



Reducing Emissions from Deforestation and Degradation in Cameroon—Assessing costs and benefits

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18 **Abstract**

19
20 A new momentum is underway to account for emissions from “avoided deforestation
21 and degradation” at the United Nations Framework Convention on Climate Change
22 (UNFCCC). This paper assesses the feasibility of one of the Reducing Emissions from
23 Deforestation and Degradation (REDD) mechanisms currently discussed, namely that of
24 “Compensated Reduction”, in the case of Cameroon. Here we assess the differential revenues
25 that a farmer could get from one hectare of land out of two alternative land-uses: shifting
26 cultivation, the traditional land-use pattern in southern Cameroon, or carbon credits as
27 compensation for the conservation of primary forest. It is found that a break-even price of
28 \$2.85 per ton of carbon dioxide equivalent would level shifting cultivation with
29 “Compensated Reduction”. This result suggests that at current carbon prices, and
30 independently from variations in the discount rate, it could already be more profitable to
31 preserve the primary forest rather than to log it in order to grow crops.

32
33 Key words: deforestation, cost-benefit analysis, Cameroon, forest, slash-and-burn, agriculture;
34 carbon; opportunity costs

35 **Introduction**

36
37 Each year, an estimated 13 million hectares of tropical forest are destroyed, leading
38 14,000-40,000 species to extinction and emitting 2.1 Gt of carbon, that is 17% of total
39 anthropogenic emissions of greenhouse gas (Kremen, *et al.*, 2000, Rogner, *et al.*, 2007).
40 These figures show why the Land-Use, Land-Use Change and Forestry (LULUCF) sector
41 ought not to be dismissed as a credible part of the solution to climate change (UNFCCC,
42 2007). It is often argued that planting trees will not sequester nearly enough carbon to offset
43 all industrial emissions, and it is quite true. However, since deforestation is an important
44 source of emissions, reducing it is a key action to tackle climate change, not only to preserve
45 stocks in forest ecosystems, but also to maintain forest sinks and their capacity to store carbon
46 in the future (Gitz and Ciais, 2004). Indeed the potential amount of carbon that could be
47 conserved and sequestered through an aggressive program of such changes in LULUCF

practices over the first half of the 21st century was estimated at 12-15% of the “business-as-usual” fossil-fuel emissions over the same time period (Brown, 1999).

This paper is focused on one particular idea for tackling the problem of deforestation, that is “Compensated Reductions” (CR), and on one particular country, Cameroon. Cameroon was especially interesting because it is one of the six countries forming the Congo Basin, an area that contains the second largest area of contiguous rainforest after the Amazon, making up to 15% of total remaining rainforests in the world and 90% those remaining in Africa (Justice, *et al.*, 2001).

Cameroon is approximately the same size as Spain and is often referred to as “Africa in miniature”. The continent’s main vegetation types are represented in the country: the north is covered by Sudano-sahelian savanna, the centre by high altitude moist savanna, and the south by tropical rainforests. It could as well be described as “African deforestation in miniature” since the causes of deforestation in this country are diverse and complex, and could be considered as a summary of the problem in Central Africa. Another advantage of Cameroon is that it is relatively well documented compared to the other countries of the Congo Basin.

In this paper we seek to find economic rationale for forest preservation versus shifting cultivation in Cameroon. To do so, we compute the “break-even price” of carbon at which these options yield comparable revenues. Several studies have already undertaken this computation for other countries (Osafo, 2005, Silva-Chavez, 2005, Grieg-Gran, 2006, Nepstad, *et al.*, 2007). However these analysis often rely on other studies for their assessment of land-use returns, and therefore never detail the uncertainty associated with crop prices variations or assumptions on other parameters. Here we explicitly model the revenues of the different land-use, and test the robustness of our analysis against parameters uncertainty through a Monte-Carlo procedure and a sensitivity analysis. This assessment of uncertainty is especially important in the case of Cameroon where data is not always perfectly reliable.

We limited the scope of our analysis to the opportunity costs of CR, and did not assess the transaction costs and the risks associated with the actual implementation of programs and projects aimed at reducing deforestation.

Methods

Compensated Reduction

Compensated Reduction (CR) is one of the “Reducing Emissions for Deforestation and Degradation” (REDD) mechanisms currently being discussed at the UNFCCC. Other competing proposals are the “nested approach” and the “compensating fund” (Estrada, 2007, Federative Republic of Brazil, 2007). As first described in Santilli *et al.*, 2005, the CR mechanism consists in setting economic incentives to reduce emissions from tropical deforestation by giving a monetary value to carbon stored in trees, thereby creating a financial incentive for forest protection by turning tropical forests into valuable assets and increasing the likelihood that they will be protected. As a result of the recent entry into force of the Kyoto Protocol (KP), as well as the start of the EU Emissions Trading Scheme (EU ETS), most developed economies now are carbon-constrained and for them carbon is no longer an economic externality. CR seeks to use this monetary value of carbon by creating an incentive to reduce deforestation emissions, which can then be turned into a tradable commodity (Santilli, *et al.*, 2005).

Under CR, developing countries that elect to voluntarily reduce their national GHG emissions from deforestation, using their historical (for example, 1980-1990) annual average rate of deforestation as a baseline, would be authorized to sell carbon certificates to government and private investors *post facto*. Measurable and quantifiable environmental

benefits will be required first before a country can receive carbon credits. National deforestation will be measured and verified by robust satellite imagery techniques and, once the emission credits are sold, participating developing countries would agree not to increase – or further reduce – deforestation rates in future commitment periods (provided developed countries fulfill their reduction obligations). As stated by European negotiators at the UNFCCC, the national approach resolves the issue of “leakage” within national boundaries (Bouyer and Merckx, 2007): if a conservation project leads to an increase of deforestation elsewhere in the country, the national emissions from deforestation will not go down and credits will not be issued.

CR would nevertheless have to deal with the issue of “permanence” that is used to plague forestry carbon credits: as CR sets a “no regret” target, it has to guarantee the carbon credits of the first commitment period against an increase in deforestation during the second commitment period. It could do so by setting up an insurance fund (Federal Republic of Germany, 2007). Based on similar existing schemes in the voluntary carbon market (Bellassen and Leguet, 2007), this could amount to a risk premium of around 20%. Thus, CR credits may not suffer such high discounts as those estimated by Chomitz and Lecocq (2003) for temporary forestry CDM credits.

The *ex post* valuation of avoided deforestation would nevertheless generate a liquidity gap for participating countries and stakeholders. To bridge this gap, they could seek advance financing to fund deforestation reduction programs from private investors or negotiate agreements with bilateral and multilateral financial institutions, provided that an appropriate liability mechanism can be agreed upon. The World Bank has already initiated a Forest Carbon Partnership Facility that will provide advance funding. They could also issue discounted carbon bonds, which could be redeemable in the future, subject to verification and certification of reductions. Provided appropriate liability, responsibility, enforcement, and verification mechanisms exist, an instrument like this is likely to create substantial incentives to reduce tropical deforestation through market access.

CR explicitly aims at valuing the carbon content of tropical forests. It is far from a perfect valuation since tropical forests provide many more ecosystem services than holding carbon: they play a role in the local climate, they are a tremendous source of biodiversity, and three quarters of the world’s population depend directly on them for medicinal plants (Serageldin, 1992). But, as imperfect as this valuation mode is, the financial incentive it offers to protect tropical forests could be strong enough to foster forest conservation in the tropics. And it is this possibility that we are trying to assess in this paper.

The specificity of CR compared to other potential REDD mechanisms is the direct link with the carbon markets issued from the Kyoto Protocol. The financial incentive provided by other mechanisms, such as the compensating fund proposed by Brazil in the UNFCCC negotiations (Federative Republic of Brazil, 2007), would likely be limited by the size of the fund. Whereas the value of carbon credits, exchangeable on all carbon markets, would probably have a wider range of variation. Their theoretical production cost, that is the opportunity costs of foregoing shifting cultivation to the financial compensation, is therefore especially worth assessing.

An essential requirement of Compensated Reduction: reliable monitoring

An absolute requirement for implementing CR is to have a reliable estimate of deforestation rates. Indeed, only after the precise measure of reductions in deforestation rates can compensation be awarded.

Deforestation – Through remote sensing, Tucker and Townshend (2000) estimated that 90% of the scenes must be sampled, in order to obtain an estimate with an accuracy

144 within $\pm 20\%$ of actual deforestation rates. However, the scenes are generally available and it
145 is most often the analysis that is lacking (Zhang, *et al.*, 2005).

146 *Forest degradation* – Zhang, *et al.* (2005) managed to discern primary forests from
147 degraded forests on satellite images in Central Africa. If this result proves to be repeatable
148 and reliable, a CR scheme could even be applied to the loss of carbon resulting from selective
149 logging. However, since it is still uncertain, we chose here to pursue only the study of CR as
150 applied to deforestation *stricto sensu*.

151 **State of southern Cameroon's Forested Lands**

152 Cameroon possesses an estimated 17 million hectares of tropical rainforest in the
153 southern part of the country, that is about one-tenth of the remaining rainforests of the Congo
154 Basin (Sunderlin, *et al.*, 2000). Estimates of the extent of closed canopy moist tropical forests
155 range from 155,000 km² (33 percent of national territory) to 206,000 km² (44 percent of
156 national territory) (Essama-Nssah and Gockowski, 2000). That is all the more worrisome
157 since Cameroon has the highest percentage of logged forest of any African nation with
158 substantial rainforest. The southern part of Cameroon, where tropical forest lies, has
159 traditionally been sparsely populated: in 1987, the average density of rural population in
160 southern Cameroon was only 8.3 inhabitants per km². This allowed shifting cultivation to be
161 practiced without excessive pressure on the rainforest. Depending on the sources, shifting
162 cultivation is estimated to provide for up to 20-50 people per km² in a sustainable way (Ndoye
163 and Kaimowitz, 2000). However, this is currently changing and the rainforest now faces two
164 dangerous threats: forest degradation and deforestation.

166 *Forest degradation* – The first threat is forest degradation. It is often due to
167 unsustainable logging and its consequences. Since roads or railroads are scarce in the region,
168 wood exploitation is costly and most of the time, it only makes economical sense to remove
169 the very few highly valuable trees such as Okoumé. On average, selective logging removes
170 only one tree per hectare and 10% of canopy cover, and overall it is only responsible for only
171 10% of the annual national loss of biomass (Justice, *et al.*, 2001). But even such “surgical”
172 removals are devastating for the forest ecosystem: in terms of direct consequences, it removes
173 20-35% of the total carbon amount and threatens the survival of the targeted tree species in
174 the long run. It also brings along a lot of other “collateral” damages: to export these trees,
175 roads are cut through the forest, leading to further damages and opening an easy access for
176 poachers, hunters, and eventually shifting cultivators (Mertens and Lambin, 2000).

178 *Deforestation stricto sensu and deforestation factors* – Although forest degradation is
179 often considered to be the most important threat to rainforests in the Congo Basin (Zhang, *et*
180 *al.*, 2005), the situation in Cameroon is different. Deforestation *stricto sensu*, that is clear-
181 cutting, has indeed become of comparable importance. As convincingly shown by Sunderlin
182 (2000), declining prices and subsidies for coffee and cocoa during the late 1980s crisis shifted
183 agricultural production from such cash crops to food crops (plantain, cassava, corn, yam, ...).
184 And as food crops require much more land than cash crops since a lot of them have to be left
185 fallow every year, this shift triggered a measurable increase in deforestation.

186 The general impoverishment of the country led many city-dwellers to migrate back to
187 the rainforested provinces: except for the South Province, all the provinces in the forest zone
188 of Cameroon had, at least until recently, a large positive migratory balance (Mertens and
189 Lambin, 2000). Consequently, the population pressure on the rainforest also dramatically
190 increased (+45% over the post-crisis decade).

191 As a result, deforestation due to shifting cultivation and fuelwood harvesting, both
192 being fuelled by population growth, has become a priority concern (Ndoye and Kaimowitz,

2000): agriculture has been rated by CARPE as a severe threat – one “expected to cause irreversible damage within the next 10 years” – and it is widely reckoned to be the cause of 80-95% of total deforestation in Cameroon (CARPE, 2005). And while these estimates are to be taken with caution, it is alarming that the models for the Congo Basin point out to a forest loss on the order of 50% by 2050 if nothing is done (Zhang, *et al.*, 2002). Taking an average figure of 309 tons of carbon emitted per hectare of deforested land (Palm, *et al.*, 2000), this would amount to a total emission of around 2.6 GtC.

A simple cost model for shifting cultivation

The process of shifting cultivation in the Congo Basin has been described in numerous studies. It is the traditional agricultural technique, and it is still in practice in most fields in Cameroon (Grieg-Gran, 2006). Figure 1 is a way of representing it, based on Brown’s description of the process (Brown, 2004).

During the long dry season, the forest is cleared and during the following rainy season, melons are planted, sometimes with plaintain. After the harvest, the old melon field (“fulu”) is cultivated with mixed crops (plaintain, cassava, groundnuts, corn, ...) for C (up to 3) years. After that time, yield becomes so low that the field is put to fallow for a variable F (4 to 23) number of years (Palm, *et al.*, 2000).

By furthering this description of shifting cultivation, we want build a simple economic model able to compute the average revenue per hectare R of a parcel over N years following the decision to put it under this use.

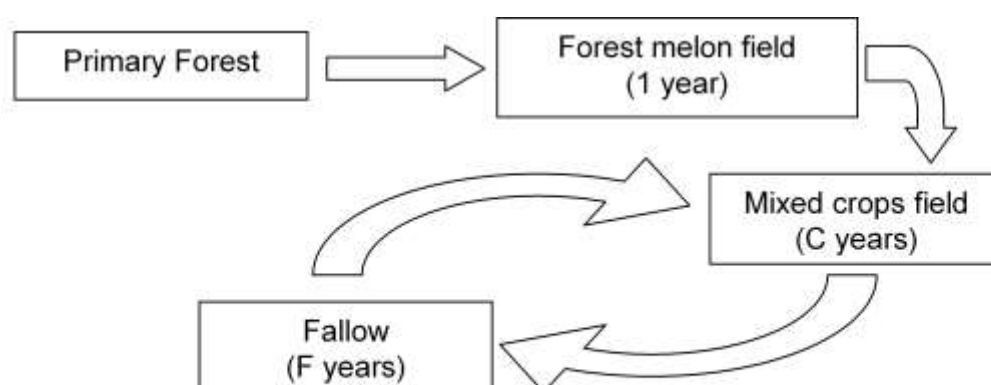


Figure 1. The process of shifting cultivation (based on Brown’s description)

Figure 1. The process of shifting cultivation (based on Brown's description)

Hypothesis – To facilitate the calculations, the model simplifies the process described in Figure 1 thanks to three seemingly reasonable assumptions:

1) The fallow time is assumed to be short enough so that the field doesn’t grow back to a primary forest. Thus, we only consider the cycle from mixed crop field back to mixed crop field, with one year of melon only when deforestation first occurs. According to most studies, fallow time rarely exceeds 20-25 years.

2) As data is most reliable for plantain and cassava, we assumed that each hectare was planted half in plantain and half in cassava. This assumption is unlikely to introduce a strong bias in results as these two crops are by far the most commonly grown subsistence crops in Cameroon (Kamegne and Degrande, 2004, FAO, 2005).

3) We set C, the cultivation time, and F, the fallow time, as constants. This is unlikely to be strictly true since farmers adapt their choices to labour and land availability, crop prices

and other factors (Dvorak, 1992). However, since the main output we are interested in is an average over time and space, it is not a great concern.

Estimated revenue – Based on this, the average revenue is obtained by the formula:

$$R = \sum_{I=1}^N (1 - \alpha)^I * R_I \text{ where } R_I \text{ is the revenue during year } I \text{ and } \alpha \text{ is the discount rate.}$$

The average revenue of a cultivated patch of land is the difference between the price of total output and the cost of total input. For shifting cultivation as it is practiced in Cameroon, the only input is individual labour: there is very little use of fertilizers, machinery or even animal traction (Brown, 2004). The average revenue R_I of a cultivated parcel at year I is therefore given by:

$$R_I = Y_I * P_I - L_I \quad (1)$$

where Y_I is the yield of the crop cultivated at year I , P_I its producer price and L_I the annual opportunity cost of labour at year I .

The opportunity cost of individual labour (that is here, how much would the farmer get from another activity since he doesn't pay himself for farming) is difficult to value. We decided to approximate it from the median income in Cameroon, weighed by the average land area cultivated by each farmer:

$$L_I = \frac{MI \times NF}{AL} \quad (2)$$

where L_I is the annual opportunity cost of labour at year I , MI is the median income in Cameroon, AL is the total area of agricultural land and NF is the total number of farmers (see paragraph on *parameters estimation* for the actual figures).

A simple cost model for Compensated Reduction

As opposed to cultivating the land patch over N years, the stakeholder could make the choice to integrate it into a CR scheme. In order to compare these two alternative, we propose the following model for the revenues of CR. Since CR takes place at the national scale, the compensation has to be divided among all the patches that are under a conservation plan: the choice of conservation rather than cultivation has to be made for all the patches, whereas only those which fall under the historical threshold D_0 are compensated for.

Model hypothesis – The commitment period after which the deforestation rate is monitored and after which compensation is received is 5-year long.

Estimated revenue – Based on this model, the average revenue per hectare (R') of forest that would be conserved under the "Compensated Reduction" scenario is given by the formula:

$$R' = \frac{\text{Total revenue for "avoided emissions" compared to historical threshold}}{\text{Total land under "conservation"}}$$

$$R' = \frac{(D_0 - D_5') * 5 * \text{Carbon price} * \Delta_{\text{carbon}} * \theta * (1 - \alpha)^5}{(D_5 - D_5') * 5}$$

$$R' = \frac{(D_0 - D_5')}{(D_5 - D_5')} * C_P * \Delta_C * \theta * (1 - \alpha)^5 \quad (3)$$

where D_0 is the historical surface of yearly deforested land
 D_5 is the surface of yearly deforested land during the 5 years under the “business as usual” scenario
 D_5' is the surface of yearly deforested land during the 5 years under the “Compensated Reduction” scenario
 C_P is the price of a ton of carbon
 Δ_C is the difference of time-averaged carbon content between a primary forest and a field under shifting cultivation
 α is the discount rate
 θ is the conversion factor from C to CO₂e
The discount rate is taken into account because under the chosen model of Compensated Reduction, the compensation is only gotten after the commitment period. The length of the commitment period is assumed to be 5 years, as the first commitment period of the Kyoto Protocol, and the second period of the European Trading Scheme.

$\frac{(D_0 - D_5')}{(D_5 - D_5')}$ in equation (3) represents a “dilution” of the compensated revenue: under a

CR scheme, compensation is awarded at the national level for every hectare preserved under the historical baseline ($D_0 - D_5$). However, if deforestation pressure is expected to increase ($D_5 > D_0$), a policy that attempts to bring it under control would have to spread this revenue over more land ($D_5 - D_5'$) than the hypothetical surface corresponding to the revenue ($D_0 - D_5'$).

Parameters estimation

In order to compare these two potential sources of revenue, it is necessary to estimate the different parameters of the two models.

- Estimated revenue of shifting cultivation: $R = \sum_{t=1}^N (1 - \alpha)^t \times (Y_t \times P_t - L_t)$ (4)

We set the discount rate α at 5%, as is sometimes the case in economic studies focused on Central Africa (Sankhayan and Hofstad, 2001). N was set at 50 years. This typical timeframe for 2 generations is long enough to compare cumulated revenues for an initial land-use decision. Other comparable studies have limited their timeframe to 30 years (Grieg-Gran, 2006).

Price, yield, and cost of labour estimates (P_t , Y_t , and L_t) – Data on yields and prices are difficult to obtain for Cameroon. Moreover, their meaningfulness is questionable since, as it is true that most farmers sell part of their crops on local markets, the bulk of the production is for self-consumption: for example, only an estimated 33% of the cassava in each exploitation is sold on markets (Dury, *et al.*, 2004).

One method to estimate both price and yield is to take the FAO average data for Cameroon. It is often not deemed to be very reliable since it is based on scarce, poorly checked reports, and on modelling. However, in our case, it corresponded well with other studies on Southern Cameroon, taking into account the discrepancy between retail price and producer price as estimated by Dury *et al.* (2004). The actual figures are displayed in table 1. As for the three parameters used to compute the opportunity cost of labour (median income, total agricultural land and total number of farmers), we relied on national statistics as provided by the FAO (2005) and the UNDP (2007): $MI = 730 \text{ \$} \cdot \text{year}^{-1}$, $AL = 7.2 \text{ million ha}$, $NF = 3.7 \text{ million}$ (this figure pools together all agricultural workers, but as there is 4 times as much cropped land as pastures, this approximation should not be too much biased). L_t was thus set at $380 \text{ \$} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$.

	Plaintain	Cassava			
Yield (t.ha ⁻¹)	6 ± 0.3	12.5 ± 1.5			
1996 – 2005 Mean (± annual standard deviation)					
Producer Price (\$·t ⁻¹)	90.9 ± 19.7	90.8 ± 19.3			
1996 – 2002 Mean (± annual standard deviation)					

Table 1. FAO data for crop prices and yields in Cameroon (Source: FAO (2005))

- Estimated revenue of Compensated Reduction: $R' = \frac{(D_0 - D_5')}{(D_5 - D_5')} * C_P * \Delta_C * \theta * (1 - \alpha)^5$ (5)

We set the same $\alpha = 5\%$, and $C_P = 27.3$ \$.tCO₂e⁻¹ which was the price of a second period credit on the European Carbon Exchange (ECX) on May 15th, 2007. θ is the conversion factor from C to CO₂e.

Time-averaged carbon content estimate (Δ_C) – At climax, tropical forests are net emitters of N₂O and net absorbers of CH₄, the two other major greenhouse gas. However, since the difference in these fluxes is slight between tropical forests and other land-uses in the tropics, we chose to ignore these gases and to concentrate here on CO₂ fluxes (Palm, *et al.*, 2000).

Several studies estimate the carbon content aspects of land use changes. We chose to use the one conducted by Palm *et al.* (2000) both because it fits our needs well and because most of her data was gathered in southern Cameroon (see table 2). Moreover, it has gained important international recognition as the IPCC relies heavily on it.

	Primary rainforest	Degraded rainforest	Short fallow (C = 2, F = 4)	Medium fallow (C = 2, F = 9)	Long fallow (C = 2, F = 23)	
Time-averaged carbon content (tC.ha ⁻¹)	306 ± 99 (Indonesia)	228 ± 27	4.52 ± 1.84	31.51 ± 8.29	77 ± 21.3	
N.B.: These figures include above-ground biomass and litter. In this study, the changes in root and soil carbon is not accounted for as the measures were not conclusive. However, it is estimated not to vary much overall for medium and long fallow times (90-100% of soil C remaining for the 0-20 cm layer) and to decrease by 35% for short fallow times.						

Table 2. Time-averaged carbon content of different land-uses (adapted from Palm *et al.* (2000))

Deforestation rates – Whereas numerous studies have estimated past deforestation rates (D₀) in Cameroon, very few venture at projecting future deforestation rates (D₅) for Cameroon in the future based on population growth, road construction, etc ... The finding of both types of studies are summarized respectively in table 3 and 4.

Source	Period	Net annual deforestation rate		
Kotto-Same, <i>et al.</i> (1997)	1973 – 1988	~0.8 % (133 000 ha)		
Mertens and Lambin (2000)	1973 – 1986	0.28 % (286 ha)		
	1986 – 1996	0.76 % (515 ha)		
FAO (2001)	1980 – 1990	0.6 % (122 000 ha)		
	1990 – 2000	0.9 % (221 763 ha)		
Laporte, <i>et al.</i> (1995)	Mid 1970s – 1989	0.8 % (130 000 ha)		
Myers (1991)	1980 – 1988	1.2 % (200 000 ha)		
as cited in Ndoye and Kaimowitz (2000)				
Schmidt (1990)	1981 – 1990	0.5 % (80 000 ha)		
as cited in Ndoye and Kaimowitz (2000)				
WRI (1994)	1976 – 1986	0.8 % (190 000 ha)		
as cited in Ndoye and Kaimowitz (2000)				

Table 3. Historical deforestation rates in Cameroon

Source	Period	Net annual deforestation rate
Zhang and Justice (2001)	1990 – 2050	0.62 % (100 713 ha)
Justice, <i>et al.</i> (2001)	1990 – 2050	0.62-0.7 % (100 713-122 000 ha)

Table 4. Projected deforestation rates in Cameroon

For the model, we chose the same $D_0 = D_5 = 150\,000$ ha/yr (middle value of the range of estimates $80\,000$ - $220\,000$ ha.yr⁻¹) and $D_5' = 0.95 \cdot D_5$ (this assumes that a CR scheme would have reduced the deforestation rate by 5% during the 5 years). The underlying assumption, backed by the review of projections displayed on table 4, is that the business as usual rate of deforestation is the historical rate. In this case, there is no “dilution” and the CR revenue is strictly proportional to the amount of land that “needed” protection.

Results

Model run

A summary of the parameters chosen to run the models is provided in table 5. By running the models for a medium fallow time ($C = 2$ and $F = 9$) which seems to be a reasonable average, we obtain the results displayed in table 6.

Parameter	Estimate used in models	Source
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(± indicates the standard deviation, as used in the monte-carlo procedure)

C (cultivation time)	2 years	Palm <i>et al.</i> 2000
F (fallow time)	9 years	Palm <i>et al.</i> 2000
α (discount rate)	5%	Sankhayan and Hofstad, 2001
Y _{IC} (cassava yield)	12.5 ± 1.5 t.ha ⁻¹	FAO 2005, Dury <i>et al.</i> 2004
Y _{IP} (plaintain yield)	6 ± 0.3 t.ha ⁻¹	FAO 2005, Dury <i>et al.</i> 2004
P _{IC} (cassava producer price)	90.8 ± 19.3 \$.t ⁻¹	FAO 2005, Dury <i>et al.</i> 2004
P _{IP} (plaintain producer price)	90.9 ± 19.7 \$.t ⁻¹	FAO 2005, Dury <i>et al.</i> 2004
L _I (opportunity cost of labour)	380 \$.ha ⁻¹ .year ⁻¹	FAO 2005, UNDP 2007
D ₀ (historical deforestation rate)	122 000 ha.year ⁻¹	see Table 3
D ₅ (deforestation rate under business as usual)	122 000 ha.year ⁻¹	see Table 3
D ₅ ' (deforestation rate under business as usual)	115 900 ha.year ⁻¹	see Table 3
C _P (carbon price)	27.3 \$.tCO ₂ e ⁻¹	EU ETS 2005
Time-averaged carbon content of a primary forest	306 ± 99 tC.ha ⁻¹	Palm <i>et al.</i> 2000
Time-averaged carbon content of a cultivated patch of land	31.5 ± 8.29 tC.ha ⁻¹	Palm <i>et al.</i> 2000
Δ _C (difference in time-averaged carbon content of a primary forest and a cultivated patch of land)	274.5 tC.ha ⁻¹	Palm <i>et al.</i> 2000
θ (conversion factor from C to CO ₂ e)	3.67	NA

Table 5. Summary of parameters used in the models

	R (net present value of cultivation)	R' (net present value of CR)	Break-even price of CO ₂ (BEP)
Net present value per ha	\$ 2 221 ± 329	\$ 21 260 ± 807	\$ 2.85 ± 0.44
Total yearly net present value over the area affected by CR (5% of 122 000 ha)	M\$ 13.5 ± 2	M\$ 129.7 ± 5	

Table 6. Model outputs

± indicates the standard deviation as computed by the Monte-Carlo analysis

The standard error is obtained by a Monte-Carlo procedure of which variables are crop yields, crop prices, and the time-averaged carbon content of primary forests.

The break-even price of CO₂ (BEP) is the price of CO₂ from which it begins to be financially more interesting to undertake Compensated Reduction rather than shifting cultivation on a parcel of land. It is computed from the following equation:

$$R = R' \Leftrightarrow R = \frac{(D_0 - D_5')}{(D_5 - D_5')} * BEP * \Delta_C * \theta * (1 - \alpha)^5 \Leftrightarrow BEP = \frac{R * (D_5 - D_5')}{\Delta_C * \theta * (1 - \alpha)^5 * (D_0 - D_5')} \quad (6)$$

Sensitivity analysis

In this analysis, effect of uncertainty is taken into account directly by a Monte-Carlo procedure. However, for the three parameters (discount rate, the fallow time and the opportunity cost of labour), for which explicit distribution of uncertainty was not known, we further conducted a sensitivity analysis. We find that a change in discount rate has only a minor effect on break even prices. The results show that the model is very robust to a change in discount rate. It is also reasonably robust to changes in fallow time or opportunity cost of labour (see table 7). The robustness of the model to changes in discount rates shows that it plays a comparable role in both land-use options. This property is nevertheless very interesting as discount rates are often an important point of controversy in economic studies. In this case, it is indeed possible that a higher discount rate than 5% would be more appropriate for shifting cultivators. Indeed, for other African farmers such as the groundnut growers of Central Senegal, Tschakert (2004) uses a discount rate of 20%.

The model is less robust to changes in fallow time or opportunity cost of labour, but this is less concerning as these parameters are less arbitrary set.

Parameter	Initial value	Change of parameter value	Change in main model output (BEP)
Discount rate (%)	5%	+300%	2%
Fallow time (years)	9	-22%	13%
Opportunity cost of labour (\$/ha ⁻¹)	131	+50%	-41%

Table 7. Results of the sensitivity analysis

Discussion

For short fallow food systems in Cameroon, Gockowski *et al.* (2001) finds an annual revenue of around 600 \$.ha⁻¹.year⁻¹, and Kotto-Same (2000) finds 623 \$.ha⁻¹.year⁻¹. Our results are slightly lower since the revenue we compute shows an average of 440 \$.ha⁻¹.year⁻¹. The difference may come from the fact that we simplified the cycle to staple crops, and from different assumptions on crop prices and the opportunity cost of labour (eg. Gockowski *et al.* (2001) uses a lower opportunity cost of labour of 1.21 \$.day⁻¹ although without explaining the underlying assumptions). And although these food systems make up for most of the cultivated crops in Cameroon, they are also the least profitable. Furthermore, the general coherence with these previous studies on this point gives some confidence in the other results based on our simple cost model.

Silva-Chavez (2005) finds a slightly higher BEP for Bolivia of 4-9 \$/tCO₂e. And so does Osafo (2005) with a BEP of 8 \$/tCO₂e for Ghana. These differences could come from the fact that these two analysis used cash crops as a benchmark against deforestation. And while this choice makes sense for such countries, staple crops seemed more relevant in

Cameroon where they are prevalent. For the Brazilian Amazon, where the low returns of most pastures are more similar to Cameroon's staple crops, Nepstad *et al.* (2007) finds an average opportunity cost of 1.6\$/tCO₂e. At the global scale, Grieg-Gran (2006) finds a cost of abatement from deforestation of 1-2 \$/tCO₂e on average.

The total estimated yearly revenue from CR for the scenario considered, (6 000 ha/yr of deforestation reduction during 5 years) estimated at about 130 million dollars would probably have a significant impact on the trade balance of Cameroon as its current exports flow is about 4.7 billion dollars per year (World Bank, 2007). Indeed, in such a developing and liquidity constraint economy, macro economic effects of an additional percent of direct fundings might be substantial (Crassous, *et al.*, 2007).

Model approximations – The major problem with such a model is that it assumes a functioning market system where the farmer can sell most of his products, whereas in the rainforested zones of Cameroon, auto-consumption is preponderant and only the surpluses are sold on local markets (Brown, 2004). This doesn't necessarily undermine the model itself, but it raises an important doubt on the conclusion of the proposed comparison: in the case of subsistence agriculture, utility is likely to differ from income. Indeed, even if the revenue from a CR scheme is forecast to be higher than one from shifting cultivation, the farmer cannot necessarily be expected to opt for CR. He will also have to weigh in the risk of food shortage: shifting cultivation will provide him with food notwithstanding external conditions whereas under CR, as he has to buy all his food, he becomes much more vulnerable to higher prices for it (van Soest, 1998).

Even so, some studies show that macro-economic factors can have an impact over farmers' local decisions in Cameroon. Indeed, when the price of cocoa and coffee dropped, farmers showed a capacity to shift to staple crops (Sunderlin, *et al.*, 2000). This historical example allows us to think that a new source of revenue (CR) could once again trigger a change of local practices, back from the shifting cultivation of staple crops.

As it has already been discussed, numerous simplifications and approximations were made both in the models and in the estimates. Therefore, it should be remembered that the model outputs are only indications on what actual revenues might be. Among others are the absence of accounting for timber and fallow revenues, and the approximation of all cultivation years to a mixed cropping of half cassava and half plaitain.

Furthermore, opportunity costs are only a simplification of the costs of reducing deforestation. Implementing programs or projects carry transaction costs of their own (eg. monitoring costs, administrative costs, ...), which increase the actual cost. On the other hand, opportunity costs need not always be fully compensated, which decrease the actual cost (Nepstad, *et al.*, 2007). However, given the large discrepancy between the break-even price and the current price of carbon, this simplification should not undermine the results: a CR mechanism would be profitable, although not necessarily achievable (see below, *Practical problems with the implementation of Compensated Reduction*).

The failure to account for timber revenues should not be an important bias, as the few valuable trees are removed in advance by logging companies. And in any case, it is the companies, and not the farmers, who benefit from timber sales. However, this points out to another problem, namely the absence of incentives for logging companies to stop selective logging which is what brings shifting cultivators in the first place. One solution, as discussed below, could be a set of national policies enforcing land tenure rights for small holders, financed locally by the benefits reaped from carbon credits.

Practical problems with the implementation of Compensated Reduction – Even if we could know for sure that CR would be economically more profitable than shifting cultivation or selective logging, whether it is practically possible for the government or any organization

to bring forth a change of practices once it has money to do so remains something to be proven in Cameroon. Past experience in projects that aim to reduce deforestation by compensating stakeholders shows contrasting levels of success (Chomitz, *et al.*, 2006). Indeed, the corruption that plagues all Africa doesn't spare Cameroon which was rated 129th out of 145 countries by Transparency International (2004), with a Corruption Perception Index of only 2.1/10. In the context of Compensated Reduction, this could be a particularly thorny issue as channeling the money to the right stakeholders and ensuring their accountability would be key to success.

However, in both cases of selective logging and slash-and-burn agriculture, causes are known and some methods have been proven to be efficient in limiting these activities. In the case of slash-and-burn agriculture in Central Africa, it has been shown that enforcing land tenure is critical since the absence of land tenure rights pushes both logging companies and small farmers to get as much of the land as they can before somebody else seizes it (van Soest, 1998). Moreover, Cameroon has been deemed to be one of only six ITTO (International Tropical Timber Organization) producer countries to have already established all conditions that enable them to manage their forest sustainably (FAO, 2001).

The BOLFOR project carried out in Bolivia shows that methods actually exist to get deforestation under control (requirement for the logging companies to carry out inventories and management plans, an independent "Forest Superintendency" that is able to monitor these activities and enforce fines and penalties when necessary, ...) and can produce results when they are funded and seriously implemented (The Nature Conservancy, 2004).

Another way would be to reduce the damages caused by selective logging (Reduced Intensity Logging). This change in logging practices could save up to two thirds of total logged biomass at the additional cost of 10\$/ton⁻¹. However, the technology to monitor these reductions in a reliable way by remote sensing is not yet fully developed (Justice, *et al.*, 2001).

Perverse incentives to grow tree or cocoa plantations – An incentive system only based on carbon content such as CR would probably generate some "perverse" incentives such as growing cocoa or timber. Indeed, these land uses have higher carbon stocks than shifting cultivation and yet yield revenues which a primary forest does not. The highest profitability could therefore be found in these uses which could have a negative impact on deforestation.

However, since CR is designed to be mainly monitored through remote sensing, these perverse incentives could be avoided. Indeed, satellites can well distinguish tree or cocoa plantations from primary forests and CR could therefore only compensate for the safeguard of primary forests, and not the growing of trees or cocoa.

There used to be a prerequisite for obtaining formal land rights known as the "mise en valeur" of forests, that is forests must be cleared for cultivation purposes before legal land titles can be obtained. However, it is difficult to assess the importance of this factor in practice: even in 1984, only an estimated 4% of the land was cultivated under formal land rights, and now, the law has been turned down (van Soest, 1998).

Conclusion

The aim of this modeling exercise was to give a rough assessment of the economic rationale of "Compensated Reduction" in Cameroon. Although it doesn't encompass the entire complexity of the deforestation process, it is robust enough for this purpose. The break-even price of 2.85\$/tCO₂e indicates that the idea would be worth a thought: indeed, with carbon prices currently over 20\$/tCO₂e for second period allowances on the European Trading Scheme, CR would be a profitable alternative to farming. Moreover, the margin

between these two land-uses could provide for the unaccounted transaction costs such as monitoring or national policy implementation.

As the UNFCCC process on “avoided deforestation” moves forward, further studies will be needed by negotiators and project managers that rely on more complex models (especially to evaluate baselines and macro-economic effects of land-use changes), updated data, and other conservation scenarios than CR.

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