BUILDING RESILIENCE OF VULNERABLE COMMUNITIES TO CLIMATE VARIABILITY IN RWANDA’S CONGO NILE DIVIDE THROUGH FOREST AND LANDSCAPE RESTORATION

Annex 22: GHG emissions reduction calculations

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1) Methodology for calculating GHG emissions reductions.

1.1 Afforestation/Reforestation Activities

Choice of Applicable Methodology

An approach mirroring the CDM's Afforestation/Reforestation methodologies (AR-ACM0003 and AR-AMS0007) is applied. While this activity does not seek to become a CDM activity, the methodology selected provides a useful framework for assessing removal benefits, taking into account additionality tests and leakage.

Applicability

For "large scale projects" expecting to generate at least 16,000 tCO2e of removals each year, AR-ACM0003 is applied, and the following criteria must be met:

- Project area is not in a wetland
- Soil disturbance in project occurs on 10% or less of any organic soils; or 10% of land under managed grassland or cropland under the baseline
- Additionality is demonstrated through the application of "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" (AR-AM-TOOL-02)

For "small scale projects" expecting to generate less than 16,000 tCO2e of removals each year, AR-AMS0007 is applied, and the following criteria must be met:

- Project area is not in a wetland
- Soil disturbance in project occurs on 10% or less of any organic soils; or 10% of land under managed grassland or cropland under the baseline
- Additionality is demonstrated only through the identification of barriers to reforestation of the project in absence of intervention

Demonstration of the baseline, additionality, and common practice

AR-ACM0003 requires the demonstration of additionality through application of "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" (AR-AM-TOOL-02). The tool requires the following steps:

- STEP 0. Preliminary screening based on the starting date of the A/R project activity
- STEP 1. Identification of alternative scenarios
- STEP 2. Barrier analysis
- STEP 3. Investment analysis (if needed)
- STEP 4. Common practice analysis

A CDM project must pass each applicable step in order to be considered "additional" and be eligible for removals crediting.

Step 0. Preliminary screening based on the starting date of the A/R project activity

This step confirms that an activity was planned after December 31, 1999 and that it was developed with the intention of sale of CERs. Because this activity is not intended to sell CERs, this step is not applicable.

STEP 1. Identification of alternative scenarios

This step is meant to identify credible alternative land use scenarios to the proposed A/R activity.

Three scenarios must be assessed:

A. Continuation of the pre-project land use
B. Forestation of the land within the project boundary performed without being registered as the A/R CDM project activity. This condition is adapted here to read “without the provision of additional restoration grants”
C. If applicable, forestation of at least a part of the land within the project boundary of the proposed A/R CDM project at a rate resulting from:
    a. Legal requirements; or
    b. Extrapolation of observed forestation activities in the geographical area with similar socio-economic and ecological conditions to the proposed A/R CDM project activity occurring in a period since 31 December 1989 as selected by the PPs.

STEP 2. Barrier analysis
In the barrier analysis, any identified scenarios are eliminated that face realistic and credible barriers to their realization.

Any scenario with credible barriers may be eliminated. Barriers may be identified from the following types:
- Investment or financial return
- Institutional
- Technological
- Local tradition
- Prevailing practice
- Local ecological conditions
- Social conditions
- Land tenure

STEP 3. Investment analysis (if needed)

Investment analysis is required where both conditions are met:
- One of the credible baselines includes reforestation without expectation of carbon finance.
- There are multiple credible baselines

Investment analysis may optionally be undertaken, as an alternative to the Common practice analysis, where both criteria are met:
- None of the credible baselines include reforestation without expectation of carbon finance.
- There are multiple credible baselines

Investment analysis is not required for any of the proposed activities.

Step 4. Common practice analysis

Common practice analysis is required where both criteria are met:
- None of the credible baselines include reforestation without expectation of carbon finance.
- Only one credible land use scenario is identified.

Common practice analysis may optionally be undertaken, as an alternative to the investment analysis, where both criteria are met:
- None of the credible baselines include reforestation without expectation of carbon finance.
- There are multiple credible baselines

A common practice requires testing the following:
- To what extent similar activities are already implemented or underway in the country,

excluding those financed by carbon payments

- Wherever similar activities are identified, compare those identified activities to the ones proposed to describe any essential differences.

A project must be able to credibly show that the proposed activity wouldn't naturally occur.

Leakage

Leakage emissions are accounted for where either animal grazing or agricultural activities are displaced to areas outside of the project through implementation.

We apply the tests presented in CDM AR-AMS0001 section IV-29 to determine whether a 15% leakage detection is applied to select activities.

Estimation of Baseline

For all AR activities, we adopt the simplified baseline approach, that assumes the most likely baseline scenario is the land-use prior to implementation of project activity, as described in AR-AMS0001.

The following simplified baselines are applied:

a) If baseline woody biomass increased by less than 10%, baseline is zero change in stocks
b) If baseline woody biomass decreases, baselines is assessed to be zero change in stocks
c) Otherwise, baseline is assessed to be the change in carbon stocks projected in absence of project activities.

For all activities presented here, either condition a) or b) applies. Baseline change in carbon stocks are assessed to be zero for all cases.

Estimation of project removals

We adopt a stock change approach for all AR categories. We identified a possible value for the total expected stock change over a 20 year period from the 2019 refinement to the 2006 IPCC guidelines, and divide it by 20 to generate an annualized stock change value. In identifying a stock change factor, where an uncertainty value was presented, we subtracted it from the estimate to adopt the lower bound of uncertainty as the removal factor:

$$\Delta DM\_AGB_{1\text{-}20} = DM\_ADB / 20$$

Where

$\Delta DM\_AGB_{1\text{-}20}$	Annual change in aboveground biomass per year for first twenty years (t DM ha^{-1} y^{-1})
DM_ADB	Aboveground biomass in forests, as provided by IPCC 2006 guidelines 2019 refinement, Table 4.7 and 4.8 (t DM ha^{-1})

Below ground biomass accumulation was estimated by applying a root to shoot ration to the change in aboveground biomass:

$$\Delta DM\_BGB_{1\text{-}20} = \Delta DM\_AGB_{1\text{-}20} * R$$

Where

$\Delta DM\_BGB_{1\text{-}20}$	Annual change in aboveground biomass per year for first twenty years (t DM ha^{-1} y^{-1})
R	Root-to-shoot ratio, dimensionless

Removal factors for each AR activity were calculated as the sum of AGB and BGB accumulation:

$$\mathbf{RF = (\Delta DM\_AGB_{1\text{-}20} + \Delta DM\_AGB_{1\text{-}20}) * CF * (44/12)}$$

Where

RF	Removal factor for woody biomass per hectare ($tCO2e\ ha^{-1}\ y^{-1}$)
CF	Carbon fraction of dry matter biomass (unitless)

Total project removals across the intervention in a given year are calculated as the product of the removal factor and the area under restoration:

$$\mathbf{\Delta CO2\_PROJ_t = RF * A_t}$$

$\Delta CO2\_PROJ_t$	Projected removals in year t of project implementation ($tCO2e\ ha^{-1}\ y^{-1}$)
A_t	Area under AR activity in year t of project implementation (ha)

Net project removals are calculated as the difference between baseline and project removals, minus any leakage emissions. Because all AR activities assessed here used a simplified assumption of zero baseline removals, and of no displacement of agricultural activity, both baseline removals and leakage are not estimated.

$$\mathbf{\Delta CO2_t = \Delta CO2\_PROJ_t - \Delta CO2\_BASE_t - \Delta CO2\_LEAK_t}$$

$\Delta CO2\_BASE_t$	Projected removals in year *t* of baseline scenario ($tCO2e\ ha^{-1}\ y^{-1}$)
$\Delta CO2\_LEAK_t$	Projected emissions from activity shifting leakage in year *t* of baseline scenario ($tCO2e\ ha^{-1}\ y^{-1}$)

1.2 Cookstoves

The main source of emission reductions from project activities is sequestration due to land use, land use change, and forestry activities. Specifically, the project will achieve emission reductions by reducing fuelwood consumption through energy efficient stoves, restoring degraded natural and plantation forest land, and increasing tree cover on croplands.

GHG reductions from improved cookstoves are calculated following the approach utilized in USAID's AFOLU Carbon Calculator[1]. This approach closely resembles the CDM methodology *Energy Efficiency measures in thermal applications of non-renewable biomass* (ASM-II.G), in that it relies on stove efficiency rating to estimate the annual savings in per-household woodfuel consumption and a 'fraction non-renewable biomass' (fNRB) factor to scale carbon emission reductions to the non-renewable fraction. We conservatively assume that only 80% of cooking in a household with an improved stove is undertaken using the improved stove, and assume that 10% of units are rendered inoperable each year.

[1] http://afolucarbon.org/static/documents/AFOLU-C-Calculator-Series_FDF.pdf

GHG removals from natural forest regeneration, plantation establishment, and tree enrichment on farms, are estimated using a Mean Annual Increment approach as described in IPCC 2006 Guidelines, Vol 4, Chapter 4, Section 4.2.1.1. Productivity estimates per forest type assigned to this project's various restoration activities are derived from a combination of local and regional published figures (outlined in section 1.3). Removals consider the annual net accumulation of both above and belowground biomass. For each restoration type, the area under restoration per year is multiplied by the annual increment and converted into tons CO2 equivalent (tCO2e). Leakage and risk non permanence is not assessed but would be required under a carbon crediting standard and would reduce the overall estimate of removals. Leakage is assumed to be zero here because no lands under non-forest land uses are being restored.

Formula for calculating GHG emission reductions

Eq A1

Reductions_CO2e_annual = Reductions_CO2_annual + Reductions_CO2e- CH4_annual + Reductions_CO2e-N2O_annual

Where

Reductions_CO2e_annual = Annual reductions in CO2e, project vs baseline (t CO2e y^{-1})
Reductions_CO2_annual = Annual reductions in CO2, project vs baseline (t CO2 y^{-1})
Reductions_CO2e-CH4_annual: Annual reductions in CH4 in CO2-equivalent, project vs baseline (t CO2e y^{-1})
Reductions_CO2e-N2O_annual = Annual reductions in N2O CO2-equivalent, project vs baseline (t CO2e y^{-1})

Eq A2

Reductions_CO2_annual = Reduction_NRB * EF_CO2 * NCV_Wood / 1000000

Where

Reduction_NRB_annual = Annual reduction in non-renewable biomass consumed, project vs baseline (t DM y^{-1})

EF_CO2 = CO2 emission factor for combustion of fuelwood (kg CO2e TJ^{-1}) NCV_wood = net caloric value of fuelwood (TJ $GgDM^{-1}$)

Eq A3

Reduction_NRB = Reduction_DM * fNRB

Where

Reduction_DM = Annual reduction in utilization of fuelwood, project vs baseline (t DM y^{-1})

fNRB = fraction non-renewable biomass (unitless)

Eq A4

Reduction_DM = DM_baseline - DM_project

Where

DM_baseline = annual fuelwood utilization in baseline (tDM y^{-1}) DM_project = annual fuelwood utilization in project (tDM y^{-1})

Eq A5, A6

Reductions_CO2e-CH4_annual = Reduction_DM * EF_CH4 * GPW_CH4 * NCV_Wood / 1000000

Reductions_CO2e-N2O_annual = Reduction_DM * EF_N2O * GWP_N2O * NCV_Wood / 1000000

Where
EF_CH4 = CH4 emission factor for combustion of fuelwood ($kgCH4\ TJ^{-1}$)
GPW_CH4 = global warming potential of CH4 ($kgCO2e\ kgCH4^{-1}$)
EF_N2O = N2O emission factor for combustion of fuelwood ($kgN2O\ TJ^{-1}$)
GPW_N2O = global warming potential of N2O ($kgCO2e\ kgN2O^{-1}$)

Eq A7
DM_baseline = Households_baseline_unimproved * Consumption_unimproved * 365.25 / 1000
Where
Households_baseline_unimproved = number of households utilizing fuelwood on unimproved stoves in baseline scenario (households)
Consumption = daily woodfuel consumption per household on unimproved stove (kg DM $household^{-1}\ day^{-1}$)

Eq A8
DM_project = DM_project_unimproved + DM_project_improved

Where
DM_project_unimproved = annual fuelwood utilization in project by households using unimproved stoves ($tDM\ y^{-1}$)

DM_project_improved = annual fuelwood utilization in project by households using improved stoves ($tDM\ y^{-1}$)

Eq A9
DM_project_unimproved = Households_project_unimproved * Consumption_unimproved * 365.25 / 1000

Where
Households_project_unimproved = Number of households utilizing fuelwood on unimproved stoves in project scenario (households)

Eq A10
(DM_project_improved = Households_project_improved * (E_unimproved / E_improved) * Consumption_unimproved * 365.25 / 1000 * Displacement) + (Households_project_improved * Consumption_unimproved * 365.25 / 1000 * (1 - Displacement)

Where
Households_project_improved = Number of households utilizing fuelwood on improved stoves in project scenario (households)
E_unimproved = thermal efficiency of unimproved stove (%) E_improved = thermal efficiency of unimproved stove (%)
Displacement = fraction of cooking in households utilizing improved stoves that is undertaken with improved stove (%)

1.3 Summary of parameters, values and data sources

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Table 1. ***Annual cumulative area (A) treated with Assisted Natural Regeneration, Afforestation, and Reforestation***

	Agroforestry	Assisted Natural Regeneration	Protective Forests		Silvopastoralism
Year	Cumulative area of farms targeted for plantings (ha)	Cumulative area prepared for ANR (ha)	Cumulative area planted - Steep Slopes (ha)	Cumulative area planted - Riparian Zones (ha)	Cumulative area restored (ha)
1	0	2000	0	0	0
2	1673	3667	1500	0	200
3	3346	4667	2500	1000	500
4	3346	5000	2500	1500	800
5-20	3346	5000	2500	1500	1000

2) Description of baseline scenario and results of emission reduction calculations

Net carbon sequestration is associated with each of the outputs 2.2, 3.2, and 3.1 compared to the business-as-usual scenario. This section provides detailed analyses of the activities and total emission reductions expected under each output.

2.1 Analysis of output 2.2, sub-activity 2.2.2.5 Assisted Natural Regeneration of Nyungwe National Park

Description of Activity

Output 2.2, sub-activity 2.2.2.5 focuses on clearing invasive fern species across 4,500ha of degraded forest in Nyungwe National Park, facilitating the natural regeneration of indigenous forests. Because P. aquilinum ferns effectively inhibit all natural forest regrowth where they occur, the BAU scenario for this output assumes that no forest regrowth would occur. The spreadsheet included with this Annex 22 presents the BAU and with-project changes in carbon sequestration over the period of analysis, taking into account periodic cutting of ferns.

Choice of Applicable Methodology

As described in section 1.1

Demonstration of the baseline, additionality, and common practice

Step 0. Preliminary screening based on the starting date of the A/R project activity.

Not applicable.

STEP 1. Identification of alternative scenarios
The identified scenarios for Nyungwe are:

1. Continued failure to restrict fern growth, and inability of natural succession to forest to occur.
2. Another funder supports assisted natural regeneration
3. Areas naturally regrow without intervention

STEP 2. Barrier analysis
Barriers are identified for all scenarios except continuation of past land management.

Table 2. Scenarios and barriers identified for sub-activity 2.2.2.5

Scenario	Barrier Identified	Justification
1) Continued failure to restrict fern growth, and inability of natural succession to forest to occur.	None	n/a
2) Another funder supports assisted natural regeneration	Similar activities have only been implemented with grants or other non-commercial finance terms. In this context similar activities are defined as activities of a similar scale that take place in a comparable environment with respect to regulatory framework and are undertaken in the relevant geographical area;	This being a national park, there is no commercial finance available.
3) Areas naturally regrow without intervention	Pervasive opportunistic species preventing land use (e.g. grasses, weeds); Unfavourable course of ecological succession;	Pervasive weeds have restricted regrowth for over 2 decades.

Based on the identified barriers, we rule out scenario 2 and 3 as plausible baselines.

STEP 3. Investment analysis (if needed)

Investment analysis is not required, because there is only one credible baseline scenario.

Reforestation without carbon finance is not a credible baseline in this activity, and therefore an investment analysis is not required.

Step 4. Common practice analysis

Common practice analysis would be required, as only one credible land use scenario is identified.

All other examples of assisted natural regeneration within Rwanda national parks has been financed by grants. There is no common practice of such activities occurring in the absence of grant funding.

We therefore believe that assisted natural regeneration is clearly additional to the baseline scenario, of continued failure of the park to recover to forest.

Leakage

No animal grazing or crop cultivation is included in the baseline, so no displacement will occur. Leakage emissions are assessed as zero.

Assumptions and parameters

Under this activity, new areas come under restoration activities in years 1 through 5, maxing out at 4500 hectares by year 5.

Table 3. Area under activity 2.2.2.5 by year

Project year *t*	New AR areas established (ha)	Total area under restoration: A_t (ha)
1	2000	2000
2	1500	3500
3	1000	4500
4	0	4500
5	0	4500
6-20	0	4500

The following values are used to parameterize equations presented in section 1.1:
Table 4. Values used to parameterize equations presented in section 1.1 for sub-activity 2.2.2.5

Parameter	Value	Source
DM_AGB_1-20 (t ha-1)	58.8	IPCC 2006 Guidelines, 2019 update, Vol 4, table 4.7: Tropical montane – Africa (lower bound)
R	0.232	IPCC 2006 Guidelines, 2019 update, Vol 4, table 4.4, Tropical Moist, Africa
CF	0.47	IPCC 2006 Vol. 4, Table 4.3, "Default Value"

Results

This activity is expected to result in the removal of 118,599 tCO2 by the end of the 5th year of the project, and 539,937 tCO2 by the 20th year.

Table 5. Cumulative carbon benefit of BAU vs Project Scenario for output 2.2, sub- activity 2.2.2.5

Year	Annual net GHG removals: ∆CO2t (tCO2 y-1)	Cumulative Net GHG removals (t CO2 e)
1	12,484	12,484
2	21,847	34,331
3	28,089	62,421
4	28,089	90,510
5	28,089	118,599
6	28,089	146,688
7	28,089	174,777
8	28,089	202,867
9	28,089	230,956
10	28,089	259,045
11	28,089	287,134
12	28,089	315,224
13	28,089	343,313
14	28,089	371,402
15	28,089	399,491
16	28,089	427,581
17	28,089	455,670
18	28,089	483,759
19	28,089	511,848
20	28,089	539,937

2.2 Analysis of output 2.2, sub-activity 2.2.2.6 - 500 ha of degraded forests in Gishwati-Mukura National Park restored through Assisted Natural regeneration.

Description of Activity

Output 2.2, sub-activity 2.2.2.6 focuses on clearing invasive species across 500ha of degraded forest in Gishwati-Mukura National Park, facilitating the natural regeneration of indigenous forests. In Gishwati-Mukura there is virtually no natural forest recovery, because in many areas there is no viable seed bank due to years of soil disturbance associated with agriculture and illegal mining activity. As such, the BAU scenario for this output assumes that no forest regrowth would occur. The spreadsheet included with this Annex 22 presents the BAU and with-project changes in carbon sequestration over the period of analysis.

Choice of Applicable Methodology

As a small-scale project expecting less than 16,000 tCO2e of annual removals, AR-AMS0007 applies. See section 1.1.

Demonstration of the baseline, additionality, and common practice

Step 0. Preliminary screening based on the starting date of the A/R project activity
Not applicable.

STEP 1. Identification of alternative scenarios

Alternative scenario identification is applicable, as this activity meets criteria of small scale restoration under CDM, with expected removals of less than 16,000 tCO_2e per year.

STEP 2. Barrier analysis

For the simplified approach described in AR-AMS000, projects only need demonstrate that the planned restoration would not occur without the project intervention by identifying barriers.

The following barriers due to local ecological conditions are identified:
- Pervasive opportunistic species preventing land use (e.g., grasses, weeds);
- Un favourable course of ecological succession;

Based on the identified barriers, we rule out the possibility that this activity could occur in the absence of project intervention.

STEP 3. Investment analysis (if needed)

Not applicable for small scale activities.

Step 4. Common practice analysis

Not applicable for small scale activities.

Leakage

No animal grazing or crop cultivation is included in the baseline, so no displacement will occur. Leakage emissions are assessed as zero.

Assumptions and parameters

Under this activity, new areas come under restoration activities in years 2 through 4, maxing out 500 hectares by year 4.

Table 6. Area under activity 2.2.2.6 by year

Project year *t*	New AR areas established (ha)	Total area under restoration: A_t (ha)
1	0	0
2	167	167
3	166	333
4	167	500
5	0	500
6-20	0	500

Table 7. Values used to parameterize equations presented in section 1.1 for sub-activity 2.2.2.6

Parameter	Value	Source
DM_AGB_1-20 (t ha)	58.8	IPCC 2006 Guidelines, 2019 update, Vol 4, table 4.7: Tropical montane – Africa (lower bound)
R	0.232	IPCC 2006 Guidelines, 2019 update, Vol 4, table 4.4, Tropical Moist, Africa
CF	0.47	IPCC 2006 Vol. 4, Table 4.3, "Default Value"

Results

This activity is expected to result in the removal of 9,363 tCO2 by the end of the 5th year of the project, and 56,178 tCO2 by the 20th year.

Table 8. Cumulative carbon benefit for output 2.2, sub- activity 2.2.2.6

Year	Annual GHG removals: ΔCO2t (tCO2 y-1)	Cumulative Net GHG removals (t CO2 e)
1	-	-
2	1,042	1,042
3	2,079	3,121
4	3,121	6,242
5	3,121	9,363
6	3,121	12,484
7	3,121	15,605
8	3,121	18,726
9	3,121	21,847
10	3,121	24,968
11	3,121	28,089
12	3,121	31,210
13	3,121	34,331
14	3,121	37,452
15	3,121	40,573
16	3,121	43,694
17	3,121	46,815
18	3,121	49,936
19	3,121	53,057
20	3,121	56,178

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2.3 Analysis of output 3.1, activity 3.1.1 - 2,500 ha of protective forests on public and private land with slope >55% identified and afforested

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Description of Activity

Output 3.1, activity 3.1.1 activities include establishment and management of 2,500 ha of protective forest plantations on steep slopes on public and smallholder private land in the CND. Targeted lands are bare or abandoned agricultural land.
On district land, district forest areas are established by local community members contracted to manage the forest. The project will establish natural forests using indigenous species, and the new forest will be well demarcated on the field (differentiating species on border line), to ensure protection against encroachment.
On smallholder private land, areas are restored by landowners and local community members contracted to manage the forest. A mixture of species will be used (with a primary focus on indigenous species), but the exact mix of species planted is dependent on landowner preferences.

Choice of Applicable Methodology

As a small-scale project expecting less than 16,000 tCO_2e of annual removals, AR-AMS0007 applies. See section 1.1.

Demonstration of the baseline, additionality, and common practice

Step 0. Preliminary screening based on the starting date of the A/R project activity

Not applicable.

STEP 1. Identification of alternative scenarios

Simplified alternative scenario identification is applicable, as this activity meets criteria of small-scale restoration under CDM, with expected removals of less than 16,000 tCO_2e per year.

The simplified alternative scenario assumes continuation of historical land use.

Under this scenario in district forests, restoration does not occur, and poor management, over-exploitation and encroachment continue to occur. District owned forests in the CND are extremely degraded. This is due to a range of issues including poor tree management, early/over-harvesting, poor species selection, and illegal cutting. These small and scattered areas also lack any clear demarcation on the field (often local forest officers don't know the boundaries). Without project intervention, district forests will remain in their current non-forested state.

On smallholder private lands, restoration does not occur, and poor management, over- exploitation and encroachment continue to occur. Smallholders lack the financial means to remove undesirable vegetation, purchase new seedlings and establish healthy forest plantations. Without project intervention these forests will remain in their current non- forest state.

STEP 2. Barrier analysis

For the simplified approach described in AR-AMS000, projects only need to demonstrate that the planned restoration would not occur without the project intervention by identifying barriers.

The following barriers to restoration without project intervention are identified:
Ecological:

- Degraded soil
- Biotic pressure in terms of grazing

Social conditions

- Demographic pressure on the land

Based on the identified barriers, we rule out the possibility that this activity could occur in the absence of project intervention.

STEP 3. Investment analysis (if needed)

Not applicable for small scale activities.

Step 4. Common practice analysis

Not applicable for small scale activities.

Leakage

Leakage from displacement of agricultural activity is accounted for following the simplified CDM-AR approach (AR-AMS0001).

In private lands, where we expect there to be a higher incidence of cropland undergoing restoration (but no more than 50% of the area), we apply a 15% leakage deduction to the total emission reduction estimates for the first five years following each planting. This deduction is not applied to public lands, where we assume displacement of agricultural lands will be less than 10% of the total area.

Assumptions and parameters

Under this activity, new areas come under restoration activities in years 2 through 3, maxing out at 2500 hectares by year 5.

Table 9. Area under output 3.1, activity 3.1.1

Project year *t*	DISTRICT - New AR areas established (ha)	DISTRICT - Total area under restoration: A_t (ha)	PRIVATE - New AR areas established (ha)	PRIVATE - Total area under restoration: A_t (ha)
1	0	0	0	0
2	750	750	750	750
3	500	1250	500	1250
4	0	1250	0	1250
5	0	1250	0	1250
6-20	0	1250	0	1250

Table 10. Values used to parameterize equations presented in section 1.1 for output 3.1, activity 3.1.1

Parameter	Value	Source
DM_AGB_1-20 (t ha-1)	40.0	IPCC 2006 Guidelines, 2019 update, Vol 4, table 4.8: Tropical Mountain system, Africa, Broadleaf <20y (Lower Bound)
U	0.0	IPCC 2006 Guidelines, 2019 update, Vol 4, table 4.8: Tropical Mountain system, Africa, Broadleaf <20y
CF	0.47	IPCC 2006 Vol. 4, Table 4.3, "Default Value"

Results

This activity is expected to result in the removal of 35,350 tCO2 by the end of the 5th year of the project, and 193,472 tCO2 by the 20th year.

Table 11 Cumulative carbon benefit of output 3.1, activity 3.1.1

Year	Annual net GHG removals: ∆CO2t (tCO2 y-1)	Cumulative Net GHG removals (t CO2 e)
1	0	0
2	5,892	5,892
3	9,820	15,711
4	9,820	25,531
5	9,820	35,350
6	9,820	45,170
7	10,297	55,467
8	10,616	66,083
9	10,616	76,699
10	10,616	87,314
11	10,616	97,930
12	10,616	108,546
13	10,616	119,162
14	10,616	129,777
15	10,616	140,393
16	10,616	151,009
17	10,616	161,625
18	10,616	172,240
19	10,616	182,856
20	10,616	193,472

2.4 Analysis of output 2.2, sub-activity 2.2.2.7 - 1,500 ha of protective forests on public and private land in riparian zones

The approach to estimating removals uses the same assumptions as the plantings on steep (>55%) slopes. On both public and private lands, 500ha will be planted in year 3 of the project, and 250 in year 4, for a total of 1,500 ha combined from public and private.

Table 12. Area under output 2.2, activity 2.2.2.7

Project year *t*	DISTRICT - New AR areas established (ha)	DISTRICT - Total area under restoration: A_t (ha)	PRIVATE - New AR areas established (ha)	PRIVATE - Total area under restoration: A_t (ha)
1	0	0	0	0
2	0	0	0	0
3	500	500	500	500
4	250	750	250	750
5	0	750	0	750
6-20	0	750	0	750

Results

This activity is expected to result in the removal of 15,711 tCO2 by the end of the 5th year of the project, and 110,138 tCO2 by the 20th year.

Table 13. Cumulative carbon for output 2.2, sub- activity 2.2.2.7

Year	Annual net GHG removals: $\Delta CO2t$ (tCO2 y-1)	Cumulative Net GHG removals (t CO2 e)
3	3,928	3,928
4	5,892	9,820
5	5,892	15,711
6	5,892	21,603
7	5,892	27,495
8	6,210	33,705
9	6,369	40,074
10	6,369	46,444
11	6,369	52,813
12	6,369	59,183
13	6,369	65,552
14	6,369	71,922
15	6,369	78,291
16	6,369	84,660
17	6,369	91,030
18	6,369	97,399
19	6,369	103,769
20	6,369	110,138

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2.5 Analysis of output 3.1, activity 3.1.2 - Erosion control & agroforestry practices implemented over 3,346 ha of smallholder farmland.

Description of Activity

Output 3.1. Activity 3.1.2 will construct radical terraces over **3,346** ha of farmland in the CND, and increase average tree cover on the terraced area from 32.3 trees/ha (2%) to 150 trees/ha (9.4%), to increase supply of woodfuel and control soil erosion & landslides. Farmers will be supported to increase tree planting on their land through technical education programs and establishment of local nurseries to increase seedling supply across the CND. A mixture of species will be used (with a primary focus on indigenous species), but the exact mix of species planted is dependent on landowner preferences. Land receiving additional trees will not be used for cropping, as trees will be planted on terrace borders and not in cropland.

Choice of Applicable Methodology

As a small scale project expecting less than 16,000 tCO2e of annual removals, AR-AMS0007 applies. See section 1.1.

Demonstration of the baseline, additionality, and common practice

Step 0. Preliminary screening based on the starting date of the A/R project activity
Not applicable.

STEP 1. Identification of alternative scenarios

Simplified alternative scenario identification is applicable, as this activity meets criteria of small scale restoration under CDM, with expected removals of less than 16,000 tCO2e per year.

The simplified alternative scenario assumes continuation of historical land use.

Under the baseline, on-farm tree cover does not increase, and poor management of existing on-farm trees continues. Smallholders often lack the financial means to purchase agroforestry seedlings in sufficient numbers to substantially increase tree cover, and supply of seedlings is extremely limited across most of the CND.

STEP 2. Barrier analysis
For the simplified approach described in AR-AMS000, projects only need demonstrate that the planned restoration would not occur without the project intervention by identifying barriers.

The following barriers to restoration without project intervention are identified:

- Lack of access to planting materials
- lack of infrastructure for the implementation of the technology.

Based on the identified barriers, we rule out the possibility that this activity could occur in the absence of project intervention.

STEP 3. Investment analysis (if needed)

Not applicable for small scale activities.
Step 4. Common practice analysis

Not applicable for small scale activities.

Leakage

No farming activity will be displaced, so leakage is not accounted for.

Assumptions and parameters

Under this activity, new areas come under restoration activities in years 2 through 3, maxing out at 3346 hectares by year 5.

Table 14. Area under output 3.1, activity 3.1.2

Project year *t*	New AR areas established (ha)	Total area under restoration: A_t (ha)
1	0	0
2	1673	1673
3	1673	3346
4	0	3346
5	0	3346
6-20	0	3346

We estimate on the basis of 2006 IPCC AFOLU guidelines, 2019 update, adopting the "Silvoarable" default on IPCC Vol 4 Table 5.1.
Silvoarable is estimated to have 72.2 +/- 60% tons of carbon at time of harvest.
We conservatively estimate that the long-term average above ground stocks would reach 50% of the maximum after 20 years. Taking into account the lower bound of uncertainty, this results in a long-term average stock of 30.7 tons of aboveground tree biomass per hectare.

We assumed that the 880 trees/ha the IPCC presents for silvoarable is equivalent to the 9.4% tree cover target for this activity.

We therefore assumed that 2% canopy cover (the current state) represented 21% of AGB of the target figure, or 6.5 t AGB ha^{-1}.

A resulting stock change factor of 24.2 t AGB was assessed from the difference of existing and post-intervention stocks.

BGB is already accounted for in Vol 4, table 5.1 of IPCC, so is not accounted for separately.

The following values are used to parameterize equations presented in section 1.1:

Table 15. Values used to parameterize equations presented in section 1.1 for output 3.1, activity 3.1.2

Parameter	Value	Source
DM_AGB_1-20 (t ha-1)	24.2	IPCC 2006 Guidelines, 2019 update, Vol 4, table 5.1, Tropical - Silvoarable
CF	0.47	IPCC 2006 Vol. 4, Table 4.3, "Default Value"

Results

This activity is expected to result in the removal of 24,407 tCO2 by the end of the 5th year of the project, and 129,006 tCO2 by the 20th year.
Cumulative carbon benefit of BAU vs Project Scenario for output 3.1, sub- activity 3.1.2

Table 16. Cumulative carbon benefit for output 3.1, activity 3.1.2

Year	Annual net GHG removals: ∆CO2t (tCO2 y-1)	Cumulative Net GHG removals (t CO2 e)
1	-	-
2	3,487	3,487
3	6,973	10,460
4	6,973	17,433
5	6,973	24,407
6	6,973	31,380
7	6,973	38,353
8	6,973	45,326
9	6,973	52,300
10	6,973	59,273
11	6,973	66,246
12	6,973	73,220
13	6,973	80,193
14	6,973	87,166
15	6,973	94,140
16	6,973	101,113
17	6,973	108,086
18	6,973	115,059
19	6,973	122,033
20	6,973	129,006

○

2.6 Analysis of output 2.2, activity 2.2.3 - Silvopastoralism implemented on 1,000ha of Gishwati National Park Description of Activity

By year 5, 1,000 ha of degraded pasture in Gishwati National Park landscape will be enriched with silvopastoral plantings. We estimate that 100 trees per hectare will be utilized to establish a mixture of shade trees and row/boundary stands.

Choice of Applicable Methodology

An applicable methodology is not identified, therefore this assessment mirrors the approach of a small scale A/R project expecting less than 16,000 tCO2e of annual removals, AR-AMS0007 applies. See section 1.1.

Demonstration of the baseline, additionality, and common practice

Step 0. Preliminary screening based on the starting date of the A/R project activity
Not applicable.

STEP 1. Identification of alternative scenarios
Simplified alternative scenario identification is applicable, as this activity meets criteria of small-scale restoration under CDM, with expected removals of less than 16,000 tCO2e per year.

The simplified alternative scenario assumes continuation of historical land use.

Under the baseline, on-farm tree cover does not increase, and poor management of existing on-farm trees continues. Smallholders often lack the financial means to purchase agroforestry seedlings in sufficient numbers to substantially increase tree cover, and supply of seedlings is extremely limited across most of the CND.

STEP 2. Barrier analysis

For the simplified approach described in AR-AMS000, projects only need demonstrate that the planned restoration would not occur without the project intervention by identifying barriers.

The following barriers to restoration without project intervention are identified:
- Barriers to regrowth in the absence of the project are ecological
- degraded soil and biotic pressure in terms of grazing.

Based on the identified barriers, we rule out the possibility that this activity could occur in the absence of project intervention.

STEP 3. Investment analysis (if needed)

Not applicable for small scale activities.

Step 4. Common practice analysis

Not applicable for small scale activities.

Leakage
No cattle grazing will be displaced from the pastures, and the time-average number of grazing animals within the project boundary will not increase, so leakage is assigned as 0% following CDM AR-AMS0001 section IV-29.

Assumptions and parameters

Under this activity, new areas come under restoration activities in years 2 through 5, maxing out at 1000 hectares by year 5.

Table 17. Area under activity 2.2.3 by year

Project year *t*	New AR areas established (ha)	Total area under restoration: A_t (ha)
1	0	0
2	200	200
3	300	500
4	300	800
5	200	1000
6-20	0	1000

There is no research currently on the potential for carbon removal from silvopastoralism in Rwanda to draw from. We therefore estimate on the basis of 2006 IPCC AFOLU guidelines, 2019 update.

Tropical silvopastoral system implemented under this project will result in roughly 100 trees per hectare. This density most closely matches "Parkland" on IPCC Vol 4 Table 5.1, and therefore parkland is adopted. Parkland is estimated to have 11.8 +/- 76% tons of carbon at time of harvest. We conservatively estimate that the long-term average above ground stocks would reach 50% of the maximum after 20 years. Taking into account the lower bound of uncertainty, this results in a long-term average stock of 3.0 tons of aboveground tree biomass per hectare. BGB is already accounted for in Vol 4, table 5.1 of IPCC, so is not accounted for separately.

Table 18. Values are used to parameterize equations presented in section 1.1, for activity 2.2.3

Parameter	Value	Source
DM_AGB_1-20 (t ha-1 y-1)	3.0	IPCC 2006 Guidelines, 2019 update, Vol 4, table 5.1, Parkland (adapted as above)
CF	0.47	IPCC 2006 Vol. 4, Table 4.3, "Default Value"

Results

This activity is expected to result in the removal of 649 tCO2 by the end of the 5th year of the project, and 4,543 tCO2 by the 20th year.

Table 19. Cumulative carbon benefit of output 2.2, activity 2.2.3

Year	Annual net GHG removals: $\Delta CO2t$ (tCO2 y-1)	Cumulative Net GHG removals (t CO2 e)
1	-	-
2	52	52
3	130	182
4	208	389
5	260	649
6	260	909
7	260	1,168
8	260	1,428
9	260	1,687
10	260	1,947
11	260	2,207
12	260	2,466
13	260	2,726
14	260	2,985
15	260	3,245
16	260	3,505
17	260	3,764
18	260	4,024
19	260	4,283
20	260	4,543

○

2.7 Analysis of output 3.2, activity 3.2.4 - Improved cookstoves adopted by 8,500 smallholder farm households

Description of Activity

Output 3.2, activity 3.2 4 will contribute to climate resilience in the CND by promoting the use of high-efficiency biomass cook stove technologies aligned with the Government of Rwanda's BEST Strategy, which aims to:

- Increase supply of woody biomass through improved sustainable management of wood biomass resources
- Improve efficiency of biomass usage by rural households by:
  - Strengthening woody pellets, gasifier and briquettes value chains (for households with problems in accessing wood)
  - Increasing penetration of high efficiency Improved Cook stoves (ICS) for firewood (for households with easy access to wood)
- Strengthen coordination and capacity building, monitoring and evaluation, to effectively manage the biomass energy sector

While the forest restoration and agroforestry activities described in the above outputs will take time to increase woodfuel supply and reduce climate vulnerability, the transition to efficient cooking technologies will immediately reduce the rate at which forested areas are cleared and thereby contribute to reduced vulnerability in the short term.

Assumptions and parameters

In line with the government's BEST strategy, the project aims to increase average rural wood cookstove efficiency in the CND from 10% to 22.5% (based on transition the from three stone fire to improved stove, as described within the Rwanda BEST), with a commensurate decrease in per-household wood fuel consumption. 8,500 households will be targeted, and these households will be located in the same areas targeted for agroforestry intervention under output 3.2, activity 3.2.4.1. This will simultaneously increase wood fuel supply while reducing woodfuel demand, helping ease pressure on forests overall.
We target adoption of energy efficient cookstoves by households currently using improved stoves in the following quantities per year: 3,500 in years 1 and 2, 1,000 in year 3 and 500 in year 4.

It is assumed that the same amount of cooking is conducted in households under the baseline and project scenario. The higher efficiency of stoves allows for less woodfuel to be consumed with project stoves than the baseline.

Under the baseline, it is assumed that the average household consumes 7.7 kg of dry matter (DM) biomass per day, 10% of the energy of which is converted to useful cooking using unimproved stoves. Improved stoves with 22.5% efficiency allow the same amount of cooking to be conducted with 3.4 kg DM per day.

Even houses with improved stoves will typically continue to cook on unimproved stoves as multiple stoves may be used simultaneously (i,e, 'stove stacking'). It is assumed here that only 80% of cooking will utilize the improved stove per household.

We assume that each year, 10% of the distributed improved cookstoves fail and are not replaced. Accounting for the number of households with working improved stoves in a given year, the total reduction in consumption of dry matter woodfuel is calculated. Only the non- renewable fraction of woodfuel (fNRB) is considered to be an emission. We adopt a fNRB of 30% from the CDM TOOL30, meaning that 30% of all wood is assumed sourced non-sustainably. We have no knowledge of whether this value is appropriate for the project site.

Table 20. Cookstove Parameters

Input Parameter	Value	Source
Households_project_improved	varies by year	Project implementation plans (see table 2 below)
Households_project_unimproved	varies by year	Project implementation plans (see table 2 below)
Households_baseline_unimproved	8,500	Total households targeted under project
Consumption_unimproved (kg/hh/day)	7.7	Rwanda Ministry of Infrastructure and Ministry of Finance, "National Survey on Cooking Fuel Energy and Technologies in Households, Commercial and Public Institutions in Rwanda 2020"
E_unimproved	0.10	Rwanda Biomass Energy Strategy, Figure 2: "3-stone fires", average of range 8-12%
E_improved	0.225	Rwanda Biomass Energy Strategy, Figure 2: "Improved stoves, (first generation)", average of range 20-25%
Displacement	0.8	Project conservative estimate
GWP_CH4 (kgCO2e kgCH4-1)	27.2	IPCC 6th Assessment Report (non-fossil carbon)
GWP_N2O (kgCO2e kgN2O-1)	273	IPCC 6th Assessment Report
EF_CO2 (kg CO2 TJ-1)	112,000	IPCC 2006 guidelines table Vol 2 table 2.2
EF_CH4 (kg CH4 TJ-1)	30	IPCC 2006 guidelines table Vol 2 table 2.2
EF_CH4 (kg N2O TJ-1)	4	IPCC 2006 guidelines table Vol 2 table 2.2
fNRB	0.3	CDM TOOL30 conservative default

NCV_wood	15.6 TJ/Gg	IPCC 2006 guidelines table Vol 2 table 1.2

Table 21. Annual values for estimate of households under project and baseline (Households_project_improved, Households_project_unimproved, Households_baseline_unimproved):

Year	Households receiving improved Stoves (Project Scenario)	Project-Households using improved stove	Stove Malfunctions after year	Project-Households using unimproved stove	Baseline-Households using unimproved stove
1	3500	3,500	350	5,000	8,500
2	3,500	6,650	665	1,850	8,500
3	1,000	6,985	699	1,515	8,500
4	500	6,787	679	1,714	8,500
5	0	6,108	611	2,392	8,500
6	0	5,497	550	3,003	8,500
7	0	4,947	495	3,553	8,500
8	0	4,453	445	4,047	8,500
9	0	4,007	401	4,493	8,500
10	0	3,607	361	4,893	8,500
11	0	3,246	325	5,254	8,500
12	0	2,921	292	5,579	8,500
13	0	2,629	263	5,871	8,500
14	0	2,366	237	6,134	8,500
15	0	2,130	213	6,370	8,500
16	0	1,917	192	6,583	8,500
17	0	1,725	173	6,775	8,500
18	0	1,553	155	6,947	8,500
19	0	1,397	140	7,103	8,500
20	0	1,258	126	7,242	8,500

Results

This activity is expected to result in the removal of 20,792 tCO_2 by the end of the 5th year of the project, and 51,017 tCO_2 by the 20^{th} year.

Table 22. Cumulative carbon benefit of output 3.2, sub- activity 3.2.4

Year	Annual net GHG removals: ΔCO_2t (tCO_2 y-1)	Cumulative Net GHG removals (t CO_2 e)
1	2,423	2,423
2	4,604	7,028
3	4,836	11,864
4	4,699	16,563
5	4,229	20,792
6	3,806	24,598
7	3,425	28,024
8	3,083	31,106
9	2,775	33,881
10	2,497	36,378
11	2,247	38,626
12	2,023	40,648
13	1,820	42,469
14	1,638	44,107
15	1,475	45,582
16	1,327	46,909
17	1,194	48,103
18	1,075	49,178
19	967	50,146
20	871	51,017

3) Overall summary of project emissions reductions

Total removals and emission reductions are presented in table 22. This project is expected to generate 224,871tCO_2e by year 5 and 1,084,291tCO_2e by year 20.

Table 23. Cumulative Emission Reductions and Removals (tCo2e)

Project Year	ANR	Agroforestry	Silvopastoralism	Protected forests Steep (>55% slope)	Riparian lands	Energy-Efficient Cookstoves	Total
1	12,484	-	-	-		2,423	14,907
2	35,374	3,487	52	5,892	-	7,028	51,832
3	65,542	10,460	182	15,711	3,928	11,864	107,686
4	96,752	17,433	389	25,531	9,820	16,563	166,488
5	127,962	24,407	649	35,350	15,711	20,792	224,871
6	159,172	31,380	909	45,170	21,603	24,598	282,832
7	190,383	38,353	1,168	55,467	27,495	28,024	340,889
8	221,593	45,326	1,428	66,083	33,705	31,106	399,241
9	252,803	52,300	1,687	76,699	40,074	33,881	457,444
10	284,013	59,273	1,947	87,314	46,444	36,378	515,370
11	315,224	66,246	2,207	97,930	52,813	38,626	573,046
12	346,434	73,220	2,466	108,546	59,183	40,648	630,497
13	377,644	80,193	2,726	119,162	65,552	42,469	687,746
14	408,854	87,166	2,985	129,777	71,922	44,107	744,812
15	440,065	94,140	3,245	140,393	78,291	45,582	801,715
16	471,275	101,113	3,505	151,009	84,660	46,909	858,471
17	502,485	108,086	3,764	161,625	91,030	48,103	915,093
18	533,695	115,059	4,024	172,240	97,399	49,178	971,597
19	564,906	122,033	4,283	182,856	103,769	50,146	1,027,992
20	596,116	129,006	4,543	193,472	110,138	51,017	1,084,291

4) Monitoring & Reporting Mitigation Benefits

As described in the Project Feasibility Study; monitoring of emissions reductions achieved by the project will be undertaken through stratified sampling of project intervention areas. For assisted natural regeneration, reforestation and agroforestry activities, the information collected will be used to inform application of the IPCC Tier 2 methodology (described earlier in this annex), replacing estimated annual growth of trees/shrubs in project areas with empirical data. By visiting a representative sample of project intervention sites over the life of the project, repeated measurements will allow for estimation of project impacts by estimating results over the entire project area.

To measure the impacts of assisted natural regeneration, forest restoration, and agroforestry activities on emissions reduction, indicators gathered will include:

Tree Biomass, estimated using allometric equations based on Tree Diameter at Breast Height (DBH), measured in sample plots throughout the project area

Non-Tree Woody Vegetation, measured by weight in sub-plots within tree DBH plots

Standing & Lying Dead Wood, measured by wood diameter in sample plots throughout the project area

Non-Woody (Herbaceous) vegetation, measured by weight in sub-plots within tree DBH plots

These indicators will be used as parameters to inform the application of IPCC Tier 2 methodology for estimating emissions removals on Forest Land (as described in IPCC 2006 Guidelines, Vol 4, Chapter 4, Section 4.2.1.1).

For cookstoves, accurate yearly values for the number of cookstoves distributed to households in the CND will be used to monitor project emissions reductions, based on the known efficiency of standard and improved cookstoves. These numbers will be used to estimate emissions reductions using USAID's AFOLU Carbon Calculator[2]. This approach closely resembles the CDM methodology Energy Efficiency measures in thermal applications of non-renewable biomass (ASM-II.G).

[2] http://afolucarbon.org/static/documents/AFOLU-C-Calculator-Series_FDF.pdf