ASES ON-CHAIN PROTOCOL

METHODOLOGY FOR ESTIMATING CARBON REMOVAL CAPACITY OF PROJECTS

IV. Methodologies V2.0

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SUMMARY

Climate change is one of the greatest threats to our planet. Greenhouse gas emissions, such as carbon dioxide (CO_2), are increasing the global temperature, which is causing a series of devastating consequences, such as rising sea levels, extreme weather events, and loss of biodiversity.

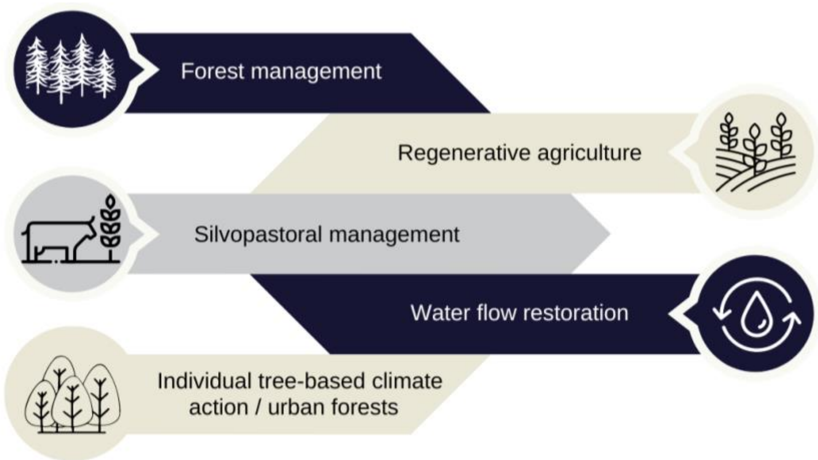
This method helps to estimate reforestation projects' capacity to remove CO_2 from the atmosphere along the project's life. This approach is based on the use of species-specific allometric equations to estimate the carbon content of planted trees and shrubs by the end of the project. It includes the estimation of survival/mortality defined by tree density as a function of mean diameter at breast height (DBH) and latitude, according to (Madrigal-González et al., 2023). When available, tree density according to regional timber plantation tables, is used to generate an additional survival/mortality rate scenario. For both approaches, Net Primary Productivity (NPP) is set as the upper limit, representing the maximum achievable carbon sequestration potential based on biophysical considerations.

I. DEFINITIONS

- **Survival and mortality:** The finite survival rate is defined as the number of individuals alive at the end of the census period, divided by the number of individuals alive at the beginning. The finite mortality rate is defined as 1.0—finite survival rate. Values of both survival and mortality rates always relate to some specific period (Krebs 1999).
- **Net Primary Productivity (NPP):** The result of the production of organic matter through the photosynthesis process.
- **Allometric equations:** Mathematical formulas used to estimate the amount of CO_2-eq that can be captured and stored in certain types of vegetation.

II. APPLICABILITY CONDITIONS

a) The type of Project is:



b) The Project complies with the standards of the aOCP Program;
c) The Project was developed less than 5 years ago;
d) The Project area has not been degraded, deforested, or burned in the last 24 months;
e) If the project area does not meet requirement "d" the project proponent must offer a technical reason arguing that ecological restoration is necessary because the area's biodiversity and environmental services are vulnerable.

III. METHODOLOGICAL CONSIDERATIONS

III.1. APPLICATION OF METHODOLOGY

The following table identifies the types of projects that should use the Methodology for estimating carbon removals and storage in vegetation, which correspond to those that lead to an increase in vegetation biomass, either by directly planting trees and shrubs or indirectly by enhancing natural forest or grassland regeneration.

TABLE 1. APPLICATION OF METHODOLOGY BY PROJECT TYPE

Type of project	Use of methodologies			
	Methodology for estimating carbon removal capacity of projects V2.0	Methodology for biodiversity assessment V2.1	Methodology for soil and erosion assessment V2.0	Methodology for water balance assessment V2.0
Regenerative agriculture	✓			

Type of project	Use of methodologies			
	Methodology for estimating carbon removal capacity of projects V2.0	Methodology for biodiversity assessment V2.1	Methodology for soil and erosion assessment V2.0	Methodology for water balance assessment V2.0
Forest management	✓			
Silvopastoral	✓			
Urban forest	✓			
Water restoration	✓			

III.2. Methodology parameters

The methodology's parameters and the factors that will be taken into account when using it are listed in the following table:

Table 2. Methodology parameters

Parameters	Description
Number of trees of each species planted	Each tree and shrub planted shall be georeferenced, including the species name in the database.
Age of the plants	Refers to the time elapsed between the date of plantation and the date of monitoring.
DBH	Diameter at breast height (at 130 cm from the ground).
Plant height	The vertical distance from the base of the plant to the tip of the highest part.
Survival rate	Percentage of the planted trees and shrubs that are still alive at the moment of counting.
NPP	Net Primary Productivity

IV. Baseline scenario

According to the aOCP applicability conditions, the project developer must affirm and demonstrate that the project area has not been deforested in the last 24 months and that the ecosystem of the project area is vulnerable to degradation or disturbance if not preserved or restored. This information will be corroborated through the Alignment Assessment as established in the *Project Procedures V2.2*, since biodiversity is a central component of the aOCP, all projects must be subject to its evaluation.

V. Description of the methodology

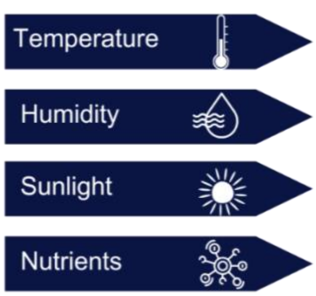
V.1. Data collection

V.1.1. Net Primary Productivity (NPP)

Net Primary Productivity is the result of the production of organic matter through the photosynthesis process. However, primary productivity requires more than photosynthesis, particularly the uptake of inorganic nutrients and the incorporation of various organic compounds into protoplasm, essential for all photosynthetic organisms.

Among all ecosystem processes, NPP is the most measured because it reflects the carbon accumulation in ecosystems. The NPP is calculated based on the increase in biomass per area unit per time unit.

NPP depends on the following factors:



Thus, the net primary productivity is equal to the carbon absorbed by the vegetation through photosynthesis (called Gross Primary Production or GPP) minus the carbon lost through respiration.

NPP is limited by temperature and precipitation, it is assumed that it increases with both temperature and precipitation. However, in both cases, the saturation value of 3000 gDM m^{-2} yr^{-1} (DM stands for dry matter) must not be exceeded (Grieser *et al*., 2006).

The NPP of the project area is calculated using the Miami methodology given in section *"IV.1. aOCP Methodology for carbon removal and storage in vegetation*". Present and future NPP are computed to take into consideration the ecosystem's vulnerability to climate change and to define the threshold for carbon sequestration. Both are computed on Google Earth Engine using the resources available in the catalog. Present NPP is calculated from 2 data sources: a) precipitation data from the "CHIRPS Daily: Climate Hazards Group InfraRed Precipitation with Station Data (Version 2.0 Final)" dataset (Funk et al., 2015) and b) temperature data from the MODIS/Terra Land Surface Temperature/Emissivity Daily L3 Global 1km SIN Grid V061 [Data set] (Wan et al., 2021). Future NPP is computed using precipitation and temperature data for 40 years from the assessment year, from the NEX-GDDP-CMIP6 dataset (Thrasher et al. 2022). This dataset, comprised of global downscaled climate scenarios derived from the General Circulation Model (GCM), runs conducted under the Coupled Model Intercomparison Project Phase 6; the CMIP6 GCM runs were developed in support of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6).

The calculation uses the following equations:

$$\mathrm{NPPdm} = \min\left(\mathrm{NPP_T}, \mathrm{NPP_P}\right) \quad [1]$$

Where:

$$NPP_T = 3000(1 + exp(1.315 - 0.119 * T))^{-1} \quad [2]$$

$$NPP_P = 3000(1 - \exp(-0.000664 * P)) \quad [3]$$

Where:

NPPdm: net primary productivity, *gDM* m^{-2} yr^{-1}

T: average annual temperature, *C°*

P: accumulated precipitation, *mm*

The climate sensitivity of the NPP can be defined as the derivative of the NPP concerning changes in climate variables, λP = ∂NPP/∂P in g(DM)/m^2/yr/(mm/yr) = gDM/ m^2/mm and λT = ∂NPP/∂T in gDM/m^2/year/°C, respectively.

Direct differentiation leads to

$$\lambda\mathrm{T} = \frac{3000*0.199\exp(1.315-0.119*T)}{(1+\exp(1.315-0.119*T))^2} \quad \text{, if } NPP_T < NPP_P \quad [4]$$

or

$$\lambda\mathrm{P} = 3000 * 0.000664 \exp(-0.000664 * P) \text{ , if } NPP_P < NPP_T \quad [5]$$

Carbon capture capacity was calculated using the conversion factor 0.47 (IPCC, 2006), using the following equation [6]:

$$NPPc = NPPdm \times 0.47 \quad [6]$$

Where:

NPPc: Net primary productivity, gC m^{-2} yr^{-1}

NPPdm: Net primary productivity, gDM m^{-2} yr^{-1}

Then, the equivalence to carbon dioxide is calculated using the conversion factor of 3.67. This factor represents the molar mass ratio of CO_2:C. CO_2 molar mass is 44 and C is 12, therefore, 44/12 = 3.67. The conversion is done using the following equation [7]:

$$NPP_{CO2} = 3.67(\text{NPPc}) \quad [7]$$

Where:

NPP_{CO2}: Net primary productivity, gCO_2 m^{-2} yr^{-1}

Finally, the maximal CO_2 capture capacity for the Project area is computed by multiplying the previous result by the Project area surface and converting to tons of CO_2-eq [8].

$$MCR = \text{PL}\frac{NPP_{CO2}(PA)}{10^6} \quad [8]$$

Where:

MCR: Maximum carbon removals (T CO_2-eq)

PL: Project lifetime (years). Usually, for the aOCP equals 40.

PA: Project restoration area surface (m^2)

The calculation was repeated for each scenario (present with real data, present with CMIP data and future with CMIP data). Real data is privileged over modelled data for the present scenario. In order to estimate future NPP, the percent change was calculated between present and future estimates done with CMIP6 data. This percent change was then applied to the present estimate done with real data, this way we obtain a future NPP estimate based on present real data.

V.1.2. ALLOMETRIC EQUATIONS

Allometric equations are mathematical formulas used to estimate the amount of CO_2-eq that can be captured and stored in certain types of vegetation, such as trees or shrubs, depending on their morphometry. By knowing the tree or shrub dimensions (height and/or diameter at breast height) and the species-specific allometric equation, one can calculate biomass. Biomass is then translated into carbon and carbon into CO_2 following the same steps described for NPP in section I (eqs. 6 and 7). Carbon removal potential based on the number of individuals and species planted is calculated as follows [9]:

$$CRP = \frac{\sum_{i=1}^{N} CO_{2i40} n_i}{1000} \quad [9]$$

Where:

CRP: carbon removal potential, T CO_2-eq

CO_{2i40}: carbon dioxide stored in an individual of species *i* at year 40; Kg CO_2-eq

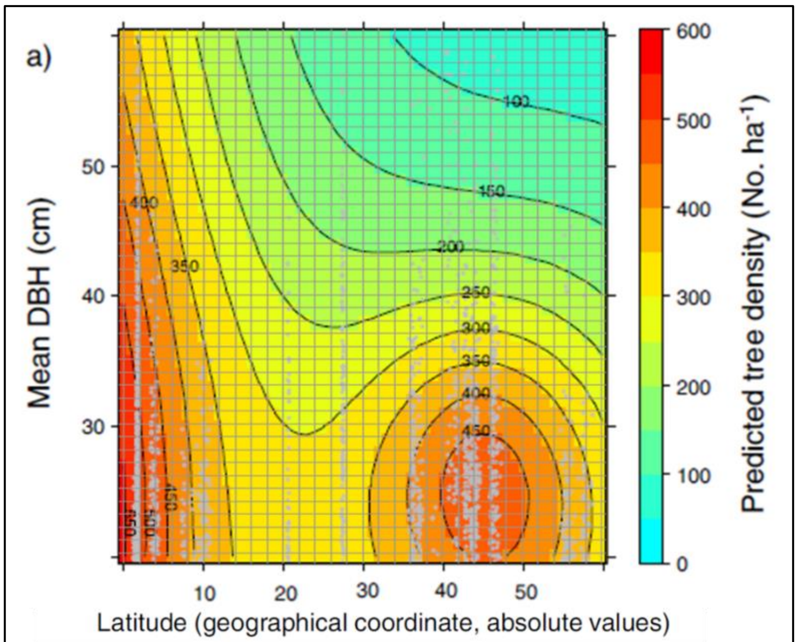
n_i: number of individual of species *i*

Due to natural ecological processes, a fraction of the planted trees and shrubs will die. Therefore, survival/mortality rates shall be considered to adjust CRP. The next section describes the approach to do so.

V.1.3. SURVIVAL RATE

V.1.3.1. Tree density as a function of mean DBH and latitude

The estimation of survival rate is based on the results from Madrigal-González et al. (2023). These authors used "a vast set of forest inventories including >3000 sampling plots from 23 well-conserved areas worldwide to encompass (as much as possible) the main forest biomes on Earth" to model the relationship between mean DBH and latitude in determining forests' tree density (figure 1).



Source: Madrigal-González et al. (2023), figure 2a.

IMAGE 1. PREDICTED TREE DENSITY AS A FUNCTION OF MEAN DBH AND LATITUDE. SOURCE: MADRIGAL-GONZÁLEZ ET AL. (2023).

The present method uses this model to retrieve the expected final stand density at the project area. Mean DBH is computed with the following equation [10]:

$$\overline{DBH} = \frac{\sum_{i=1}^{N} n_i DBH_i}{N} \qquad [10]$$

Where:

$\overline{DBH}$: mean DBH of the plantation (cm)

n_i: number of individuals of species *i*

DBH_i: DBH of species *i* at year 40

N: total number of planted trees and shrubs

Then, the intersection of mean DBH and project area's latitude is found in figure 1, which gives the expected final stand density. Finally, survival rate is computed as follows [11]:

$$SR = \frac{Density_{pl}}{Density_{pr}} \quad [11]$$

Where:

SR: Survival rate,

Density$_{pl}$: Plantation density (trees and shrubs per hectare),

Density$_{pr}$: Predicted density, from Madrigal-Gonzalez *et al*. (2023; figure 2a).

V.1.3.2. Tree density according to timber plantation tables

When available, tree density according to timber plantation tables is used as a second scenario for the estimation of expected density at the end of the project. Biogeographic regions and species group types are considered when selecting timber plantation tables. The survival rate is computed using equation 10, using as a denominator the predicted density from the selected timber plantation table.

V.2. Quantification of carbon removal at year 40

The final estimation of the expected carbon removal at year 40, which determines the number of carbon credits the project can potentially generate is computed by integrating the previous elements. The carbon removal potential calculated (eq.9) from allometric equations for the whole plantation is then adjusted to the survival rate as follows [12]. If 2 scenarios of survival rate were computed, then 2 scenarios of estimated carbon removal are computed. Maximum carbon removals, calculated in equation 8, are used as the threshold for carbon removal capacity for a given project.

$$\boldsymbol{ECR} = \mathbf{min}\,(\boldsymbol{CRP}(\boldsymbol{SR}), \boldsymbol{MCR}) \quad [12]$$

Where:

ECR: Estimated carbon removals for the project area along the project's life (T CO_2-eq)

CRP: carbon removal potential (eq.9)

SR: Survival rate (eq.11)

MCR: Maximum carbon removals (eq. 8)

VI. MONITORING

Project monitoring to evaluate carbon capture will be carried out by applying the aOCP *Methodology for Carbon Capture Monitoring V1.0* at the periodicity determined in the Monitoring Plan for each project.

VI.1. DATA AND PARAMETERS CONSIDERED IN THE MONITORING

TABLE 3. PARAMETER CONSIDERED IN THE MONITORING

Parameter	CO_2 (mass of carbon dioxide, kg or tn)
Description	Carbon emissions removed from the atmosphere through photosynthesis and stored in vegetal biomass.
Equation	$CV=(PV*49)*1200*3.67$ / 1000
Source of data	Machine learning model trained with field data
Purpose of data	Quantify the project's carbon removals
Stage to be realized	At the periodicity determined by the project's Monitoring Plan

DOCUMENT HISTORY		
Version	**Date**	**Comments**
V2.0	15/01/2024	• The second version was released for review by the aOCP Steering Committee under the aOCP Version 1.
V1.0	10/01/2023	• Initial version released for review by the aOCP Steering Committee under the aOCP Version 1.