TERO.002 - REDD

VERSION 1.0

METHODOLOGY, AFOLU, REDD

TERO CARBON AVALIAÇÕES E CERTIFICAÇÕES LTDA

IDENTIFICATION

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BIOME	Amazon
ASSET GENERATED	Verified Carbon Credit (tCO_2e)
PROJECT ACTIVITY	Avoided Planned Deforestation (APD)

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
BGB	Below Ground Biomass
Btot	Total forest biomass (AGB + BGB)
CAR	Rural Environmental Registry
CND	Debt Negative Certificates
COP	Conference of the Parties
CO_2e	Equivalent Carbon Dioxide
DAP	Diameter at Breast Height /Diameter at 1.3 m from the ground
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
GPS	Global Positioning System
IBGE	Brazilian Institute of Geography and Statistics
IC	Confidence Interval
IFC	Continuous Forest Inventory
INCRA	National Institute of Colonization and Agrarian Reform
IPCC	Intergovernmental Panel on Climate Change
MDL	Clean Development Mechanism
MMA	Ministry of the Environment

MRV	Measurement, Reporting and Verification
SNIF	National Forestry Information System
OMM	World Meteorological Organization
ONU	United Nations Organization
PDD	Project Design Document
PF	Physical person
PJ	Legal person
REDD	Reduction of Emissions from Deforestation and Forest Degradation
REDD+	Reducing Emissions from Deforestation and Forest Degradation, including conservation and enhancement of carbon stocks
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 broadened to include approaches related to 'financial additionality', 'investment additionality' and 'technology additionality'."* These additional definitions mainly apply to the market concept established in the CDM.
Financial Additionality	Project funding is in addition to the available budget for the standard activity.
Additional Investment	The Reduced Emission Unit / Certified Reduced Emission value should significantly improve the financial aspect and/or commercial viability of the project activity.
Technology Additionality	The technology applied in the project activity must be the best available for the circumstances of the project site/region.
Allometry	Study of variations in the forms and processes of organisms. From the "whole" (carbon) to the "parts of the whole" (DAP, for example), that is, adjustment of mathematical equations (functions or models).
Brazilian Amazon	It comprises the entirety of the states of Acre, Amapá, Amazonas, Pará, Roraima, Rondônia and parts of the states of Maranhão, Mato Grosso and Tocantins.
Amazon Biome	The Amazon biome is characterized by tropical rainforests and rich biodiversity, covering a mosaic of phytophysiognomies, ecosystems, fauna and diverse microorganisms, including the Amazon basin, which exerts a great influence on water, making the biome one of the most diverse and of great economic interest on the planet.

Forest Biomass (IPCC, 2006)	Forest biomass is subdivided into three compartments: Total Biomass (Btot), Aboveground (AGB) and Belowground (BGB). 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. It can be given as "fresh" or "dry" 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.
Climate (IPCC, 2021)	Defined as the average of descriptive weather statistics over a period of at least 30 years, according to the World Meteorological Organization (WMO).
Carbon Credit (tCO_2e)	Financial, environmental, transferable assets representing the reduction, removal and avoidance of greenhouse gas emissions, represented by a ton of carbon dioxide equivalent (tCO_2e), which has been recognized and generated as credit in the voluntary or regulated market.
Avoided Planned Deforestation (APD)	Waive the right to carry out the vegetation suppression of the natural forest within the geographic limits of the Multiple Use Area (AUM), committing to a zero deforestation policy in the Project Area (PA).
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 through an estimated average, followed by its uncertainty margin, or in absolute terms, when referring to the total area. The carbon of living and dead trees, shrubs, palm trees and other plant organisms, in addition to carbon in soils, 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 minus the dead biomass (dead trees and litter). The stock is given in units of area, abbreviated by 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).

Forest	The definition of forests can vary by source. According to FAO and SNIF: *Forest is all vegetation that extends for more than 0.5 hectares (0.005 km²) and is formed by trees with a height greater than five meters, in addition to a canopy cover greater than 10%. Areas with different land uses, such as agricultural or urban areas, are not included in this definition.* According to IBGE: *The 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 synusia.*
Igapo Forest (Junk, 1993; Ribeiro *et al.* 1999)	Type of Amazon forest that is seasonally flooded by water from rivers and/or streams with black or clear water, such as the Negro and Tapajós rivers, respectively.
Floodplain forest (Junk, 1993; Ribeiro *et al.* 1999)	Type of Amazon forest that is seasonally flooded by water from rivers and/or streams with white or muddy water, such as the Amazon and Solimões rivers, respectively.
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 in charge of 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 the negative impacts resulting from negligence and/or omission.
IC (x %)	Confidence interval, at a probability of x%. Default probability levels: 90%, 95% and 99%.

Regular Property	The property needs to be duly documented and all zoning identified and established in the Rural Environmental Registry (CAR) and no overlaps with other areas, public or private
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 from or added to the mean. Uncertainty depends on the amount of data used, as well as the sampling methods.
Baseline	It is defined as a 'non-intervention' scenario, in which, in the absence of project implementation, what would be the most likely destination of the forest.
Forest Planting	Area of cultivation of tree species, either for the production of timber and/or non-timber products. It may consist of native or exotic species. Monocultures or mixed and/or hybrid systems.
REDD	Type of mechanism for generating carbon credits, through avoided emissions of Greenhouse Gases (GHG) from deforestation. Introduced at the United Nations Framework Convention on Climate Change (UNFCCC) discussions at COP 11 in Montreal (2005). It assumes four basic conditions/assumptions: I. Baseline - No 'project' scenario that would inevitably result in GHG emissions; II. Co-benefits - In addition to avoided emissions, what additional positive impact does the 'project' brings; III. MRV quantifications - Report carbon estimates clearly and with known levels of uncertainty; IV. Monitoring - 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 the sustainable management of forests and the conservation and enhancement of forest carbon stocks.
Forest Litter	It is the layer formed by the deposition of plant remains (leaves, branches) and the accumulation of living organic material in different stages of decomposition that superficially covers the soil or aquatic sediment.
Silviculture (Embrapa, 2023)	It is the cultivation of forests, natural and artificial, with the aim of restoring and/or improving the forest population, to meet specific market requirements.
Land Use, Land Use Change and Forestry	Anthropogenic activity in forested areas. Implement an economic activity on the 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.
Tero Platform	Technological platform developed by Tero Carbon to support the registration, certification and verification processes of projects that generate environmental assets.
Crediting Period	It is the time period in which environmental assets are generated, arising from the activities foreseen by this methodology.

I - SAFEGUARDS SOCIAL AND ENVIRONMENTAL ADOPTED

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

"Safeguards" shall be understood as guidelines that aim to enhance the positive impacts and avoid or reduce the negative impacts related to the project. Thus, 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 socio-environmental safeguards were defined. By decision 1/ CP. 16 countries, when implementing REDD+ activities, should promote and support:

I. Actions that are complementary or consistent with the objectives of national forestry programs and other relevant international conventions and agreements;
II. Transparent and effective national forest governance structures, bearing in mind national sovereignty and national legislation;
III. Respect for the knowledge and rights of indigenous peoples and members of local communities, taking into account relevant international obligations, national circumstances and laws and noting that the UN General Assembly adopted the United Nations Declaration on the Rights of Indigenous Peoples;
IV. Full and effective participation of stakeholders, in particular indigenous peoples and local communities, in the actions referred to in paragraphs 70 and 72 of this decision;
V. That the actions are consistent with the conservation of natural forests and biological diversity, ensuring that the actions referred to in paragraph 70 of this decision are not used for the conversion of natural forests, but rather to encourage the protection and conservation of natural forests and their ecosystem services , and to enhance other social and environmental benefits;
VI. Actions to address the risks of reversals in REDD+ results;
VII. Actions to reduce the displacement of carbon emissions to other areas.

Safeguards treatment is essential for REDD+. It was established in the UNFCCC that countries wishing to implement actions to reduce emissions in the forest sector must, among other requirements, implement a system of safeguards.

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 up to 2008, duly accredited by the current state environmental agency) will be considered AUM.

II.1 Permanent Preservation Area (APP)

According to Federal 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, the stability geology and biodiversity, facilitate the gene flow of fauna and flora, protect the soil and ensure the well-being of human populations.

It is considered APP margins of bodies of water, tops of hills, 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 Federal Law nº 12.651 of 2012 (New Brazilian Forest Code), the Legal Reserve Area (ARL) is the area located inside 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 with native vegetation cover, 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 property area . The precise and specific definition of ARL and its proportions by biome/region are established in Law nº 12.561/2012.

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

According to Federal Law No. 12,651 of 2012 (New Brazilian Forestry Code), “alternative land use” is the replacement of native vegetation and successor formations (suppression) by other land cover, such as agricultural, industrial,

generation and transmission activities energy, mining and transportation, 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 deforestation that exceeds the limits defined by law is subject to legal sanctions. However, in the past, due to the lack of control over the territory and the constant changes in legislation, many rural properties exceeded the limits allowed for alternative use.

To mitigate this issue, the term “Consolidated Area” was created. Based on Law n. 12,651 of 2012 (New Brazilian Forest Code), the Consolidated Area is the area of rural property with pre-existing anthropic occupation on July 22, 2008, with buildings, improvements or agrosilvopastoral activities, admitting, in the latter case, the adoption of the fallow regime .

II.4. Non-Forest Area

Any and all territorial extension that is not characterized as forest must be duly identified. The main classifications of 'non-forests' 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;
    - Distinct vegetational formations, shrubs and/or herbs (for example: mangrove, caatinga and cerrado).

III - CLASSES OF RURAL PROPERTIES

This methodology divides the size of rural properties into “classes”. The three “classes” of real estate are based on the “Amazonian superlatives”[1] and the size classification of rural properties by INCRA[2]:

- Small Property: that property with up to three thousand hectares (3,000 ha) will be considered;
- Medium Property: that property will be considered above and three thousand hectares (3,000 ha) up to twenty thousand hectares (20,000 ha);
- Large Property: over twenty thousand hectares (20,000 ha).

[1] The Legal Amazon covers a territory of approximately 5.4 million km². This represents just over 50% of the Brazilian territory. According to INCRA, “small properties” can add 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. OBJECTIVES

The objective of this methodology is to generate environmental assets in projects that promote Reduction of Emissions from Deforestation and Forest Degradation (REDD) in the Amazon Biome.

2. GENERATED ASSETS

The asset generated by projects that use this methodology is Verified Carbon Credit (in tons of carbon dioxide equivalent - tCO_2e) regarding the process of avoidance of Greenhouse Gas (GHG) emissions into the atmosphere. through the activity of Avoided Planned Deforestation (APD).

3. PLANNED ACTIVITY

The activity envisaged by this methodology is the Avoided Planned Deforestation (APD).

4. ELIGIBILITY

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

GEOGRAPHICAL BOUNDARIES	Boundaries of Project Areas (APs) need to be totally inserted in the Brazilian Amazon Region.
MOSAIC	Single or grouped of legitimate rural property within the same reference region.
TYPE OF RURAL PROPERTY	• Private rural property duly documented and regularized; • Government and/or private Conservation Units (UC) for Sustainable Use that have the prerogative to generate environmental assets.
TYPE OF FOREST	• Native natural forests, dry land (“Terra Firme”) and/or seasonally flooded areas (“igapó” and “várzea”); • Planted forests (forest planting), of native and/or exotic species.

MINIMUM PROPERTY SIZE	At least 5 ha (five hectares or 50,000 m²).
MINIMUM SIZE OF THE PROJECT AREA	At least 1 ha (one hectare or 10,000 m²) of forest.
REGULAR PROPERTY	The property needs to be duly documented and with zoning carried out in the Rural Environmental Registry (CAR) and no overlaps with other areas, public or private. It is also necessary to present a legal opinion on Land Due Diligence.
NO DOUBLE COUNT GUARANTEE	The project area cannot have a Carbon Credits project or any other asset linked to the Carbon environmental asset, registered and/or certified by another "standard/ methodology" in the same crediting period.
PROJECT ACTIVITY	It is necessary to perform at least one of the activities provided for in this methodology.

5. ADDITIONALITY

For the purposes of this methodology, it is understood that every private rural property in the Amazon Biome, whose land situation is duly regulated, has the prerogative of alternative land use[3], in up to 20% of the area of the property[4]

Thus, in the absence of a project such as the Reduction of Emissions from Deforestation and Forest Degradation (REDD), the existing forest outside the limits of the Legal Reserve Area (ARL) and the Permanent Preservation Areas (APP), that is, in the Multiple Use Area (AUM), would be deforested or degraded for the implementation of alternative land use.

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

6. PERMANENCE

This methodology understands that the risk of permanence is inherent and consequent to Public and Market Policies. The risk of permanence during

[3] Federal Constitution of 1988, paragraph 4, of Art. 225 of Chapter VI - The environment.
[4] Brazilian Forest Code, Law No. 12.651 of May 25, 2012.

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

Tero Carbon only issues “verified carbon credits” certificates after verification of compliance with the project objective, that is, zero deforestation.

That way, every carbon credit issued by the present methodology is guaranteed that the carbon remains in the forest biomass during the commitment period.

7. SAFEGUARDS

All projects certified and verified by this methodology must meet the internationally recognized Safeguards described in this document. In this sense, the project it cannot:

1. Break the Law;
2. Compromise the integrity of the environment;
3. Disrespect and fail to preserve the rights of traditional populations and/or minority communities;
4. Generate assets whose activities are the result of a court order or resulting from a Conduct Adjustment Term, required by the responsible government body;
5. Implement additional or concomitant projects to the carbon project that may compromise any of the aforementioned safeguards.

8. TEMPORAL BOUNDARIES

8.1. Project Duration Period

The duration of the project (T), that is, the time of commitment to the project's objective (maintenance of standing forest and "zero deforestation") varies according to the class of rural property, as follows:

Rural Property Size	Project Duration Period (T)
Small	1 (one) year
Medium	5 (five) years
Large	10 (ten) years

8.2. Start Date of the Project

The start date of the project corresponds to the Project Certification date.

8.3. Retroactivity

This methodology does not consider retroactive periods from the date of certification of the project.

8.4. Crediting Period

The Crediting Period corresponds to the period of the asset's acquisition, which represents a period of time of one (1) year, minimum, between the date of the project's Certification ($Date_{T0}$) and the subsequent Verification ($Date_{Tn}$).

For projects at Medium and Large areas, this period can correspond to the year between two Verification dates ($Date_{Tn-1}$ and $Date_{Tn}$)

$$First\ Crediting\ Period = Date_{T0}\ to\ Date_{Tn}$$

$$Subsequent\ Crediting\ Periods = Date_{T(n-1)}\ to\ Date_{Tn}$$

where:

$Date_{T0}$ = Date of Certification;
$Date_{Tn}$ = Date of Verification;
$Date_{Tn-1}$ = Date of previous Verification;
n = 1, 2, 3... 'n' years after the first Verification date, which varies from 1 to n, depending on the time life of the project.

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

9. PROJECT PARTICIPANTS

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

PROPONENT	The responsible for the environmental assets generated in the rural property: ● It can be Individual (PF) or a Legal Entity (PJ); ● Must be the legal representative of the owner of the rural property OR the owner; ● In case the rural property has more than one owner or the project is a "mosaic of multiple owners": ○ Present the Term of Free and Informed Consent (TCPLI) of all those responsible for the property(s); ○ The legal representative must be duly documented and notarized. ● Must be residing/installed in Brazil.
DEVELOPER	The responsible for the development of the project, registration of the project on the Tero Platform, coordination of the Technical Team(s) etc., considering that: ● It can be Individual (PF) or Legal Entity (PJ); It is ● There must be only 1 (one) Developer for each Project.
IMPLEMENTER (PROJECT MANAGER)	The responsible for project governance during the Crediting period. It is up to the Project Manager to execute and/or coordinate the activities foreseen in the methodologies.
TECHNICAL TEAM	The responsible for collecting primary data (Sample Forest Inventory for Estimating the Carbon Stock) in the project area and/or activities related to socio-environmental, responsible for preparing the Term of Free and Informed Consent (TCPLI) or any other technical activities related to the project, and : ● It can be Individual (PF) or Legal Entity (PJ); ● There can be more than one entity in each project; It is ● There may be a Technical Team in each primary data collection (Sample Forest Inventory).

10. RURAL PROPERTIES

This methodology foresees carbon projects with one (1) or more (mosaic) rural properties.

10.1. Types

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

1. Private rural properties; or
2. Government and/or private Conservation Units (UC) of Sustainable Use that have the prerogative of alternative land use.

10.2. Geographic Boundaries

Rural properties must be fully included in the Geographical Scope: Amazon Biome.

10.3. Limits of Territorial Extension

Rural properties 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.

10.4. Land Due Diligence

Rural properties need to be regular, both at the time of Certification and in all Verifications. In order to reduce the risks of fraud, for the Certification Process, in addition to legal documentation, it will be requested a third party verification of the Land Due Diligence.

10.5. Owners' Consent or Free and Informed Consent

In the case of private rural properties, it is necessary to present a Term of Free and Informed Consent from the owners of rural properties, declaring their intention to use the property, by their own free will, to carry out the REDD Project.

In the case of a Conservation Unit (UC), proof of workshops and/or collective meetings with local communities leaders and/or population (if any) will be required, in addition to the presentation of a document attesting to the free and informed prior consent for carrying out the REDD Project in the project area.

10.6. Zoning of the Rural Property

Rural properties need to have their zoning defined and duly registered in the Rural Environmental Registry (CAR), in the case of being a private property. For Conservation Units (CU) the boundaries of the property have already been defined and registered with the competent bodies. The property must have its spatial boundaries defined as follows:

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

The map in Figure 1 shows an example of zoning of a mosaic of rural properties in the Amazon Biome.

Figure 1. Example of zoning of a rural property.

10.7. Project Area (AP)

The boundaries of the Project Area (PA) must be determined and identified by the Project Proponent and registered on the Tero Platform and may encompass all forest areas, including: APP; ARL and AUM.

It can be a portion or the totality of the AUM.

NOTE: Once the project is registered and certified, it must honor the "Zero Deforestation Commitment".

10.8. Zero Deforestation Commitment

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

NOTE: 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.

10.9. Sampling Forest Inventory to Estimate the Carbon Stock in the Project Area

For the Certification process, it will be necessary to present the Sampling Forest Inventory (IFA) worksheets for estimating the Carbon Stock in the Project Area (PA) in the standard established by Tero. The IFA has a validity of 5 (five) years, it is necessary to be renewed after this period. This implies the need to present new data collected in any Verification Processes.

NOTE: Secondary data will only be accepted as a complement, not being used to calculate the carbon stock.

11. BASELINE

The Baseline of Planned Avoided Deforestation (LB_{APD}) of this methodology assumes that the forest within the AUM would be deforested and/or degraded for the implementation of alternative land use activities. Thus, the carbon stored in the biomass of this forest would be 100% emitted in the

form of carbon dioxide equivalent (CO_2e) linearly over time. The emission time interval varies according to the size of the area, in hectares.

In this way, the scenario of LB_{APD} would result in GHG emissions as follows (mathematically), for each of the properties in the project:

$$ELB_{APD} = \sum_{t=1}^{T} \frac{(AP \times (Ctot - I.C.))}{T}$$

where:

ELB_{APD} = CO_2 emission and in the ODA Baseline scenario, in tons of carbon dioxide equivalent;

$\sum_{t=1}^{T}$ = Sum of emissions at time "T", for integer values of "t", of the crediting period;

AP = Project Area, in hectares.

Ctot = Estimated average carbon stock, in tons of carbon dioxide equivalent per hectare ($tCO_2$and has);

IC = Confidence interval for estimating the mean, in tons of carbon dioxide equivalent per hectare (tCO_2 and has);

T = total project time period, in whole years.

11.1. Avoided Planned Deforestation (APD)

In the Amazon, the minimum area allocated to the Legal Reserve Area (ARL) is 80% of the property. Therefore, within the registration of the property, it is possible to delimit up to 20% of the property area as Multiple Use Area (AUM). In this area it is possible to implement an alternative land use activity.

The main activities in the region include: i. beef cattle for beef; ii. cassava cultivation.

The dynamics of land use change (deforestation) is standard. It begins with the selective logging of specific tree species, followed by suppression of the remaining vegetation and, finally, with slash-and-burn of the biomass (ASNER *et al.* 2005; FERNSIDE, 2006; SOARES-FILHO *et al*. 2006; SARAIVA, 2022).

From the suppression process, all the carbon stored in that forest is emitted into the atmosphere, in the form of carbon dioxide equivalent (CO_2e).

The average carbon stock in the target forest of the project must be estimated based on the forest inventory of the Project Area.

The area eligible for the generation of credits for each of the rural properties is called the Project Area (AP), it must be within the limits of the AUM, or its entirety. It must be covered with forests and discounted from APPs and other land uses.

Mathematically:

$$AP = AUM - APP - A_{Anthropized'}$$

where "$A_{Anthropized}$" is an area of alternative land use already implemented before the REDD Project.

By ensuring the maintenance of the forest standing, for the commitment period (crediting period), the proponent generates credits for avoiding the emission of Greenhouse Gases (GHG).

11.2. Legal substantiation

Paragraph 4 of Art. 225 of Chapter VI - The environment - the Brazilian Constitution of 1988 establishes that the Brazilian Amazon forest is national heritage and its use will be made, in accordance with the law, under conditions that ensure the preservation of the environment, including the use of natural resources.

The new Brazilian Forest Code, Law No. 12,651 of May 25, 2012, provides for the protection of native vegetation and amends three laws and revokes two laws and one provisional measure.

The Forest Code establishes the limits and extensions of the Permanent Preservation Areas (APP) and Legal Reserve (ARL) in all the country's biomes.

For the Amazon, it is established that each and every private rural property must register 80% of its area for the RL. It presents guidelines on the use and exploitation of forest products.

At the State level, the environmental licensing process for alternative land use activities, in up to 20% (twenty percent) of the total property area, is governed based on state laws:

- Amazonas: Licensing Law n. 3,785, of 07/24/2012.
- Acre: IMAC Ordinance n. 27, from 04/12/2021; CEMACT Resolution n. 3, of 06/27/2008
- Amapá :Procedures, according to MMA
- Pará: Procedures, according to MMA
- Rondônia: Procedures, according to MMA
- Roraima: Procedures, according to MMA.

12. QUANTIFICATION

This section presents the method of quantifying forest carbon stocks and credits accepted by this methodology in order to meet international standards for Measurement, Reporting and Verification (MRV).

12.1. Guidelines for Collecting Primary Data and Estimating Carbon Stock in Forests

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

- Sampling distribution system of fixed area sampling units (plots);
- All plots must have their geographical coordinates recorded using GPS signal receivers:
    - The points to be registered can be the beginning, center or end of each sample;
    - However, for the submission of these data, it is recommended to generate plot polygons;
    - When using a GPS navigation device, the recommended coordinate recording method is:
        - Keep the GPS signal receiver device parked at the specific point for a period of approximately 1 (one) minute;
        - Use the “point average” tool for a period between 2 (two) and 5 (five) minutes.
- Random, systematic sampling distribution or combination through conglomerates (transects or cross type);
- Measurement of the diameters at 1.3m from the ground (DBH) of all living and dead trees found within the plot:
- The minimum measurement DBH is 10 cm;
- Palm trees are not a required class
    - Can be included, but the allometric equation must be specific.
- Application of the biomass/carbon equation to estimate the individual stock (of each measured tree) and per unit area (hectare):
    - The individual biomass/carbon of the trees should be estimated, preferably, by means of specific site equations;
    - If the individual biomass/carbon of the trees is estimated based on Silva's (2007) equation, the estimate must be corrected by the correction factor based on the dominant height (Hdom) of the forest.
- Estimate the average ($\bar{x}$) and the level of uncertainty of the estimate (I.C.), based on the statistical parameters described in Annex I;
- If the forest in the Project Area needs to be stratified, follow the

stratification procedure available in Annex I.

12.2. Quantitative Sample Forest Inventory

The guidelines for the quantitative Sample Forest Inventory (IFA) for collecting the primary data used in the quantification of 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, through fixed area sampling units (see Annex I);
- Measurement of dendrometric variables, such as: diameter at 1.3 m from the ground (DBH):
- Heights (full and/or bole) are optional.
- Estimation of biomass and carbon stocks:
    - AGB = required;
    - BGB = optional;
    - Btot = optional.

12.3. Calculation of Forest Carbon Stock 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 components of the project's forest biomass:
    - Above ground (AGB);
    - Below soils or roots (BGB);
    - Total (GTC + 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 stock average per unit area (hectare) with its respective level of uncertainty (confidence interval - CI);
- Multiply the minimum estimate (mean - confidence interval) of the stock and the Project Area (PA):

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

where:

$\overline{x_{CO2}}$ = Estimated average stock of carbon dioxide equivalent, per hectare, in tons;

IC = Confidence interval, calculated at a probability level of 95%;

AP = Project Area, in hectares.

12.4. Calculation of Forest Carbon Stocks With Statistically Defined Strata

Analogously to the previous item, for the case with statistically defined strata, the guidelines are as follows:

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

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

$$net\ stock_{AGB} = \sum AGB_{lives} - \sum AGB_{necromass}$$

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

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

where:

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

12.5. 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 of the ANNEX I of this methodology.

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

I. 68.27% between plus or minus 1 standard deviation from the mean;
II. 95.45% between plus or minus 2 deviations; It is
III. 99.73% between plus or minus 3 deviations.

The exact multiplier of the standard deviation of the mean for the rounded levels of 95 or 99% can be found by integrating the probability density function up 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 reporting purposes of 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.[5]

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

12.6. Calculation of the Annual Carbon Credit Generated

The generation of annual carbon credits is based on the crediting period, depending on the size of the property:

$$Annual\ generation\ = \frac{carbon\ credit}{T(years)}$$

Where T is the duration of the project.

13. ADDITIONAL BENEFITS (CO-BENEFITS)

The additional carbon benefits, or co-benefits, for projects whose methodology is REDD, is the conservation and preservation of the greatest biodiversity land of the planet, that is, it is the guarantee of maintenance of the evolutionary cycles of biodiversity.

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

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

13.1. Qualitative Forest Inventory (Optional)

The guidelines for the Qualitative Forest Inventory for collecting the primary data used in the presentation of co-benefits 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);
- Botanical sampling, with the collection of specimens of the sampled tree species (samples can be deposited in herbariums).

14. GOVERNANCE

The project must present how the Governance of the rural property will be carried out, aiming at the Avoided Planned Deforestation (APD) activity. It is indicated to physical identification, on the property, at the access point, that that area is destined for a REDD project.

Minimal interventions are also suggested, such as, but not only:

- Installation of infrastructure as headquarters/support base for project activities;
- Installation of fences and signs around the perimeter of the property and/or Project Area;
- Implementation of monitoring and surveillance system *in place*, with rounds and periodic 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 allowed during the crediting period.
- Alternative land use activities, through the implementation of agro-silvo-pastoral production systems, in the Project Area will not be allowed 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); It is
- 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; It is
- 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; It is
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; It is
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; It is
$Hdom_{ZF2}$ = 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 m² and 2,500 m², 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	$s^2 = \frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1}$
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	$SQC_{and} = \sum_{i=1}^{n} and_i^2 - \frac{\left(\sum_{i=1}^{n} a$
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; It is
  - 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; It is
  - 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; It is
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; It is
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	$\overline{x}_{st} = \sum_{h=1}^{L} In_h \bar{x}_h$
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; It is
“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**	-	-	-	-

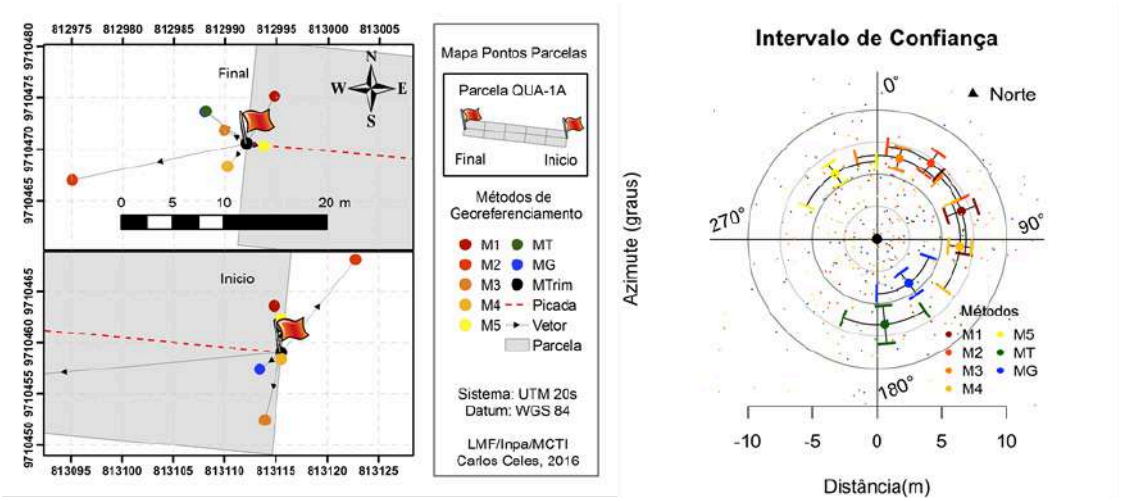

Figure 2. Map showing the different methods of positioning the initial and final points of the plot (left) and graph showing the mean and confidence interval of each georeferencing method of the plot (right).

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.

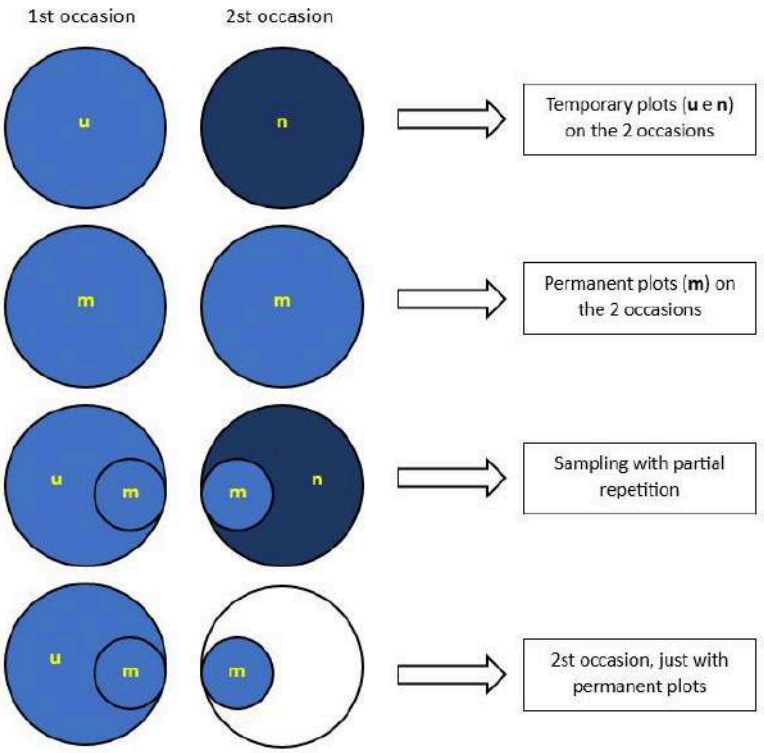

Figure 3. Illustrative scheme of the four types of continuous sampling processes.

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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