Carbon stock projection in North Sumatera using multi objective land allocation approach

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Abstract. Nowadays, GHG emission is a critical issue for environmental management due to the large scale of land cover change, especially forest cover. This study provides a protection development strategy for North Sumatera as one way to manage the area. By using Multi Objective Land Allocation (MOLA), we evaluated two GHG emission scenarios, including a Business As Usual (BAU) scenario and Protection scenario. The result shows that the province will lose the carbon stock up to 24 million tons in the year of 2035 by using a BAU scenario. On the other hand, by implementing the Protection scenario, total carbon stock that is lost in the same period is about 5 millions tons solely. It proves that protection scenario is a good scenario and effective to reduce the carbon loss. Furthermore, this scenario can be an alternative for North Sumatera spatial plan.

1. Introduction

GHG emission issue comes up from environmental destruction impact. It raised year by year mostly caused by deforestation. Therefore, Indonesian Government has a commitment to reduce the emission as much as 26% by 2020 from its own efforts, and 41% from international funding. It was stated by Susilo Bambang Yudhoyono, President of the Republic of Indonesia at that time, in G-20, the international forum for the governments and central bank governors with 20 countries member, in 2009 in Pittsburgh, United States. To support the statement of President, the local government need to ensure that the development on their area will not create a huge impact on the GHG emission. One way to handle this problem is to conduct a study of Strategic Environmental Assessment (SEA).

Strategic Environmental Assessment (SEA) is a series of analysis that are systematic, comprehensive, and participative to ensure that the principles of sustainable development have become the basis and integrated in the development planning within the region. It is expected to reach the prosperity through sustainable development. Moreover, the SEA is mandatory for each region stated in Government Regulation Number 46 Year 2016 about Organizing Procedures of Strategic Environmental Assessment.

The study of carbon stock, which is related to GHG emissions, is part of SEA for North Sumatera Province. It is needed in defining the “alternative” spatial plan for the province. The aim of the study is to calculate the carbon stock in year 2035 that could be “other option” for the spatial land allocation with the highest consideration on the regulation applied in Indonesia and also the sustainability of the landscape in the North Sumatera Province. Moreover, MOLA (Multi Objective Land Allocation) is one approach to process the analysis of carbon stock.
In addition, two selected scenarios will be applied in MOLA process. These two scenarios are Protection scenario and a BAU scenario. The selection between Protection scenario and BAU scenario in order to evaluate GHG emission has different opportunities in analyzing the impact of each scenario. Although, the Protection scenario reduces the possibility of developing land-based economic activity areas compared to BAU scenario, it is projected to be able to reduce the significant carbon loss with increasing protected areas. The objectives of this study is to calculate the carbon stock in year 2035 as the projection by using MOLA approach. Carbon stock projection is needed as part of the SEA and as the alternative of spatial plan in North Sumatera Province. The analysis consists of definition of Protected Area, definition of Cultivation Area, combination of both using MOLA process, and carbon stock calculation.

2. Methods
The Impact analysis is conducted by comparing two scenarios; these are Business as Usual (BAU) Scenario and MOLA Scenario, hereinafter namely Protection Scenario. On BAU scenario, it is assumed that all forested areas fall under Non-Forest Use (Area Penggunaan Lain/ APL) and Convertible Production Forest Area (Hutan Produksi Konversi/HPK) are will be converted to open land in 2035 as a projection. APL and HPK areas used in this scenario are obtained from SK579/Menhut-II/2014 on North Sumatera Forest Area. Next, Protection Scenario follows the same rules as BAU scenario that all forested areas under APL and HPK will be converted to open land area. However, in this scenario, HPK areas are obtained from the MOLA analysis (see Figure 1).

![Figure 1 The comparison of BAU scenario and Protection scenario](image)

MOLA (Multi Objective Land Allocation) is an approach that can be used to solve calculation between different uses or transitions to allocate the estimated changes in the simulation step [1]. MOLA could be a solution to the land use conflict of interest. It can allocate a land to a several land use by considering the land suitability, weight priority, and land use space [2]. This analysis has been used in several studies in the world, such as by Eastman JR et al. (1997) [3] and Hajehforooshnia S et al. (2011) [4]. There are several steps to analyze the MOLA, including defining the protected area and cultivation area, selecting the main law and regulation, and overlaying the processed data with land cover. Moreover, the results was calculated by emission factor to find the carbon stock in North Sumatera.

Land cover that is used in this analyses uses data from Ministry of Environmental and Forestry in the year of 2000, 2006, and 2013. It will be a base map of scenario to reflect the future spatial planning.

2.1. Defining the protected area and cultivation area
Based on Government of Indonesia Act Number 26 Year 2007 regarding Spatial Planning, it is divided into protected area and cultivation area. To define them, there are law and regulation for each parameter to be used. It is presented in Figure 2. Figure 2 also presents the hierarchy of law and regulation used for MOLA selection.
**Protected Area Allocation**

1. Conservation Area (KepPres No. 32/1990)
2. Protected Forest (KepPres No. 32/1990; KepMenHut No. 837/KPTS/UM/11/1980)
3. Local protected area (UU No. 27/2004; Perpu PU No. 63/1993; and KepPres No. 32/1990)
4. Lowland protected area (UU Kehutanan No. 41/1999; PP No. 71/2014; and KepPres No. 32/1990)
5. Prone to Natural Disaster Area (KepPres No. 32/1990)

**Cultivation Area Allocation**

1. Forestry (KepMenHut No. 837/KPTS/UM/11/1980: for Limited Production Forest (HPT); Production Forest (HP); and Convertible Production Forest (HPK))
2. Non Forest Use (APL):
   a. Farming (Priority in spatial plan, UU No. 18/2004; UU No. 12/1992; PerMen PU No. 41/PRT/M/2007)
   b. Settlement (UU No. 4/1992; PerMen Pu No. 41/PRT/M/2007)
   c. Industry (UU No. 5/1984);

**Figure 2** Regulation for defining protected area and cultivation area

Protected area is the area that has been set to protect the environment. In Minister of Public Work Decree Number 15 Year 2009 about Guidance of Province Spatial Planning Arrangement, the protected area are divided into 7 categories including protected forest, lowland protection, local protected area, conservation area, high risk to disaster area, geology protected area, and other protected areas. Nevertheless, this study defines 5 categories only as presented Figure 3. For protected forest, lowland protection, and local protected area, there are some parameters that should be used; while conservation area and high risk to disaster area use the existing data. The data of Conservation area are taken from Ministry of Environmental & Forestry (MOEF) and high risk to disaster area’s data are taken from Regional Disaster Management Agency (BPBD).

**Figure 3** Work flow for protected area land allocation
Cultivation area is divided into forestry area, farming area, mining area, fisheries area, industry area, tourism area, settlement area, and other cultivation areas. For this study, 5 categories are defined as mentioned in Figure 4.

After protected area and cultivation area are defined, the data needs to be overlay by land cover in the year of 2000, 2006, and 2013. All forest areas which are selected into BAU Scenario and Protection Scenario will be converted to open land, as predicted in 2035.

2.2. Calculating the carbon stocks
The land cover needs to be calculated with emission factor mentioned in Table 1 to find carbon stocks in North Sumatera Province.

| No | Land Cover                  | Emission Factor | No | Land Cover                  | Emission Factor |
|----|-----------------------------|-----------------|----|-----------------------------|-----------------|
| 1  | Primary Dryland Forest      | 195             | 11 | Open Land                  | 2.5             |
| 2  | Secondary Dryland Forest    | 169             | 12 | Dryland Agriculture        | 10              |
| 3  | Primary Mangrove Forest     | 170             | 13 | Mixed Dryland Agriculture  | 30              |
| 4  | Secondary Mangrove Forest   | 120             | 14 | Mining                     | 0               |
| 5  | Primary Swamp Forest        | 196             | 15 | Plantation                 | 63              |
| 6  | Secondary Swamp Forest      | 155             | 16 | Swamp                      | 0               |
| 7  | Plantation Forest           | 64              | 17 | Savanna                    | 4               |
| 8  | Shrub                       | 30              | 18 | Paddy Field                | 2               |
| 9  | Swamp Shrub                 | 30              | 19 | Fish Pond                  | 0               |
| 10 | Settlement                  | 4               | 20 | Transmigration             | 10              |

3. Results and Discussion
Forest conversion analysis was done based on the assumption that all the forested area under APL and HPK will be cleared. For BAU scenario, APL and HPK area are derived from SK 579/Menhut-II/2014 and the projection year for this analysis is 2035, which is the end period of the Provincial Spatial Plan implementation. The projection of land cover changes for the 2013 to 2035 based on BAU and Protection Scenario are provided in Figure 4.
3.1. **BAU Scenario and Protection Scenario**

BAU Scenario uses SK 579 that is an existing projection data for North Sumatera Spatial Plan year 2035. The result is shown in Table 2. Based on SK 579, protected area is about 1.7 million hectares. The largest land allocation for protected area is for protected forest. Besides that, cultivation area is about 5.5 million hectares. Plantation is allocated as the largest area for cultivation; that is about 2 million hectares, followed by plantation forest (accumulative number of HPT, HP, and HPK) about 1 million hectares.

| Spatial Plan | Land Allocation                       | Area (Ha) |
|--------------|---------------------------------------|-----------|
| Protected Area (SK579) | Protected Forest (HL) | 1,206,881 |
|              | Natural Reserve Forest (KSA/KPA)     | 427,009   |
| Cultivation Area (SK579 and North Sumatera Spatial Plan) | Plantation Forest Area | Limited Production Forest (HPT) | 641,770 |
|              |                                      | Production Forest (HP) | 704,452 |
|              |                                      | Convertible Production Forest (HPK) | 75,684 |
|              | Plantation                           | 2,071,767 |
|              | Settlement                            | 209,335   |
|              | Wetland Agriculture                   | 558,634   |
|              | Dryland Agriculture                   | 1,188,551 |

The result of Protection Scenario is presented in Table 3. It has been found, first of all, by dividing into protected area and cultivation area. The largest land allocation for protected area is lowland protection area which is 1.2 million hectares. The total of protected area is 2.9 million hectares. The difference with BAU scenario is about 1.5 million hectare. As a consequence, the total of cultivation area is only 4.2 million hectares, where the largest land allocation is still for plantation and followed by plantation forest (accumulative number of HP, HPT, HPK).

| Spatial Plan | Land Allocation                       | Area (Ha) |
|--------------|---------------------------------------|-----------|
| Protected Area | Local Protected Area                  | 675,820   |
|              | Lowland Protection Area                | 1,214,392 |
|              | Prone to Natural Disaster Area        | 69,813    |
|              | Conservation Area                     | 427,009   |
|              | Protected Forest                      | 528,759   |
| Cultivation Area | Plantation Forest Area                | Limited Production Forest (HPT) | 785,062 |
|              |                                      | Production Forest (HP) | 345,039 |
|              |                                      | Convertible Production Forest (HPK) | 32,684 |
|              | Agriculture Area                      | 1,002,702 |
|              | Industrial Area                       | 298       |
|              | Plantation                            | 2,013,881 |
|              | Settlement Area                       | 155,102   |
|              | Tourism Area                          | 5         |
The land allocation of protected area and cultivation area is calculated with land cover in 2000, 2006, and 2013, afterwards. The result is shown in Figure 5. Converted area is only for forest area which are located in HPK and other use (APL). The others will be considered not having a land cover change. Based on Figure 5, the graph illustrates that class of forest cover in 2000 to 2013 decreased, Secondary dryland forest and secondary swamp forest are the largest area converted to others class.

In the year of 2035, by using BAU scenario, the conversion from forest area to other use (APL) is larger than that by using Protection scenario. As shown in Figure 5, Protection scenario can reduce the loss of forest. In secondary dryland forest in 2035, it is predicted that the forest loss is only 20 hectare while by BAU scenario its loss becomes nearly 100 thousand hectare.

Figure 5 Forest Cover in 2000-2035 (predicted)

Figure 6 illustrates the comparison map of BAU scenario and Protection scenario. The figure shows the largest conversion is located in South West and West of North Sumatera Province. The secondary swamp forest is still exist in South West of province, based on Protection Scenario map, and it has been converted into open land in BAU Scenario map.
3.2. Carbon Stock
Carbon stock calculation is defined based on the land cover data as “activity layers” and coefficient carbon. Aligned with changes in land cover, carbon stock dynamics also follow the same trends. Historical land cover data were obtained from MoEF year 2000, 2006 and 2013 and projected land cover data were obtained from the land conversion analysis result as explained in the methodology. The result of the carbon stock calculation for BAU scenario and Protection Scenario is shown in Figure 7. Nonetheless, the scenarios is only converted the forested area to open land, so others class will be considered to have the same carbon stock between 2015 and 2035.

Based on Figure 7, previous data from year 2000 to 2013 shows that the average decrease of the carbon stock is about 3.5 million ton/year. The largest decrease occurred during the period of 2006 to 2013 when this province experienced a decrease in carbon stock up to 33 million tons. By using BAU scenario, in the projection year, carbon stock will decrease up to 24 million tons. The average of carbon loss is 1 million ton/year from year 2013 to 2035.
Furthermore, Figure 7 also shows the carbon stock using protection scenario. In this scenario, the projection year will have carbon stock for about 277 million tons. It only lost 5 million tons of carbon stock than BAU scenario. The average of losing carbon stock is about 235 thousand tons/year. It proves that protection scenario is effective to reduce the carbon loss.

4. Conclusion and Recommendation
The objectives of this study is to calculate the carbon stock in year 2035 as the projection by using MOLA approach. The result of this study shows that the province will lose the carbon stock up to 1.1 million ton/year from year 2013 to 2035 by using BAU scenario. On the other hand, by implementing the Protection scenario, total carbon stock that is lost at the same period is about 5 million tons. It shows that Protection scenario could effectively prevent the carbon loss rather than BAU scenario which is a current spatial plan in North Sumatera. The Protection Scenario is a good scenario that can be an alternative for North Sumatera spatial plan.

Nevertheless, this study is only a preliminary study. There are many factors that might influence the carbon loss such as economical factor that are not mentioned in this study. Moreover, this study also weighing based on law besides many software, such as Terrset, that can automatically weighing based on priorities in the province. Therefore, the further study is needed in order to prove this argumentation.

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