

**CLEAN DEVELOPMENT MECHANISM
PROPOSED NEW METHODOLOGY FOR AFFORESTATION AND REFORESTATION
PROJECT ACTIVITIES: BASELINE (CDM-AR -NMB)**

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SECTION A. Identification of methodology

A.1. Title of the proposed methodology:

Component A: *Determining carbon offsets by stop timber harvesting in projects avoiding deforestation in open economies.*

A.2. List of type(s) of A/R CDM project activity to which the methodology may apply:

The methodology is applicable to stop timber harvesting projects in natural forests. These activities are currently not eligible to the CDM.

A.3. Conditions under which the methodology is applicable to A/R CDM project activities:

The methodology is based on a model of the Bolivian timber markets, which projects a baseline timber harvest within the country and within the project area. The applied methodology has been developed by Brent Sohngen and Sandra Brown (Sohngen / Brown 2004¹). The model is based on the assumption, that Bolivia is a small open economy, that is a price taker on global timber markets. The potential pathway of future harvests in Bolivia both in the project area and within the entire country are simulated within a dynamic optimization model. Carbon offsets are generated by setting aside and indemnifying existing forest concessions.

The model is applicable, where similar forestry conditions to selective logging in concession holdings based on forest management plans exist. The model requires comprehensive data about timber species' market potential (volumes commercialised, prices, demand elasticity of domestic and international markets), specifications about the concessions (management regime, species density) and timber processing (investment, capital, labour, access, harvesting; and transportation costs). As far as to our knowledge, no other methodology exists for the same conditions of application.

A.4. Carbon pools covered by the methodology:

- above-ground biomass
- dead wood

We choose not to account for the changes in carbon stock from belowground biomass, litter and soil organic carbon pools, in the Component A. This choice will not increase the carbon offsets.

Given the nature of the highly selective logging in the concessions of Bolivia we assumed no change in soil carbon content of the forest. This is confirmed by Detwiler and Hall (1988; Science 239:42-47) who came to the same conclusion. Even if there was a slight loss due to increased soil organic matter decomposition this would be quickly recovered within a few years as the gap filled in and new litter and logging slash decomposed. It is likely that the logging roads and skid trails would reduce the soil carbon in the top 30 cm or so of soil, but given the likely area of roads and trails compared to the total logged area, the effect would be practically negligible.

The changes in carbon stock from litter and belowground biomass carbon pools are not verified. When logging occurs it is very likely that the carbon in the belowground biomass decreases, because of the decomposition. Since this decrease is not being accounted, the estimated carbon offsets are an underestimation.

¹ The description of the proposed new methodology is based on Sohngen/Brown 2004, the implementation of the model in GAMS™, and further explanations, the authors shared, kindly.

It also is very likely that logging causes an increase of carbon in the litter pool- but there are few studies clearly documenting the effects of management such as timber harvesting on litter carbon. This increase does not need to be taken into account since the biomass calculated to be extracted refers only to the trunk and big branches and not the twigs and leaves which go into the litter pool.

A.5. What are the potential strengths and weaknesses of this proposed new methodology?

Strengths:

- The stop timber harvesting model developed by Brent Sohngen is a major step forward in simulating timber harvest related to timber market behaviour. Its capability to link the varying biophysical potential of timber harvest concessions to the economic drivers is one of its most important strengths, as it allows to catch the driving forces governing forest exploitation. It is programmed in an easy to learn algebraic modelling language (GAMS), which offers full access to the code to test different scenarios. Thus, the model is sufficiently open for further development and modifications, which might become necessary in the future due to changing market dynamics.
- The stop timber harvesting model is capable to simulate market behaviours at different regional scales (stocks, concessions, departments, state) using a spatiotemporal approach. Thus, it is scalable and replicable to different conditions and could be used to develop other projects focussing on avoided logging.
- An other important feature is the model's capability to simulate the impact of alternative management scenarios for secondary forest stocks. This feature will become more important in a situation, where the legal and technical regulation of forest activities changes over time. The project administrator can anticipate these changes in the programming environment.
- The interface of the programming environment offers full control over tracking the development of all endogenous parameters, variables, and results over time. Thus, the model results can be compared with the development of co-related parameters, which offers high transparency referring model performance and validity of the results. These results can easily be incorporated in further spreadsheet calculations.
- The methodology uses values, equations and assumptions considered good practice by the IPCC and recognised experts in the field of forestry .

Weaknesses:

- Although the algebraic programming environment is easy to understand, the implemented model itself is highly complex. This degree of complexity referring the appropriate choice of biophysical and economic parameters demands a multidisciplinary approach combining forest engineering and forestry' economics. Under the actual conditions of developing countries it might be difficult to comply with this demand.
- Referring the demands in terms of parameters and data to calibrate the model this restriction might be valid, too. A modelling approach relating species' and stand specific parameters to market behaviour relies on the quality of data at various spatial and sectoral domains. It is nearly impossible, to reach sufficient scientific evidence for all parameters used. As in the case of global circulation models, some parameters have to be defined based on expert judgement to fit to market behaviour.

- An other weakness relates to linking the results of different models using different spatial scales. In case of NK-CAP, results of both components (A: stop timber harvesting; B: avoided deforestation) have to be calculated independently to be balanced afterwards. The spatial units of component A are defined legally (concessions, departments), whereas the simulation of GEOMOD works on a higher spatial resolution, which truly permits the spatial distribution of carbon credits on a semi-continuous surface. In its existing state of development the stop timber harvesting model is not capable of locating logged stands. Thus, a mechanism has to be applied, to discount for the risk, that, theoretically, an intersection between both components might have occurred. A higher degree of spatial coherence in terms of scale would be desirable, but is far from being easy to achieve.
- The model itself and the modelling environment have to be treated separately, although they are closely linked. Compared to other modelling environments, GAMS is costly (around US\$ 12,000 including the solver being used). At the same time, it offers only limited functions and programming interfaces to integrate GAMS models in other software environments. This might be a limitation in projects, where a more comprehensive modelling approach is recommendable.

SECTION B. Overall summary description:

The determination of carbon offsets relies on comparing a baseline scenario of timber production to an alternative scenario that assumes indemnification of concessions to extend and conserve the NKMNP. These scenarios are based on a dynamic economic optimization model, which maximizes social welfare created by the Bolivian timber market in the context of a global market. The model assumes that two types of species are harvested and processed: high quality timber for export and lower quality timber for internal markets. By maximizing social welfare, the model determines the harvests of mature and second-growth forests, the temporal frequency of the rotation cycles, the share of production commercialized in the domestic market, and investment for each concession. Yield functions and the domestic demand function are exogenously given.

The optimization model is calculating timber harvests for the without project case for both, the project area (4 concessions) and 5 Bolivia's departments, where timber harvesting occurs. In a second run, the productive area of concessions will be reduced by this part, which is affected by indemnification to expand the park area. Removing concessions causes market effects due to price changes and shifting of market actors. This shift will not effect prices on the export market (as a small country referring timber production Bolivia is a price taker), but highly impact the domestic market. It can be expected, that reduced supply and raised prices would stimulate other concessionaires to reduce the gap in the domestic supply by producing additional wood. Thus, the direct impact the removal of concessions will be accompanied by secondary market adjustments, which the methodology aims to determine by comparing the baseline and the "with project" case.

The baseline scenario gives the volume, which would have been harvested in the concessions in the without project case. The volume has to be converted in the equivalent offsets taking into account avoided damage due to logging, decomposition of dead wood, carbon storage in dead wood products and the difference in regrowth between logged and unlogged areas.

Comparing these results with the second run (with project) shows the extent, to which other domestic producers compensate the temporal supply reduction by augmenting their production. The difference between both scenario results for all Bolivian timber producing departments indicates the level of leakage, the project is causing.

The methodology includes the following steps:

- 1) Quantification of potential timber supply
- 2) Determination of the domestic timber demand function and export prices
- 3) Determination of the parameters for the yield functions, harvesting parameters, and productions functions
- 4) Definition of the constraints
- 5) Simulation of the baseline scenario
- 6) Estimating carbon flows for avoided timber logging
- 7) Estimating leakage
- 8) Sensitivity analysis

The baseline shows the concession and age-specific timber volumes, which would have been harvested without project. The project's activities are additional, as it removed selected concessions by indemnifying their owners and preventing them by contract, not to initiate new logging activities for a defined period (5 years).

SECTION C. Choice of and justification as to why one of the baseline approaches listed in paragraph 22 of CDM A/R modalities and procedures is considered to be the most appropriate :

C.1. General baseline approach for A/R project activities:

- ☒ Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary;
- ☒ Changes in carbon stocks in the carbon pools within the project boundary from a land use that represents an economically attractive course of action, taking into account barriers to investment;
- ☒ Changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts.

C.2. Justification of why the baseline approach for A/ R project activities chosen in C.1. above is considered the most appropriate:

Although the CDM guidelines demand the selection of one single option NK-CAP qualifies for all of them: The project initiates changes in carbon stocks in the carbon pools within the project boundary by terminating logging activities (option 1). This leads to changes in carbon stocks in the carbon pools within the project boundary from timber logging representing an economically attractive course of action (option 2) towards forest conservation. As offsets are calculated by comparing changes in carbon stocks in the pools within the project boundary from the most likely land use at the time the project starts with the case without project, NK-CAP qualifies for option 3 as well.

SECTION D. Explanation of how, by applying the baseline methodology, baselines are developed in a transparent and conservative manner:

The following section E will introduce step by step to the applied baseline methodology in a transparent and comprehensive manner. All related assumptions, applied variables, parameters, and algorithms will be explained in detail. All choices related to different methodological options are substantiated. In case of doubts, values that generate a higher baseline net GHG removals by sinks are used.

The proposed methodology is conservative, as it does not take into account possible offsets generated by avoided road construction in the case without project. Emissions due to forest biomass losses caused by construction of roads and skid trails will be halted and emissions from fuel consumption related timber activities will be reduced. These last sources of offsets, and others not mentioned here, have not been included in the calculation of Project benefits for purposes of the proposal, due to the limitations of

currently available data. These sources, however, are important, and add to the conservatism of the analysis set forth below. They also will be considered over the life of the Project to the extent practicable.

SECTION E. Explanation and justification of the proposed new baseline methodology:

E.1. Explanation of how national and/or sectoral policies and circumstances could be taken into account by the application of the methodology:

The methodology determines carbon offsets by removing existing timber concessions. Thus, the methodology is based on the national forest policy, which defines the fundamentals, procedures, and requirements in general, and specifically the legal framework for timber concessions. According to the revised forestry laws of 1997 Bolivian concessions are granted for 40 years with an option to be extended. The methodology has been developed for the CAPNK, which indemnified 4 existing forest concessions operating since the 80s. The vegetation in concession areas² intersecting with NK- reached some 628,083 ha with an net productive forest area of 524,144 ha (cf. Section A.4.1.4. Detail of geographical location and project boundary, on the PDD Form, p. 8). Therefore, the methodology is applicable where a comparable system of timber concession exists, and where a substantial part of these concessions is dedicated to be removed to generate carbon offsets by avoiding future logging activities.

The methodology does not depend on specific legal procedures for the removal of concessions. However, it is assumed, that the removal of concessions is irreversible during project lifetime, and that effective mechanisms will be set up to guarantee the recovery of biomass. In case of NKMNP, the park area has been extended by an presidential decree to include a certain part of the former concessions. Being part of the National System of Protected Areas the extended area of NKMNP is subject to carefully defined and monitoring schemes executed by the National Service for Protected Areas (Servicio Nacional de Áreas Protegidas, SERNAP).

E.2. Explanation of how the methodology determines the baseline scenario (that is, how it indicates the scenario that reasonably represents the sum of the changes in carbon stocks in the carbon pools within the project boundary that would occur in the absence of the proposed A/R project activity):

The baseline methodology is based on the continuation of the current situation: logging activities. It is based on a model of the Bolivian timber markets, which projects a baseline timber harvest within the country and within the project area. (see details in Section E.4)

E.3. Explanation of how, through the methodology, it can be demonstrated that a proposed A/R project activity is additional and therefore not the baseline scenario (section B.3 of the CDM-AR-PDD):

A project activity is additional if the actual net greenhouse gas removals by sinks are increased above the sum of the changes in carbon stocks in the carbon pools within the project boundary that would have occurred in the absence of the project activity.

The methodology (optimization dynamic model) demonstrates that without project, biomass loss due to timber harvesting would have continued following the harvesting paths determined by Component A. Due to the indemnification the concessions could be withdrawn, which would not have been possible without financial support of the project.

² The concessions areas are reduced by the area intersecting with protected areas (Las Lagunas Bella Vista, El Refugio, La Bahía), which already existed during the forestry use.

E.4. Explain and justify formulae/algorithms and/or models used to determine the baseline scenario. Variables, fixed parameters, values and different strata identified have to be reported (e.g. species, growth rates):

To simulate the potential pathway of future timber harvests in Bolivia, both in the project area and within the entire country, specific assumptions have to be made referring the dynamics between domestic and export markets, the past and future harvesting regimes. All assumptions are stated and explained in the specific context of each step. The methodology's roots in mainstream welfare economics assuming that Bolivian timber market attempts to maximize social welfare, i.e. the difference between income generated by commercialising timber in domestic and export markets and production costs.

(1) Quantification of potential timber supply

Any timber producing country is addressing different domestic and international markets, which demand different products in terms of quality, quantity, type, price, and state processing. In case of wood, these aspects are strongly related to the choice of species and its the competition on domestic and international markets. Specific assumptions have to be made to aggregate the diversity of products and their economic characteristics in a way, which makes it possible to model markets' dynamics.

Based on surveys of the Bolivian Chamber of Forestry (Cámara Forestal de Bolivia, CFB) and FAO the following assumptions related to timber market characteristic have been taken:

- The Bolivian forest production is small compared to the supply generated by other states (Brazil, Canada, Russia). Thus, Bolivia is assumed to be a price taker on the global market and its forest sector acts in a small open economy. As a consequence, export prices are given exogenously.
- Tropical forests offer a broad variety of timer species, but only few of them have a potential to be commercialized in international markets. There is clear evidence, that concessionaires are choosing these valuable species (Mahogany, Cedar, Robles) first when defining harvested areas and intensity of harvests. The remaining species enter into the domestic market depending on price and demand. Thus, domestic markets are supplied as a consequence of satisfying export demand.

(2) Determination of the domestic timber demand function and export prices

The model assumes, that Bolivian timber markets attempt to maximize social welfare of a given year (S_t) as the difference between income form wood production for international and domestic markets and the costs of wood production:

$$[1a] \quad S_t = P_t^E q_t^E + P_t^I q_t^I - C_t$$

where:

P_t^E :	Export price at time t
q_t^E :	Quantity of export boards at time t
P_t^I :	Domestic price at time t
q_t^I :	Quantity of boards sold in the domestic market at time t
C_t :	Total costs at time t

As export demand is governing timber production, it is reasonable to define the production for the domestic market as a share (α_t) of the export production. Thus, equation [1] can be reformulated as follows:

$$[1b] \quad S_t = P_t^E q_t^E + \int_0^{\alpha_t q_t^E} [D(n_t, Z_t)] dn_t - C_t$$

where:

$D(n_t, Z_t) = q(P_t^I)$:	Domestic demand function for boards
$\alpha_t q_t^E$:	Quantity of boards sold in the domestic market at time t
Z_t :	Demand shifter for the domestic Bolivian demand function

The benefits of industrial round wood harvest sold in the domestic market is Marshallian Consumer surplus, or the area underneath the domestic demand function determined by integral in [1b].

The domestic demand function is assumed to be linear following the general form:

$$[1c] \quad q_t^I = mP_t^I + b$$

It is evident, that the domestic demand function for boards is downward sloping, with $m < 0$. To apply the demand function in the dynamic optimization model, its elasticity and further parameters have to be determined, which depend on the specific market conditions in each country.

The price elasticity of the domestic demand (η^I) is a crucial parameter for the demand function, as it determines its slope (m). The following equation gives the general relation between slope and elasticity:

$$[1d] \quad \eta^I = \frac{\Delta q}{\Delta P} * \frac{P_t^I}{q_t^I} = m * \frac{P_t^I}{q_t^I}$$

Domestic market prices are constraint to remain beneath the export market prices. This constraint is based on the assumption, that if the domestic prices rise above the export prices, the supply will shift to the domestic market.

Export prices for timber products are a driving force for management decisions about timber harvesting. They are exogenously determined. Additionally, long-term projections of economic timber prices have to take into account, that carbon sequestration by setting aside and replanting forests might become a competitive economic alternative or complementary form of managing forests. The relative economic importance of sequestration programmes will depend on the carbon price amongst other factors. Thus, projection have to anticipate the price effects of the potential paths of global sequestration programmes on timber export prices.

(3) Determination of the parameters for the yield functions, harvesting parameters, and productions functions

Different types of forests within one country have different timber harvesting potentials. Harvesting intensities change the potential yield of future harvests in the same area. Thus, site- and stand specific yield functions have to be defined. As the model assumes, that domestic markets are supplied as a consequence of satisfying export demand with selected valuable species yield functions have to be defined for low and high quality species. As second-growth forest may yield lower quantities of merchantable timber than mature forests, the yield function may change over time.

Based on this, a concave yield function for a stand of age a at time t can be defined applying standard logistic growth functions as follows:

$$[2] \quad V_{a,t} = C * \exp(B_1 - B_2 / a) \text{ in } [m^3/ha]$$

Where:

a:	age class of the stand
C:	second growth yield multiplier
B ₁ :	yield parameter 1
B ₂ :	yield parameter 2

Although climate change could alter the productivity of forests, and consequently timber supply, such changes in forest productivity are not considered in the model. The age of harvesting is determined endogenously by the timber model.

A production function has been chosen following Lyon et al. (1987):

$$[3] \quad Q_t = AK_t^B L_t^{1-B} \text{ in } [m^3]$$

Where:

Q _t :	Total quantity of produced boards at time t
A:	1 st constant of the production function
B:	2 nd constant of the production function
K:	Capital invested in timber industry
L:	numeraire representing other inputs (including labour)

As certain share (α_t) of the quantity of boards produced for export purposes (q_t^E) is sold in the domestic market, equation [3] can be modified as follows:

$$[4] \quad Q_t = (1 + \alpha_t)q_t^E \text{ in } [m^3]$$

Where:

q_t^E :	quantity of boards produced for export purposes at time t
α_t :	proportion of production for domestic markets at time t

Depending on production efficiency (ε), only a certain part of the total merchantable log volume at time t (H_t) can be converted into sellable boards:

$$[5] \quad Q_t \leq \varepsilon * H_t \text{ in } [m^3]$$

Where:

H_t :	total merchantable log volume at time t
ε :	production efficiency

The total merchantable log volume at time t depends on the decision about hectares harvested in each age class ($h_{a,t}$) and the specific yield function ($V_{a,t}$) of the harvested area in old-growth (h_t^{OG}) and second-growth land (h_t^{SG}) at time t. Taking into account [4], equation [5] can be transformed to:

$$[5a] \quad Q_t \leq \varepsilon H_t = \varepsilon * (H_t^{OG} + H_t^{SG}) = \varepsilon * \left[\sum_a (1 + \alpha_t) h_{a,t}^{SG} V_{a,t} + \sum_a (1 + \alpha_t) h_t^{OG} V^{OG} \right]$$

Where:

H_t^{OG} :	harvested volume in old-growth stands at time t
H_t^{SG} :	harvested volume in second-growth stands at time t
h_t^{OG} :	harvested area in old-growth stands at time t
$h_{ta,t}^{SG}$:	harvested area of age class a in second-growth stands at time t
$V_{a,t}$:	yield function of a of age class a at time t
V^{OG} :	yield function of old-growth stands a at time t

It is assumed, that managers of concessions are harvesting the old stocks first, which afterwards enter into the stock of second-growth. Depending on the demand and the length of rotation cycles, second-growth stands will be harvested, too. Therefore, equations of motion of the different timber stocks have to be developed. Mature or old-growth forest are assumed to hold the maximum potential biomass. Thus, it is not necessary, to track the age class of these forests.

The change in stocks of mature forests over time can be described as follows:

$$[6] \quad X_{t+1}^{OG} = X_t^{OG} - h_t^{OG}$$

Where:

X_t^{OG} : Stock of old-growth stands at time t in [ha]
 h_t^{OG} : harvested area in old-growth stands at time t

Second-growth stocks are supposed to change as follows:

$$[7] \quad X_{a,t+1}^{SG} = X_{a,t}^{SG} - h_{a,t}^{SG}$$

Where:

$X_{a,t}^{SG}$: Stock age class a in second-growth stands at time t in [ha]
 $h_{a,t}^{SG}$: harvested area in second-growth stands at time t

As second-growth stands' development is initiated by harvesting old-growth stocks, the following relationship can be defined:

$$[8] \quad X_{1,t+1}^{SG} = \sum_a h_{a,t}^{SG} + h_t^{OG}$$

The following example illustrates the motion defined by equation [8]: At time t=1 a concession consists of 5 areas of different age classes and one old-growth stock. For demonstration purposes all stocks are set to 100 ha:

100 ha plots at time period t = 1

$X_{1,1}^{SG}$	$X_{2,1}^{SG}$
$X_{3,1}^{SG}$	$X_{4,1}^{SG}$
$X_{5,1}^{SG}$	X_1^{OG}

Stocks at time period t = 1

Age class	Age [years]	Stock name	Stock [ha]
a1	10	$X_{1,1}^{SG}$	100
a2	20	$X_{2,1}^{SG}$	100
a3	30	$X_{3,1}^{SG}$	100
a4	40	$X_{4,1}^{SG}$	100
a5	50	$X_{5,1}^{SG}$	100
<i>Old growth</i>	<i>mature</i>	X_1^{OG}	100

Suppose, in time period 1 all stocks of the age classes a4, a5 plus all old-growth stands are harvested (see the grey-shaded plots). That is $\sum h_{a,t}^{SG}$ sums up to those harvests in the second-growth component (200 ha) plus 100 ha of harvests in the old-growth stands. At time period 2, the stocks are as follows :

100 ha plots at time period $t = 2$

$X_{2,2}^{SG}$	$X_{3,2}^{SG}$
$X_{4,2}^{SG}$	$X_{1,2}^{SG}$
$X_{1,2}^{SG}$	$X_{1,2}^{SG}$

Stocks at time period $t = 2$

Age class	Age [years]	Stock name	Stock [ha]
a1	10	$X_{1,1}^{SG}$	300
a2	20	$X_{2,1}^{SG}$	100
a3	30	$X_{3,1}^{SG}$	100
a4	40	$X_{4,1}^{SG}$	100
a5	50	$X_{5,1}^{SG}$	0
Old growth	mature	X_1^{OG}	0

The movement $X_{1,1}^{SG}$ to $X_{2,2}^{SG}$ indicates, that the stand in the upper left corner has grown into the next age class. The total stock of second-growth stands a time period $t = 2$ sums up to 300 ha. Furthermore, the motion of the timber processing capital stock K_t has to be defined:

$$[9] \quad K_{t+1} = (1 - d)K_t + I_t$$

Where:

d: depreciation of the capital
 I_t : Investment at time t

(4) Definition of the constraints

Generally, production is constraint by the availability of its factors, i.e. capital, labour, and other inputs. Basically, it is assumed, that capital and labour are greater than 0. Additional constraints can be introduced to define the upper limits of investment or available labour depending on the specific situation of the country and region. Depending on the type of forest regime harvests might be constraint in terms of or harvested areas or volumes. These constraints can be included, as well.

(5) Solving the model: simulation of the baseline scenario

The model is solved by maximizing the discounted social welfare defined by equation [1b] and [10] subject to the constraint given in the equations [5a], [6], [7], [8], and [9].

$$[1b] \quad S_t = P_t^E q_t^E + \int_0^{\alpha_t q_t^E} [D(n_t, Z_t)] dn_t - C_t$$

$$[10] \quad Max \sum_1^{T-1} \rho^t S_t + \rho^T S_T$$

Where:

ρ^t : discount factor
 S_t : social welfare a time t (cf. equation [1])
 T: terminal time period
 $D(n_t, Z_t)$: Domestic demand function for boards
 $\alpha_t q_t^E$: Quantity of boards sold in the domestic market at time t
 Z_t : Demand shifter for the domestic Bolivian demand function

Appropriate terminal conditions have to be defined and a solvers have to be chosen. Yield functions are exogenously given. All choice variables are constraint to be greater than or equal to 0. By searching the maximum the model chooses harvesting areas of old- and second-growth stands for all the 9 regions, the Quantity of boards sold in the domestic market and the Investment at time T.

By solving the maximization problem the model determines the harvested volumes for each of the indemnified concessions areas intersecting with the project area.

(6) Estimating carbon flows for avoided timber logging

The carbon offsets from logging are calculated as:

$$[11] \quad C^A = C^{extracted} + C^{damaged} + \Delta C^{dead} + \Delta C^{woodproducts} + Rg^A \text{ [tC]}$$

Where:

- C^A : total offsets from Component A [tC]
- Rg^A : assigned regrowth in logged areas [tC]
- ΔC^{dead} : change in carbon of dead biomass by timber harvesting³ [tC]
- $\Delta C^{woodproducts}$: change in carbon of long-lived wood products biomass by timber harvesting⁴ [tC]

The above equation is showing that the total offsets from logging are based on the changes of live biomass, dead biomass and log-lived products.

To estimate the amount of damaged and dead biomass produced in the logging operations, and to quantify the effects of logging on rates of carbon accumulation of the residual stand, 102 Carbon Impact Zone (CIZ) plots and 102 pairs of permanent plots in the Cerro Pelao concession were established. A paired nested plot (as in the NKCAP area) was located nearby, and all trees ≥ 10 cm dbh measured and tagged for future measurements also. Remeasurements of the paired plots in 2003 provided the necessary information to estimate the growth factor. The dimensions of the CIZ plots were established (rectangles with length based on height of tree and width based on width of the crown), and all standing trees ≥ 10 cm dbh that were damaged as a result of the timber tree falling to the ground were measured. All damaged trees were tagged using numbered aluminum tags. To estimate the amount of damaged vegetation in each CIZ plot, the biomass of trees in the severely damaged classes was estimated using the same equations as for the initial carbon inventory.

(a) Δ live biomass C = (biomass C from logging damage + C in timber extracted) x growth factor

The change in live biomass caused by logging is a result of the extraction of timber and damage to residual trees.

Changes in live biomass caused by timber extraction are calculated as follows:

$$[12] \quad C_t^{extracted} = V_t^{logged} * \phi * CF \text{ [tC]}$$

Where:

- V_t^{logged} : Timber Volume logged at time t
- ϕ : density of harvested wood [tC/m³]
- CF: carbon fraction of dry matter

Collateral damage to vegetation caused by logging activities has to be taken into account:

³ This change is negative.

⁴ This change is negative.

$$[13] \quad B_t^{damage} = B_t^{extracted} * \delta \quad [tC]$$

Where:

δ : damage factor

The PDD form in the Section B.1 Application of the proposed baseline methodology Component A, explains, how the damage factor has been estimated.

The regrowth factor accounts for the impact of logging on the growth of the residual stand. To monitor the impact of logging on rates of regrowth in the CIZ plots, a paired plot will be installed adjacent to each CIZ plot. The measurements and remeasurements will enable the net biomass carbon that accumulated during the interval to be calculated and thus the difference between the CIZ plot and its unlogged pair.

Regrowth can be estimated according to the following methodology:

Carbon credits from changes in logging are based on estimating the change directly from the amount of wood extracted and the damage during extraction

The change in live biomass from logging--over one year =

[(growth rate with project +live biomass with project) - (growth rate w/o project + live biomass w/o project)]

Simplifying: =

[growth rate with project +live biomass with project - growth rate w/o project - live biomass w/o project]

If growth rates are the same with and w/o project then this simplifies to:

[live biomass with project - live biomass w/o project]

Or the amount of wood extracted and the damage as is normally calculated.

If growth rate with project is higher than w/o project then this is expressed as:

[difference in growth rates per area affected by logging + (damage and extraction)]

If growth rate with project is lower than w/o project then this is expressed as:

[(damage and extraction) - difference in growth rate per area affected by logging]

To actually calculate the carbon offsets due to the regrowth factor, the following steps were taken:

1. Estimate the difference in growth rates per unit area;
2. From the logging impact plots, the average area affected per cubic meter of timber removed is estimated;
3. Multiply the annual amount of timber removed (from Sohngen and Brown scenarios) by the area affected (step 1.) multiplied by the regrowth rate difference (step 2); the resulting value is the additional carbon offsets in t C per year.

The estimated offsets based on regrowth are added to those calculated from the logging model.

(b) Estimating the change in dead biomass

In projects related to preventing or reducing logging impacts, dead wood cannot be ignored because logging increases the size of this pool. Thus stopping logging (with-project case) has the effect of reducing the dead biomass C pool, and the change in the dead biomass C will be negative, i.e., the dead biomass C in the with-project case is less than in the without-project case. Research has shown that dead wood decomposes relatively slowly in tropical forests and it is a pool that has a long turnover time (Delaney et al., 1998). However, the change in the dead biomass pool has to be corrected for decomposition. This is explained by the following example: in a concession that is logged over a 30 year rotation, there would be blocks logged 30 years ago, 29 years ago, etc. to one that was logged 1 year ago, and the dead wood in each block has different time periods over which decomposition occurs. The actual amount of dead wood is computed yearly based on the amount of timber harvested and the ratio of damage per unit of wood harvested. The damaged wood is assumed to enter the dead wood pool, where it starts to decompose. Each year more dead wood is added from harvesting, but each year some is lost because of decomposition and resulting emissions of carbon. Decomposition of dead wood is modeled as a simple exponential function based on mass of dead wood and a decomposition coefficient (proportion decomposed per year):

$$[14] \quad C_{t+1}^{dead} = (C_t^{dead} * e^{-r_d}) + C_{t+1}^{damaged} \quad [tC]$$

$$[15] \quad \Delta C_{t+1}^{dead} = C_{t+1}^{dead} - C_t^{dead} \quad [tC]$$

Where:

C_{t+1}^{dead} : Carbon pool of dead wood in t+1
 r_d : decomposition coefficient

The decomposition coefficient is assumed to range from 0.07 – 0.12/yr based on literature sources for the tropics (Brown 1997, Delaney et al. 1998). No plans have been made to measure this in the field as this type of work is time consuming and costly; however the values used in this report are well within the range of expected values for a range of tropical moist forest types.

(c) Estimating the change in carbon stocks of long term wood products

Not all of the decrease in live biomass due to logging is emitted to the atmosphere as a carbon emission: some is stored as dead wood which decomposes through time as mentioned above, and some goes into long-lived wood products which decomposes very slowly. Thus the baseline emissions from harvesting need to be reduced by the amount of live biomass that ends up in long-lived wood products.

$$[16] \quad C_t^{woodproducts} = V_t^{logged} * \phi * CF * p \quad [tC]$$

Where:

V_t^{logged} : Timber Volume logged at time t
 ϕ : density of harvested wood [tC/m³]
 CF: carbon fraction of dry matter
 p: percent of harvest industrial roundwood going into long term wood products

(7) Estimating leakage

Stopping timber harvesting at a regional scale could cause significant shifts in traded volumes and timber prices in the domestic market. As Bolivia's timber production proceeds in a small open economy effects on international markets are unlikely. As the country's responsibility for carbon leakage stops at its border, export demand has been modelled as perfectly elastic. This assumption means that we do not calculate potential leakage outside of Bolivia.

As explained above, the baseline scenario gives the volume, which would have been harvested in the concessions in the without project case. The volume has to be converted in the equivalent offsets taking into account avoided damage due to logging, decomposition of dead wood, carbon storage in dead wood products and the difference in regrowth between logged and unlogged areas. Comparing these results with the second run (with project) shows the extent, to which other domestic producers compensate the temporal supply reduction by augmenting their production. The difference between both scenario results for all Bolivian timber producing departments indicates the level of leakage, the project is causing. (see details in the Section E.6)

(8) Sensitivity analysis

As the stop timber harvesting model is highly complex, it is impossible to test the sensitivity of all parameters. Thus, a reasonable selection of those parameters has to be made, which might cause a high impact on the results or which are subject to higher risks. Sohngen and Brown (2004) carried out a sensitivity analysis based on the elasticity of domestic timber demand, the capital constraint, the annual change of export prices, and the decomposition rate. The results are explained in the application of the proposed methodology.

E.5. Explain and justify formulae/algorithms and/or models used to determine the actual net GHG removals by sinks from the proposed A/R CDM project activity. Variables, fixed parameters, values and different strata identified have to be reported (e.g. fuel(s) used, fuel consumption rates):

All the formulae/algorithms and models used to determine the actual net GHG removals by sinks from the project activity, are well explained in the previous section. Because the methodology uses the same model for the determination of the baseline net GHG removals by sinks and the actual net GHG removals by sinks, it is not necessary to split the methodology for a better understanding.

E.6. Explain how the baseline methodology addresses any potential leakage of the proposed A/R project activity:

According to FCCC/SBSTA/2003/L.27 (p.5) "Leakage" is the increase in greenhouse gas emissions by sources which occurs outside the boundary of an afforestation or reforestation project activity under the CDM which is measurable and attributable to the afforestation or reforestation project activity." Stopping timber harvesting at a regional scale could cause significant shifts in traded volumes and timber prices in the domestic market. As it is assumed that the country's timber production proceeds in a small open economy effects on international markets are unlikely. As the country's responsibility for carbon leakage stops at its border, export demand has to be modelled as perfectly elastic. This assumption means that we do not calculate potential leakage outside of the country.

Leakage is to be estimated ex-ante, by running the baseline simulation, which simulates the timber production of the 5 departments producing timber and the 4 concessions intersecting with the project area modelled separately. For the second run, the area of the 4 concessions is set to 0⁵. One could expect, that

⁵ Technically spoken, the parameter values for the areas of the 4 concessions do not change. Instead, the actual variable that initializes the forest area in the forest area constraints will be set to 0 for the scenarios where NKCAP harvests are reduced to 0 in indemnification.

due various trade-offs, specifically the adjustments in prices, in traded timber volumes, and capital stocks, the reduction in Bolivia's timber production will be smaller than the production of the 4 indemnified concessions. Comparing the simulated annual timber production Bolivia indicates the quantity of this trade-off. This difference between the avoided annual production of the 4 concessions and the reduced overall Bolivian timber production (compared to the baseline) has to be regarded as leakage attributable to Component A.

Leakage will be calculated as in equations [40a] and [40b] described in the application of the Baseline methodology of the Component A.

Projects that remove concessions from the timberland base, can have effects beyond the direct hectares that are conserved by the project itself, apart from market shifts leakage might occur, in case former concessionaires will reinvest the money received by the indemnification in other economic activities causing emissions. The project administrator has to monitor these activities in a reasonable manner based on the legal agreements between the project owners and the concessionaires. Note, that the stop timber harvesting model simulates the whole timber production of Bolivia. Thus, the model covers the risk, that the indemnified concessionaires might re-enter into the production of timber re-investing a certain part of indemnification. Based on the assumption, that concessions holders can't produce timber missing the demand in the long run, it is reasonable to state, that this specific form of leakage is implicitly included in the calculation.

Furthermore, the monitoring of the baseline includes the monitoring of the leakage associated with the staff travel associated with the project activity. The application monitoring methodology explains how leakage is treated in the Component A.

E.7. Explain and justify formulae/algorithms and/or models used to determine the net anthropogenic GHG removals by sinks from the proposed A/R CDM project activity:

The carbon offsets from logging are calculated as, (a slight modification of the equation [11] is used):

$$[11'] \quad C_{wl}^A = C_{wl}^{extracted} + C_{wl}^{damaged} + \Delta C_{wl}^{dead} + \Delta C_{wl}^{woodproducts} + Rg_{wl}^A \quad [tC]$$

Where:

C_{wl}^A :	total offsets from Component A (with leakage) [tC]
Rg_{wl}^A :	assigned regrowth (with leakage) in logged areas [tC]
ΔC_{wl}^{dead} :	change in carbon of dead biomass(with leakage) by timber harvesting ⁶ [tC]
$\Delta C_{wl}^{woodproducts}$:	change in carbon of long-lived wood products biomass (with leakage) by timber harvesting ⁷ [tC]

SECTION F. Data sources and assumptions:

F.1. Describe all parameters and assumptions (e.g. regarding biomass expansion factors and activity levels):

The parameters and assumptions are described in detail in the Application of the Baseline Methodology Component A (cf. Section B.1 of the PDD form)

⁶ This change is negative.

⁷ This change is negative.

F.2. List of data used and their sources :

Above-ground biomass to carbon conversion:

Carbon fraction of dry matter = 0.5 tC/m³

(Source:IPCC (2003). Good Practice Guidance for LULUCF; p. 3.25)

Decomposition coefficient (r_d)= 0,07

Source:Brown 1997, Delaney et al. 1998

Percent of harvest industrial roundwood going into long term wood products (p) = 30%

Source: Winjum, Brown and Schlamadinger (1998)

F.3. Vintage of data (e.g. relative to starting date of the proposed A/R CDM project activity):

The data mentioned under F.2 is not related to a limited vintage. As indicated above parameters determined prior to the years 1998 and 2003 have been used.

F.4. Spatial resolution of data (e.g. local, regional, national):

The Methodology combines plot specific data with regional and national forest census data.

SECTION G. Assessment of uncertainties:

In the baseline methodology for Component A , quantitative risk and uncertainty are assessed through the leakage and sensitivity analysis described above.

Qualitative risk are not assessed by the baseline methodology. Nevertheless, as the Government of Bolivia is already a partner in the NK-CAP, and the project occurs on national park lands, so qualitative risk as nationalization of the project is unlikely as the Government has already agreed to participate and has signed an international legal agreement to uphold its commitments to the Park and to the project.

The project is being implemented for almost nine years, and has overcome several periods of social, economic and political instability.

Furthermore, the Government of Bolivia is taking a great role in certifying and marketing offsets from this project.
