MODULE FOR ESTIMATING LEAKAGE FROM ARR ACTIVITIES

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Relationship to Approved or Pending Methodologies

Approved and pending methodologies under the VCS Program and approved GHG programs, that fall under afforestation/reforestation/revegetation (ARR) activities within the agriculture, forestry, and other land use (AFOLU) sector, were reviewed to determine whether an existing methodology could be reasonably revised to meet the objective of this proposed methodology. Two methodologies were identified and are set out in Table 1 below.

Table 1: Similar Methodologies

Methodology	Title	GHG Program	Comments
AR-ACM003	Afforestation and reforestation of lands except wetlands --- Version 2.0	CDM	Does not incorporate market leakage effects, can only be revised with approval of CDM Executive Board
AR-ACM0014	Afforestation and reforestation of degraded mangrove habitats --- Version 3.0	CDM	Does not incorporate market leakage effects, can only be revised with approval of CDM Executive Board, applicable only to mangrove habitats

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1 SOURCES

This module is based on the following modules/tools/methodologies:

- Clean Development Mechanism (CDM) AR-Tool 15, version 2.0, *Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity*

The following have also informed the development of the module:

- *Greenhouse Gas Potential in U.S. Agriculture and Forestry*, U.S. Environmental Protection Agency, Prepared by Brian Murray, Brent Sohngen, et al. 2005

2 SUMMARY DESCRIPTION OF THE ARR LEAKAGE TOOL

This tool must be used by afforestation/reforestation/revegetation (ARR) projects to estimate the greenhouse gas (GHG) emissions outside the project area due to the implementation of project activities (leakage). This tool accounts for leakage related to displacement of pre-project agricultural activities (including grazing) whether it is caused by the baseline agent (activity-shifting leakage) or by other actors (market leakage); it does not account for leakage occurring outside the host country (international leakage). It uses a standardized approach to estimate the emissions from leakage based on project specific conditions. It utilizes a standardized leakage discount rate based on the relative productivity of pre-project agricultural activities. The standardized leakage discount rate is then adjusted for the relative carbon stocks and minimum accounting period of the project to determine a leakage discount rate which is applied as a deduction to the net GHG benefits of the project. The standardized leakage discount rate and the adjustment factors have been reviewed by industry experts and are subject to periodic review and potential revision.

3 DEFINITIONS

Agricultural activity
Production of an agricultural commodity on agricultural land.

Agricultural commodity

For the purpose of this methodology, any (part of) plant, animal, or animal product, produced on agricultural land.

4 APPLICABILITY CONDITIONS

This module applies to estimating leakage emissions from afforestation/reforestation/ revegetation (ARR) activities occurring anywhere in the world and under all conditions where the applicability conditions of the methodology using this tool have been met and where it is applied as percentage deduction to the net GHG benefits of the AR project activity.

5 PROCEDURES

The following steps must be completed to calculate the leakage discount factor (*LDF*) that is applied to account for leakage from ARR activities. In the event that ARR project activities have been implemented on less than 100% of the project area (e.g., staggered planting schedule), the LDF must be calculated only with respect to the portions of the project area where such ARR project activities have been implemented and must be updated at each monitoring event if ARR activities are implemented on new portions of the project area.

5.1 Step 1: Determine standardized leakage discount rate

5.1.1 A standardized leakage discount rate (SLDR) must be determined with information available at the time of the leakage assessment based on the relative productivity of the pre-project land use as provided in Table 2 below.

Table 2. Standardized leakage discount rate (SLDR)[1]

Scenario	Criteria	SLDR
High	Relative productivity greater than 0.75	20%
Medium	Relative productivity greater than 0.50 but less than or equal to 0.75	15%
Low	Relative productivity greater than 0.25 but less than or equal to 0.50	10%
Very Low	Relative productivity less than or equal to 0.25	5%

[1] Justification for values is provided in the parameter table for SLDR in section 6 of this tool.

No Leakage	No productive activities in the 2 years before the project start date	0

Relative productivity (RP) must be calculated as the ratio of quantity of agricultural commodities produced per unit area in the project area prior to the project activity compared to national averages. It must be calculated as the simple average of the annual relative productivity for the portion of the project area where project activities have been implemented for 3 years preceding the implementation of the ARR project activity.

If more than one agricultural commodity is produced in the project area preceding the ARR project activity, then the portion of the project area where ARR activities have been implemented must be stratified by commodity type and relative productivity must be calculated on a weighted average basis according to the proportion of the project area utilized for each commodity produced for the year that relative productivity is calculated.

Relative productivity (RP) for each agricultural commodity i in any year t must be calculated as follows:

$$RP_i = {}^{AP_i}/_{NP_i} \quad \textbf{(1)}$$

Where:

$RP_{i,t}$ Relative productivity for agricultural commodity i in year *t*

$AP_{i,}$ Project area productivity for agricultural commodity *i* prior to project start (average productivity in the three years prior to the project start)

NP_i National productivity for agricultural commodity *i* (average productivity in the three years prior to the project start)

The weighted average RP for all agricultural commodities produced in the project area must be calculated as follows:

$$RP = \Sigma_{i=1}^{n} \left(RP_i \times \frac{AG_i}{A} \right) \quad \textbf{(2)}$$

Where:

RP Relative productivity

n Total number of agricultural commodities *i*

A Project area

AG_i Average project area used for agricultural commodity *i*

If ARR project activities are implemented on new portions of the project area after the date of the initial leakage assessment, then the relative productivity must be recalculated on an area-weighted average basis based on the relative productivity for each portion of the

combined project area at the next monitoring event, and the SDLR and LDF accordingly must be recalculated accordingly.

Pre-project production data used for the project area must be verifiable and may be based on grower records or on remotely sensing data provided that remote sensing procedures have been peer-reviewed and tested in a similar region and for the agricultural activity displaced by the project activity.

National productivity data must be obtained or calculated using verifiable national-information (e.g., published studies or official government statistics) if available, or using data from FAOSTAT (crops: production quantity, area harvested; livestock: livestock, area under permanent pasture and meadows) if such information is not available.

In the absence of national productivity data for any given year, the most recent national productivity data can be used instead provided such data references a period within 5 years prior the project start date.

In the absence of national productivity data within the 5 years prior to the project start date or production data from the project area for any given year, a value of 1.0 for relative productivity may be assumed for that year.

5.2 Step 2: Determine carbon stock adjustment factor

The carbon stock adjustment factor (CSAF) is used to adjust the LDR for the relative carbon stocks in the project as compared to the carbon stocks in lands that could receive displaced production. The CSAF must be determined as of the project start date using the information available at the time of the assessment using Table 2 below.

Table 2. Carbon stock adjustment factor (CSAF)[2]

Scenario	Criteria	CSAF
Very High	Relative carbon stock in project area is less than 0.80	1.50
High	Relative carbon stock in project area is between 0.80 and 1.00	1.25
Medium	Relative carbon stock in project area is between 1.00 and 1.20	1.00
Low	Relative carbon stock in project area is greater than 1.20	0.80

Relative carbon stock is the ratio of the amount of carbon that is expected to be sequestered in the project area compared to the amount of carbon on forested lands that could receive displaced activities from the project[3].

$$RC = PC / NC \quad \textbf{(3)}$$

[2] Justification for values is provided in the parameter table for CSAF in section 6 of this tool.

[3] Conservatively ignores lower carbon stocks in non-forested lands (e.g. shrublands) that may receive displaced activities.

Where:

RC Relative carbon stock;

PC Long-term average biomass carbon stock in the project; t C ha^{-1}

NC Mean carbon stocks in forest biomass in the country where the project is located; t C ha^{-1}

Where:

$$PC = \frac{\sum_{t=1}^{n} C_{WP-biomass,t}}{n} \quad (4)$$

$C_{WP\text{-}biomass,t}$ Carbon stock in biomass carbon pools in trees and shrubs in the project scenario in year t; t C ha^{-1}

n Total number of years in the established time period for determining long-term average carbon stock changes in the project; this period *includes the last cut, even if it falls outside the crediting period; years*

The long-term average biomass carbon stock in the project scenario must be calculated over the same period (n) used to determine the long-term average carbon stock changes as detailed in section 8 of the Methodology for Afforestation, Reforestation and Revegetation Projects, be based on growth and yield models for the region and species planted, and supported by management plans.

The national carbon stock must reference mean carbon stocks in biomass and must be obtained from published studies or official government statistics if available, or derived from above-ground biomass estimates in Table 3A.1.4 of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF 2003) if such information is not available.

5.3 Step 3: Determine accounting period adjustment factor

The accounting period adjustment factor (APAF) is used to adjust the LDR according to the minimum number of years that leakage will be accounted and reported. This adjustment recognizes that leakage, estimated as a percentage of net GHG benefits from the project, varies over different time scales and will be higher over shorter time scales where fewer GHG benefits from the project have been generated. The APAF must be determined using Table 3 below.

Table 3. Accounting period adjustment factor[4]

Scenario	Criteria	APAF

[4] Justification for values is provided in the parameter table for APAF in section 6 of this tool.

High	Crediting period is between 20 and 29 years	1.75
Medium	Crediting period is between 30 and 39 years	1.50
Low	Crediting period is between 40 and 49 years	1.25
No Adjustment	Crediting period is equal to or greater than 50 years	1.00

5.4 Step 4: Calculate leakage discount factor

The leakage discount factor is applied annually to the net emission reductions during the initial crediting period only and is calculated using Equation 4 below.

$$LDF = SLDR * CSAF * APAF \quad (5)$$

Where:

LDF Leakage Discount Factor

SLDR Standardized Leakage Discount Rate, as determined in Step 1

CSAF Carbon Stock Adjustment Factor, as determined in Step 2

APAF Accounting Period Adjustment Factor, as determined in Step 3

6 DATA AND PARAMETERS

6.1 Data and Parameters Available at Validation

Data / Parameter	*SLDR*
Data unit	Percent
Description	Standardized Leakage Discount Rate
Equations	5
Source of data	Table 1
Value applied	Conditional on relative productivity
Justification of choice of data or description of measurement methods and procedures applied	The standardized leakage discount rate of 20% was determined based on expert consultation. The standardized leakage discount rates for each relative productivity range are derived to correspond to the incremental impact on land required to replace lost production at the upper values of each range. For example, the standardized leakage discount for relative productivity between 0.25 to 0.50 references the high end of 0.50, which corresponds to 50% less production on project area lands and a leakage rate that is 50% lower (10%) than the standard leakage discount rate (20%).
Purpose of Data	Calculation of leakage
Comments	None

Data / Parameter	*CSAF*
Data unit	Dimensionless
Description	Carbon Stock Adjustment Factor
Equations	5

Source of data	Table 2
Value applied	Conditional on relative carbon stocks
Justification of choice of data or description of measurement methods and procedures applied	The carbon stock adjustment factor for each relative carbon stocks range correspond to the low end of each range from Low to High. For example, the carbon stock adjustment factor for relative carbon stocks of 0.80-1.00 references the low end of 0.80 which corresponds to 25% more carbon stocks in receiving lands and to an adjustment factor that is 25% higher (1.25) than the standard leakage discount rate. The Very High scenario conservatively applies a 50% increase (factor of 1.50) where carbon stocks in the project area are more than 20% lower than carbon stocks outside the project area.
Purpose of Data	Calculation of leakage
Comments	None

Data / Parameter	*APAF*
Data unit	Dimensionless
Description	Accounting Period Adjustment Factor
Equations	5
Source of data	Table 3
Value applied	Conditional on initial crediting period
Justification of choice of data or description of measurement methods and procedures applied	The accounting period adjustment factors are conservatively derived and informed by published study of leakage rates in the U.S. over accounting periods of 20, 50, and 100 years *(EPA, 2005)*. The accounting period adjustment factors for periods between 20 and 50 years are derived conservatively using the low end of accounting period of each range. For example, the factor used for accounting periods of 20-29 years assumes the accounting period corresponds to the low end of the range (20 years).
Purpose of Data	Calculation of leakage

Comments	None

Data / Parameter	*AP*
Data unit	Production units per hectare per year
Description	Project area productivity
Equations	2
Source of data	Must be verifiable and may be based on grower records or on remotely sensed data provided that remote sensing procedures have been peer-reviewed and tested in a similar region and for the agricultural activity displaced by the project activity.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Determined by the quantity of specific agricultural commodity produced per unit area utilized for that commodity in the portion of the project area prior to the implementation date of the project activity. Calculated for a minimum of 3 consecutive years preceding the implementation date of the project activity. If more than one agricultural commodity is produced in the project area preceding the implementation of the ARR project activity, then the portion of the project area where ARR activities have been implemented must be stratified by commodity type, and relative productivity must be calculated on a weighted average basis according to the proportion of the project area utilized for each commodity produced for the year that relative productivity is calculated.
Purpose of Data	Calculation of leakage
Comments	In the absence of production data from the project area for any year, a value of 1.0 for relative productivity may be assumed for that year.

Data / Parameter	$NP_{i,}$
Data unit	Production units per hectare per year
Description	National productivity of commodity i
Equations	2
Source of data	National productivity data must be obtained or calculated using published studies or official government statistics if available, or using data from FAOSTAT[5] if such information is not available.
Value applied	Conditional based on source of data
Justification of choice of data or description of measurement methods and procedures applied	Refers to the quantity of a specific agricultural commodity produced per unit area in the country where the project is located prior to the project activity Must be collected or calculated for 3 consecutive years preceding the implementation date of the project activity and for each agricultural commodity produced in the project are over that same time period.
Purpose of Data	Calculation of leakage
Comments	In the absence of production from the country for any year, a value of 1.0 for relative productivity may be assumed for that year.

Data parameter	AG_i
Data unit	Hectares
Description	Project area used for agricultural production for agricultural commodity i
Equations	2

[5] See fao.org/faostat/en/#compare. 1. For livestock (a) Area subject to livestock production can be found at Group: Land, Inputs, and Sustainability. Domains: Land use. Element: Area. Item: Land under permanent meadows and pastures. (b) Quantity of livestock production can be found at If using FAOSTAT, data sources for productivity is available within the Group: Land, Inputs, Sustainability. 2. For crops: Area subject to crop production and quantify of production can be found at Group:Production. Domain: Crops and livestock products. Element: Production Quantity, Area Harvested.

Source of data	Grower records or remotely sensing data provided that remote sensing procedures have been peer-reviewed and tested in a similar region and for the agricultural production displaced by the project activity.
Value applied	Conditional based on source of data
Justification of choice of data or description of measurement methods and procedures applied	Must be collected for 3 consecutive years preceding the implementation date of the project activity and for each agricultural commodity produced in the project area over that same time period.
Purpose of Data	Calculation of leakage
Comments	None

Data parameter	A
Data unit	Hectares
Description	Project area
Equations	2
Source of data	Calculated from GIS data
Value applied	Conditional based on source of data
Justification of choice of data or description of measurement methods and procedures applied	Delineation of the project area may use a combination of GIS coverages, ground survey data with GPS, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.
Purpose of Data	Calculation of leakage
Comments	The project activity may contain more than one discrete area of land. Each discrete area of land must have a unique geographical identification.

Data / Parameter	*NC*
Data unit	Tonnes of C per hectare
Description	Mean national carbon stock in forest biomass
Equations	3
Source of data	Published studies with data from country where the project is located if such data is available, or derived from Table 3A.1.4 of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF 2003) if such data is not available.
Value applied	Conditional based on source of data
Justification of choice of data or description of measurement methods and procedures applied	Determined based on data available at the time of the assessment and reflecting area-weighted mean stocks in biomass at the nearest date to the project start date. If biomass is presented in tonnes of dry biomass per hectare, then carbon stocks should be determined using a carbon fraction default value of 0.50, unless transparent and verifiable information can be provided to justify a different value. If only above ground biomass stocks are reported, a biomass expansion factor of 1.25 should be applied to convert unless transparent and verifiable information can be provided to justify a different value.
Purpose of Data	Calculation of leakage
Comments	None

Data / Parameter	$C_{WP\text{-}biomass,t}$
Data unit	Tonnes of C per hectare per year
Description	Carbon stock in biomass pools in trees and shrubs in the project scenario in year t
Equations	4

Source of data	Derived from projections using measurement methods below
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Must be calculated for each year over the same period (n) used to determine the long-term average carbon stock changes as described in section 8 of VM000XX and consistently applying the same growth and yield assumptions.
Purpose of Data	Calculation of leakage
Comments	None

Data / Parameter	*n*
Data unit	years
Description	Total number of years in the established time period for determining long-term average carbon stock changes in the project
Equations	4
Source of data	N/A
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Should be the same period used to determine the long-term average carbon stock changes as described in section 8 of VM000XX
Purpose of Data	Calculation of leakage
Comments	This period includes the last cut, even if it falls outside the crediting period.

6.2 Data and Parameters Monitored

No data or parameters must be monitored unless ARR activities are implemented in new portions of the project area after validation or after the last monitoring event, in which case

the Leakage Discount Factor must be recalculated using the data and parameters in section 6.1 above.

7 REFERENCES

Murray, B. et al. “Greenhouse Gas Potential in U.S. Agriculture and Forestry”, United States Environmental Protection Agency (2005)

8 APPENDIX - EXAMPLE

A project area (A) is 1,000 hectares and is planted in year t. In the 3 years prior to the planting date, 300 hectares (AG) was used to graze 300, 330, and 360 cattle, resulting in project area productivity (AP) is equal to 1.1 cattle/ha, 1.2 cattle/ha and 1.3 cattle/ha for the 3 years preceding the start date. The national productivity (NP) from published literature is 1.5 cattle/ha for each of the three years.

Step 1: Determine standardized leakage discount rate (SDLR)

The SDLR is based on relative productivity (RP). RP for cattle is calculated as follows:

$$RP_i = {}^{AP_i}/_{NP_i} \quad \text{(Eq 1)}$$

RP_{cattle} in Year t-1: (1.1 per ha/1.5 per ha) = 0.73

RP_{cattle} in Year t-2: (1.2 per ha/1.5 per ha) = 0.80

RP_{cattle} in Year t-3: (1.3 per ha/1.5 per ha) = 0.87

RP_{cattle} = 3-year average = (0.73 + 0.80 + 0.87) / 3 = 0.80,

RP for the project area with one commodity (cattle) that was produced in the 3 years prior to the project start is calculated as follows:

$$RP = \Sigma_{i=1}^{n} \left(RP_i \times \frac{AG_i}{A} \right) \quad \text{(Eq 2)}$$

RP=0.80 * 300/100 = 0.24

resulting in 5% standardized leakage discount using Table 2 above.

Continuing with the previous example,

In year t+5, during the period of the first monitoring event, an additional project area of 500 hectares is planted to bring the cumulative project area planted to 1,500 ha. In each of the three years prior to planting in year 5, 250 cattle were grazed in the 500 hectares resulting project area productivity of 0.5 cattle/ha. National productivity for the corresponding three years was 1.5 cattle/ha. The relative productivity for each of the 3 years, and therefore the 3-year average is:

(0.5 per ha/1.5 per ha) = 0.33

The relative productivity for the combined project area is re-calculated as the area-weighted average of the relative productivity of the area planted in year t and year t+5 as follows:

0.24 * (1000 ha/1,500 ha) + 0.33 * (500 ha/1,500 ha) = 0.27, resulting in 10% standardized leakage deduction per Table 2 above.

Step 2: Determine Carbon Stock Adjustment Factor (CSAF)

The long-term average biomass carbon stock in the project (PC) is calculated in accordance with Equation 4 above as 150.0 tons of carbon per hectare.

The mean forest biomass stocks in the country where the project is located is determined as 209 tons of above ground dry biomass/hectare by reference to Table 3A.1.4 of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC GPG-LULUCF 2003). The equivalent carbon stock in above and below ground biomass is determined as:

NC=Aboveground biomass * Carbon fraction * Biomass Expansion factor (BEF) = 209*0.50 *1.25 = 130.6 tons C/ha

The relative carbon stock (RC) is determined as follows:

RC=PC/NC (Eq 3)

RC=50.0/130.6=1.15

Using Table 2, CSAF is set to 1.00, which corresponds to RC=1.15 (relative carbon stock in project area is between 1.00 and 1.20).

Step 3: Determine Accounting Period Adjustment Factor (APAF)

The project selects an initial crediting period of 30 years. Using Table 3, the accounting period adjustment factor (APAF) is set to 1.50.

Step 4: Calculate Leakage Discount Factor (LDF)

The LDF in year t is calculated as follows:

LDF = SLDR * CSAF * APAF (Eq 5)

LDF= 5% * 1.00 *1.50 = 7.5%

The LDF in year t+5 is calculated as follows:

LDF = SLDR * CSAF * APAF

LDF= 10% * 1.00 *1.50 = 15%