

Emission reductions calculations for the FICAFE project

- *Version 04 – 15-09-2008 – Till Neeff*

Definitions

The land-use categories i shall be defined in the PDD.

Applicability

This methodology was written specifically for the FICAFE project. It is not intended to be applicable to other projects. This fact makes a sound list of applicability conditions obsolete. Nevertheless, there are some key issues that are worth highlighting:

- a. The methodology concerns the conversion of forest to non-forest through abandonment. There will be no other land uses that would replace forests and land will not be used after abandonment.
- b. The only “use” of the abandoned lands will be for the collection of fuelwood. The collection is, however, not the driver of the abandonment. Collection of fuelwood merely occurs incidentally.
- c. The project will claim carbon credits for avoided deforestation, i.e., avoided land-use conversion. There will be no credits claimed for recovery of existing plantations, nor for establishment of no plantations.

Project boundary

Physical boundary

The project is carried out in forests that the project proponent’s intervention covers. The project intervention has some bearing on the deforestation rate; either directly or through its proxy variable X (see below).

The project boundary corresponds to the physical area of forests under threat to be deforested. The total area is composed of sub-areas c, for which deforestation rates and forest areas are tracked separately.

The total forest area is composed of the forest areas in smaller sub-areas, such that:

$$A_{For A t s=BL} = \sum_c A_{For c t} \quad (1)$$

Where:

s – baseline (BL) and project (PJ) scenarios; dimensionless

$A_{For A t s=BL}$ – total area of forests in year t for s is the baseline scenario; ha

$A_{For c t}$ – area of forests in year t in sub-area c; ha

Before project start, at $t=0$, the area $A_{For A (t=0)}$ corresponds to the entire area within the project boundary and $A_{For c (t=0)}$ is the contribution that sub-area c makes to the project area at project start.

Greenhouse gases

The methodology only considers one greenhouse gas, namely CO₂. This decision is conservative because most of the emissions occur due to deforestation and much of the trees are ultimately burnt as fuelwood. When burning the trees as fuelwood, non-CO₂ greenhouse gases with high global-warming potential also occur that this methodology chooses not to account for.

Carbon pools

Everywhere in this document unless specified otherwise, the carbon densities shall reflect all carbon pools including tree and non-tree above-ground biomass, below-ground biomass, litter, deadwood and soil-organic carbon.

Additionality

The additionality of the project's emission reductions shall be argued in the PDD.

Selection of the baseline scenario

The baseline scenario corresponds to a baseline deforestation rate that the project seeks to lower. The procedures for modelling the baseline deforestation rate in function of monitoring results are contained below in the section on annual areas undergoing deforestation.

Emission reductions

The amount of carbon credits to be generated corresponds to the net reduction of GHG emissions. The net emission reductions are the baseline-scenario emissions minus the project-scenario emissions minus leakage. Therefore, the following general formula can be used to calculate the reduction of GHG emissions in a given year:

$$\text{CRED} = \text{C}_{\text{s=BL}} - \text{C}_{\text{s=PJ}} - \text{LK} \quad (2)$$

Where:

CRED – annual emission reductions; t CO₂e yr⁻¹

C_{s=BL} – annual emissions under the baseline scenario; t CO₂e yr⁻¹

C_{s=PJ} – annual emissions under the project scenario; t CO₂e yr⁻¹

LK – annual leakage; t CO₂e yr⁻¹

The annual project emissions C_{s=PJ} and baseline emissions C_{s=BL} are both calculated using Equation 3. Leakage is calculated using Equation 10.

Buffer approach for ensuring non-permanence

This methodology ensures permanence of achieved emission reductions through a buffer approach. At the issuance interval a percentage of the achieved emission reductions shall be withheld and put into a buffer. The buffer caters for the risk of unforeseen events that may lead to the reversal of

achieved emission reductions. The size of the buffer therefore reflects the risk inherent to the specific project.

This methodology uses the buffer approach as outlined for RED projects in the AFOLU section of VCS-2007¹.

Calculation of annual emissions under both the project scenario and the baseline scenario

The emissions under both the baseline scenario and the project scenario are the emissions from deforestation. The most important activity data is the area undergoing deforestation after abandonment. The corresponding emission factors are the differences in carbon densities between the forests and the abandoned areas.

$$C_t = \sum_i C_{Def\ i} * A_{Def\ A\ i\ t} \quad (3)$$

Where:

C_t – annual emissions in year t ; t CO₂e

i – post-conversion land-use types from 1 through I ; dimensionless

t – years across project lifetime from 0 through T , 0 is the year of the baseline study and T is the project lifetime; dimensionless

$C_{Def\ i}$ – average emissions per area-unit of deforestation towards post-conversion land-use type i ; t CO₂e ha⁻¹

$A_{Def\ A\ i\ t}$ – total annual area of deforestation towards post-conversion land-use type i in year t ; ha

This methodology and project consider only one post-conversion land-use type only, namely abandonment, such that i =abandonment. The subscript i is needed nevertheless because if forest remains, then i =remains.

Equation 3 shall be used for calculating both the project emissions and the baseline emissions. Equation 3 is applied twice with different activity data and the same emission factors. I.e., there is one set of procedures for deriving the annual area of deforestation that applies to the baseline scenario and another set of procedures that applies to the project scenario. There is, however, only one set of emissions per area-unit of deforestation.

Calculation of the annual areas undergoing deforestation (activity data)

Deforestation is distinguished according to the post-conversion land-use types I and the corresponding areas can be distinguished in the calculations. The area not undergoing deforestation can be calculated in the same way, the conversion pathway i =remains and the probability p_{ct} ($Def\ i$ =remains) then is the probability that forests remain forest. More precisely, the approach considers two post-conversion land-use types, namely abandonment and no-conversion, i.e., that the forest remains. In the case of observing conversion to other land-use types, these shall be omitted in the calculations and no credits can be earned for reducing such deforestation trends.

¹ <http://www.v-c-s.org/>.

The area of forests across project lifetime and the probability of deforestation across project lifetime need to be determined for both the project scenario and the baseline scenario. Moreover, they need to be determined ex-ante for estimating the project's potential to deliver carbon credits beforehand, and ex-post for the issuance of carbon credits. Accordingly, the following different approaches will be used for estimation:

- ex-ante baseline scenario: Area and probability will be projected based on the statistical deforestation model. The model will be parameterized with assumptions about future development of market conditions.
- ex-ante project scenario: The area will be projected relative to the ex-ante baseline scenario, assuming a relative reduction of deforestation rates.
- ex-post baseline scenario: The area is result of monitoring, because the probability will be modelled based on the statistical deforestation model where the model will be parameterized with actual, observed conditions during the monitoring interval.
- ex-post project scenario: The area results from monitoring.

Calculation of the deforestation rate for the baseline scenario

The probability of deforestation for conversion towards the land-use types is modelled. In doing so, it is permissible to use a proxy variable in the following way:

$$p_{ct}(\text{Def } i) = p(\text{Def } i | X) * p_{ct}(X) \quad (4)$$

Where:

$p_{ct}(\text{Def } i)$ – probability of deforestation towards post-conversion land-use type i in year t in sub-area c ; dimensionless

c – sub-area from 1 through C ; dimensionless

$p(\text{Def } i | X)$ – probability of deforestation towards post-conversion land-use type i , given that condition X is fulfilled; dimensionless

$p_{ct}(X)$ – probability that condition X is fulfilled in year t in sub-area c ; dimensionless

Step a. Select a proxy variable X . The proxy variable shall be selected to ensure that a) it is related to deforestation and therefore effective in modelling deforestation, and b) that there is a dataset available that would allow for modelling.

Step b. $p_{ct}(X)$ shall be modelled through a logistic regression model. Various candidate predictor variables shall be used and stepwise regression shall be applied for model selection. The dataset for calibrating the model shall come from observations of past periods or similar example cases.

Stepwise regression is an automated procedure for building regression in cases where a set of predictor variables could in principle be used but where the choice between those is not straightforward. Stepwise regression chooses a optimal set of predictors in an iterative procedure. The resulting statistical model will contain only those independent variables that significantly contribute to explain the dependent variable, and it will do this in an optimal way. Since the procedure is automated there is no room for manipulation.

Therefore:

$$p_{ct}(X) = f(\text{predX } t) \quad (5)$$

Where:

$p_{ct}(X)$ – probability that condition X is fulfilled in year t in sub-area c; dimensionless

$f(\text{predX } t)$ – functional form to predict $p_{ct}(X)$ from $\text{predX } t$; dimensionless

$\text{predX } t$ – various predictor variables that will be used to predict $p_{ct}(X)$ in year t; various dimensions

Ex-ante, the dataset ($\text{predX } t$) for adjusting the model of $p_{ct}(X)$ to the future context shall be selected based on assumptions from expert judgment. Ex-post, the dataset ($\text{predX } t$) for adjusting the model of $p_{ct}(X)$ to the future context is monitored.

Step c. $p(\text{Def } i | X)$ shall be modelled as ratios for the i 's. The dataset for deriving the ratios shall base on observations of past periods or similar example cases.

The model for $p(\text{Def } i | X)$ is the same ex-ante and ex-post. The ratios shall be fixed during the validation.

Step d. Calculate $p_{ct}(\text{Def } i)$ for all years and for all sub-areas using the results of steps a and b.

Calculation of forest area for the baseline scenario

Step a. Inventory the overall forest area and the forest area in the sub-areas at project start $t=0$. This inventory is part of the pre-project inventory.

Step b. Calculate the remaining forest areas for all years. In a given year, the remaining forest area within each sub-area is a function of the forest area in the previous year and the deforestation rate:

$$A_{For\ c}(t+1) = A_{For\ c}(t) * p_{ct}(\text{Def } i=\text{remains}) \quad (6)$$

Where:

$A_{For\ c}(t)$ – area of forests in year t in sub-area c; ha

$p_{ct}(\text{Def } i=\text{remains})$ – probability of not deforestation in year t in sub-area c; dimensionless

Step c. Calculate the deforestation areas within all sub-areas and for all years using the following equation:

$$A_{Def\ cit} = A_{For\ c}(t) * p_{ct}(\text{Def } i) \quad (7)$$

Where:

$A_{Def\ cit}$ – annual area of deforestation towards post-conversion land-use type i in year t, in sub-area c; ha

$A_{For\ c}(t)$ – area of forests in year t in sub-area c; ha

$p_{ct}(\text{Def } i)$ – probability of deforestation towards post-conversion land-use type i in year t in sub-area c; dimensionless

The area of forests in any year is the result of applying Equation 6 that uses the forest area in the previous year and the probability of no-change. Ultimately, the forest area in a given year will be recovered from the initial forest area ($A_{For\ c}(t=0)$) and a chain of conversion probabilities ($p_{c\ i}(t=1)$ (Def i =remains), $p_{c\ i}(t=2)$ (Def i =remains), etc.). Each of these probabilities ($p_{c\ i}$) are calculated using Equation 4. Forest area in any year can be recovered recursively because the equations work in the way that $A_{Def\ c\ i\ remains} = A_{For\ c\ t+1}$.

Step d. Calculate the total deforestation area under the baseline scenario as the sum of the deforestation in the sub-areas for all years.

The total annual area undergoing deforestation in a given year is the sum of the areas within sub-areas that undergo deforestation:

$$A_{Def\ A\ it} = \sum_c A_{Def\ cit} \tag{8}$$

Where:

$A_{Def\ A\ it}$ – total annual area of deforestation towards post-conversion land-use type i in year t ; ha
 $A_{Def\ cit}$ – annual area of deforestation towards post-conversion land-use type i in year t , in sub-area c ; ha

Calculation of the deforestation rate for the project scenario

The definition of the project scenario does not rely on the calculation of a deforestation rate – although there is implicitly a deforestation rate involved. Rather than calculating a deforestation rate for the project scenario, deforestation areas for the project scenario will be arrived at through direct monitoring.

Calculation of forest area for the project scenario

For the ex-ante calculations, this approach assumes a relative reduction of the overall deforestation rate under the baseline scenario level.

For the ex-post calculations, the deforestation that actually occurred between two years is the result of monitoring. The conversion areas shall be monitored through sampling and it is not necessary to conduct a wall-to-wall inventory. The deforestation areas between two years $A_{Def\ A\ it\ s=PJ}$ is then understood to correspond to the difference in forest area between those two years. For the monitoring in the first year when $t=1$, the pre-project inventory shall function as the previous inventory at $t=0$.

Calculation of the average emission per area-unit of deforestation (emission factors)

The average emissions per area-unit of deforestation do not vary across time. The emission factors are fixed ex-ante for the various pathways of conversion between land-use types. The emission factors are based on inventories.

$$C_{Def\ i} = (C_{For} - C_{LU\ i}) * MW_{CO_2-C} \quad (9)$$

Where:

$C_{Def\ i}$ – average emissions per area-unit of deforestation towards post-conversion land-use type i ; $t\ CO_2e\ ha^{-1}$

C_{For} – average carbon density in forests; $t\ C\ ha^{-1}$

$C_{LU\ i}$ – average carbon density in land-use type i ; $t\ C\ ha^{-1}$

MW_{CO_2-C} – ratio of molecular weights of CO_2 and C ($44/12$); $t\ CO_2e\ (t\ C)^{-1}$

Literature estimates can be used for the carbon densities of forests and of the other land-use types. If appropriate literature sources cannot be identified, carbon densities can also be measured in the field following the Winrock methodology². It is also permissible to use estimates based on expert judgment if these are likely to lead to a conservative estimate of the project's carbon credit generation potential.

Calculation of leakage

This methodology considers the conversion of forest due to abandonment and resulting destruction through fuelwood collection. Other drivers of deforestation are not considered (e.g., generation of sawn timber, generation of cropland, generation of residential areas). Leakage can therefore be calculated as follows:

$$LK = LKFW \quad (10)$$

Where:

LK – annual leakage; $t\ CO_2e\ yr^{-1}$

$LKFW$ – annual leakage from lack of fuelwood; $t\ CO_2e\ yr^{-1}$

Leakage from fuelwood collection

Leakage can occur because of a lack of fuelwood supply under the project scenario. The lack of supply would occur because under the project scenario forests will not be converted to fuelwood that would have been converted into fuelwood upon conversion to other land-use types under the baseline scenario. If the conversion does not occur under the project scenario, then the fuelwood would need to be collected somewhere else. On the other hand, in absence of the availability of cheap fuel sources from fuelwood, other fuels may substitute for fuelwood. Therefore, annual leakage from lack of fuelwood shall be calculated in various steps:

- a) Identify how much fuelwood would have been collected within the project boundary under the baseline scenario that cannot be collected under the project scenario ($FW_{lack\ t}$).
- b) Estimate how much of that fuelwood identified in a) needs to be collected elsewhere and how much fuelwood is substituted by other fuels ($percSubs$).
- c) Calculate the leakage caused by other fuels that substitute for the fuelwood ($LKFWSubs$).
- d) Calculate the leakage caused by shifting fuelwood collection elsewhere because of incomplete substitution through other fuels ($LKFWS_{shift}$).

² MacDicken, KG. 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International. P. 91.

Then, leakage from avoided fuelwood collection can be collected through the following equations:

$$LKFW = LKFWSubs + LKFWSHift \quad (11)$$

Where:

LKFW – annual leakage from avoided fuelwood collection; t CO₂e

LKFWSubs – annual leakage from fuelwood that other fuels substitute for; t CO₂e

LKFWSHift – annual leakage from shifting fuelwood collection elsewhere; t CO₂e

Step a. The amount of fuelwood that would have been collected in a given year within the project boundary under the baseline scenario that cannot be collected under the project scenario shall be estimated as follows:

$$FWlack\ t = (ADef\ ts=BL - ADef\ ts=PJ) * CFor * percFWinTB - (\sum(i=1->t) ADef\ is=BL - \sum(i=1->t) ADef\ is=PJ) * sustFWProd \quad (12)$$

Where:

FWlack t – amount of fuelwood that needs to be substituted for in year t; t C in FW

ADef ts – annual area of deforestation in year t under scenario s; ha

CFor – average carbon density in forests; t C ha⁻¹

percFWinTB – fraction of total biomass that on average becomes fuelwood upon deforestation; dimensionless

ADef is – annual area of deforestation in year i under scenario s; ha

($\sum(i=1->t) ADef\ i$) is therefore the sum of deforestation over years i up to year t under scenario s

sustFWProd – annual sustainable production of fuelwood in plantations; t C in FW ha⁻¹

The factor percFWinTB shall be estimated in the PDD in order to account for two purposes. Firstly, CFor includes all carbon pools and therefore needs to be corrected in order to derive biomass usable as fuelwood. Secondly, it may happen that less than the entire biomass that could become fuelwood is actually converted to fuelwood. The factor percFWinTB is calculated as follows:

$$percFWinTB = (CFor - average\{CLU\ i\}) / EFShift / CFor \quad (13)$$

Where:

percFWinTB – fraction of total biomass that on average becomes fuelwood upon deforestation; dimensionless

CFor – average carbon density in forests; t C ha⁻¹

CLU i – average carbon density in land-use type i; t C ha⁻¹

EFShift – factor for emissions per unit of fuelwood; t CO₂e (t CO₂e in FW)⁻¹

The factor sustFWProd shall be estimated in the PDD based on literature data. It shall represent the average amount of fuelwood that the plantations generate yearly on a sustainable basis under common operation practices.

Step b. The fraction of fuelwood substituted for by other fuels in a given year (percSubs t) shall be estimated in the PDD based on inventory data and literature sources of average fuel use in the country.

Step c. Emission factors need to be calculated for substituting fuelwood by other fuels and from shifting fuelwood collection elsewhere is calculated.

The emissions from substituting the use of fuelwood by other fuels may be different due to different efficiencies in using those other fuels. A corresponding EFSubs shall be calculated in the PDD.

The emissions per unit of fuelwood in EFShift need to be calculated in a way that would cover the decomposition of roots when a tree is harvested.

Step d. Using the emission factors, the leakage from substituting fuelwood by other fuels and from shifting fuelwood collection elsewhere is calculated.

The leakage from substituting other fuels for fuelwood is calculated as follows:

$$LKFWSubs = FWlack t * MWCO2-C * percSubs t * EFSubs \quad (14)$$

Where:

LKFWSubs – annual leakage from fuelwood that other fuels substitute for; t CO₂e
 FWlack t – amount of fuelwood that needs to be substituted for in year t; t C in FW
 MWCO₂-C – ratio of molecular weights of CO₂ and C (44/12); t CO₂e (t C)⁻¹
 percSubs t – fraction of fuelwood that other fuels substitute for in year t; dimensionless
 EFSubs – factor for emissions per unit of fuelwood that other fuels substitute for; t CO₂e (t CO₂e in FW)⁻¹

The leakage from relocating fuelwood collection elsewhere is calculated as follows:

$$LKFWSHift = FWlack t * MWCO2-C * (1-percSubs t) * EFShift \quad (15)$$

Where:

LKFWSHift – annual leakage from shifting fuelwood collection elsewhere; t CO₂e
 FWlack t – amount of fuelwood that needs to be substituted for in year t; t C in FW
 MWCO₂-C – ratio of molecular weights of CO₂ and C (44/12); t CO₂e (t C)⁻¹
 percSubs – fraction of fuelwood that other fuels substitute for in year t; dimensionless
 EFShift – factor for emissions per unit of fuelwood; t CO₂e (t CO₂e in FW)⁻¹

Data and parameters

Data and parameters not monitored

ID Number:	001
Parameter:	<i>f</i> (predX t)

Data unit:	dimensionless
Description:	functional form to predict p ct (X)
Source of data:	
Measurement procedures (if any):	
Any comment:	Although the parameters of the regression model will be fixed and the same for all years, it will be parameterized every year based on actual development of monitored variables (012).

ID Number:	002
Parameter:	p (Def i X)
Data unit:	dimensionless
Description:	probability of deforestation towards post-conversion land-use type i, given that condition X is fulfilled
Source of data:	Survey
Measurement procedures (if any):	
Any comment:	The approach for the survey shall be the same as the monitoring surveys that will be conducted for determining 012.

ID Number:	003
Parameter:	AFor c (t=0)
Data unit:	ha
Description:	area of forest in year t=0 at project start in sub-area c
Source of data:	Inventory
Measurement procedures (if any):	
Any comment:	

ID Number:	004
Parameter:	CFor
Data unit:	t C ha ⁻¹
Description:	average carbon density in forests
Source of data:	Field inventory or literature sources
Measurement procedures (if any):	
Any comment:	

ID Number:	005
Parameter:	CLU i
Data unit:	t C ha ⁻¹

Description:	average carbon density in land-use type i
Source of data:	Field inventory or literature sources
Measurement procedures (if any):	
Any comment:	

ID Number:	006
Parameter:	EFSubs
Data unit:	t CO ₂ e (t CO ₂ e in FW) ⁻¹
Description:	factor for emissions per unit of fuelwood that other fuels substitute for
Source of data:	Literature sources
Measurement procedures (if any):	
Any comment:	

ID Number:	007
Parameter:	EFSHift
Data unit:	t CO ₂ e (t CO ₂ e in FW) ⁻¹
Description:	factor for emissions per unit of fuelwood
Source of data:	Literature sources
Measurement procedures (if any):	
Any comment:	

ID Number:	008
Parameter:	sustFWProd
Data unit:	t C in FW
Description:	annual sustainable production of fuelwood in plantations
Source of data:	Literature sources
Measurement procedures (if any):	
Any comment:	

ID Number:	009
Parameter:	MWCO ₂ -C
Data unit:	t CO ₂ e (t C) ⁻¹
Description:	ratio of molecular weights of CO ₂ and C
Source of data:	Global default
Measurement procedures (if any):	44/12

Any comment:	
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Data and parameters monitored

ID Number:	010
Parameter:	predX t
Data unit:	various dimensions
Description:	various predictor variables that will be used to predict p ct (X) in year t
Source of data:	
Measurement procedures (if any):	
Any comment:	The adjusted regression model (001) remains the same for all years. predX t are the parameters in that regression model.

ID Number:	011
Parameter:	percSubs t
Data unit:	dimensionless
Description:	fraction of fuelwood that other fuels substitute for in year t
Source of data:	Inventory or literature
Measurement procedures (if any):	
Any comment:	

ID Number:	012
Parameter:	ADef A it s=PJ
Data unit:	ha
Description:	total annual area of deforestation towards post-conversion land-use type i in year t for s is the project scenario
Source of data:	
Measurement procedures (if any):	The results of the survey shall be upscaled from the sample to the entire project area by simple extrapolation.
Any comment:	The approach for the survey shall be the same as the baseline survey that will be conducted for determining 002.