Towards low carbon development strategies from forestry sector in West Papua

by Syafrudin Raharjo

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Abstract. The forestry sector plays an important role in mitigating and adapting to climate change. In the NDC Indonesia Report (2021), forestry and other land use (FOLU) sectors contribute emission based on BAU projected 2030 of 714 Mt CO_2e and emission reduction for both unconditional (Counter Measure, CM1) of 17.2% and conditional (CM2) of 24.5%. FOLU emissions correlated with changes in the primary forest to secondary (degradation) and primary/secondary forest to other uses for agriculture, transmigration, plantations and others (deforestation). Due to climate change, the conditions of degradation and deforestation can bring disaster, especially triggered by hydrometeorological hazards that have catastrophic impacts such as floods, flash floods, droughts, erosion, and abrasion due to changes in land cover. Therefore, low carbon development strategies from the forestry sector are needed to reduce climate-related disasters in West Papua.

1. Introduction

Located in the heart of the Coral Triangle, the Bird's Head Seascape (BHS) of West Papua includes more than 22.5 million hectares of sea and more than 4,000 small islands with endemic birds, mammals, insects and plants as global centers of diverse tropical marine life located on the Sahul shelf. Seascapes imply a diversity of habitats, including 1711 reef fish, 600+ coral species, 17 dolphin and whale species, whale sharks, and critical habitats for globally endangered marine species, such as turtles and cetaceans [1,2,3,4,5]. Besides that, the Papua (West Papua and Papua) and Papua New Guinea regions are included in the third tropical rain forest in the world after Brazil and the Congo, which have high biodiversity both in the highlands, medium, low to coastal areas (mangrove forests) both mineral soils and peat [6,7,8]. Besides mega-biodiversity, the strength side (S) of the SWOT analysis, it was also found that West Papua already has several important documents, including the Regional Action Plan (RAP) for Reducing Greenhouse Gas (GHGs) Emissions of West Papua Province 2017-2021, Environmental Strategic Environmental Studies (SES) Medium-Term Development Plan (MTDP) West Papua Province 2017-2022, SES of Zoning Plan for Coastal Areas and Small Islands (ZPCASI) West Papua Province, Local Regulation of ZPCASI, Disaster Management Plan (DMP) of West Papua Province, and Regional Regulations for the Implementation of Disaster Management in West Papua Province [9,10,11,12,13,14].

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However, in the management of natural resources, several problems become the weak side (W), namely the not yet optimal level of welfare of the local community (Papuan Indigenous People, PIP), which is reflected in the low Human Development Index (HDI) which occupies the lowest 2nd rank at the national level (65.09%) after Papua Province (60.44%). HDI is also influenced by the fact that West Papua Province is the 34th youngest province which is still in the development stage so that it focuses on economic development, which has implications for decreasing the carrying capacity and carrying capacity of its environment. Furthermore, it is affected by environmental damage and increased greenhouse gas emissions (GHG) from agriculture, forestry, industry, energy and transportation, and waste [9,15].

The main problem of GHG emissions from the land-based sector included the forestry sector comes from the conversion of forest land into other uses known as degradation, which change of primary forest to secondary forest. Meanwhile, deforestation is changing of forest to non-forest such as agricultural areas, plantations, regional expansion, mining, settlements in the form of land clearing, and no biomass left at all (clear-cutting) [16,17].

Besides internal factors (strengths and weaknesses), external factors from opportunity factors (O) to maintain environmental sustainability are also available in West Papua Province including the Manokwari Declaration (International Conference on Biodiversity, Ecotourism, and Creative Economy, 2018) regarding Sustainable Development Based on Customary Areas in Papua with several important points related to maintaining 70% of the forest area and protecting and strengthening the role of indigenous peoples as stated in the Specified Local Regulation; MoU between Bappenas and the Provincial Government of West Papua (18 June 2018) regarding Low Carbon Development Planning in West Papua Province; and internationally, Indonesia has also ratified the Paris Agreement related to the Nationally Determined Contribution (NDC) of National Emission Reduction and adaptation to climate change impacts, Sustainable Development Goals (SDGs), and the Sendai Framework which is also applied at the sub-national level by making Regional Action Plans [18,19,20,21].

Other external factors from threat factors found in West Papua Province are natural and non-natural disasters, which are categorized as a high-risk class with a value of 144.05 consisting of threats of earthquakes, tsunamis, floods, landslides, droughts, extreme weather, forest and land fires and extreme waves/abrasion [22]. In addition, the impact of climate change triggers hydrometeorological disasters (42%, 2010-2019) that occur on large islands, coasts, and small islands. In general, this hydrometeorological disaster is triggered by an increase in rainfall that is higher or lower than normal. If the rainfall is higher, then floods, landslides and flash floods are caused by changes in forest and land use in the upstream part of the watershed. Meanwhile, low rainfall impacts the ease of fuel in forests and land experiencing fires due to the effects of drought. West Papua region is directly opposite the Pacific Ocean, tropical storms are often passed by the tails of tropical storms, which along with climate change experience an increase in both frequency and intensity. So that it impacts strong winds and heavy rain on the northern coast of West Papua, which is also followed by high waves and strong currents and affects the fisheries sector and abrasion on the coast [23,24,25].

By taking into account the negative factors of the internal and external SWOT analysis, the Low Carbon Development Indonesia (LCDI) in West Papua is needed for sustainable development by paying attention to mega-biodiversity, green economy and increasing the welfare level of indigenous Papuans. The LCDI also assists West Papua in fulfilling the commitments in the Regional Action Plan for emission reductions at the sub-national level and at the same time fulfilling Indonesia's NDC commitments in the ratification of the Paris Agreement.

2. Methods

2.1. Study area

The research was conducted in West Papua Province, which is geographically located between 4° 30' S - 1° 30' N and 128° 50' - 135° 20' E with elevation ranging from 0 – 2.955 m asl. The average annual rainfall for the period 2002-2020 is approximately 3450 mm, with a range of 400-6500 mm. While the average temperature per year during the period is 30.5°C with a range of values from 29.0-32.0°C and the average humidity per year during the period is 81.3%, with a range of values from 75.0% - 87.5% [26]. In general, the physiography of the West Papua Province consists of coastal areas and coastal areas islands, lowlands and swamps, highlands and mountains, and basins and attenuation. The Bird's Head region is massive rugged mountains in the southeast consisting of metamorphic and granitic rocks. In the south and west, which gradually decreases in height, it consists of highlands limestone, alluvial plains, and swamps. This lowland is divided in two by the bay which stretches in an East-West direction and is flanked by swamps and plains of recent (recent) and tertiary alluvium material called Teluk Bintuni (resembling a mouth bird) [27].

Geographically, the boundaries of West Papua Province (Figure 1) are as follows:

• the Northern area: Pacific Ocean
•the Southern area: Banda Sea (Maluku Province)
• the Eastern area: Papua Province
• the Western area: Seram Sea (Maluku Province)

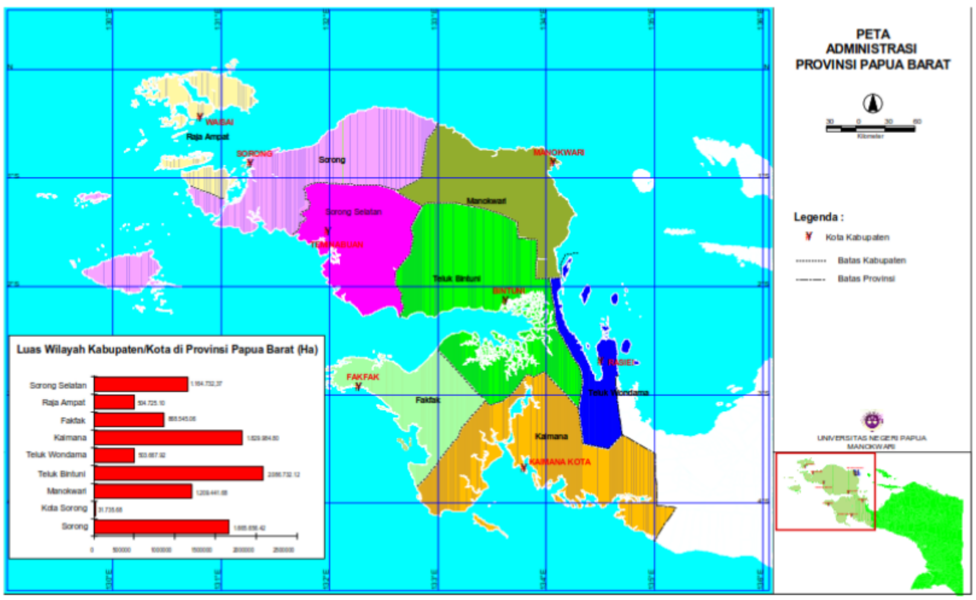

Figure 1. West Papua Province map

2.2. GHGs Emission from Forestry Sector

Emissions from the forestry sector of West Papua in the period 2009-2011, there was a significant change in emissions compared to the period of 2002-2003. Most of the emission sources in the period of 2002-2003 came from the conversion of primary dryland forest to secondary dryland forest/logged over (97.28%). The condition of these changes is much different from the 2009-2011 period, where the emission sources come from several types of changes (Table 1) [19].

Table 1. Emissions from the forestry sector in West Papua Province for the period 2009-2011

LU_CODE	LU-CHG	EM (CO_2.eq)	PERCENTAGE
PSFTSSwF	Primary swamp forest to Secondary swamp forest	468,901.220	27.97
PDFTS/LDF	Primary dryland forest to Secondary/logged dryland forest	421,634.556	25.15
PDFTOL	Primary dryland forest to Open land	315,200.005	18.8
PDFTSh	Primary dryland forest to Shrub	129,233.031	7.71
PDFTSw	Primary dryland forest to Swamp	128,414.621	7.66
S/LDFTOL	Secondary/logged dryland forest to Open land	112,032.475	6.68
PMFTSMF	Primary mangrove forest to Secondary mangrove forest	79,619.622	4.75
S/LDFTB	Secondary/logged dryland forest to Bush	21,216.710	1.27

2.3. Method of data analysis

2.3.1. Concept Development
The preparation of LCDI of West Papua uses the development of a system dynamics model which is a simulation model approach to test, predict, optimize, and analyse policies in the context of sustainable natural resource management. The main data used in the LCDI of West Papua is figured out in Table 2.

Table 2. The main variables of the West Papua LCDI model of forestry

No	Variable	Value	Unit	Estimation Method
1	Availability of forest land	8,411,561 (2010)	Ha	MoEF (2011)
2	Non-forest	945,798 (2010)	Ha	MoEF (2011)
3	Forest Emission	1,018,005 (2010)	tCO_2e	Emission Data x Emission Factor (IPCC, 2006)
4	Total Goss Regional Domestic Product (GRDP)	41,361.7 (2010)	Billion Rp	BPS Papua Barat (2011)
5	Forestry GRDP	1,362.1	Billion Rp	BPS Papua Barat (2011)

2.3.2. Modelling
System dynamics is a complex system, has dynamic and non-linear behaviour, and has feedback, or a closed system (feedback closed system) that focuses on structure and behaviour with interacting feedback. The development of the system dynamics model consists of 2 important stages, namely (1) the conceptualization stage (from story to structure), which produces a Causal Loop Diagram (CLD) and (2) the complexity stage (from structure to behaviour) by building a Stock Flow Diagram (SFD) based on the principle of structural consistency, which is then stimulated to imitate the performance and behaviour of the system being modelled. Furthermore, the formulation of the model is done by testing the consistency of the model is by the objectives or by the behaviour of the real world. After the model is built, then verification is carried out. Next, the system dynamics model is simulated and the results are validated to ensure that the model can represent the actual system (real world) [28].

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2.3.3. Simulation and validation of the model

At this stage, the Causal Loop Diagram (CLD) and Stock Flow Diagram (SFD) with Powersim 10 Software are used. CLD consists of causal relationships of variables described in positive and negative relationships. While SFD represents the types of variables in the form of stock (level) & flow (rate). SFD is a more detailed description and pays attention to the effect of time on the relationship between variables so that later each variable can show the accumulated results for a variable level, and the variable which is the level of system activity for each period.

Furthermore, a mathematical model is needed to verify whether conceptual errors in computer programs and implementation do not occur after the inclusion of the formulation model on the variables in the stock flow chart. After verification, validation is carried out to ensure that the behavioural output of the model is accurate and by expectations and realities in the field. The AME (Absolute Mean Error) equation used to validate the model can be seen below:

$$AME = (Si - Ai) / Ai \times 100\% \quad (1)$$

where AME is the absolute mean error, A is the actual value, and S is the simulated value.
The limit of the AME value based on the uncontrolled variable in this study was 30% [29].

3. Results and discussion

3.1. CLD Model from Forestry Sector

The CLD results from the Forestry and Peatlands sub-sector can be seen in Figure 2. The figure shows a causal relationship from one variable to another. Each arrow indicates the effect of one variable on the other because it has a positive (+) or negative (-) loop. Loop + shows that the relationship between these variables is directly proportional. If there is an increase in the value of the variable, it will cause an increase in the value of the variable it affects. On the other hand, a negative loop shows an inversely proportional relationship (not in the same direction). If there is an increase in the value of the variable, it will cause a decrease in the value of the variable it affects.

The number of people or population is correlated with the increase in non-forest areas (deforestation). Likewise, the addition of non-forest areas has implications for the increasing population. So, the relationship between these two variables is called loop reinforcing (positive feedback, R1). Non-forest variables affect the decrease in the availability of forest land. However, on the other hand, the availability of forest land also has an increasing impact on non-forest areas. Thus, this variable relationship is known as loop balancing (negative feedback, B1). Furthermore, the availability of forest land increases the availability of surface water and in turn has a positive impact on the population. The relationship of these variables is included in the balancing loop (negative feedback, B2). Then, the availability of forest land affects the reduction in the rate of forest emissions and the rate of forest emissions contributes to an increase in total emissions, which will hurt the population. So that the variable has a loop balancing relationship (negative feedback, B3).

There are several policy interventions in reducing GHG emissions from the forestry and peatland sub-sectors by increasing forest availability, namely through a forest moratorium, a policy of 70% forest area, afforestation, and forest rehabilitation.

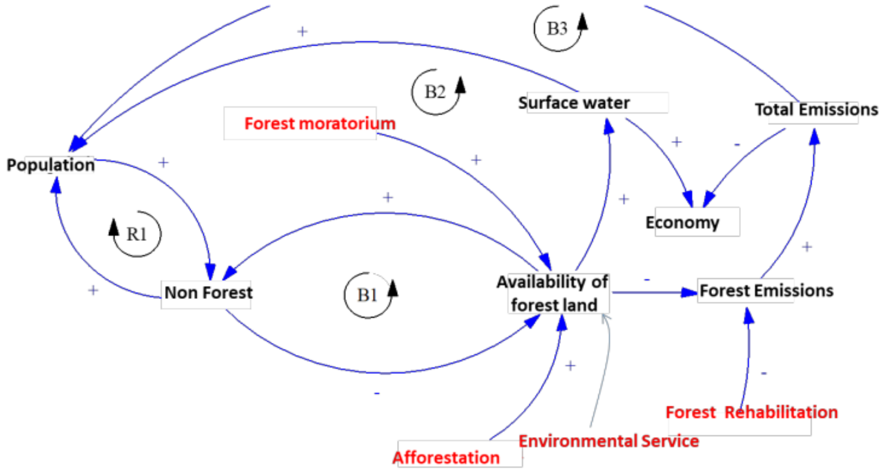

Figure 2. CLD from the forestry sector

3.2. Validation Model

Forest history data for 2010-2020 was used to validate the model (11 years). Validation was carried out for the mineral forest of West Papua in the forest sub-model. The forest area of West Papua fluctuates every year. The years 2010-2017 decreased from year to year (overtime) and subsequently increased and decreased (oscillations), which continued to increase again and tended to slope.

Calculating the error rate from the average value (Ei) obtained a validation value of 0.02%. The validation value means that the system dynamics model built can represent the actual change in forest area over time because the error percentage value is <5% (Figure 3). The model is started with a deviation limit that is still acceptable in the range of 5-10% [29].

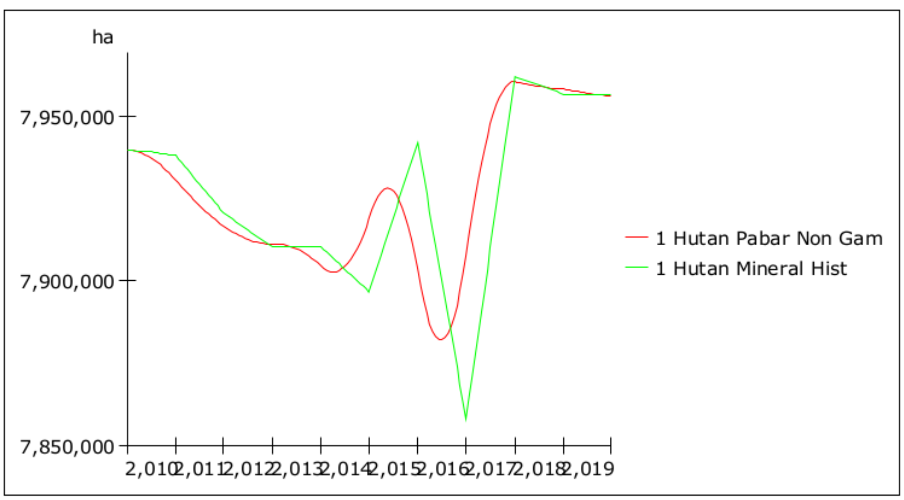

Figure 3. Comparison of historical forest data (green) versus simulated (red)

3.3. LCDI Forestry Scenario of West Papua

There are two scenarios developed in the LCDI of the forestry sector in West Papua, a fair scenario (for a 29% emission reduction) and an ambitious scenario (for a 41% emission reduction) with policy interventions as shown in Table 3.

Table 3. Forestry LCDI scenarios

Policies		Fair Scenario			Ambitious Scenario		
	Baseline	**2030**	**2045**	**2060**	**2030**	**2045**	**2060**
Minimum forest cover area maintained in total forest area (ha)	0	7,850,000	7,850,000	7,850,000	7,900,000	7,900,000	7,900,000
Area of forest and land rehabilitation (ha)	0	100,000	150,000	250,000	150,000	250,000	400,000
Area of additional forest cover (ha)	0	0	0	0	0	0	0

The simulation results show that the policies carried out with a fair scenario impact reducing emissions in 2060 and West Papua becoming a net sink emission reaching an accumulation of 200,000 tons of CO_2 (Figure 4). Likewise, the policies implemented for scenario ambitions have the effect of reducing emissions in 2060 and net sink emissions with a total accumulation of 400,000 tons of CO_2 (Figure 5).

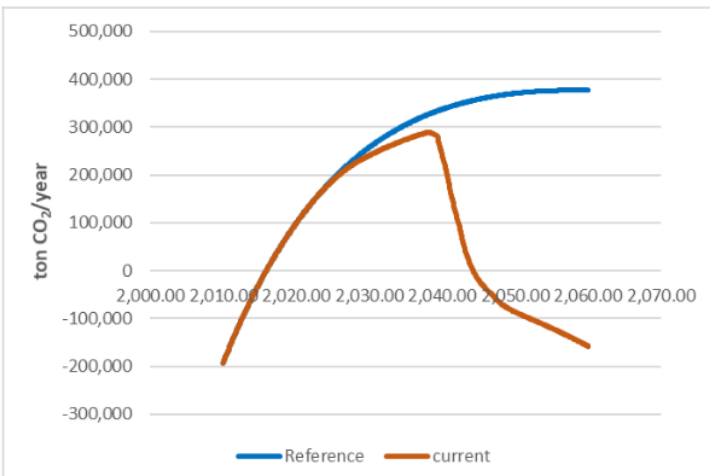

Figure 4. Net sink emission for fair scenario

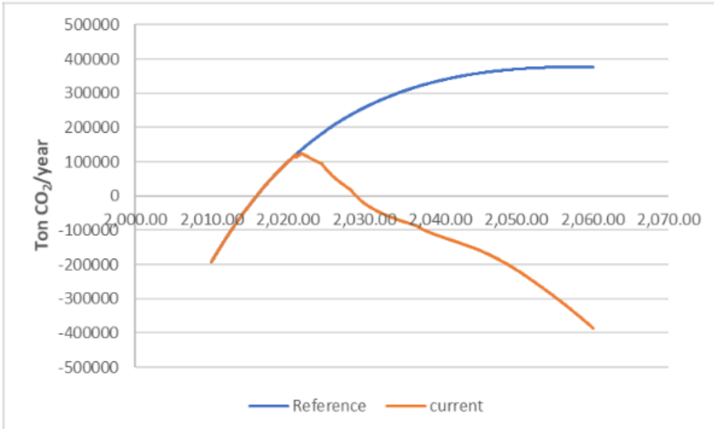

Figure 5. Net sink emission for ambitious scenario

The total GRDP issued for the fair scenario requires a 2.8% increase in the budget for a 29% emission reduction. Meanwhile, the ambitious scenario requires an increase in Total GDRP by 5.6% for a 41% emission reduction.

4. Conclusion

The net sink emission is the LCDI target and Long-Term Strategies for Low Carbon and Climate Resilience (LTS – LCCR) 2060 in West Papua. The calculation of the fair scenario (29% reduction emissions) and ambitious scenarios (41% emission reductions) show values of 200,000 and 400,000 tonnes CO_2, respectively. However, achieving this requires an additional 2.8% Total GRDP for the fair scenario and 5.6% for the ambitious scenario. Thus, the government can take steps to develop work programs related to LCDI in West Papua Province to reduce emissions and at the same time build community resilience to disasters.

Acknowledgements

The author gives the highest appreciation to the LCDI Team from WRI Indonesia, who has assisted in facilitating the preparation of the LCDI document in West Papua Province.

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