Readiness and Avoided deforestation policies: on the use of the REDD fund*

Philippe Delacote [†,‡,§], Gabriela Simonet [¶]

Abstract

The first phase of the REDD+ mechanism consists of helping countries to improve their capacity to carry out national forest inventories, notably to assess land-use changes and forest carbon stocks and fluxes. However, there might be some links between the funding of this first phase and the quantity of avoided deforestation that will happen during the following phases of REDD+. This paper precisely investigates those links, using a simple two-step, two-players, subsidiary-based REDD+ mechanism.

Keywords: REDD+, Readiness, deforestation, forest inventories

*This paper has been presented at a LAMETA seminar (Montpellier, France, March 2012) and to the 2013 EAERE conference (Toulouse, France, June 2013). We thank Bart Harstad, Chuck Mason, Stefano Pagiola, and all the participants for valuable comments.

†INRA, UMR 356 économie Forestière, F-54000 Nancy, France, philippe.delacote@nancy.inra.fr, Tel: +33 (0)3 83 39 68 53

‡Agroparistech, Engref, Laboratoire d'économie forestière, F-54000 Nancy, France

§Chaire d'économie du Climat, Paris, France

¶Chaire d'économie du Climat, Palais Brongniart 4th floor, 28 place de la Bourse, Paris, France, gabriela.simonet@chaireeconomieduclimat.org, Tel: +33 1 73 01 93 42, Fax: +33 1 73 01 93 28

1 Introduction

It is now broadly accepted that the protection of tropical forests represents a priority due to the many economic, social and environmental services they provide. With the emergence of several initiatives aiming at fighting climate change, notably through carbon economics, the possibility of limiting greenhouse gases (GHG) emissions arising from deforestation constitutes another strong argument for preserving tropical forests. Indeed, deforestation and forest degradation occurring in tropical forests lead to gross emissions of GHG estimated between 5.5 (Werf, 2009) to 10.8 (Pan et al., 2011) billion tons of CO_2 per year. The protection of the large stock of carbon contained in tropical forests would thus avoid releasing several billion tons of carbon to the atmosphere every year.

In spite of the major contribution of forests in global GHG emissions, this sector remained a neglected topic in the international negotiations on climate change until the 11th Conference Of Parties (Montreal, 2005). During this COP, Costa Rica and Papua New Guinea suggested creating a system that would provide incentives for reducing deforestation by assigning a value to the carbon stored in forests (Climate Economics in Progress, 2011). With the creation of this mechanism aiming at Reducing Emissions from Deforestation and forest Degradation (REDD), tropical forests came in the spotlight of international negotiations.

REDD was broadened to REDD+ to encompass the role of the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon. The now called REDD+ mechanism will proceed in three steps: (1) a preliminary Readiness phase followed by (2) a phase of Implementation of national policies and measures, and then by (3) the financial Compensation of result-based actions. The most advanced phase in terms of design and financing is the on-going Readiness phase. Already 42 countries have been selected to receive support under the Forest Carbon Partnership Facility (FCPF) of the World Bank and/or under the United Nations Collaborative Programme on REDD (UN REDD). As of January 2013, 33 of them have submitted their Readiness Preparation Program (R-PP).

The aim of this paper is to understand how the first phase of readiness may be related to the second and third phase of implementation. Indeed, in a world were financial resources are crucially constrained, the spendings of the Readiness phase may no longer be available in the REDD+ phase. Moreover, the degree of measurement precision chosen is likely to have an impact of the willingness to pay for avoided deforestation credit. In order to give a better understanding of those effects, we build a very simple, two-step two-players model, in which the North and South agree upon a level of forest carbon measurement and a level of avoided deforestation. We show that, in a world with tight budget constraint, and depending on the North and South risk aversion, the REDD+ budget will trade off between the measurement precision and the level of expected avoided deforestation.

In section 2, we introduce the issue of the lack of accuracy in forestry emissions measurement and explain what is at stake with the Readiness phase. Section 3 highlights the potential lack of financial means for the different phases of the REDD+, leading to a discussion in section 4 on the way the REDD fund should be shared between the Readiness phases and the next ones. We develop a two-players model to illustrate this issue. We then discuss the main results of this model.

2 Accuracy and Readiness

One of the reasons for the late inclusion of the forestry sector in carbon economics is the complexity for measuring, monitoring and verifying forestry carbon fluxes. In addition to the leakage (Atmadja and Verchot, 2011) and the permanence issues, specific measurement problems appear when tackling forestry carbon.

Three main dimensions have to be considered when measuring emissions reduction from the forestry sector: (1) an assessment of the change in forest area, which requires a specific monitoring, hardly feasible without having recourse to remote sensing; (2) an estimation of the per-hectare carbon stock, which involves field inventories; (3) the deduction of the carbon fluxes between the land and the atmosphere. Each step entails a high level of uncertainty and it is thus particularly challenging to calculate the emissions of carbon within the boundaries of a forest with a satisfactory level of accuracy. Pelletier et al. (2010) identified that the key sources of uncertainty in the quantification of emissions from deforestation for Panama were the forest carbon stocks and the quality of land-cover maps, a result which might probably be applied to other countries involved in REDD+. Barbier (2012) and Barbier and Tesfaw (2012) underline the importance of transaction costs of the REDD+ mechanism, that are related to monitoring and verifying changes in deforestation rates in developing countries. Those costs are likely to significantly increase the total cost of REDD implementation.

Indeed, most developing countries have a weak capacity to assess the changes in their forestry cover, as well as forest carbon stocks. Several studies based on remote sensing revealed that the deforestation rates compiled by the FAO from national surveys and published in their Forest Resource Assessment were often overestimated (Achard et al. 2002; DeFries et al. 2002; Hansen et al. 2010). Achard et al. (2002) for example found that the global net rate of deforestation in the humid tropics over the period 1990-1997 was 23% lower when using remote sensing data instead of national surveys. The development of remote sensing technologies should lead to major progress in the capacity to monitor the changes in forest area in the coming years.

Assessing forest carbon stocks is more challenging since this stock varies from a forest to the other, depending on species, climate, latitude, density or management. Default values of carbon stocks are provided by IPCC guidelines or the FAO but they contain a significant error. The only way to obtain accurate data is to proceed to numerous local inventories, which is time-consuming and costly. A new approach using airborne Lidar sensors is being tried out at the project or regional scale (see for instance (Asner et al., 2010), showing promising results but whose cost is still prohibitive.

It should be noticed that, even after having assessed forest area and the forest carbon stocks, an additional uncertainty arises from step 3 as most estimates neglect tracking the carbon after deforestation, whereas the fate of land and the fate of wood clearly impact carbon emissions (Simonet, 2011).

Achieving a correct level of accuracy requires having recourse to expensive remote sensing tools and ground inventories, something that most developing countries are currently not able to do. The UNFCCC assessed that the majority of developing countries (referred to as non-annex I countries) have limited capacity in providing complete and accurate estimates of their forestry emissions (UNFCCC 2009). However, to be efficient, the REDD+ mechanism should be based on accurate data on the amount of avoided deforestation and the related avoided emissions. Without accurate measurements of emission reductions, the environmental integrity of the system could be threatened and a potential "hot air" could be introduced in the climate regime (Angelsen 2008, Karsenty 2008). Grassi et al.(2008) study the way the conservativeness principle could be applied to reduce the uncertainty in forestry emission data, arguing that high uncertainties could undermine the credibility of REDD+ as a mitigation option.

The Readiness phase was thus designed to "assist developing countries to determine a national reference scenario of deforestation, develop a monitoring system for REDD+, and adopt a national strategy for reducing deforestation and forest degradation."(Davis et al. 2008). This preliminary step is necessary to ensure that the emissions reductions claimed by developing countries under REDD+ are actual. Pelletier et al. (2011) highlights the importance of current efforts to establish forest monitoring systems and enhance capabilities for REDD+ in developing countries, "to avoid that real emissions reductions in developing countries be obscured by their associated uncertainties".

However, improving countries capacity to provide accurate estimates of their forestry emissions has a significant cost, and the money available for REDD+ is limited.

3 Cost of REDD+ and available funds

An issue which remains unresolved after the 18th Conference of Parties in Doha (December 2012) is the financial modalities of the following steps of REDD+. If the second step should be financed by fund, two main options are currently considered for the thirs one: a fund-based mechanism and a market-based mechanism. In this paper, we consider the case where a fund-based implementation is chosen, which has been the chosen option so far to finance the first phase of REDD+. Significant amount of money will be needed for REDD+, in contrast with the money currently available.

The amount of money required for the implementation phases of the REDD+ has been estimated by several authors. Stern (2007) estimated that between USD 3 and 11 billion would be needed to halve emissions from deforestation depending on the valuation of any timber and on land use opportunity cost. Other estimates are much higher, like Kindermann et al. (2008) who estimated the cost of reducing deforestation by 50 percent to be between 17.2 and 28 billion dollars. Finally, the United Nations Environment Programme Finance Initiative (UNEP FI) estimates that USD 17-40 billion per year is required to halve emissions from the forest sector by 2030 (UNEP 2011). The large variety of REDD+ costs estimated is a good illustration of the uncertainty related to transaction costs, among which MRV costs are one of the most important components.

To date, several public funds have been raised by developed countries to finance REDD+. According to Creed and Nakhooda (2011), around USD 5 billion has been committed for REDD+ until now, mainly by Norway with USD 2.8 billion committed, but also by Australia, France, Germany, Japan, US and UK. Several multilateral funds have also been raised up to finance the Readiness phase of REDD+. They are for example the Forest Carbon Partnership Facility - Readiness Fund (World Bank), the UN-REDD Program (FAO, UNDP, UNEP) or the Congo Basin Forest Fund (African Development Bank). Their cumulated pledges reach around USD 500 million. Three main bilateral funds have been raised to finance the whole REDD+ process for the Amazon area (USD 1 billion pledged by Brazilian Development Bank), Indonesia (USD 1 billion pledged by the UNDP) and the Guyana (250 million pledged by the World Bank).

However, it is not clear how the second and third phases of REDD+ will be financed. The financial crisis that affects developed countries improve the uncertainty on available funds for

REDD+. The World Bank already pledged USD 578 million for the implementation phase through its Forest Investment Program, and USD 174 million for the compensation phase through its Carbon Fund. However, this represents a small budget compared to UNEP forecast of between USD 18 and 40 billion per year needed. The Green Climate Fund could participate in reaching such a sum, but it is still unfunded and REDD+ would not constitute its only beneficiary.

4 Sharing the REDD+ fund between the Readiness phase and the next ones

There is no simple answer to what should be the minimal accuracy for REDD+. The mechanism could not start before the participants have the capacity to measure the avoided deforestation with enough accuracy not to threaten the environmental integrity of the system. Measuring avoided deforestation therefore encompasses three combined elements in the context of this paper: (1) assessing the carbon stock in standing forests; (2) evaluating the net rate of deforestation; (3) setting a trustful deforestation baseline or Business-As-Usual scenario. An important error could harm both developed and developing countries. Indeed, if emissions reductions are overestimated, developed countries might pay for emissions reduction that did not happened. Conversely, the error could lead to underestimated emissions reduction, thus harming developing countries which will be granted less than the efforts deployed.

However, requiring a high level of accuracy might exclude some countries with low MRV capacity but high potential for reducing forestry emissions. If a lot is invested to allow all countries to achieve the sufficient level of accuracy, the money engaged in Readiness will not be used for the compensation phase. Consequently, spending too much money in improving countries' capacity might prevent from financing the avoided deforestation to come, thus potentially reducing avoided deforestation.

As seen in section 2, several papers tackle accuracy issues. Research has also been led on the financing of REDD+, either assessing the funds available (Creed and Nakhooda, 2011) or discussing the right financing system for REDD+ (Karousakis and Corfee-Morlot 2007, Leplay et al. 2011, Neeff and Ascui 2011). However, the issue of the right distribution of the limited REDD+ fund between the Readiness phase and the implementation and compensation ones has not been tackled so far.

This paper analyzes the way the Readiness phase could impact the future avoided deforestation. We develop a model which represents the competition between investing in diminishing measurement errors and paying for actual avoided deforestation in a subsidiary-based REDD+ mechanism.

We consider a two-players and two-period game: North (N) and South (S). In the first period, the North pays the South for accounting its forests, with some chosen precision P. Precision P provides a symmetric distribution of measurement errors. In the second period, the North pays the South for avoided deforestation A. We solve the game backward, starting from the second period. Both periods are subject to related budget constraints, i.e. the REDD+ program is financed by a fund and what is spent in the first period can no longer be spent afterwards: $B = B_1 + B_2$. [1]

4.1 Second period

In the second period, precision $\overline{P}$ and second-period budget $\overline{B_2}$ are given. The second-period budget is directly related to (given) first-period budget: $\overline{B_2} = B - \overline{B_1}$. South and North have to agree upon a measured amount of avoided deforestation MA. [2] Measured avoided deforestation and actual avoided deforestation have to be distinguished. Indeed, there is some measurement error, that is determined by precision $\overline{P}$ chosen in the first period. This error determines the variance between measured avoided deforestation MA and actual avoided deforestation A: $V(MA, \overline{P})$, with $\frac{\partial V}{\partial MA} \geq 0$ and $\frac{\partial V}{\partial \overline{P}} \leq 0$.

The North pays p per unit of measured avoided deforestation, and values it at v (which is for instance the carbon price on other markets or the cost of reducing CO_2 in the industry), while the South's unit cost of avoided deforestation is c. Both players maximize their expected utility $E_S(U)$and $E_N(U)$, under a Markowitz framework [3]: South and North expected utility depends on measured avoided deforestation MA, which is the result of the South deforestation policy, and on the variance of avoided deforestation measurement, which is the result of the degree of precision chosen. Indeed, both players' expected utility decreases with the variance of the avoided deforestation measurement: the North does not want to pay for an excessive amount of avoided deforestation, if the measured avoided deforestation is above its actual level $MA - A > 0$; the

[1] This framework is also valid for a project manager (N) willing to implement a REDD+ project within a rural community (S).

[2] Note here that avoided deforestation is not a command-and-control instrument as efficient as suggested here, and costly policies may be implemented and eventually not bring much avoided deforestation. However interesting and important, this concern is not in the scope of this paper.

[3] The elementary utility function is: $u_S(A) = -e^{-(2\alpha_S)^{1/2}(p-c)A}$ and $u_N(A) = -e^{-(2\alpha_N)^{1/2}(v-p)A}$. $(2\alpha_S)^{1/2}$ and $(2\alpha_N)^{1/2}$ are the South and North risk aversion coefficient, respectively.

South does not want not to be paid for some avoided deforestation, if its measured level is under its actual level $MA - A < 0$.

The second-period game thus takes the form [4]:

$$\max_{MA} E_S(U) = (p-c)MA - \alpha_S (p-c)^2 V(MA, \overline{P}) \quad (1)$$
$$\max_{MA} E_N(U) = (v-p)MA - \alpha_N (v-p)^2 V(MA, \overline{P}) \quad (2)$$
$$\overline{B_2} = B - \overline{B_1} \geq pMA \quad (3)$$
$$\overline{B_1}, \overline{P}, \quad given \quad (4)$$

First-order conditions implicitly give the supply and demand for avoided deforestation.

$$p - c - \alpha_S (p-c)^2 \frac{\partial V}{\partial MA} = 0 \quad (5)$$
$$v - p - \alpha_N (v-p)^2 \frac{\partial V}{\partial MA} = 0 \quad (6)$$
$$\overline{B_2} = B - \overline{B_1} = pMA \quad (7)$$

From equations 5 and 6, and using the implicit function theorem, it is possible to show that:

- avoided deforestation supply is increasing in price p and decreasing in cost c, decreasing in South risk aversion α_S and increasing in measurement precision $\overline{P}$.
- avoided deforestation demand is decreasing in price p and increasing in value v, decreasing in North risk aversion α_S, increasing in measurement precision $\overline{P}$, and increasing in second-period budget $\overline{B_2}$.

The avoided deforestation agreement $MA^*(\alpha_N, \alpha_S, \overline{P}, \overline{B_2})$ is selected at the intersection of supply and demand.

Result 1 : *The equilibrium level of avoided deforestation is decreasing in North and South risk aversion, increasing in measurement precision and increasing in second-period budget:* $MA^*(\alpha_N, \alpha_S, P, B_2)$, $\frac{\partial MA^*}{\partial \alpha_N} < 0$, $\frac{\partial MA^*}{\partial \alpha_S} < 0$, $\frac{\partial MA^*}{\partial \overline{P}} > 0$, $\frac{\partial MA^*}{\partial \overline{B_2}} > 0$.

From this first set of results, it is then shown that avoided deforestation is directly related to the first-period measurement. Indeed, measurement errors tend to decrease the North willingness

[4] This set-up provides results compatible with a Nash-bargaining game with identical bargaining powers. Extreme situations of bargaining powers can also be considered. If the North has full bargaining power, only equation (2) is maximized. If the South has full bargaining power, only equation (2) is maximized.

to pay and the South willingness to accept for avoided deforestation: if measurement is less precise, there is a risk for the North to pay for some avoided deforestation that actually does not exist, and for the South not to be paid for some avoided deforestation that actually exists.

4.2 First period

In the first period, South and North have to agree upon a budget B_1, that will be spent to assess the South's forest resources and determine the measurement precision P. We know by result 1 that the first period budget determines the measured amount of avoided deforestation in the second period: $\frac{\partial MA^*}{\partial B_2} > 0$, implying $\frac{\partial MA^*}{\partial B_1} < 0$.

The first-period game thus takes the form:

$$\max_{B_1} E_S(U) = (p-c)MA^*(\alpha_N, \alpha_S, P, B_1) - \alpha_S(p-c)^2 V(MA^*(\alpha_N, \alpha_S, P, B_1), P) \quad (8)$$
$$\max_{B_1} E_N(U) = (v-p)MA^*(\alpha_N, \alpha_S, P, B_1) - \alpha_N(v-p)^2 V(MA^*(\alpha_N, \alpha_S, P, B_1), P) \quad (9)$$
$$B_1 \geq C(P) \quad (10)$$

First-order conditions implicitly give the first-period budget and thus the level of measurement precision:

$$(p-c)(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) - \alpha_S(p-c)^2(\frac{\partial V}{\partial MA}(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) + \frac{\partial V}{\partial P}\frac{\partial P}{\partial B1}) = 0$$
$$(v-p)(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) - \alpha_N(v-p)^2(\frac{\partial V}{\partial MA}(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) + \frac{\partial V}{\partial P}\frac{\partial P}{\partial B1}) = 0$$
$$B_1 = C(P) \quad (11)$$

Equation 11 describes a simple tradeoff concerning the choice of the first period budget. By increasing B_1, precision is increased, which tends to increase the level of avoided deforestation in the second period. Nevertheless, increasing B_1 reduces the amount of money available to finance the second part of the game B_2, which tends to decrease avoided deforestation in the second period. What is important to know in this case is to which factor the equilibrium level of avoided deforestation is the most sensitive: precision or second-period budget.

One may argue that choosing precision in the first period is likely to commit to future recurring costs, related to the cost of monitoring that may be positively related to precision. In this case, equation 3 becomes: $B_2 \geq pMA - CF(P)$. This insight is indeed true, but do not tend to go against our result, as long as this fixed-cost in increasing with precision ($\frac{\partial CF}{\partial P} > 0$). Indeed, introducing this cost in the second period only decreases the second-period budget even more, which tends to exacerbate the effect we describe. As an extreme case, this may even exceed the participation constraint of the sellers, if those costs have not been properly estimated in the first place.

The main variables determining this outcome are the North and South risk aversion coefficient. If North and South are very risk averse, they may prefer to increase the first-period budget in order to increase precision, even if this decreases the second-period budget and thus avoided deforestation. In contrast, if South and North have low coefficients of risk aversion, they may prefer less precise measurement, in order to be able to invest more in the second period in avoided deforestation policies.

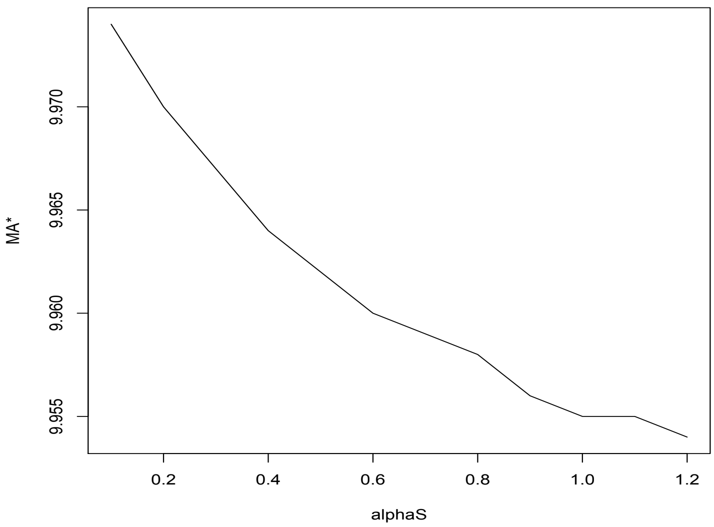
Result 2 : *If North and South have low coefficients of risk aversion, they may choose a small first-period budget and relatively low measurement precision, in order to increase the second-period budget and avoided deforestation. In contrast, if they have high risk aversion coefficients, they may prefer to invest more in the first period, in order to increase precision and increase their willingness to pay and to accept for avoided deforestation, even if this decreases the second-period budget.*

Overall, this result suggests that, as North and South risk aversion increases, both countries trade measured avoided deforestation for increased measurement precision. This result is illustrated with the simulations represented in figure 1 and 2, showing the sensitivity of the key choice variables MA^* and $B1^*$. The parameters and functional forms are to be found in appendix.

Note that this result directly relies on the fact that the REDD+ budget is fixed from the first to the second period. A way to overcome this tradeoff could be for the North (if it is particularly sensitive to the issue of precision measurement and has stronger risk aversion than the South) to condition a part of the second period budget to the quality of measurement decided in the first period. This would consist of modifying the budget constraint of equation (3) to: $\overline{B_2} = B - \overline{B_1} + B_p(\overline{P})$. In this "deep-pocket" case, indeed, the tradeoff existing between precision and the second-period budget would be reduced [5]. However, note that the tradeoff described here is still valid as long as $\frac{\partial B_2}{\partial B_1} \geq 0$. Moreover, such an option would require the North to be able to commit to increase the size of the fund *ex post*, which may be a hard case in times of pressure on public resources.

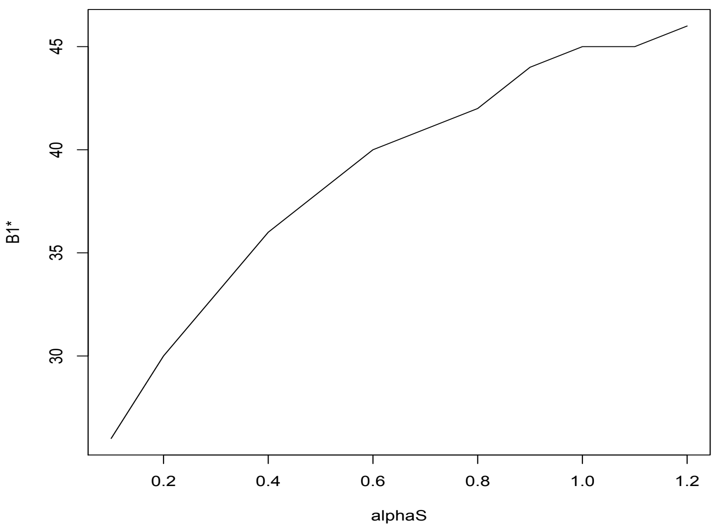
[5] It could even be over-compensated if $\frac{\partial B_p}{\partial \overline{P}} \geq 1$.

Figure 1: **Increased risk aversion reduces the equilibrium amount of avoided deforestation**



Parameters: appendix

Figure 2: **Increased risk aversion increases the first-period budget and measurement accuracy**



Parameters: appendix

5 The case of asymmetric measurement error

In the previous section, we examined what may happen if the measurement error is symmetric, i.e. if the risk of underestimation equals the risk of overestimation. In this case, we need to consider the fact that one player can benefit from measurement errors: the North would benefit from underestimation of avoided deforestation, since it would pay for a smaller amount of avoided deforestation than the actual one; the South would benefit from overestimation of avoided deforestation, since it would get rewarded for a larger level of avoided deforestation than the actual one.

In this context, preferences of North and South are thus different: North's (South's) utility is increasing in the risk of underestimation (overestimation) and decreasing in the risk of overestimation (underestimation). We adapt equations (1), (2), (8) and (9) to represent those preferences.

5.1 Second period

If distinguishing the risk of under and overestimation of avoided deforestation, North and South's utility functions become in the second period:

$$\max_{MA} E_S(U) = (p-c)MA + (p-c)^2(\gamma_S O(MA,\overline{P}) - \beta_S U(MA,\overline{P})) \quad (12)$$

$$\max_{MA} E_N(U) = (v-p)MA + (v-p)^2(-\gamma_N O(MA,\overline{P}) + \beta_N U(MA,\overline{P})) \quad (13)$$

$$\overline{B_2} = B - \overline{B_1} \geq pMA \quad (14)$$

$$\overline{B_1}, \overline{P}, \quad given \quad (15)$$

In this new configuration, γ_S and β_S are the South's taste for overestimation and aversion for underestimation. Similarly, γ_N and β_N are the South's aversion for overestimation and taste for underestimation. Both players being risk-averse, we can assume that $\gamma_S < \beta_S$ and $\gamma_N > \beta_N$.

$O(MA,\overline{P})$ represents the risk of overestimation, while $U(MA,\overline{P})$ represents the risk of underestimation. In order to keep a link with the previous analysis, we can consider that:

$$O(MA,\overline{P}) = oV(MA,P) \quad (16)$$

$$U(MA,\overline{P}) = (1-o)V(MA,P) \quad (17)$$

The variance of measured avoided deforestation is then decomposed between overvalued and undervalued observations. o can be considered as the degree of overestimation. If $o > 1/2$, measurement errors are biased toward overestimation, if $o < 1/2$ they are biased toward underestimation.

First-order conditions implicitly give the equilibrium level of avoided deforestation:

$$p - c + (p - c)^2(\gamma_S o - \beta_S(1 - o))\frac{\partial V}{\partial MA} = 0 \tag{18}$$

$$v - p + (v - p)^2(-\gamma_N o + \beta_N(1 - o))\frac{\partial V}{\partial MA} = 0 \tag{19}$$

$$\overline{B_2} = B - \overline{B_1} = pMA \tag{20}$$

What is important here to determine the equilibrium amount of avoided deforestation is the degree of asymmetry and the comparative risk aversion coefficients. For instance, if the risk of underestimation is larger than the risk of overestimation ($o < 1/2$), $(\gamma_S o - \beta_S(1-o))$ is negative (as $\gamma_S < \beta_S$ insures South's risk aversion), and decreasing in the South's aversion for underestimation, and increasing in its taste for overestimation. This simply means that the South's supply for avoided deforestation decreases with the variance of avoided deforestation (that is with measurement errors). In contrast, $(-\gamma_N o + \beta_N(1-o))$ may be positive, if the North's aversion for overestimation is small enough or if it's taste for underestimation large enough: $\gamma_N < \frac{1-o}{o}\beta_N$. It follows in this case that the North's demand for avoided deforestation may increase with measurement errors if its taste for overestimation is large enough compared to its aversion for underestimation.

Similarly, if the risk of underestimation is smaller than the risk of overestimation ($o > 1/2$), the North's demand for avoided deforestation decreases in measurement errors (as $\gamma_N > \beta_N$ insures North's risk aversion). However, the South's demand for avoided deforestation may be increasing in measurement error if its taste for overestimation is large enough or if its aversion for underestimation is small enough: $\gamma_S > \frac{1-o}{o}\beta_S$.

Result 3 : *If the risk of underestimation is larger than the risk of overestimation ($o < 1/2$), the equilibrium avoided deforestation may increase with measurement errors if the North's taste for underestimation is large enough or the North's aversion for overestimation is small enough. If the risk of overestimation is larger than the risk of underestimation ($o > 1/2$), the equilibrium avoided deforestation may increase with measurement errors if the South's taste for overestimation is large enough or the South's aversion for underestimation is small enough.*

For instance, if the measurement error is largely biased toward overestimation of avoided deforestation, the South may have a tendency to supply larger amount of expected avoided deforestation, while the North will tend to have a smaller demand. If the South aversion for underestimation is not too small or if its taste for overestimation is large enough, the equilibrium amount of avoided deforestation may be increasing in measurement error.

5.2 First period

The North and South program in the first period becomes:

$$\max_{B_1} E_S(U) = (p-c)MA^*(\gamma_N, \beta_N, \gamma_S, \beta_S, P, B_1) \tag{21}$$
$$+ (p-c)^2(\gamma_S O(MA^*\gamma_N, \beta_N, \gamma_S, \beta_S, P, B_1), P) - \beta_S U(MA^*(\gamma_N, \beta_N, \gamma_S, \beta_S, P, B_1), P))$$
$$\max_{B_1} E_N(U) = (v-p)MA^*(\gamma_N, \beta_N, \gamma_S, \beta_S, P, B_1) \tag{22}$$
$$+ (v-p)^2(-\gamma_N O(MA^*(\gamma_N, \beta_N, \gamma_S, \beta_S, P, B_1), P) + \beta_N U(MA^*(\gamma_N, \beta_N, \gamma_S, \beta_S, P, B_1), P))$$
$$B_1 \geq C(P) \tag{23}$$

First-order conditions implicitly give the equilibrium level of the first-period budget and measurement precision:

$$(p-c)(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) \tag{24}$$
$$+(p-c)^2(\gamma_S o - \beta_S(1-o))(\frac{\partial V}{\partial MA}(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) + \frac{\partial V}{\partial P}\frac{\partial P}{\partial B1}) = 0$$
$$(v-p)(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1})$$
$$+(p-c)^2(-\gamma_N o + \beta_N(1-o))(\frac{\partial V}{\partial MA}(\frac{\partial MA^*}{\partial B_1} + \frac{\partial MA^*}{\partial P}\frac{\partial P}{\partial B_1}) + \frac{\partial V}{\partial P}\frac{\partial P}{\partial B1}) = 0$$
$$B_1 = C(P)$$

Here again, what is important in the first period if the degree of asymmetry and the respective values of tastes and aversions. If the risk of underestimation is larger than the risk of overestimation ($o < 1/2$), $(\gamma_S o - \beta_S(1-o))$ is negative, and decreasing in the South's aversion for underestimation, and increasing in its taste for overestimation. This simply means that the South's preferred first-period budget increases with its marginal impact on measurement error, i.e of the efficiency of one extra dollar invested in increasing measurement precision. In contrast, $(-\gamma_N o + \beta_N(1-o))$ may be positive, if the North's aversion for overestimation is small enough or if its taste for underestimation is large enough: $\gamma_N < \frac{1-o}{o}\beta_N$. It follows in this case that the North's preferred measurement precision (equivalently first-period budget) is decreasing in the marginal efficiency[6] on increasing the first-period budget. Indeed, since the North somehow benefits from measurement errors, it prefers keeping the first-period budget small and then reduce the equilibrium measurement accuracy.

Similarly, if the risk of underestimation is smaller than the risk of overestimation ($o > 1/2$), North is willing to invest more in the first-period budget, especially if it improves a lot measurement precision. However, the South's may be willing to invest less in more efficient measurement

[6] We define marginal efficiency as the increase in precision that comes from an increase in first-period budget: $\frac{\partial V}{\partial B1}$

accuracy if its taste for overestimation is large or its aversion for underestimation is small: $\gamma_S > \frac{1-o}{o}\beta_S$.

Result 4 : *If the risk of underestimation is larger than the risk of overestimation ($o < 1/2$), the equilibrium first-period budget and measurement precision may decrease with its marginal efficiency if the North's aversion for overestimation is small enough or if its taste for underestimation is large enough. If the risk of underestimation is smaller than the risk of overestimation ($o > 1/2$), the equilibrium first-period budget and measurement precision may decrease with its marginal efficiency if the South's taste for overestimation is large enough or if its aversion for underestimation is small enough.*

In this case, if measured avoided deforestation is largely biased toward underestimation, the North's may be willing to invest less in the first-period budget, especially if the money invested in increasing accuracy is very effective. This way, the North benefit from more underestimation in the second period.

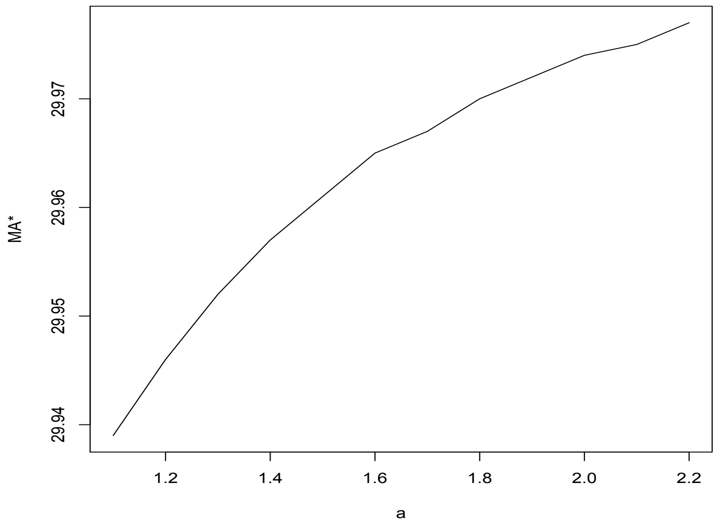
We show in the following figures a simulation of those two cases of asymmetry. Our indicator of marginal efficiency of the first-period budget is the coefficient a in: $C(P) = P^a$. A larger a corresponds to a larger marginal cost of precision, and then smaller marginal efficiency of the first-period budget.

6 Conclusion

How may REDD+ funding be spent, between the readiness phase and the avoided-deforestation phase? Using a simple two-step and two-players model, this paper tackles this issue. First, we consider that the funding of both phases are related: what is spent in the first phase reduces the amount of funds available afterwards. If, for instance, funders of the Readiness phase are different from buyers of the REDD-implementation phase, our results would be different. Second, we consider that a more precise measure of forest inventories is positively related to the willingness-to-accept by the South and the willingness-to-pay by the North for avoided deforestation.

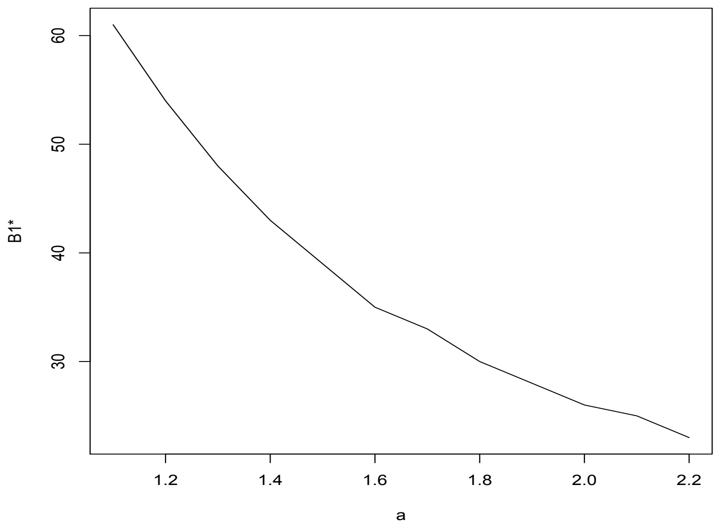
A simple tradeoff is therefore in place: increasing the first-period budget and thus measurement precision increases the willingness to pay and to accept for avoided deforestation in the second period; at the same time, increasing the first-period budget decreases the available budget in the second phase, which decreases the potential to implement avoided deforestation policies. It is shown

Figure 3: **If the risk of overestimation is smaller than the risk of underestimation, avoided deforestation is increasing in marginal cost of precision if the North's aversion for overestimation is small enough or if its taste for underestimation is large enough**



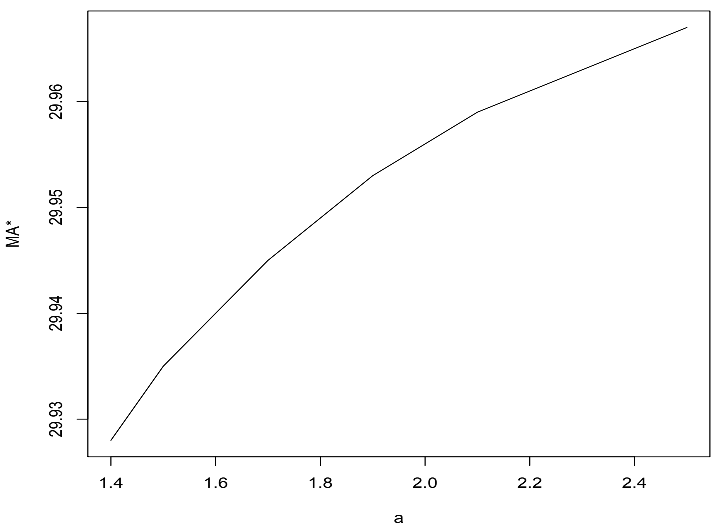
Parameters: appendix

Figure 4: **If the risk of overestimation is smaller than the risk of underestimation, the first-period budget is decreasing in marginal cost of precision North's aversion for overestimation is small enough or if its taste for underestimation is large enough**



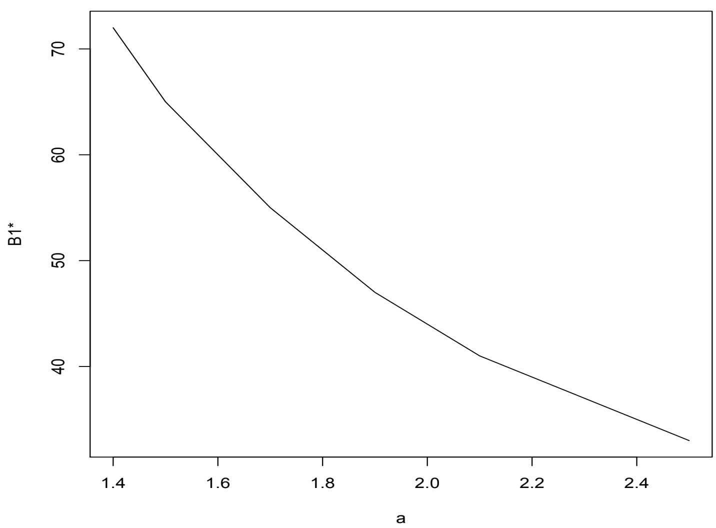
Parameters: appendix

Figure 5: **If the risk of overestimation is larger than the risk of underestimation, avoided deforestation is increasing in marginal cost of precision if the South's taste for overestimation is large enough or if its aversion for underestimation is small enough**



Parameters: appendix

Figure 6: **If the risk of overestimation is larger than the risk of underestimation, the first-period budget is decreasing in marginal cost of precision if the South's taste for overestimation is large enough or if its aversion for underestimation is small enough**



Parameters: appendix

that the North and South risk aversion, that is to say the aversion to the risk of over-paying and under-receiving, determines in which direction this tradeoff goes. If both agents have relatively low risk aversion, they may prefer to have lower precision set in the first place, in order to invest more in avoided deforestation policies in the second place.

If a symmetric distribution of the errors is assumed, so that the probability to over and under-estimate emission reductions are similar, North and South are equally affected by error measurement. However, there is an uncertainty in the distribution of the error associated to forestry emissions measurement. According to the tools and methodologies used to assess emissions reductions, the distribution of the error could be asymmetric and there could be a tendency to over or under-estimate emission reductions, a case discussed in a second version of the model.

If the measurement methodology is proved to over-estimate emissions reduction, North willingness to pay for avoided deforestation will decrease whereas an incentive will be created for the South to supply more avoided deforestation. In this case, it is possible that the amount of avoided deforestation increases with the marginal cost of increasing measurement accuracy, especially if the South have a relatively large taste for overestimation (equivalently small aversion for underestimation). Conversely, a tool which tends to under-estimate emissions reduction will have the opposite effect. In the same manner, if improving precision also tend to reduce the errors distribution asymmetry, this can have an impact on the North and South willingness to accept: by reducing the risk of overestimation (underestimation), improving precision increases (decreases) the North's preference for higher precision and decreases (increases) the South's preference for such improvement.

These discussions are particularly in line with the debate between Norway and Brazil at the last Conference of Parties in Doha (December 2012). The main bone of contention was about the issue of the verification of emission reductions. On the one hand, Norway - and other donor countries - want robust verifications to ensure that the funds they provide result in real emission reductions. On the other hand, Brazil - representing other countries involved in REDD+ - refuses the establishment of an international verification scheme, arguing that even rich polluting countries are not yet subject to such stringent verification. This debate highlights the risk aversion of both North and South. Both want to choose the way of measuring emission reductions and potentially to control its over or underestimation.

However, it is important to note that the amount actually spent in the Readiness phase are far away from what should be spent in the implementation phase. For instance, the grants of the Forest Carbon Partnership Facility (Bosquet et al. (2010)) to support countries in their Readiness Preparation Plans is of USD3.6 million, based on the cost of essential elements of REDD readiness, while the total FCPF budget is of USD155 million for 37 involved countries. This huge discrepancy between the two budgets can be considered in the light of our model. If the measurement error is symmetric, the small B_1 compared to B_2 may be related to a low marginal cost of improving measurement precision (precision is high without spending much money) and/or low risk aversions of the North and South (North and South do not care much about precision). It can also be the case that countries do not have much potential to implement proper MRV systems (which in the case of our model would be represented by a rapidly increasing marginal cost curve of increasing precision). It this case, indeed, there may be no point to increase the spending on MRV if it results in low quality improvement. If the measurement error is biased toward overestimation, the small readiness budget may be due to a high taste for overestimation by the South, or a low aversion for overestimation by the North. This may be the case if the North's objective for REDD is to combine environmental and development objectives. If measurement errors are biased toward underestimation, this may be due to a low South aversion for underestimation or a North high taste for underestimation.

The point is, most of the time, the distribution of the error is not known. However, in some cases, a trend in over or under estimating emissions reduction can be observed. First, the use of remote sensing recently provided evidence that deforestation rates in the last Forest Resource Assessment (FRA 2010) were over-estimated. Over the period 2000-2005, data reported by individual countries in Asia and Africa were found to be approximately twice those derived from moderate and high resolution remote sensing imagery (Hansen et al. 2010). As we have no or few remote sensing images before the 90's, over-estimated historical deforestation rates could be used as the baseline to assess avoided deforestation. If the actual deforestation rates are measured by remote sensing (ongoing step), then emissions reduction will be over-estimated. Second, since the South is in charge of choosing the instrument to estimate emissions reductions, the North can make the assumption that the South will systematically try to over-estimate the emissions reduction, which will decrease North's willingness to pay.

Finally, several standards in the voluntary market (notably the Verified Carbon Standard, or VCS, which is the most used standard in the voluntary market) apply the conservativeness principle: from a certain error, the value for emission reduction which is conserved will be the limit inferior of the interval, which tends to underestimate emission reduction and thus to decrease the South avoided deforestation. This application of this principle reduces the risk of overestimation of the avoided deforestation and thus increases North's willingness to pay.

A better knowledge of North and South risk aversion, and of the measurement error distribution in forestry carbon, would help arbitrating between the funding spent in the Readiness phase and in the following phases of REDD+.

Appendix: Parameters of the numerical simulation

Functional form of the measurement variance

$$C(P) = P^a \tag{25}$$

$$V(MA, P) = \epsilon \frac{MA}{P} \tag{26}$$

$$O(MA, P) = o\epsilon \frac{MA}{P} \tag{27}$$

$$U(MA, P) = (1 - o)\epsilon \frac{MA}{P} \tag{28}$$

Results of the numerical simulation

Symmetric case (figures 1 and 2)

Table 1

Parameter	Value
α_S	[0.1, 1]
α_N	0.8
v	8
c	4
B	4
a	2
Results	
$B1^*$	[26, 46]
$B2^*$	[74, 54]
MA^*	[9.974, 9.954]
V^*	[0.98, 0.73]
pc^*	[7.4, 5.4]

Asymmetric case: larger risk of underestimation (figures 3 and 4)

Table 2

Parameter	Value
γ_S	0.1
γ_N	0.6
β_S	0.9
β_N	0.5
v	8
c	6
B	100
o	0.45
a	[1.1, 2.2]
Results	
$B1^*$	[61, 23]
$B2^*$	[39, 77]
MA^*	[29.94, 29. 98]
V^*	[0.19, 1.98]
pc^*	[1.3, 2.56]

Asymmetric case: larger risk of overestimation (figures 5 and 6)

Table 3

Parameter	Value
γ_S	0.46
γ_N	0.8
β_S	0.9
β_N	0.2
v	8
c	6
B	100
o	0.60
a	[1.1, 2.2]
Results	
$B1^*$	[72, 33]
$B2^*$	[28, 67]
MA^*	[29.93, 29.97]
V^*	[0.28, 1.48]
pc^*	[0.4, 2.22]

References

Achard, F., Eva, H., Stibig, H., Mayaux, P., Gallego, J., Richards, T., and Malingreau, J. (2002). Determination of deforestation rates of the world's humid tropical forests. *Science*, 297(5583):999.

Angelsen, A. (2008). Redd models and baselines. *International Forestry Review*, 10(3):465–475.

Asner, G., Powell, G., Mascaro, J., Knapp, D., Clark, J., Jacobson, J., Kennedy-Bowdoin, T., Balaji, A., Paez-Acosta, G., Victoria, E., et al. (2010). High-resolution forest carbon stocks and emissions in the amazon. *Proceedings of the National Academy of Sciences*, 107(38):16738. 2

Atmadja, S. and Verchot, L. (2011). A review of the state of research, policies and strategies in addressing leakage from reducing emissions from deforestation and forest degradation (redd+). *Mitigation and Adaptation Strategies for Global Change*, pages 1–26.

Barbier, E. (2012). Can global payments for ecosystem services work? *World Economics*, 13(1):157–171.

Barbier, E. and Tesfaw, A. (2012). Can redd+ save the forest? the role of payment and tenure. *Forests*, 3:881–895.

Bosquet, B., Pagiola, S., and Aquino, A. (2010). *Deforestation and Climate Change: Reducing Carbon Emissions from Deforestation and Forest Degradation*, chapter Preparing for REDD: The Forest Carbon Partnership Facility, pages p.208–230. Edward Elgar Publishing. 6

Creed, A. and Nakhooda, S. (2011). Redd+ finance delivery: lessons from early experience.

Davis, C., Daviet, F., Nakhooda, S., and Thuault, A. (2009). A review of 25 readiness plan idea notes from the world bank forest carbon partnership facility. *World Resources Institute, Washington, DC*.

DeFries, R. S. (2002). Changes in forest area from ptca estimates, fra/fao remote-sensing survey, and fra country data for the 1980s and 1990s in tropical latin america, asia, andafrica.

FCPF (2012). Introduction to the forest carbon partnership facility.

Grassi, G., Monni, S., Federici, S., Achard, F., and Mollicone, D. (2008). Applying the conservativeness principle to redd to deal with the uncertainties of the estimates. *Environmental Research Letters*, 3:035005.

Hansen, M., Stehman, S., and Potapov, P. (2010). Reply to wernick et al.: Global scale quantification of forest change. *Proceedings of the National Academy of Sciences*, 107(38):E148–E148.

Karsenty, A. (2008). The architecture of proposed redd schemes after bali: facing critical choices. *International Forestry Review*, 10(3):443–457.

Karsenty, A. and Ongolo, S. (2012). Can fragile states decide to reduce their deforestation? the inappropriate use of the theory of incentives with respect to the redd mechanism. *Forest Policy and Economics*, 18(C):38–45.

Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., and Beach, R. (2008). Global cost estimates of reducing carbon emissions through avoided deforestation. *Proceedings of the National Academy of Sciences*, 105(30):10302.

Pan, Y., Birdsey, R., Fang, J., Houghton, R., Kauppi, P., Kurz, W., Phillips, O., Shvidenko, A., Lewis, S., Canadell, J., et al. (2011). A large and persistent carbon sink in the world's forests. *Science*.

Pelletier, J., Ramankutty, N., and Potvin, C. (2011). Diagnosing the uncertainty and detectability of emission reductions for redd+ under current capabilities: an example for panama. *Environmental Research Letters*, 6:024005.

Simonet, G. (2011). Conférence de durban : l'enjeu de la mesure des flux de carbone forestier. *Les Cahiers de la Chaire: série Informations et débats*.

Singh, N. (2005). Nash bargaining versus market outcomes. *Indian Economic Review*, 40(1):23–35.

Stern, N. and Treasury, G. (2007). *The economics of climate change: the Stern review*. Cambridge Univ Pr.

UNEP-FI (2011). Reddy set grow. Technical report, United Nation Environment Program Finance Initiative.

UNFCCC (2009). Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries- decision cop 15/4. Technical report, United Nation Framework Convention for Climate Change.

van der Werf, G. R. (2009). Co2 emissions from forest loss. *Nature GeoScience*, 2:737–738.