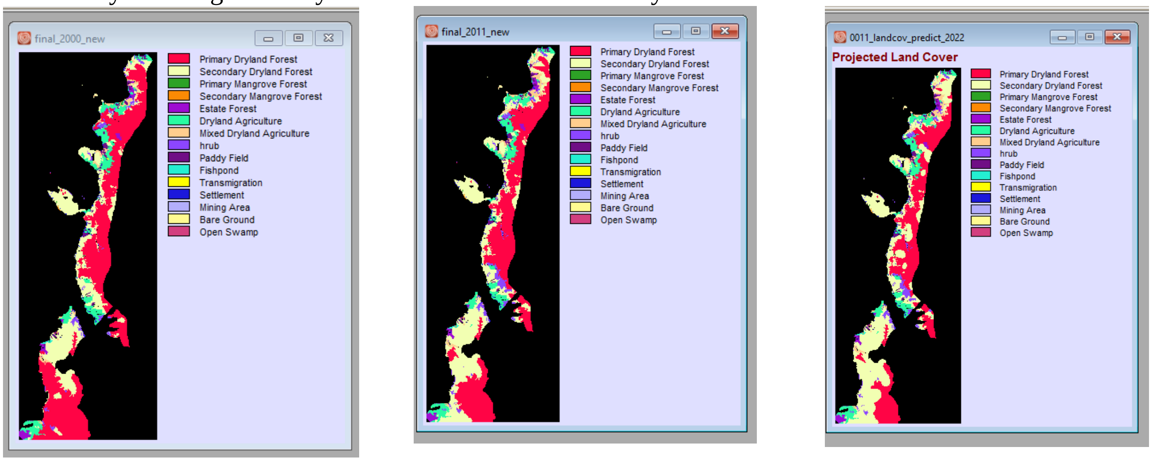
1.2 Objective

The study aimed : 1) to determine the deforestation during the period of 2000- 2011, 2) to make modelling the forest cover change using logistic regression model, 3) to measure carbon emissions and valution base on impact of deforestation.

2. MATERIALS AND METHOD

2.1 Data Used:

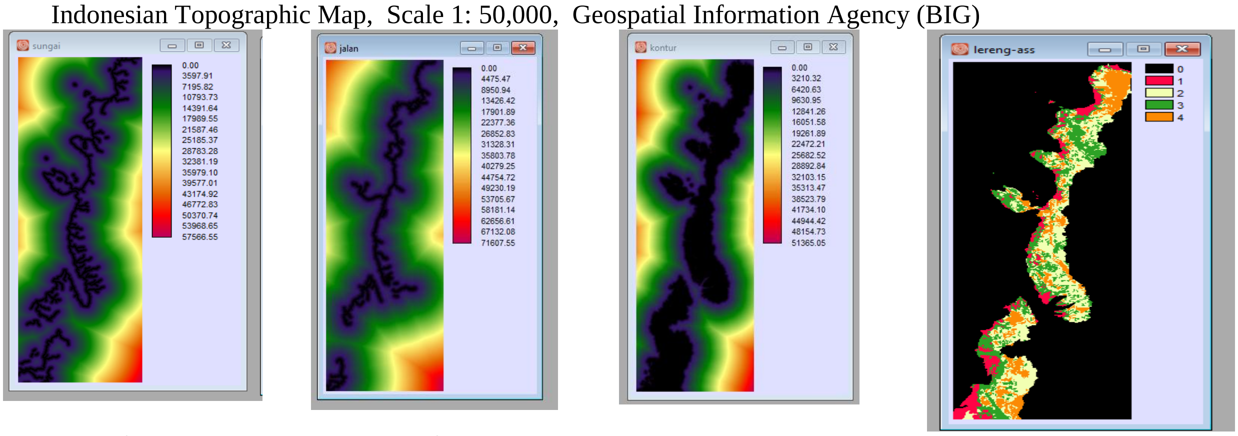
- Indonesian Topographic Map, Scale 1: 50,000, Geospatial Information Agency (BIG)
- Forest Area, Inland Water, Coastal and Marine Ecosystem Map of Dongggala Regency, Scale 1: 250,000 Directorate General of Forestry Planning Ministry of Enviromental and Forestry.
- Land Use Land Cover Map of Donggala Regency, Scale 1: 250,000 (2000 and 2011), Directorate General of Forestry Planning Ministry of Enviromental and Forestry



Landcover 2000 Landcover 2011 Landcover 2022 (Projected)

Figure 1. Donggala's Landcover : a) 2000, B0 2011 c) 2022*

- Enviromental variable (dependent variable) : distance from streams, distance from streams, elevaton and slopes, Indonesian Topographic Map, Scale 1: 50,000, Geospatial Information Agency (BIG)



a. Distance from streams (m) b. Distance from road (m) c. Elevation (meter) d. Slopes(degrees)

Figure 2. Enviromental variable (dependent variable)

- Economic data: carbon price (US$ 15) and discount rates (7 %)
- A table of Land Use Cover (LULC) classes, containing data on carbon stored in each of the four fundamental pools for each LULC class. This study only calculate carbon above (carbon density in above ground mass (Mg/Ha) (**Tabel 1**)

Table 1. Emission Factor for Baplan land cover class in Central Sulawesi

No	Land Cover	C Above
1	Primary dryland forest (PF)	195.4
2	Secondary dryland forest (SF)	169.7
3	Primary mangrove forest(PMF)	170
4	Secondary mangrove forest (SMF)	120
5	Estate crop (EP)	63
6	Pure dry agriculture (AUA)	8
7	Mixed dry agriculture (MxUA)	10
8	Shrub (Sr)	15
9	Paddy Field (Rc)	5
10	Fish pond/aquaculture (Po)	0
11	Transmigration areas (Tr)	10
12	Settlement areas (Se)	1
13	Mining areas (Mn)	0
14	Bare ground (Br)	0
15	Open Swamp (WB)	0

Source : Suryadi, *et. al* . 2012

2.2 Landcover Change Analysis and Prediction Modelling Landcover Change

Analysis landuse/landcover change performed by the method of comparison of landcover map. The determination of land cover area used the spatial analysis which is done by overlaying process of Donggala Regency's landcover map in years 1990, 2000 and 2011. Flowchart stage research activities are presented **Figure 3.**

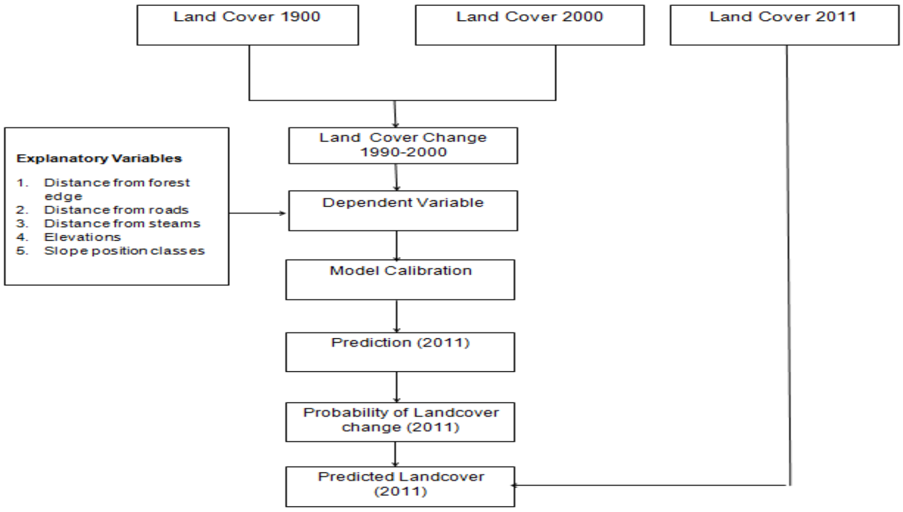


Figure 3. Flowchart Stage Research Activities

Logistic regression model (LRM) was used to model and analyze the lancover change in IDRISI TerrSet. The objective of the present study was to assess the importance of the explanatory variables on landcover change from 1990 to 2000 and predicting the probability of change by 2011. The binary presence or absence is the dependent variable for the periods 1990–2000. The predicted landcover of 2011 was validated using ROC / AUC (Relative Operating Characteristic/Area Under Curve) module of IDRISI TerrSet. The ROC module is comparing a suitability image depicting the likelihood of that class occurring (the input image) and a boolean image showing where that class actually exists (the reference image). The ROC curve is the true positive fraction vs false positive fraction and the AUC is a measure of overall performance (Kumar, et.al. 2014)

2.3 Carbon strorage / Sequestration model and valuation

Calculation of emissions using the stock changes approach (*stock difference*) which was measured at two different time points using two factors, namely: activity data and emission factors. The main data of carbon stocks changes was derived from the data of the land cover change (Nahib and Widjojo, 2016).

Carbon storage / Sequestration model needs the map and data tables, including the economic data. Land use/land cover (LULC) map must be A raster format, with a LULC code for each cell. The dataset should be projected in meters (UTM 50 S). The year (2000, 2011 and 2022) depicted by the LULC map, for use in calculating sequestration and economic values (Anonymous, 2016.).

The carbon prices observed in these instruments vary significantly, from less than US$ 1/tCO2e to $US 130/t CO2e. Majority of emissions (85 percent) are priced at less than US$ 10/t CO2e (Kossoy, et.al, 2016). In this study use assumptions the social cost of carbon (SCC) US$ 15 per metric ton of C and market discount rate (r = 7% per year). The value of carbon sequestration over time for a given parcel x is:

$$value\_seq_x = V \frac{sequest_x}{yr\_fut - yr\_cur} \sum_{t=0}^{yr\_fut - yr\_cur - 1} \frac{1}{\left(1+\frac{r}{100}\right)^t \left(1+\frac{c}{100}\right)^t}$$

3. RESULTS AND DISCUSSION

3.1 Landcover Changes

Landcover change analysis was done for Donggala compared time series data from 2000 until 2011. Table 2 show the changes of land cover Donggala Regency in from 1990 to 2022*.

Table 2. Recapitulation of Donggala Regency's Landcover from 2000, 2011 and 2022 *

No	Type of Landcover	Years 2000		Years 2011		Years 2022 *	
		Ha	Percent	Ha	Percent	Ha	Percent
1	Primary Dryland Forest	259,717.59	54.52	206,347.59	43.31	165,387.60	34.72
2	Secondary Dryland Forest	129,316.23	27.14	169,246.62	35.53	209,263.41	43.93
3	Primary Mangrove Forest	562.5	0.12	506.88	0.11	506.88	0.11
4	Secondary Mangrove Forest	300.15	0.06	347.31	0.07	347.31	0.07
	Sub Total Non Forest	389,896.47	81.84	76,448.40	79.02	75,505.20	78.82
5	Estate Forest	7,704.72	1.62	7,704.72	1.62	7,704.72	1.62
6	Dryland Agriculture	43,060.23	9.04	44,007.12	9.24	44,599.50	9.36
7	Mixed Dryland Agriculture	10,820.07	2.27	15,131.16	3.18	15,131.16	3.18
8	Shrub	11,324.88	2.38	18,744.57	3.93	19,095.39	4.01
9	Paddy Field	7,905.87	1.66	8,666.82	1.82	8,666.82	1.82
10	Fishpond	1,336.95	0.28	1,345.41	0.28	1,345.41	0.28
11	Transmigration	151.11	0.03	151.11	0.03	151.11	0.03
12	Settlement	3,721.50	0.78	3,721.95	0.78	3,721.95	0.78
13	Mining Area	218.52	0.05	218.52	0.05	218.52	0.05
14	Bare Ground	216.72	0.05	216.72	0.05	216.72	0.05
15	Open Swamp	47.79	0.01	47.79	0.01	47.79	0.01
	Sub Total Non Forest	86,508.36	18.16	99,955.89	20.98	100,899.09	21.18
	Total	476,404.83	100	476,404.83	100	476,404.83	100

Source : Result of Analysis of Landcover Map in year 2000, 2011 and 2022* (Projected)

The forest cover area in Donggala in 2011 was 376,448.40 ha or approximately 79.02 % of the total area. It has been decreased by 13,448.07 ha (16.15 %) compared to 2000. The forest degradation was 40.960 ha or 4.096 ha year$^{-1.}$

Primary dryland forest conditions in Donggala Regency in 2000 covered 259,717 ha and in 2011 reduced into 206,347.59 ha. A reduction was 53,370.00 ha or approximately 20.553 % over the 11 years. The average deforestation of primary dryland forest occurred in Donggala was 1.86 % per year or about -4,851.82 ha per year. The reduction was caused by deforestation which has changed primary dryland forest into a secondary dryland forest. The reduction of primary dryland forest caused an additional extensive secondary dry forest directly, because deforestation in Indonesia is the selective cutting of trees which had 50 cm and up diameter of the tress .

In 2000 the secondary dry forest area in Donggala was 129,616.38 ha and in 2011 decreased to 169,593.93 ha. The replenishment of secondary dryland forest area was 39,977.55 ha, or approximately 46.59 % over the 11 years. The increasing average of secondary dryland forest was 4.23 % per year, or about 3,634.32 ha per year. The replenishment of secondry dryland forest was caused by the degradation, which has changed the primary dryland forest into secondary dryland forest. **Tabel 3** shows lancover changes (increasing and decreasing)

Table 3. Landcover changes of Donggala Regency peroid 2000-2011 and 2011-2022*

No	Type of Lancover	2000 -2011		2011- 2022*	
		Ha	Percent	Ha	Percent
1	Primary Dryland Forest	-53,370.00	-20.55	-40,959.99	-19.85
2	Secondary Dryland Forest	39,930.39	30.88	40,016.79	23.64
3	Primary Mangrove Forest	-55.62	-9.89	0.00	0.00
4	Secondary Mangrove Forest	47.16	15.71	0.00	0.00
	Total Forest	-13,448.07	16.15	-943.20	3.79
5	Estate Forest				
6	Dryland Agriculture	0.00	0.00	0.00	0.00
7	Mixed Dryland Agriculture	946.89	2.20	592.38	1.35
8	Shrub	4,311.09	39.84	0.00	0.00
9	Paddy Field	7,419.69	65.52	350.82	1.87
10	Fishpond	760.95	9.63	0.00	0.00
11	Transmigration	8.46	0.63	0.00	0.00
12	Settlement	0.00	0.00	0.00	0.00
13	Mining Area	0.45	0.01	0.00	0.00
14	Bare Ground	0.00	0.00	0.00	0.00
15	Open Swamp	0.00	0.00	0.00	0.00
	Total Non Forest	*13,447.53*	*15.54*	*943.20*	*0.94*

Over the 11 years (2000-2011) the increase of non-forest area was 13,448,07 ha or 15.54 % compared to the condition of the forest cover in 2000. The rate of change was 1,222.50 ha per year or the reduction was 1.41 % per year compared to non-forest areas condition in 2000. The increase of non-forest areas was caused by the activity of forest land conversion into non-forest areas (other uses).

The changes of forest cover was caused by the deforestation, either planned or not. Planned deforestation is usually in the form of changes planned by the government for the benefit of forest land for plantations, agricultural or residential development, which is carried out lawfully in accordance with the legislation. Unplanned deforestation is a deforestation through illegal activities. The forest degradation can be caused by illegal or unauthorized activities, such as harvesting and illegal logging.

3.2 Carbon strorage / Sequestration model and valuation

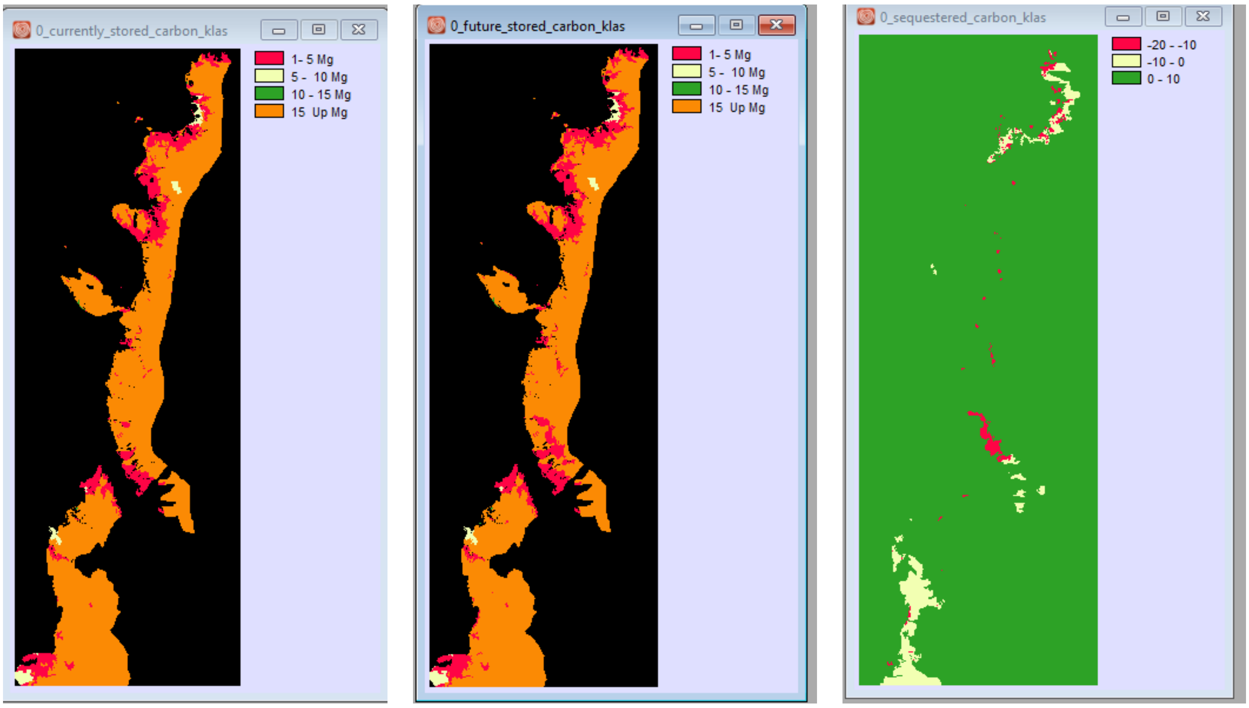
The output from model simulation is raster maps, produced by carbon stroage and sequestration modul are 1) Map of current carbon storage, Map of future carbon storage, Carbon sequestration map, Map of economic value of carbon **(Figure 4**) and 2) a summary of storage and sequestration and net present values of sequestration (**Table 4**).

Total current carbon (year 2000) is 73.980 Mton. Meanwhile in the future, total carbon (year 2011)) is 70.49 million ton. Hence, total sequestered is -3.49 million on. Negative values indicate carbon lost to the atmosphere. Areas with large negative e values will have the largest changes in land cover. In the study, Donggala has been decreased by 13,448.07 ha (16.15 %) compared to 2000. The forest degradation was 40.960 ha or 4.096 ha year$^{-1.}$

By measuring the amount of C storage in the bodies of living plants (biomass) in the landscape, can calculate the amount of CO_2 in the atmosphere is absorbed by plants. Donggala area almost as large an area with carbon strotage content more than 15 up Mg per cell (166,67 Mg per ha).

Table 4. Carbon storage, Sequestration and Net prensent value in Donggala Regency

No	Parameter	Period 2000-2011	Period 2011-2022*
1	Total current carbon (Mg)	73,978,140	70,487,819
2	Total value of currently stored carbon (US $)	110,967,2117	10,57,317,306
3	Total scenario carbon (Mg)	70,487,819	69,285,088
4	Total sequestered carbon (Mg)	-3,490,321	-1,202,732
5	Total value of sequestered carbon (US $)	-38,188,465	-13,159,386



a) Current carbon storage b) future carbon storage c) Carbon sequestration

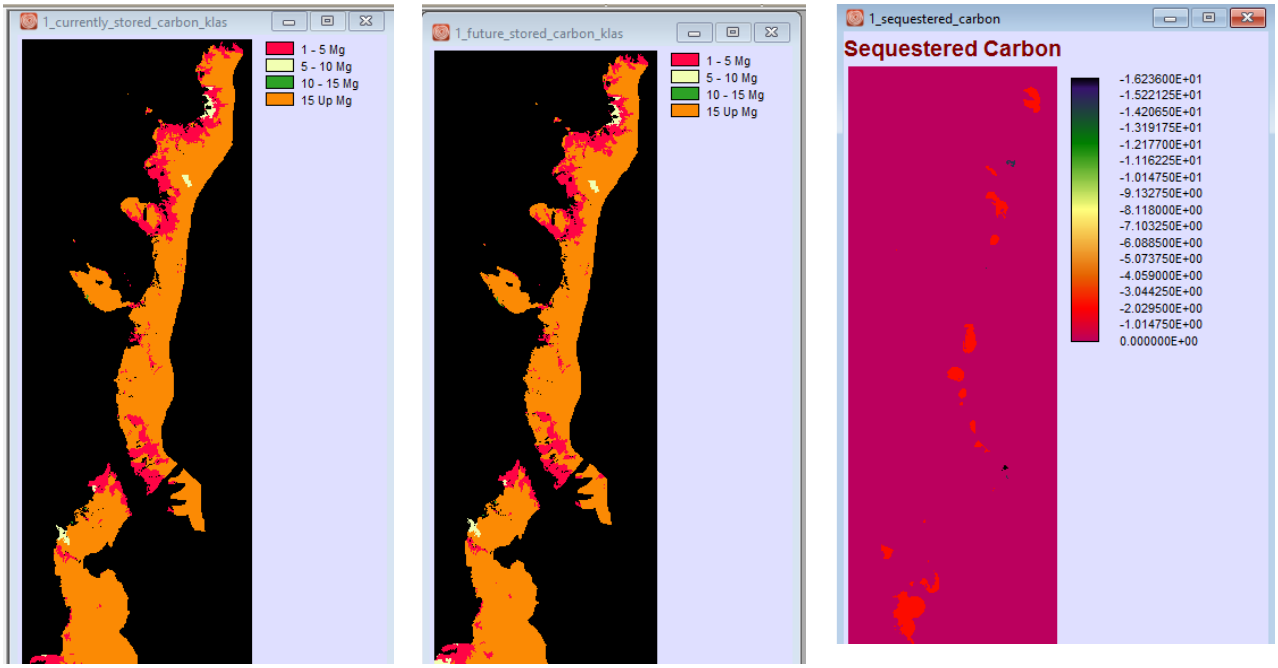
Figure 4. Map representing Carbon strorage and Carbon sequestration in period 2000-2011

The impact of land cover changes caused decreased carbon stocks, especially in the forest area. In 2000 the forest area is 389,896 ha, equivalent to the carbon storage of 72.83 million ton. In 2011, decline in forest area of by 13.448 ha, resulted in a decrease of carbon 3.66 million tons.

The reduction of CO_2 in the air by the plants was called sequestration process (C sequestration). This C sequestration process occurs for the survival of plants which need sunlight, carbon dioxide gas (CO_2) is absorbed from the air and water as well as nutrients absorbed from the soil. Through the photosynthesis process, the CO_2 in the air is absorbed by plants and converted into carbohydrates, afterwards they are distributed throughout the body of the plants and eventually are dumped throughout the plant body. Thus, measuring the amount of C stored in the body of living plants (biomass) in a field can describe the amount of CO_2 in the atmosphere absorbed by plants (Hairiah et al.. 2001).

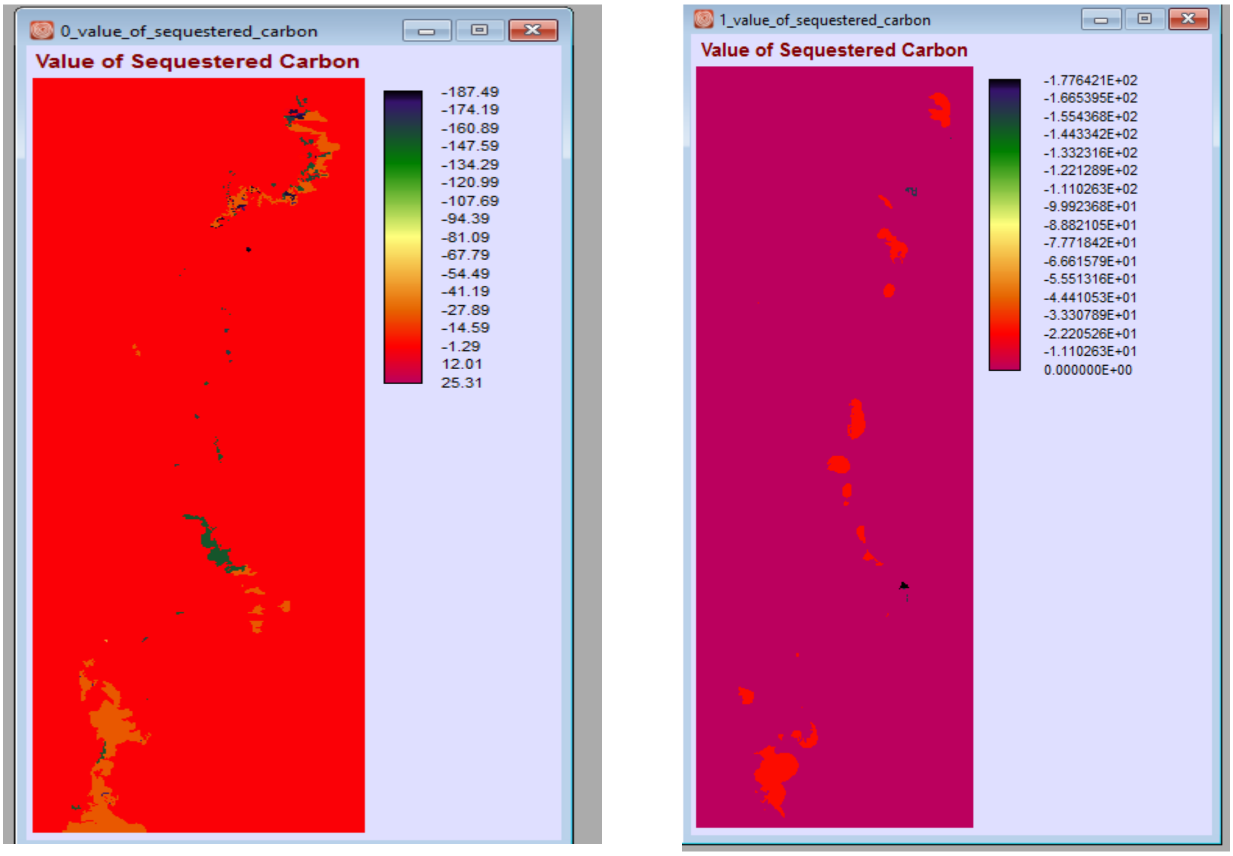
The map of the Net Present Value (NPV), is the economic value of total sequestration in Donggala Regency area. It can be observed from 2000 to 2011 (and 2011 to 2022 *) there was a value of US$ -187.48 to 25. 269 per metric ton per pixel in areas. Meanwhile in period 2011- 2022 * there was a value of US$ 0 to - 177,66.

The output map are the changes in land cover and its effects in sequestration. It is possible to see that the raster has a large variety of classes and that more areas are close to becoming emmiters while others have already made the transition. (Klass, 2008)



a) Current carbon storage b) future carbon storage c) Carbon sequestration

Figure 5. Map representing Carbon strorage and Carbon sequestration in period 2011-2022



a) NPV (2000-2011) NPV (2011-2022*)

Figure 6. Map representing the carbon Net present value of Sequestration (2000-2011) and (2011-2022*)

Base on Table 4, the Net Present Value (NPV) over time of total sequestration (between the current and the future) in Donggala Regency is US$ -38.19 million caused by the carbon emissions, base on prioce of carbon is US$ 15 and discount market is 7 %. Negative values indicate carbon lost to the atmosphere (emissions of CO_2). Costs required to restore the initial conditions , so that the forest come back to normal and can absorb $CO_{2.}$

4. CONCLUSION

The forest cover area in Donggala in 2011 was 376,448.40 ha or approximately 79.02 % of the total area. It has been decreased by 13,448.07 ha (16.15 %) compared to 2000. The forest degradation was 40.960 ha or 4.096 ha $year^{-1}$

Total of carbon storage (only carbon above) throughout the land cover in Donggala Regency in 2011 reached 3.49 million tons C. The carbon storage had been decreased by 317,301.91 ton C or the average was 317,301.91 tons C $year^{-1}$ compared to the carbon storage in 2000.

The impact of land cover changes caused decreased carbon stocks, especially in the forest area. In 2000 the forest area is 389,896 ha, equivalent to the carbon storage of 72.83 million ton. In 2011, decline in forest area of by 13.448 ha, resulted in a decrease of carbon 3.66 million tons.

The net present values of sequestration (between the current and the future) US$ -38.19 million caused by the carbon emissions, based on price of carbon is US$ 15 and discount market is 7 %.

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REFERENCES

Adiriono T . 2009. Method of Measuring Carbon (Carbon Stock) on Industrial Plantation Forest Crassicarpa Acasia Type. Thesis. Faculty of Forestry Programs Graduate. University of Gadjah Mada. Yogyakarta. not published

Anonymous. 2016. Carbon Storage and Sequestration : Climate Regulation. http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/carbonstorage.html

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T. A., Barlow, J., … Sodhi, N. S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. Nature, 478, 378–381. doi:10.1038/nature10425

Government of Indonesia. 2014. National Forest Reference Emission Le,el for Deforestation and Forest Degradation in the Context of the Acti,ities Referred to Decision 1/CP.16. Paragraph 70 (REDD+) Under the UNFCCC. Submission by Indonesia.

Hairiah K.. SM Sitompul. M V,an Noordwijk. C. Palm. 2001. Sampling Method For Carbon Stocks Above and Below Ground. ASB Lecture Note 4B. ICRAF. Bogor. 23 pp.

Kossoy, A., Peszko, G., Oppermann, K., Prytz, N., Klein, N., Blok, K., ... & Borkent, B. 2015. State and trends of carbon pricing 2015 (No. 22630). The World Bank

Kumar, S. Nandy, S., Agarwal,R., Kushwaha, S.P.S.,2014. Forest Cover Dynamics Analysis and Prediction Modeling Using Logistic Regression Model. Ecological Indicators 45 (2014) 444–455

Margono. B. A. et al.. 2014. Primary forest cover loss in Indonesia over 2000- 2012.Nature Climate Change. volume 4. pp. 730-735.

Ministry of Forestry, 2009. Indonesia Forestry Outlook Study. Working Paper No.APFSOS II/WP/2009/13,Bangkok : FAO Regional Office For Asia And The Pacific.

Nahib, I and Widjojo, S. 2016. The Impact of Landcover Changes on Carbon Stock : A Study Case in Central Kalimantan Forest. 36th Asian Conference Onremote Sensing 2015 (Acrs 2015). Fostering Resilient Growth In Asia. Quezon City, Metro Manila Philippine 19-23 October 2015. Volume 1. ISBN: 978-1-5108-1721-0224-232. Page 224-232.

Klass, A. B., & Wilson, E. J. 2008. Climate change and carbon sequestration: Assessing a liability regime for long-term storage of carbon dioxide.

Sumargo W. Nanggara SG. Nainggolan. FA dan Apriani. I. 2011. Potret Keadaan Hutan Indonesia (The state of Indonesia's Forests 2000-2009) 2000-2009. Edisi I. Forest Watch Indonesia 2011

Suryadi, I; Rauf,A; and Maulida, M. 2012. Provisional Reference Emission Level of Central Sulawesi. UN-REDD Indonesia Programme - 2012

Turmudi and Nahib, I. 2015. Potret Hutan Sulawesi Tengah Berdasarkan Data Geospasial. Buku Mosaik Indormasi Geospasial Wilayah Sulawesi Tengah. IPB Press.

United Nations Office for REDD Coordination in Indonesia (UNORCID), 2015. Forest Ecosystem Valuation Study : Indonesia.