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CERTIFICAÇÃO DIGITAL DE ATIVOS AMBIENTAIS

TERO.003 - CARBON STOCK IN FORESTS

VERSION 1.0

METHODOLOGY, AFOLU, CARBON STOCK

TERO CARBON AVALIAÇÕES E CERTIFICAÇÕES S.A.

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PROJECT ACTIVITIES	• Maintenance of carbon stocks in the forest • Forestry

ACRONYMS

AFOLU	Agriculture, Forestry and Other Land Uses
AGB	Above Ground Biomass
AP	Project Area
APD	Avoided Planned Deforestation
APP	Permanent Preservation Area
ARL	Legal Reserve Area
AUM	Multiple Use Area
BAU	Business as Usual
BGB	Below Ground Biomass
Btot	Total forest biomass (AGB + BGB)
CAR	Rural Environmental Registry
CDM	Clean Development Mechanism
CI	Confidence Interval
CND	Debt Clearance Certificates
COP	Conference of the Parties
CO_2e	Carbon dioxide equivalent
DBH	Diameter at Breast Height
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gases
GPS	Global Positioning System
IBGE	Brazilian Institute of Geography and Statistics
IFC	Continuous Forest Inventory
INCRA	National Institute of Colonization and Agrarian Reform
IPCC	Intergovernmental Panel on Climate Change

MMA	Ministry of the Environment
MRV	Measurement, Reporting and Verification
SLB	Sustainability-Linked Bond
SNIF	National Forest Information System
OMM	World Meteorological Organization
UN	United Nations
PDD	Project Design Document
PF	Individual
PJ	Legal Entity
REDD	Reduction of Emissions from Deforestation and Forest Degradation
REDD+	Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks
RPPN	Private Natural Heritage Reserve
TCPLI	Free and Informed Prior Consent Term
UC	Conservation Unit
UNFCCC	United Nations Framework Convention on Climate Change

DEFINITIONS

Additionality (IPCC)	According to the IPCC, Additionality of carbon projects is defined under the scope of the Clean Development Mechanism (CDM) as: "Additionality is defined as: the reduction or removal of emissions would not occur in the absence of the project. This definition of additionality can be encompassed to include approaches related to 'financial additionality', 'investment additionality' and 'technology additionality'." These additional definitions apply mainly to the market concept established in the CDM.
Amazon biome	The Amazon biome is characterized by tropical rain forests and rich biodiversity, encompassing a mosaic of phytophysiognomies, ecosystems, fauna and disparate microorganisms, including the Amazon basin, which exerts great water influence, making the biome one of the most diverse and of great economic interest on the planet.
Avoided Planned Deforestation (APD)	Waiver of right to carry out forest suppression of the natural vegetation within the geographic limits of the Multiple Use Area (AUM), committing to a zero deforestation policy in the Project Area (AP).
Baseline	It is defined as a 'non-intervention' scenario, in which in the absence of project implementation, what would be the most likely fate of the forest.
Brazilian Amazon	It comprises the entire states of Acre, Amapá, Amazonas, Pará, Roraima, Rondônia and parts of the States of Maranhão, Mato Grosso and Tocantins.
Litter	It is the layer formed by the deposition of plant remains (leaves, branches) and accumulation of living organic material in different stages of decomposition that superficially covers the soil or aquatic sediment.

Carbon Credit (tCO_2e)	Financial, environmental, transferable asset representing the reduction, removal and avoidance of greenhouse gas emissions, represented by one metric ton of carbon dioxide equivalent (tCO_2e), which has been recognized and generated as credit in the voluntary or regulated market.
Carbon Stock (tCO_2e)	Financial, environmental, transferable asset representing the maintenance or storage of one ton of carbon dioxide equivalent (tCO_2e), thus including all means of carbon deposition, except greenhouse gases, present in the atmosphere.
Carbon stock or carbon reservoir in the forest	It is the estimated amount of carbon present in the trees that make up the forest in question. It can be presented using an estimated average, followed by its uncertainty levels or in absolute terms, when referring to the total area. The carbon in living and dead trees, shrubs, palm trees and other plant organisms, in addition to carbon in the soil, may be included in the quantification of the stock. Net carbon stock is the amount of carbon stored in the forest corresponding to the stock of living organisms subtracted from the dead biomass (dead trees and litter). The stock is given in area units, abbreviated as grams or tons: (i) millions in mega (Mg or Mt); billions in giga (Gg or Gt); (iii) trillions in tera (Tg or Tt); and (iv) quadrillions in peta (Pg or Pt).
CI (x %)	Confidence interval, at a probability of x%. Standard probability levels: 90%, 95% and 99%.
Climate (IPCC, 2021)	Defined with the average of descriptive weather statistics over a minimum period of 30 years, according to the World Meteorological Organization (WMO).
Crediting Period	It is the period of time in which environmental assets are generated, arising from the activities foreseen by this methodology.

Environmental or ecosystem services	According to Embrapa: These are the benefits that people obtain from ecosystems, that is, they are services that the environment naturally performs and that result in benefits for human beings. Second IPAM: These are processes generated by nature itself through ecosystems, with the purpose of sustaining life on Earth. Environmental services are responsible for maintaining biodiversity, which allows the generation of products such as wood, fiber, fish, medicines, seeds, natural fuels, etc., which are consumed by humans. According to the Ministry of the Environment (MMA): Environmental services are individual or collective human activities that favor the maintenance, recovery or improvement of ecosystem services. For example, the restoration of a permanent preservation area with the planting of seedlings will improve the native vegetation ecosystem on the riverbank and thus favor the service of regulating water flow and controlling erosion. According to Law n° 14,119/2021: **Ecosystem services** are relevant benefits for society generated by ecosystems, in terms of maintenance, recovery or improvement of environmental conditions **Environmental services** are individual or collective activities that favor the maintenance, recovery or improvement of ecosystem services.
Financial additionality	Project funding is in addition to the budget available for the standard activity.
Floodplain Forest (Junk, 1993; Ribeiroet *al.* 1999)	Type of Amazonian forest that is seasonally flooded by water from rivers and/or streams of white or muddy water, such as the Amazon and Solimões rivers, respectively.

Forest	The definition of forests may vary depending on the source. According to FAO and SNIF: *A forest is any vegetation group that extends over more than 0.5 hectare (0.005 km²) and is formed by trees taller than five meters, in addition to a canopy coverage greater than 10%. Areas with different land uses, such as agricultural or urbanized areas, are not included in this definition.* According to the IBGE: *Forests are characterized by the density of tall trees, with a reduction in the amount of light that reaches the ground, which limits the development of herbaceous and shrubby vegetation.* According to Higuchi et al. (2012): Ecosystem formed by living organisms, such as humans, tree plants, animals and microorganisms, which provide a permanent network of co-benefits and services; that supports, strengthens and protects development and quality of life; that interacts with each other and with the environment (abiotic factors such as: climate, soil, light, etc.) in which it is found.
Forest biomass (IPCC, 2006)	Forest biomass is subdivided into three compartments: Total Biomass (Btot), Above Ground (AGB) and Below Ground (BGB). Biomass is defined by the weight of the tree, in kilos (Kg) or tons (t), the first being used for individual weight and the second when referring to stocks. It can be given as “fresh” or “dry weight” biomass, where the first considers the presence of water in the matter and the second considers the mass dried in an oven until constant weight.
Forest enrichment	According to Embrapa: It consists of the introduction of species, mainly from the final stages of ecological succession, in areas with better soil conditions, already with the presence of native vegetation, but with low species diversity. It is a technique that should be proposed to fill spaces with gaps in natural regeneration.

Forest planting	Area of cultivation of tree species, whether for the production of wood or non-timber products. It can be made up of native or exotic species. Monocultures or mixed and/or hybrid systems.
Forestry (Embrapa, 2023)	It is the cultivation of forests, natural and artificial, with the objective of restoring and/or improving forest population, to meet specific market requirements.
Governance	It is the action or way of governing (definition of 'governance', from the Oxford Dictionary). Governance comprises all processes of "governing" over a social system or through rules, norms and actions that are structured, sustained, regulated and held accountable. For the purposes of REDD Projects, the Governance of a rural property is established by the person responsible for the property and/or who will implement the actions and activities necessary to ensure the maintenance of the forest standing and investments in sustainable development projects and who will be responsible for negative impacts resulting from negligence and/or omission.
Allometry	Study of variations in the forms and processes of organisms. From the "whole" (carbon) in function of "parts of the whole" (DBH, for example), that is, adjustment of mathematical equations (functions or models).
Igapó Forest (Junk, 1993; Ribeiroet *al.* 1999)	Type of Amazonian forest that is seasonally flooded by water from rivers and/or streams of black or light water, such as the Negro and Tapajós rivers, respectively.
Investment additionality	The value of the Reduced Emission Unit / Certified Reduced Emission must significantly improve the financial aspect and/or commercial viability of the project activity.

Leak (*Leakage*)	According to IUFRO and UN-REDD Program: The unexpected loss of anticipated carbon benefits due to the relocation of activities in the project area to non-project areas, resulting in carbon emissions. According to Atmadja & Verchot (2012); Streck (2021): It is the decrease or increase in GHG reductions and removals outside a project or program boundaries that is directly or indirectly attributable to the intervention implemented within those boundaries, i.e., the project/program itself. According to UNFCCC: It meets the same definition of “displacement” in the CDM. Leakage occurs when containing deforestation and forest degradation in REDD+ implementation areas leads to increased deforestation or forest degradation in other areas.
REDD	Type of mechanism for generating carbon credits, through the avoided emission of Greenhouse Gases (GHG), from forest deforestation. Introduced in the discussions of the United Nations Framework Convention on Climate Change (UNFCCC) at COP 11, in Montreal (2005). It assumes four basic conditions/assumptions: I. Baseline - Scenario of absence of a ‘project’ that would inevitably result in GHG emissions; II. Co-benefits - In addition to the avoided emissions, what additional positive impact does the ‘project’ bring; III. MRV Quantifications - Report carbon estimates clearly and with known levels of uncertainty; IV. Monitoring the ‘project’; commitment to zero deforestation.
REDD+	In addition to the points described in REDD, the '+' represents additional forest-related activities that protect the climate, namely sustainable forest management and the conservation and improvement of forest carbon stocks.
Regular Property	The property must be duly documented and with zoning carried out in the Rural Environmental Registry (CAR) and no overlaps with other areas, public or private.

Technology additionality	The technology applied in the project activity must be the best available for the circumstances of the project location/region.
TERO Platform	Technological platform developed by Tero Carbon to support the registration, certification and verification processes of projects that generate environmental assets.
Uncertainty (IPCC, 2006)	Uncertainty is characterized by the lack of knowledge of the true value of a variable of a descriptive measure (central tendency -most used-, dispersion or relationship). It is the Confidence Interval (CI) itself under a certain confidence level. More precisely, it is the part of the CI that is subtracted or added to the mean. Uncertainty depends on the amount of data used, as well as the sampling methods.
Land Use and Land Use Change in and Forests (LULUCF)	Anthropogenic activity in forest areas. Implement an economic activity on land that involves the rational use of natural resources or the transformation of the landscape into areas for alternative uses, such as agricultural crops or removal of natural vegetation for other purposes.

I - SOCIAL AND ENVIRONMENTAL SAFEGUARDS ADOPTED

The conceptual basis of “Safeguards” comes from debates involving Projects such as Reducing Emissions from Deforestation and Forest Degradation, including the conservation and increase of carbon stocks (REDD+) and has as a reference the United Nations Framework Convention on Change Climate (UNFCCC) and the Ministry of the Environment (MMA).

“Safeguards” should be understood as guidelines which aim to enhance positive impacts and avoid or reduce negative impacts related to the project. Therefore, project actions must anticipate risks and establish measures to predict, minimize, mitigate or deal with adverse impacts associated with a given activity.

Thus, at the 16th Conference of the Parties (COP), in Cancun, a set of seven safeguards socio-environmental issues addressed to National Programs. In support of these programs, whenever the carbon project takes place in public areas, where there are traditional communities, it is necessary to prove, within the processes certification and verification, the following safeguards:

I. Right of protection of the territory;
II. Free, Prior and Informed Consultation;
III. Benefit sharing;
IV. Assessment of social and environmental impacts;
V. Incidence of an administrative law regime with mandatory state monitoring, depending on the current land regime, always safeguarding traditional ways of life.

In practice, carbon projects of public interest, and specifically when incident on public forests, must be observed:

1. In contracts, due to their administrative nature, there must be due state intervention to define the rights levied on carbon credits;
2. In contracts, care must be taken to recognize public ownership and avoid contracts in which there are acts of misappropriation of public assets (land encroachment and/or misappropriation);
3. In contracts, there must be a flexibility clause, in order to allow revision at any time due to justified demand from traditional peoples and communities;
4. Adoption of necessary measures for the cancellation of Rural Environmental Registries (CAR) applicable to affected public assets that are being used for certification or negotiations involving carbon, in order to avoid carrying out legal transactions to the detriment of the protection of public assets and rights of traditional peoples and communities;
5. Compliance with the Environmental Services Law, among which the following stand out: the obligation to register the contract in the Public Registry of the Property on which it applies and free, prior and informed

consent;

6. Obtaining free, prior and informed consent by the State and under any conditions, which cannot be suppressed by approval in a General Assembly or isolated deliberation by the Board of Directors of an Association;
7. Non-exclusion of the legitimate right of traditional peoples and communities to benefit-sharing in recognition of the role they play as guardians of biodiversity;
8. Sharing of benefits must be done based on the respect and autonomy of traditional peoples and communities;
9. In the case of projects in Indigenous Lands (TIs), the consent of the Attorney General's Office of the National Indian Foundation (FUNAI) must be taken into account, as well as FUNAI's participation in project contracts and discussions.

II - ZONING OF THE PROPERTY

The zoning of the property must be divided into: Legal Reserve Area (ARL), Permanent Preservation Area (APP) and Multiple Use Area (AUM). Consolidated areas (deforestation until 2008, duly accredited by the current state environmental agency) will be considered AUM.

II.1 Permanent Preservation Area (APP)

According to the Law No. 12,651 of 2012 (New Brazilian Forest Code), the Permanent Preservation Area (APP) is a protected area, covered or not by native vegetation, with the environmental function of preserving water resources, the landscape, stability geological and biodiversity, facilitate the gene flow of fauna and flora, protect the soil and ensure the well-being of human populations.

APP is considered to be the banks of water bodies, hilltops, steep slopes, among others. The precise and specific definition of APP is established in Chapter II, Section I, Art. 4 of Law No. 12,651/2012.

II.2. Legal Reserve Area (ARL)

According to the Law No. 12,651 of 2012 (New Brazilian Forest Code), the Legal Reserve Area (ARL) is the area located within a property or rural possession, delimited under the terms of art. 12, with the function of ensuring the sustainable economic use of the natural resources of the rural property, assisting the conservation and rehabilitation of ecological processes and promoting the conservation of biodiversity, as well as the shelter and protection of wild fauna and native flora .

According to Chapter IV, Section I, art. 12 of Law No. 12,651/2012, Every rural property must maintain an area covered with native vegetation, as a Legal Reserve, without prejudice to the application of the rules on Permanent Preservation Areas, observing the following minimum percentages in relation to the area of the property . The precise and specific definition of ARL and its proportions per biome/region are established in Law No. 12,561/2012.

II.3. Multiple Use Area (AUM) and/or Consolidated Areas

Based on Law No. 12,651 of 2012 (New Brazilian Forest Code), “alternative land use” is the replacement of native vegetation and successor formations (suppression) with other land covers, such as agricultural, industrial, generation and transmission activities energy, mining and transport, urban settlements or other forms of human occupation.

The replacement of native vegetation is prohibited in the APP and ARL areas. In the Amazon region, the area subject to suppression is limited to 20% of the rural property.

Any suppression that exceeds the limits defined by law is subject to sanctions imposed and provided for by law. However, in the past, due to the lack of control over the territory and constant changes in legislation, many rural properties exceeded the limits permitted for alternative use.

To mitigate this issue, the term “Consolidated area” was created. Based on Law no. 12,651 of 2012 (New Brazilian Forest Code), the Consolidated Area is the area of rural property with pre-existing human occupation on July 22, 2008, with buildings, improvements or agroforestry activities, admitted, in the latter case, the adoption of the fallow regime .

II.4. Non-Forest Area

Any and all territorial extensions that are not characterized as forests must be duly identified. The main “non-forest” classifications are:

- Water;
- Exposed soils;
- Rock formations;
- Infrastructure (highways, rural roads, civil constructions and the like);
- Other plant formations that are not classified as forests, such as:
    - Agricultural crops;
    - Natural fields; and
    - Distinct vegetation formations, shrubs and/or herbaceous (for example: mangrove, caatinga and savannah).

III - PROPERTY CLASSES

This methodology divides the size of rural properties into "classes". The three "classes" of properties are based on "Amazonian superlatives"[1] and INCRA's rural property size classification[2]:

- Small Property: property with up to three thousand hectares (3,000 ha) will be considered;
- Average Property: the property size ranging from three thousand hectares (3,000 ha) up to twenty thousand hectares (20,000 ha) will be considered; and
- Large Property: above twenty thousand hectares (20,000 ha).

[1] The Legal Amazon has a territory of approximately 5.4 million km². This represents just over 50% of the Brazilian territory. According to INCRA, "small properties" can total up to 400 ha. These superlatives need to be considered to adapt to the local reality.
[2] https://www.gov.br/incra/pt-br/assuntos/governanca-fundiaria/modulo-fiscal

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1. OBJECTIVE

The objective of this methodology is to generate environmental assets in projects that promote maintenance, conservation and preservation of carbon stocks in forests (natural or planted) at Amazon biome.

2. GENERATED ASSETS

This methodology provides for the generation of up to 2 (two) distinct assets, they are:

2.1. Verified Carbon Stock

The Verified Carbon Stock (in tons of carbon dioxide equivalent - tCO2e) is similar to a Green Bond. It is inferred referring to the amount of tons of carbon dioxide equivalent in the forest biomass at the moment of measurement.

2.2. Verified Carbon Credit

The Verified Carbon Credit (in tons of carbon dioxide equivalent - tCO_2e): referring to the increase in carbon stock, given in tons of carbon dioxide equivalent, in the forest measured from one period to the next.

3. PREDICTED ACTIVITIES

The activities planned for this methodology are:

3.1. Maintenance of Carbon Stocks in the Forest

The proponent must plan and implement activities that enable and ensure the maintenance of carbon stocks in forests, throughout the duration of the project and the commitment to "zero deforestation and forest degradation".

Any and all activities or actions that result in GHG emissions, whether through deforestation and/or forest degradation, will be accounted for and charged to the stock. The limit for terminating the project and its respective registration and certification on the Tero platform is 10% (ten percent) of deforestation and/or forest degradation in the project area.

Eligible and applicable activities and actions to guarantee and ensure the maintenance of carbon stocks in forests through the preservation and conservation of natural forests may include, but not limited to:

- Implementation of Governance in the property, such as:
  - Identification and physical demarcation of the project area with signposts and fences on the boundaries of the property/project area;
  - Implementation of economic activity focused on non-timber products and/or ecosystem services:
    - Extraction of fruits, seeds, exudates (resins, latex and the like);
    - Ecotourism, etc.
- Project to implement a Private Natural Heritage Reserve (RPPN).

3.2. Forestry

The proponent may consider forestry plantations to increase the carbon sequestration rate in the Project Area (PA). Forest plantations do not necessarily need to be commercial or represent an economic activity.

However, forest plantations must comply with the safeguards described in this methodology and, for example, not be the result of court orders to recover degraded areas. These will not be considered for the quantification of Carbon Credits.

Eligible and applicable activities and actions to guarantee and ensure the maintenance of carbon stocks in forests through forestry may include, but not limited to:

- Forestation of areas that have never been or are not forests for a minimum period of 10 (ten) years, counting from the date of registration of the project;
- Reforestation of degraded and/or deforested areas; and
- Forest enrichment of natural forest areas, through the planting of seedlings of specific species in the forest.

NOTE #1: Projects that include "forest enrichment" are eligible and can be considered as "forest plantings".

NOTE #2: Forest plantations of native and/or exotic species will be permitted, the latter only if it is a plantation intended for non-timber use (fruit production or resin production, for example).

3.3. Agriculture Crops Systems

The proponent can implement agro-pastoral cultivation systems on the property or already have them previously. Crops should not be part of the project. Carbon projects in agricultural crops will be addressed in a specific methodology.

Land use activities must be duly licensed and located within the limits of the consolidated areas (law 12,651 of 2012), as long as it is proven that no deforestation, exceeding the limit permitted by law, has occurred on the property after 2008.

The property or even the cultivation system cannot be subject to legal dispute. In addition to respecting all the safeguards already mentioned in this methodology.

4. MINIMUM CRITERIA

Carbon projects in *Agriculture Forests and Land Use* (AFOLU) certificates, must necessarily meet minimum criteria:

1. Full compliance with the New Forest Code (Law No. 12,651, of May 25, 2012);
2. Rural property duly registered in the Rural Environmental Registry (CAR) with zoning and absence of overlap with other areas (public or private);
3. Full ownership of the rural property;
4. Lack of mention on the Ministry of Labor's Slave Labor Dirty List of project proponents and rural property owners;
5. Absence of embargoes on rural property to be financed by environmental agencies;
6. Comply with sectoral and regional agreements established for the crop (Soy Moratorium and the Green Protocol for Grains of Pará);
7. In the Cerrado biome, no conversion of natural areas occurred after June 2017.

5. ELIGIBILITY

Projects that meet all of the following criteria are eligible for this methodology.

GEOGRAPHIC BOUNDARIES	The boundaries of the Project Areas (APs) must be totally inserted into the Amazon biome.
UNIQUE RURAL PROPERTY	It is permitted to use unique rural property, or multiple grouped in a mosaic.
TYPE OF RURAL PROPERTY	• Private rural property; • Governmental and/or private Conservation Units (CU) for Sustainable Use that have the prerogative of generating environmental assets.
TYPE OF FOREST	• Natural forests, on dry land and/or in seasonally flooded areas (e.g.: floodplains and igapó); • Planted forests (forest plantation), of native and/or exotic species.
MINIMUM PROPERTY SIZE	At least 5 ha (five hectares or 50,000 m^2).
MINIMUM SIZE OF THE PROJECT AREA	At least 1 ha (one hectare or 10,000 m^2) of forest.
NO DOUBLE COUNTING GUARANTEE	The project area cannot have a Carbon Stock or Credits project or any other asset linked to the Carbon environmental asset, registered and/or certified by another "standard/ methodology" during the same crediting period.
PROJECT ACTIVITY	It is necessary to carry out at least one of the activities provided for in this methodology.

6. ADDITIONALITY

For the purposes of this methodology, it is understood that the main uses of Amazonian lands are: agriculture, selective logging, energy production (hydroelectric plants, oil and natural gas) and extractivism.

According to Fearnside (2006), the Amazon forest has been deforested in the north of the State of Mato Grosso and parts of the south and east of the State of Pará, mainly for the implementation of large, low-productive livestock farms.

The most common land use model in the region is very well described by Soares-Filho et al. (2006). The process begins with accessibility, through the opening of roads. The vast majority of these routes are to enable selective logging, characterized by a rustic, inadequate, antiquated system limited to a few species (ASNER et al. 2005). Then, after depleting the usable timber stock, the remaining vegetation is replaced by pasture for cattle raising or, more recently, agricultural crops (SOARES-FILHOet al. 2006).

Intense logging is also responsible for large deforested areas. Asner et al. (2005) stated that selective logging can add up to 123% to deforestation in the Amazon, based on studies carried out on timber harvests from 1999 to 2002. This means that selective logging is pre-investment in agricultural projects even replacing extinct tax incentives. Higuchi (2006) concluded that selective exploitation has a close correlation with deforestation ($r = 0.99$, $p < 0.00001$).

According to data from PRODES/INPE (2023), accumulated deforestation in the Legal Amazon totals almost 845 thousand km² (Figure 1).

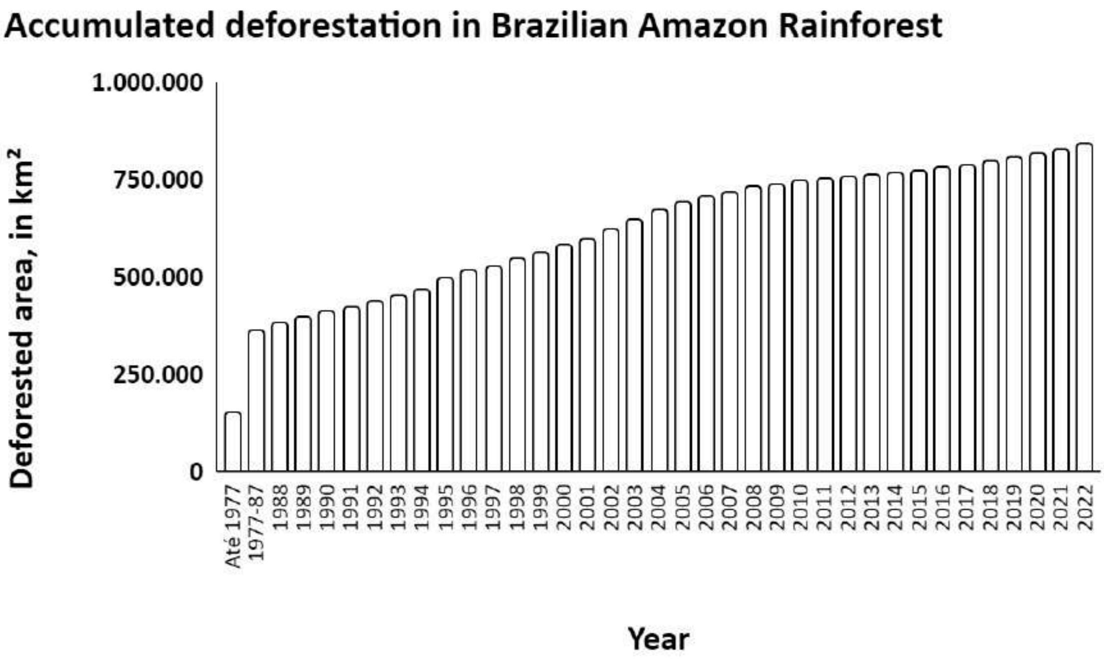

Figure 1. Area, in km², of accumulated deforestation in the Legal Amazon. (Source: PRODES/INPE, 2023).

The current annual average of deforested area in the Legal Amazon, according to official data, is 11,557 km² (± 2,143 km²). With minimum peaks of 4,571 km² (2012) and maximum peaks of 29,059 km² (1995), as shown in Figure 2.

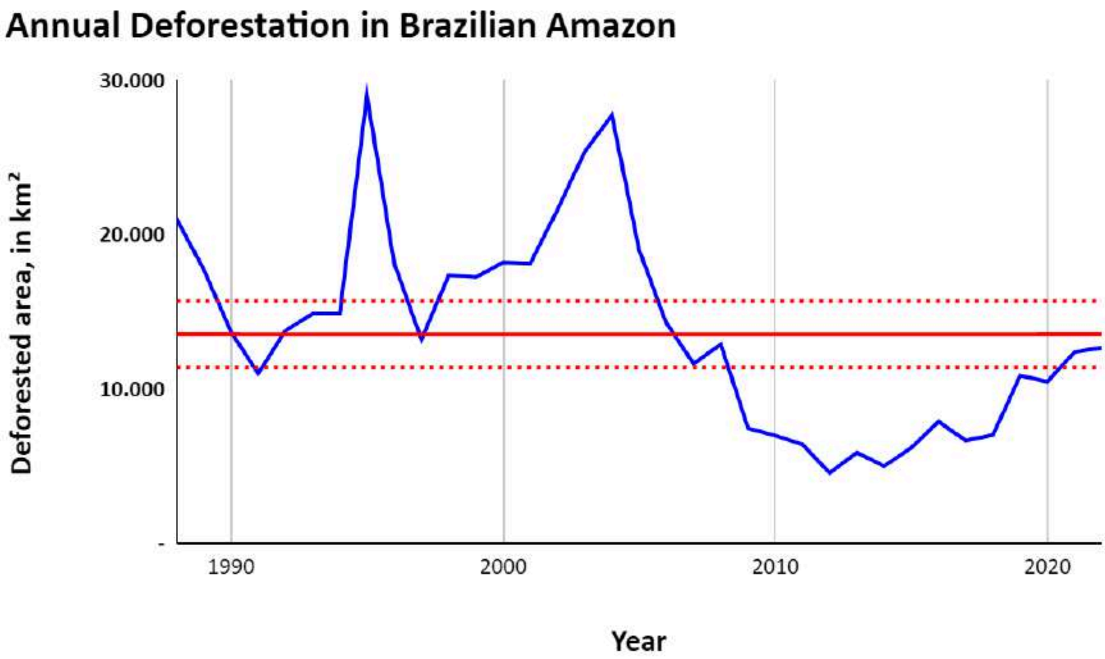

Figure 2. Dynamics of annual deforestation in the Legal Amazon, in km². Where: blue line is annual deforestation; red line is the historical annual arithmetic mean; dotted red lines are the maximum and minimum limits of the mean estimate. Source: PRODES, 2023.

The big problem is the way in which deforestation in the Amazon occurs. Higuchi (2006) correlated deforestation and increase in GDP as well as other socio economics indicators and found weak evidence ($r = 0.36$, $p = 0.17$) to state that there is a correlation between these variables.

The lack of correlation between development and forest loss can be explained by the relationship between authorized and unauthorized (illegal) deforestation. As shown in Figure 3, in the period from 1997 to 2004, based on official data (Ibama), the average deforestation authorized in the period was 18%, varying between 7% and a maximum of 43% (HIGUCHI, 2006). Additionally, Saraiva (2021) analyzed environmental licensing processes (authorizations for deforestation and/or selective logging) and found that the vast majority of processes contain at least one type of fraud and/or inconsistency.

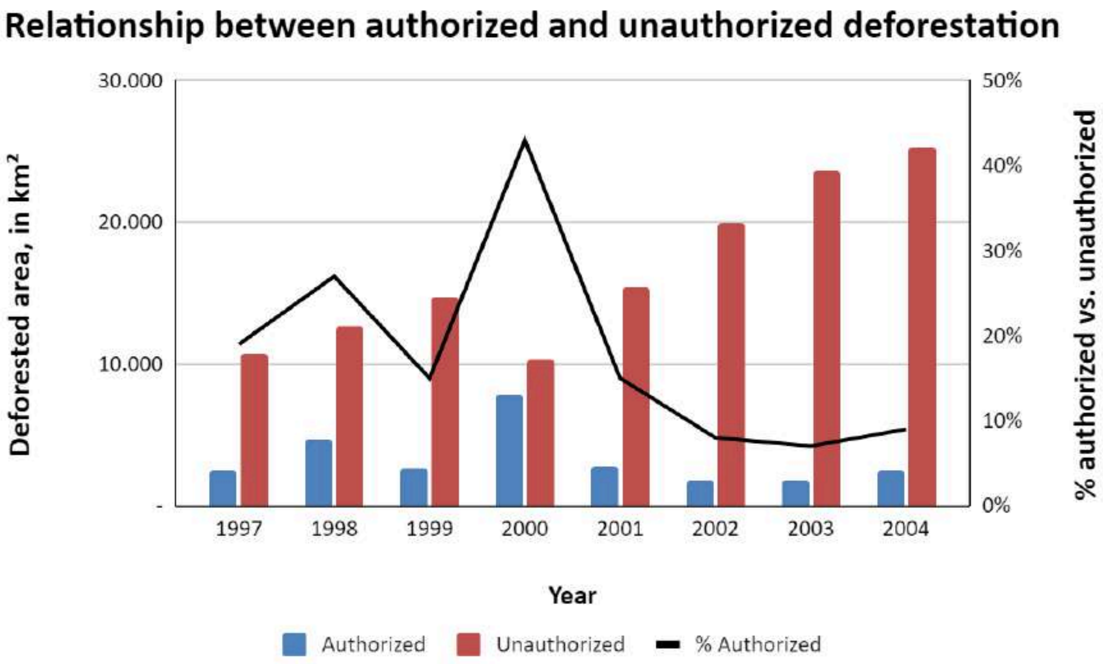

Figure 3. Relationship (%) between authorized and unauthorized deforestation in the Brazilian Amazon. (Source: Higuchi, 2006; Ibama, 2006; INPE, 2014).

Thus, in the absence of a Carbon Stock in Amazonian Tropical Forests type project, the existing forest within the limits of the Project Area (AP) would be deforested or degraded, either for the implementation of alternative land use, focusing on agriculture crops or cattle ranching activities ; or illegally.

Therefore, the carbon stored in the forest would be emitted in the form of carbon dioxide equivalent (CO_2e), through burning, decomposition and/or export of tree biomass.

7. PERMANENCE

This methodology understands that the risk of permanence is inherent and a consequence of Public and Market Policies.

The risk of permanence during project implementation is reduced due to market action and, consequently, monitoring of the area (Annex II).

Tero Carbon only issues "verified carbon credit" certificates after verifying compliance with the project objective, that is, zero deforestation.

That way, every carbon credit issued by this methodology has the guarantee that the carbon remains in the forest biomass during the commitment period.

8. SAFEGUARDS

All projects certified and verified using this methodology must comply with the internationally recognized Safeguards described in this document.

9. TEMPORAL LIMITS

9.1. Project Duration Period

The duration of the project is unlimited:

9.2. Project Start Date

The project start date is given by the date of the First verified Carbon Stock estimate for the Project Area.

USE: A verified carbon estimate is understood to be one that meets the technical premises of this methodology, as well as the possibility of analyzing the history of soil use and change through remote sensing.

9.3. Project End Date

The project end date can be given at any time through formal communication to Tero Carbon.

9.4. Retroactivity

This methodology considers retroactive periods from the project Certification date.

9.5. Carbon Stock Issuance Date

The issue date of the Verified Carbon Stock corresponds to the verification date ($Data_{Tn}$) of the forest biomass stock and can only occur in active projects.

9.6. Crediting Period for Generating Carbon Credits

The Nth (n) Crediting Period, that is, the acquisition period of the Verified Carbon Credit environmental asset corresponds to the period between the last carbon stock verification date ($Data_{Tn-1}$) and the date of the current carbon stock check ($Data_{Tn}$):

$$Period\ of\ the\ Nth\ Crediting\ = Data_{Tn-1}\ to\ Data_{Tn}$$

where:

$Data_{T0}$ = Date of first carbon stock check;
$Data_{Tn-1}$ = Date of last carbon stock check;
$Data_{Tn}$ = Date of current carbon stock verification;
n = 1, 2, 3... T (accreditation number, which varies from 1 to T, depending on the project duration); and
Nth = First, Second, Third... Tenth.

NOTE: The results, in terms of sequestered GHG emissions (tCO_2e), observed during the crediting period will determine the amount of verified carbon credits that the project will generate.

10. PROJECT PARTICIPANTS

Project participants must be reported on the Tero Platform and will be publicly mentioned in the Project Design Document (PDD), including:

PROPONENT	It is the entity responsible for the environmental assets generated on the rural property: ● It can be an Individual (PF) or Legal Entity (PJ); ● Must be the legal representative (owner) of the rural property; ● If the rural property has more than one owner or the project is a "mosaic of multiple owners": ○ Present the Free and Informed Prior Consent (TCPLI) from all those responsible for the property(ies); ○ The legal representative must be duly documented and notarized. ● Must be residing/installed in Brazil.
DEVELOPER	It is the entity responsible for developing the project, registering the project on the Tero Platform, coordinating the Technical Team(s), etc., being that: ● It can be an Individual (PF) or Legal Entity (PJ); and ● There must be only 1 (one) Developer for each Project.
IMPLEMENTATOR	It is the entity responsible for project governance during the execution period. It is up to the implementer to execute and/or coordinate the activities provided for in the methodologies.
TECHNICAL TEAM	It is the entity responsible for collecting primary data (Sample Forest Inventory for Carbon Stock Estimation) in the project area and/or socio-environmental activities, responsible for preparing the Prior Informed Consent or any other technical activities related to the project, and : ● It can be an Individual (PF) or Legal Entity (PJ); ● There may be more than one entity in each project; and ● There may be a Technical Team in each primary data collection (Sample Forest Inventory).

11. RURAL PROPERTY

This methodology is applicable to a carbon project in one (1) or more (mosaic) rural properties.

11.1. Rural property type

The rural property accepted by this methodology can be of the type:

1. Private rural property; or
2. Governmental and/or private Sustainable Use Conservation Unit (UC) that has the prerogative of alternative land use.

11.2. Spatial boundaries

The rural property must be fully included in the Geographic Scope: Amazon biome.

11.3. Territorial extension limits

The rural property must have a minimum size of 5 ha (five hectares or 50,000 m²) and a project area with a minimum size of 1 ha (one hectare or 10,000 m²) of forest.

11.4. Land Diligence

The rural property must be in good standing, both at the time of Certification and during subsequent checks. To reduce the risk of fraud, for the Certification Process, in addition to the documentation that proves the ownership and regularization of the property, in accordance with current Laws, you will be asked to present a legal document with the opinion of the Land Due Diligence carried out on the property.

11.5. Owners' Consent or Free and Informed Prior Consent

In the case of a private rural property, it is necessary to present a Term of Consent from the owners of the rural property, declaring the intention to use the property, of their own free will, to carry out the carbon project.

In the case of a Conservation Unit (UC), it will be necessary to prove that workshops have been held with local communities (if any), in addition to the presentation of a document that attests to free and informed prior consent to carry out the carbon project in the project area.

11.6. Zoning of Rural Property

Private rural property must have its zoning defined and duly registered in the Rural Environmental Registry (CAR). For Conservation Units (CU), the property limits have already been defined and registered with the competent bodies. The property must have its spatial limits defined as follows:

- Property Boundaries (LI);
- Permanent Preservation Area (APP);
- Legal Reserve Area (ARL);
- Multiple Use Area (AUM) or Consolidated Area;
- Project Area (AP):
  - It must be located within the property limits;
  - It can be a fraction or the entire property;
  - It must have a forest;
  - The minimum area of the AP must be 1 ha (one hectare).

The map in Figure 4 shows an example of zoning of a rural property in the Amazon Biome.

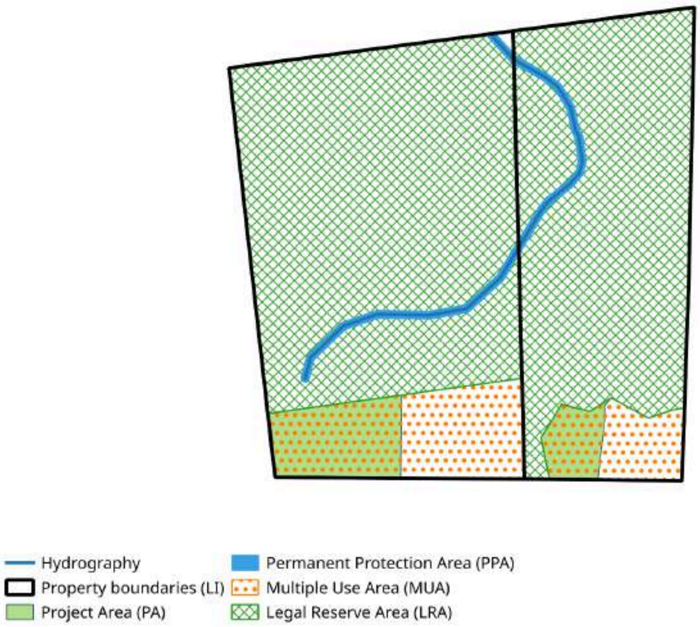

Figure 4. Example of zoning of a rural property.

11.7. Project Area (AP)

The boundaries of the Project Area (PA) will be defined by the Project Developer and registered on the Tero Platform and may encompass all forest areas, including:APP; ARL e AUM.

NOTE: If the proponent chooses to use part or all of the AUM in the AP, pay attention to the "Zero Deforestation Commitment" assumed.

11.8. Zero Deforestation Commitment

During the project period, the proponent must sign a "Zero Deforestation" commitment. Thus, any and all deforestation within the project area (PA) will "debit" the credits to be generated in future accreditations.

NOTE #01: If deforestation is identified within the property that is equal to or greater than 50% of the Project Area (AP), the project will be canceled.

NOTE #02: In properties/properties that have consolidated areas, that is, in which the suppression of natural vegetation has exceeded the limits set out in legislation until July 22, 2008, if they present any additional deforestation on the date described above, the project will be canceled.

11.9. Forest Inventory to Estimate Carbon Stock in the Project Area

For the Certification process, it will be necessary to present the Forest Inventory (IFA) spreadsheets to estimate the Carbon Stock in the Project Area (AP) in the standard established by Tero. The IFA has a validity of 5 (five) years, requiring renewal after this period. This implies the need to present new data collected in any Verification Processes.

USE: Secondary data will only be accepted as a complement and will not be used to calculate the carbon stock.

12. BASELINE

This methodology assumes the "business as usual" (BAU) scenario as described in item "6. ADDITIONALITY".

It is assumed that, in the absence of a project that has as its object "the carbon stock of the forest", whose objective is the "maintenance of the forest and its stocks", within a scope linked to "sustainable development", the forest of the property would be degraded and/or deforested over time, resulting in Greenhouse Gas (GHG) emissions into the atmosphere in the forms of carbon monoxide (CO), carbon dioxide (CO_2) e methane (CH_4), the latter through the decomposition of organic matter.

13. QUANTIFICATION

This section presents how to quantify forest carbon stocks and credits accepted by this methodology in order to meet international Measurement, Reporting and Verification (MRV) standards.

13.1. Guidelines for Primary Data Collection and Carbon Stock Estimation in Forests

The estimated average stock ($\bar{x}$), with its respective level of uncertainty (C.I.), must be calculated based on a forest sampling system, application of allometric equations and extrapolation of the average for the Project Area (AP). Therefore, the following points need to be observed when collecting primary data:

- Consider a sampling system of installing sampling units with a fixed area (plots);
- All plots must have their geographic coordinates recorded using GPS signal receiver device (GPS):
  - The points to be recorded can be the initial, central and/or final point of each sample plot;
  - However, to submit this data, it is recommended to generate polygons of spatial boundaries of each sampled plot;
  - When using a GPS navigation device, the recommended coordinate recording method is:
    - Keep the GPS parked at the specific point for a period of approximately 1 (one) minute;
    - Use the "point average" tool for a period of at least 2 (two) and up to 5 (five) minutes.
- Random-systematic sample distribution or a combination through conglomerates (transects or cross type);
- Measurement of diameters at 1.3m above the ground (DBH) of all living and dead trees found within the plot:
  - The minimum DBH is 10 cm;
  - Palm trees are not a mandatory class:
    - They can be included, but the allometric equation must be specific.
- Application of the biomass/carbon equation to estimate the individual stock (of each tree measured) and per unit area (hectare):
  - The individual biomass/carbon of trees must be estimated, preferably, using site-specific equations;
  - If individual tree biomass/carbon is estimated based on the Silva (2007) equation, the estimate must be corrected by the correction factor based on the dominant height (Hdom) of the forest.
- Estimate on average $(\overline{x})$ and the level of uncertainty of the estimate (C.I.), based on the statistical parameters described in Annex I;
- If the forest in the Project Area requires stratification, follow the stratification procedure available in Annex I.

13.2. Quantitative Sample Forest Inventory

The guidelines for the quantitative Forest Inventory (IFA) for collecting primary data used in quantifying carbon stocks are:

- Minimum data to be considered: live trees, with DBH > 10 cm;
- Secondary data will only be accepted as a complement;
- Implementation of a sampling system, using fixed area sampling units (see Annex I);

- Measurement of dendrometric variables, such as: diameter at 1.3 m from the ground (DBH):
- Heights (total and/or shaft) are optional.
- Estimation of biomass and carbon stocks:
    - AGB = mandatory;
    - BGB = optional;
    - Btot = optional.

13.3. Calculation of Forest Carbon Stocks Without Statistically Defined Strata

It is necessary, for each rural property in the project, to calculate the Forest Carbon Stock. For the case which statistically defined strata, the guidelines are as follows:

- Establish the project's forest biomass components:
    - Above ground (AGB);
    - Below ground or roots (BGB);
    - Total (AGB + BGB).
- Estimate the "net" stock, that is, subtract the 'necromass' (dead trees sampled in the inventory):

$$Net\ Stock_{AGB} = \sum AGB_{lives} - \sum AGB_{necromass}$$

- Based on statistical tools, calculate the average stock per unit area (hectare) with its respective level of uncertainty (confidence interval - C.I.);
- Multiply the minimum estimate (mean - confidence interval) of the stock and the Project Area (PA):

$$Carbon\ Credit = \left(\overline{x_{CO2}} - C.I.\right) \times\ AP$$

where:

$\overline{x_{CO2}}$ = Estimated average carbon dioxide equivalent stock, per hectare, in tons;
C.I. = Confidence interval, calculated at a probability level of 95%;
AP = Project Area, in hectares.

13.4. Calculation of Forest Carbon Stocks With Statistically Defined Strata

In a similar way to the previous item, in the case with Statistically defined strata, the guidelines are as follows:

- Establish the project's forest biomass components:
    - Above ground (AGB);
    - Below ground or roots (BGB);
    - Total (AGB + BGB).

- Estimate the "net" stock per stratum, that is, subtract the 'necromass' (dead trees sampled in the inventory):

$$Net\ Stock_{AGB} = \sum AGB_{lives} - \sum AGB_{necromass}$$

- Based on statistical tools, calculate the average stock, per stratum, per unit area (hectare) with its respective level of uncertainty (confidence interval - C.I.);
- Multiply the minimum estimate (mean - confidence interval) of the stock of each stratum by the Area of each Project stratum (AP):

$$Carbon\ Credit = \left(\overline{x_{CO2i}} - C.I.\right) \times AP_i + \left(\overline{x_{CO2i+1}} - C.I.\right) \times AP_{i+1}$$

where:

$\overline{x_{CO2i}}$ = Estimated average of the stratum's equivalent carbon dioxide stock "*i*", per hectare, in tons;
C.I. = Confidence interval, calculated at a probability level of 95%;
AP_i = Project Area referring to the stratum "*i*", in hectares.

13.5. Calculation of Carbon Stock Uncertainty

The uncertainty of the estimated mean is given by the variation of the Confidence Interval at a specific probability level, in the case of this methodology, we consider a valid probability level of 95% (ninety-five percent). The calculation method is available in Table 2, in ANNEX I of this methodology.

From basic statistics (WEISS & HASSETT, 1982), normally distributed data are:

I. 68.27% within plus or minus 1 standard deviation of the mean;
II. 95.45% between plus or minus 2 deviations; and
III. 99.73% between plus or minus 3 deviations.

The exact multiplier of the standard deviation of the mean for the rounded 95 or 99% levels can be found by integrating the probabilistic density function to these points under the standard normal curve.

Depending on the sampling intensity, the value is "t" (small samples, n < 30) or z (large samples, n > 30). In the IPCC guide, the multiplier is 2 for the 95% level or 3 for the 99% level, regardless of sampling intensity.

For the purposes of reporting estimates of carbon stocks in the forest, uncertainty can be objectively characterized by the Confidence Interval, estimated with a probability of 95%, calculated based on the sampling carried out.[3]

IMPORTANT: Using only remote sensing data does not produce uncertainty estimates. Therefore, Remote Sensing must be combined with data from sampling forest inventories (or censuses). The use of spectral information (satellite image data) can be used to improve the extrapolation of the estimated average, improving (reducing the level of uncertainty) the estimate of stocks.

13.6. Calculation of Carbon Credit Generated Between Verification Periods

The generation of carbon credits is calculated by the increase in carbon stock in the Project Area (AP) between verification periods:

$$Carbon\ Credits\ from\ the\ Nth\ Accreditation = Net\ Stock_{AGB}(tn) - Net\ Stock_{AGB}(\text{tn-1})$$

where:

Net $Stock_{AGB}(T0)$= Carbon stock from the first check;
Net $Stock_{AGB}(Tn\text{-}1)$ = Carbon stock from last check;
Net $Stock_{AGB}(Tn)$ = Current verified carbon stock;
n = 1, 2, 3... T (accreditation number, which varies from 1 to T, depending on the project duration); and
Nth = First, Second, Third... Tenth.

[3] Ideally, the level of uncertainty in the mean is below 10%. The better the sampling, the smaller the error and the greater the amount of carbon credits to be certified.

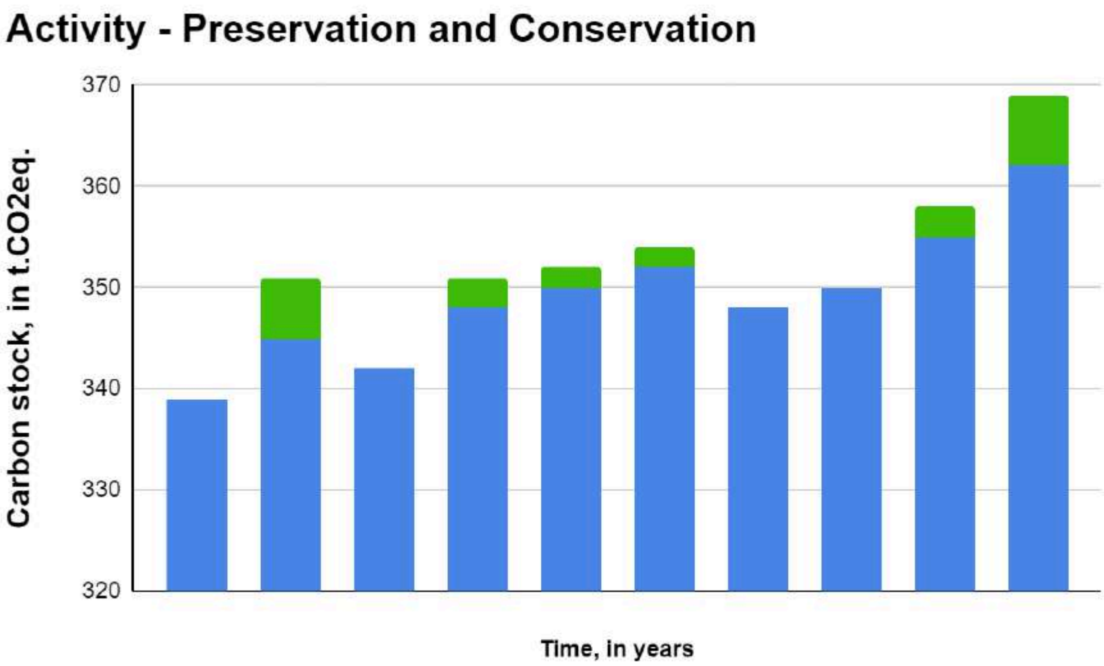

Figure 5. Illustrative example of the generation of carbon credits through an increase in the stock over time, in projects whose main activity is "Preservation and Conservation".

PS. 1: The natural stock of mature tropical forests can fluctuate over time; the increment is not necessarily linear.

PS. 2: Amazonian forests dynamics are subject to natural disturbances, such as periods of drought and/or heavy rainfall, with tropical downburst storms.[4]".

PS 3: The natural dynamics of mortality in the Amazon forest can impact the stock, given the relationship between this dynamic, in which large trees leave the measurement system and only small ones enter (Higuchi, 2015).

PS 4: The credit generation itself is only recorded when the largest past stock (blue bar) is exceeded by the current stock (green bar).

[4] NEGRÓN-JUAREZ, R. I.; CHAMBERS, J.; GUIMARÃES, G.; ZENG, H.; RAUPP, C. F. M.; MARRA, D. M.; RIBEIRO, G. H. P. M.; SAATCHI, S. S.; NELSON, B.; HIGUCHI, N. 2010. Widespread Amazon forest tree mortality from a single cross-basin line event. Geophysical Research Letters. Vol. 37, L16701.

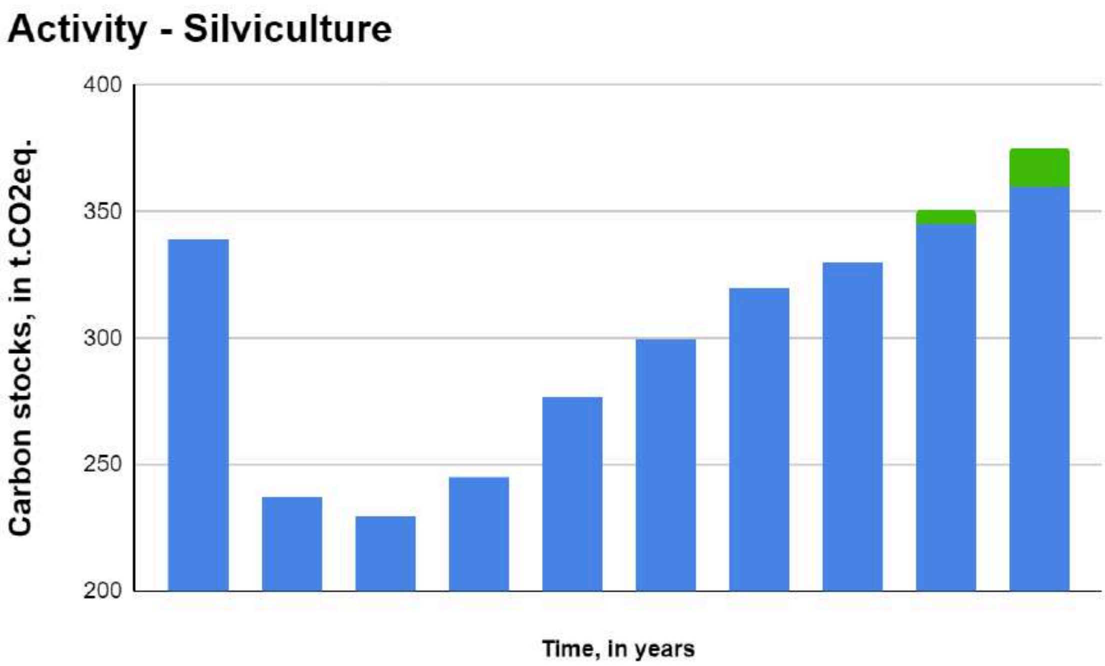

Figure 6. Illustrative example of the generation of carbon credits through the increase in stock over time, in projects whose main activity is "Forestry".

PS. 1: In this case, it is assumed that the native forest was replaced by a planted forest, thus, the reduction in stock in the transformation process is significant.

PS 2: Practical experiences in controlled environments indicate that even after intervention in the forest, stocks tend to continue falling, for up to 3 (three) years following the intervention, this is caused by the impacts of feeling on the remaining trees, in which many are damaged and may eventually not survive, causing a further reduction in stock.

PS 3: Credit generation starts counting after the silviculture stock (forest plantation) has recovered to the original stock (green bar).

NOTE: The results, in terms of sequestered GHG emissions (tCO_2e), observed during the crediting period will determine the amount of verified carbon credits that the project will generate.

Assumptions for Direct to Generation of Verified Carbon Credits

In order for verified carbon credits to be generated, arising from the sequestration (increase) of the carbon stock in the Project Area (AP), the following assumptions will need to be met:

I. It is necessary to have two, or more, carbon stocks verified, at different times, following the criteria of this methodology;
II. The most recent carbon stock must be greater than the maximum carbon stock ever recorded in the Project Area (AP), that is, in the case of natural fluctuations in the carbon stock, it will always be considered the largest carbon stock prior to*Tn*.

14. ADDITIONAL BENEFITS (CO-BENEFITS)

The additional carbon benefits, or co-benefits, for projects using this methodology are:

14.1. Conservation and preservation of the largest terrestrial biodiversity on the planet

An additional benefit inherent to the carbon project of this methodology is the guarantee of maintaining the evolutionary cycles of biodiversity.

NOTE: The project proponent is allowed to demonstrate in detail the additional benefits specific to their area through data collected in Fauna and Flora Diagnostics, but these are not mandatory. If details are not presented, the biodiversity considered as an additional benefit is that present in the literature.

Qualitative Forest Inventory (Optional)

The guidelines for the Qualitative Forest Inventory for collecting primary data used in presenting co-benefits are:

- Minimum data to be considered: live trees and palm trees, with DBH > 10 cm;
- Secondary data will only be accepted as a complement;
- Implementation of a sampling system, using fixed area sampling units (see Annex I);
- Botanical sampling, with the collection of sampled tree leafs of different species (samples can be deposited in herbaria).

14.2. Sustainable development

According to the United Nations (UN), sustainable development[5] is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainable development requires joint efforts to build an inclusive, sustainable and resilient future for people and the planet.

For sustainable development to be achieved, it is crucial to harmonize three central elements: economic growth, social inclusion and environmental protection. These elements are interconnected and are all crucial to the well-being of individuals and societies.

The eradication of poverty in all its forms and dimensions is an indispensable requirement for sustainable development. To this end, there must be the promotion of sustainable, inclusive and equitable economic growth, creating greater opportunities for all, reducing inequalities, raising basic standards of living, promoting equitable social development and inclusion and promoting integrated and sustainable management of resources, natural resources and ecosystems.

Of the 17 (seventeen) Sustainable Development Goals (SDG), this methodology highlights:

1. Eradication of poverty (#01):
    a. Description: end poverty in all its forms;
    b. Criterion: that the proponent(s) can live on more than R$5.93 (US$1.25) per day;
    c. Indicator: job creation and/or increase in proven revenue, through the commercialization of environmental assets generated (stock and carbon credit).
2. Zero hunger and sustainable agriculture (#02):
    a. Description: achieve food security and improved nutrition and promote sustainable agriculture;
    b. Criterion: that the proponent(s) can, through project activities, have access to the best practices of agricultural cultivation systems (low impact and carbon), if they so wish;
    c. Indicator #01: registration and licensing of the activity with the current environmental agency;
    d. Indicator #02: increase in productivity per unit area.

[5] https://www.un.org/sustainabledevelopment/development-agenda-retired/#:~:text=%E2%97%8F,future%20for%20people%20and%20planet.

3. Decent employment and economic growth (#08)
    a. Description: promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all;
    b. Criterion: achieve higher levels of economic productivity through diversification, technological upgrading and/or innovation, including through a focus on high value-added and labor-intensive sectors;
    c. Indicator: proven increase in 'agro' production yield (should there be an agricultural activity).
        i. Bonus indicator: For projects in private areas of family farmers, the generation of at least one (1) formal job;
        ii. Bonus indicator #02: For projects in private areas that are not characterized as family farming, the increase of at least one (1) more formal job, without increasing the productive area.
4. Sustainable cities and communities (#11)
    a. Description: make cities and human settlements inclusive, safe, resilient and sustainable;
    b. Criterion: guarantee everyone's access to adequate, safe and affordable housing and basic services (such as: sanitation);
    c. Indicator #01: proven improvements to housing/infrastructure of the rural property targeted by the project;
    d. Indicator #02: installation and/or improvements to the basic services system in the rural property targeted by the project (if applicable), such as: sanitation and energy efficiency.
5. Combating climate change (#13):
    a. Description: take measures to combat climate change and its impacts;
    b. Criterion: avoid the emission of greenhouse gases into the atmosphere, through deforestation and/or forest degradation;
    c. Indicator: maintenance of forest area in the project area and/or increase in stock through enrichment of natural/native forest or reforestation of degraded areas.

15. GOVERNANCE

The project must present how the Governance of the rural property will be carried out, aiming to carry out the activities foreseen in this methodology. Physical identification is indicated, on the property, at the access point, that that area is destined for a carbon project.

Minimum interventions are also suggested:

- Installation/Maintenance of infrastructure as headquarters/support base for project activities;
- Installation/Maintenance of fences and signs on the perimeter of the property and/or Project Area;
- Implementation/Maintenance of surveillance system *in place*, with periodic rounds and inspections;
- Any other activity that does not involve degradation and/or deforestation of more than 0.5 hectares.

NOTES:

- Activities involving forest degradation, through selective logging, in the Project Area will not be permitted during the crediting period.
- Alternative land use activities, through the implementation of agro-silvo-pastoral production systems, in the Project Area will not be permitted during the crediting period.

ANNEX I - THE METHODOLOGICAL BASIS FOR ESTIMATING BIOMASS AND CARBON STOCKS IN THE FOREST

The main technical point of REDD projects. Methods for estimating biomass and carbon stocks in the project's target forest are essential for carbon credit certification. Next, the methodological basis.

AI.1. Biomass Compartments

Biomass is defined by the weight of the tree, in kilograms (kg) or tons (t), the first being used for individual weight and the second when referring to stocks (IPCC, 2006). Estimates of stocks per unit area, and especially when extrapolated to a region (such as a tropical country or the Amazon as a whole), are presented in abbreviated form, in grams or tons: (i) million in mega (Mg or Mt) ; billion to giga (Gg or Gt); (iii) trillions in tera (Tg or Tt); and (iv) quadrillions in peta (Pg or Pt) (IPCC, 2006).

According to the National Greenhouse Gas Inventory Guide of the Intergovernmental Panel on Climate Change (IPCC), forest biomass is subdivided into three compartments:

- Aboveground biomass = trunk, branches, leaves, flowers and fruits (AGB);
- Biomass Below soils = roots (BGB); and
- Biomass Total (AGB + BGB).

According to Silva (2007), of the total weight of a tree in the Manaus region, 41.6% is water; of the dry mass weight, 48.5% is carbon. This means that: of the total weight of a living tree, approximately 40% is water and 30% is carbon.

The quantification of the biomass of a tree can be performed by two methods:

1. **Direct**

It consists of felling and weighing the trees at fixed area points, later extrapolated to an area unit. For this, it is necessary to cut and fell the individual tree and weigh it on a scale (SILVA, 2007). In addition to being impractical, the estimates generated by this method are not reliable, because they are based on a low number of plots, small and biasedly chosen.

Due to the dimensions of a tree and the operational scale of a scale, the tree is usually divided into specific compartments: crown, trunk and root system (Figure 1). In the Amazon, it is possible to find trees weighing between a few kilograms (smaller trees) and even individuals weighing tens of tons (SILVA, 2007).

The main result of the direct method is the adjustment of allometric equations, through regression analysis. In the Amazon, the following works are highlighted: Araújo *et al.* (1999); Silva (2007); Lima *et al.* (2012).

Figure 1. Images of the field activities of the destructive method of determination of the total weight, above and below the soils of a tree.

2. Indirect

In the indirect method, estimates are produced from equations and allometric models, associated with data from forest inventories (forest sampling systems).

Based on a sample of the forest, individuals are measured and their estimates calculated using an equation. From the sum of the stock of each sampling unit, the average per area unit (hectare, for example) is extrapolated.

In this method, the average of the stock is estimated with a statistical uncertainty level, calculated using the Confidence Interval of the mean, based on a probability level. More details to follow.

AI.2. Allometric Equations

Allometry is the study of variations in the forms and processes of organisms and has two meanings (NIKLAS, 1994; GRAHAM, 2003):

- The development of a part of the organism in relation to the development of the whole organism or part of it; and
- The study of the consequences of size on shapes and processes.

In forestry, it is the study of the whole (biomass and/or carbon) as a function of parts of the whole (Diameter at Breast Height - DBH or H's), that is, adjustment of mathematical equations (functions or models).

Mathematical models can be linear or not, single or multiple input (MARQUET *et al*. 2005). The model input refers to the number of independent variables (X) used to predict the dependent variable, Y:

- Simple linear models have a graphical representation of a straight line (growing or not);
- Nonlinear models are power-based equations and their relationships are characterized by a scale of invariance (self-similarity) and universality.

Even with so many distinctions, any equation must present, at least, a normalization constant (proportionality), represented by “a”; or by the Greek letter “β_0”, and the exponent, represented by the letter “b” or “β_n” (SILESHI, 2014).

Nonlinear models are the typical functions of allometric equations, especially for estimating biomass in plants (WEST *et al*. 1999; SILESHI, 2014). However, in the case of plants (trees), the universal exponent can assume different values according to their respective stages of development (PILLI *et al*. 2006).

AI.3. Allometry of Biomass and Carbon in the Amazon

The main and most reliable studies of biomass allometry in the Brazilian Amazon are: SANTOS, 1996; HIGUCHI *et al*. 1998; ARAÚJO *et al*. 1999; CHAMBERS *et al*. 2000 therefore used destructive data, even if some still “incomplete” (only aboveground biomass data).

Underground biomass data are difficult to collect and for this reason there are not many published works in the Amazon, in addition to Silva (2007), Borges (2010) and Lima *et al.* (2012).

In the Amazon, there are only records of two studies with destructive data on below-ground biomass (SILVA, 2007; LIMA *et al.* 2012). These models have produced satisfactory results, with a coefficient of determination (R^2aj) always greater than 0.80 and standard error of the estimate (Syx%) below 10%.

The Coefficient of Determination (R^2aj) is a parameter that evaluates how much an allometric model contemplates the range of variation of the population, ranging from 0 to 1, where 0 does not represent the population and 1 represents perfectly. The standard error of the estimate (Syx%) is the uncertainty margin of the allometric model, given in percentage. The maximum acceptable limit in forest engineering is 10% (ten percent).

In the absence of a 'site-specific' equation, Tero recommends Silva's (2007) equation, adapted based on a “correction factor” (fc), estimated by the relationship between the dominant height (Hdom) of the sampled site and the Hdom from where the equation was fitted.

The dominant height is determined based on the results found by Higuchi (2015), which suggests that Hdom = average height of the 10% thickest trees sampled.

Corroborating with the work of Malhi et al. (2006), Anderson et al. (2009) and Feldpausch et al. (2011), the challenge of using the adjusted biomass equation in the Manaus region (SILVA, 2007) in another region of the Amazon is recognized. Thus, to compensate for the differences between the vertical structure of the forests in the sampled locations, it is recommended to apply a “correction factor” (fc) of the biomass equation through the relationship between the Hdom of the Experimental Station of Tropical Silviculture (ZF2) from INPA and the Hdom from the sampled site, based on the approach suggested by Higuchi (2015), based on the results presented by Lima et al. (2012).

$BStot = 2,7179 \times ANDP^{1,8774} \times 0,584 \times fc$, where R^2 = 0,94 e Syx% = 3,91.

$AGB = 2,2737 \times ANDP^{1,9156} \times 0,584 \times fc$, where R^2 = 0,85 e Syx% = 4,20.

$BGB = 0.0469 \times ANDP^{2,4754} \times 0,533 \times fc$, where R^2 = 0,95 e Syx% = 5,12.

where:

BStot = total dry biomass, in kg;
AGB = aboveground dry biomass, in kg;
BGB = dry biomass below ground, in kg;
DBH = diameter at 1.3m from the floor, in cm;
fc = correction factor;
R^2 = Coefficient of determination; and
Syx% = Standard Error of the Estimate, in %.

$$Cabg = AGB \times 0,485$$
$$Cblg = BGB \times 0,464$$
$$Ctot = Cabg + Cblg$$

where:

Ctot = total carbon, em kg;
Cabg = aboveground carbon, in kg; and
Cblg = belowground carbon.

The fc is calculated through the ratio between the Hdom of the sampled location and the Hdom of ZF2:

$$fc = \frac{Whom_i}{Whom_{ZF2}}$$

where:

fc = correction factor;
$Hdom_i$ = estimated dominant height for site "i" sampled; and
$Hdom_{ZF2}$ = dominant height of ZF2 = 30.2 m [6].

IMPORTANT NOTE #01:

Projects may feature "site specific" biomass equation(s). Adjusted based on local data.

The equation(s) must follow the "Measurable, Reportable and Verifiable - MRV" method.

[6] According to Higuchi (2015).

IMPORTANT NOTE #02:

The most used independent variables are Diameter at Breast Height (DBH) and total height. There are authors who defend the inclusion of wood density as an independent variable (OVERMAN *et al*. 1994; CHAVE *et al*. 2005; NOGUEIRA *et al*. 2008).

IMPORTANT NOTE #03:

The question that emerges is about the cost-benefit ratio when introducing a variable that is extremely difficult to collect, with high levels of variations and its increase in precision to the model (WIEMANN & WILLIAMSON, 2014). Furthermore, density is a dependent variable.

With regard to the inclusion of height (total and/or stem/trunk) there are two points. The first: in all allometric studies in the Amazon, based on destructive data, no substantial difference was observed, in terms of precision (Syx%) and reliability (R2aj), between the double equations (diameter and height) and single (diameter only) input. The second: measuring the height of trees in Amazonian forests is a huge challenge, in addition to substantially raising the cost of field work, it also generates more uncertainties due to non-sampling errors when measuring the variable.

> *Non-sampling errors are errors caused by human error or the equipment/tool used. In sampling works, this is the type of error that must always be avoided, at the risk of invalidating the work. It is not possible to compute or quantify the impact of this type of error in estimating the mean.*

AI.4. Sampling System

There are two basic ways to acquire the desired information about a forest: through the total measurement of the trees (Census) or through sampling. However, forests generally occupy large areas, which makes the census unfeasible (both in terms of time and operational cost), making sampling the best option.

Sampling in forests is given by Forest Inventories (FI). The IFs are activities to describe the quantity and quality of trees in a forest and any and all characteristics of the area where these trees are growing (HUSCH, 1971; HUSCH *et al*. 1972; LOETSCH *et al*. 1973; PÉLLICO NETTO and BRENA, 1997; LIMA, 2010).

The use of sampling allows inferences to be made about it (HUSCH, 1971). This is such an established and consolidated concept that Loetsch *et al*. (1973)

mentioned that: the use of sampling units (plots) is as old as Forest Engineering.

The sample plots may or may not have a fixed area (LOETSCH *et al*. 1973; PÉLLICO NETTO & BRENA, 1997). Sampling methods without a fixed area (Bitterlich, Strand, Prodan and 3-P, for example) have no practical application in the Amazon. There are no records of forest inventories performed using this method. The fixed area method has been used since the first published work (OLIVEIRA, 2000).

When it comes to sampling forest inventories, sampling errors are inevitable and, consequently, levels of uncertainty. But it is providential that measures are taken to make this error controllable.

The most common way of presenting the error in forestry works is through the “standard error of the mean” or the “confidence interval” (HUSCH, 1971).

Depending on the forest and the area to be inventoried, it may be necessary to stratify the forest, by two methods: by “variance” or according to “forest class”. According to Péllico Netto and Brena (1997), the main objective in stratifying a population is to reduce variance within strata and sampling costs.

The two main sample distribution methods are random and systematic.

In the Amazon, Higuchi (1987) compared the two methods in an area of upland forest in the Manaus region and confirmed that the use of systematic sampling was more accurate and less expensive.

The ideal plot shape for natural forests (Amazon) is rectangular. They generate fewer non-sampling errors and allow for greater sampling of forest variability. The ideal plot size ranges from 1,000 m^2 and 2,500 m^2, dimensioned at 10 x 100 m and 20 x 125 m, respectively (HIGUCHI *et al*. 1982; OLIVEIRA *et al*. 2014).

For areas of planted forests, with standardized spacing, circular plots are recommended. They cover the largest area by the smallest perimeter, reduce the number of marginal trees (at the edge of the plot area) and are simpler to install. In terms of size, it depends on the spacing. The larger the spacing, the larger the plot radius should be.

AI.5. Variable of Interest

The variables of interest can be divided into: dependent and independent.

Dependent variables are characterized by being difficult to measure, which need to be estimated through others. Hence the name "dependent".

Independent variables are those that are easy to obtain. They can be measured and/or checked using high-quality tools and equipment. They are used to estimate, through allometric equations, the dependent variables.

Are they:

Table 1. Relationship of variables considered to determine the carbon stock in an area of tropical forest in the Amazon.

Variable Name	Variable Type	Unit of Measurement	Description
Forest Area	Independent	Hectares (ha)	Any estimate of carbon stock in a forest is given per unit area, most commonly in hectares (ha), with one (1) hectare equaling ten thousand square meters (10,000 m^2)
Spectral Reflectance	Independent	Nanometer (nm)	The extrapolation of estimated averages per unit area, for the entire forest, is carried out through remote sensing and geoprocessing of aerial images
Spatial Resolution	Independent	Meter (m)	Refers to the size of a pixel on the ground. It is the ability of the sensor to see objects in relation to their size. A satellite image with a resolution of 30 cm can capture ground detail greater than or equal to 30 cm by 30 cm. Based on this definition, images with a spatial resolution of 30 cm capture more surface detail than images with a resolution of 1 m. Therefore, the higher the resolution, the lower the image and object detail level.

Variable Name	Variable Type	Unit of Measurement	Description
Diameter at 1.3m from the floor (DBH)	Independent	Centimeter (cm)	Measurement of the diameter of the tree trunk in the standard position (1.3 m from the ground), which can be measured at higher heights, provided there are physical impediments in the original position.
Total height (Ht) and shaft (Hf)	Independent	Meter (m)	Measurement of the total height (Ht) or the trunk (Hf) of the tree. Ht is height to the highest part of the canopy. Hf is the height to the top of the canopy.
Dominant height (Hdom)	Dependent	Meter (m)	Average of the total heights of the 10% of the dominant individuals of the site
Correction factor (fc) of the biomass/carbon equation	Dependent	-	Relationship between the Hdom of the sampled site and the Hdom of the site where the equation was developed
Fresh aerial biomass (BFabg)	Dependent	Metric ton (t)	Weight or mass of the aerial part of the tree (trunk, branches, leaves, flowers, fruits and seeds), considering the water in the structure
Fresh Biomass Below Soils (BFblg)	Dependent	Metric ton (t)	Weight or mass of tree roots, considering the water in the structure
Total fresh biomass (BFtot)	Dependent	Metric ton (t)	Total weight or mass of the tree (aerial + roots), considering the water in the structure
Above ground dry biomass (AGB)	Dependent	Metric ton (t)	Weight or mass of the aerial part of the tree (trunk, branches, leaves, flowers, fruits and seeds), discounting the water in the structure

Variable Name	Variable Type	Unit of Measurement	Description
Dry biomass below ground (BGB)	Dependent	Metric ton (t)	Weight or mass of tree roots, discounting water in the structure
Total dry biomass (BStot)	Dependent	Metric ton (t)	Total weight or mass of the tree (aerial + roots), excluding water in the structure
Air carbon (Cabg)	Dependent	Metric ton (t)	Weight or mass of carbon stored in the aerial part of the tree (trunk, branches, leaves, flowers, fruits and seeds)
Carbon below ground (Cblg)	Dependent	Metric ton (t)	Weight or mass of carbon stored in tree roots
Carbon total (Ctot)	Dependent	Metric ton (t)	Total weight or mass of carbon stored in the tree (aerial + roots)
Air equivalent carbon dioxide (CO_2e.abg)	Dependent	Metric ton (t)	Weight or mass, in carbon dioxide equivalent, stored in the aerial part of the tree
Carbon dioxide equivalent below the soil (CO_2e.blg)	Dependent	Metric ton (t)	Weight or mass, in carbon dioxide equivalent, stored in tree roots
Total carbon dioxide equivalent (CO_2e.tot)	Dependent	Metric ton (t)	Total weight or mass, in carbon dioxide equivalent, stored in the tree (aerial + roots)

AI.6. Statistics

To quantify forest biomass/carbon stocks, statistical inference tools are needed. Statistics is the field of mathematics that relates facts and numbers in which there is a set of methods that allow us to collect data and analyze them, so that it is possible to perform some interpretation of them.

Table 2. Statistical parameters, their descriptions and mathematical formulas.

Parameter	Description	Formula
Average	Sum of all observations divided by the total number of observations	$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
Variance (s^2)	Sum of squared deviations	$s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$
Standard Deviation(s)	Measure of dispersion of the observed values in relation to the average	$s = \pm \sqrt{s^2}$
Standard Error	It is the measure of variation of a sample mean in relation to the population mean.	$s_{\bar{x}} = \frac{s}{\sqrt{n}}$
Confidence Interval	Mean variation as a function of population variability at a specific confidence level, commonly 95%	$\bar{x} \pm With \times \frac{\sigma}{\sqrt{n}}$
Sum of Corrected Squares of the dependent variable "Y"	Measure of variation of the variable's mean	$SQC_{and} = \sum_{i=1}^{n} and_i^2 - \frac{\left(\sum_{i=1}^{n} ai\right.}{n}$
Sum of Corrected Squares of the independent variable "X"	Measure of variation of the variable's mean	$SQC_x = \sum_{i=1}^{n} x_i^2 - \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n}$

Parameter	Description	Formula
Sum of Corrected Products	It is the product between the independent and dependent variable, used to estimate the Correlation Coefficient	$SPC_{xy} = \sum_{i=1}^{n} x_i and_i - \frac{\left(\sum x_i\right) \times \left(\sum a\right.}{n}$
Correlation coefficient	Measures the degree of correlation between the independent variables with the dependent one	$r = \frac{SPCxy}{\sqrt{SQC_x SQC_{and}}}$

AI.7. Stratification

The main objective in stratifying a population is to reduce variance within strata, increase estimation accuracy, and optimize sampling.

Stratification of the forest can be carried out by two methods: by the “variance” of the data or according to the “forest class”:

- By variance:
  - It depends on a preliminary sampling;
  - Low cost/benefit ratio; and
  - May generate biased information/estimates.
- By forest class:
  - It depends on remote sensing and geoprocessing of satellite images from different sensors (RGB and Near Infrared, for example);
  - Optimizes sampling through pre-planning; and
  - Increases estimation reliability and reduces uncertainties.

However, even if the remote characterization of the forest points to evidence of different forest classes, it is necessary to apply a statistical test to prove the difference. If the test does not identify a significant statistical difference, the stratification of the sample and the inference statistics becomes unnecessary. Of the tests, the most applied by forest engineering is the Analysis of Variance (ANOVA), followed by a Tukey post hoc test.

AI.8. Analysis of Variance (ANOVA)

ANOVA is a mean comparison test. Applied to understanding the nature of natural variation from different sources or testing hypotheses. In this case, we have:

Hypothesis:

- H0: All strata have statistically equal stock averages;
- H1: Not all strata have statistically equal stock averages.

To test this hypothesis, we must develop the "ANOVA table".

Chart 1. Analysis of variance chart - ANOVA.

SOURCES OF VARIATION	GL	SQ	MQ	F
In between	k -1	$SQE = \sum_{i=1}^{n} (x - \bar{x})^2$	$MQE = \frac{(SQE)}{(k-1)}$	$F = \frac{MQE}{MQR}$
Residue	n - k	$SQD = \sum_{i=1}^{n} x_{ij}^2 - \frac{\sum_{i=1}^{k}\left(\sum_{i=1}^{g} x_{ij}\right)^2}{g}$	$MQD = \frac{(SQR)}{(n-k)}$	
Total	n			

where:

n= total number of observations;
k = number of groups;
TOF = Sum of Squares Between Groups;
MQE = Mean Square between groups; and
F = probability F-test.

If the ANOVA presents strong evidence that there is any statistical difference between the means, a Tukey post hoc test is applied to specifically identify which means stand out.

$$\Delta = q\sqrt{\frac{MQR}{r}}$$

where:

q = tabulated value;
MQR = residual mean square; and
r = number of repetitions.

The result is a correlation probability matrix, for example:

Chart 2. Example of a probability matrix for Tukey's test.

	Med.1	**Med. 2**	**Med. 3**	**Med. 4**	**Med. 5**	**Med. 6**	**Med. 7**	**Med. 8**	**Med. 9**
Med. 1	1								
Med. 2	0.0202	1							
Med. 3	0.0009	**0.9999**	1						
Med. 4	0.5456	0.6508	0.2086	1					
Med. 5	**0.0012**	0.0000	0.0000	0.0000	1				
Med. 6	0.0141	0.9999	0.9999	0.5979	0.0000	1			
Med. 7	0.6441	0.7947	0.4078	0.9999	0.0000	0.7597	1		
Med. 8	0.0143	0.9937	0.8424	0.8786	0.0000	0.9905	0.9680	1	
Med. 9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1

where:

average i = refers to the population "i" sampled;
probability values ranging from 0 (totally different) a 1 (identical).

AI.9. Stratified Statistics

The mathematical formulas for inference statistics, considering the sampling stratification, are presented by Péllico Netto and Brena (1997), they are:

Table 3. Stratified statistical parameters, their descriptions and mathematical formulas.

Parameter	**Description**	**Formula**
Average per stratum	Arithmetic mean per sampled stratum	$\overline{x}_h = \frac{\sum_{i=1}^{n_h} X_{them}}{n_h}$
Stratified mean	Weighted average according to the sampled strata	$\overline{x}_{st} = \sum_{h=1}^{L} In_h \overline{x}_h$
Variance by stratum	Population variance, by sampled stratum	$s_h^2 = \frac{\sum_{i=1}^{n_h} \left(x_{them} - \overline{x}_h\right)^2}{n_h - 1}$

Parameter	Description	Formula
Stratified variance	Weighted population variance according to the sampled strata	$s_{st}^{2} = \sum_{h=1}^{L} In_{h} s_{h}^{2}$
Stratified mean variance	Weighted variance of the mean of the sampled population	$s_{\bar{x}(st)}^{2} = \sum_{h=1}^{L} In_{h}^{2} \times \frac{s_{h}^{2}}{n_{h}}$
stratified standard error	Weighted standard error of the sampled population	$s_{\bar{x}(st)} = \sqrt{s_{\bar{x}(st)}^{2}}$
Stratified sampling error	Weighted sampling error of the inference estimate for the sampled population	$AND_{r} = \pm \frac{t \times s_{\bar{x}(st)}}{\bar{x}_{st}} \times 100$
Confidence interval (95%)	Range of variation of the estimated mean, with a probability of 95%	$I.C. = \bar{x} \pm With \times \frac{\sigma}{\sqrt{n}}$ Where: z = confidence level based on population standard deviation; σ = population standard deviation; n = population size

AI.10. Spatialization (*Scale up*)

Georeferencing of trees and plots makes it possible to correlate information from the forest inventory with images from remote sensors at different mapping scales. The acquisition of GPS coordinates is sensitive to the equipment, the collection procedure and the satellite coverage and mainly with the forest cover (JUN; GUENSLER; OGLE, 2006; RODRÍGUEZ-PÉREZ; ÁLVAREZ; SANZABLANEDO, 2007; SIGRIST; COPPIN; HERMY , 1999).

Combining field information with remote sensing data is done by comparing geographic positions between field data and images, which directly depends on the resolution and spatial scale of the data. The use of multi-sensors for carbon stock estimates is a recommendation (LU *et al*., 2012), from the local to regional map (TRUMBORE; BRANDO; HARTMANN, 2015; ZHANG *et al*., 2014) and with control of the error (IPCC 2010).

In terms of recording methods of geographic coordinates of forest inventories vs. geographic coordinate accuracy, Celes *et al*. (2016) worked on Quality Control and Assurance (QA/QC) and the main points of the study were:

Tested methods

Table 4. Methods for collecting coordinates and positioning of sampling units (plots) sampled in the forest inventory.

Method (code)	Description
GPS.M1	Satellite signal stabilization for 1 minute (EST); coordinate record: single point.
GPS. M2	EST; point average (xi) for 1 minute; coordinate record
GPS. M3	EST; xi for 5 minutes
GPS.M4	EST; xi for 10 minutes
GPS.M5	EST; xi for 15 minutes
GPS.Track (MT)	Option "tracking" for 5 minutes
GEO.GPS (MG)	Georeferencing (GeoRef) using points from all trees
Trimble (MTrim.)	Trimble Points

where:

GPS = Global Positioning System, in English; and
"Trimble" = device for receiving GPS signals of the differential type, with post-processing accuracy of up to 2 m (two meters).

Results

From the analysis carried out, it was concluded that the MG method, using "false coordinates" (inclusion of control points within the plot, that is, trees) generated the most accurate coordinates. The "MT" method was the one that generated the maximum "displacement", greater than 40 m. Even so, in the comparison analysis of the means (ANOVA) between the methods, no statistically significant differences were found between them, that is, the precision and accuracy of the coordinate is not influenced by the selected method (Table5). Finally, any of the methods generate reliable and verifiable information, being considered valid for REDD projects, since displacements do not show an evident trend (Figure 2).

Table 5. Descriptive statistics, mean and maximum displacements of the evaluated methods and the results of the Analysis of Variance (ANOVA) of the means.

ANOVA			Displacement, in meters		Test *t* - GeoGPS	
Methods			Media ± I.C. (95%)	Maximum	p-value	Pearson
GPS.M1	GPS.M1	GPS.M1	6.9 ± 1.2	23.2	0.040	0.077
GPS. M2	GPS. M2	GPS. M2	7.2 ± 1.0	17.7	< 0.001	0.360
GPS. M3	GPS. M3	GPS. M3	6.5 ± 0.9	17.7	0.001	0.380
GPS.M4	GPS.M4	GPS.M4	6.4 ± 0.9	17.0	0.004	0.359
GPS.M5	GPS.M5	GPS.M5	6.0 ± 0.9	18.3	0.033	0.208
MT	-	-	6.6 ± 1.5	42.6	0.041	0.026
-	-	MG	4.2 ± 1.0	10.6		
p = 0.737	**p = 0.510**	**p = 0.010**	-	-	-	-

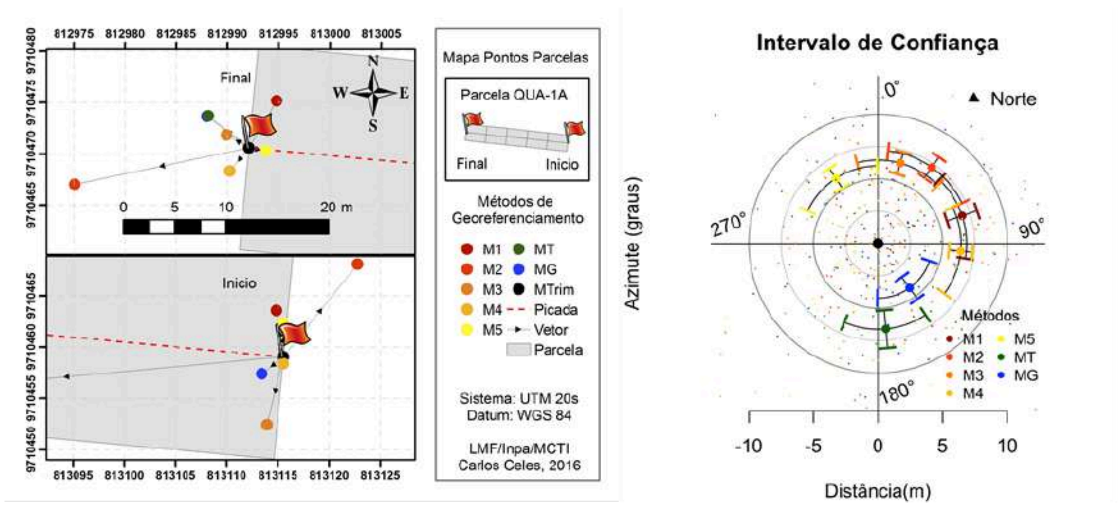

Figure 2. Map showing the different methods of positioning the initial and final points of the plot (left) and graph showing the mean and confidence interval of each georeferencing method of the plot (right).

Types of GPS (Global Positioning System) signal receiver devices most common on the market and capable of producing coordinate records with acceptable levels of uncertainty, provided they are properly operated, are:

- Geodesic:
  - More precise/accurate;
  - High cost;
  - Specialized operation.
- Topographic:
  - High precision/accuracy;
  - Medium cost;
  - Specialized operation.
- Navigation:
  - Verifiable precision/accuracy;
  - Low cost;
  - Simple operation.

In terms of satellite images and/or different sensors, we have:

Table 6. Spatial resolution of optical data.

Spatial Resolution Range	Nomenclature	Sensor Systems*
< 1 m	Very high spatial resolution (VHSR)	QuickBird, Planet, WorldView, Pleiades, ARP
1 m a 10 m	High Spatial Resolution (HSR)	ICONS, SPOT, RapidEye
10 m a 100 m	Medium spatial resolution (MSR)	LandSat, Sentinel, ASTER
100 m a 1.000 m	Low spatial resolution (LSR)	WAYS, MERIS
> 1.000 m	Very Low Spatial Resolution (VLSR)	AVHRR, VAI

where: m = meter; * examples of sensors available on the market.

Table 7. Platform, sensor, available period and spatial resolution of some satellite imagery providers in the market

Platform	Sensor	Period Available	Spatial Resolution
LandSat 5	TM	1984 a 2011	30 m
LandSat 7	ETM+	1999 a 2003	30 m
LandSat 8	OLI/TIRS	From 2013	30 m
LandSat 9	OLI-2/TIRS-2	Starting in 2021	30 m
Sentinel	MSI	From 2014	10 m
Planet	Where	From 2013	3 m

After collecting all the information for carbon mapping, it is necessary to choose the mathematical model that will represent this relationship. Linear, multiple, non-linear or adjusted models with ordinary least squares, generalized additive model, random forest, and support vector regression (SVR) are used to estimate carbon (LU *et al.*, 2014) (FENG *et al.*, 2017) (LI *et al.*, 2014). The SVR had the best performance in comparison tests of the above models (LI *et al.*, 2014). Complex models are difficult to interpret. Simpler models present greater interpretation of the coefficients and the cause and consequence of the relationship. However, regardless of the chosen models, errors need to be identified, quantified and propagated throughout the process and the effort to reduce them is critical (LU, 2006).

AI.11. Continuous Forest Inventory

The Continuous Forest Inventory (CFI) is the monitoring of a forest area through the periodic measurement of its population (census) or part of it (sampling). The IFC is essential to assess the dynamic character of a forest's growth, for example, after an exploratory intervention of wood resources (PÉLLICO NETTO & BRENA, 1997; QUEIROZ, 1998). This procedure results in obtaining a series of fundamental information for decision makers, such as growth, entry, mortality, cutting cycle, succession and stock density, among others.

The main method for monitoring a forest is through sampling on multiple occasions (PÉLLICO NETTO & BRENA, 1997), in which there are basically four types of sampling processes:
Independent Sampling

In this process, according to Péllico Netto and Brena (1997), the approaches on both occasions are performed independently of each other. On the first occasion, temporary plots (u) are installed, according to the selected method, and on the second occasion, new sampling units (n) are installed, following the same methodology, but in different locations. The use of this process leads to the evaluation only of the differences between the initial and final stocks of the analyzed period and there is no way to evaluate the individual growth of the trees, nor to monitor mortality and/or recruitment rates.

Sampling with Total Repetition

According to Husch *et al*. (1972), this process is the "concept of using permanent plots and the basis of the Continuous Forest Inventory". In this, the permanent plots (m) installed on the first occasion are periodically monitored. There is no installation of new plots and no sampled unit is left out of the remeasurement. The main advantage is the monitoring of recruitment, mortality and increment rates of the sampled trees. However, the data are permanently subject to the same levels of bias.

Sampling with Partial Repetition

It is the combination of the two previous processes (HUSCH *et al*. 1972; PÉLLICO NETTO & BRENA, 1997). In the forest inventory carried out on the first occasion, permanent (m) and temporary (u) plots are installed. On the second occasion, the permanent plots (m) are remeasured and new temporary plots (n) installed. In this way, individual monitoring of the trees and their respective rates is possible, as well as maintaining a certain independence between the sampled data.

Dual Sampling

Very similar to sampling with partial repetition, however, new temporary plots are not installed on the second occasion. It has the same advantages and disadvantages as sampling with full repetition.

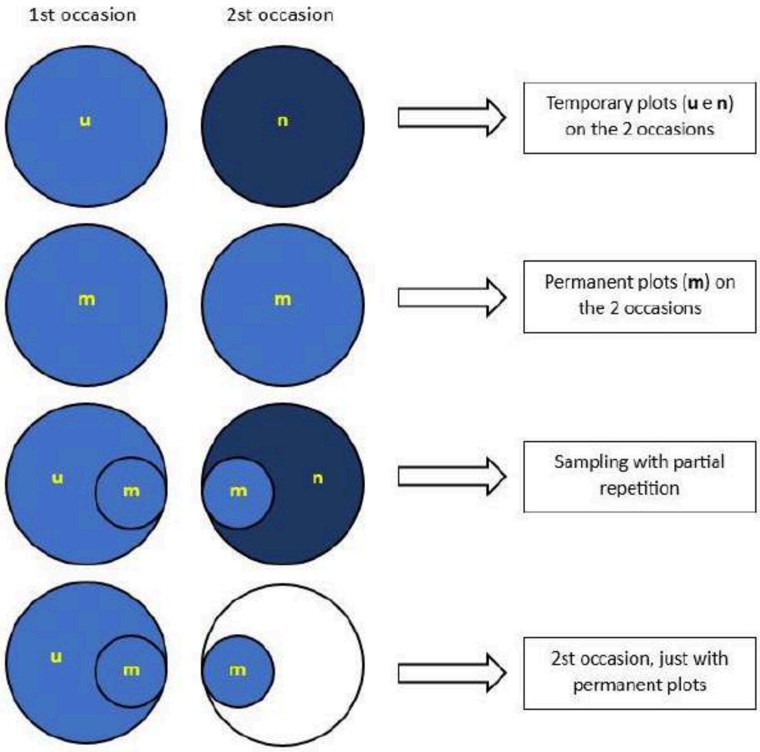

Figure 3. Illustrative scheme of the four types of continuous sampling processes.

Individuals are continuously lost and replaced through local ecological processes, in a balance given by the mortality/recruitment ratio (SWAINE *et al*. 1987; SWAINE, 1990). This dynamic balance provides the establishment and growth of new species, reflecting on the plant diversity of communities (PHILIPS *et al*. 1994; REES *et al*. 2001). Briefly, it can be said that the three main components of forest dynamics are: recruitment, mortality and growth of individuals.

According to Rezende (2002), recruitment refers to the number of new trees that reached and/or exceeded a measurable minimum size in the forest inventory. The exit of individuals from the monitoring system due to their death is called the mortality rate. Finally, growth is the evaluation of the increment of measured dimensions of one or more individuals of a forest in a given period of time. In monitoring tropical forests, these components can only be estimated by remeasuring permanent plots.

ANNEX II - REMOTE MONITORING AND PERMANENCE ANALYSIS

Remote monitoring is the periodic monitoring of the vegetation cover of the Project Area (PA). Through satellite images, it is possible to verify the status of the forest, in terms of "occupied area". This process is used for land use change history analysis and permanence verification.

The points observed for this analysis are:

- A satellite image suitable for the project period is acquired:
  - A suitable image is configured that:
    - It has less than 10% (ten percent) cloud coverage;
    - With less than 30 (thirty) days from the project submission date;
    - With spatial resolution of at least 30 m (thirty meters);
    - That includes RGB (visible field) and Near Infrared sensors.
- At each verification period, the*download* of a new, updated image;
- The vegetation cover is verified, if deforestation points are identified, these are mapped and their extension (area, in hectares) quantified:
  - In the case of identified deforestation, the corresponding emissions must be subtracted from the potential credits to be generated in the crediting period;
  - If the deforested area results in an emission equal to or greater than 50% of the total potential of carbon credits to be generated in the property, the project will be canceled.

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