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Systems Dynamics Approach to Reducing Carbon Emissions from Deforestation and Forest Degradation at Provincial Level

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Abstract: Forest and land use change contribute 18% of greenhouse gas emissions, which cause global warming. The Conference of Parties (COP) 16 in Mexico increased political commitment to reduce emissions from deforestation and degradation and to enhance carbon stock (REDD+). We believe this support will continue at COP 18 in Doha, Qatar. However, various actors including local communities may or may not support REDD+ depending on, among others, their perceived impacts. To explore this situation, we have developed a systems dynamics model This model comprises sectors of landscape, population, local livelihoods, environmental services and government incomes. The model simulates landscape and carbon dynamics and their impacts. We compare "business as usual" with various REDD+ scenarios. The simulation results are examined by criteria of effectiveness in carbon emission reduction, cost efficiency, equity among involved stakeholders and co-benefit of other activities. This study took Jambi Province of Indonesia as a case study. We found REDD+ to be effective in reducing carbon emissions; forest concessions are the most efficient places for running REDD+ projects and mining the most inefficient.

***Keywords**:* REDD+, systems dynamics, actor, forest, landscape

1 INTRODUCTION

The efforts put into reducing deforestation and forest degradation have gained momentum as global interest in combating climate change increases. The science of climate change is clear, and the impacts are real. Reducing Emissions from Deforestation and Degradation plus (REDD+) as a way to combat deforestation and forest degradation through carbon funding and market schemes has been discussed at global arena, e.g., COP 16, 17 and will be at the coming COP 18. REDD+ aims to reduce emissions, better manage forests and give more value added for conserving and enhancing carbon stock.

REDD+ has become a common debate in the policy arena at national and local levels. This includes local communities because, for many, forests are a vital source of local livelihoods (Purnomo *et al.* 2012a). It is expected that all stakeholders will make a concerted effort to develop plans and actions to reduce carbon emissions below business as usual (BAU).

1. The momentum for the policy has come mainly from developed countries. However, interest in REDD+ is spreading fast across the globe. REDD+ was born out of a number of UNFCCC meetings attended by UN members. REDD+ is voluntary and will adopt a market mechanism to ensure the opportunity costs of reducing carbon emissions are compensated. Carbon emitters located in or outside forest areas will contribute to the costs and receive benefits from REDD+.

This paper describes a systems dynamics model of REDD+ at the landscape level. We used Jambi Province of Indonesia as a case study. Jambi has been identified as a priority province for the implementation of REDD+ in Indonesia. The model simulates landscape and carbon dynamics and its impact. We compare "business as usual" (BAU) scenarios with various REDD+ scenarios. The simulation results are examined by criteria of effectiveness in reducing carbon emissions, cost efficiency and equity among stakeholders (Angelsen 2008).

2 CONTEXT AND METHODS

2.1 Context

Jambi Province of Indonesia was formed in 1958 based on Law no. 61 covering an area of 53,436 km² of which 51,000 km^2 is land and 426 km^2 is sea. It is located on the east coast of the Island of Sumatra facing Southern China and the Pacific Ocean(see Figure 1). The total population in 2008 was 2,788,269 with an annual growth rate of 1.68%.

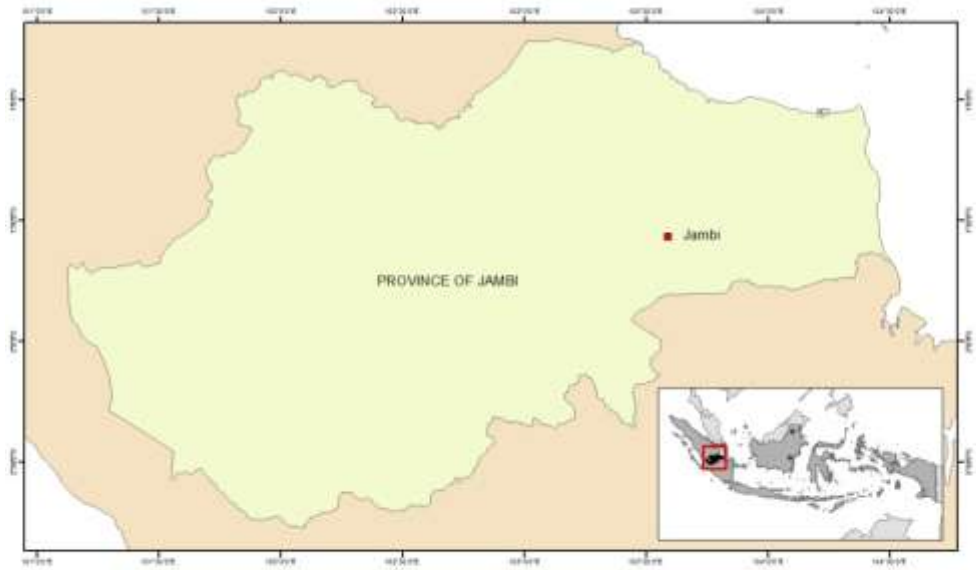


Figure 1. An overview map of Jambi

The government of Indonesia, under National Appropriate Mitigation Actions (NAMAs), is committed to reducing carbon emissions by 26% (0.767 Gt) below BAU by 2020 without international assistance and 41% (1.189 Gt) with financial assistance from donor countries from the projected 2.95 Gt to avoid 2^oC temperature increase. The forestry sector

is charged with managing more than half (14%) of these emission reductions. The provincial government of Jambi has developed Local Appropriate Mitigation Actions (LAMAs) and plans to reduce carbon emissions by 70 Mt by 2020. Fire prevention will contribute 26 Mt (37%) to the reduction of CO_2, sustainable forest management 22 Mt (32%), peat management 10 Mt (14%), and various other actions 12 Mt (17%).

2.2 Method

The system is modeled with the systems dynamics method (Forrester 1961; Sterman, 2000). The methods comprise: (a) development of a conceptual model; (b) specification and execution of the model using STELLA; (c) evaluation of the model; and (d) use of the model (Grant et al., 1997). The model was implemented with STELLA 9.0, which uses stocks, flows and influence diagrams to mimic real systems.

3 RESULT

3.1 Conceptual Model

The conceptual diagram of the model is represented by a block diagram as shown in Figure 2. The core is the 'Land use change' block, which contains the various land uses of Jambi such as natural forest, plantations, agriculture and housing and how they change. The 'Population' block represents the population of Jambi and its dynamics involving birth, growth, mortality and migration. The 'Livelihoods' block represents how much local communities earn from various land uses, while the 'Government Income' block represents how much income the government obtains from a range of land uses. 'Policy scenarios' represents the current policy in Jambi including business as usual (BAU), and the REDD+ scheme.

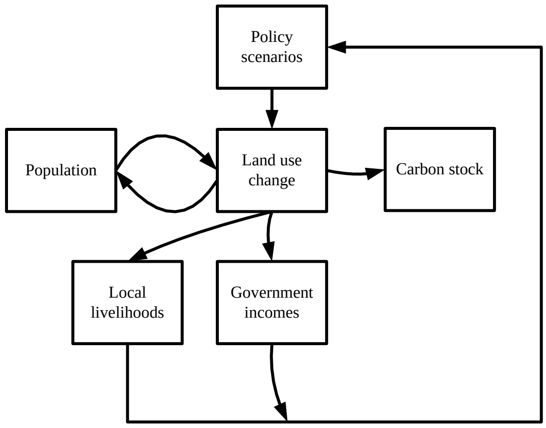


Figure 2. Conceptual diagram of Jambi land use and carbon dynamics

3.2 Specification of the model

The Jambi landscape consists of forest area (*kawasan hutan*) and other land use areas (*Areal Penggunaan Lain* or APL). The forest area is divided into (a) permanent forest, which includes conversion, protection and production forests, and (b) non-permanent forest, which embraces conversion production forest. This conversion forest is allocated for conversion from forest to agricultural land. Permanent and non-permanent forests have forested and non-forested areas. Other land uses consist of forested areas where community logging and conservation areas take place and non-forested areas where settlements, mining and agricultural fields are located.

Jambi forests are located on state property and non-forest areas are on community property. The government defines forest areas as *a specific territory of forest ecosystems determined and or decided by the government as a permanent forest.* Forest areas are legally determined by the government and currently not all of its areas are forested. Areas outside the forest area are called 'other land uses' (*Areal Penggunaan Lain* or APL). The forest cover and its uses for each forest category and other land use are shown in Table 1.

Table 1. Forest cover and its uses (in 1000 ha; MoF, 2010)

Forest cover	Forest area						Other land uses	Total area
	Permanent forest				Conversion production forest	Total forest area		
	Conservation area	Protection forest	Limited production forest	Production forest				
Forest	589	134	188	499	0	1,411	161	1,571
Activity	National parks	Water conservation	A)	A)	Oil palm & rubber	National parks	Community forests	
Non-Forest	122	39	107	500	0	767	2,409	3,176
Activity	coffee	Coal	Coal	Coal	B)		B)	
No data	6	1	6	12	0	25	39	64
Total	718	174	301	1,010	0	2,203	2,609	4,812

Note: A) concessions, plantations, illegal logging, encroachment and conversion to oil palm plantation; B) oil palm and rubber plantations and paddy fields.

Common components in changes to the Jambi landscape are: (1) 'deforestation' for development of non-forestry sectors e.g. agricultural plantations, mining and transmigration; (b) 'mutation' or change in different forest functions e.g. from conservation forest to protected forest or production forest; (c) 'illegal logging and encroachment'; and (d) 'forest planting' in degraded production forests.

Conversion to agricultural plantation, mining, transmigration, fire and encroachment are the main causes of deforestation. Deforestation amounts to 34,787.5 ha over a three-year period or 11,595.8 ha annually. Deforestation occurs mostly in production forest, followed by limited production forest, conservation areas and protected forest. There is no conversion production forest in Jambi, and therefore no forest allocated for conversion to agricultural land or other land uses. This is frequently the very reason for deforestation in permanent forest.

The land use dynamics describes how a particular land use changes to another type of land use as shown in Figure 3. Permanent forest is on the left and non-forest area is on the right. Forests are converted to mining areas, plantations and transmigration areas with different rates. The forest stock flows from the left to right. The carbon stock figure is obtained by the conversion from forest standing stock to carbon stock.

The local, provincial and central governments receive an income from taxes and fees from the use of natural resources and their products. The forest concessionaires, for instance, pay taxes for land use and concession permits. They also pay a fee for each cubic meter of harvested timber. The oil palm plantations also pay taxes to the government.

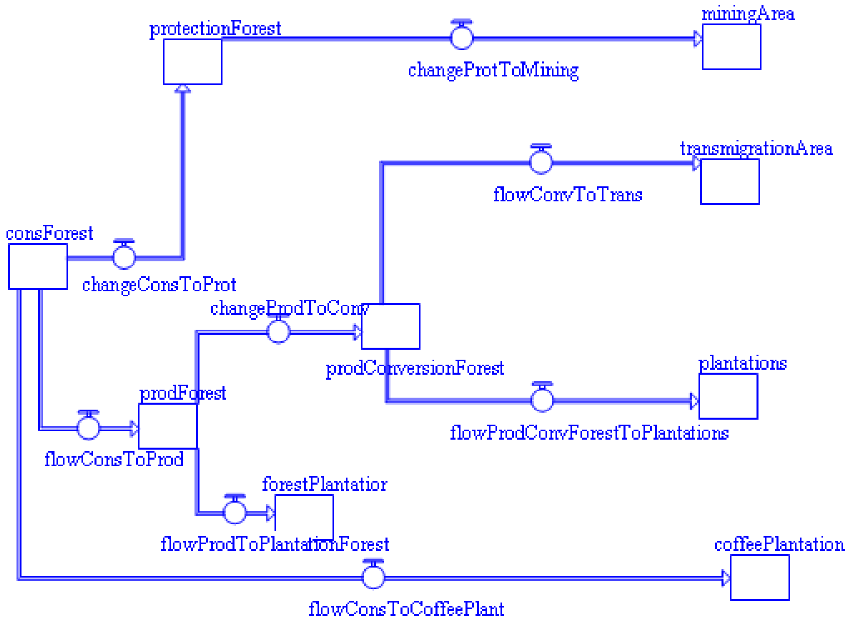


Figure 3. Stock and flow diagram of land use change from forests (left) to non forests (right)

3.3 Model Evaluation: Business as Usual

Under BAU the Jambi landscape experiences deforestation, mutation, illegal logging and planting as described in Table 2. 'Deforestation' refers to the permanent conversion of production and limited production forests to non-forest at the current rate. 'Mutation' is the change in forest function, e.g., from protection forest to production forest. 'Illegal logging and encroachment' is the conversion from conversion forest to coffee plantation. While 'planting' of forest plantation occurs in production forest. The indicators used for the BAU are change in carbon stock and government and local incomes.

Table 2. Landscape dynamics under BAU and REDD+ scenarios

Scenario	Deforestation	Degradation		Planting
		Mutation	Illegal logging and encroachment	
Where?	Production and limited production forests	Conversion forest, protected forest and limited production forest	Conversion forest	Production forest
BAU	Current deforestation rate	A)	B)	C)
RED (scenario D)	No deforestation	BAU	BAU	BAU
REDD (scenario DD)	No deforestation	No degradation	No degradation	BAU
REDD+ (scenario DD+)	No deforestation	No degradation	No degradation	D)

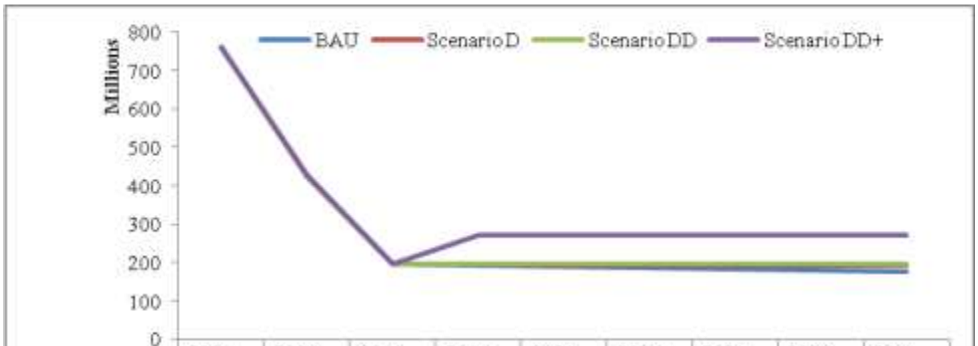
Note: A) from conservation forest to protected forest; from protected forest to production forest; from conservation forest to limited production forest; from limited production forest to conversion forest; B) conversion forest converted into coffee plantation; C) planting trees in degraded limited production forest and production forest at a low rate of about 30% when permission granted; and D) planting increases from 30% to 100% of the plan

Under BAU, the total forest decreases from more than two million ha to one million ha after 10 years. The production and conservation forests decrease, but the protection forest increases due to mutation from conservation forest. Conservation forest decreases at a rate of 33,542 ha/year and production forest at 92,956 ha/year. While protection forest increases at a rate of 17.228 ha/year and conversion forest at 563 ha/year. This model shows that REDD+ has good potentially for conservation forest and production forest.

3.4 Use for REDD+ scenarios

The model was used to test REDD+ scenarios and scrutinize how they differ from BAU. The REDD+ scenarios involve three scenarios i.e. RED, REDD and REDD+ as shown in Table 2. The results of each scenario are shown in Figure 4.

From the simulation results RED, REDD and REDD+ scenarios provide a larger amount of carbon stock than BAU. The affectivity of each scenario is the difference between the scenario results and BAU. However, compared to year 2000, the three scenarios cannot recover the standing stock in 2001. This is due to the deforestation and mutation that caused the forest degradation. The income from RED, REDD and REDD+ scenarios was simulated with an assumed carbon credit price of US$6/ton (pessimistic) and $25/ton (optimistic). The income simulation shows clearly that a higher carbon price will provide stakeholders with better incomes. REDD+ can provide a gross financial benefit of between US$1.5 and6.7 billion.



	2001	2006	2011	2016	2021	2026	2031	2036	2041
BAU	761,511,	426,195,	196,337,	193,135,	189,935,	186,736,	183,538,	180,343,	177,148,
Scenario D	761,511,	426,195,	196,337,	195,174,	194,523,	193,874,	193,226,	192,579,	191,934,
Scenario DD	761,643,	426,982,	197,778,	197,268,	197,268,	197,268,	197,268,	197,268,	197,268,
Scenario DD+	761,643,	426,982,	197,778,	270,773,	270,773,	270,773,	270,773,	270,773,	270,773,

Figure 4. Carbon stock results of RED, REDD and REDD+ scenarios compared to BAU

In terms of equity the Government of Indonesia, through the Ministry of Forestry regulation No. 36/ II/2009, states that the government should receive the most benefit for RED. The assumption being that the government has the biggest role to play in reducing deforestation, e.g., illegal logging. Meanwhile, the private sector should receive the biggest benefits from REDD as forest degradation occurs in forest concession areas run by the private sector. Likewise, tree planting or increasing carbon stock will be conducted in forest concession areas. Local communities do have a significant role to play in RED, REDD and REDD+, but not the biggest.

REDD+ provides more benefits compared to RED and REDD. If the carbon price is $25/ton from REDD+, then the government will receive US$3,500, the private sector $2,000 and the local communities $1,500 for each hectare of land. The efficiency of REDD+ is given in Table 5, which illustrates the amount of carbon emissions that can be reduced (ton) per $1. Efficiency is how much money is needed to reduce carbon emissions. Less money will provide greater efficiency. It shows that forest logging concessions (HPH) and forest plantations (HTI) are the most efficient places for reducing carbon emissions. Mining, however, is inefficient at reducing carbon emissions

Table 4. Efficiency of REDD+

	Efficiency (Ton/USD)				
Year	Mining	Plantation	Coffee plantation	Forest plantation	Forest concession
2006	0.005	0.066	0.096	0.273	0.27
2011	0.005	0.011	0.087	0.164	0.295
2016	0.005	0.011	0.115	0.164	0.305
2021	0.005	0.011	0.151	0.164	0.31
2026	0.005	0.011	0.187	0.164	0.313
2031	0.005	0.011	0.223	0.164	0.316
2036	0.005	0.011	0.259	0.164	0.317
2041	0.005	0.011	0.294	0.164	0.319

4 DISCUSSION

Land use change is a complex process. Converting to systems dynamics is another layer of complexity, given that the data and the rate of change are not always available. However, we used the most accurate data we could possibly obtain with which to make the model work without eliminating the model's uncertainties.

The model was able to represent the forest situation in the past and predict the situation in the future. The model uses systems dynamics to understand the process of change. It is different from statistical projection that underlines the accuracy of prediction and empirical observation. Another modeling technique called agent based modeling emphasizes the role of various actors, behaviors and interactions (Purnomo et al. 2012b).

The model can provide an understanding of how RED, REDD and REDD+ is structured and connected. The simulation provides the basic understanding of how impacts of REDD+, if it is implemented, at the landscape level. The conceptual block diagram makes it easier for stakeholders, including the government, private sector and local communities, to understand and to be encouraged to consider REDD+. The model provides a transparent process of how REDD+ is going to be implemented through scenario building.

The results show that RED, REDD or REDD+ are effective ways of reducing the amount of carbon emitted into the atmosphere by up to 100 million ton/ha more than BAU. REDD+ stocks more carbon than REDD and RED. This can be easily understood because REDD+ has more components for carbon emission reduction than REDD or RED. REDD+ has tree planting as a means of carbon stocking that REDD does not have. REDD+ also has the component of reducing forest degradation that REDD also has but RED does not have.

In terms of equity, the paper follows the Ministry of Forestry regulation No. 36/ II/2009 that states the distribution benefit of REDD+. In the regulation for RED, governments will receive the most benefits while for REDD and REDD+ the private sector will receive the most. However, in the real implementation, the benefit distribution shall follow the carbon property rights, which are not only the legal rights recognized but also traditional rights as well as the fairness principle among various involved stakeholders (Purnomo et al. 2012b).

Working on forest concessions is the most efficient use of money for reducing carbon emissions. Conversely mining is the most inefficient for REDD+. More money is needed to reduce emissions in mining than in plantations and forest concessions. This is due to the opportunity costs for not mining, e.g., coal and gold mining have much more to lose than plantation or forest concessions.

5 CONCLUSION

Forest and land use change is a complex process that needs to be elaborated and clearly defined. This model helps to clarify the REDD+ processes from the point of view of land use change. The model was able to describe BAU as the current evaluated situation and prospecting scenarios of RED, REDD and REDD+. These scenarios are used to show how effective the three programs are at reducing carbon emissions. The government will receive the most benefits from RED, but the private sector will receive the most from REDD and REDD+. Mining is the most inefficient use of money for reducing emissions and forest concessions are the most efficient. .

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