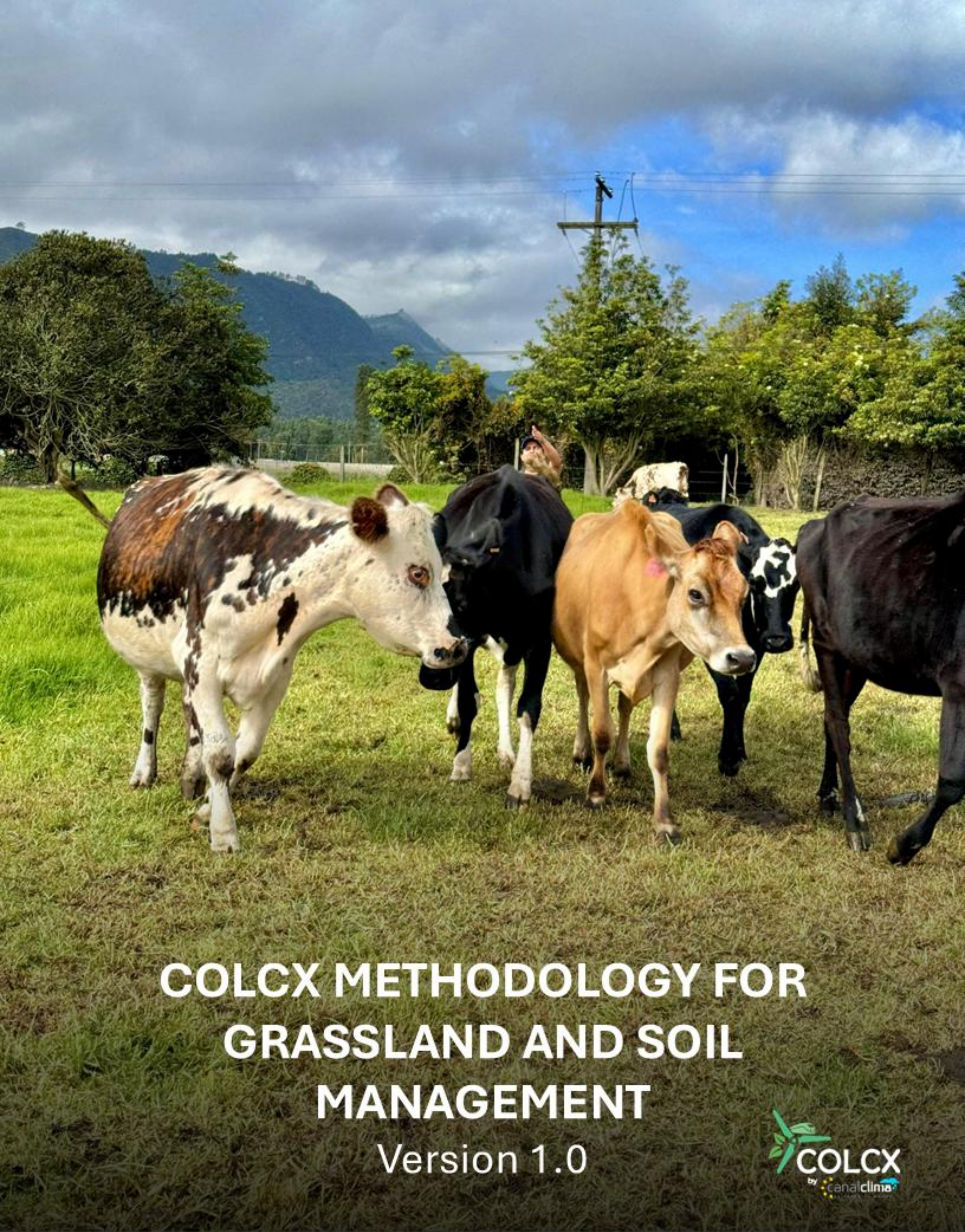

COLCX METHODOLOGY FOR GRASSLAND AND SOIL MANAGEMENT

Version 1.0

COLCX
by canalclima

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Consultants:

Juan Daniel Melendez Chapetta
Nicolas Andrés Canaria Cotacio
Andrés Abondano Pineda

Organizations:

Caja de Herramienta
CO2CERO SAS
Fundación para la Conservación y el Desarrollo Sostenible FCDS

ACRONYMS

ISMC	Internal Sanitary Movement Certificate
ICA	*Instituto Colombiano Agropecuario* (Colombian Agricultural Institute)
IDEAM	*Instituto de Hidrología, Meteorología y Estudios Ambientales* (Institute of Hydrology, Meteorology and Environmental Studies)
MRV	Monitoring, Reporting and Verification
GHGMP	Greenhouse Gas Mitigation Project
SRLH	Sanitary Registration for Livestock Holding
UVR	Unified Vaccination Registry
ISRAP	Information System for Rural Agricultural Planning
UPRA	*Unidad de Planificación Rural Agropecuaria* (Rural Agricultural Planning Unit)
PAA	Project Analysis Area

1 DEFINITIONS

Replacement Animal: An animal raised to replace other productive animals that are expected to be removed from the herd or flock.

Gross Energy: The total caloric energy contained in the feed, measured in units such as MJ/kg.

Net Energy Requirement for Maintenance: Represents the amount of net energy required to keep the animal in balance, without weight gain or loss.

Nitrogen-Fixing Species: Plants that are associated with nitrogen-fixing microbes in their roots, such as soybean and alfalfa.

Enteric Fermentation: Digestive process in ruminants where microbes break down feed in the rumen, producing methane as a by-product.

Methanogenesis: Anaerobic formation of methane in the rumen by microorganisms known as methanogens.

Enteric Methane: Methane emissions from ruminants due to the enteric fermentation of feed.

Improved Agricultural Land Management Practice: An agricultural practice that increases soil carbon storage or provides another climate benefit, such as improved fertilization, water management, or cropping techniques.

Rotational Grazing: Alternating grazing paddocks with rest periods to allow vegetation recovery, enhancing above- and below-ground biomass and supporting soil carbon retention.

Regenerative Grazing: Use of high instantaneous stocking densities with short grazing periods, mimicking natural herbivory patterns. This stimulates deep root growth, improves water infiltration and organic matter accumulation, reduces erosion, and supports biodiversity.

Deferred Grazing: Exclusion of certain areas from grazing for extended periods to allow the regeneration of perennial forage species, improving vegetation cover and soil stability.

Herd: Animals on a farm, grouped according to homogeneous characteristics such as type of animal, weight, production stage, or feeding regime.

Ruminant: Mammal with a digestive system adapted to form a rumen, including species such as cattle, goats, and sheep.

Overgrazing: Grazing resulting in permanent changes to plant species and reduction of ground cover.

In addition to the definitions mentioned above, the GHGMP should consider the *Guide of Terms and Definitions COLCX* in its most updated version.

2 OBJECTIVES

To provide a methodology for project holders and proponents involved in grassland and soil management activities on livestock farms that increase soil organic carbon content and promote the removal and/or reduction of GHG[1].

- Establish project eligibility criteria and quantification parameters in the baseline scenario.
- Quantify GHG associated with grassland and soil management, and livestock activities.
- Provide guidelines on means of tracking and monitoring carbon sources and reservoirs within the project boundaries.

3 TECHNICAL AND REGULATORY REFERENCE FRAMEWORK

The methodology contemplates the following documentary framework:

- The United Nations Framework Convention on Climate Change (UNFCCC) guidelines for the reduction of GHG emissions.
- ISO 14064-2: 2019 guidance for the development of GHG mitigation and removal projects.
- COLCX program guidelines.
- The Grass for Carbon Methodology developed by Farm & Forestry Management Services SRL.

This methodology provides the different actors involved in GHGMP related to grassland and soil management focused on livestock production with the following elements:

- Requirements for the identification and selection of GHG sources and reservoirs.
- Criteria to evaluate and define livestock practices, soil organic carbon status and plant biomass preliminary to the implementation of the GHGMP.
- Describes procedures for evaluating and quantifying GHG reductions and removals resulting from the implementation of the GHGMP.
- Defines the procedures and tools necessary for monitoring and follow-up of the GHGMP.
- Establishes mechanisms to assess and quantify potential carbon leakage that may occur because of project implementation.

The GHGMP must evaluate and apply the sectoral regulations of the host country where the initiative is developed, demonstrating that the application of one of these regulations is not prevented when developing the GHGMP.

[1] This methodology is not applicable to REDD+ or ARR projects. Its scope is limited to grassland and soil management activities on livestock farms, thus avoiding any confusion about its use in other mitigation approaches.

4 SCOPE OF THE METHODOLOGY

The methodology guides the proponent/holder of the GHGMP in the quantification of GHG emission reductions/removals on livestock farms through sustainable pasture and soil management. This methodology addresses the following key areas:

- **Applicable Activities:** Guidelines are established for the development of the GHGMP focused solely on the implementation of sustainable grassland management practices, such as rotational grazing and/or the establishment of improved forage species.
- **Strengthening MRV processes:** Incorporates procedures for the measurement, verification and monitoring of GHG emissions for the quantification of the project's COLCERS.
- **Promote animal welfare:** Provides guidelines to ensure the protection and welfare of animals during project implementation.

5 APPLICABLE ACTIVITIES

The GHGMP that can apply this methodology belongs exclusively to the Agriculture and Livestock sectors, which includes at least one of the following activities:

I. Improved grazing and livestock management practices focused on improving soil fertility and soil degradation and optimizing nutrient cycling.

The GHGMP implements one of the following activities:

a. Optimized forage management and grazing planning.
b. Efficient water management, shade provision, stocking rate control and/or improved paddock infrastructure (See Annex 1).
c. Sustainable grazing practices (e.g., rotational, regenerative, deferred grazing, among others), which optimize regeneration of degraded grasslands, improves soil carbon sequestration and reduce soil compaction.

II. Silvopastoral activities

GHGMP generates integration of trees and grazing to improve animal welfare and carbon sequestration.

III. Crop Rotations and Agroforestry

The GHGMP implements one of the following activities:

a. Include native or naturalized perennial species with no invasive potential, adapted to the local conditions of the GHGMP
b. Crop planning and rotation are improved and/or agroforestry systems are implemented, which optimize biomass production and soil regeneration

c. Priority is given to the inclusion of perennial forage species, cover crops and/or legumes that contribute organic matter to the soil, improve nutrient availability and contribute to livestock feed.

IV. Reduction of emissions from fossil fuel combustion

The GHGMP reduces tillage and the use of agricultural machinery that requires fossil fuels.

V. Improvements in Water/Irrigation Management

The GHGMP implements one of the following activities:

a. Efficient irrigation systems (e.g., drip irrigation, humidity sensors, among others), which improve water efficiency in the GHGMP

b. Rainwater harvesting and use systems that minimize the consumption of potable water, reducing dependence on conventional sources

6 APPLICABILITY CONDITIONS

This methodology is applicable to projects developed under the following conditions:

- GHGMP implements at least one of the activities mentioned in Section 6. APPLICABLE ACTIVITIES .
- The owner(s) of the property(ies) where the GHGMP is implemented own the extent and right to use the land. The properties must not present disputes or other legal conflicts. If one or more properties have legal land transfer practices, such as leases or other agreements, they will be valid if they cover the accreditation period of the initiative and the legal regulations of the host country.
- GHGMP's activities are carried out in accordance with the current regulatory framework of the host country where the initiative is being developed, thus avoiding any violations of the law. In addition, GHGMP follows the orientations and guidelines established by the competent agricultural authorities, which are supported respectively (e.g., sanitary registration, vaccination registration, sanitary guides for the internal movement of animals, among others).
  GHGMPs that apply biochar as a soil amendment are applicable, as long as the total organic carbon content of the biochar is discounted to the change in SOC in the project scenario.
- In situations where the causes are external or force majeure, it must be demonstrated, through a situational analysis, that the problem is generalized in more than 30% of the project area, and that the causes that generate it are common. All information supporting such generalized problems, together with the solution mechanisms, will be accepted by the VVB.
- The GHGMP does not present a productivity loss of more than 8% compared to the historical reference period because of the implementation of the project activities. The evaluation of productivity must be demonstrated according to the guidelines of

Equation 35. If the loss of productivity is caused by external agents such as extreme weather events, official evidence must be presented to justify the occurrence of the event.

This methodology is NOT applicable to projects developed under the following conditions:

- The GHGMP area has been transformed, generating the loss of native ecosystems such as natural forests in different stages of succession, natural savannas, wetlands, paramos, natural grasslands, shrublands and/or natural covers that provide key ecosystem services such as water regulation, carbon sequestration and biodiversity during the 10 years prior to the start of the initiative[2].
- The GHGMP is implemented in wetlands or RAMSAR sites. This condition does not exclude crops subject to artificial flooding, if it is demonstrated that the crop does not affect the hydrology of nearby wetlands or areas that have organic soils, such as moorlands and mangroves, which contain soils with high organic matter content.

Each of the items described above must be supported by traceable and verifiable information.

7 SOIL DEGRADATION ASSESSMENT

The GHGMPs that are implemented in degraded soils must demonstrate this characteristic through the reduction of SOC levels considering:

1. **Historical soil analysis**: Use of data from scientific studies, soil inventories, institutional records, among others that show the decrease of SOC in the GHGMP area.

2. **Land management records**: Land management records: History of land use and pre-project management practices, such as overgrazing, intensive tillage, and removal of vegetation cover, that contribute to SOC loss. This information may be obtained from landowner records, local interviews, technical documents, among others.

This analysis should be consistent with what is described in section 0.

8 TEMPORAL AND SPATIAL LIMITS

This chapter establishes guidelines related to the credit period of the GHGMP, as well as the spatial limits that define the effective area of evaluation of the COLCERS during its implementation.

[2] The multi-temporal coverage analysis should be carried out considering the official coverage classification of the host country where the GHGMP will be developed.

8.1 Time limits

The time limits of the project must be defined from the structuring of the GHGMP, and be reported in the documentation prepared by the initiative (PDD, MR, among others), considering the following aspects:

- **Start Date:** Exact date (dd/mm/yyyy), when the project activities were established. This must be objectively supported with traceable and verifiable documentation. Some examples of documents that support the start of the GHGMP are contracts for land preparation, evidence of the establishment of activities, purchase of inputs, among others. The retroactivity period of the project must contemplate the guidelines of the ColCX Standard for the certification of mitigation initiatives in its most updated version.
- **Accreditation period:** 0 years in accordance with the guidelines of the ColCX Standard for the certification of mitigation initiatives in its most current version.
- **Historical reference period:** Corresponds to the three years prior to the start date of the project, defined as t = -3. Based on this, the baseline scenario is identified, the pre-existing land use and management practices are identified.

8.2 Spatial limits

The spatial boundaries correspond to each of the areas involved in the implementation and quantification of the GHGMP COLCERS. These boundaries include:

- **GHGMP Area**
- **Project Analysis Area**

Each of these must be available in vector format (shape, KML or similar), including attributes such as area, perimeter, production type, carrying capacity and a unique identifier for each project area.

8.2.1 GHGMP Area

This refers to the amount of land on which the proponent has the legal right of tenure and use, allowing it to carry out activities related to grassland and soil management and sustainable livestock production. The rights must be in force from the start of the project and during the implementation of the GHGMP. The following criteria should be considered to identify and establish this spatial limit:

- **Identification of properties:** Unique identifier, name of the property and/or area involved in the GHGMP.
- **Current land tenure status:** Description of the current land tenure status and legal ownership of the territory, according to the host country's formal ownership documents. This information should be updated and adequately documented.

- **Participants and responsibilities:** Complete list of all participants and roles in the project. This includes names, company name of each participant, identification number, contact number and email address.
- **Area:** Land surface expressed in hectares, available in vector formats compatible with a GIS (e.g., .shp, Geopackage, KML, among others).

8.2.2 Project Analysis Area

To document the real impact of the project it is necessary to have a project analysis area (PAA), this limit allows the collection of data for the delimitation of the baseline. There are two alternatives for delimiting the PAA, which must be reevaluated each time the project's credit period is renewed.

8.2.2.1 Alternative 1

In this alternative, the PAA must be delimited in an area different from the properties participating in the project; it must not coincide or overlap with the project area, with its implemented activities or with other registered GHGMP. The GHGMP must consider at least the following similarity criteria:

- Soil characteristics (composition, load-bearing capacity and type of soil).
- Ecosystem type and ecological structural and functional criteria of the ecosystem.
- Landscape types, topography, and geographic units
- Administrative boundaries considering maximum scale municipality or its equivalent in the host country where the GHGMP is developed.
- Elevation and slope
- Current land use
- Soil management practices
- Historical land use during the historical reference period (t = -3)
- Land tenure (public, private and/or community)
- Productivity expressed as yields in commodities production [3].

Each of the above criteria must be duly supported by cartographic information. The areas corresponding to the PAA resulting from this step must have a maximum variation in each criterion of no more than **±15%** with respect to the project area. Finally, it is important to mention that the PAA must exclude areas with recent events such as deforestation or drastic changes in land use during the historical reference period. The area resulting from this analysis corresponds to the PAA.

[3] Commodities are standardized products that are traded in large volumes in domestic and international markets. In the agricultural, livestock and forestry context, they include goods such as grains (corn, wheat, rice), livestock products (milk, meat) and timber or other forest products. Their main characteristic is that they are interchangeable, with little differentiation between the products of different producers, and their price is generally determined by supply and demand in global markets.

8.2.2.2 Alternative 2

This alternative will be valid only in case of not being able to access direct data collection in the PAA identified in section 8.2.2.1, because they are private properties. In this alternative, the PAA corresponds to areas within the property(ies) involved in the GHGMP where no activities will be implemented, i.e., areas not included within the project area. Its extension must correspond to a percentage between 1 and 5% of the eligible area of the GHGMP. This reserved area will not be subject to project activities and will be used exclusively for baseline data collection. Its size must ensure a statistically significant sampling with respect to the total project area.

The project proponent must justify the selection and validity of the PAA based on similarity to pre-existing conditions in the project area, following Step 1 of section 8.2.2.1.

8.2.3 Significance of samples in the PAA

To determine the number of sampling units needed to quantify the existing carbon in the project reservoirs, as well as the emissions attributable to the GHGMP according to section **¡Error! No se encuentra el origen de la referencia.**, it is essential to perform a statistical analysis. Therefore, the GHGMP must comply with a sampling error of no more than 10% of the average carbon value, with a confidence level of 95%.

8.2.4 Calculation of average carbon in the historical reference period

Once the PAA is delimited, the GHGMP must calculate the average carbon in the historical reference period in the reservoirs contemplated by the initiative in accordance with section **¡Error! No se encuentra el origen de la referencia.** of this methodology. For this purpose, GHGMP may use the following models:

1. **Linear Average.** It can be used only if the data collected from the reservoirs during the historical reference period shows a stable trend.
2. **Nonlinear Simulation Models.** Nonlinear Simulation Models. If significant variations in reservoir data are observed in the historical reference period, a nonlinear model must be built to capture these fluctuations. The GHGMP must demonstrate by means of the necessary statistical estimators that it has a good level of prediction from the respective statistics (AIC, R2, F1-Score, RMSE, among others).

As a result of the calculation of the average carbon in the historical reference period, the GHGMP must obtain an annual value of carbon in the reservoirs in the absence of the project, thus facilitating a comparison between the scenario without intervention and the projected scenario after the implementation of the project.

8.3 Grouped projects

For a GHGMP to be considered as a grouped project, it is necessary to establish an expansion area that meets at least the homogeneity criteria defined in Step 1 of section 8.2.2.1. These criteria ensure that the expansion area is similar and allow for the uniform implementation of sustainable livestock practices. As in the process for determining the PAA, the expansion area can have a maximum variation of ±15% with respect to each criterion, thus ensuring uniformity in its implementation and results. If the GHGMP implements other criteria for the delimitation of the expansion area, these must be established during validation in the corresponding PDD.

Each of the areas included in the subsequent project certifications must have a description showing how these areas meet the validated grouping criteria and comply with the maximum retroactivity allowed by the COLCX program. To ensure that the evidence provided is objective and robust, it must include spatial data[4] from reliable sources, such as GIS studies or satellite imagery, technical and/or scientific studies, reports of pre-existing management activities, and reports of the project's management activities.

9 GHGMP RESERVOIRS

The GHGMP must consider the change in carbon reservoirs after the adoption of soil and pasture improvement activities. The reservoirs should be the same in both the baseline scenario and the project scenario, to generate a comparable quantification, monitoring and verification process.

A reservoir may be considered significant when it contributes more than 5% of the total GHGMP removals compared to the baseline.

Table 1. Eligible reservoirs in baseline and project scenarios

Reservoir	Included/excluded	Justification
Aerial herbaceous biomass (AHB)	Optional	May be included if coverage changes are significant compared to the baseline.
Belowground Herbaceous Biomass (BHB)	Excluded	It is not considered a carbon reservoir with significant changes after implementation of project activities.
Aboveground woody biomass (AGWB)	Optional	It should be included if coverage modifications generate significant increases compared to the baseline.

[4] It is important to clarify that the expansion area and, consequently, the project area should not be within the area of influence defined to establish the baseline scenario of the initiative.

Reservoir	Included/excluded	Justification
Belowground Woody Biomass (BGWB)	Optional	Include it whether changes in coverage result in significant increases compared to the baseline.
Soil Organic Carbon (SOC)	Included	Main carbon reservoir from project activities, expected to increase in the scenario with project.
Dead Wood (DW)	Excluded	The carbon reservoir is not expected to change significantly after implementation of the project activities.
Litterfall (LT)	Excluded	The carbon reservoir is not expected to change significantly after implementation of the project activities.

10 GHGMP EMISSION SOURCES

The project proponent must quantify the increase or decrease in GHG emissions that are considered significant because of project activities. According to the above and taking into account IPCC guidelines, livestock production may result in GHG emissions associated with the enteric fermentation process (CH_4), manure management (N_2O and CH_4), fertilization (N_2O) and liming (CO_2) for soil and pasture management, and fossil fuel combustion (CO_2, CH_4 y N_2O), due to the transport activities of the goods required to develop this type of practices, as well as for their subsequent commercialization (IPCC, 2019).

A GHG emission source may be considered non-significant when it represents less than 5% of the total GHGMP emissions compared to the baseline scenario.

Table 2. Emission sources included in or excluded from the baseline and project scenarios.

Emission source	Gas	Included /Excluded	Justification
Fossil fuel combustion	CO_2	Included	Main gas resulting from fossil combustion process
	CH_4	Excluded	Emissions are insignificant
	N_2O	Excluded	Emissions are insignificant
Biomass burning	CO_2	Excluded	It should be considered as a change in carbon assets

Emission source	Gas	Included /Excluded	Justification
	CH_4	Optional	Biomass burning generates Methane and Nitrous Oxide emissions, quantification should include whether the project activity reduces or increases emissions with respect to the baseline scenario by ± 5%
	N_2O	Optional	
Fertilizer application by soil management	N_2O	Optional	Include whether fertilization activities with nitrogen (N) containing inputs are carried out within the project boundaries.
Application of lime for soil management	CO_2	Optional	It must be included when liming occurs in the baseline scenario or when the activity is intensified in the project scenario.
Use of nitrogen-fixing species	N_2O	Optional	Include whether nitrogen-fixing species are present within the project boundaries
Enteric fermentation	CH_4	Included	Main gas resulting from the methanogenesis process in the rumen of cattle
Manure management	CH_4	Included	Significant emissions generated by volatile solids contained in cattle manure
	N_2O	Included	Significant emissions generated by volatile solids contained in cattle manure

11 BASELINE SCENARIO

The baseline scenario is the description of grassland and soil production and management activities in the area of the initiative in the absence of its implementation. The baseline scenario should consider the estimation of carbon stocks accumulated in the selected reservoirs and the estimation of GHG emission sources represented in tCO_2e.

In case the livestock land use is more than 65% representative in the project analysis area, the baseline scenario will have to be described according to the traditional livestock activities carried out during the historical reference period of the project, which represent the most likely scenario in case the project would not be carried out. The activities considered should be listed in Table 5. To report the management history by paddock, if necessary, use tables for each paddock, when the practices are carried out in the whole area, use one table.

Table 3. Minimum specifications of the activities defining the baseline scenario.

Activity	Year 1	Year 2	Year 3
Type of production (intensive, extensive, stall or non-intensive livestock)			
Species of crop/grazing			
Sowing date			
Crop yield (kg/ha)			
Area affected by agricultural and livestock activities (ha)			
Tillage (yes/no) When applicable indicate date			
Type of fertilizer (e.g. Triple 15, NPK, organic, manure, etc.)			
Applied dose (t/ha)			
Re-fertilization (yes/no) When applicable indicate date			
Burning (yes/no) When applicable indicate date			
Number of paddocks			
Area per paddock			

Activity	Year 1	Year 2	Year 3
Stocking rate (head/ha)			
Grazing frequency (days)			
Shade availability (ha)			
Water availability (l/head)			

The reevaluation of the baseline scenario must be performed every 10 years, considering the procedures in sections **¡Error! No se encuentra el origen de la referencia.**, **¡Error! No se encuentra el origen de la referencia.** and **¡Error! No se encuentra el origen de la referencia.**, for each of the reservoirs and emission sources applicable to the GHGMP. This reevaluation must be accompanied by the adjustment of the quantification of the GHGMP ex-ante calculations.

12 ADDITIONALITY

The additionality analysis should be carried out following the guidelines of the *COLCX Guide to demonstrate additionality* in its most updated version. Its objective is to evaluate additionality by political, social, cultural and other criteria.

13 STRATIFICATION

The GHGMP must stratify the head of cattle, identifying the type of production system managed. This stratification is based on their productive stage and considering the existing lots in the project area.

13.1 Variables

To organize and classify the animals, the following variables should be considered:

- **Species and Type of Animal:** Inicialmente, se focaliza en el bovino como el principal tipo de ganado involucrado.
- **Final Product:** It is classified between cattle intended for milk production and cattle intended for meat production.
- **Production Type:** It is subdivided into three levels: low, medium, and high. This variable is used in accordance with the IPCC Guidelines for National GHG Inventories: Volume 4 – Agriculture, Forestry and Other Land Use, Chapter 10 – Livestock Emissions, Table 10.1.
- **Cattle age:** A factor influencing growth rates, methane production and feed conversion efficiency.

Table 4. Example of stratification.

Stratum	Final product	Type of production	Plot
1	Milk	Low Productivity	Female calves
2	Milk	Medium Productivity	Heifers
3	Milk	High Productivity	Cows
4	Meat	Low Productivity	Breeding bulls
5	Meat	Medium Productivity	Cows
6	Meat	High Productivity	Fattening bulls

14 QUANTIFICATION OF REMOVALS AND GEI EMISSION REDUCTIONS IN THE BASELINE SCENARIO

To estimate GHG emissions in the baseline scenario, this methodology suggests three quantification methods, considering the availability of information. These are proposed based on CO_2, CH_4 and N_2O emissions expressed in tCO_2e for each of the carbon reservoirs and GHG emission sources considered by the GHGMP.

Method 1: Measurement

Corresponds to the scenario where the GHGMP must use direct measurement methods in the GHGMP area and in the PAA.

Method 2: Model and calibration

In this quantification method, exclusive for Soil Organic Carbon, the GHGMP must generate or use a validated model to estimate carbon assets changes in these reservoirs. The model must be based on soil characteristics, such as texture, bulk density, climatic conditions and the practices implemented in the GHGMP. The construction and use of models for SOC quantification must be based on measurements within the GHGMP of SOC assets and have constant recalibration processes through data collection in the GHGMP in a timeframe between three (3) and five (5) years.

Method 3: Application of quantification models level 2 or higher

In this method the GHGMP must use information from IPCC 2019 refinement data/models or emission factors[5] or that which updates it, the GHGMP may also use FAO GLEAM methodology[6] values to quantify GHG emissions. The GHGMP must ensure that the values used are conservative and applicable to the initiative, considering Tier 2 or 3 data only.

Quantification methods 1 and 2 should contemplate sampling areas with strata that group homogeneous zones with respect to soil type, geomorphology, management practices, among others that are contemplated by the GHGMP.

In case the land use determined in the baseline scenario does not correspond to livestock activities, the project proponent must quantify the emissions taking into account the guidance provided by IPCC Tier 2 or supported bibliography and according to the context where the initiative is developed.

Table 5 shows the GHG removal or emission quantification methods allowed for each reservoir or emission source.

Table 5. Applicable quantification models per emission source or carbon reservoir.

GHG	Emission source/Reservoir	Method 1	Method 2	Method 3
CO_2	SOC	x	x	
	Herbaceous biomass	x		
	Woody biomass	x		
	Fossil fuel combustion			x
	Lime Application			x
CH_4	Enteric fermentation			x
	Manure management			x
N_2O	Manure management			x
	Fertilizer application by soil management			x
	Use of nitrogen-fixing species			x

[5] https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html
[6] https://www.fao.org/gleam/resources/es/

14.1 Carbon assets at baseline

Carbon reserves in the baseline scenario are determined using the CDM AR TOOL -14, the COLCX Module for the calculation of removals by woody/herbaceous biomass V1.0, the COLCX Module for the quantification of soil organic carbon (SOC) V1.0.

The existing woody and herbaceous biomass prior to the start of project activities should be evaluated in the historical reference period and projected for the credit period of the initiative. This projection should consider the annual increase in these reservoirs as well as the practices applied during the historical reference period.

If pre-existing biomass is removed due to project-related activities, its subtraction should be estimated at the nearest monitoring event.

The estimate of carbon reserves in the baseline is calculated as follows:

Equation 1. Baseline carbon reserve estimation.

$$C_{lb,t} = C_{BL,t} + C_{BHA,t} + C_{COS,t}$$

Where:

$C_{lb,t}$	Total carbon in the project for the selected reservoirs in the baseline scenario at time *t* (tCO_2e).
$C_{BL,t}$	Total carbon in the project present in woody biomass in the project area at time *t* (tCO_2e).
$C_{BHA,t}$	Total carbon in the project area present in the herbaceous biomass at time *t* (tCO_2e).
$C_{COS,t}$	Total carbon in the project area present in soil organic carbon at time *t* (tCO_2e).
t	Years passed since the project start date

14.1.1 Soil organic carbon

To estimate the organic carbon content present in the soil, the methods of Yepes *et al*. (2011) are followed. The estimation of the organic carbon calculation for ex-ante projections and the quantification for ex-post projections are developed using method 1 or 2, as appropriate. For this process, the COLCX Soil Organic Carbon (COS) Quantification Module V1.0 is used.

Method of quantification 1- Control sampling unit

To determine the change in carbon reserves, reference sampling units to be installed in the PAA should be considered. These sampling units should make it possible to represent the dynamics of carbon assetes in the without-project scenario.

The monitoring of the reference sampling units should allow establishing and updating the reference values of organic soil carbon in the baseline scenario during the different monitoring events carried out by the GHGMP.

The GHGMP that implements this method of quantification must comply with the following procedure:

Step 1. Definition of the study area and sampling design

- **Delimitation of the sampling area within the PAA:** The areas where soil sampling will be carried out are selected and delimited. The delimitation should be based on the specific characteristics of the project, to ensure that the sampling is representative of the conditions of the area.

- **Sampling design:** A sampling plan must be established (stratified random, stratified systematic, among others), which contemplates the different strata of the GHGMP. The sampling used must guarantee an error of no more than 10% of the average carbon value, with a confidence level of 95%[7].

Step 2. Soil sampling

- **Sample extraction:** The GHGMP must define the number of soil samples to be collected, contemplating different depths, commonly in intervals of 0-10, 10-20, 20 -50 cm, or others contemplated by the GHGMP. The GHGMP must consider collecting samples at least up to a depth of 30 cm.

- **Conservation and transport:** Soil samples should be stored in an adequate manner to avoid moisture loss and other changes that may alter the physical and chemical parameters to be evaluated.

Step 3. Laboratory analysis

The purpose of this step is to determine the organic matter in the soil and perform the subsequent conversion to carbon equivalent. The GHGMP must guarantee and support that the analysis of soil samples is carried out in a laboratory that meets the following characteristics:

- Be accredited by nationally or internationally recognized entities that certify the quality of the processes and analytical techniques used, under the ISO 17025 standard.
- Have specific equipment for soil organic carbon analysis, such as total organic carbon (TOC) analyzers or equipment for dry combustion.
- Rigorous quality control protocols, including the use of reference samples, duplicates and blank controls.

[7] Para determinar la cantidad de unidades muestrales se recomienda utilizar la herramienta "*Winrock International's CDM A/R sample plot calculator spreadsheet tool*". https://globalclimateactionpartnership.org/resource/winrock-internationals-cdm-ar-sample-plot-calculator-spreadsheet-tool/

Step 4. SOC quantification

Changes in soil organic carbon content should be quantified. This model can be linear or incremental, depending on the quality and availability of the historical data collected. In the retroactive periods, the trend of the model will depend on the quantity and accuracy of the carbon assets in this reservoir that are available. From the verification periods, the changes in carbon assets in this reservoir should be adjusted according to the carbon assets measured during each period.

The calculation of the equivalent carbon present in this reservoir during the historical reference period is expressed as follows:

$C_{COS,ti}$	Total carbon in the project area existing in the soil at time *t =0* (tCO_2e).

The change in soil organic carbon reserves in the project between two points in time is calculated as follows:

Equation 2. Change in soil organic carbon reserves.

$$\Delta C_{COS,ti} = \frac{C_{COS,ti} - C_{COS,tj}}{T}$$

Where:

$\Delta C_{COS,ti}$	Change in total carbon in the project area present in the soil at time *i* (tCO_2e/year)
$C_{COS,ti}$	Total carbon in the project area present in the soil at time *i* (tCO_2e)
$C_{COS,tj}$	Total carbon in the project area present in the soil at time *j* (tCO_2e)
T	Time elapsed between two successive measurements (years)
j	Year of current project certification (years)
i	Year of preliminary project certification (years)

Quantification method 2- Prediction models

In this method, soil carbon assets quantification models should be developed and/or used, taking into account information on the spatial limits considered by the GHGMP. It is essential that these models consider factors such as geographical conditions, soil units, soil type and composition, as well as other edaphic and climatic aspects that may influence carbon accumulation.

The data used to develop these models should come directly from the spatial boundaries considered by the GHGMP. Ensuring that model predictions are accurate and consistent.

Once the model has been developed, the data used in its construction should be presented and justified in detail. This will include an explanation of the origin of the data, the methods of data collection, and the representativeness of the data. ¡.

The proponent has the option of using established models or developing its own model, if it meets the criteria of rigor and representativeness.

For a model to be considered valid and reliable in the context of the GHGMP, it must meet the following accuracy and consistency requirements:

1. The model must demonstrate, at a minimum, the following statistical metrics to assess its accuracy and consistency:
   - Coefficient of determination (R^2): The model must achieve an R^2 value greater than 0.85, indicating that the model explains at least 85% of the variability in the data.
   - Mean square error (MSE): The MSE should be low enough to ensure a minimum deviation between predicted and observed values.
2. A cross-validation process should be carried out, using at least 10% of the data for testing and ensuring that the model is not over-fit.
3. The model should show stability in its results when applied to data from different periods or to different data sets on a continuous basis.
4. Model residuals (differences between predicted and actual values) should show a random distribution without systematic patterns, showing that the model is not biased.
5. The model must be tested under different input conditions to evaluate its robustness and responsiveness to data variability.

14.1.2 Herbaceous Biomass

To estimate herbaceous biomass using quantification method 1, destructive sampling should be used to collect all the biomass within sampling units. The selection of the number, type and size of sampling units may be delimited following the guidelines of Yepes et al. (2011)[8], The Nature Conservancy & Amazon Conservation Team (2019)[9], among other guidelines that are appropriate for the GHGMP. The sampling units may be temporary from 2 m^2 to 4 m^2. Collection methods and in-situ data collection should be complemented with laboratory analysis to determine carbon content.

The projection of carbon assets in the baseline should be done linearly or non-linearly, according to section **¡Error! No se encuentra el origen de la referencia.**. Quantification of the carbon assets in this reservoir requires a detailed record of the resting time of each paddock. The effective capture time refers specifically to the period during which the paddock is at rest, allowing the herbaceous biomass to grow before being utilized by livestock. Thus, at the end of each year it will be possible to determine the number of hectares of paddock that were in a state of carbon sequestration and for how long, this represented in months or weeks, while the remaining months were used to supply fodder to the livestock.

[8] https://www.researchgate.net/publication/273307419_Protocolo_para_la_estimacion_nacional_y_subnacional_de_biomasa_-_carbono_en_Colombia

[9] https://www.nature.org/content/dam/tnc/nature/en/documents/AFC_Protocolo_Carbono_Pagina_Baja.pdf

When projects have more than one type of herbaceous stratum due to the use of different species or particular soil characteristics, monitoring should include all strata, and quantification should consider the differences in growth and carbon sequestration capacity between them.

If projects use other carbon quantification methods for activities such as silage or haymaking, in which biomass is processed and stored, the captured carbon must be measured and adjusted according to the biomass processing and preservation methods. This implies specific monitoring of the initial mass and the final mass after drying or conservation. The GHGMP should clearly define grazing rotation times and applicable growth patterns.

The procedures for calculating carbon assets are detailed in the COLCX Woody and Herbaceous Biomass Removal Calculation Module V1.0.

The carbon assets in the herbaceous biomass reservoir in the baseline scenario is expressed as follows:

$C_{BHA,t0}$	Total carbon in the project area present in the herbaceous biomass at time *t=0* (tCO_2e)

The delta of carbon assets growth in the aboveground herbaceous biomass of the GHGMP between two points in time is calculated as follows:

Equation 3. Changes in carbon reserves in herbaceous biomass.

$$\Delta C_{BHA,ti} = \frac{C_{BHA,ti} - C_{BHA,tj}}{T}$$

Where:

$\Delta C_{BHA,ti}$	Change in total carbon in the project area present in herbaceous biomass at time *i* (tCO_2e/year)
$C_{BHA,ti}$	Total carbon in project area present in herbaceous biomass at time *i* (tCO_2e)
$C_{BHA,tj}$	Total carbon in the project area present in aboveground biomass at time *j* (tCO_2e)
T	Time passed between two successive measurements (years)
i	Year of current project certification (years)
j	Year of preliminary project certification (years)

14.1.3 Total woody biomass

The estimation of aboveground woody biomass using quantification method 1 can be carried out using two forms of measurement, sampling or census, which should be considered according to the characteristics of the reservoir in the GHGMP area.

Table 6. Types of inventories for the calculation of aboveground woody biomass.

Type	Description
Sampling	This type of sampling should be selected when the planted individuals resulting from the project activities are part of systems such as live fences, agroforestry systems that cover an area equal to or greater than one (1) hectare. The sampling intensity should be developed in such a way that the uncertainty does not exceed 10% with a probability of 95%.
Census	This type of sampling should be selected when the planting activities developed by the project are part of systems such as live fences, agroforestry systems, isolated trees or trees for resting animals and any other form that does not generate a continuous extension of more than 1 hectare.

Regarding the measurement and estimation of aboveground woody biomass, the indications of the *COLCX Woody and Herbaceous Biomass Removal Calculation Module V1.0* should be followed.

Regardless of the sampling design, the GHGMP must perform an uncertainty analysis to ensure the accuracy of quantifications, considering factors such as variability in the allometric equations used, and types of errors that may occur during data collection and processing.

The processing and transformation of the collected information must be documented and justified by the GHGMP in the different project documents. The procedures for calculating carbon in this reservoir are detailed in the COLCX Module for the calculation of removals by woody and herbaceous biomass V1.0.

The total carbon in the project area existing in aboveground woody biomass in the baseline is denoted as follows:

$C_{BL,t0}$	Total carbon in the project area present in the aboveground woody biomass at time $t = 0$ (tCO_2e).

The change in woody biomass carbon assets in the project area between two points in time is calculated as follows:

Equation 4. Change in aboveground woody biomass carbon reserves in the project.

$$\Delta C_{BL,ti} = \frac{C_{BL,ti} - C_{BL,tj}}{T}$$

Where:

$\Delta C_{BL,ti}$	Change in total carbon in the project area existing in aboveground woody biomass over time i (tCO_2e/year)
$C_{BL,ti}$	Total carbon in the project area existing in the aboveground woody biomass at time i (tCO_2e)

$C_{BL,tj}$	Total carbon in the project area existing in aboveground woody biomass at time *j* (tCO_2e)
T	Time passed between two successive measurements (years)
j	Year of current project certification (years)
i	Year of preliminary project certification (years)

14.2 GHG emissions [10]

To quantify total annual emissions in the baseline scenario and in the project scenario, the GHGMP should follow the guidelines in the following sections.

14.2.1 Fossil fuel combustion

Emissions from fossil fuel combustion should be quantified considering method 3 described in Quantification Table 5 using the following equation[11].

Equation 5. Emissions from fossil fuel combustion.

$$E_{cf,lb} = \frac{(Ai \times FE_{CO2,i} \times PCG)}{1000}$$

Where:

$E_{cf,lb}$	Emissions from fossil fuel combustion (tCO_2e)
Ai	Amount of fuel burned (gal)
$FE_{CO2,i}$	CO_2 emission factor for each type of fuel used (kg CO_2/gal)
PCG	Global Warming Potential of gas
i	Type of fossil fuel (Gasoline, Diesel, CNG, among others)

14.2.2 Enteric fermentation

According to the IPCC 2019 Refinement Guidelines, methane produced by enteric fermentation is generated as part of the biological process of ruminant animals. The amount of CH_4 generated depends on the type of animal, its age, weight and the quality and quantity of feed consumed.

This methodology does not allow the use of Tier 1 calculations from the IPCC, as they do not account for the characteristics of livestock feeding and management systems. In this case, Tier 2 requires detailed and system-specific data, such as gross energy intake, average daily weight gain of animals, and emission factors specific to each livestock lot.

[10] To facilitate the process of developing the calculations described in this section, the project proponent may use the emission quantification tool developed by COLCX.
[11] It is important to note that fossil, non-fossil CH4 and nitrous oxide emissions are excluded from the quantification of emissions because their contribution is substantially low compared to CO_2.

As mentioned above, to use Tier 2 of the 2019 IPCC refinement, the Methane emission factor must be constructed considering the net energy content consumed by animals and specific Methane conversion factors for each animal category. To do so, the GHGMP must consider the following equation.

Equation 6. Calculation of emission factor for cattle.

$$FE = \frac{EN \times (\frac{Ym}{100}) \times 365}{55{,}65}$$

Where:

FE	Emission factor (kg CH_4/ head/year)
EN	Net energy consumed (MJ/head/day)
Ym	Methane conversion factor, percentage of net energy converted to methane (See Table 9).
55,65	Methane energy content (MJ/kg CH_4)

To estimate the net energy consumed, Equation 7, should be used, which is derived from the amount of net energy required and the energy availability characteristics of the food.

Equation 7. Net energy consumed.

$$EN = \frac{\left(\frac{ENRm + ENRa + ENRi + ENRt + ENRp}{REM}\right) + \left(\frac{ENRg}{REG}\right)}{DA\%}$$

Where:

EN	Net energy consumed (MJ/day)
$ENRm$	Net energy required by the animal for maintenance (MJ/day)
$ENRa$	Net energy required by the animal for its activity (MJ/day)
$ENRi$	Net energy required for lactation (MJ/day)
$ENRt$	Net energy required for working animals (MJ/day)
$ENRp$	Net energy required for pregnant animals (MJ/day)
REM	Ratio of net energy available in the diet for maintenance that is converted to digestible energy.
$ENRg$	Net energy required for growth (MJ/day)
REG	Ratio of net energy available for growth that is converted to digestible energy consumed.
$DA\%$	Digestibility of feed expressed as a fraction of net energy (DA%/100)

To calculate the energy requirements, the GHGMP must follow the equations described below, according to the availability of information and the animal flocks present in the project areas.

Net energy required for maintenance: Represents the amount of net energy required to maintain the animal in equilibrium, with no weight gain or loss.

Equation 8. Net energy for maintenance.

$$ENRm = Cfi \times (PVA)^{0,75}$$

Where:

$ENRm$	Net energy required for maintenance.
Cfi	Calculation coefficient see Table 7 (MJ/day/head).
PVA	Animal live weight (kg).

Table 7. Calculation coefficients for net energy required for maintenance.

Livestock group	CF_i (MJ/day/head)
Non-lactating cattle	0,322
Cattle (lactating cows)	0,386
Cattle (bulls)	0,370

Net energy required for the activity: Amount of net energy required to feed and access water.

Equation 9. Net energy for the activity.

$$ENRa = Ca \times ENRm$$

Where:

$ENRa$	Net energy required by the animal for its activity (MJ/day)
Ca	Coefficient corresponding to the animal's feeding conditions (See Table 8)
$ENRm$	Net energy required by the animal for maintenance (See Equation 8) (MJ/day)

Table 8. Activity coefficient corresponding to the animal's feeding conditions.

Feeding condition	Description	Ca
Intensive grazing	The animals are confined in areas with sufficient forage, requiring moderate amounts of energy for feeding	0,17
Extensive grazing areas	The animals are found on large tracts of land where they require large amounts of energy for their diet	0,36

Energy required for growth: Refers to the energy required for fattening.

Equation 10. Net energy required for growth.

$$ENRg = 22,02 \times \left(\frac{PVp}{C \times PAm}\right)^{0,75} \times GPd^{1,097}$$

Where:

$ENRg$	Net energy required for growth (MJ/day)

PVp	Average live weight of animals (kg)
C	Coefficient where 0.8 is used for females, 1 for geldings and 1.2 for breeding males
PAm	Weight of mature animals individually represented for males and females (kg)
GPd	Daily weight gain (kg/day)

Net energy required for lactation: Net energy for lactation in terms of the amount of milk produced and its calorie content.

Equation 11. Net energy required for lactation.

$$ENRi = Leche \times (1{,}47 + 0{,}40 \times Grasa)$$

Where:

$ENRi$	Net energy required for lactation (MJ/day)
$Leche$	Quantity of milk produced (kg)
$Grasa$	Fat contained in milk (% by weight)

Net energy required for working animals: Net energy required for working animals

Equation 12. Energy for working animals.

$$ENRt = 0{,}10 \times ENRm \times Horas$$

Where:

$ENRt$	Net energy required for working animals (MJ/day)
$ENRm$	Net energy required by the animal for its maintenance see Equation 8 (MJ/day)
$Horas$	Number of worksheets per day

Net energy required for pregnancy: Net energy required for the average 281 days of pregnancy considering 10% of $ENRm$.

Equation 13. Net energy for pregnancy.

$$ENRp = Cp \times ENRm$$

Where:

$ENRp$	Net energy required for pregnant animals (MJ/day)
Cp	Pregnancy coefficient (0.10)
$ENRm$	Net energy required by the animal for its maintenance (MJ/day) See Equation 8

Equation 14. Converted net energy to metabolizable energy.

$$REM = 1.123 - 4{,}092 \times 10^{-3} \times DE\% + 1{,}126 \times 10^{-5} \times DE\%^2 - \frac{25{,}4}{DE\%}$$

Where:

REM	Ratio of net energy available in the diet for maintenance that is converted to digestible energy.
$DE\%$	Digestible energy expressed as a percentage of gross energy (Digestible energy/Net energy x 100) (See Table 9)

Equation 15. Ratio between net energy available and digestible energy consumed.

$$REG = 1{,}164 - 5{,}16 \times 10^{-3} \times DE\% + 1{,}308 \times 10^{-5} \times DE\%^2 - \frac{37{,}4}{DE\%}$$

Where:

REG	Ratio of net energy available for growth that is converted to digestible energy consumed.
$DE\%$	Digestible energy expressed as a percentage of gross energy (Digestible energy/Net energy x100) see Table 9.

To characterize livestock groups, the GHGMP must follow the guidelines in Chapter 10, “Emissions from Livestock and Manure Management,” of Volume 4 (AFOLU) of the IPCC Guidelines, which outlines the process for characterizing animals within the project areas.

Table 9. Feed digestibility percentage and methane correction factors.

Livestock group	Description[12]	DE (%)	Ym (%)
Milk cows	High-producing cows	≥70	5,7-6,0
	Medium productivity cows	63-70	6,3
	Low productivity cows	≤62	6,5
Multipurpose cows	<75% forage	≤62	7,0
	Rations of >75% high quality forage or mixed rations between 15%-75% forage with grain or silage	62-71	6,3
	Housed (0–15% forage in diet)	≥72	4,0
	Housed (between 0-10%)	≥75	3,0

Finally, to estimate the total amount of methane emissions from enteric fermentation of the livestock in the project area, Equation 16 should be used.

[12] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf

Equation 16. Methane emissions from enteric fermentation.

$$E_{CH4,FE} = FE \times \frac{N}{10^6}$$

Where:

$E_{CH4,FE}$	Methane Emissions from Enteric Fermentation ($GgCH_4$/year)
FE	Emission factor (kg CH4/head/year)
N	Number of head of cattle (See Equation ***17***)

The number of livestock in the system should be quantified taking into account

Equation ***17***.

Equation 17. Number of livestock heads per year.

$$N = Days\ alive \times \frac{NAPA}{365}$$

Where:

N	Average number of head of cattle
$Días\ vivo$	Days spent at the farm
$NAPA$	Total number of cattle produced annually

Finally, to express emissions in terms of CO_2e, methane emissions from enteric fermentation must be multiplied by the Global Warming Potential (GWP) in accordance with the current IPCC report.

Equation 18. CO_2e emissions from enteric fermentation.

$$E_{FE,lb} = E_{CH4} \times PCG \times 1000$$

Where:

$E_{FE,lb}$	Carbon Emissions from Enteric Fermentation (tCO_2e)
E_{CH4}	Methane Emissions from Enteric Fermentation ($GgCH_4$/year)
PCG	Global Warming Potential from Methane

14.2.3 Manure management

14.2.3.1. CH_4 emissions from manure management

The main variables that influence the release of CH_4 to the atmosphere are the amount of manure produced and the portion that decomposes anaerobically. These criteria depend on the rate of waste production per animal, the number of animals and the manure management mechanism. In this case, when manure is managed in anaerobic mechanisms, more methane is produced than when it is managed under aerobic conditions (deposition in pastures).

To estimate methane emissions from manure management, the methodology proposes to use calculation method 3, which is based on the use of Tier 2 data from the IPCC 2019 Refinement, as it allows to adequately characterize the project systems by requiring detailed information on animals and manure management practices to estimate the emission factor.

Equation 19. Emission factor for CH_4 emissions from manure management.

$$FE_{CH4,ge} = SV \times 365 \times Bo \times 0{,}67 \times \frac{MCF}{100} \times SMEA_{CH4}$$

Where:

$FE_{CH4,ge}$	Methane emission factor for manure management (kg CH_4/ animal/year)
SV	Volatile solids excreted by the animal (kg MS/day)
Bo	Maximum manure capacity produced by animal (m^3CH_4/kg SV) (See IPCC)
MCF	Methane conversion factor by manure management system (%) (see IPCC[13]).
$SMEA_{CH4}$	Fraction of manure from animals managed by a management system

Estimation of excreted volatile solids: To estimate the amount of kg of volatile solids excreted per day, it is necessary to know the amount of feed consumed, which is not digested and, therefore, becomes manure, for this it is necessary to know the gross feed intake and the digestibility fraction of the feed and use Equation 20.

Equation 20. Excreted volatile solids.

$$SV = EN \times \left(1 - \frac{DE\%}{100}\right) + UE \times EN \times \frac{(1 - CEN)}{18{,}45}$$

Where:

SV	Amount of volatile solids excreted (kg SV/day)
EN	Net energy consumed (MJ/day)
$DE\%$	Digestible energy expressed as a percentage of gross energy (Digestible energy/Net energy x 100) (%) (see Table 9)
$UE \times EN$	Urinary energy expressed as a fraction of GE. Typically, a urinary energy loss of 0.04 GE can be assumed for most ruminants (reduced to 0.02 for ruminants fed diets containing 85% or more grain, or for swine). Country-specific values should be used if available.
CEN	Ash content in feed calculated as a fraction of dry matter consumed.
18,45	Conversion factor for dietary EN per kg dry matter (MJ/kg MS). This value is relatively constant across a range of forages and grain-based feeds regularly consumed by livestock.

Once the CH_4, emission factor has been calculated, the GHGMP should estimate the emissions from manure management considering Equation 21.

[13] See annex 10A.2 from chapter 10 of volume 4 from the IPCC, 2006.

Equation 21. CH_4 emissions from manure management.

$$E_{CH4,ge,lb} = \frac{N \times FE_{CH4,ge}}{1000}$$

Where:

$E_{CH4,ge,lb}$	Methane emissions from manure management (tCO_2e)
N	Number of heads of cattle (See Equation ***17***)
$FE_{CH4,ge}$	Methane emission factor for manure management (kg CH_4/ animal/year)

To express methane emissions in terms of tCO_2e, the most updated CH_4 Global Warming Potential according to IPCC guidelines should be used.

Equation 22. tCO2e emitted from manure management.

$$E_{GE,CH4,lb} = E_{CH4,ge} \times PCG$$

Where:

$E_{GE,CH4,lb}$	Carbon Emissions from Manure Management (tCO_2e)
$E_{CH4,ge}$	Methane emissions from manure management (tCH_4)
PCG	Global Warming Potential from Methane

14.2.3.2. N_2O emissions from manure management

Direct emissions of nitrous oxide (N_2O) are produced through nitrification and denitrification of the nitrogen content in manure. In this case, the GHGMP should follow the guidelines of quantification method 3 and use the Tier 2 formulas proposed in the 2019 IPCC[14] refinement where specific data on production systems such as nitrogen excretion rates are used.

Equation 23. Direct emissions of N_2O from manure management.

$$E_{GE,N2O,lb} = \frac{(N \times Nav \times SMEA_{N2O} + Ncdg) \times FE \times \frac{44}{28} \times PCG}{1000}$$

Where:

$E_{GE,N2O,lb}$	Direct N_2O emissions from manure management (tCO_2e/year) in the baseline scenario
N	Number of head of cattle (See Equation ***17***)
Nav	Average annual nitrogen excretion by productive system (kg N/head/year)
$SMEA_{N2O}$	Fraction of N_2O excreted per animal and management system
$Ncdg$	Amount of nitrogen input to anaerobic digestion systems (kg N/year)
FE	N_2O emission factor for manure management (kg N_2O-N/kg N in the management system)
$\frac{44}{28}$	Conversion from N_2O-N to N_2O

[14] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf

PCG	Global Warming Potential

To estimate the rate of nitrogen excretion, the total amount of nitrogen consumed, and the retention rate of the animal must be estimated according to Equation 24.

Equation 24. Annual nitrogen excretion rate.

$$Nav = Nconsumo \times (1 - Nretención) \times 365$$

Where:

Nav	Average annual nitrogen excretion by productive system (kg N/head/year)
$Nconsumo$	Amount of Nitrogen consumed (Kg N/animal/day)
$Nretención$	Amount of nitrogen retained (kg N/animal/day)

The amount of N consumed by the animals is calculated according to Equation ***25***.

Equation 25. Nitrogen consumption rate.

$$Nconsumption = \frac{EN}{18{,}45} \times \frac{\left(\frac{PC\%}{100}\right)}{6{,}25}$$

Where:

$Nconsumption$	Amount of nitrogen consumed (Kg/animal/day)
EN	Net energy consumed (MJ/day) (See Equation 7)
$PC\%$	Percentage of crude protein in the dry matter
18,45	Conversion factor for net energy consumed per kg of dry matter (MJ/kg)
6,25	Conversion factor from kg of dietary protein to kg of N (kg feed/kg N)

The amount of N retained by the animals is calculated according to Equation 26.

Equation 26. N retention in animals.

$$Nretention = \frac{Milk \times \frac{Protein\ in\ milk\ \%}{100}}{6{,}38} + \frac{GPd \times \frac{268 - \left(\frac{7{,}03 \times ENRg}{GPd}\right)}{1000}}{6{,}25}$$

Where:

$Nretention$	Amount of nitrogen retained (kg N/animal/day)
$Milk$	Milk production (kg animal/day)
$protein\ in\ milk\ \%$	Percentage of protein in milk, calculated as $(1{,}9 + 0{,}4 \times \%\ grasa)$ where % fat is usually assumed to be 4% only for dairy cows according to IPCC guidelines
GPd	Daily weight gain (kg/day)
$ENRg$	Net energy required for growth (MJ/day) (See Equation 10)

14.2.3.3. Indirect N_2O emissions from manure volatilization

The calculation of volatilized N in the form of NH_3 and NO_X from manure is estimated by considering manure excretion rates and volatilized fraction as shown in Equation 27.

Equation 27. N losses due to manure volatilization.

$$E_{VOL,lb} = N \times Nav \times SMEA_{N2O} + Ncdg \times FRACvol \times FE4 \times \frac{44}{28} \times \frac{PCG}{1000}$$

Where:

$E_{VOL,lb}$	Indirect emissions from manure volatilization (tCO_2e) in the baseline scenario.
N	Number of head of cattle (See Equation *17*)
Nav	Average annual nitrogen excretion per production system (kg N/head/year) (See Equation 24. Annual nitrogen excretion rate.)
$SMEA_{N2O}$	Fraction of N_2O excreted per animal and management system
$Ncdg$	Amount of nitrogen input to anaerobic digestion systems (kg N/year)
$FRACvol$	Fraction of managed manure that volatilizes in management systems[15]
$FE4$	Volatilization emission factor (kg NH_3-N + NO_X-N)
PCG	Global Warming Potential

14.2.3.4. Indirect N_2O emissions from manure leaching

Nitrogen leaching to the soil and runoff during storage of solids outdoors or in stabled systems is estimated according to Equation 28.

Equation 28. N losses due to leaching from manure management systems.

$$E_{LIX,lb} = N \times Nav \times SMEA_{N2O} + Ncdg \times FRAClix \times FE5 \times \frac{44}{28} \times \frac{PCG}{1000}$$

Where:

$E_{LIX,lb}$	Indirect manure leaching emissions (tCO_2e) in baseline scenario
N	Number of heads of cattle (See Equation *17*)
Nav	Average annual nitrogen excretion per production system (kg N/head/year) (See Equation 24. Annual nitrogen excretion rate.)
$SMEA_{N2O}$	Fraction of N_2O excreted per animal and management system
$Ncdg$	Amount of nitrogen input to anaerobic digestion systems (kg N/year)
$FRAClix$	Fraction of managed manure leached into management systems [16]
$FE5$	Leaching emission factor (kg N_2O-N)

[15] For the values of the variable, refer to Table 10.22 in Chapter 10 of Volume 4, Chapter 10 of the 2019 IPCC Refinement.
[16] For the values of the variable, refer to Table 10.22 in Chapter 10 of Volume 4, Chapter 10 of the 2019 IPCC Refinement.

PCG	Global Warming Potential

14.2.4 Fertilizer application by soil management

Increases in available N in the soil are due to increases in available nitrogen, which increases the rates of nitrification and denitrification, these increases can be produced by aggregate sources or changes in land use, in this case additions are considered associated to:

- Synthetic fertilization.
- Organic nitrogen applied as fertilizer (manure, compost, sludge or waste)
- Nitrogen in urine and manure deposited directly on pastures
- Nitrogen in agricultural residues

In this case, the project proponent shall follow calculation method 3 and the IPCC refinement level 2 guidelines as shown in **Equation *29***.

Equation 29. Direct emissions of N_2O in managed soils.

$$E_{AF,lb} = (Fsn + Fon) \times FEi + Fcr \times FEii \times \frac{44}{28} \times \frac{PCG}{A}$$

Where:

$E_{AF,lb}$	Nitrous Oxide Emissions from N (tCO_2e)
Fsn	Annual amount of N applied to soils in the form of synthetic fertilizer (t N/year)
Fon	Annual amount of nitrogen from animal manure, compost, sludge, and other inputs (t N/year)
FEi	Emission factor for N additions from synthetic fertilization (t N_2O-N/t N applied)
Fcr	Annual amount of N in agricultural residues, including N-fixing crops and forage or pasture renovation (t N/year)
$FEii$	Emission factor of N additions in N-fixing species (t N2O-N/t N applied)
PCG	Global Warming Potential
A	Hectares (ha)

14.2.5 Use of nitrogen-fixing species

To estimate the amount of N contained in nitrogen-fixing species, the project proponent should use the guidelines in Equation 30.

Equation 30. Amount of N in nitrogen-fixing species.

$$Fcr = Nmsab \times Ncontent$$

Where:

Fcr	Annual amount of N in agricultural residues, including N-fixing crops and renewal of forage or pasture (kg N/year)
$Nmsab$	Amount of aerial and belowground dry matter of nitrogen-fixing species (t MS)
$Ncontent$	Fraction of N in dry matter (t N/t MS)[17]

[17] The value can be consulted in official sources or through the results of laboratory analysis.

14.2.6 Lime Application by Soil Management

According to the 2019 IPCC Refinement Guidelines, the addition of carbonates to soils in the form of calcium limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) leads to CO_2 emissions. Considering this, the proponent must use the following equation to estimate the emissions resulting from soil amendment applications.

Equation 31. CO_2-C emissions from the application of dolomitic lime and calcium limestone.

$$E_{cal,lb} = Climestone \times FElimestone + Cdolomite \times FEdolomite \times \frac{44}{12}$$

Where:

$E_{cal,lb}$	C emissions from lime application (tCO_2e/year)
$Climestone$	Annual amount of $CaCO_3$ (t/year)
$FEcaliza$	Emission factor (tC/t of $CaCO_3$)
$Cdolomite$	Annual amount of $CaMg(CO_3)_2$ (t/year)
$FEdolomite$	Emission factor (tC/t of $CaMg(CO_3)_2$)

14.3 Total emissions

The total emissions in the baseline scenario and the project scenario correspond to the sum of each of the tCO_2e obtained after identification and application of the calculation methods described in the **¡Error! No se encuentra el origen de la referencia.** section according to Equation 32.

Equation 32. Total emissions in the baseline scenario.

$$Emt_{lb,t} = E_{cf,lb,t} + E_{\mathrm{FE,lb,t}} + E_{GE,CH4,lb,t} + E_{GE,N2O,lb,t} + E_{VOL,lb,t} + E_{LIX,lb,t} + E_{AF,lb,t} + E_{Cal,lb,t}$$

Where:

$Emt_{lb,t}$	Total GHG emissions in the baseline scenario (tCO_2e/year)
$E_{cf,lb,t}$	GHG emissions from fossil fuel combustion in the baseline scenario (tCO_2e/year)
$E_{\mathrm{FE,lb,t}}$	Total GHG emissions from enteric fermentation in baseline scenario (tCO_2e/year)
$E_{GE,CH4,lb,t}$	Total GHG emissions from manure (methane) management in baseline scenario (tCO_2e/year)
$E_{GE,N2O,lb,t}$	Total GHG emissions from manure management (nitrous oxide) in baseline scenario (tCO_2e/year)
$E_{VOL,lb,t}$	Total GHG emissions from manure volatilization in the baseline scenario (tCO_2e/year)
$E_{LIX,lb,t}$	Total GHG emissions from manure leaching in the baseline scenario (tCO_2e/year)
$E_{AF,lb,t}$	Total GHG emissions from soil nitrogen application in baseline scenario (tCO_2e/year)
$E_{Cal,lb,t}$	Total GHG emissions from liming in the baseline scenario (tCO_2e/year)

15 SCENARIO WITH PROJECT

Emissions and the calculation of carbon assets in the GHGMP reservoirs in the scenario with project should be quantified according to the guidelines in section **¡Error! No se encuentra el origen de la referencia.**, replacing the "*lb*" criterion in each of the equations with "*p*". The methods are applicable for the ex-ante and ex-post scenario, limited to the source of information that determines their result.

16 LEAKS

In the context of this methodology, leakage attributable to the GHGMP may result from the application of amendments or manure, the movement of livestock out of the project area, and loss of productivity.

The following are the procedures to be carried out by the GHGMP to identify and quantify potential leakages attributable to project activities.

16.1 Quantification of leakage resulting from the application of amendments or manure outside of the project area

Quantification of leakage from the application of amendments and manure outside the project area should be considered if increases in applications/deposits are identified since implementation of the initiative as follows:

- Applied amendments or manure must be produced and stored within the project area.
- It is identified that the manure has not been treated in mechanisms that allow the recovery of methane for energy use.

Emissions should be quantified following the guidelines in sections **¡Error! No se encuentra el origen de la referencia.** and 0 of this methodology.

16.2 Quantification of leakage from livestock movement outside the project area

If livestock movement outside the project boundaries is identified, CH_4 and N_2O emissions should be quantified following the guidelines in sections **¡Error! No se encuentra el origen de la referencia.** and of this methodology, providing annualized quantifications. It is important to clarify that, in order to avoid the claim of emissions reduction by intensity of individuals within the project area due to livestock displacement (reduction of GHG emissions within the project area in relation to the historical reference period by reducing the number of individuals within the project area), the number of heads of livestock should not be lower in the scenario with project with respect to the historical reference period.

16.3 Quantification of leakage due to productivity loss

Understanding that the project area must remain productive during the GHGMP crediting period, it is unlikely that leakage related to productivity loss will be generated. Additionally, according to the section of this methodology, the project proponent must demonstrate that no loss of productivity has occurred following project implementation[18], Therefore, reductions in yield are not permitted, based on the goods produced within the project boundaries.

To provide evidence of the above, the proposer must follow the steps below and demonstrate NO loss of productivity during each verification period.

Step 1. Selection of production indicators

The GHGMP must select the indicator that reflects its productivity according to the characterization of the livestock or the stratification process of the coverage identified within the project area (l of milk/ha, kg of standing cattle/ha, kg of crops/ha, among others).

Step 2. Average productivity estimate

The GHGMP must calculate the average productivity during the historical period and during the three years prior to each year of certification in the PAA in comparison with the project areas, for each of the productive indicators, according to the following equations.

Equation 33. Quantifying productivity in the historical reference period.

$$PROMPr,lb,i = \frac{Pr_{lb,t1,i} + Pr_{lb,t2,i} + Pr_{lb,t3,i}}{3}$$

Where:

$PROMPr,lb,i$	Average productivity during the historical reference period per production unit
$Pr_{lb,t}$	Annual productivity per hectare at time t
t	Time in years
i	Production unit
1, 2, 3...	Years of the historical reference period

Equation 34. Quantification of productivity in the credit period.

$$PROMPr,p,i = \frac{Pr_{p,t1,i} + Pr_{p,t2,i} + \ldots + Pr_{p,t5,i}}{n}$$

Where:

$PROMPr,p,i$	Average productivity during the certification period by production unit
$Pr_{p,t}$	Annual productivity per hectare at time t
t	Years of current project certification period
n	Time period covered by the current project certification (years)
i	Production unit

Step 3. Comparison of baseline productivity vs. project area productivity

[18] If a productivity loss of more than 8% is evidenced, the productive activity will not be eligible.

The GHGMP must compare the productivity of the project area with the average productivity of the PAA per selected productive unit (liters of milk/ha, kg of standing cattle/ha, among others) as shown in Equation 35. If the GHGMP area and the PAA experience external natural or market phenomena that imply a change in productivity, these phenomena may be excluded from the productivity average, if they are adequately documented and supported.

Equation 35. Productivity comparison.

$$\Delta Pr,i = \frac{PROMPr,p,i - PROMPr,lb,i}{PROMPr,lb,i} \times 100$$

Where:

$\Delta Pr,i$	Difference in productivity (%)

If the $\Delta Pr,i$ obtained for each production unit corresponds to a negative value, it is identified that the project has lost productivity with respect to the baseline scenario; on the other hand, if the value is positive, the leakage attributable to the project is zero.

Step 4. Quantification of leakage

After obtaining the productivity change delta, the GHGMP must calculate an intensity indicator expressed in tCO_2e per production unit (tCO_2e/l of milk, tCO_2e/kg of meat, among others and multiply it by the annual productivity difference obtained in terms of hectares. This process should only be carried out when the delta productivity is less than 8%.

Equation 36. Calculation of the difference in average productivity per year by production unit.

$$Pr,i = PROMPr,lb,i \; - \; PROMPr,p,i$$

Where:

Pr,i	Difference in average productivity

Equation 37. Calculation of emissions due to productivity leakage.

$$FG_{t,i} = \frac{Pr,i}{PROMPr,lb,i} \times 1\,ha \times FE_{forest}$$

Where:

$FG_{t,i}$	Leakage due to loss of productivity (tCO_2e/year)
FE_{forest}	Emission factor of 1 ha of stable forest in the areas bordering the project area

The FE_{forest} should be supported from secondary information sources relevant to the project area. Finally, the total project leakage for each certification period is calculated according to Equation 38.

Equation 38. Calculation of emissions due to productivity leakage

$$Leaks_t = \sum_{i=1}^{j} \frac{FG_{t,i}}{n}$$

Where:

$Leaks_t$	Carbon emissions from leakage at time t (tCO2e)

It is important to mention that the value obtained must remain stable for the years considered within the GHGMP certification period and calculated throughout each certification period.

17 NON-PERMANENCE RISK ANALYSIS

The analysis of non-permanence and reversal risks consists of monitoring strategic indicators that allow identifying the integrity of carbon stocks in the long term. The analysis of non-permanence risks should be developed in accordance with the *ColCX Guide for the management of reversal risks, non-permanence risks and uncertainty* in its most updated version.

18 DETERMINATION OF UNCERTAINTY

The calculation of uncertainty in the estimation of carbon in herbaceous biomass, woody biomass and organic carbon, as well as in the different emission sources considered in the GHGMP must be developed according to the guidelines established in the *ColCX Guide for the management of reversal risks, non-permanence risks and uncertainty* in its most updated version.

19 COLCERS ESTIMATION OF THE FORMULATION SCENARIO

The quantification of COLCERS resulting from the implementation of the project activities must consider the following equation:

Equation 39. COLCERS Estimate.

$$COLCERS_t = [\ (\Delta Em_{red,t} + \Delta Em_{rem,t}) - [(\Delta Em_{red,t} + \Delta Em_{rem,t}) \times Buffer\,\%] \\ - Leaks_t\ ]\ \times (1 - Uncertainty)$$

Where:

$COLCERS$	Number of COLCERS at time t (tCO_2e/year)
$\Delta Em_{red,t}$	GHG emissions reduced over time t (tCO_2e/year)
$\Delta Em_{rem,t}$	Carbon removals at time t (tCO_2e/year)
$Leaks_t$	Carbon emissions from leakage at time t (tCO_2e/year)
$Buffer\,\%$	Discount for non-permanence risk based on non-permanence risk tool

The delta of GHG emissions reduced per year is estimated according to the following equation

Equation 40. Quantification of the emission reduction delta [19].

$$\Delta Em_{red,t} = Emt_{lb,t} - Emt_{p,t}$$

Where:

$\Delta Em_{red,t}$	GHG emissions reduced over time t (tCO_2e/year)
$Emt_{lb,t}$	Total GHG emissions in baseline scenario at time t (tCO_2e/year)
$Emt_{p,t}$	Total GHG emissions in the project scenario at time t (tCO_2e/year)

On the other hand, the delta of GHG removals should be calculated considering the following equation:

Equation 41. Quantification of carbon stocks in the reservoirs.

$$\Delta Em_{rem,t} = \Delta C_{COS,t} + \Delta C_{BHA,t} + \Delta C_{BL,t}$$

Where:

ΔEm_{rem}	Total carbon removals at time t (tCO_2e/year)
$\Delta C_{BL,t}$	Change in project carbon assets present in woody biomass at time *t* (tCO_2e/year)
$\Delta C_{BHA,t}$	Change in project carbon assets present in herbaceous biomass at time *t* (tCO_2e/year)
$\Delta C_{COS,t}$	Change in project carbon stock present in soil organic carbon at time *t* (tCO_2e/year)

20 NO NET DAMAGE

The No Net Harm assessment should be carried out following the guidelines of the *COLCX No Net Harm and Socio-environmental Safeguards Guide* in its most updated version. Its objective is to evaluate the environmental risks and impacts that may be generated by project activities, highlighting the importance of identifying, predicting and assessing the possible effects on the environment and society

21 MONITORING PLAN

The project proponent must monitor on an annual basis the activities implemented in the initiative by adequately tracking the GHG removals and removals contemplated, compliance with social and environmental safeguards, animal welfare safeguards, and the environmental risks and impacts derived from the implementation of the activities.

The monitoring plan should contain variables, monitoring methods, frequency, and quality control processes with respect to the following items:

- Project activities
- Changes in carbon stocks and selected emission sources
- Risks of non-permanence

[19] It is important to note that the delta of each emission source corresponds to the difference between the emissions of the baseline scenario and the scenario with project.

- Potential impacts after the implementation of project activities
- Social, environmental and animal welfare safeguards
- Contribution to the SDG

It is important to note that the project proponent must document the procedure for collecting and processing the information and that the information must be duly preserved in physical or digital form for at least three years after the last verification period.

21.1 Description of actions for monitoring in the project area

The GHGMP must monitor the applicability conditions and geographical limits of the project using Geographic Information Systems (GIS) for each of the properties that comprise the project area.

A scheme must be developed to verify the chronology of the implementation of the initiative's activities within the previously defined limits and to document relevant aspects such as frequency, unit of measurement, scope and management plans for the project areas.

21.2 Description of actions to monitor non-permanence risks

According to the risks and impacts identified according to the procedure of the *COLCX No Net Harm and Socio-environmental Safeguards Guide*, the GHGMP must create a management plan for the risks that may represent a threat to the permanence of the initiative and thus mitigate the possible risks of reversion.

21.3 Monitoring variables related to changes in carbon assets and emission sources

The quantification of COLCERS derived from the removal and reduction of GHG emissions requires specific variables that must be monitored by the GHGMP throughout the crediting period, within the different spatial limits established in this methodology. In this sense, the GHGMP must report, in each of the documents corresponding to the stage it is in, the variables and other aspects defined in the different forms established by the COLCX program.

22 SOCIO-ENVIRONMENTAL SAFEGUARDS AND ANIMAL WELFARE

The following are the specific guidelines that the project proponent must follow to identify a clear contribution to compliance with social, environmental and animal welfare safeguards.

22.1 Evaluation of the socio-environmental safeguards applicable to the project

The evaluation of social and environmental safeguards is applied under the *COLCX No Net Harm and Socio-environmental Safeguards Guide*. The project proponent must use the UNFCCC Cancun Safeguards in accordance with the interpretation of the host country where the initiative is developed, if any. To comply with the social and environmental safeguards, the GHGMP must contemplate the following principles:

- Guarantee the ethnic and differential approach

- Guarantee of the free, prior and informed consent of the stakeholders involved in decision making
- Full and effective participation of the communities or actors involved
- Respect and recognition of the authorities, forms of government and decision-making mechanisms (ancestral and legal) of the communities or stakeholders involved
- Management and maintenance of documented project information

Within the framework of the above, the project must promote and ensure compliance with the safeguards. The following are the specific and additional aspects to the *COLCX No Net Harm and Socio-environmental Safeguards Guide* that the project proponent must evaluate.

- Safeguard (a) is applied according to the guide, considering the regulatory framework related to the agricultural sector and climate change mitigation.
- Safeguard (b) must demonstrate that the governance arrangements created or existing in the project area and the PAA, as well as the treatment of information, meet the legal criteria of the host country. In addition, the project must demonstrate that the property is free of deforestation, that it respects pre-existing land cover and the ownership of ethnic communities in neighboring collective lands. Subsequently, apply the guidelines in context.
- Other safeguards (c - g) are applied according to the guide.

22.2 Assessment of animal welfare domains

The project proponent must evaluate compliance with the five freedoms[20] of animal welfare in the grassland systems identified within the project boundaries, by identifying and monitoring indicators of at least three out of the five guidelines. The analysis seeks to ensure the existence of optimal conditions for the development of the animals, promoting both their welfare and the sustainability of the project.

The incorporation of animal welfare considerations is an ethical imperative, which contributes to the sustainability of the initiative. Animal welfare, as defined through the five freedoms, ensures that animals under humane management live in conditions that promote their health, natural behavior and general well-being. These freedoms, which include the absence of hunger and thirst, discomfort, pain, injury and disease, the ability to express natural behaviors, and the absence of fear and distress, are globally recognized as the basis for responsible management practices.

According to the World Organization for Animal Health (WOAH), animal welfare is defined as the physical and mental state of an animal in relation to the conditions in which it lives. The project proponent must provide evidence of compliance with the following indicators, at a minimum. If additional contributions can be demonstrated, they will be considered during the evaluation process.

[20] Ver: https://www.woah.org/en/home/

- **Forage and water availability:** Demonstrate quality, availability of forage and access to clean water so that animals have sufficient feed to meet their maintenance, growth and/or reproduction requirements. Apply periodic monitoring of forage quality through nutritional analysis and regular inspection of access to water sources at will.
- **Feed quality:** The quality of the forage consumed affects the grazing time and the intensity of the forage intake. According to Pinheiro (2020), low fiber content and higher digestibility of the grass favors grazing time, increases the rate of bites and therefore produces higher intake.
  In turn, the denser and closer the pasture is to 20 - 30 cm, the greater the size and the higher the bite rate, which defines the intake of grass by the animals. Therefore, the ideal grazing situation is when the animal is able to ingest the maximum amount of the highest quality feed. Grazing should be enabled when the grass has young leaves, with a higher amount of nutrients and is more palatable. The consumption of lignified, aged pastures should be avoided, since they have a low nutritional value and are ingested in smaller quantities due to longer rumination time.
  This is possible when animals enter the paddock at the optimal pasture regrowth point. Another benefit of providing high-quality feed is the reduction of methane (CH_4) emissions from the herd. A 2022 study by INIA (2022)[21] on steers found that, with a lower-fiber diet, not only did daily weight gains and live weight increase, but CH_4 emissions per kilogram of dry matter (DM) and per unit of gross energy (Ym) consumed also decreased.
- **Grazing behavior:** Constant presence of shelter and shade. Apply visual inspections and evidence of shade availability per hectare.
- **Animal welfare:** Avoiding the presence of dogs in animal management reduces an important stress factor for livestock, as they see dogs as their predators. In addition, once the animals are used to the passage between paddocks along the roads, they can be led on foot, without the need for dogs. In the case of very long distances, horses can be used.
  The exit from the paddock should be calm. Entry should be on foot to carry out the animal count, and it is recommended to wait 10 to 15 minutes so that animals leave additional dung and urine deposits[22]. Similarly, animal handling and movement during work in the handling facilities and other related activities should be conducted calmly and with care.
- **Animal health:** There must be a health calendar prepared by a veterinarian indicating the vaccination dates, and all existing vaccines in the region must be included. It must have an adequate follow-up. In the case of working with reproducers, they must have the corresponding evaluation prior to each service. Although it has been argued about

[21] Santander, M. et al (2022). Emisiones de metano de novillos en fase de terminación alimentados con dietas contrastantes en los niveles de fibra. Revista INIA. N°68. 84 – 87 pp.
[22] INIA Tacuarembó, 2002. Cruzamientos en bovinos para carnes. Seminario de actualización técnica.

the benefits of working with high animal loads, this concentration can benefit infectious diseases; to prevent this, a constant evaluation of the whole herd must be maintained.

23 CONTRIBUTION TO THE SUSTAINABLE DEVELOPMENT GOALS (SDG)

The project proponent must indicate how the project activities contribute to the achievement of the Sustainable Development Goals (SDG) targets proposed by the 2030 Agenda. If the country where the initiative is developed has an adaptation of the SDG targets, the proponent may demonstrate its alignment with the specific objectives of the territory.

The project must consider the criteria and guidelines defined by the *COLCX Guidelines for Reporting Contributions to the Sustainable Development Goals* in its most updated version

24 ANNEXES

24.1 Annex 1 Good farming practices

For a livestock system to function optimally, it is essential to meet the nutritional needs of the animals at all stages of their development, offer them clean and sufficient water, provide shade and follow a schedule of sanitary activities, among other practices included in this protocol. These actions not only improve animal welfare, but also increase production, since, according to Smith (1998), environmental stress can reduce their performance by 20-30%.

In addition, implementing these improvements in livestock management brings benefits to the farm environment, such as improved soil fertility and increased dry matter production in grasslands, which reduces production costs. By applying these guidelines, the farm has the potential to store soil organic carbon (SOC), which can represent an improvement in the efficiency of the system. This also contributes to improving biodiversity and optimizing water and nutrient cycling in the ecosystem.

24.1.1 Soil management

Soil plays a key role in nutrient and water cycles, being essential to maintain current food production. However, intensive agriculture, with years of tillage and the use of nitrogen fertilizers, has led to physicochemical deterioration and acidification of soils, leading to the loss of organic matter and fertility.

Aware of the importance of maintaining healthy soils to produce quality food efficiently, this chapter will address practices that help reduce or prevent erosion and improve nutrient cycling.

- **Management to avoid and/or reduce erosion:** Erosion reduces soil productivity by reducing the surface layer, where most of the organic matter is found. According to FAO, losing centimeters of this layer can reduce pasture and crop yields by up to 50%. Erosion also deteriorates ecosystem functions by affecting drainage, the soil's capacity to retain water, nutrient availability and biological activity. In severe cases of degradation, it can lead to desertification and cause the displacement of communities.

- **Reduce tillage:** Tilling the soil causes soil structure degradation, loss of organic matter, compaction and release of CO_2 into the atmosphere. This process alters soil porosity and capillarity, affecting both aerobic and anaerobic life, and changes the habitat of organisms that contribute to nutrient cycling and soil health and fertility. This generates a vicious circle, where more and more external inputs are needed to maintain good yields.
- Reducing tillage activities is therefore essential for soil conservation. No-till farming is a technique that minimizes soil disturbance by avoiding soil turnover and maintaining ground cover, thus preventing prolonged exposure. In addition, unlike conventional tillage, no-till farming preserves aerobic microorganisms in contact with the project's analysis area, and anaerobic microorganisms in oxygen-deprived zones, maintaining balance in the soil ecosystem.
- **Slope management:** The slope of the land is a contributing factor to water erosion, although this also depends on soil properties and vegetation cover. Runoff is affected by the volume and velocity of water; therefore, the risk of sediment loss is greater on steep slopes. Maintaining vegetation in these areas helps prevent runoff erosion, since vegetation cover reduces particle detachment by intercepting raindrops and dissipating their energy, as well as slowing the velocity of water over the ground.
- In areas where tillage is necessary on slopes, it should be carried out perpendicular to the slope or along contour lines, optimizing drainage and reducing the erosive impact of rainfall. The use of contour lines and other practices to channel water flow in the field is essential to prevent erosion and protect the soil.
- **Grazing:** Excessive animal presence on the land can lead to soil compaction due to trampling, which limits water infiltration, hinders the growth of new plant species, and reduces air and water circulation in the soil. According to Pinheiro (2020), the effect of compaction is particularly significant in extensive grazing systems, where animals constantly roam in search of food and water. Maintaining a high instantaneous stocking rate through a rotational grazing design can help reduce the impact of trampling by limiting the occupation time in each paddock area. In addition, all practices that increase soil organic matter content and maintain vegetative ground cover—as outlined later in this protocol—contribute to improving the soil's structural stability, making it more resistant to erosion.
- **Reduce burning activities:** The use of fire is not a recommended practice, as it can significantly increase the risk of erosion. Burning plant debris exposes the soil, which increases its roughness and surface runoff, as well as intensifying the impact of raindrops on the surface. This, in turn, favors soil compaction by reducing its organic matter content and damaging its structure. The lack of vegetation cover also affects the soil's capacity to store water, promoting evaporation and runoff, and decreasing infiltration. Therefore, reducing or avoiding burning activities is beneficial to the

ecosystem, as it helps to minimize the risk of erosion and conserve organic matter levels soil.

- **Improving nutrient cycling:** Biogeochemical nutrient cycling is an essential service provided by nature. Its main function is to regulate, store and recycle nutrients, which directly contributes to maintaining soil quality and agroecosystem productivity. Effective nutrient cycling ensures that the soil has sufficient organic matter, is fertile, well aerated and has the necessary energy to support the microorganisms that interact with elements in the atmosphere. However, this process cannot function properly in degraded soil, which highlights the importance of protecting and caring for soil health.
- **Root production:** Maintaining a diverse grassland, with species having different types of root systems, helps aerate the soil and encourages symbiosis between the rhizosphere and microorganisms. This contributes to more efficient nutrient cycling, increasing the availability of nutrients in the soil.
- To achieve this balance, it is recommended to include in the grassland species with deep roots, such as *Festuca arundinacea*, *Phalaris aquatica*, *Trifolium pratense*, *Medicago sativa* and *Chichorium intybus*, which can capture nutrients at greater depth. It is also suggested to incorporate species with superficial roots, such as *Lolium multiflorum* and *Trifolium subterraneum*, which help to reverse soil compaction in the upper layers, as a complement, rows of shrubs and trees can be planted at the borders of the paddocks.
- **Inclusion of legumes:** Legumes stand out for their ability to fix atmospheric nitrogen (N) in the soil thanks to their symbiotic relationship with Rhizobia. Incorporating legumes in pastures increases nitrogen levels in the soil, which improves the cycling of this nutrient and benefits other plants, such as grasses, which can produce more dry matter. This additional nitrogen supply not only increases the amount of forage available, but also its quality by including more protein in the livestock diet. This, as well, contributes to reducing methane emissions per kilogram of meat produced, favoring both the sustainability and efficiency of the livestock system.
- **Plant biomass production:** The aerial part and roots of plants play a crucial role in the carbon (C) and nitrogen (N) cycles in the soil. Through their leaves, plants capture atmospheric carbon, feeding life in the subsoil, while their roots absorb nitrogen and other essential nutrients from the soil, promoting plant growth. Having pastures with good biomass production increases the amount of carbon returned to the soil through the decomposition of plant debris, both above and below ground. In addition, roots and root exudates provide carbon to rhizosphere microorganisms, strengthening microbial biomass. This carbon is transformed into organic matter (OM), the main carbon reservoir in the soil
- Proper grassland management can have a positive environmental impact. Allowing plants to reach their maximum growth rate and accumulate nutrients in their roots for regrowth increases net primary production. Good practice is to observe the senescent

leaves of the crop: the ideal time to graze is when the basal leaves turn yellowish, if it is not due to stress factors.

- Another strategy to enhance biomass production is to enrich the grassland with more productive species. This includes the incorporation of legumes or the implementation of cover crops, which improves both the quantity and quality of available biomass.

24.1.2 Vegetation management

Native grasslands and pastures have been used as food for livestock for millennia. For example, native fields in Uruguay occupy approximately 90% of the pastoral area (Berreta, 1990). In addition to the economic contribution they provide to society through the production of biomass needed to supply the meat market, grasslands provide ecosystem services. They contribute to climate regulation, pollination, purification and recharge of aquifers, control of invasive species and carbon sequestration.

However, livestock productions with extensive grazing systems show a decrease in species diversity. Surveys of 50 years in fields with traditional livestock systems in Uruguay show a reduction in the presence of grasses and an increase in the number of invasive species. Therefore, grassland conservation should be a key issue when making management decisions on the farm. Considering the ecosystem as a whole, the relationship between plants - soil - animals must be in balance.

By observing livestock and pasture growth, an efficient rotational grazing plan can be determined that improves soil conditions and structures. A pasture with high growth rates increases animal production, increases biodiversity in the field, improves soil structure by increasing fertility, generating efficient nutrient cycling and a system that functions better and better through the relationship of animals with the pasture and the environment. These objectives can be achieved through rotational grazing with high stocking rates, incorporation of productive species in the field and good management of pasture implantation and maintenance. This type of production is based on Voisin's 4 grazing laws: the law of rest, the law of occupation, the law of maximum yield and the law of regular yield.

High stocking rate: Rational grazing is based on maintaining a high stocking rate in small paddocks, which generates several benefits to the ecosystem. Unlike extensive grazing, where the continuous trampling of animals in large areas causes permanent compaction (especially near water sources) and hinders the recovery of soil and vegetation, rational grazing limits the time of this disturbance. Although temporary trampling generates an initial impact, it allows a significant regrowth that improves the quality of pastures in the plot.

Another key benefit of this type of management is the return of organic matter to the soil through animal waste. High instantaneous loads result in a greater accumulation of manure and urine, which increases soil organic matter and fertility, strengthening the soil's ability to sustain plant growth over the long term.

Grassland improvement: Introducing more productive species into pasturelands brings clear benefits, but it is crucial to do so without harming the soil. Sowing should be carried out over the existing vegetation, preferably by broadcasting, and without resorting to invasive practices. To ensure successful establishment, it is best to perform this task after a prior grazing event followed by rainfall, taking advantage of animal trampling to help the seeds adhere to the soil.

Once the pasture is established, it is important to wait until the root system of the new species has developed before starting the first grazing. This moment can coincide with a few days after the optimal resting point.

As for the choice of species, greater diversity in the composition of the grassland will always be better. Some recommended grasses are *Lolium multiflorum*, *Avena sativa*, *Festuca arundinacea*, *Dactylis glomerata*, *Phalaris arundinacea*, *Pennisetum americanum*, *Paspalum notatum*, *Paspalum dilatatum* and *Pennisetum clandestinum*. Legumes play a fundamental role due to their capacity to fix nitrogen in the soil through their symbiosis with Rhizobia and their high protein levels, which exceed those of grasses. Among the suggested legumes are *Trifolium repens*, *Trifolium pratense*, *Medicago sativa*, *Lotus corniculatus* and *Vicia sativa*.

It is essential to consider pasture seasonality when selecting species to be introduced. For example, if summer species predominate, there will be a forage deficit during the winter. In such cases, incorporating species that grow during the cooler season is key to maintaining pasture stability and ensuring livestock productivity throughout the year.

24.1.3 Water management

The importance of water for animals lies in their requirements. It is estimated that a cattle must consume between 10 and 15% of its weight in water, that is, approximately 60 liters of water per day. Livestock production faces crises linked to droughts, so having a water supply plan in terms of quantity and quality ensures stable production. That is, the farm must maintain an effective water cycle with rainfall that can be efficiently captured and minimal water losses through runoff or evaporation from the soil, where most of the water penetrates the soil and is used by plants and flows to rivers, streams and groundwater.

Another important point is water quality, in rural areas there is organic and chemical pollution of watercourses (Masciadri, 2018) through surface runoff of fertilizers and pesticides used in agriculture and drift from productive and industrial activities. Due to this, some management of watercourses will be mentioned below to improve their utilization and/or decrease losses. In addition to ensuring that livestock has access to enough water, it is crucial that it be of good quality. If there are natural sources such as streams, creeks, ponds or lagoons, it is advisable to surround them with shrubs or trees. This vegetation acts as a natural filter, helping to protect the water and reducing erosion caused by constant animal traffic in these areas.

To avoid chemical contamination of water sources, it is essential to apply chemical products, such as phytosanitary products, at a prudent distance from these sources. In this regard, government regulations on the application of these products, if available, should be followed to ensure responsible and sustainable management.

Creation and management of reservoirs: There are various ways and sources for storing water intended for livestock. Surface water can be used by means of work such as direct intakes, dams, dams, reservoirs and drinking troughs. Groundwater, on the other hand, is used through wells. Although these practices are common in many regions, according to Pinheiro (2020), they can be inefficient. This is because animals must travel long distances in search of water, which implies significant energy expenditure. In addition, the hierarchy in the herd causes inequalities in access to water, where some animals consume enough water while others may only drink water every other day.

Therefore, Pinheiro emphasizes that “water should go to the animal, not the animal to the water”. A more efficient solution is to install strategically distributed water troughs in the paddocks. This not only ensures equitable access to quality water but also avoids physical wear and improves the welfare and performance of the cattle.

24.1.4 Infrastructure

Proper design of a grazing system is key to facilitating livestock management and ensuring the successful implementation of rational grazing. This design should include essential infrastructure such as roads, paddocks, watering troughs and other facilities necessary for efficient management.

- **Roads and paddocks:** Plots should be connected by well-defined corridors or roads. According to Pinheiro (2020), the design starts with a perimeter road surrounding the entire project area, followed by main roads within the area. The objective is that all the plots have direct access to a road, avoiding the step of the cattle through other paddocks.
- **Shade and windbreaks:** Trees play an important role in animal welfare by providing shade in hot climates and acting as barriers to reduce the impact of cold winds in winter. These conditions improve thermal comfort, reduce animal energy expenditure and optimize animal performance. If there are not enough trees, roofed areas for shade and windbreaks can be incorporated.
- **Paddock size:** In rotational grazing projects, the size and number of paddocks can be adjusted over time according to experience and specific needs. Pinheiro (2020) recommends that paddocks should not exceed 5 hectares, although this figure may vary depending on the number of animals and the availability of dry matter on the farm.
- **Investment and maintenance:** The implementation of a rotational grazing system implies an initial investment, especially in hydraulic watering systems and area divisions. To reduce costs, the use of electric fences is an efficient alternative, as long as they are kept in good condition and connected with the proper voltage to guarantee their functionality.

24.1.5 Personnel

To effectively implement the guidelines described in this protocol, it is essential to have trained personnel. This team must have the necessary knowledge to identify the right time to graze, move the animals correctly and assign them to the appropriate paddock. In addition, they must be attentive to the early detection of possible infections in livestock.

Since the design of the infrastructure requires a significant investment, it is equally important that the staff is responsible for maintaining it in good condition. This includes regular inspections of water troughs and fences, especially electric fences, to ensure their functionality and prolong their useful life. Proper maintenance not only protects the investment but also ensures the proper functioning of the grazing system.

24.1.6 Biodiversity

A key aspect to ensure ecosystem stability is the conservation of native species. It is essential to avoid cutting native vegetation and to be aware of local regulations related to the protection of natural systems. Likewise, hunting should be strictly prohibited on the property, promoting a safe environment for local fauna.

The presence of native species, such as plants, shrubs and trees, together with the reduction in the use of phytosanitary products, contributes to the protection of local insects, many of which act as natural enemies of pests. This approach not only promotes ecological balance but also reinforces the sustainability of the production system.

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HISTORY OF THE DOCUMENT

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