Modeling Deforestation and Green Houses Gas Emissions in Morowali Utara District, Central Sulawesi Province, Indonesia

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Abstract. Land use cover conversion from forest to another land was contributing for total green houses gas (GHS) emission, especially from forestry sector. The Central Sulawesi Province has forest area about 4.258 million ha. The deforestation in Central Sulawesi Province for period 2000-2009 reached 432,111.50 Ha (10.15 %). Morowali Utara District is one of district in Central Sulawesi Province, which contribution 15.20 % total deforestation in Central Sulawesi province. This study aims to calculate the rate of deforestation and simulation carbon emission in Morowali Utara District by using REDD+ model. The main data used in this study are land use or cover map (2003, 2009 and 2015), driver variable (distance from: forest edge, roads, streams, and slope) as the explanatory variables of deforestation. The results show that the deforestation on the period 2003-2015 reached 62,017.47 (9.19 %) or the rate of deforestation 5,168.12 ha year⁻¹. Logistic regression model for prediction of deforestation is Y1 = -2.2649 + 0.001126 X1 - 0.000152 X2 - 0.000225 X3 + 0.010704 X4 (ROC = 0.7408), meanwhile the amount of carbon that the REDD project will protect given a departure from the business as usual deforestation scenario up to 18.868 million tCO₂e.

1. Introduction
Tropical deforestation is a major contributor to green house gas emissions in developing countries. Incentive mechanisms, such as reducing emissions from deforestation and forest degradation (REDD+), are currently being considered as a possible emissions reduction and offset solution [1].

Tropical forests and other vegetated landscapes like grasslands and wooded savannahs play a major role in the global carbon sequestration process. Their conservation and protection offers immense potential for reducing greenhouse gas emissions and global warming [2].

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 [3].

Indonesia has the highest deforestation rates in the world, exceeding even Brazil while having only a quarter of Brazil’s forest area [4]. Refer [5] 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 island. The other research, refers to [6] the rate of deforestation Sulawesi Island in period 2000-2009 for was 1.667 million ha (15.58 %). In 2009, forest cover in Sulawesi Island was 9.039 million ha or approximately 46.65 % of the total area. It has been decreased by 1.667 compared to year 2000.

The Central Sulawesi province has forest about 4.258 million ha, so it have a strategic role in the implementation of REDD+. The deforestation occurred central Sulawesi Province in period 2000-2009, reached 432,111.50 ha (10.15 %), so forest cover in 2009 up to 3.826 ha. Morowali Utara District is one of district in Central Sulawesi Province, with contribution of 15.20 % total deforestation in Central Sulawesi Province. The forest cover in Morowali Utara district in 2011 was 632,756.70 ha or approximately 73.84 % of the total area. It has been decreased by 33,013.80 ha (4.96%) compared to 2000. The rate of deforestation in period 2000-2011 adalah 3,001.25 ha year\(^{-1}\).

Refer [7], land use cover conversion from forest to another land was contributing for total GHS emission, especially from forestry sector. In order to implement the REDD model, the constraints and incentives defined to produce the sustainable development scenario were used to create the input spatial data required. This study aims to calculate the rate of deforestation and simulation carbon emission in Morowali Utara District by using REDD+ model. The REDD project location for this study is conservation forest area (assumed) in Morowali Utara District.

2. Materials and method
2.1. Tools and Data
Tools use in this study area ArcGIS 10.2 and Terrset software. Refer [7], Terrset is an integrated geospatial software system for monitoring and modeling the earth system for sustainable development. The TerrSet System incorporates the IDRISI GIS Analysis and IDRISI Image Processing tools along with a constellation of vertical applications.

2.2. Data Used
Data used in this study:
- Indonesian topographic map, Scale 1: 50,000, Geospatial Information Agency
- Land cover map of Morowali Utara District, Scale 1: 250,000 (2003, 2009 and 2015), Directorate General of Forestry Planning - Ministry of Environmental and Forestry (Figure 1)
- Environmental variable (dependent variable): distance from forest edge, distance from roads, distance from stream, and slopes, Indonesian Topographic Map, Scale 1: 50,000, Geospatial Information Agency (Figure 2)
Figure 1. Morowali Utara’s Landcover: a) 2003, b) 2009, c) 2015

Figure 2. Environmental variable (dependent variable)

- The Bio-Carbon Fund Project (BioCF) methodology requires three basic spatial or geographical data inputs, the project area, the leakage area, and the reference area (Figure 3).

Figure 3: Spatial data inputs for REDD project
Refer [7], the project area is the geographic extent of the area under consideration for a REDD project; the leakage area refers to the area around the project area that may experience impacts as a result of the creation of the protected area, and the reference area is the entire area of study encompassing the project and leakage areas.

- Refer [8] in central Sulawesi province, the carbon density for forest area which is 163.5 Mg/ha and non forest area is 16 Mg/ha. In this study, only two carbon pools were counted (ei: above ground: constant, below ground: Cairns),
- Calculated net GHG emission with the anticipated effectiveness assumption of the REDD of the life of project

### 2.3 Land use analysis and prediction model.

Land use maps of 2003, 2009 and 2015 were produced from the LANDSAT images. It consists of five land cover categories namely: dry forest, wet forest, estate crop, agricultural, non forest, and water bodies. Land use change analysis done by Land change modeler module in TerrSet software. Land change modeler is one of many tools which concern for environmental spatial analyst. We can predict future land cover based on actual and previous land cover, the model also consider some driver variable such as road, river, settlement (distance), elevation, slopes, etc.

We was conducted the study in the area by cross tabulating the derived land cover map of 2003 as the early input image and the 2015 land cover map as land cover the later input image. Refer [7, 9], flowchart of the general procedure used in forest cover change modelling were shown in Figure 4.

Potential transition modeling was used to group land use transitions into a set of sub-models and then utilized to explore the potential power of the chosen explanatory variables. In the current study, the change analysis showed that there is only one set of transition, from forest to non forest category.

The explanatory variables chosen for this study are distance from existing forest edge, distance from road, distance from streams, and slope. In order to predict change, the transition was empirically modelled using multi-layer perception (MLP) neural network and logistic regression.

Logistic regression model (LRM) was used to model and analyze the landcover change in IDRISI TerrSet. The binary presence or absence is the dependent variable for the periods 2003–2009. The predicted landcover of 2015 was validated using ROC / AUC (Relative Operating Characteristic/Area Under Curve) module of IDRISI TerrSet.

The ROC module compares a suitability image by depicting the likelihood of that class occurrence (the input image) and a boolean image showing where that class actually exists (the reference image). Refer [7, 11] the ROC module compares suitability image by depicting the likelihood of that class occurrence (the input image) and a boolean image showing where that class actually exists (the reference image). The ROC curve is the true vs false positive fraction and the AUC is a measurement of overall performance.
2.4 Calculating gas emission

Greenhouse gas emission reductions were calculated by taking the estimated carbon loss without a REDD project intervention and subtracting the estimated carbon that would be saved through a REDD project intervention, along with the estimated carbon loss through leakage. The difference is called additionality, as the net of GHG emissions that are reduced as a result of the REDD project [8]. Refer [2, 7] stage for calculating gas emission:

- The REDD model utilizes a methodology for calculating and evaluating net anthropogenic greenhouse gas (GHG) emission reductions due to the implementation of a REDD project refer to World Bank’s Bio-Carbon Fund Project (BioCF) Methodology for Estimation.
- The REDD projects are modelled based on a 30 year projection with intermittent assessments every 5 years, that 6 prediction maps will be produced over the 30 year prediction between 2015 and 2045. The carbon reporting is done based on these intervals.
- Reductions in GHG emissions are calculated by subtracting the estimated carbon that would be saved through REDD project intervention, along with the estimated carbon loss through leakage from the estimated carbon loss (in this case through land use and cover change) without the implementation of a REDD project intervention.
- The formula employed in the calculation is stated by:

\[ C - \text{REDD} = (C - \text{Baseline}) - (C - \text{Actual}) - (C - \text{Leakage}) \]  

Where,

- C-Baseline = Baseline greenhouse gas emissions within the project area; tCO2e
- C-Actual = Actual greenhouse gas emissions within the project area; tCO2e
- C-Leakage = Leakage greenhouse gas emissions; tCO2e

Figure 4. Flowchart of the general procedure used in forest cover change modelling (Source: Refer [9])
C-REDD = Net anthropogenic greenhouse gas emission reduction attributable to the REDD project activity; tCO2e

In this study, the conservation forest area is assumed to be a REDD project area, as wide as 205,151.49 ha.

3. Results and discussion
3.1 Landcover Change
Landcover change analysis was done for Morowali Utara district data time series comparison data from 2003 until 2015. Table 1, Table 2, and Figure 5 show the land cover and its changes of Morowali Utara District.

| No | Landcover    | 2003          | 2009          | 2015          |
|----|--------------|---------------|---------------|---------------|
|    |              | Ha            | Percent       | Ha            | Percent       | Ha            | Percent       |
| 1  | Dry Forest   | 664,482.24    | 75.97         | 638,846.01    | 73.04         | 603,161.37    | 68.96         |
| 2  | Wet Forest   | 10,007.73     | 1.14          | 10,063.80     | 1.15          | 9,311.13      | 1.06          |
|    | Total Forest | 674,489.97    | 77.11         | 648,909.81    | 74.17         | 612,472.50    | 69.71         |
| 3  | Estate Crops | 13,783.68     | 1.58          | 5,553.27      | 0.63          | 22,454.91     | 2.57          |
| 4  | Agricultural | 100,859.85    | 11.53         | 101,665.62    | 11.62         | 100,966.41    | 11.54         |
| 5  | Non Forest   | 81,210.06     | 9.28          | 114,214.86    | 13.06         | 134,449.74    | 15.37         |
| 6  | Water Body   | 4,321.08      | 0.49          | 4,321.08      | 0.49          | 4,321.08      | 0.49          |
|    | Total        | 874,664.64    | 100.00        | 874,664.64    | 100           | 874,664.64    | 100.00        |

The forest cover area in Morowali Utara district in 2015 was 612,472.50 ha or approximately 69.71 % of the total area. It decreased by 62,017.74 ha (9.19%) compared to 2003. The rate of deforestation 5,168.14 ha year⁻¹. The rate of deforestation in this area is lower than deforestation in central sulawesi province. this condition is in accordance with Tumudi’s research. Refer [10] Central Sulawesi province has forest area of 4.477 ha (year 2000) and 4.360 ha (year 2011). The rate of deforestation of Central Sulawesi Province in the period 2000-2011 amounted to 117,430 ha or 10.675 ha per year. The largest deforestation occurred in the Tojo Una-Una District up to 29,170 ha (25.01%) and the second, Morowali with 17. 850 ha. This condition shows deforestation in Morowali Utara district contributes for about 15.20% of all deforestation in Central Sulawesi Province.

Dryland forest conditions in Morowali Utara District in 2003 covered 664,482.24 ha and reduced into 603,161.37 ha in 2015. The reduction of 61,320.87 ha or approximately 9.22 % over the 12 years. The average deforestation of dryland forest occurred in Morowali utara was 0.76 % per year or about 5,110.07 ha per year. This reduction was caused by deforestation which has changed dryland forest into a non forest.

In 2003, wet forest area in Moroowali Utra District was 10,007.73 ha and decreased to 9,311.13 ha in 2015. The reduction of wet forest area was 696.60 ha, or approximately 6.96 % over the 12 years. The average decrease of wet forest was 0.58 % per year, or about 58.05 ha per year. This reduction of wet forest was caused by the deforestation, which has changed the wet forest into non forest. Mostly occur in mangrove forests, converted into ponds.
Figure 5. Morowali Utara District Landcover Map of years 2003, 2009 and 2015

Table 2. Morowali Utara district land cover change from 2003 to 2015

| No | Land Cover    | 2003 – 2009 | 2009 – 2015 | 2003 – 2015 |
|----|---------------|-------------|-------------|-------------|
|    | Hectare       | Percent     | Hectare     | Percent     | Hectare     | Percent   |
| 1  | Forest        | 25,580.16   | 3.79        | 36,437.31   | 5.62        | 62,017.47 | 9.19      |
| 2  | Non Forest    | -25,762.14  | -13.15      | -36,437.31  | -16.44      | -62,017.47| -31.66     |
| 3  | Water bodies  | 0.00        | 0.00        | 0.00        | 0.00        | 0.00      | 0.00      |

Source: Result of Analysis of Landcover Map from 2003 to 2015

Over 62,017.47 ha were lost between 2003 and 2015 inside the study area (25,590.16 ha between 2003-2009 and 36,437.31 ha between 2009-2015). This roughly corresponds to 9.19% of the forest area that existed in the year 2003 (674,489.97 ha). Annual deforestation occurred at the rate of 0.76% between 2003-2015. Between 2003 and 2009 the deforestation gross rate was 0.63%, whereas between 2009-2015 reaching 0.93.

Over the 12 years (2003-2015) the increase of non-forest area was 65,984.67 ha or 33.69%. The cause of deforestation is mining activity. Starting in 2009, there is a significant addition of mining company area. Up to 2016, in Morowali Utara district there are as many as 51 nickel mining companies, 29 of the company has production license and just 22 company has exploration license. Mining activities with open pit systems making forest cover changes into non-forest areas. Besides that also in Morowali Utara district there are about 30 plantation companies. Plantation activity also causes the change of
forest to non-forest (plantation) cover compared to the condition of the land cover in 2003. The rate of change was 5,498.72 ha per year or the reduction was 2.81% per year compared to non-forest areas condition in 2003. The increase of non-forest areas was caused by the activity of forest land conversion into non-forest areas (other uses).

Meanwhile, there were no change on the water bodies. The water bodies category recorded neither increase nor decrease. Refer [12] conveys that no changes in the body of water in certain period of time indicate that the changes of land cover are mostly oriented on agriculture and new settlements.

Meanwhile [13] declare that the changes of forest cover were 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 Greenhouse Gas Emission

Based on the results of the land use change analysis for the period between 2003 and 2009, the evaluation of the 4 explanatory variables in the transition potential sub-model and the transition potential surface that was subsequently created, the model was calibrated and employed to predict and simulate deforestation an 6-year period from 2009 until the year 2015. The model for predicting the forest cover change,

\[ Y_1 = -2.2649 + 0.001126 \times X_1 - 0.000152 \times X_2 - 0.000225 \times X_3 + 0.010704 \times X_4 \]  

Table 3. Statistic of logistic regression

| Statistic of logistic regression | Based on forest changes 2003-2015 |
|---------------------------------|-----------------------------------|
| Number of total observations    | 715,440                           |
| -2logL0                         | 230,240.0843                      |
| -2log(likelihood)               | 08,156.8311                      |
| Goodness of fit                 | 632,710.3433                      |
| Pseudo R²                       | 0.5946                            |
| Chi-square (df=5)               | 22,083.2531                       |
| AUC                             | 0.7408                            |
|                                  | 0.7516                            |

The validation of the model was undertaken by computing the ROC statistic using a map of actual change between 2003 and 2009 as the reference image and the simulated land cover map of 2015 as the input image. The ROC statistic was obtained at 0.7408, a reasonably strong value that is good enough to make the results of the simulation acceptable. Pseudo R2 value greater (0.5946 and 0.3750) than 0.2 indicates that the model is a relatively good fit for the data. The simulated map is shown in figure 6. The result of that simulation shows that the forest category further decreased from 674,489.97 ha (77.11%) to 612,472.50 Ha (69.71) invariably reducing the size of the non forest category by the same measure. The rate of deforestation 5,168.12 ha year⁻¹. This is the future business as usual scenario (figure 6). Deforestation has been observed mainly along the main road, in mining areas and close to previously deforested areas. The result of that simulation shows that the forest category further
decreased from 674,489.97 ha (77.11 %) to 612,472.50 Ha (69.71) invariably reducing the size of the non forest category by the same measure.

Figure 6: Simulated map and Transition potential Deforested of 2015

Figure 7. Future BAU and Suitable Deforestation

The result of REDD modeling that the scenario of future sustainable development with the protection of conservation forest area in Morowali Utara District as wide as 205,151.49 ha. For the next 30 years, the cumulative carbon is 18,868,706.00 tCO2e will be saved or prevented from being released into the atmosphere as the consequences of reduction conversion of forest cover categories to Non-Forest categories until 2045. While continuing usual business scenarios without REDD project intervention, only 26,533,552.00 tCO2e will be saved by 2045. Detail of deforestation and carbon emissions estimates base on time series presented in Table 4 and Figure 8.

Table 4. Ex ante net anthropogenic carbon emission reduction (million t CO2E)

| Project | Years | Year | Carbon Baseline | Carbon Actual | Carbon Leakage | Carbon REDD |
|---------|-------|------|----------------|---------------|----------------|-------------|
| 1       | 2016  | -    | 0.906          | -             | 0.308          | -           | 0.181 | - | 0.417 |
| 6       | 2021  | -    | 5.349          | -             | 1.704          | -           | 1.070 | - | 2.575 |
| 11      | 2026  | -    | 9.485          | -             | 2.445          | -           | 1.810 | - | 5.230 |
| 16      | 2031  | -    | 13.828         | -             | 2.879          | -           | 2.245 | - | 8.704 |
| 21      | 2036  | -    | 18.256         | -             | 3.322          | -           | 2.687 | - | 12.247 |
| 26      | 2041  | -    | 22.894         | -             | 3.786          | -           | 3.151 | - | 15.957 |
| Project Years | Carbon Baseline | Carbon Actual | Carbon Leakage | Carbon REDD |
|---------------|-----------------|---------------|----------------|-------------|
| 30            | 2045            | -26.534       | -4.150         | -3.515      |
|               |                 | -18.869       |                |             |

**Figure 8.** Deforestation and Net Emission at REDD Project, Morawali Utara District

### 4. Conclusion

Results show that the deforestation on the period 2003-2015 reached 62,017.47 (9.19%) or the rate of deforestation 5,168.12 ha year⁻¹. The logistic model regression for prediction of deforestation is \( Y_1 = -2.2649 + 0.001126X_1 - 0.000152X_2 - 0.000225X_3 + 0.010704X_4 \) (ROC = 0.7408), while the amount of carbon that the REDD project will protect from the business as usual deforestation scenario up to 18.868 million tCO₂e.

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Acknowledgements
This paper is the development of the activities of "Data and Spatial Information Collection for Natural Resources of Central Sulawesi Province", which is the cooperation of Development Planning Board of Central Sulawesi Province with Geospatial Information Agency. We are grateful to Head of Centers for Research, Promotion and Cooperation, Geospatial Information Agency (BIG) for the data and laboratory facilities, and to Head of the Regional Development Planning Board of Central Sulawesi Province, which has financed part of its funding activities.