LETTER

REDD payments as incentive for reducing forest loss

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Abstract

Strategies for reducing emissions from deforestation and forest degradation (REDD) could become an important part of a new agreement for climate change mitigation under the United Nations Framework Convention on Climate Change. We constructed a system dynamics model for a cocoa agroforest landscape in southwestern Ghana to explore whether REDD payments are likely to promote forest conservation and what socio-economic implications would be. Scenarios were constructed for business as usual (cocoa production at the expense of forest), for payments for avoided deforestation of old-growth forest only and for payments for avoided deforestation of all forests, including degraded forest. The results indicate that in the short term, REDD is likely to be preferred by farmers when the policy focuses on payments that halt the destruction of old-growth forests only. However, there is the risk that REDD contracts may be abandoned in the short term. The likeliness of farmers to opt for REDD is much lower when also avoiding deforestation of degraded forest since this land is needed for the expansion of cocoa production. Given that it is mainly the wealthier households that control the remaining forest outside the reserves, REDD payments may increase community differentiation, with negative consequences for REDD policies.

Introduction

Reducing emissions from deforestation and forest degradation (REDD) is considered as a possible means for mitigating climate change (UNFCCC 2007). Payments for decreased CO_2 emissions from deforestation and degradation is considered one possible mechanism, with payments based on the difference between realized emissions and projected emissions from a historical emission baseline (Kanninen *et al*. 2007; Righelato & Spracklen 2007).

A concerted effort of policies and payments for environmental services can reduce deforestation (e.g., Pagiola 2007). However, in many tropical landscapes governance is weak and funds for payments for environmental services schemes are limited. In addition, in many tropical landscapes commercial agriculture is the main agent of deforestation (oil palm, cocoa, rubber, and soy) (Lambin *et al.* 2001). Under these circumstances, can REDD payments provide the incentives to halt deforestation? We examined this question for southwestern Ghana, a region where forest has been and continues to be lost to cocoa production. Ghana receives support for developing early REDD activities from the World Bank's Forest Carbon Partnership Facility. Using simulation modeling, we examine whether REDD payments to farmers would provide the necessary incentives for farmers to opt for reducing deforestation and forest degradation instead of cultivating their land. We also examine some of the socioeconomic implications of REDD, given that many policy makers are driven by development issues rather than environmental issues.

Methods

The landscape

The Wasa Amenfi West district in southwestern Ghana covers an area of 34,646 km^2 of which 25% is natural forest. The district experienced heavy in-migration by farmers growing cocoa, the most important cash crop, resulting in a population of 156,260 inhabitants in 2000 (District Report 2005, unpublished). Forest reserves account for 12% of the total landscape and are largely managed by private logging companies. A smaller part of the reserves are Globally Significant Biodiversity Areas (NRMP 1999), which are excluded from any extractive use, just as the sacred forests outside the reserves. Deforestation in the landscape has occurred mainly outside forest reserves, driven by local farmers clearing for cocoa production.

Participatory modeling

Participatory modeling consists of building a model together with actors from the landscape with the aim of exploring future landscape pathways. The aim of this specific model building exercise was to assess the current state and dynamics of the Wasa Amenfi West landscape, sketch expected future dynamics, compare REDD payments with the opportunity costs of cocoa production in this setting and feed this into expert discussion. REDD's feasibility will depend strongly on local government and landholders' motivation to participate. Through participatory scenario exploration these actors directly communicate foreseen obstacles and likely preferences. To be built in a participatory way, the model needed to compromise on complexity to gain in continuous participant input and validation. The simulation outcomes therefore are rough indications rather than precise predictions, but they are validated by expert opinion.

The model building was initiated in a workshop setting, involving a district official from the Ministry of Food and Agriculture, cocoa farmers, a representative of a timber company, personnel from local and international environmental NGOs, and remote sensing and modeling experts. Data were obtained from a study on land cover change (Förster 2009), district reports and the literature (e.g., for carbon stocks). The model was produced using the best available data, whenever data was lacking a mediated estimate was made by the local experts (Table 1).

The system dynamics model was built using the stock-and-flow model software STELLA (HPS 1996). With its icon-based interface, STELLA is readily understood by participants without a modeling background (Sandker *et al*. 2007, 2009; Van den Belt 2004). The model structure consisted of several submodels or "sectors" representing components of the social-ecological system such as land-use change, population dynamics, carbon dynamics, income, and REDD payments (Table 1).

In the model, deforestation is driven by growth in rural population and in line with forest conversion rates as for the period 2000–2007. We modeled the conversion of forest to cocoa plantations for large and small landholders. Some of the large landholders have old-growth forest on their land, while smallholders have only access to secondary forest. When available, 90% of the large landholders' demand for cocoa land will be taken from old-growth forest; after depletion of the old-growth forest, the entire demand will shift to secondary forest. Little off-farm employment exists in this remote rural part of southwest Ghana. As a result, farmers all stated that growing enough food for the family and making some cash from cocoa were the two main farming goals (G. Shepherd and S. Nyame 2009, personal observation). We modeled all households to reserve at least one ha of land for food crops.

Farmer income was modeled calculating the net income from the cocoa plantations. The time to maturation of cocoa is 8 years, followed by a 20 year production period. In the first 2 years the cocoa saplings are intercropped with food crops. Average values are used in the model, e.g., for cocoa production per ha. Further assumptions and data inputs are provided in Table 1 and the full model details are given in Appendix S1.

Farmer decision making was not modeled since there was not enough information on how this occurs (see Wilson 2007 on the complexity of farmer decision making). Rather, we explored what would happen to farmer income and carbon stocks if farmers opted for or did not opt for REDD. To compare the scenario's attractiveness we used the discounted value of per capita cash income over 20 years, referred to as net present value (Appendix S1), though this is only one element of a very complex decision making process. We also approximate after how many years in the simulation the net present value of the REDD scenario would drop below the net present value of cocoa cultivation, indicating likely contract breaking,

Table 1 Model structure, data input and assumptions

Model sector	Contents	Assumptions and data	Information source
Land use dynamics	Main land-uses: young cocoa intercropped with food crops, productive cocoa agroforest systems, secondary (tree height <25 m) and old growth forest (tree height >25 m) outside the reserves; reserves, timber and rubber plantations. Conversion is mainly from primary and secondary forest to cocoa, driven by the rural population	District size is 346,462 ha of which 12% is forest reserve Land cover outside forest reserves in 2008: 2% urban and bare soil, 3% non forested fallow, 8% food crops, 6% food crops intercropped with young cocoa, 19% 2–8-year-old cocoa, 42% productive cocoa, 0% forested fallow, 5% timber and rubber, 10% secondary forest, and 5% old growth (of which one quarter is sacred forest) We assume deforestation of old growth forest to continue linearly with the same annual quantity as seen between 2000 and 2007 Sacred forest is not converted Old growth forest is located on the land of the large landholders as well as 80% of the secondary forest Smallholders have average parcel sizes of 6 ha of which on average 5 ha are currently in use (including fallow), 4.5 ha being cocoa Large landholders have average parcel sizes of 30 ha of which on average 21 ha are currently in use, 18 ha being cocoa Cocoa starts to produce after 8 years, remains productive for 20 years followed by a fallow period of 3 years For the first 2 years, young cocoa is intercropped with food crops The food crop area will be at least 1 ha per rural household There is a preference for converting old growth forest rather than secondary forest into cocoa by large landholders. Without restrictions 90% of their demand for new cocoa land is assumed to come from old growth forest Timber and rubber area remain fixed	District report 2005 Mediated estimates using Aster 2007 images and 2009 household surveys Mediated estimates using Aster 2007 and Landsat 2000 images Local expert knowledge Mediated estimates based on 2009 household surveys and local expert knowledge
Rural population dynamics	Population increase is mainly caused by birth in the district as the in- and out migration was expected to be minor	Population size 2008 = 190,400 people Population growth rate = 2.5% 85% of the population is rural Average household size = 5 people 14% of the households are large landholders, 86% smallholders	Mediated estimate using district report 2005 data and local expert knowledge Average from data collected in 2000 Local expert estimates

Continued

Table 1 Continued

Model sector	Contents	Assumptions and data	Information source
Carbon	The carbon stock is calculated for the land-uses on the off-reserve area which is currently covered with old growth forest (for scenario 2) and with old growth and secondary forest (for scenario 3)	Average carbon contents (ton C/ha) per land-use: Urban, bare soil = 0; nonforested fallow = 15; food crops = 30; food crops intercropped with young cocoa = 50; 3–8 year old cocoa = 70; productive cocoa = 100; forested fallow = 130; timber and rubber = 135; secondary forest = 160; old growth = 200	Mediated estimations from Swallow *et al*. (2007), Wauters *et al* (2008) and De Bruijn (2005)
Income	Profit from cocoa = productive cocoa area ∗ average production per ha ∗ net profit per ha (income minus costs fertilizer and pesticides) REDD income is calculated in the REDD payments sector	The Ghanaian cocoa prices of 2007 and 2008 (US$ 1.14 and 1.37/kg) are compared to global market prices to calculate the percentage going to the government (44%) Cocoa price is projected to 2030 following and extending the trend of the World Bank forecast to 2020 resulting in a 40% decrease in 20 years Average production per hectare: 11.8 bags (=767 kg) Costs are 20% of profit Cocoa profit contributes $>$ 90% of rural cash income Cocoa income is used as proxy for total rural cash income excluding cash from REDD We assume labor is not paid and the cost of this is not included in the model	Information from district official and cocoa farmer, and World Bank (2009a) World Bank (2009b) Data from Technoserve Extension Offices in the district Estimation district officials Expert judgment
REDD payments	Total carbon payment is calculated by: CO_2 stock (tons) of land-uses in 20 years from now on land now covered with off-reserve old growth forest (scenario 2) and secondary forest (scenario 3) minus carbon stock old growth forest (scenario 2) and secondary forest (scenario 3) multiplied by the price farmers would receive per ton CO_2	We assume an international carbon price of US$ 10/ton CO_2 paid by investors, We obtained this number mediating the average contracted price throughout 2007 and early 2008 on the Clean Development Mechanism market (US$ 13.60/ton CO_2) and the average price on the voluntary market (US$ 4.40/ton CO_2) Transaction costs of REDD are presumed high and thus we assume only 25% will reach the farmers (US$ 2.5/ton CO_2), We adapted this number from Indonesian transaction costs which can be as high as 80% We assume a 20-year contract with: 20% paid up front; large payments paid every 5-years (10%) and 20% paid after 20 years if there is contract compliance; and regular small payments in other years (2%)	Capoor and Ambrosi (2008) for CDM price, and Butler *et al* (2009) for voluntary market price CarbonPositive (2009) for Indonesian transaction costs How REDD contracts will be constructed has yet to be determined. We assume a large up-front payment in order to attract sellers of carbon and provide finance for start-up costs of sellers

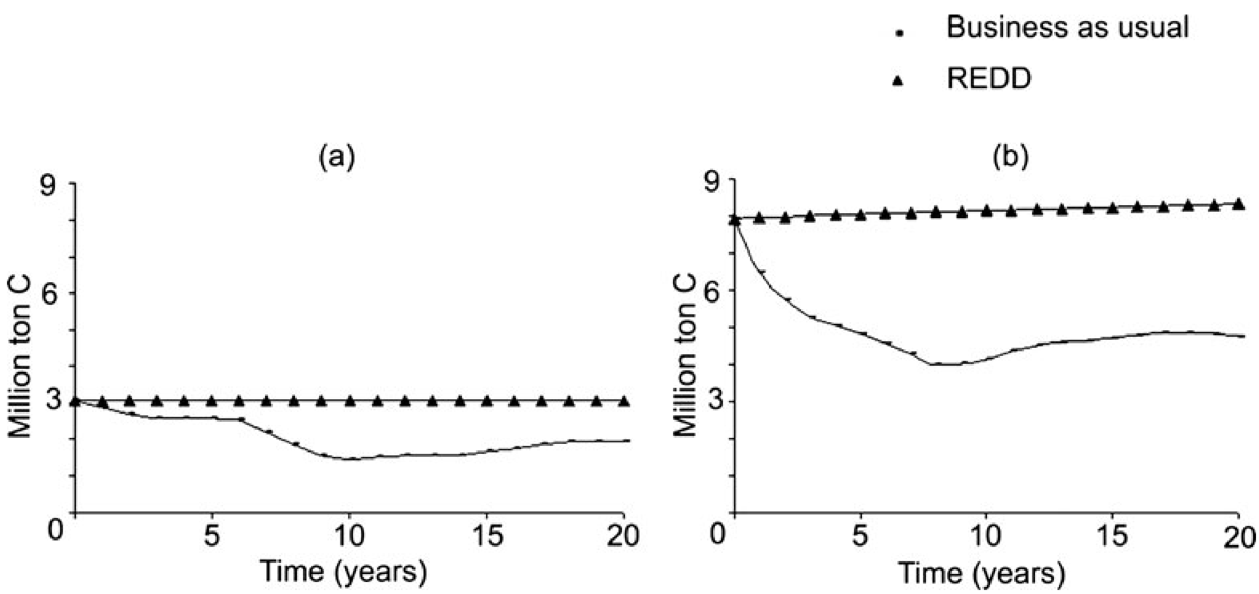

Figure 1 Total carbon stock in the off-reserve area for (a) area currently covered with old-growth forest under "business as usual" (scenario 1) and "avoided deforestation of old-growth forest" (scenario 2); and (b) area now covered with secondary and old-growth forest under "business as usual" and "avoided deforestation of standing secondary and old-growth forest" (scenario 3).

and at what carbon price this would not happen (Appendix S1). In general, discount rates are high among low-income farmers (Campbell *et al*. 2006). However, Richards & Asare (1999) argue discount rates to be low among Ghanaian cocoa farmers, since many see cocoa farming as a type of old age pension, suggesting a discount rate of 6%. We used discount rates of 6 and 20%.

Three scenarios were modeled. Scenario 1 explores business as usual: old-growth and secondary forest are converted into cocoa plantations extrapolating the linear trend for the period 2000–2007. Scenario 2 explores avoided deforestation of old-growth forest. In this scenario, we assume all large landholders with old-growth forest on their land opt to receive REDD payments and no old-growth forest is converted into cocoa plantations. Scenario 3 explores avoided deforestation of all forest. In this scenario, we assume all farmers with standing old-growth and secondary forest on their land opt to receive REDD payments and no forest is converted into cocoa plantations. Only degraded cocoa plantations and non-forested land is used for new cocoa plantations.

Payments are simulated only for forest outside reserves since the forest reserves are already under a national forest conservation strategy and are not available to local farmers. We assume an international carbon price of US\$10/ton CO_2 to be paid by investors (Table 1), of which 75% is lost to transaction costs (Table 1) and thus US\$ 2.5/ton CO_2 would be received by the farmer reducing emissions on his land. For the payments we assumed a 20 year payment contract, with a high up-front payment because of the start-up costs involved in REDD (Table 1).

Results

Land use changes and carbon

For scenario 1, carbon stock declines rapidly over 20 years (Figure 1). These scenarios (Figure 1a and b) are used as the baseline for the calculation of REDD payments. The carbon stock on the land now covered with old-growth forests outside reserves decreases by 37% from 3 to 1.9 million ton C (Figure 1a) and for old-growth and secondary forest together the carbon stock decreases by 40% from 7.9 to 4.8 million ton C (Figure 1b). Already after 3 years, all old-growth forest outside the reserves is converted into cocoa plantation, excluding sacred forests. Once old-growth forest is gone, secondary forest cover decreases faster as it gives way to new cocoa plantations. The total cocoa area expands approximately 10% after 11 years to 220,000 ha after which there is no secondary forest or other land for further expansion. After 20 years the food crop area per household has decreased by 10% due to population growth and cocoa expansion.

Under scenario 2, the expansion of cocoa comes to an end after 7 years, when cocoa has increased by 4% to 212,000 ha. At the start of the simulation the farmers with old-growth forest shift their demand for new cocoa land to secondary forest resulting in the depletion of

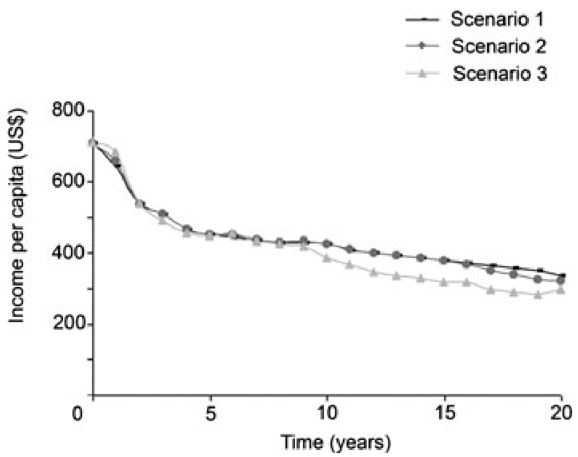

Figure 2 Income per capita for the rural population in the district under three scenarios: (1) business as usual, (2) no conversion of old-growth forest, and (3) no conversion of standing secondary and old-growth forest.

secondary forest after 6 years. Under scenario 2, 1.2 million ton C is prevented from being emitted compared to business as usual (Figure 1a).

Under scenario 3, after 1 year, all nonforested fallow land has been converted to cocoa plantations reaching their maximum cover of 205,000 ha. The rest of the simulation the cocoa area decreases as old cocoa turns into fallow land left unused for 3 years. The food crop area per household drops by 15% after 20 years because of the limitations placed on forest conversion. Some secondary forest regenerates into old-growth forest. Under scenario 3 carbon in the off-reserve area currently covered by old-growth and secondary forest increases from 7.9 to 8.3 million ton C (Figure 1b) and 3.5 million ton C is prevented from being emitted compared to business as usual.

Rural income and opportunity costs

The average per capita income under scenario 1 decreases from US$ 710 to 340 over 20 years for Wasa Amenfi West's rural population (Figure 2). This is partly due to the decrease in cocoa price, dropping by 40% after 20 years following the World Bank's forecast (Table 1). It is also due to the shortage of land for new cocoa plantations and declining soil fertility, while at the same time land has to be shared among the expanding future generation. It is likely that migration out of the district will increase in this situation, though this was not simulated.

Smallholders have no access to old-growth forest and are therefore not receiving payments for halting deforestation. Under scenario 2, average annual REDD payments vary between US$ 18–180 per ha, while average annual cocoa net income varies between US$ 388–563 per ha. For the first 7 years of the simulation large landholders have enough land without old-growth forest to continue cocoa expansion at the current rate. Since cocoa is simulated to become productive after 8 years, the cocoa planting restrictions after year seven only impact income after year 15 when it drops below income under business as usual (Figure 2).

Under scenario 3, average annual REDD payments vary between US$ 16–159 per ha, while average annual cocoa net income varies between US$ 388–563 per ha. Cocoa expansion is already restricted after 1 year, impacting income after 9 years (Figure 2). However already after 2 years, average per capita income under scenario 3 drops below business as usual caused by the lack of food crop land for smallholders. Smallholders are simulated to shorten their cocoa cycle, converting older productive cocoa to food crops, in order to maintain the minimum food crop plot of one ha per household.

The opportunity costs of cocoa production are not met by REDD payments. However, since REDD payments would be received immediately while cocoa starts producing after 8 years, discounting the income flows increases REDD's attractiveness. There is little to choose between the scenarios in terms of net present value (Table 2, first column), though scenario 3 appears to provide the least incentives. Scenario 2 becomes slightly more attractive to business as usual applying a high discount rate; big future losses in income can be compensated by a small up-front payment when discounting. The low level of net present value variation among the scenarios is largely due to the fact that limiting cocoa expansion affects income with an 8-year delay, the time for cocoa to start producing.

Alternative assumptions

Changing some assumptions on cocoa and carbon prices in the model, result in the net present values given in Table 2 (the alternative assumptions columns). The outcomes appear sensitive to the discount rate applied, though scenario preferences do not change with altering cocoa prices. When applying a 20% discount rate, increasing the carbon price paid by investors from US$ 10 to 15, net present values for scenario 1 and 3 are about equal and doubling the carbon price, scenario 3 even gives a slightly higher net present value.

Contract breaking and the price of stopping deforestation

If the farmers conserving their old-growth forest (scenario 2) would merely aim at profit maximization they would break the contract after year five and continue the

Table 2 Net present values (US$) for 20 year income flows under the three scenarios with current and alternative model assumptions applying a 6 and 20% discount rate

	Net present value – 6% discount rate					Net present value – 20% discount rate				
		Alternative assumptions					Alternative assumptions			
		Cocoa price for farmer fixed at US$1.46/kg (price 2009)	Cocoa price increasing with 40% over 20 years	Carbon price paid by investors US$15	Carbon price paid by investors US$20		Cocoa price for famer fixed at US$1.46/kg (price 2009)	Cocoa price increasing with 40% over 20 years	Carbon price paid by investors US$15	Carbon price paid by investors US$20
Scenario 1	5,169	7,455	8,677	5,169	5,169	2,405	3,270	3,608	2,405	2,405
Scenario 2	5,170	7,437	8,641	5,186	5,202	2,419	3,283	3,619	2,428	2,437
Scenario 3	4,922	7,013	8,092	4,974	5,026	2,377	3,198	3,512	2,405	2,432

conversion to cocoa. This scenario results in some delay in carbon emissions but not in net emission reduction or conservation of old-growth forest over 20 years. To stop the deforestation of old-growth forest, a carbon price of at least US$ 55–60/ton CO_2 is needed. Deforestation of old-growth and degraded forest is stopped at a minimum of US$ 70–75/ton CO_2.

Discussion

Assuming an annual REDD payment, farmers are likely to accept REDD initiatives, especially if a large up-front payment is planned as may occur with REDD funds pouring into new initiatives (Angelsen 2008, p. 128). But soon after the up-front payment is made, there may be a high incentive to break the contract, given the higher financial benefits from cocoa production. To keep avoiding deforestation after the contract period, payments should continue after 20 years increasing the price per ton CO_2. If cocoa prices remain at current values or increase, opportunity costs of cocoa will be even higher and therefore carbon prices should be even more than US$ 55/ton CO_2 to stop deforestation of old-growth forest. Price fluctuations in tropical agricultural commodities are high (e.g., World Bank 2009a and b), providing a difficult context for REDD which has to be based on long-term contracts.

If farmers opt for REDD this will likely widen the gap between rich and poor given that 90% of the carbon is stored in forest on large landholdings owned by <14% of the rural population. Furthermore, poor people who lease land may lose access to the land as large landholders may claim back their leased-out land for REDD purposes. The food crop area per capita decreases more under scenario 3 than under business as usual, and they may opt for cash cropping rather than growing enough food exposing households to greater food insecurity. If REDD has negative impacts on human wellbeing, and it increases rural differentiation, then policy makers may not support REDD, given their overriding concern with development and not environmental issues. A potential source of conflict is the unclear tenure over carbon; agreements on access to carbon payments and benefit sharing need to be negotiated.

If REDD becomes an option it is likely that some landholders will opt for REDD and others wont, unlike our scenarios where all do. There may be forest patches with lower cocoa suitability and thus lower opportunity costs where REDD is more attractive (e.g., on steep slopes). However, in our simulation REDD payments are so far from competing with opportunity costs of cocoa that even low-productive areas may be preferred for cocoa than REDD.

In landscapes comparable to this study, with little remaining unprotected old-growth forest, high population pressure, and lucrative income from cash crop production, REDD payments based on current carbon prices would not outcompete agricultural production. REDD investments based on current carbon market conditions made in such landscapes would most likely be received with some enthusiasm, perhaps initially shift deforestation from old-growth to degraded forest, for the strategy to be abandoned after some years. Such an investment would not result in long-term reduction of carbon emissions. That high prices for cash crops (including biofuels) can undermine REDD strategies has also been shown in Asia (Butler *et al*. 2009), while in some parts of Africa, e.g., where shifting cultivation is practiced, REDD could be a more lucrative option than current land uses (e.g., Bellassen & Gitz 2008).

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Full description of the method, model structure and dynamics.

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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