



SCD0002.

Module for estimating leakage from ARR activities.

Version 1.0

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1. Sources

The following CDM tool has informed the development of this module:

- CDM AR-TOOL15: Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity, v2.0
- VCS VMD0053: Module for estimating leakage from ARR activities v1.0

2. Summary Description of the Module

Project activities utilizing the SCM0009 Afforestation, Reforestation, and Revegetation methodology are required to employ this module for leakage estimation. This module takes into consideration leakage arising from the displacement of agricultural activities (including grazing) and fuelwood collection activities occurring before the project initiation. It encompasses leakage attributed to the baseline agent (activity-shifting leakage) and other entities (market leakage).

The module assesses leakage by considering two key factors:

- Decrease in the production of agricultural commodities or fuelwood within the project area.
- Impact of leakage mitigation activities aimed at boosting production beyond the project area.

The module calculates the replacement of net production in the project area within the market, the extent of new forest lands brought into production outside the project area, and the associated emissions from carbon stock.

3. Definitions

In addition to the definitions set out in the SOCIALCARBON document Program Definitions, the following definitions apply to this module.

Agricultural activities

Refers to crop cultivation activities and grazing activities occurring on land.

Agricultural commodity

Any (part of) plant, animal or animal product, produced on agricultural land.

Crop cultivation activities

Refers to human induced activities, occurring on land, that are aimed at vegetation control for producing food, forage, fiber, oilseed crops, etc., including harvesting of the produce.

Displacement of agricultural activities

Refers to shifting of the agricultural activities from areas of land within the project boundary to areas of land outside the project boundary.

Fuelwood

Includes firewood or charcoal produced from woody biomass.

Grazing activities

Refers to human induced activities, occurring on land, that are aimed at livestock production.

Leakage emission

Refers to the increase in GHG emissions resulting from displacement of pre-project activities.

Subsistence commodity

Agricultural commodity that is not destined for commercial markets.

4. Applicability Conditions

This module is designed for the assessment of leakage emissions resulting from Afforestation, Reforestation, and Revegetation (ARR) activities. Projects utilizing this module are required to fulfill all the applicability conditions outlined in the methodology SCM0009: Methodology for Afforestation, Reforestation, and Revegetation.

5. Procedures

To calculate leakage emissions from Afforestation, Reforestation, and Revegetation (ARR) activities, the following measures need to be implemented. The assessment and calculation of leakage emissions for ARR activities should span a five-year duration from the project commencement date or, in the case of grouped projects, the start date of each project instance. This timeframe aligns with the anticipated occurrence of leakage effects resulting from displaced agricultural production.

5.1. Determine Foregone Production in Project Area

The production of baseline agricultural and fuelwood commodities in the project area must be substantiated through historical production records for each commodity within the selected reference period. Employ the following process to determine historical production for each commodity.

Part 1: Set the historical reference period.

The historical reference period is the greater of either:

- 1) The 3-year period immediately preceding the project start date (or the project instance start date in the case of grouped projects); or
- 2) One complete crop rotation (where applicable).

Part 2: Document commodities displaced and production

Subsequently, utilize historical data to record the quantity of production for each displaced commodity.

The permissible types of historical production records are outlined below. Data sources should be employed in the specified sequence, prioritizing the data source listed at the top in cases where multiple sources are accessible.

- 1) Grower records (e.g., management logs, receipts or invoices, logs or files containing machine and/or sensor data); or
- 2) Remote sensing methods where requisite information on production can be reliably determined with these methods; or
- 3) The most recent regional (sub-national) average values derived from published census data; or

- 4) The most recent national average values derived from published census data; or
- 5) The most recent relevant commodity or ownership class where estimates have been disaggregated by those attributes and substantiated with a signed attestation from the farmer or landowner.
- 6) For fuelwood production, use average aboveground biomass growth rates published by the IPCC applicable to the region if regional or national averages are unavailable.

The historical production data should be substantiated with credible evidence from grower records or remote sensing data. However, the use of remote sensing procedures is contingent upon their prior peer review and testing in a comparable region, specifically for the agricultural activity displaced by the project.

$$BP_{j,t} = \frac{\sum_{h=1}^H P_{j,h}}{H} \times (1 + r_j)^t \quad (\text{Equation 1})$$

Where:

- $BP_{j,t}$ = Baseline production in the project area for commodity j in year t; units of production
- $P_{j,h}$ = Production in the project area for commodity j in year h of the historical reference period; units of production
- H = Duration of historical reference period; years
- r_j = Annual growth rate of yield for commodity j; percent or the default value (2.5 percent)
- t = 1, 2, 3, ..., t years elapsed since the project start date

Foregone production must be computed for commodities produced within the project area during the historical reference period. The foregone production in the project area is determined by the variance between the baseline production for each commodity produced in the project area and the monitored production of that same commodity within the project area.

$$FP_{j,t} = BP_{j,t} - MP_{j,t} \quad (\text{Equation 2})$$

Where:

- $FP_{j,t}$ = Foregone production in the project area for commodity j in year t; units of production



- $BP_{j,t}$ = Baseline production in the project area for commodity j in year t; units of production
- $MP_{j,t}$ = Monitored production in the project area for up to five years after the project start date for commodity j in year t; units of production
- t = 1, 2, 3, ..., t years elapsed since the project/instance start date

5.2. Determine the Impact of Leakage Mitigation Activities

The project proponent has the option to carry out activities beyond the project area to diminish leakage, and the designated regions for such activities are termed leakage mitigation areas. However, engaging in leakage mitigation is discretionary and must adhere to the following criteria:

1. Leakage mitigation should occur in geographically defined areas within the same region as the project. The project proponent must substantiate the chosen region for leakage mitigation by referencing the production region of the displaced agricultural commodity.
2. Leakage mitigation areas must not overlap with:
 - i) The project area
 - ii) Areas covered by other existing carbon projects,¹
 - iii) Leakage mitigation areas associated with other carbon projects.
3. The project proponent is required to enter into an agreement with the landowner, explicitly granting the project proponent the exclusive right to attribute the increase in productivity in that area as leakage mitigation resulting from foregone production in the project area. The agreement's duration must be a minimum of five years from the project start date (or the last project instance start date in the case of grouped projects).
4. Mitigation of fuelwood production is permissible solely through the establishment of new tree plantations.

Leakage mitigation ($LM_{j,t}$) is equal to the difference in production between the project and baseline scenarios of the leakage mitigation area. Baseline production in the leakage mitigation area is derived from production over the historical reference period

¹ **Exemption:** in the case of livestock, projects are permitted to utilise Leakage Mitigation areas that are existing carbon projects that focus on sustainable livestock grazing practices. Project proponents must evidence that stocking rates in leakage mitigation areas are not anticipated to surpass the maximum carrying capacity and no new land will be acquired to compensate for the additional livestock.

as defined in Section 5.1. Baseline production of agricultural commodities in the leakage mitigation area is calculated as follows:

$$LMBP_{j,t} = \frac{\sum_{h=1}^H PLM_{j,h}}{H} \times (1 + r_j)^t \quad (\text{Equation 3})$$

Where:

- $LMBP_{j,t}$ = Baseline production in the leakage mitigation area for commodity j in year t; units of production
- $PLM_{j,h}$ = Production in the leakage mitigation area for commodity j in year h of the historical reference period; units of production
- H = Duration of historical reference period; years
- r_j = Annual growth rate of yield for commodity j; percent or the default value (2.5 percent)
- t = 1, 2, 3, ..., t years elapsed since the project start date

Baseline production of fuelwood in the leakage mitigation area ($LMBP$) is zero (i.e., only newly established tree plantations are eligible). Leakage mitigation is the monitored increase in production in the leakage mitigation area that is above the baseline levels of production and is calculated as follows:

$$LM_{j,t} = LMMP_{j,t} - LMBP_{j,t} \quad (\text{Equation 4})$$

Where:

- $LM_{j,t}$ = Leakage mitigation of commodity j in year t; units of production
- $LMMP_{j,t}$ = Monitored production in the leakage mitigation area for commodity j in year t; units of production
- $LMBP_{j,t}$ = Baseline production in the leakage mitigation area for commodity j in year t; units of production
- t = 1, 2, 3, ..., t years elapsed since the project start date

The amount of foregone production that may result in leakage is calculated as follows:

$$l_{j,t} = \text{MAX} (FP_{j,t} - LM_{j,t}, 0) \quad (\text{Equation 5})$$

Where:

$l_{j,t}$ = Leakage mitigation of commodity j in year t; units of production

$FP_{j,t}$ = Foregone production in the project area of commodity j in year t; units of production

$LM_{j,t}$ = Leakage mitigation of commodity j in year t; units of production

Leakage mitigation activities, such as agricultural intensification in the leakage mitigation area, have the potential to escalate greenhouse gas (GHG) emissions (e.g., due to increased fertilization or stocking rates). Project proponents are obligated to consider and account for leakage unless they can demonstrate that it is negligible. Appendix 2 provides details on how project proponents must assess whether reductions in carbon pools and increases in GHG emissions are indeed de minimis.

In the context of livestock intensification, project proponents must provide evidence that stocking rates in leakage mitigation areas are not anticipated to surpass the maximum carrying capacity, ensuring there will be no depletion of vegetation and soil resources. Additionally, accounting for leakage resulting from heightened production of supplemental feedstocks is necessary when supplemental feeding is employed. Verification of maximum carrying capacity should be supported by reports from qualified independent local experts (e.g., agricultural extension agents, professional agronomists) or signed attestations.

In situations where the leakage mitigation area is part of a registered carbon project and assessments of changes in greenhouse gas emissions and soil carbon stocks are conducted, there is no requirement for the assessment of nitrous oxide emissions or a demonstration of stocking rates compared to carrying capacity.

5.3. Determine Amount of New Land Brought into Production

If the calculated displaced production amount, which may lead to leakage (l) for commodity j in year t, exceeds zero, the computation of the new land brought into production outside the project area in year t is determined as follows:

$$INL_{j,t} = \frac{l_{j,t} \times IS \times NL}{y_{j,t}} \quad (\text{Equation 6})$$

Where:

- $INL_{j,t}$ = Area of new land brought into production in year t ; ha
- $l_{j,t}$ = Amount of foregone production subject to leakage for commodity j in year t ; units of production
- IS = Share of leakage resulting in increased supply outside the project area, or default value of 0.75 (75 percent) for agricultural commodities or 1.00 (100 percent) for fuelwood
- NL = Share of increased supply from new land brought into production for commodity j , or default value of 0.40 (40 percent) for agricultural commodities or 1.00 (100 percent) for fuelwood
- $y_{j,t}$ = Yield on new land brought into production for commodity j in year t ; units of production/ha
- t = 1, 2, 3, ..., t years elapsed since the project start date

A fundamental premise underpinning leakage is that when production decreases by one unit, other locations will substitute some, but not all, of the forgone production. In this module, a cautious default value of 75 percent is employed for the Indirect Substitution (IS), assuming that 75 percent of the agricultural production lost in the project area is compensated by increases in supply outside the project area (refer to Appendix 1 for details on default values). It is conservatively assumed that 100 percent of the fuelwood production lost in the project area is replenished through increases outside the project area.

The augmentations in supply outside the project area may or may not lead to the cultivation of new lands. Supply increases resulting from agricultural intensification and enhanced yields on non-forest lands will not necessarily result in new lands being brought into agricultural production. For Non-Leakage (NL), this module employs a conservative default value of 40 percent, assuming that 40 percent of the increased supply of agricultural commodities outside the project involves bringing new land into production (see Appendix 1 for information on default values). It is conservatively assumed that 100 percent of the increased supply of fuelwood outside the project involves bringing new land into production.

In cases where the default value for IS or NL is not applied, the project proponent must provide evidence justifying the use of a different value, especially if it is less conservative than the default value. Such evidence could include peer-reviewed studies relevant to the agricultural commodity and the project's region. Project proponents have the option to use more conservative values for IS or NL without requiring additional evidence.

For subsistence commodities, the yield of new land brought into production should be compared to the yield in the project area during the historical reference period.

In the case of fuelwood production, if regional or national data are unavailable, the yields may be based on the average above-ground biomass growth rates published by the IPCC and applicable to the project's region.

For non-subsistence commodities, the yield on new land (NL) brought into production should be referenced from the following data sources, prioritized in the order listed (e.g., if two data sources are available, the one at the top of the list should be utilized):

1. The yield in the project area during the historical reference period; or
2. Regional data on yields for the relevant agricultural commodities subject to foregone production; or
3. National data on yields for the relevant agricultural commodities subject to foregone production.

The area of new land brought into production ($INL_{j,t}$) must be summed across all commodities produced in the project area during the historical reference period, as identified in above in Section 5.1, to determine the total area generating leakage emissions. The area generating leakage emissions is calculated as follows:

$$AL_t = \sum_{j=1}^T INL_{j,t} \quad (\text{Equation 7})$$

Where:

- AL_t = Area generating leakage emissions in year t; ha
- $INL_{j,t}$ = Area of new land brought into production in year t; ha
- T = Total number of commodities produced in historical reference period
- t = 1, 2, 3, ..., t years elapsed since the project start date

5.4. Determine Change in Carbon Stocks in New Lands Brought into Production

This module operates under the assumption that the new land brought into production is forested land. The computation of the change in carbon stocks on the newly cultivated land is conducted as follows:

$$CS = \Delta C_{biomass} + \Delta SOC \quad (\text{Equation 8})$$

Where:

- CS = Change in carbon stocks on new lands brought into production; tC/ha
- $\Delta C_{biomass}$ = Loss of forest biomass carbon stocks in the region where the project is located²; tC/ha
- ΔSOC = Change in soil organic carbon (SOC) stocks in the region in which the project is located; tC/ha

The change in SOC stock is calculated as the difference between initial reference stocks and estimated future, steady-state stocks at the end of 20 years.

$$\Delta SOC = SOC_{REF} + (1 - f_{LU} \times f_{MG} \times f_{IN}) \quad (\text{Equation 9})$$

Where:

- ΔSOC = Change in soil organic carbon (SOC) stocks in the region in which the project is located; tC/ha
- SOC_{REF} = SOC stock corresponding to the reference condition in native ecosystems by climate region and soil type applicable to the land receiving the displaced activity; t C/ha
- f_{LU} = Relative SOC stock change factors over 20 years for land use applicable to the displaced production; dimensionless
- f_{MG} = Relative SOC stock change factors over 20 years for management practices applicable to the displaced production; dimensionless
- f_{IN} = Relative SOC stock change factors over 20 years for inputs respectively, applicable to the displaced production; dimensionless

² It is assumed that the area generating leakage emissions will experience a complete loss of aboveground and belowground biomass, deadwood and litter. The project shall use regional average carbon stock values for the carbon pools.

5.5. Determine Leakage Emissions

The leakage emissions from new land that is brought into production and where t does not exceed 5 years beyond the last project instance start date are calculated as follows:

$$LK_t = AL_t \times CS \times \frac{44}{12} \quad \text{(Equation 10)}$$

Where:

- LK_t = Cumulative leakage up to year t; tCO₂e
- AL_t = Area generating leakage emissions in year t; ha
- CS = Change in carbon stocks on new lands brought into production; tC/ha
- $\frac{44}{12}$ = Conversion factor from C to CO₂e; dimensionless

6. Data and Parameters

6.1. Data and Parameters Available at Validation

Data / Parameter	$P_{j,h}$
Data unit	Unit of production, varies by commodity.
Description	Production in the project area for commodity j in year h of the historical reference period.
Equations	1
Source of data	<p>When accessible, grower records (e.g., management logs, receipts or invoices, logs or files containing machine and/or sensor data) or remote sensing methods (e.g., satellite imagery, manned aerial vehicle footage, drone imagery) should be employed, provided they reliably provide the necessary information on production.</p> <p>In cases where historical production records for the project area are unavailable, it is recommended to utilize regional (sub-national) average values derived</p>

	<p>from published census data. When both project area records and regional (sub-national) average values are unavailable, national average values derived from census data must be utilized. For fuelwood production, average aboveground biomass growth rates published by the IPCC (Tables 4.9–4.11 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories) may be applied if regional or national averages are not accessible.</p> <p>When using regional or national average values, it is imperative to use official government sources whenever possible. In instances where official government sources are absent, published studies may be used to justify these values, with a preference for peer-reviewed studies. Additionally, regional or national average values must be derived from all data points within the historical reference period, if available, or from the most recent data point to the conclusion of the historical reference period otherwise. Historical production records should specifically reference the relevant commodity or ownership class, and if estimates have been disaggregated by these attributes, they should be supported by a signed attestation from the farmer or landowner.</p>
Value applied	Conditional based on source of data.
Justification of choice of data or description of measurement methods and procedures applied	Should be collected for a period that includes all years within the three year period immediately preceding the project start date or all years of one complete crop rotation where applicable, whichever is longer.
Purpose of Data	Calculation of foregone production.
Comments	Units of production for livestock commodities may be expressed in terms of stocks and may include number of animals, animal units or forage intake units.

Data / Parameter	<i>H</i>
Data unit	Years

Description	Number of years within historical reference period used to determine baseline production within the project area.
Equations	1 & 3
Source of data	N/A
Value applied	A value between 3 and the number of years for one complete crop rotation where applicable, whichever is greater.
Justification of choice of data or description of measurement methods and procedures applied	Selected by the project proponent.
Purpose of Data	Calculation of foregone production.
Comments	None

Data / Parameter	$PLM_{j,h}$
Data unit	Unit of production, varies by commodity.
Description	Production in the leakage management area for commodity j in year h of the historical reference period
Equations	3
Source of data	When accessible, grower records (e.g., management logs, receipts or invoices, logs or files containing machine and/or sensor data) or remote sensing methods (e.g., satellite imagery, manned aerial vehicle footage, drone imagery) should be employed, provided they reliably provide the necessary information on production.
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 each commodity produced in the project area over the historical reference period.
Purpose of Data	Calculation of leakage mitigation for foregone production.
Comments	Units of production for livestock commodities may be expressed in terms of stocks and may include number of animals, animal units and forage intake units.

6.2. Data and Parameters Monitored

Data / Parameter	$P_{j,h}$
Data unit	Unit of production, varies by commodity.
Description	Production in the project area for commodity j in year h of the historical reference period.
Equations	1
Source of data	<p>When accessible, grower records (e.g., management logs, receipts or invoices, logs or files containing machine and/or sensor data) or remote sensing methods (e.g., satellite imagery, manned aerial vehicle footage, drone imagery) should be employed, provided they reliably provide the necessary information on production.</p> <p>In cases where historical production records for the project area are unavailable, it is recommended to utilize regional (sub-national) average values derived from published census data. When both project area records and regional (sub-national) average values are unavailable, national average values derived from census data must be utilized. For fuelwood production, average aboveground biomass growth rates published by the IPCC (Tables 4.9–4.11 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories) may be applied if regional or national averages are not accessible.</p> <p>When resorting to regional or national average values, it is imperative to use official government sources whenever possible. In instances where official government sources are absent, published studies may be used to justify these values, with a preference for peer-reviewed studies. Additionally, regional or national average values must be derived from all data points within the historical reference period, if available, or from the most recent data point to the conclusion of the historical reference period otherwise. Historical production records should specifically reference the</p>

	relevant commodity or ownership class, and if estimates have been disaggregated by these attributes, they should be supported by a signed attestation from the farmer or landowner.
Description of measurement methods and procedures to be applied	Conditional based on source of data.
Frequency of monitoring/recording	Should be collected for a period that includes all years within the three year period immediately preceding the project start date or all years of one complete crop rotation where applicable, whichever is longer.
QA/QC procedures to be applied	Calculation of foregone production.
Purpose of data	Enable the calculation of foregone production.
Calculation method	N/A
Comments	None

Data / Parameter	r_j
Data unit	Percent
Description	Annual growth rate of yield for commodity j
Equations	Equations 1 & 3
Source of data	<p>Regional yield data, when accessible, should be acquired or computed utilizing published studies or official government statistics. This data should reference the smallest territorial administrative division (e.g., district or municipality) encompassing all land areas involved in the Afforestation, Reforestation, and Revegetation (ARR) project activity. The yield data should be broken down by ownership classes, where production data are obtainable. For crop commodities, in instances where published studies or official government statistics are unavailable, data from FAOSTAT may be employed.</p> <p>Alternatively, a default value of 0.025 (2.5 percent) may be utilized.</p>

Description of measurement methods and procedures to be applied	<p>When using data from FAOSTAT (for crop commodities only), the following procedures must be applied to calculate the annual growth rate of yield for commodity j:</p> <ol style="list-style-type: none"> 1) For year t (years elapsed since the project start date), find the yield for commodity j by selecting Group: Production; Domains: Crops and livestock products; Area: Country where ARR project activity is located; Element: Yield; and Item: Commodity j. 2) Calculate annual growth rate in yield for commodity j as: $r_j = \left(\frac{yield_{j,t}}{yield_{j,t-1}} \right) - 1$
Frequency of monitoring/recording	At each monitoring period.
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of baseline commodity production in the project area and the leakage mitigation area
Calculation method	N/A
Comments	<p>Where default value is not applied, the yield data from the year closest to year t must be used unless otherwise justified.</p> <p>Yield data for livestock commodities is expressed in terms of stocking rate and may include number of animals, animal units and forage intake units per hectare.</p>

Data / Parameter	$LMMP_{j,t}$
Data unit	Units of production
Description	Monitored production in the leakage mitigation area for commodity j in year t
Equations	4
Source of data	Grower records (e.g., management logs, receipts or invoices, logs or files containing machine and/or sensor data), or data derived from remote sensing methods

	(e.g., satellite imagery, manned aerial vehicle footage, drone imagery) where it is possible to reliably determine requisite information on production with these remote sensing methods
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	At every monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of leakage mitigation
Calculation method	N/A
Comments	None

Data / Parameter	IS
Data unit	Percent
Description	Share of leakage resulting in increased supply outside the project area
Equations	6
Source of data	Default values outlined below, government-approved or peer-reviewed studies.
Description of measurement methods and procedures to be applied	Default value of 0.75 (75 percent) for agricultural commodities or 1.00 (100 percent) for fuelwood. Where the default value is not applied, evidence justifying the use of a different value must be provided. Such evidence may include government-approved or peer-reviewed studies relevant to the agricultural commodity and region in which the project is located.
Frequency of monitoring/recording	At every monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	Estimation of area of new land brought into production
Calculation method	N/A
Comments	See Appendix 1 for further details on the default values

Data / Parameter	NL_j
Data unit	Percent
Description	Share of increased supply from new land brought into production for commodity j
Equations	6
Source of data	Default value of 0.40 (40 percent) for agricultural commodities or 1.00 (100 percent) for fuelwood. Where the default value is not applied, evidence justifying the use of a different value must be provided. Such evidence may include government-approved or peer-reviewed studies relevant to the commodity produced and region in which the project is located.
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	At every monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	Estimation of area of new land brought into production
Calculation method	N/A
Comments	See Appendix 1 for further details on the default values

Data / Parameter	$y_{j,t}$
Data unit	Production units per hectare per year
Description	Yield on new lands brought into production for commodity j in year t
Equations	6
Source of data	Government data or published studies. Productivity data must be obtained or calculated using official government statistics or published studies where available. For crop commodities, data from FAOSTAT may be used where official government statistics or published studies are not available. Where none of the

	<p>above sources of data are available, or for subsistence commodities, yield in the project area during the historical reference period may be used.</p>
<p>Description of measurement methods and procedures to be applied</p>	<p>Use data from the year closest to that for which leakage emissions are being calculated.</p> <p>For non-subsistence commodities, the yield on new land brought into production should be based on regional yields for the relevant agricultural commodities affected by foregone production. If regional data is unavailable, national data should be utilized. In the absence of both regional and national data for the commodity, the yield in the project area during the historical reference period must be employed. Regarding fuelwood production, if regional or national data is inaccessible, yields based on the average aboveground biomass growth rates published by the IPCC for the region of the project may be applied.</p> <p>For subsistence commodities, the yield of new land brought into production must be compared to the yield in the project area during the historical reference period.</p> <p>When utilizing data from FAOSTAT (for crop commodities exclusively), follow the specified procedure. For the year t (number of years since the project start date), locate the yield for commodity j by selecting Group: Production; Domains: Crops and livestock products; Area: Country where the ARR project activity is situated; Element: Yield; Item: Commodity j.</p>
<p>Frequency of monitoring/recording</p>	<p>At each monitoring event.</p>
<p>QA/QC procedures to be applied</p>	<p>N/A</p>
<p>Purpose of data</p>	<p>Calculation of area of new land brought into production</p>
<p>Calculation method</p>	<p>N/A</p>
<p>Comments</p>	<p>Where yield data are not available for year t, yield data from the year closest to the year t must be used unless otherwise justified.</p>

	Yield on new lands brought into production for livestock commodities may be expressed in terms of stocking rate and may include number of animals, animal units and forage intake units per hectare per year.
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Data / Parameter	$\Delta C_{biomass}$
Data unit	t C/ha
Description	Loss of forest biomass carbon stocks in the region where the project is located
Equations	8
Source of data	Published studies with data from country in which the project is located where such data are available, or derived from Table 3A.1.4 of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2003) where such data are not available.
Description of measurement methods and procedures to be applied	<p>$\Delta C_{biomass}$ must reference the following data sources as available in the order listed, (e.g., if two data sources are available the data source nearest the top of the list must be used):</p> <ul style="list-style-type: none"> • mean carbon stocks in forest biomass in the region; or • mean carbon stocks in forest biomass in the country where the project is located and must be obtained from published studies or official government statistics; or • mean carbon stocks in forest biomass 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 2003) if such information is not available. <p>Determined based on data available at the time of the assessment and reflecting area-weighted mean stocks in above- and belowground biomass, dead wood and litter pools at the nearest date to the assessment date.</p> <p>If biomass is presented in tonnes of dry biomass per hectare, then carbon stocks should be determined using a carbon fraction default value of 0.47.</p>

	<p>If only aboveground biomass stocks are reported, then belowground biomass stocks should be estimated using allometric equations contained in Table 4.A.4 of IPCC (2003), unless verifiable information is provided to justify a different value.</p> <p>Similarly, if data presented include tree biomass only, then the carbon stocks in deadwood and litter must be estimated by multiplying the sum of aboveground and belowground biomass stocks by a factor of 1.1³.</p>
Frequency of monitoring/recording	At each monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	None

Data / Parameter	SOC_{REF}
Data unit	tC/ha
Description	Soil organic carbon (SOC) stock corresponding to the reference condition in native ecosystems by climate region and soil type applicable to the land receiving the displaced activity
Equations	9
Source of data	Table 2.3 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Description of measurement methods and procedures to be applied	Where soils vary across the region of production, a weighted average (based on relative commodity production) or the highest, most conservative value may be used.
Frequency of monitoring/recording	At each monitoring period
QA/QC procedures to be applied	N/A

³ Source: CDM AR-TOOL15, v2.0

Purpose of data	To calculate change in carbon stocks on new lands brought into production
Calculation method	N/A
Comments	None

Data / Parameter	f_{LU}, f_{MG}, f_{IN}
Data unit	Dimensionless
Description	Relative SOC stock change factors applicable to the displaced production over 20 years for land use, management practices and inputs respectively
Equations	9
Source of data	Table 5.5 (displaced crops, referencing tree crops in the case of fuelwood) and Table 6.2 (displaced grazing) of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories
Description of measurement methods and procedures to be applied	N/A
Frequency of monitoring/recording	At each monitoring period
QA/QC procedures to be applied	N/A
Purpose of data	Calculation of leakage emissions
Calculation method	N/A
Comments	None

7. References

- Alexandratos, N., & Bruinsma, J. (2012). World Agriculture towards 2030/2050: The 2012 Revision. Food and Agricultural Organization Agricultural Development Economics Division. <http://www.fao.org/docrep/016/ap106e/ap106e.pdf>
- Fuglie, K., & Nin-Pratt, A. (2012). Agricultural productivity: A changing global harvest. In International Food Policy Research Institute (Ed.), 2012 Global food policy report (pp. 14–27). International Food Policy Research Institute. <http://dx.doi.org/10.2499/9780896295537>
- IPCC (2003). Good practice guidance for land use, land-use change and forestry. Institute for Global Environmental Strategies (IGES). <https://www.ipcc.ch/publication/good-practice-guidancefor-land-use-land-use-change-and-forestry/>
- IPCC (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 4. IPCC. <https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html>
- Roberts, M. J., & Schlenker, W. (2013). Identifying supply and demand elasticities of agricultural commodities: Implications for the US ethanol mandate. American Economic Review, 103(6), 2265–2295. <https://www.doi.org/10.1257/aer.103.6.2265>
- Verra (2023). VMD0053: Module for estimating leakage from ARR activities v1.0. 28 September 2023. https://verra.org/wp-content/uploads/2023/09/VMD0054_ARR-Leakage-Module_v1.0.pdf

Appendix 1: Background on Default Values

Growth rate of production

The default value for production growth rates has been derived from reports provided by the International Food Policy Research Institute (IFPRI) and the Food and Agriculture Organization (FAO). This default value, based on production growth rates, is utilized in this module as a substitute for growth rates in yields. According to IFPRI's analysis, global average agricultural growth rates over the last 40 years have consistently remained below 2.5 percent per decade, with values ranging from 2.08 percent to 2.42 percent (Fuglie & Nin-Pratt, 2012). FAO reports affirm that this represents a conservative default value for growth rates. FAO anticipates a decrease in agricultural growth rates within developing countries in the upcoming decades, with an average value of 1.6 percent from 2007 to 2030 and 0.9 percent from 2030 to 2050 (Alexandratos & Bruinsma, 2012). Therefore, the selection of 2.5 percent as a conservative default value for commodity production is justified. Projects have the flexibility to substantiate the use of regional or country-specific values where relevant and available.

Share of leakage resulting in increased supply

The default value for the proportion of leakage leading to an augmented supply of agricultural commodities outside the project area was formulated by taking into account elasticities of supply and demand, along with observed prices and quantities. This involved the development of constant elasticity of substitution (CES) demand, supply, and reduced supply curves. The creation of this conservative default value relied on the examination of elasticities of supply and demand across various commodities and countries, drawing insights from peer-reviewed economic studies.

Data on exogenous prices and quantities of commodities in specific geographic regions were collected from multiple sources, including the USDA Economic Research Service (ERS), the Food and Agricultural Organization of the United Nations (FAO), Federal Reserve Economic Data (FRED), and Trading Economics. The elasticity data, encompassing agricultural commodities and forest products, indicated that none of the commodities exhibited perfectly inelastic supply or demand. On a global scale, averaging across commodities, the analysis suggested that production losses within the project would lead to a 13 to 72 percent increase in supply elsewhere. Consequently, 75 percent was chosen as a conservative default value.

Share of increased supply coming from new land brought into production

The default value for the augmented supply arising from new land brought into production was established using data and reports from the FAO. These studies suggest that globally, only 10 percent of the increases in agricultural production will originate from new land being brought into production (Alexandratos & Bruinsma, 2012). However, certain sub-regions, such as Latin America and the Caribbean, may witness 40 percent of future supply coming from newly cultivated land. It's important to note that while these studies offer insights into long-term production trends, other research on short-term trends, such as the work of Roberts and Schlenker (2013), suggests different conclusions. They provide evidence that shorter-term price shocks do not align with these longer-term trends, and the increase in production is mainly attributed to bringing new land into production.

The default value has been determined under the assumption that projects will have lasting impacts on commodity markets. Drawing from FAO data, 40 percent has been chosen as a conservative threshold for the default value for agricultural commodities. It is acknowledged that this default value may undergo updates in the future if ARR projects demonstrate shorter-term impacts on commodity markets.

Conservative assumptions used

The use of the above default values is further supported by the following conservative assumptions that have been employed elsewhere in this module:

- 1) New lands brought into production are assumed to be forested lands;
- 2) Positive leakage effects from ARR activities that provide timber to the market and reduce harvesting on existing forested lands are not included. Similarly, increases in production in leakage mitigation areas that occur after leakage emissions are calculated are not included;
- 3) Leakage calculations conservatively ignore that new lands brought into production outside the host country would reduce the amount of new land brought into production within the host country and would reduce leakage emissions (limited to domestic emissions under the SOCIALCARBON Standard);
and
- 4) Leakage estimated in this module do not decrease with time, however, the actual leakage effects may be expected to decrease as the share of carbon projects and



the impact on market supply and prices from foregone production increase over time.

Appendix 2: Testing the significance of carbon pools and GHG emissions

This appendix outlines the steps for identifying negligible emission sources and/or alterations in carbon pools.

Specific carbon pools and emission sources can be disregarded if their proportional impact, either in the reduction of a carbon pool or the augmentation of an emissions source, is less than 5 percent of the cumulative effect of all reductions in carbon pools and augmentations in emissions, or less than 5 percent of carbon dioxide removals, whichever is smaller.

$$RC_{Es} = \frac{Es}{\sum_{s=1}^S Es} \quad (\text{Equation 11})$$

Where:

- RC_{Es} = Relative contribution of each source s to the sum of project and leakage GHG emissions
- Es = GHG project emissions, leakage emissions and decreases in carbon pools
- s = 1, 2, 3, ..., S sources of project and leakage GHG emissions, and decreases in carbon pools

Arrange the reductions in carbon pools and emissions in a descending order based on their relative contributions (RCEs), assigning ranks accordingly (i.e., the lowest emission attains the highest rank and occupies the final position in the ordered sequence of emissions).

Compute the cumulative sum of the relative contributions (RCEs), starting with the lowest rank. Halt the summation when the cumulative sum equals or surpasses the threshold of 0.95.

Greenhouse gas emissions, potential declines in carbon pools, and leakage emissions that are not part of the summation are deemed insignificant if their combined total is less than five percent of carbon dioxide removals. If this condition is not met, proceed with the outlined procedure beyond the 0.95 threshold until the specified condition is fulfilled.

Appendix 3: Leakage example

The subsequent illustration showcases the utilization of the leakage module in a hypothetical scenario. To enhance readability, all presented values have been rounded.

In year 1, a project area of 1,000 hectares is planted to trees. All cattle that were grazed in the project area are sold prior to tree planting. In the three years prior to the planting date, 400, 450 and 440 cattle were grazed in the project area respectively.

The project proponent undertakes leakage mitigation activities in a designated area outside the project area (leakage mitigation area) to increase production of cattle. In the three years prior to the planting date, 410, 420 and 430 cattle were grazed in the leakage mitigation area.

In year 5, the production of cattle in the leakage mitigation area has increased to 548 cattle (+5.0 percent per year). The yield for cattle in the region of the project area is 1.70 cattle/ha.

The total forest biomass carbon stock is 123 tonnes, calculated as the product of aboveground tree biomass (209 tonnes biomass), carbon fraction of tree biomass (0.47) and biomass expansion factor (1.25). Initial reference SOC stocks in native forest in the region of production are 60 tonnes, corresponding to tropical wet climate, high activity clay soils per Table 2.3 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Relative stock change factors for grassland management used are 1.0 (land use), 0.7 (management) and 1.0 (inputs) per Table 6.2 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Step 1: Determine foregone production in the project area

A historical reference period (H) of 3 years is selected by the project proponent. With Equation 1, baseline production of cattle in the project area, using the default production growth rate of 2.5 percent, is calculated in year 5 as follows:

$$BP_{j,t} = \frac{\sum_{h=1}^H p_{j,h}}{H} \times (1 + r_j)^t$$

$$BP_{Cattle,t=5} = \frac{400 + 450 + 430}{3} \times (1 + 0.025)^5 = 483 \text{ Cattle}$$

In year 5, the project area is monitored to quantify the number of cattle grazed in the area after the project start date. Because the cattle previously in the project area were completely removed, and no cattle are grazed after the start date, the foregone production (FP) in the project area in year 5 of the project is calculated using Equation 2:

$$FP_{j,t} = BP_{j,t} - MP_{j,t}$$

$$FP_{Cattle,t=5} = 483 \text{ Cattle} - 0 \text{ Cattle} = 483 \text{ Cattle}$$

Step 2: Determine the impact of leakage mitigation activities

Using Equation 3, the baseline production in the leakage mitigation area in year 5 is calculated as follows:

$$OBP_{j,t} = \frac{\sum_{h=1}^H op_{j,h}}{H} \times (1 + r_j)^t$$

$$OBP_{Cattle,t=5} = \frac{410 + 420 + 430}{3} \times (1 + 0.025)^5 = 475 \text{ Cattle}$$

Using Equation 4, and per the assumption above that the number of cattle grazed in the leakage mitigation area in year 5 is 548, the amount of leakage mitigation (LM) in year 5 is calculated as follows:

$$LM_{j,t} = OMP_{j,t} - OBP_{j,t}$$

$$LM_{Cattle,t=5} = 548 - 475 = 73 \text{ Cattle}$$

Using Equation 5, the amount of foregone production subject to leakage in year 5 is calculated as follows:

$$l_{j,t} = FP_{j,t} - LM_{j,t}$$

$$l_{Cattle,t=5} = 483 - 73 = 410 \text{ Cattle}$$

Step 3: Determine amount of new land brought into production

Using Equation 6 and the default values for IS (75 percent) and NL (40 percent), the amount of new land brought into production (INL) is calculated as follows:

$$INL_{j,t} = \frac{l_{j,t} \times IS \times NL}{y_{j,t}}$$

$$INL_{Cattle,t=5} = \frac{410 \times 0.75 \times 0.40}{1.70} = 72 \text{ ha}$$

Using Equation 7, considering that cattle were the only agricultural commodity produced in the historical reference period in the project area, then the area of new land brought into production and generating leakage is calculated as follows:

$$AL_t = \sum_{j=1}^T INL_{j,t}$$

$$AL_{t=5} = 72 \text{ ha}$$

Step 4: Determine change in carbon stocks in new land brought into production

Using Equation 8, the change in carbon stocks on new land that is brought into production in year 5 is calculated as follows:

$$CS = \Delta C_{biomass} + \Delta SOC$$

$$CS = 123 \text{ tC/ha} + 18 \text{ tC/ha} = 141 \text{ tC/ha}$$

Where:

$$\Delta SOC = SOC_{REF} + (1 - f_{LU} \times f_{MG} \times f_{IN})$$

$$\Delta SOC = 60 \text{ tC/ha} + (1 - 1 \times 0.7 \times 1) = 18 \text{ tC/ha}$$

Step 5: Determine leakage emissions

Using Equation 10, leakage emissions from new land that is brought into production in year 5 is calculated as follows:

$$LK_t = AL_t \times CS \times \frac{44}{12}$$

$$LK_{t=5} = 72 \times 141 \times \frac{44}{12} = 37,224 \text{ tCO}_2\text{e}$$

Document History

Version	Date	Changes
1.0	28 th February 2024	Initial version published for public consultation