Harnessing the Climate Commons: An agent-based modelling approach to reduce carbon emission from deforestation and degradation

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Abstract

Humans have created a worldwide tragedy through free access to the global common atmosphere. Forest land use change contributes 18% of greenhouse gas emissions, which cause global warming. The 15th Conference of the Parties in Copenhagen increased political commitment to reduce emission from deforestation and degradation and to enhance carbon stocks (REDD+). However, government sectors, political actors, business groups, civil societies, tree growers and other interest groups at different levels may support or reject REDD+. This paper describes REDD+ dynamics through the following methods: identifying key actors that influence REDD+ policy; categorizing their objectives and interests, types of rationality and policy preferences; pointing out the strategies they used to fulfill their goals and simulating their actions and behaviors with an agent-based modelling approach.

Through analysis of actors, arenas and institutions, various possible REDD+ options are explored. The model simulates: (1) how providers are likely to decrease or increase carbon stocks on their landscapes for their livelihoods under ‘business as usual’ institutions; (2) how they are likely to negotiate with potential buyers to implement REDD+, with regards to the involvement of brokers (governments or nongovernmental organizations); and (3) how they are likely to implement REDD+ after the agreement. The model has been/was developed as a spatially explicit model to consider the complexity of REDD+ target landscapes. The simulation results are examined against the 3E+ criteria, i.e. effectiveness in carbon emission reduction, cost efficiency and equity among involved stakeholders and co-benefit of other activities. This study took the Jambi landscape in Indonesia as a case/case study. The results explain why REDD+ works and does not work, who wins and loses, and develops scenarios for REDD+ institutional arrangements which would help to harness the global commons of climate change.

Keywords: Climate change, deforestation, agent-based modeling, Indonesia, institutional arrangement

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I. Introduction

Global warming is a fact that all parties need to quickly act upon, otherwise humanity will not survive. The United Nations Framework Convention on Climate Change provides a global common framework for all parties to combat global warming. Stern (2006) and Chomitz (2007) found that reducing emissions from deforestation and degradation is highly cost effective. Successive meetings of the Conference of the Parties produced structure and agenda to provide incentives for non–Annex 1 countries to reduce emissions from deforestation and degradation. Nevertheless, many civil society organizations are concerned about the effectiveness of REDD+, particularly in relation to unclear forested land property, weak governance and fairness of payment distribution of REDD+ credit (C_{REDD}).

Forest land use change/Change in forest land use is estimated to contribute 18% of greenhouse gas (GHG) emissions. GHG emissions from the forestry sector are projected to be the same in 2030 as in 2004 at 5.8 Gt CO_2 equivalent. This excludes conversion of peat land and other carbon-rich swamp lands. UNFCCC (2007) revealed three global direct drivers of deforestation and degradation: (a) commercial agriculture for commercial crops and cattle ranging; (b) subsistence farming of small-scale agriculture, shifting cultivation, and fuelwood and non-timber forest products (harvesting); (c) legal and illegal commercial timber extraction and traded fuelwood. These drivers determine the opportunity costs of maintaining the forest.

The mitigation options for the forestry sector are (a) reduce deforestation; (b) improve the management of productive forest; and (c) afforestation and reforestation to increase forest area. About 50% of global forestry mitigation options can be achieved at a cost of under US$ 20 per tonne of CO_2. The financial flow needed to reduce deforestation and degradation is estimated as the opportunity cost of converting forest to other land use. The estimated opportunity costs is US$ 12.2 billion annually, to reduce deforestation and degradation of 12.9 million ha globally (UNFCCC, 2007).

The direct drivers for deforestation and degradation differ in each country. Drivers of deforestation and degradation in Indonesia can be categorized into direct drivers and underlying causes. The direct drivers are natural causes (e.g. El Nino, natural fires and high rainfall) and human activities (e.g. logging, illegal logging, forest fires related to land preparation for forest plantation and estate crops and mining). The underlying causes of deforestation and degradation are market failures (e.g. underpricing of stumpage value and an abundance of illegally logged timber), policy failures (20-year concession periods, overlarge concession areas and premature implementation of regional autonomy), weak governance (e.g. weak law enforcement and land tenure), and broader socio-economic and political issues (e.g. economic crisis, reform era and high population growth) (Contreras-Hermosilla 2000).

In many countries, most forests have already been distributed to different actors for various uses. To obtain commitment on behalf of forest users, national governments must negotiate with these forest users including forest concessionaires, companies that plan to convert forests, local communities, forest conservation managers and local governments. Local communities in particular do not have the power and capacity to negotiate on a level field with national governments. Under such a circumstance REDD+ could produce more negatives than benefits for local communities. Equally, REDD+ may well cause conflict between local communities and the national government, and among community members. Conscious intervention to level the playing field is therefore a necessary condition for REDD+ to be successful.

REDD+ aims to reduce carbon emissions to the atmosphere. The atmosphere is a carbon sink. The atmosphere is a global common, which no one person or state may own or control and which is central to life. Paavola (2008) indicates how crucial parts of the institutional framework for governing atmospheric sinks are still missing, a shortcoming which maintains the ‘‘tragedy of the commons’’ in their use. The tragedy of the commons is a dilemma arising from the situation in which multiple individuals, acting independently, and solely and rationally consulting their own self-interest, will ultimately deplete a shared limited resource even when it is clear that it is not in anyone's long-term interest for this to happen (Hardin, 1961).

Understanding people’s behavior in relation to land use is key to making REDD+ work. Agent-based modeling (ABM) is suggested by institutionalists to model common property. The Implementation of ABM in land use planning and policy has been reviewed by Matthews et al. (2007). They categorized applications of agent based land use models under the headings of (a) policy analysis and planning, (b) participatory modelling, (c) explaining spatial patterns of land use or settlement, (d) testing social science concepts and (e) explaining land use functions. They believe that it is important to see the rural economy and land use as properties of ‘socio-ecological systems’ (SESs), consisting of social, economic and biophysical components interacting together. SESs show external variables i.e. policy, climate and demographic changes which ‘drive’ the system. The socio-ecological system itself containing its various components and their interrelationships.

ABM focuses on social dimension, modeling particularly human cognitive process. The hallmark of ABM is the recognition of “agents”, which are entities with defined goals, actions, and domain knowledge. Agents operate and exist in an environment. The environment might be open or closed, and it might or might not contain other agents. If it contains other agents, it can be seen as a society of agents. Simulating the stakeholders’ activities and interactions requires a tool that is able to represent the individual’s knowledge, beliefs, communication and behavior. Individual agents are typically characterized as having bound rationality. They are presumed to be acting in what they perceive as their own interests, such as reproduction, economic benefit, or social status, using heuristics or simple decision-making rules. ABM agents may experience ’learning’, ‘adaptation’, and ‘reproduction’.

This paper describes a model of a general district/provincial landscape with a forest core, forest margin, and agricultural mosaic with various actors i.e. local government, service providers, buyers, DNA, national government, international supervisory body. We use a conceptual map rather than a real map to enhance the usability of the model. The model will be primary for policy makers. Issues pursued are related to the effect of carbon prices and institutional arrangements on the effectiveness, efficiency and equity of the reduction of carbon emissions.

.II. Approach and Methods

This paper uses Arena-Actor-Institution (A2I) concept to understand that in every system there are arenas, actors and institutions that interact dynamically. 'Arena' is defined as a playing field, i.e., a field or arena in which actors act; 'Actor' is a set of actors; and 'Institution' refers to formal and informal rules and their enforcement. We adopted the Structure-Institution-Actor (SIA) approach of Sato (2005) but replaced 'structure' with 'arena' to better illustrate the playing field in the so-called A2I approach. (If we applied the SIA approach to a sumo wrestling match, then the sumo ring is the structure, the rules of the sumo game are the institution, and the two sumo players and the referee are the actors.) Ostrom *et al*. (1994) used the term 'action arena' in their framework for institutional analysis to illustrate the playing field where actors meet and negotiate. Institutions can change the arena only through the actors' work and intervention.

Institution is defined as "the rules actually used (the working rule or rules-in use) by a set of individuals to organize repetitive activities that produce outcomes affecting those individuals and potentially affecting others" (Ostrom, 2004). Weber (1995) defines institution, by contrast, with agreements issued by an organization. An institution is an agreement, which compels more people than the members of the group, which issued this agreement. An organization produces agreements, which apply only to its members. Institution is developed by and a result of actors' interactions among themselves in order to use or manage landscape.

Actors were identified according to their role in deforestation and degradation, legal or traditional rights over the forest and those impacted by REDD+. Actor characteristics were recognized through a literature review and discussions (Bernard 1994). Researchers facilitated the discussions to establish stakeholder identities, their rationale, and their behavior and actions. These characteristics formed the basis for the ABM model developed subsequently. The pattern of interaction among these actors can be collaboration, conflict or competition and individualized strategy. In this context the arena is defined as the landscape where actors are located or concerned. The landscape follows patterns in general (Chomitz 2007), which consists of forest core, forest margin and agricultural mosaic land.

There are four key phases in the development of a model (Grant et al. 1997) i.e. (a) Forming a conceptual model is to state the model's objectives, bound the system of interest, categorize its components, identify relationships, and to describe the expected patterns of the model's behavior; (b) Specifying the model is to identify the functional forms of the model's equations, estimate the parameters, and to represent it in NetLogo; (c) Evaluating the model is to re-assess the logic underpinning the model, and compare model predictions with expectations; (d) Using the model is to develop scenarios. At the current stage we emphasize the development of a general model of REDD+. Thus, the model is more a general model rather than a site-specific model. The model was implemented with ABM software, NetLogo. 4.1.

Railsback *et al.* (2006) reviewed ABM software platforms i.e. NetLogo, MASON, Repast, and Swarm for scientific agent-based models by implementing example models in each. NetLogo is the highest-level platform, providing a simple yet powerful programming language, built-in graphical interfaces, and comprehensive documentation. It is designed primarily for ABMs of mobile individuals with local interactions in a grid space. NetLogo is highly recommended, even for prototyping complex models.

III. Results

3.1. Forming a conceptual model

The model is conceptualized as A2I as shown in Figure 2. The arena is a general landscape, which consists of a forest core, margin and mosaic land. The forest core represents pristine forests and contains many indigenous people. The forest edge is the area where agricultural expansion is occurring. Mosaic land is the area with the highest land value, which is where agriculture is mostly located and only contains a small fraction of forest. Each part can be an object of REDD or its extension e.g. REDD+ or REDD++. This different scope will give different magnitude of carbon emission reduction and credits. The actors are those who are involved and are impacted by REDD+. The institution is all the rules related to the current REDD+ debate, which comprises payment mechanisms and distribution, scope, reference level, leakage/liability, emission monitoring, reporting, verification (MRV), and governance.

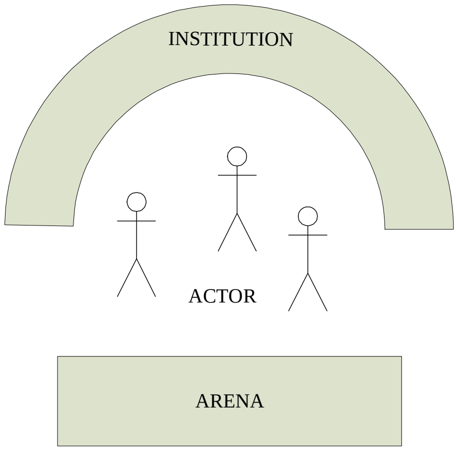


Figure 2. Arena-Actor-Institution (A2I) approach

The identified actors of REDD+ are service providers, local government, buyers, Designated National Authority (DNA), national government, and international supervisory bodies. The service providers develop environmental services (ES) i.e. emission reduction and sell them. They can be individuals, local communities, NGOs, private companies and/or local government. The local government can act as a facilitator for ES development. Some NGOs or private companies may act as brokers between sellers and buyers of ES. A verification body is an independent third party responsible for verifying the ES. The DNA that works at the national level provides approval of ES development and credit. The national government provides policy and measure for developing ES, while international supervisory bodies, such as the UNFCC secretariat, provide guidance on REDD+ trade. The table provides the goal, strategy and social group of issues for each actor.

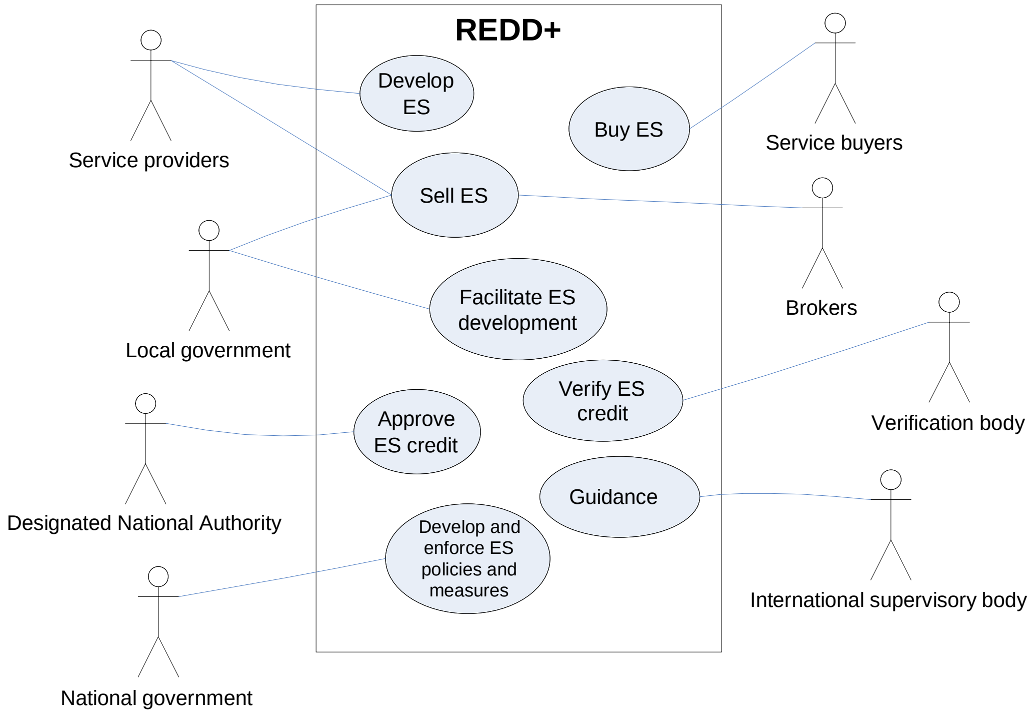


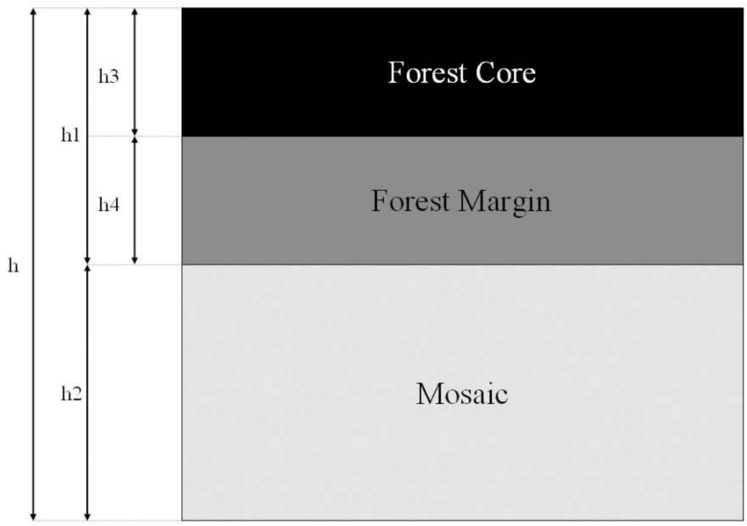
Figure 4. UML use case diagram of REDD+ showing actors and some of their roles

Effectiveness, efficiency and equity (3E) will be used to measure the REDD+ model. Effectiveness refers to the magnitude of the emission reduction so-called 'carbon effectiveness'. Efficiency refers to whether the given emission reduction is achieved at a minimum cost. While equity refers to fair distribution of benefits between and within countries and the effects of REDD+ activities on local communities (Angelsen *et al.* 2008)

3.2. Model Specification

The arena is spatially explicit, in a sense that it simulates the dynamics of carbon-related patches in space, but it is not aimed at simulating geographically verifiable outputs at pixel level. Thus, the model outputs should be evaluated at an aggregate level of pixels. In order to incorporate various possible patterns of Chomitzian landscape at an initial state as shown in Figure 2, the landscape is stratified in a vertical arrangement from top to bottom into three main sub arenas as described in Table 1, *i.e.*:

forest core, forest margin and mosaic (Figure 1). At a fixed width of the landscape (*i.e.* 100 pixels), the height of each sub arena is defined based on an area fraction as follows:



Where:

h : height of the landscape (*i.e.* 90 pixels),

h_1 : height forest core (h_3) or forest margin (h_4) in pixels,

h_2 : height of mosaic in pixels,

h_3 : height of forest core in pixels, and

h_4 : height of forest margin in pixels.

Figure 5. .Vertical arrangement of Chomitzian landscape into sub arenas: forest core, forest margin and mosaic.

The forest core of the landscape is managed as conservation forest that could be part of REDD+. However, illegal logging which happens randomly can occur. Forest conversion concessions and logging are located in the forest margin, which are objects of RED and REDD+ respectively. Small-scale forest, agroforestry and plantations such as rubber and oil palm are located in agricultural mosaic land, which could be objects of

REDD. Illegal logging can occur anywhere in the forest core and/or margin. Table 1 shows the arena-actor-institution (A_2I) approach of the model.

Table 1. The model design based on Chomitzian landscape and used A_2I approach

Sub Arena	**Actors**	**Activity**
Forest core	Local community in the forest core	Random logging
Forest margin	Local community in theforest margin	Random logging
	Forest concessionaires	Systematic logging
	Plantation companies in theforest margin	Large-scale rubber plantations (establishment)
		Large-scale oil palm plantations (establishment)
Mosaic of agricultural lands	Local community in themosaic	Random logging
		Agricultural lands (establishment)
		Small-holder rubber (establishment)
		Small-holder coffee (establishment)
		Small-holder cacao (establishment)
		Small-holder oil palm (establishment)
	Plantation companies in themosaic	Large-scale rubber plantations (establishment)
		Large-scale oil palm plantations (establishment)

The dynamics of the landscape are induced by logging both legal and illegal and forest growth. Forest concessionaires log the forest in their area, while illegal logging will occur randomly. This dynamics are so-called ‘business as usual’ (BAU). Drivers of landscape change are policy, population and climate. Legal logging occurs in theforest core and margin systematically. It is based on a rotation period.

To show how the model works, it is applied to a generic REDD+ target landscape (Figure 6), where 30% of the landscape was occupied by forest core, 30% by forest margin and 40% by mosaic. Under BAU institution, carbon providers transformed the landscape through logging, mining and other land use conversions.

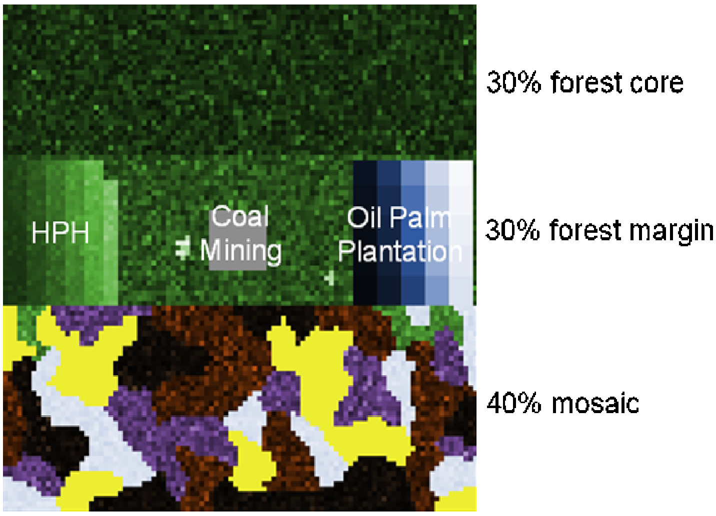


Figure 6. The initial state of the area

The way actors interact with each other is described using a Unified Modelling Language (UML) sequence diagram. In this negotiation, carbon price at the provider level ($\$.t^{-1}$) is the price on the global market, corrected to 'threat' of the patch and 'trust' between buyer and provider. Threat and trust are qualitative, ranging from 0 to 1. Threat is calculated based on patch historical records of carbon growth and removal, while trust is randomly generated. The accounted quantity of carbon for trading (t) is determined by BAU carbon-stocks, expected carbon-stocks under REDD+, and agreed reference level between buyer and provider. Considering transaction costs from brokering and facilitation, providers will have expected REDD+ profits from their patches ($/ha). Only if this profit is greater than the current land rent under BAU ($/ha), will providers sell their patches to buyers. All actors are assumed economically rational or benefit maximizers.

Figure 7 provides a simplified sequence of actor's interactions in carbon trade. News on carbon trade from carbon buyer brokers has been spread out among potential credit providers. Providers then ask the facilitator to assess their patches on land rent, carbon stock, reference level, additionality and threat. The facilitator then informs the patch owners/managers of the available carbon creditThe facilitator also offers the carbon credit to carbon provider brokers that want to buy carbon credit. The negotiation occurs at this point. Meanwhile the potential buyers will assess the degree of trust that the providers hold. Negotiation between two kind of brokers i.e. buyer brokers and provider brokers will or will not produce an agreement on the carbon trade. The facilitator is a local government, with help from central government, DNA and international supervisory bodies. The verification body works to verify the carbon emission potential from the patches facilitated by the facilitator.

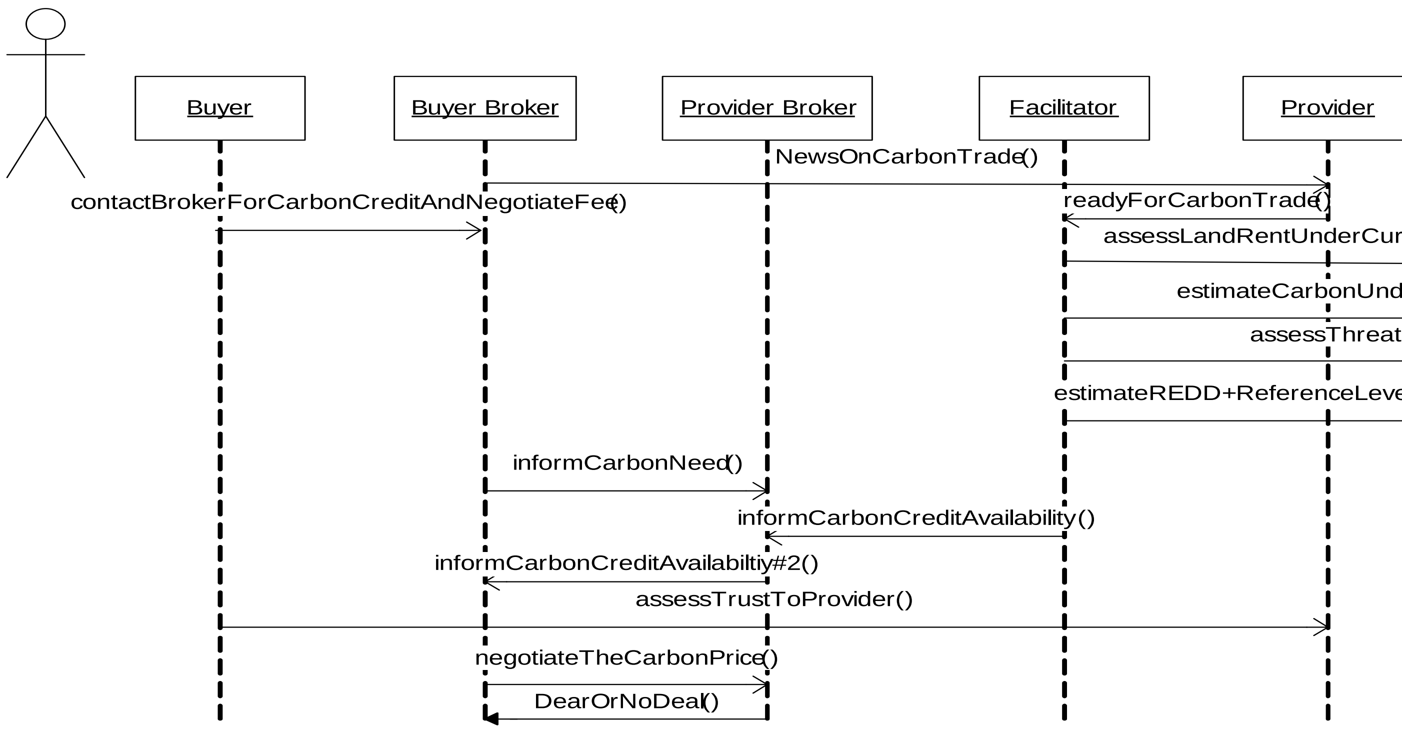


Figure 7. UML sequence diagram of the actors' negotiations

Table 2 provides assumed actors goal and rationalities. The main actors are all economically rational wanting to maximize their own interests and benefits. Their rationality determines the way they negotiate to reach an agreement. Only when they can all benefit can REDD+ work.

Table 2. REDD+ actors, goals and rationalities

	Category	Actor	Goal	Rationality
Outside the landscape area	Buyers		Reduce emission and minimize cost	Economy
	Buyer broker		Maximize benefits	Self interest and economy
	Provider broker		Maximize benefits	Self interest and economy
	Verification body		Maximize benefits	Economy
	Facilitator	NGO	Reduce emissions	Common interest

		Local government	Reduce emissions and increase government income	Public interest
		Central government	Reduce emissions	Public interest
		DNA	Reduce emissions	Public interest
		International supervisory body/ies	Reduce emissions	Public interest
Inside the Landscape area	Providers	Local communities	Maximize benefits	Self interest and economy
		Forest concessionaires	Maximize benefits	Self interest and economy
		Big plantations	Maximize benefits	Self interest and economy
		Small plantations (rubber, coffee, cacao)	Maximize benefits	Self interest and economy
		Mining companies	Maximize benefits	Self interest and economy
		Protected area managers	Maximize benefits	Self interest and economy

There is no collective action based on the common goal and interest among actors. All are driven by self interest and economic rationality to maximize their benefits from the resources they exploit and manage. Altruism is not characteristic of the actors.

3.3. Verification of the Model: Business As Usual

The model considers both biophysical and socio-economical factors causing changes in c-stocks in a REDD+ target landscape under business as usual (BAU) and REDD+ scheme. Business as usual (BAU) is a condition when the current situation continues. Under the BAU institution, carbon providers transformed the landscape through logging, mining and other land use conversions. Here, the carbon provider is defined as the actor who has direct responsibility for carbon-stock changes within the REDD+ target landscapes, either under BAU or REDD+ institutions. It includes local communities (farmers and loggers), forest concessionaires, plantation companies, and mining companies. REDD+ target landscapes are stratified based on general patterns of forested landscapes as described by Chomitz (2007), *i.e.* forest core, forest margin and mosaic of annual crop lands. Outside the REDD+ target landscape, government, NGOs, carbon buyers and brokers are considered to have significant roles to play in changing carbon stocks under REDD+.

In a BAU scenario, if a REDD+ credit area and carbon stock are identified but because there is no carbon market and then no- carbon deal, the forest area may well decrease, while agriculture, oil palm and mining increase. Coffee, cacao and rubber plantations are dynamics that tend to remain the same. The forest decreases because it is converted to other land uses such as oil palm, agriculture and mining. Those conversions are triggered by economic logic i.e. greater economic rent. The landscape pattern after the simulation is given in Figure 8. Figure 9 shows how the landscape changed over 30 years.

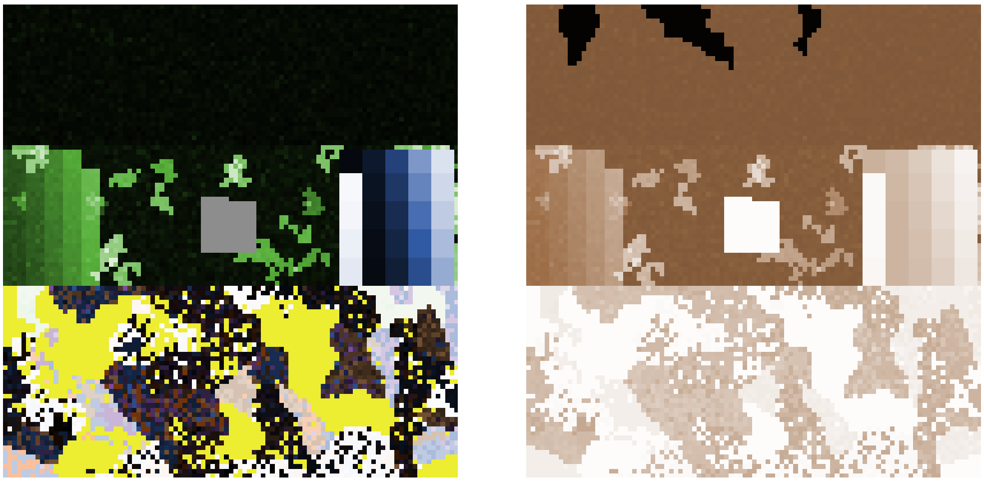


Figure 8. End of (a) Landscape vegetation pattern (b) Carbon stock under BAU

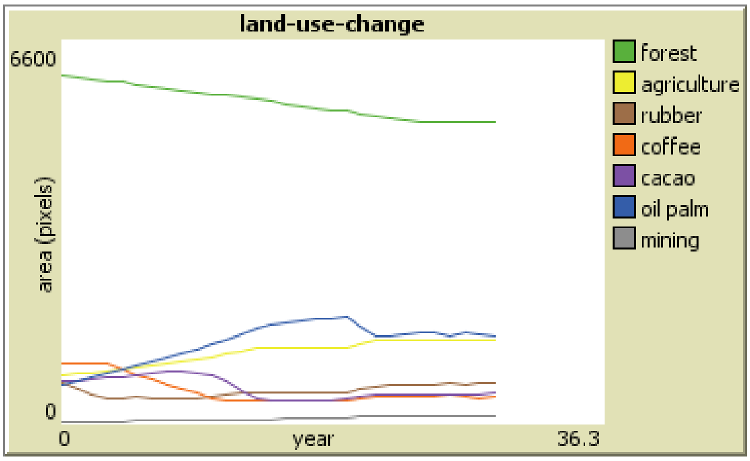


Figure 9. Landscape dynamics under BAU

Because the REDD+ market has not functioned nobody enters it or becomes a REDD+ credit seller. No one receives any benefits or detriment. No change! The carbon stock has not been affected as given in Figure 9. The total carbon stock is about 1.5 Mt and depleting.

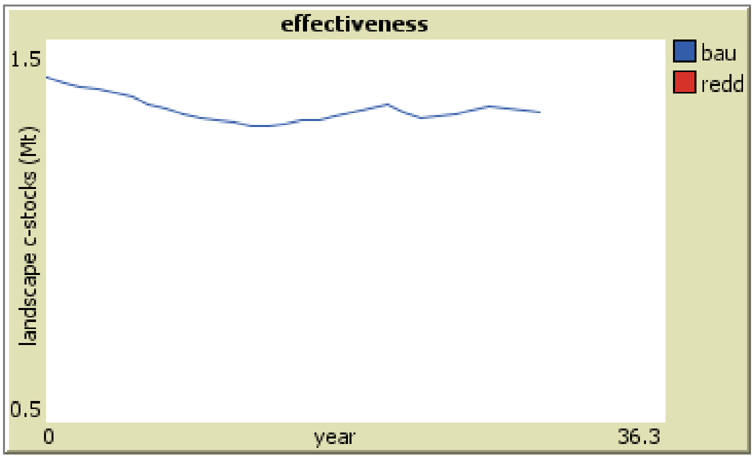


Figure 10. Carbon stock under BAU when REDD+ has/does not functioned

Equality distribution is given in the Lorenz curve (Figure 11). The curve is a graphical representation of the cumulative distribution function of the empirical probability distribution of wealth. The percentage of actors is plotted on the x-axis, the percentage of income on the y-axis. The 45 degree represents the line of equality. The figure clearly shows that the BAU provides unequal distribution of income. However, it does not mean REDD+ will guarantee better equality.

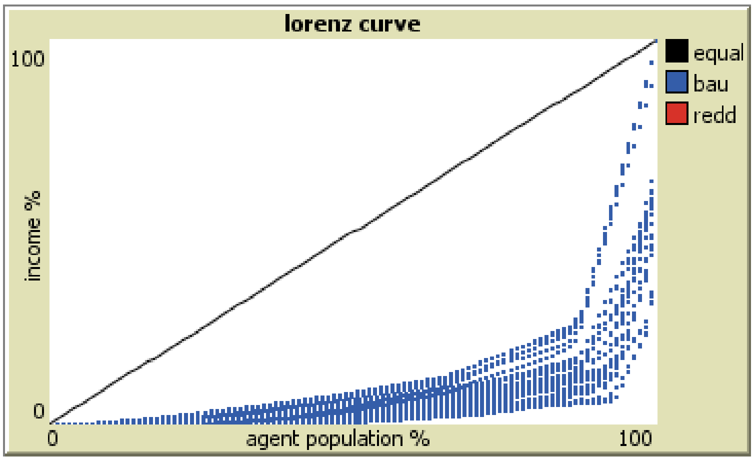


Figure 11. Inequality distribution under BAU

The verification process was conducted by scrutinizing the simulation results.

3.4. Model Use: Price scenarios

In the price scenarios, we simulated global carbon prices of $10 and $15 $35 per ton. Price of carbon at $10, no REDD+ area is generated. Increasing the area of REDD+ zones occurs by increasing the carbon prices as seen in Figure 12.

Figure 12. REDD+ area deals at carbon price $10, $15 and $25

The carbon sellers of can be seen in Figure 13. At $15 per ton of carbon, local communities and large-scale plantation managers operating in the mosaic area expected profits through REDD+. At a higher carbon price, more providers/sellers joined REDD+, including national parks.

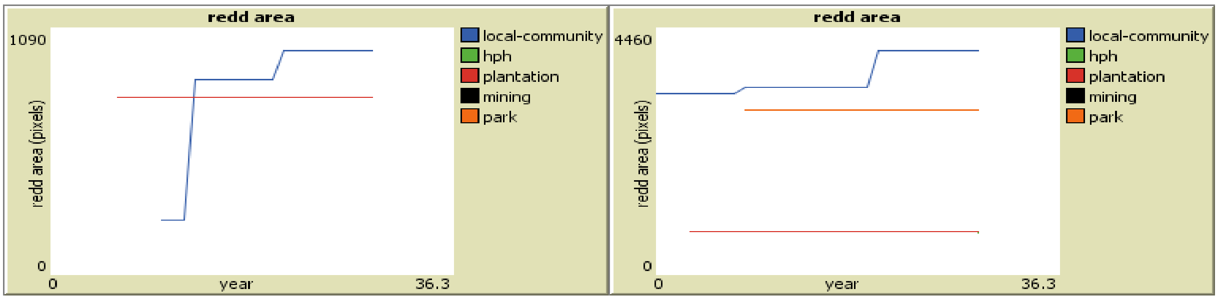


Figure 13. Carbon sellers at $15 and $35

In this case, REDD+ can effectively maintain carbon stock in the landscape starting from a carbon price of $15 per ton (Figure 14). Effectiveness refers to the magnitude of the emissions reduction. If the price of carbon stock is increased to $25, the carbon stock will increase.

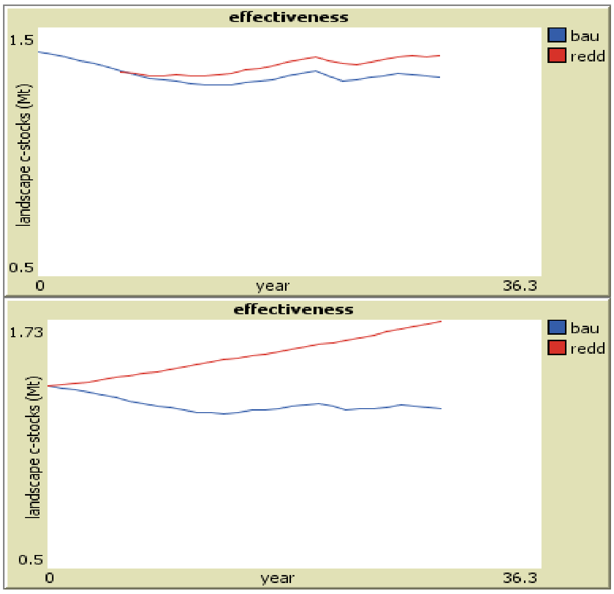


Figure 14. Effectiveness of REDD+ in reducing emission at $15 and $25

Efficiency refers to whether the given emission reduction is achieved at a minimum cost. Figure 15 shows that REDD+ in a mosaic area is less efficient than in a forest margin at a carbon price of $15 per ton. The forest core is the least efficient at a carbon price of $25 per ton. At an appropriate carbon price, more forest concessionaires in forest margins would be attracted to sell carbon than timber.

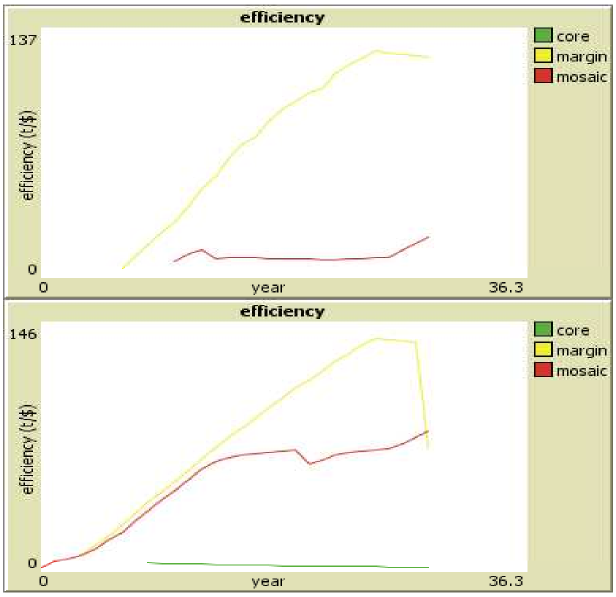


Figure 15. Efficiency at carbon price $15 and $25

The threat consideration in REDD+ would create disparity in carbon pricing at the 'farm gate' in space. Thus REDD+ would give negative impacts on wealth distribution, as shown by Figure 16, where the Lorenz curves are skewed more to the right, indicating more unequal distribution. However with the increase of the carbon price the wealth distribution is better giving more agents the chance to participate in REDD+.

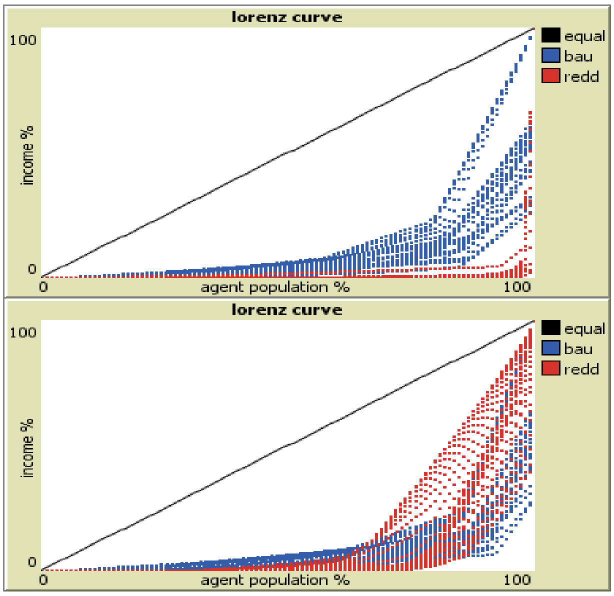


Figure 16. Lorenz curve for at carbon price $15 and $25

IV. Discussion

Clearly from the simulation above, if, and only if, the global price of carbon is more than $25, will the carbon stock be enhanced firmly. in the landscape The problem is whether this price will always be possible. The global simulation of the carbon price in the next 30 years is oscillated at $16. So, it is impossible to use solely the carbon price to reduce carbon emissions. Given all actors maximize their own interests, all individuals are selfish, norm-free, and maximizers of short-run results. the tragedy of the climate commons is happening. The question is how to solve this problem? Can moral and ethics be alternative solutions to wisely maintain the atmosphere?

Ostrom et al. (1999) provide possible solutions to this dilemma Solving commons problems involves two distinct elements: Restricting access, and Creating incentives (usually by assigning individual rights to, or shares of, the resource) for users to invest in the resource instead of overexploiting it. Both changes are needed. Limiting access alone can fail if the resource users compete for shares, and the resource will become depleted unless incentives or regulations prevent overexploitation. Furthermore, self maximization is not always a common behavior of all actors. Ostrom et al (1999) categorized the commons user into (i) those who always behave in a narrow, self-interested way and never cooperate in dilemma situations (free-riders); (ii) those who are unwilling to cooperate with others unless assured that they will not be exploited by free-riders; (iii) those who are willing to initiate reciprocal cooperation in the hope that others will return their trust; and (iv) perhaps a few genuine altruists who always try to achieve higher returns for a group.

Developing Institutions for governing and managing atmosphere is tremendously important if climate change is to be tackled. Collaboration can be established, self sustaining, and even grow if the proportion of those who are always will to act in a narrow, self-interested manner is initially not too high. When interactions enable those who use reciprocity to gain a reputation for trustworthiness, others will be willing to collaborate with them to overcome climate dilemmas, which leads to increased gains for themselves and their offspring (Ostrom *et al.* 1999). Creating incentives for collaboration is a key for this climate dilemma. To make collaboration possible we have to design institution or working rules so that perceived benefits are greater than costs. They must commonly highly value the future sustainability of the resource. Perceived costs are higher when the resource is large and complex, users lack a common understanding of resource dynamics, and users have substantially diverse interests.

Since REDD+ is currently being studied, it is hard to find this kind of collaboration on the ground. Fortunately, ABM is a tool that can be used to investigate how changing rationality can affect the common resources. Can common interests of stakeholders be improved so that they can collaborate to reduce carbon emissions, even with a lower carbon price? The following equation will show how the common interest can probably be improved, collaboration can be institutionalized and carbon emissions reduced, even with a lower carbon price. How can this collaboration arrangement work better in terms of equity?

If campaigns (say ‘c’) of global warming is intensified and actors are willing to pay for reducing global warming then it is possible to reduce carbon emission even with a lower price through collective action. The altruism index (a) of each actor is influenced by welfare (w), equity (e) and how they perceive environmental risk (p). If ’’t is the actual threat to the landscape then we formulate altruism as:

$$a = p + e*(1 - p)$$

where,

a = 0 (selfish)…1 (perfectly altruist)
e = 0 (equal) …1 (not equal)
p = 0 (don’t care) … 1 (very responsible)

if equity is very bad (=0 or very selfish) then altruism is determined by the actors’ perceptions of environmental damage (p). On the other hand if equity is perfect (=1) then altruism is perfect (=1 or perfectly altruist). Thus ’p’ can be formulated as:

$$p = c + w*(t-c)$$

where,

’’c is affectivity of campaign ranging from 0 (not effective) to 1 (very effective).

’’t is a threat of environmental damage which threatens the actors.

’t’ ranges from 0 (not threatened) to 1 (very threatened).

From the above formula the perceived risks are determined by the affectivity of the campaign for emission reduction and welfare. The welfare influences the perceived risks by comparing real threats and affectivity of the campaign. If actors’ welfare is very bad compared to the other actors then “p” is determined by ’c’ only. And to the contrary, if welfare is very good (w=1) then ’p’ is determined by the threat of environmental damage (t).

From this scenario we found that an environmental awareness campaign on carbon may well work and help improve the effectiveness of REDD+. Figure 17 provides Simulated effectiveness of REDD+ at various carbon prices (t/ha) with or without altruism triggering campaigns. Starting from a carbon price of $15/t, effectiveness increases as the price increases and the campaign is carried out effectively.

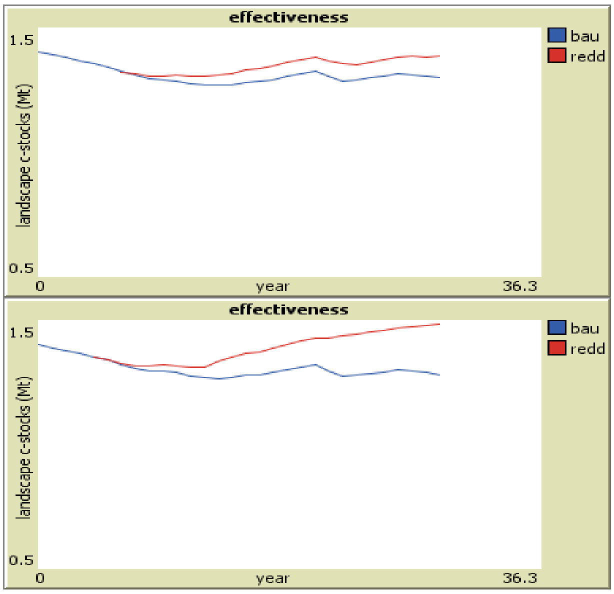


Figure 17. Effectiveness of REDD+ at $ 15/t carbon price but different social awareness

This shows that awareness of global problems such as climate change can make a difference. If effective campaigns and collective action work then carbon prices are not everything. It is in line with what Paavola (2008) who suggested that a workable governance solution for global atmospheric sinks needs to create institutional solutions for enhancing participation in environmental decisions in order to guarantee progress in and legitimacy of the governance framework. The other suggestions are that the outlines are to cap the use of atmospheric sinks; provide for a more equitable benefit sharing; and provide compensation for climate change impacts and provide assistance for adaptation to climate change impacts.

V. Conclusion

Agent-based models are useful for simulating actors' behavior vis-à-vis REDD+ initiatives. When REDD+ enters the implementation phase in the targeted landscapes, carbon pricing will determine whether it will succeed. REDD+ can work if the carbon price starts no lower than US$15 per tonne of carbon. REDD+ agreement areas increase with higher carbon prices, e.g. US$25 or US$35. The carbon price is important, but not everything. This simulation shows that even with low carbon prices GHG emissions will decrease if the 'altruism' index of the actors increases.

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