

Annex 22c Formulae Used for Impact Estimates Assessment

Heritage Colombia (HECO): Maximizing the Contributions of Sustainably Managed Landscapes in Colombia for Achievement of Climate Goals

V.4

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1. Estimated Avoided emissions

$$[1] \quad A_e = FREL_e - HECO_e$$

where:

A_e = Avoided emissions
 $FREL_e$ = emissions reference level
 $HECO_e$ = expected emissions under HECO scenario

$$[2] \quad FREL_e = \frac{\sum_{2008}^{2017} (AD_{R_i} \times EF_{R_i})}{10}$$

where:

AD_{R_i} = Activity data (mapped deforestation) for region “i” between 2008 and 2017
 EF_{R_i} = Emissions factor for region “i” as per the 2020 FREL submission to UNFCCC

$$[3] \quad HECO_e = \frac{\sum_1^{30} (eAD_{RT_i} \times EF_{tDR_{R_i}})}{10}$$

where:

eAD_{RT_i} = expected activity data (deforestation) at target deforestation rates for region “R” during project implementation, as assigned to each area of intervention “i” (based on decision tree)

$$[4] \quad eAD_{RT_i} = \sum_1^{30} (TDef_{yr_i})$$

where:

$$[5] \quad TDef_{yr_i} = FA_{yr_i} \times tDR_{R_i}$$

where:

$$[6] \quad FA_{yr_i} = FA_{yr_{i-1}} - TDef_{yr_{i-1}}$$

where:

$TDef_{yr_i}$ = target deforestation for specific region and intervention for year “i”.
 FA_{yr_i} = Remaining forest areas for each area of intervention in year “i”.
 tDR_{R_i} = Target deforestation rate for area if intervention “R”

2. Estimated removals by natural sinks

a. Yearly total sinks:

$$[7] \quad TSnk_{yr_i} = FA_{yr_i} \times SR_i$$

where:

$TSnk_{yr_i}$ = Yearly sink for the forest area in year “i”.

FA_{yr_i} = Remaining forest area in year “i”

SR_i = Sink rate = 0.12 tBiomass/ha/yr (Source: Hubau et al 2020¹)

NOTE: This rate was selected as a conservative estimate as compared with values in table 4.9 of IPCC 2006 Guidelines updated in 2019²

b. Yearly additional sink:

$$[8] \quad AdSnk_{yr_i} = (AD_{R_i} - eAD_{RT_i}) \times SR_i$$

Where

$AdSnk_{yr_i}$ = Additional sink in year “i”. Represented the salvaged sink coming from the avoided deforestation areas (the difference between the reference deforestation and the actual or expected under the implementation of the project).

AD_{R_i} = Activity data or deforestation under reference level scenario

eAD_{RT_i} = Activity data expected or observed under project implementation scenario

SR_i = Sink rate = 0.12 tBiomass/ha/yr (Source: Hubau et al 2020)

3. Removals by Restoration and Rehabilitation

Restoration and rehabilitation carbon uptake rates were estimated based on the IPCC 2019 refined 2006 guidelines default values reported in table 4.9 for restoration and 5.1 for rehabilitation silvopasture and agroforestry components (see table 1), following Bernal et al 2018³, based on the Chapman-Richards equation⁴⁵.

$$y(t) = y_{\max}[1 - e^{-kt}]^p$$

$$[9] \quad Y_{(t)} = Y_{\max}(1 - e^{-kt})^p$$

where Y_{\max} is the maximum yield for the forest are productive system type., k is a constant =0.091 for restoration and = 2 for rehabilitation systems and $p = 4$ for both. In the case of Restoration Y_{\max} was fit using the solver tool in excel based on the average growth rates reported in table 4.9 of the IPCC guidelines for years 1-20 and then 21-30 for the corresponding forest types (see table 1).

Table 1. restoration and rehabilitation input parameters for yearly rate estimates in tCO₂eq.

	Restoration growth rate (tCO ₂ eq)	Solver Estimated Ymax	Rehabilitation ymax (tCO ₂ eq)
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¹ Hubau et al. 2020. Asynchronous carbon sink saturation in African and Amazonian tropical forests. Nature, Vol 579. p80: <https://www.nature.com/articles/s41586-020-2035-0>

² Table 4.9 (Updated): ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS (TONNES D.M. HA-1 YR-1). IPCC 2009 refined guideline, AFOLU VOL 4, Chapter 4. Forest Land. page 4.34. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch04_Forest%20Land.pdf

³ Bernal et al 2018. Global carbon dioxide removal rates from forest landscape restoration activities. Carbon Balance and Management <https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-018-0110-8>

⁴ Richards FJ. A flexible growth function for empirical use. J Exp Bot. 1959;10(2):290–301. <https://doi.org/10.1093/jxb/10.2.290>

⁵ Pienaar LV, Turnbull KJ. The Chapman-Richards generalization of Von Bertalanffy's growth model for basal area growth and yield in even-aged stands. For Sci. 1973;19(1):2–22. <https://doi.org/10.1093/jxb/10.2.290>

			(t C/ha)		
Mosaic	< 20 yrs	> 20 yrs		Silvopasture	Agroforestry
Caribe	6.90	1.72	162.15	100.39	82.80
Amazon	18.97	5.35	239.16		
Orinoquia	18.97	5.35	239.16		
Andes	5.61	1.55	137.82		

a. Restoration

$$[10] \quad RSr = \sum RSa_{ri} \times {}_{RS}Rf$$

RSr = Restoration removals (tCO₂eq)

RSa_{ri} = Restoration area *a* in region/intervention *r* in year *i*

${}_{RS}Rf$ = Estimated removal factor (tCO₂eq/yr) following Bernal et al 2018. sources:

Table 4.9. IPCC 2006 Guidelines Updated 2019.

NOTE: Removal factor considered at 100% for restoration areas: expected tree density planted = 600 trees/ha

b. Rehabilitation

$$[11] \quad RHr = \sum RHa_r \times (0.75 \times {}_{RS}Rf)$$

RHr = Rehabilitation removals (tCO₂eq)

RHa_r = Rehabilitation area *a* in region/intervention *r*

${}_{RS}Rf$ = Removal factor (tCO₂eq/yr) source: Table 4.9. IPCC 2006 Guidelines Updated 2019.

NOTE: Removal factor considered at 75% for rehabilitation areas: expected tree density planted = 400 trees/ha (75% of that for restoration areas).