Ruuts Protocol
Soil Carbon Sequestration Methodology V. 1.0

March 2021
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Index

1 Glossary & Acronyms

Additionality: an action is deemed additional if it leads to lower levels of emissions than would have otherwise occurred under business as usual.

Baseline Scenario - See Business as Usual

Business As Usual - is defined as the prevailing land use or agricultural management practices before the regeneration project began. - See Section 6.1

Carbon Credit - A transactional certificate that represents avoiding emissions or removing from the atmosphere 1 tonne of CO_2e. Ruuts carbon credits are called Regeneration Units.

Carbon sequestration - The rate of increase in long-term storage of soil organic carbon (SOC).

Composite sample - A sample in which the sampling units are pooled together and homogenized.

Carbon Dioxide Equivalent - Unit for comparing the radiative forcing of a GHG to carbon dioxide.

Eligible Management Activity - See section 4.3

GRASS - Grasslands Regeneration and Sustainability Standard.

Grasslands Regeneration and Sustainability Standard - GRASS compatible standard widely used in Patagonia.

Leakage - indirect greenhouse gases emissions or soil organic carbon losses that can occur outside the project's boundaries but are still attributable to the project's activities.

Monitoring - Is the process of collecting data, following and analyzing information over time and in space and overall implementation progress, with the purpose of providing information for reports.

Ovis 21 - Argentina Hub for the Savory Institute. Pioneer in the introduction of regenerative grazing in South America. See www.ovis21.com

Permanence - The minimum legal period that this protocol guarantees that the carbon will be stored in the soil after the credit is issued. See section 4.5

Pool Buffer - A percentage of all Regeneration Units (RU) issuances that is stored in the Ruuts Registry as an insurance for possible future reversals. See Section 4.5.

Removals - The withdrawal of GHGs from the atmosphere, as a result of deliberate human activities. In this Protocol, it refers to the withdrawal of CO_2 and its storage in soils as soil organic carbon.

Reporting - The delivery of monitoring results. Reporting should be done in a transparent manner and sharing information on the MRV's project impacts. Also the reporting shall provide background data, data sources and methodologies applied for data quantification and modelling

Reversal - A situation where the net GHG benefit, taking into account project or program emissions, removals and leakage, in any monitoring period is negative. The amount of a reversal is calculated as the difference between the current total to date SOC benefit of the project or program, compared to the total to-date SOC benefit of the project or program at the previous verification event.

RU - Ruuts carbon removal unit equivalent to 1 $tnCO_2e$. Carbon is stored in the soil in a regeneration process that also improves the ecosystem biodiversity and water cycle.

RU Legal Agreement - A contract signed between Ruuts and the Project Owner that defines the legal considerations of this Protocol, including permanence commitment period.

Ruuts - For purpose, for profit start up that aims to scale ecosystem regeneration through a dedicated environmental services platform (Ruuts Platform).

Ruuts Platform - A platform where farmers receive support and finance to transition to regenerative agriculture, while individuals and corporations can reduce their environmental footprint by investing in the farmers' improved ecological outcomes.

Ruuts Registry - Ruuts database where all issuance, transaction and claims are registered. It is based on blockchain technology to make it secure and inmutable.

Net Removal - The net amount of tons of CO_2e sequestered in the soil in a project area for a given period of time. It is calculated by subtracting the total period emissions from the total carbon sequestration. See Section 9.3

Savory Institute - Global NGO promoting large scale grasslands regeneration through Holistic Management.

Savory Network - Savory Institute's global network of hubs, professionals and farmers.

Soil organic carbon concentration - The amount of organic carbon in a soil sample relative to the total mineral content of the sample. Soil organic carbon content is expressed as a (mass) percentage, restricted to the fraction <2 mm in size.

Soil organic carbon stocks - The content or mass of organic carbon in a sample of known bulk density. Soil organic carbon stocks are expressed in tonnes or Mg C per hectare for a nominated depth and restricted to the fraction <2mm in size.

Strata -The areas in which an intervention area is divided as a result from the stratification process

Stratification - The division of a population into parts known as strata, particularly for the purpose of accounting for variation for a drawn sample.

Verifying - The systematic, independent and documented process in which the methodological consistency of the actions proposed is evaluated.

Acronyms

BAU - Business as Usual
C - Carbon
CEA - Carbon Estimation Area. See section 5.1
CO2e - Carbon Dioxide Equivalent
DM -: Dry Matter
GRASS - Grasslands Regeneration and Sustainability Standard
ESM - Equivalent Soil Mass
GHG - Greenhouse Gases (CO_2 = carbon dioxide; N_2O= nitrous oxide; CH_4 = methane)
FAO - Food and Agriculture Organization
GRASS - Grasslands Regeneration and Sustainability Standard
IPCC - Intergovernmental Panel on Climate Change
LTM - Long Term Monitor - See Section 7.3
MRV - Monitoring, Reporting and Verification
QA - Quality Assurance
RA - Regenerative Agriculture
RU - Regeneration Unit
SI - Savory Institute
SOC - Soil Organic Carbon
STM - Short Term Monitoring - See Section 7.2

2 Introduction

Regenerative Agriculture is proposed as a solution that addresses 13 of the 17 U.N. Sustainable Development Goals (SDG), including helping to reverse climate change, environmental degradation, rural poverty and depopulation, and to provide clean water and nutrient-dense foods that are essential to human health.

Considering the worldwide impact of human activity on soils, vegetation, water, air and climate, a fast adoption rate of regenerative agriculture (RA) is of paramount importance. The faster the rise of RA, the higher the possibilities of succeeding in addressing climate change, desertification, biodiversity loss, food security and quality of life.

> Regenerative agriculture is an emergent paradigm for food and fibre production. It may be described as:
>
> - An approach that mimics Nature in terms of design and function.
> - It starts with a change in decision making, with a holistic approach.
> - Low input production processes.
> - The aim is to achieve profit while increasing biological and social capital, instead of doing it at their expense.
> - In terms of ecological processes, regenerative agriculture improves the water cycle, the mineral cycle, the energy flow and community dynamics in relation to each Ecoregion potential.
> - Regeneration could be quantified by: a) Increasing or maintaining vegetative cover, with no bare ground; b) Increasing water infiltration rates, to maximize soil water retention and minimize runoff and evaporation losses; c) Increasing biodiversity in a wide sense, implying increase in the amount of functional groups, plant species richness and mass distribution , soil biota biodiversity, domestic herbivores, wildlife, and so forth; d) increasing photosynthesis and biomass production; and e) increasing soil carbon stocks and enhancing soil biology functioning.
> - Despite that regeneration is a mindset or a concept, its ecological outcomes can be measured using objective methods. The Ecological Outcome Verification (GRASS) method developed by the Savory Institute is an outcome based, scientifically sound methodological framework that provides metrics to land regeneration.

Voluntary markets for environmental services have a crucial role in accelerating the change from conventional agriculture to RA. They allow companies that have carbon, water and biodiversity footprints to neutralize them or even become carbon negative. Purchasing carbon offsets done by regenerative farmers, and measured using sound methods, they can make a strong contribution to accelerate the process. In many places of the world, the value of the Environmental Services outperforms the value of the products that are generated during the process.

Ruuts and Ovis 21 developed this Protocol that defines the criteria and methods to convert GRASS measured environmental outcomes into credits that can be transacted in the Voluntary Market. The Ruuts platform provides a traceable, transparent marketplace where buyers and sellers can meet. Blockchain technology and other technological tools provide support to a quality assurance process that secures operations for both parties.

GRASS provides standardized procedures to evaluate changes in biodiversity, water infiltration and soil carbon. Data collection, storage and reporting is performed by a Network of professionals trained and accredited by Ovis 21. GRASS has a multilayer quality assurance structure that is responsible for data soundness and consistency. GRASS data is uploaded to the Ruuts Platform, an online, georeferenced database.

This Protocol provides procedures and statistical tools to process GRASS data from project farms and to convert the ecological outcomes into Regeneration Units, a certificate that can be transacted in the Ruuts Platform.
The structure and equations used in this Protocol follow technical guidelines from Carter and Gregorich [1] ; The Australian Carbon Scheme [2] , VM0042 VCS Standard Protocol[3] and FAO[4], This protocol is aligned, and complies with most of the requirements of the previous work cited.

3 Regeneration Project Definition

A regeneration project is a farm-scale project defined as the adoption of agricultural management practices that aim to increase soil organic carbon (SOC), water infiltration and enhance biodiversity through agricultural operations, as compared to the baseline scenario.

3.1 Project Roles & Ownership

Regeneration projects involve several parties that play different roles.

Regeneration activities and ownership of RU rights

a. **Land Owner:** The entity with title to the physical property that contains one or more CEA within the project area. There is no requirement for this party to participate in the project but Land Owners must sign their conformity with the RU legal agreement.

b. **Project Owner:** The entity with legal ownership of the RU rights for the entire project area. It must have a clear ownership of the project during the period covered by the RU legal agreement.
The Project Owner must attest that no other entities are reporting or claiming (e.g., for voluntary reporting or regulatory compliance purposes) the credits generated by the project
They are ultimately responsible for timely submission of all required forms and complying with the terms of this protocol.

[1] Carter,M. and Gregorich. 2008 Eds. Soil sampling and methods of analysis / edited by M.R. Carter and E.G. Gregorich. -- 2nd ed. Canadian Society for Soil Science p. cm.
[2] Frydenberg, J. 2018. Carbon Credits (Carbon Farming Initiative— Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination. https://www.legislation.gov.au/Details/F2018L00089
[3] https://verra.org/methodology/vm0042-methodology-for-improved-agricultural-land-management-v1-0/
[4]https://www.researchgate.net/publication/344433551_GSOC-MRV_Protocol_measurement_monitoring_reporting_and_verification_of_soil_organic_carbon_in_agricultural_landscapes

Project Owner may be the Land Owner or the Field Manager, but it may be a different entity according to private agreements between parties.

c. **Field Manager:** The entity or party with management control over agricultural management activities for one or more CEA within the project area. Normally assumed to be the project owner unless a legal instrument transfers the legal rights to a third party. (e.g. land tenant).

Monitoring and Reporting (GRASS)

The QA structure of GRASS/GRASS includes the following roles:

d. **GRASS Monitor:** A SI Accredited professional that designs monitoring activities, conducts and performs GRASS procedures at farm level under supervision of a Hub Verifier. . Roles include creating a farm monitoring plan, performing short and long term monitoring, with the corresponding reporting and uploading of information to the Ruuts Platform.
e. Hub Verifier: A SI accredited professional that is responsible for GRASS QA in a district. Hub Verifiers perform Ecoregion setting, training of GRASS monitors, supervision of data quality and farm auditing. Hub Verifiers are Project Proponents in terms of this Protocol. Project Proponents manag~~e~~s the monitoring and reporting, including interaction with the RU registry. The project proponent must be able to identify the land title holder for any given CEA if requested by the verifier. Project proponents are encouraged to ensure the land title holder has been fully informed about the project on their land, and has contractually assented to the project.
f. Master Verifiers: A group of highly experienced GRASS professionals. They conduct and perform Hub Verifier training, Hub Audits, and have an advisory role in the improvement of GRASS Protocols.
g. GRASS QA: Responsible for GRASS Project Management and QA at global scale. Performs verification, accredits GRASS Monitors, Hub Verifiers and Master Verifiers. Provides training for new Hub Verifiers and Monitors. Performs Hub Audits. It revises and proposes changes in the GRASS Protocols.
h. Scientific Advisory Group: A group of scientists that have the following roles: revising the GRASS protocols and suggesting changes, perform metadata analysis and produce scientific papers using GRASS data, and in some cases, perform Hub Audits.

Verification and RU issuance

i. **Ruuts.** Owner of this protocol. Processes GRASS data to generate RU according to this protocol statistical analysis. Issues RU Certificates after verification by third party. Manages the RU Ledger and Registry and the online platform for transactions.
j. **Verification entity:** An independent group of experts that revises data consistency, accordance to verification criteria and RU calculations. They can endorse or reject RU calculations from regeneration projects.

4 Eligibility

4.1 Location

This protocol can be used for regeneration projects worldwide, where the GRASS or GRASS verification process can be implemented.

4.2 Eligible Land

The project area must include legally allowed lands meeting the following requirements:

a. During the last 10 years the land was used for one or more of the following:
   (i) pasture or native grasslands
   (ii) savannas, silvopastoral systems
   (iii) wetlands.
   (iv)Integrated crop-livestock (ICL)
   (v)permanent cropland
b. the land was not forest land at any point during the last 10 years and is not currently native forest land;
c. during the last 10 years the land has not been subject to the drainage of a wetland or peatland;
d. it is possible to sample the soil on the land consistently with the requirements of this protocol.
e. all cases in which scientific criteria justify the intervention

4.3 Project Activities

Project activities are those activities that are necessary for the implementation and maintenance of one or more new agricultural land management practices which are reasonably expected (over the project crediting period) to increase SOC storage, water infiltration, and enhancing biodiversity from agricultural land management activities. Ecological outcomes in the project scenario are compared against a baseline scenario, which assumes that, in the absence of the project, the baseline land management activities would have been continued.

A management activity is an **eligible management activity** if it involves one of the following list, as proposed by FAO:

a) Increase in biomass production by managing water availability for plants with soil water conservation practices and adequate and efficient irrigation management.

b) Balanced fertilizer applications with appropriate and judicious fertilizer application methods, types, rates and timing, following the International Code of Conduct for the Use and Management of Fertilizers (FAO, 2019 b);

c) Effective use of organic amendments, such as animal manure, plant residues, compost, digestates, biochar; following the International Code of Conduct for the Use and Management of Fertilizers (FAO, 2019 b);

d) Effective use of inorganic amendments (e.g. lime or gypsum to remediate acid soils, gypsum to remediate sodic soils), following the International Code of Conduct for the Use and Management of Fertilizers (FAO, 2019 b); integrated soil fertility management (combined application of inorganic and organic nutrient resources/fertilizers);

e) Soil health improvement with biofertilizers (beneficial microbes), such as mycorrhiza, phosphate solubilizing bacteria, bio-inoculants and bio-inducers;

f) Crop residue management: applying organic residues, mulches or providing the soil with permanent cover;

g) Use of cover crops or green manure, and/or perennials in crop rotations; establishing a pasture in croplands or bare fallow;

h) Reduction of tillage events and or the adoption of residue management techniques, minimum or no-tillage;

i) Implementation of practices oriented to prevent and/or alleviate soil compaction (e.g. controlled traffic operations; ‘bio-drilling’ by using tap-root species; judicious subsoiling labors)

j) Grazing management (stocking rate, grazing duration and intensity) to promote soil vegetation cover; rejuvenating pastures by seeding;

k) Implementation and diversification of crop rotations, integration of production systems (e.g. crop-livestock, silvopastoral, agroforestry, etc), use of improved species (e.g. deep rooting and tap rooting crops);

l) Landscape management modification such as those implemented for erosion control (e.g. terraces), surface water management, and drainage/flood control, excluding drainage of wetlands and peatlands;

m) Planting indigenous species (e.g. N2 fixing legumes) adapted to local ecological conditions by interseeding

4.4 Additionality

Additionality for a regeneration project is demonstrated by the adoption of one or more changes in pre-existing agricultural management practices that are reasonably expected (over the project crediting period) to increase SOC storage, water infiltration and to enhance biodiversity from agricultural land management activities. Adoption is defined as a change from a baseline or business as usual scenario to a regeneration project scenario.

In addition to the adoption, to be considered additional an eligible management practice must:

a. not be a regional common practice
b. not been adopted in more than 50% of the project area before the earliest accepted activity switch date defined by this protocol. See Section 5.2.2
c. not be a legal requirement.

This Protocol defines a regional common practice when more than 20% of the farmers in that ecoregion have adopted the eligible management activity.

Categories of project activities for the demonstration of common practice may be defined according to the categories in the evidence provided in the form of publicly available information contained in:
1. Agricultural census or other government (e.g., survey) data;
2. Peer-reviewed scientific literature;
3. Independent research data; or
4. Reports or assessments compiled by industry associations

Once regenerative agriculture has become a common practice in an ecoregion, additionality will be given by the investments needed to improve the management and accelerate the carbon sequestration rate (For example: Fencing for better grazing management).

4.5 Permanence

Permanence means the minimum period during which the removed CO_2e represented by the issued RUs under this Protocol is required to remain removed and sequestered from the atmosphere.
Project Owners must ensure at least 20 years permanence after the RU credits are issued.

This protocol ensures permanence through different ways:

a. On the ground Monitoring and Verification: All project owners need to be GRASS verified applying Short and Long Term monitoring procedures during the permanence period, to control for potential reversals of environmental outcomes. This means a standard monitoring procedure with an active QA program that includes farm audits.

b. Remote Sensing: We are developing remote sensing models to monitor and verify SOC levels and reversals.
c. Pool Buffer: All projects have a 5% discount on the net removal. This buffer works as an insurance for possible future reversals.
d. RU Legal Agreement: Permanence is defined by a legal agreement between the registry (Ruuts), the project owner and the land owner conformity (if different).
If, before their permanence period ends, project owners terminate their project, stop land management activities or carbon stores are reversed, legal action may take place.

Ruuts strategy for long term permanence is a holistic approach, generating the social and economic incentives for the farmers to keep regenerating even without the carbon credits.

Through our partners we provide education and assistance to farmers to ensure that they generate new capabilities. This is not about agronomic practices, it means a different decision making framework for their everyday decisions. This is the single most important thing to ensure that they will be successful and stay regenerative over time. This generates three direct incentives:

- Better Wellbeing: Is documented that regenerative farmers have a more optimistic view about their life and their future.[5]

- Economic Incentives: Regenerative farmers increase their business resiliency and profitability. They do better by doing good.

- Social Incentives: With the Savory Network hubs, NGOs, Government institutions we create a community of farmers, professionals and local organizations that share experiences and learn together, increasing the social incentives to stay regenerative.

4.6 Reversals

A reversal occurs when sequestered carbon that was represented by the issued RUs is released back to the atmosphere during the permanence period. A reversal event can be intentional or unintentional.

- **Intentional Reversal Event:** Any reversal event that is linked to the project owner management decisions. In this case Ruuts will demand legal action and full compensation according to the Ruuts Legal Agreement.

[5] https://www.vbs.net.au/wp-content/uploads/2019/03/Graziers-with-better-profit-and-biodiversity_Final-2019.pdf

- **Unintentional Reversal Event:** reversal events linked to weather conditions, regional fires, or any other condition impossible to control and not predicted by the project owner. In this case no legal action will take place.

In both cases the pool buffer will be used to guarantee buyers that the CO_2e represented by the RU credits has been removed from the atmosphere.

4.6.1 Reversals Reporting

Possible Reversal events are monitored on an annual basis, through the Short Term Monitoring (STM) and remote sensing models (when available), where either intended or unintended events are reported.

If the reported event is expected to generate reversals that exceed 10% of the last RU Issuance, two actions will take place:

- Buyers will be notified.
- The project RU credits for sale will be on hold until the next long term monitoring.

Through the Long Term Monitoring (LTM) the reversals are quantified . Reversals that effectively exceed 10% of the last RU issuance are reported and buyers are compensated with new RUs. According to the nature of the reversal Ruuts may take legal action with the Project Owner.

4.7 No Double Accounting

In order to be eligible, Project Owners must sign the RU legal agreement with Ruuts, where they specify that this is the only carbon credits scheme they are participating in.

Ruuts is creating a public registry on the blockchain, which ensures that every credit issued is unique and inviolable.

4.8 Leakage

As FAO defines, leakage refers to indirect GHG emissions or SOC losses that can occur outside the project's boundaries but are still attributable to the project's activities. For example, a project aims at converting areas under croplands to permanent grasslands in order to enhance SOC sequestration; however, it indirectly results in deforestation or converting other areas under grasslands to croplands in a region or area outside the declared boundaries.

Under the methodology applicability conditions, the project activity must not result in a sustained reduction in productivity or sustained displacement of any pre-existing productive activity in the project area. The requirement that the project activity does not result in sustained reduction in productivity ensures that there is no increase in emissions outside of the project area as a result of intensification production elsewhere to compensate for decreased productivity inside the project area. The requirement that the project activity does not result in displacement of any pre-existing productive activity in the project area ensures that there is no increase in emissions outside of the project area that results from shifting pre-existing productive activities to areas outside of the project boundaries.

4.8.1 Activity Implementation restrictions

The eligible activities must comply with the following restrictions to avoid leakage:

A. Project activities must be implemented on land that remains in agricultural production throughout the project crediting period.
B. The project activity is not expected to result in a sustained reduction (i.e. over at least 10 consecutive years from the project start date, supported by peer-reviewed and/or published studies) in productivity or sustained displacement of any pre-existing productive activity in the project area.
C. The project activity should not involve significant displacement of livestock production outside of the project area, and safeguards must be in place to avoid unintended displacement of livestock outside of the project area caused by the project activity (e.g., fencing, grazing forages).

5 Delineating Boundaries

5.1 Spatial Boundaries and Strata

As a requirement for GRASS Verification, each project needs to have a defined spatial boundary (area). As a result of this, each project must present a georeferenced map of the project area, separating and labelling the project area into one or more **carbon estimation areas** (CEAs) such that:

- all the land included in the CEA:
    1. is eligible land; and
    2. is subject to the carrying out or maintenance of at least one eligible management activity until the end of the permanence obligation period for the project;
- non-contiguous parts of the project area are mapped as separate CEAs;
- the boundaries of the CEA used in the baseline sampling round must be the same as the boundaries used in each subsequent sampling round;

- Each CEA is divided into Strata. CEAs mapping must include the exact location and geospatial map of each stratum, including:
    - boundaries or GPS tracks of the strata limits (polygon vector type: KML or .SHP formats);
    - Google Earth, Bing Aerial or satellite images indicating the project's different strata areas and sizes (in hectares), labeling locations and areas within each strata to be excluded (e.g. wet depressions, woodlots, forests, waterways, farm buildings etc.);
    - Google Earth, Bing Aerial, or satellite historic images providing evidence that the CEAs are not located in lands that have been forests or wetlands/peatlands during the past 10 years (see Eligible lands, section 4.2).

- The project proponent may map other land within the project area for the project into one or more exclusion areas such that:

(a) either:
(i) no land management or agricultural activities are to be conducted in the area; or
(ii) the land is native forest and out of the scope of the practices adopted. No emissions occur that are relevant to the calculations in section 11; and
(b) none of the land is included in a CEA.

Note: Exclusion areas would generally be native forests, dwellings, roads, dams or other infrastructure.
The World Geodetic System (WGS84) shall be used as the reference coordinate system in all cases.

- Any part of the project area which is neither a CEA nor an exclusion area is an emissions accounting area.

5.2 Temporal Boundaries

5.2.1 Project Registration Date

The date when the project was accepted in the Ruuts Registry.

5.2.2 Activity Switch Date

The activity switch date is defined as the date when the new eligible management activity was adopted. This protocol accepts regeneration projects with activity switch date beginning after 1/2008.

5.2.3 Project Start Date

The start date of a project is defined as the date when the baseline carbon stocks were measured or the date to which they were reconstructed . This date will depend on the baseline definition (See Baseline section):

	Time Based Measurements Baseline	Contrasting Management Baseline
Start Date	Date of baseline monitoring	Activity Switch Date

5.2.4 Crediting Period

The crediting period starts at the project start date and finishes 10 years after the project registration date , renewable indefinitely. However, Project Owners must ensure at least 20 years permanence after the RU credits are issued.

To renew, the project must:

-Pass eligibility requirements of the most updated version of this protocol.
-The eligible management activity must not be a legal requirement.
-The eligible management activity must still be additional.

5.2.5 Baseline Period

The baseline period is defined as the five years previous to the activity switch date. A five year baseline period is standardized as a reasonable timeframe prior to the implementation of eligible practices, in which activity data that can be used to define a BAU scenario are available, credible, and updated for most projects. See Section 6.1

6 Defining Baseline Scenario

The baseline scenario assumes the continuation of pre-project agricultural management practices, against which the new management will be compared (Project Scenario). Defining the baseline scenario includes what the baseline management is and what soil carbon levels correspond to that management.

6.1 Baseline Management Scenario

It shall be determined by identifying farm ‘business as usual’ (BAU) conditions:

a) the land use and management practices that were in place during the five (5) years prior to the intervention or
b) regional ‘business as usual’ conditions: the land use and management practices that represent the typical land uses and agricultural management practices (prevailing practices) which are dominant within the larger intervention region (e.g. neighbouring areas with similar soils and production systems) or specific intervention areas of the project, prior to the start of the interventions.

Projects will be requested to complete and submit a fulfilled Project Registration Report, describing the BAU scenario and, when necessary, Google Earth, Bing Aerial, or satellite historic images of the CEA. BAU scenario will be documented with five-year historic activity data for the CEAs to be assessed. This activity report must be prepared by an GRASS accredited professional. Information in Baseline Report , follows FAO suggestions.

○ cash and cover crops per year (approximate sowing and harvest dates), and harvested yields or biomass (kg DM ha-1 yr-1),

○ residue management; residue returns and removals estimation (%; or kg DM ha-1 yr-1)

○ forage type, silage, estimated total biomass production (kg DM ha-1 yr-1)

○ and estimated consumption/harvest (%; or kg DM ha-1 yr-1)

○ livestock species, density (annual average stocking rate), categories (average weight), and general grazing management description

○ tillage practices (tillage system; number and type of tillage operations per year),

○ prescribed burning (% of area, time of the year)

○ annually mechanized farm operations (number) and fossil fuel consumed: tillage, planting, pest control, fertilizer/organic and inorganic amendments/manure application and distribution, harvesting, mowing, baling hay, internal transportation, other operations.

○ fertilizer and inorganic amendment use (product, application method, moment/s of application, fertilizer and nutrient doses per year in kg ha-1),

○ organic amendment use (type, form of application, placement method, timing and application rate per year),

○ irrigation management (type, water source, water quality parameters including electrical conductivity and sodium adsorption ratio, irrigation period, periodicity/frequency, total annual mm); irrigation annual fossil fuel consumption;

○ Silvopastoral: Number and species of trees used, projected or actual diameter at breast height (DBH) of trees.

6.2 Baseline Soil Carbon Definition

As FAO states[6], there are two approaches to define a baseline soil carbon level, depending on the available information.

6.2.1 Time Based Measurements Baseline

Repeated GRASS measurements over time against a measured base period, where the baseline trend carbon stocks are assumed to be constant.

'This approach is most suitable where sampling sites can be revisited every 1 to 10 years to monitor change and where additional data is available, such as seasonal climate and management practices. Results are commonly analysed as t1 vs. base period (t0) or using statistical tools such as regression analysis to detect significant trends in SOC stocks over time when several measurement times are available'.

6.2.2 Contrasting Management Baseline

As FAO states: ' This approach does not require a 'before management change' baseline measurement. Instead, it compares SOC stocks at different sites at one single time after a contrasting management was implemented in one of them. The underlying assumption is that the business-as-usual site and the differently managed sites were the same prior to the change in management (e.g. in terms of soil type, climate, land use, productivity)'

In this case, project proponents must demonstrate that the business as usual site can be considered the baseline period by providing evidence of similar soil type, climate, land use with the managed sites, defined in the Contrasting Management Subprotocol (Annex C).

The contrasting management baseline approach is used in IPCC (2014) and UNFCCC (2014) accounting. For Ruuts it will be used during the first three seasons of this Protocol (2021-2023) to allow early adopters participation in the program.

[6] FAO. 2019. Measuring and modelling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership. Rome, FAO. 170 pp. Licence: CC BY-NC-SA 3.0 IGO

7 MRV Overview

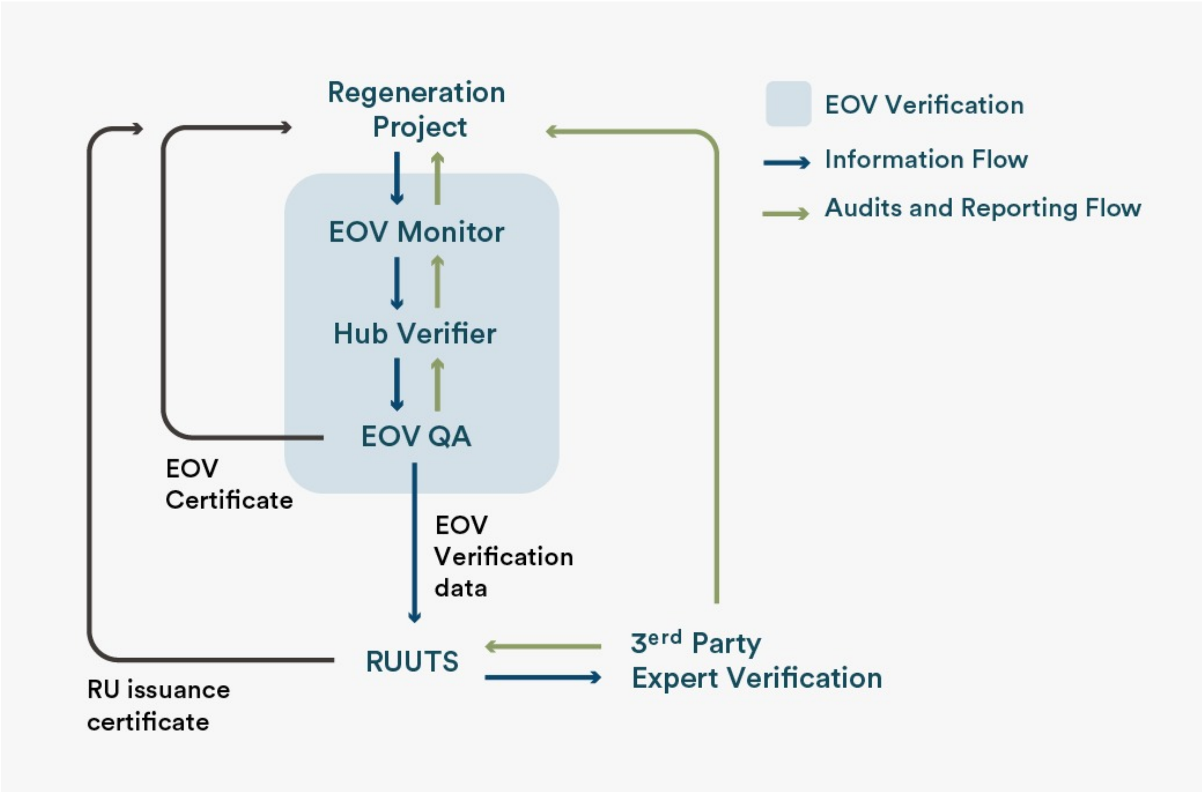

Figure 1: MRV diagram based on GRASS monitoring and reporting

7.1 Monitoring

Regeneration Projects are required to have GRASS Verification on a yearly basis. Monitoring procedures follow the latest version of GRASS Training Manual, Version 3.0 or subsequent[7].

Each farm has to create a Monitoring Plan, which will include a combination of Short Term and Long Term monitoring sites, which are georeferenced. Using remote sensing tools, heterogeneity sources are identified, and strata are delimited inside each CEA. Each strata is labelled and area estimation is provided for each one. Strata definition follows soil types, topography, vegetation type, land use. In small, homogeneous farms only one strata will be defined and monitoring sites distributed across the whole area.

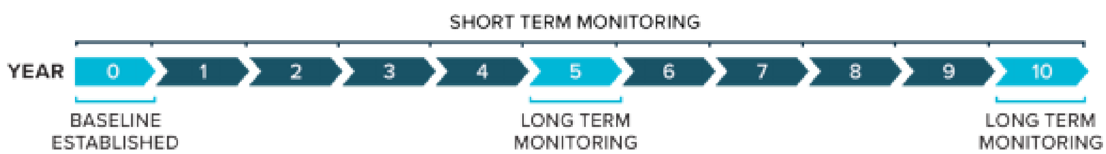

Figure 2: GRASS monitoring program

[7] Savory Institute. 2021. Ecological Outcome Verification. Training Manual. Version 3.0.

GRASS has two field procedures that are combined to provide monitoring of land regeneration. Those are Short Term Monitoring (STM), which is performed on a yearly basis, generally at the end of the growing season, and long term monitoring (LTM), which is performed at the baseline year and every 4-5 subsequent years. While the first is done to inform grazing management and to infer if regeneration is happening, the latter provides lagging indicators like biodiversity, water infiltration and soil carbon content. Both procedures generate reports and the backup information is stored at the GRASS Platform.
Compliance with the monitoring protocols and evidence of positive regeneration trend are required to get a yearly GRASS Verification, issued by the Savory Institute.

7.2 Short Term Monitoring

7.2.1 Ecological Health Index

STM has to be performed by an GRASS Accredited Monitor. This is a quick and inexpensive assessment that provides information for farm managers, but also provides leading indicators of land regeneration. Forage availability and Ecological Health Index (EHI) are assessed in a stratified sampling scheme that covers the CEA. The Ecological Health Index is a scoring method that uses 15 ecological indicators that define the status of the ecosystem processes. EHI correlates with lagging indicators, and its positive trend can be used as an indication that positive changes might be occurring in the attributes that are measured in LTM[8]. GRASS yearly verification is issued by SI when EHI shows positive trend, or it is stable in high scores.

A minimum of 10 STM monitoring sites per CEA is required to comply with the GRASS STM procedures, assigned in proportion to the area of each strata inside a CEA.

7.2.2 Remote Sensing & SOC Modelling. Not available in this version.

7.2.3 Emission monitoring requirements

Project emissions should be calculated on a yearly basis, based on farmer reporting and evidence. The project proponent for a soil carbon project must comply with the monitoring requirements set out in the following table in accordance with the instructions given in table 1, in order to estimate GHG emissions following the methodologies described in section 11.

Table 1: Emission monitoring requirements

Monitoring requirements

[8] Sutie Xu 1, Jason Rowntree 1,*, Pablo Borrelli 2, Jennifer Hodbod 3 and Matt R. Raven. 2019 Ecological Health Index: A Short Term Monitoring Method for Land Managers to Assess Grazing Lands Ecological Health. Environments doi:10.3390/environments6060067

Item	Parameter	Description	Units	Instructions
1	$Q_{LS_{gijk},BL,PA}$	**Number of animals in livestock group** *gijk* within the CEAs and emissions accounting areas of each project area in each year (*B*) of the baseline period.	Livestock head	Form 7 - GRASS Short Term monitoring
2	$D_{gijk,B,PA}$	**Period (in days) in year *B* of the baseline period that livestock group *gijk* was within the CEA**s and emissions accounting areas of each project area.	Days	Form 7 - GRASS Short Term monitoring
3	$Q_{LS_{gijk},RP,PA}$	**Number of animals in livestock group *gijk* that were within the CEAs and emissions accounting areas of each project area.**	Livestock head	Form 7 - GRASS Short Term monitoring
5	$G_{SF_{fij},RP,PA}$	**quantity of synthetic fertiliser** group *fij* applied to the CEAs and emissions accounting areas of each project area.	t fertiliser	Evidenced by invoices, contractual arrangements or sales records.
6	$U_{RP,PA}$	**Quantity of urea** applied to the CEAs and emissions accounting areas of each project area.	t urea	Evidenced by invoices, contractual arrangements or sales records.
7	$L_{l,RP,PA}$	**Quantity of lime** type *l* applied in the CEAs and emissions accounting areas of each project area.	t	Evidenced by invoices, contractual arrangements or sales records.
8	$VQ_{v,RP,PA}$	**Quantity of harvested crop by crop type** *v* in the reporting period in the CEAs and emissions accounting areas of each project area.	t of crop	Evidenced by invoices, contractual arrangements or other industry standard practices.
9	$RF_{v,RP,PA}$	**Fraction of crop residue from crop type** *v* that was removed from the CEAs and emissions accounting areas of each project area.	Decimal	Evidenced by industry standard practices, such as cover rating assessments.
10	$AreaT_{RP,PA}$	**Tilled area for pasture establishment or renovation** in the CEAs and emissions accounting areas of each project area.	ha	Mapping approach using satellite imagery during reporting period

11	$Q_{I,RP,PA}$	**Quantity of fuel used to irrigate the CEA**s and emissions accounting areas of each project area.	kL	Evidenced by invoices or contractual arrangements and apportioned based on hectares of the carbon estimation area irrigated as a fraction of the total hectares of land irrigated and the fuel used to run all pumps on that land
12	$Q_{IP,RP,PA}$	**Quantity of electricity used to irrigate the CEA**s and emissions accounting areas of each project area.	kWh or GJ	Evidenced by invoices or contractual arrangements and apportioned based on hectares of the carbon estimation area irrigated as a fraction of the total hectares of land irrigated and the fuel used to run all pumps on that land. Where electricity purchased is measured in gigajoules, the quantity of kWh must be calculated by dividing the amount of GJ by 0.0036.
13	Q_F	**Quantity of fuel used to carry out soil landscape modification activiti**es in the CEAs and emissions accounting areas of each project area.	kL	Evidenced by invoices or contractual arrangements.
14	Q_{PB}	**Quantity of prescribed burning** (area has and biomass estimation)	t	Evidenced by satellite imagery (NDVI series)

7.3 Long Term Monitoring

7.3.1 SOC Sampling (According to GRASS 3.0)

7.3.1.1 Sampling strategy

Sample distribution follows the STM monitoring plan. This gives a stratified random sampling scheme. As a minimum 20 georeferenced soil sampling plots are installed per CEA,assigned to each strata following area proportion. At each site,1 composite soil sample is taken following a grid sampling scheme inside a sampling plot of 20m x 20m. Each composite soil sample is the result of 6 cores or subsamples. A minimum of 20 sampling plots are defined by CEA. Each monitoring plot is separated from the other by at least 100 meters to avoid sampling in the same pixel. Miscellaneous strata (smaller than 10% of total area) are added to strata of similar or lesser productivity.

7.3.1.2 Sampling number

As suggested by several authors, data from GRASS baselines were used as a pre-sample to calculate the minimum number of samples to estimate the average Soil Carbon mass with 10% of error. The formula used was proposed by Carter and Gregorich (2008).
The amount of required samples n is given by the following equation:

$$n = \frac{t_{a\,(n-1)} \times V(\underline{x})}{(d \times \underline{x})^2}$$

Where:
$t_{a\,(n-1)}$ is the t Student value for a<0.05 and (n-1) degrees of freedom;
$V(\underline{x})$ is the sample variance,
d is the maximum allowed margin of error (10%) and
$\underline{x}$ is the average of the sample.

The pre-sampling study covered a wide gradient of environments, from subtropical grasslands from North Eastern Argentina, to the Pampas region and Patagonian steppes.
Percentage CV of the soil carbon mass ranged from 6% to 18%, with an average of 12.3%. The required number of samples per farm ranged from 9 to 13 using stratification, and up to 18 samples when data was analyzed without stratification. Results suggest that a fixed amount of 20 samples per farm would provide a safe estimation of the soil carbon mass average all across a wide range of environmental conditions.
After performing baseline sampling with 20 soil sampling sites, Minimal Detectable Difference analysis will be performed (FAO 2019), and if soil sample number proved to be insufficient, a second sampling round would be conducted.

See Annex B to access pre - sampling tests.

7.3.1.3 Soil sampling frequency

Soil sampling will be performed at Baseline and then every 4-6 years, depending on expected carbon sequestration rates.

7.3.1.4 Soil Depth Intervals

Soil sampling for the 0-30 depth interval is mandatory. Optionally, 30-50 and 50-100 cm intervals could be added.

7.3.1.5 Bulk Density estimation and soil carbon mass

Bulk density calculations are performed directly from the weight of intact soil cores, as proposed by the Australian Soil Carbon Scheme[9]. Soil probe diameter, depth interval and number of subsamples is recorded in GRASS field form 12, to calculate sample volume. The material is carefully collected and dry weight obtained in the lab. Gravel greater than 2 mm diameter is grinded and weighed separately, to assess gravel-free soil mass.

For soils where the use of a soil probe is limited, the cylinder method or the excavation method can be used for bulk density determination (FAO, 2019[10]).

Soil Carbon Mass is expressed in terms of Fixed Soil Mass (FSM), following the procedure described by the Australian Soil Carbon Scheme. This means that soil carbon mass is expressed in terms of equivalent soil masses and not in terms of depth intervals. This allows dealing with changes in bulk density that may cause error on C mass results.

7.3.1.6 Soil sample management and handling

Soil subsamples are mixed in labeled bags. Fresh weight is recorded before shipping. Samples are stored at 4 ºC until shipment.

7.3.1.7 Soil Lab Measurements

Soils Lab selection must have standardized procedures and accreditations /auditing. Eligible Labs must have National or International Quality Assessments, like GLOSOLAN or SAMLA in Argentina.

Soil C will be preferently determined by Total Combustion Auto-Analyzer (LECO, ERBA or similar).
This protocol will accept determinations using Walkley Black or Loss on Ignition (LOI), when the preferred method is not available at a reasonable shipping distance.

Soil dry weight and gravel weight > 2mm diameter will also be determined for each sample.

Soil biology tests like Cornell or Haney are also accepted as part of the soil regeneration assessment.

7.3.2 Biodiversity and Water Infiltration

7.3.2.1 Sampling strategy

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9 Frydenberg, J. 2018. Carbon Credits (Carbon Farming Initiative— Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination. https://www.legislation.gov.au/Details/F2018L00089

10 **FAO.** 2019. *Measuring and modelling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1).* Livestock Environmental Assessment and Performance (LEAP) Partnership. Rome, FAO. 170 pp. Licence: CC BY-NC-SA 3.0 IGO.

Photographic plots, vegetation biodiversity and water infiltration are assessed at Long Term Monitoring sites, in a stratified benchmark sampling arrangement.

Minimal number of LTM sites will depend on landbase heterogeneity, which is reflected by the number of strata. Strata are differentiated as heterogeneity sources that affect results, like soil type, vegetation type, topographic position, land use, etc. Very homogeneous landscapes may be treated as one strata. As heterogeneity increases, more strata are required to design the LTM sampling. Very heterogeneous landbases may benefit from differentiating 3 or more strata.

The number of LTM sites per each strata is shown in table 2.

Table 2: Number of LTM sites per strata

Size of Strata	Number of LTM /strata
Up to 3000 ha	1
3000 to 10000 ha	2
More than 10000 ha	3

The final number of LTM sites will depend on the number of strata and their size.

Examples of LTM number of sites calculation

1: a 100 ha landbase, quite homogeneous:

Strata	Area of Strata (ha)	Number of LTM/strata
A	100	1
Total	100	1

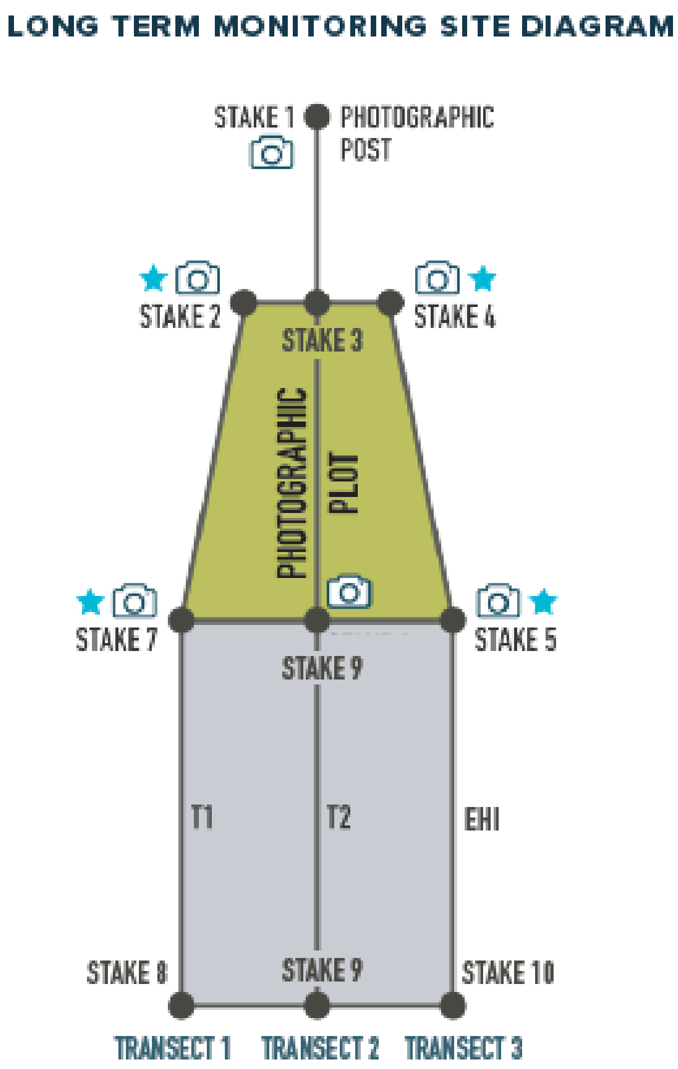
2: a 1800 hectare landbase, moderately variable

Strata	Area of Strata	Number of LTM/strata
A	1000	1
B	800	1
Total	1800	2

3: a 20000 hectare landbase, highly variable

Strata	Area of Strata	Number of LTM/strata
A	4000	2
B	12000	3
C	1300	1
D	2700	1
Total	20000	7

7.3.2.2 LTM site diagram

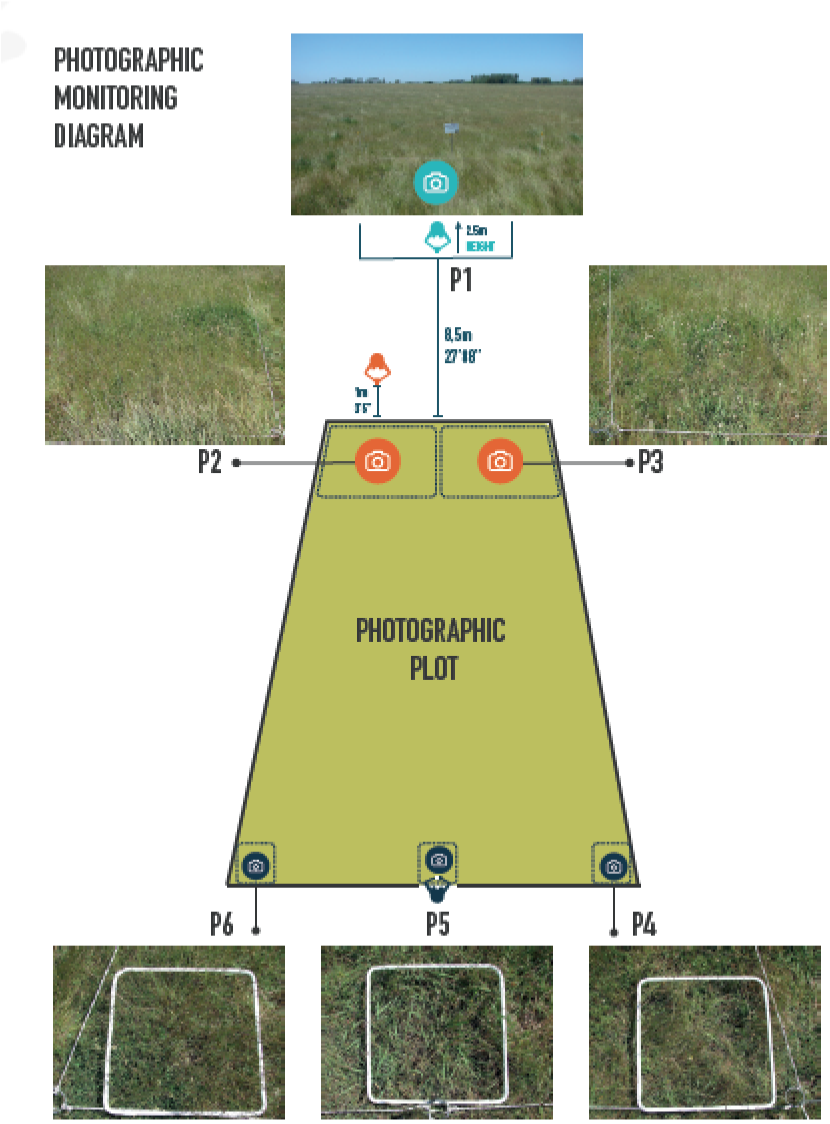


LTM sites have a photographic plot and three 25m transects named T1, T2 and T3. The first 2 are used to determine vegetation biodiversity, while T3 is used to define Ecological Health

Index (that relates with Short Term Monitoring) and to take 10 vertical pictures. Water infiltration estimates are done 5 m away from stakes 5,7, 8 and 10.

7.3.2.3 Photographic plot

LTM sites are GPS referenced and also marked permanently with metal posts. 6 pictures are taken from preselected positions, to monitor structural vegetation change



7.3.2.4 Biodiversity

Biodiversity assessment follows the procedure proposed by Halloy et al [11]. Line point method is applied to two 100 points transects to a total 200 points that are read using a pin.

[11] Halloy, S, Ibarra, M. y Yager, K. 2011. Puntos y Areas Flexibles para inventarios rápidos de estado de biodiversidad. Ecología en Bolivia 46 46-56.

Bare ground, litter and plants are recorded by functional groups and species. After performing the line point readings, a flexible area procedure allows to detect and include all the species that have not been hit previously, with their absolute cover estimated. A complete species list for the area that extends from T1 to T3 (13 x 25 m) is gathered, with absolute cover estimates.

Data is processed to calculate the following biodiversity indicators:

- Functional group richness (Number of functional groups)
- Species richness (Total number of species)
- Shannon-Wienner Index, which brings an estimate of equitativity in mass distribution.

7.3.2.5 Water Infiltration

A single 6" ring infiltrometer is used[12]. Infiltration rate is assessed directly by measuring the time taken for a known amount of water to soak in (equivalent to a 25 mm rain). A first rain is simulated, and then readings are taken during a second one. Infiltration rate (mm/min) is calculated as 25 mm divided by the time taken for the water to infiltrate. If time is longer than 30 minutes, a standard time of 40 minutes is recorded.
A number of 3-4 replications of water infiltration is done per LTM site.

7.3.3 Previous Monitoring Methodologies

This protocol is based on GRASS version 3.0 and subsequent. Nevertheless, Projects that performed monitoring plans before December 2020 under previous protocol versions will be accepted. This includes the following:

GRASS Standard Version 1.0; 2.0; 3.0; 4.0;
GRASS Version 2.2

[12] USDA 1999. Soil Quality Test Kit Guide. 88 pp

8 Reporting and Verification

8.1 Reporting

Four types of reports are necessary to comply with this MRV protocol:

a) Project Registration report

-Project Definition compliance
-Eligibility Compliance
- Project Boundaries

b) Baseline Report

-Baseline definition
-Ecological Health Index of the CEA and LTM sites
-Biodiversity indexes
-Soil Sampling and SOC results
-Infiltration rate

c) STM reports

-EHI yearly assessment and trend
- GRASS Verification certificate issued by SI
- Annual Emissions Calculation
- Possible Reversals Events

d) LTM reports

-Ecological Health Index of the CEA and LTM sites
-Biodiversity indexes
-Soil Sampling and SOC results
-Infiltration rate
-Reversals that exceed 10%
-Net removal Calculation

8.2 Verification Process

8.2.1 GRASS Quality Assurance

GRASS is supported by sound quality assurance procedures and protocols. Each monitoring activity is carried out by accredited Verifiers and Monitors with deep knowledge and experience in the given regional context. Data uploaded onto the

GRASS platform is reviewed and analyzed by the regional Hub Verifier and the Global Network of Master Verifiers. On an annual basis, an average of 5% of all participating farms are subject to an on-site audit. The selection of farms to be audited are a result of data analysis (any farm with suspicious or inconsistent data relative to the regional trends will be audited) and random selection.

For more detailed description see GRASS 3.0 Chapter 7: GRASS Quality Assurance

8.2.2 Ruuts Independent Experts Verification

In addition to the GRASS quality assurance process, Ruuts has a 3erd party verification whose role is:

- Verify Regeneration Project Eligibility
- Verify RU Net removals Calculations
- Audit Regeneration Projects (desk & random field audits)

This 3er party can be independent experts, consultant companies, Universities or NGOs. Must have:

- Scientifically robust background on Soil Organic Carbon and agricultural GHG Quantification Methodologies.
- Regional Knowledge
- Peers Recognition.
- Declare no conflict of interest with the project, the monitoring and reporting process or ruuts.

9 Regeneration Units issuance

9.1 RU issuance process

An RU represents 1 tonne of CO_2e that is a net removal from the atmosphere captured through a verified soil regeneration process. In order to Issue an RU an eligible project must go through the following stages:

1. Demonstrate a positive trend in the Ecological Health Index for the reporting period, according to section 7.2.
2. Calculate the creditable change in soil organic carbon stock according to section 10.
3. Calculate the Average project emissions for baseline and for the reporting period, according to section 11.
4. Calculate the RU Issuance according to this section.

9.2 Overview of gases accounted for in RU calculations

Table 3 provides an overview of the emissions sources and carbon pools, and the associated greenhouse gases, that are relevant to working out the net removal amount for a regeneration project.

Table 3: GHC accounted for RU calculations

Overview of gases accounted for in abatement calculations

Item	Relevant carbon pool or emission source		Greenhouse gas
1	Carbon pool	Soil	Organic carbon (C)
2	Emissions source	Livestock	Methane (CH_4) Nitrous oxide (N_2O)
3	Emissions source	Synthetic fertilizer and urea	Nitrous oxide (N_2O) Carbon dioxide (CO_2)
4	Emissions source	Lime	Carbon dioxide (CO_2)
5	Emissions source	Tillage events	Nitrous oxide (N_2O) Carbon dioxide (CO_2) Methane (CH_4)
6	Emissions source	Soil landscape modification activities	Nitrous oxide (N_2O) Carbon dioxide (CO_2) Methane (CH_4)
7	Emissions source	Residues	Nitrous oxide (N_2O) Carbon dioxide (CO_2) Methane (CH_4)

8	Emissions source	Irrigation energy	Nitrous oxide (N_2O) Carbon dioxide (CO_2) Methane (CH_4)
9	Emissions source	Prescribed Burning	Nitrous oxide (N_2O) Carbon dioxide (CO_2) Carbon Monoxide (CO) Methane (CH_4)

9.3 RU issuance for a Reporting Period

The amount of Regeneration Units (RU) to be issued for a reporting period, is given by the following equation:

$$RU_{(RP)} = A_{PA}\, x\, (1 - Buffer) \qquad \text{equation 1}$$

where:

$\boldsymbol{A_{PA}}$ is the net removal amount for the reporting period for the project area *PA*, in tonnes of CO_2-*e*, given by equation 2.

Buffer is a percentage of the net removal that will be stored as a pool buffer in the Ruuts Registry for possible future reversals.

9.4 The net removal amount for a project area, A_{pa}

(1)For equation 1, A_{PA} is worked out using the following equation:

$$A_{PA} = \Delta CO_2e_{60\, PA\, (RP)} - EA_{PA} \qquad \text{equation 2}$$

where:

$\Delta CO_2e_{60\,PA\,(RP)}$ is the creditable change in soil organic carbon associated with a 60% probability of exceedance for a reporting period RP, in tonnes of CO_2-e, given by Subsection 10.

EA_{PA} is the emissions adjustment for the project area and reporting period that is:

(a) Where only baseline and one subsequent sampling conducted:

(a.1) if $\Delta Eall_{RP,PA}$ given by equation 57 in Subsection 11 is less than or equal to 0—0;

(a.2) Otherwise - given by equation 57 in Subsection 11

(b)Where 3 or more subsequent samplings conducted , EA_{PA} is given by equation 58 in Subsection 11.

10 Calculation of Soil Organic Carbon

This section provides the guide for the calculation of a project creditable change in SOC stocks for a reporting period in tonnes of CO2eq, known as $\Delta CO_2e_{PA\,(RP)}$. Calculations are done every ⅘ years. This section follows the Australian Carbon Credits (Carbon Farming Initiative— Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination 2018[13].

10.1 Calculating the soil organic carbon stock in a sample

Following FAO (2020) "Carbon stocks must be expressed in units of equivalent mass, to avoid the influence of different compaction states that involve soils of different weight. For this, the calculated stocks must be referred to an equivalent soil mass (Australian Carbon Scheme, 2018), which should exclude carbon concentration during the calculation of soil mass (dry). Assuming that in this case it is important to know whether or not there was additionality in the impact of the practices, it is taken as a criterion to express it on the basis of the less compact soil (i.e. lower bulk density)".

10.1.1 **Calculation of density of core segment**[14]

Calculate density of a sample i,(D_i), with the following equation:

$$D_i = \frac{M_{cs_i} - M_{g_i}}{L_i \times \pi \times r_{cs}^{2}} \qquad \text{equation 3}$$

[13] https://www.legislation.gov.au/Details/F2018L00089

[14] B.H. Ellert, H.H. Janzen, A.J. VandenBygaart, and E. Bremer. 2008 Chapter 3. Measuring Change in Soil Organic Carbon Storage. In Carter,M. and Gregorich. 2008 Eds. Soil sampling and methods of analysis. - 2nd ed. Canadian Society for Soil Science

where

M_{cs_i} is the total oven-dry mass of the sample i in grams;

M_{g_i} is the total gravel (fragments coarser than 2mm) mass of the sample i in grams;

L_i is the depth of the core sample i in cm; and

r_{cs} is the core radius in cm.

10.1.2 Calculation of fixed depth soil mass

Calculate the fixed depth soil mass for each core sample i in tonnes per hectare using the following equation

$$M_{fd_i} = D_i \times L_i \times 1000 \qquad \text{equation 4}$$

where

D_i is density of the core sample i given by equation 3

L_i is the depth of the core sample i in cm;

Note: The value 1000 converts $\frac{D_{cs}}{cm}$ into tonnes per hectare.

In case of having deeper core depth intervals, calculations are done by each depth interval separately and then added at the end of the process.

10.1.3 Calculation of fixed depth Soil Carbon stock

Calculate the fixed depth soil carbon stock for each sample i (SOC_{fd_i}) in tonnes of carbon per hectare using the following equation

$$SOC_{fd_i} = M_{fd_i} \times C_i \qquad \text{equation 5}$$

where

C_i is the total carbon content of the soil sample i, in percentage.

M_{fd_i} is the fixed depth soil mass for core sample i in tonnes per hectare given by equation 4

10.1.4 Determining Equivalent Soil Mass (ESM) from sampling round masses

The soil masses M_{fd_i} from equation 4, from the sampling round t_0 must be:

a. ranked from lowest to highest for each CEA; and
b. assigned a sequential rank *k* from 1 to the number of samples in the CEA *N*.
c. A percentile *P* must be calculated for each value of *k* using the following equation:

$$P = 100 \times \frac{(k-1)}{(N-1)} \qquad \text{equation 6}$$

d. If one of the percentiles given by equation 6 is 10—the *ESM* for the CEA is the mass of the soil layer given by equation 6 for the relevant rank of *k*.

e. If subsection (d) does not apply—the *ESM* for each CEA is given by the following equation:

$$ESM = M_{LB} + \left(M_{UB} - M_{LB}\right) \times \left(\frac{10 - P_{LB}}{P_{UB} - P_{LB}}\right) \qquad \text{equation 7}$$

where:

$\boldsymbol{M_{LB}}$ is the corrected soil mass M_i of the sample *i*, which has been assigned the lower bound rank *LB* as having the value of *P* from equation 3 closest to and lower than 10, in tonnes of soil per hectare, as given by equation 4.

$\boldsymbol{M_{UB}}$ is the corrected soil mass M_i of the sample *i,* which has been assigned the upper bound rank *UB* as having the value of *P* from equation 6 closest to and higher than 10, in tonnes of soil per hectare, as given by equation 4.

$\boldsymbol{P_{LB}}$ is the percentile *P* associated with the lower bound rank *LB* given by equation 6.

$\boldsymbol{P_{UB}}$ is the percentile *P* associated with the upper bound rank *UB* given by equation 6.

10.1.5 Excess Mass of the soil sample

Calculate the excess mass of soil for each soil sample i , M_{ex_i}, in tonnes of soil mass per hectare.

$$M_{ex_i} = M_{fd_i} - ESM \qquad \text{equation 8}$$

where

M_{fd_i} the fixed depth soil mass for core sample i in tonnes per hectare given by equation 4

ESM is the equivalent soil mass in tonnes per hectare given by equation 7

10.1.6 Calculation of fixed mass Soil Carbon stock

Calculate the fixed mass soil carbon stock, SOC_{fm_i} in tonnes per hectare for sample i, using the following equation:

$$SOC_{fm_i} = SOC_{fd_i} - \left(\frac{M_{ex_i} \times C_i}{100}\right) \qquad \text{equation 9}$$

where

SOC_{fd_i} is the fixed depth soil carbon stock for sample i in tonnes per hectare given by equation 5

M_{ex_i} is the excess mass of soil for sample I in tonnes per hectare given by equation 8

C_i is the total carbon content of the soil sample i, in percentage

Note: The value 100 converts percentage into decimal values.

10.2 Calculating the soil organic carbon stock and variance for a CEA[15]

10.2.1 Average soil organic carbon stock for a stratum

Calculate the average soil organic carbon stock for each stratum *h* (the $\underline{SOC}_h$), in tonnes of soil organic carbon per hectare, using the following equation:

$$\underline{SOC}_h = \frac{\sum_{i=1}^{n} SOC_{fm_i}}{n} \qquad \text{equation 10}$$

where:

SOC_{fm_i} is the fixed mass SOC_i for each sample *i* from stratum *h*, in tonnes of carbon per hectare, given by equation 9.

n is the number of samples from the stratum *h*.

10.2.2 Sampling variance of the soil organic carbon stock for a stratum

Calculate the sampling variance of the average soil organic carbon for each stratum *h* (the $V(\underline{SOC}_h)$, in tonnes of carbon per stratum squared, using the following equation:

[15] Based on the Australian Carbon Credits (Carbon Farming Initiative— Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination 2018

$$V(\underline{SOC}_h) = \frac{\sum_{i=1}^{n}\left(SOC_{fm_i} - \underline{SOC}_h\right)^2}{n(n-1)}$$ equation 11

where:

SOC_{fm_i} is the SOC$_i$ for each sample i from stratum h, in tonnes of carbon per hectare, given by equation 9 .

$\underline{SOC}_h$ is the average soil organic carbon stock in each stratum h, in tonnes of soil organic carbon per hectare, given by equation 10.

n is the number of samples for stratum h.

Note: If n>10 (n-1) is used as denominator. If different, denominator is deemed to be n .

10.2.3 Average total soil organic carbon stock for a CEA

Calculate the average soil organic carbon stock for each CEA (the $\underline{SOC}_{CEA}$), in tonnes of carbon per hectare, using the following equation:

$$\underline{SOC}_{CEA} = \sum_{h=1}^{H}\left(a_h \times \underline{SOC}_h\right)$$ equation 12

where:

a_h is the relative area of the CEA covered by the stratum, as a percentage.

$\underline{SOC}_h$ is the average soil organic carbon stock in each stratum h, in tonnes of soil organic carbon per hectare, given by equation 10.

H is the number of strata for the CEA.

10.2.4 Sampling variance of the average soil organic carbon stock for a CEA

Calculate the sampling variance of the average soil organic carbon for each CEA (the $V\left(\underline{SOC}_{CEA}\right)$), in tonnes of carbon per CEA squared, using the following equation:

$$V\left(\underline{SOC}_{CEA}\right) = \sum_{h=1}^{H}\left(a_h^{\,2} \times V\left(\underline{SOC}_h\right)\right)$$ equation 13

where:

H is the number of strata for the CEA.

a_h is the relative area of the CEA covered by the stratum, as a percentage.

$V\left(\underline{SOC}_h\right)$ is the sampling variance of the average soil organic carbon for each stratum h, in tonnes of carbon per CEA squared, given by equation 11.

10.2.5 **Soil organic carbon stock for a CEA**

Calculate the soil organic carbon stock (the SOC_{CEA}), in tonnes of soil organic carbon per CEA, is given by the following equation:

$$SOC_{CEA} = \underline{SOC}_{CEA} \times A_{CEA} \qquad \text{equation 14}$$

where:

$\underline{SOC}_{CEA}$ is the average soil organic carbon stock for a CEA, in tonnes of carbon per hectare, given by equation 12.

$\boldsymbol{A_{CEA}}$ is the area of the CEA, in hectares.

10.2.6 **Sampling variance of the soil organic carbon stock for a CEA**

Calculate the soil carbon stock sampling variance (the $V\left(SOC_{CEA}\right)$), in tonnes of carbon per CEA squared, using the following equation:

$$V\left(SOC_{CEA}\right) = A_{CEA}^{\ 2} \times V\left(\underline{SOC}_{CEA}\right) \qquad \text{equation 15}$$

where:

$\boldsymbol{A_{CEA}}$ is the area of the CEA, in hectares.

$V(\underline{SOC}_{CEA})$ is the sampling variance of the average soil organic carbon in each CEA, in tonnes of carbon per CEA squared, given by equation 13.

10.3 Calculating the creditable change in soil organic carbon stock

10.3.1 Where only baseline and 1 subsequent sampling round conducted

This subdivision applies to the calculation of $\Delta CO_2e_{60\,PA\,(RP)}$ if only the baseline sampling round and 1 subsequent sampling round have been conducted in relation to the project area.

Note: For when 2 or more subsequent sampling rounds have been conducted—see Subdivision 3.

10.3.1.1 Change in carbon stock between sampling rounds

Calculate the change in soil organic carbon stock between the baseline sampling round t_0 and the subsequent sampling round t_1 (the $\Delta SOC_{CEA(t_0-t_1)}$), in tonnes of soil organic carbon per CEA, using the following equation:

$$\Delta SOC_{CEA(t_0-t_1)} = SOC_{CEA\,t_1} - SOC_{CEA\,t_0} \qquad \text{equation 16}$$

where:

$SOC_{CEA\,t_1}$ is the value for SOC_{CEA} for the subsequent sampling round, in tonnes of soil organic carbon per CEA, given by equation 14;

$SOC_{CEA\,t_0}$ is the value for SOC_{CEA} for the baseline sampling round, in tonnes of soil organic carbon per CEA, given by equation 14.-

10.3.1.2 Standard error for change in carbon stock

Calculate the standard error of the mean difference between total soil organic carbon for each CEA between the baseline sampling round t_0 and subsequent sampling round t_1 (the SE), in tonnes of soil organic carbon per CEA, using the following equation:

$$SE = \sqrt{V\left(SOC_{CEA\,t_0}\right) + V\left(SOC_{CEA\,t_1}\right)} \qquad \text{equation 17}$$

where:

$V\left(SOC_{CEA\,t_0}\right)$ is the value for $V\left(SOC_{CEA}\right)$ for the baseline sampling round, in tonnes of soil organic carbon per CEA, given by equation 15.

$V\left(SOC_{CEA\,t_1}\right)$ is the value for $V\left(SOC_{CEA}\right)$ for the subsequent sampling round, in tonnes of soil organic carbon per CEA, given by equation 15.

10.3.1.3 Alpha value for students t test

Calculate the alpha value α using the following equation:

$$\alpha = \frac{(100 - probability\ of\ exceedance)}{100} \qquad \text{equation 18}$$

:probability of exceedance is deemed to be 60, based on a conservative estimate of the probability that the true soil organic carbon stock value will exceed the calculated value.

10.3.1.4 Degrees of freedom for students t test

Calculate the degrees of freedom (the df) for a one tailed t students test, using the following equation:

$$df = \left(n_{it_0 CEA} - n_{ht_0}\right) + \left(n_{it_1 CEA} - n_{ht_1}\right) \qquad \text{equation 19}$$

where:

$n_{it_0 CEA}$ is the number of samples i taken in the baseline sampling round t_0 in the CEA.

n_{ht_0} is the number of strata h in the baseline sampling round t_0 in the CEA.

$n_{it_1 CEA}$ is the number of samples i taken in the subsequent sampling round t_1 in the CEA.

n_{ht_1} is the number of strata h in the subsequent sampling round t_1 in the CEA.

10.3.1.5 Change in carbon stock in a CEA with 60% probability of exceedance

Calculate the change in soil organic carbon stock for the CEA between two sampling rounds associated with a 60% probability of exceedance (the $\Delta SOC_{60\ CEA}$), in tonnes of carbon per CEA, using the following equation:

$$\Delta SOC_{60\ CEA} = \Delta SOC_{CEA\left(t_0 - t_1\right)} + SE \times t_{\alpha(df)} \qquad \text{equation 20}$$

where:

$\Delta SOC_{CEA\left(t_0 - t_1\right)}$ is the is the value for $\Delta SOC_{CEA\left(t_0 - t_1\right)}$, in tonnes of soil organic carbon per CEA, given by equation 16.

$\boldsymbol{SE}$ is the value for SE given by equation 17.

$t_{\alpha(df)}$ is t value derived from a one-tailed student's t-distribution with the value for alpha α given by equation 21 and the degrees of freedom df given by equation 19.

10.3.1.6 Change in carbon stock in a project area with 60% probability of exceedance

Calculate the change in soil organic carbon stock for a project area between the baseline sampling round and subsequent sampling round associated with a 60% probability of exceedance (the $\Delta SOC_{60\ PA}$), in tonnes of carbon per project area, using the following equation:

$$\Delta SOC_{PA} = \sum_{CEA=1}^{n_{CEA}} \Delta SOC_{60\ CEA} \qquad \text{equation 21}$$

where:

$\Delta SOC_{60\ CEA}$ is the value for $\Delta SOC_{60\ CEA}$, in tonnes of soil organic carbon per CEA, given by equation 20.

n_{CEA} is the number of CEAs in the project area.

10.3.1.7 Carbon dioxide equivalence of change carbon stock for a project area with 60% probability of exceedance

Calculate the carbon dioxide equivalence of the change in soil organic carbon stock for a project area, in tonnes of CO_2-e, using the following equation:

$$\Delta CO_2e_{60\ PA} = \Delta SOC_{PA} \times \frac{44}{12} \qquad \text{equation 22}$$

where:

ΔSOC_{PA} is the value for ΔSOC_{PA}, in tonnes of soil organic carbon per project area, given by equation 21.

Note: The value $\frac{44}{12}$ converts tonnes of carbon to tonnes of CO_2-e.

10.3.1.8 Creditable change in soil organic carbon for a project area for a reporting period

The $\Delta CO_2e_{60\ PA\ (RP)}$, in tonnes of CO_2-e, is given by the following equation:

$$\Delta CO_2e_{60\ PA\ (RP)} = \Delta CO_2e_{60\ PA} \times 0.5 \qquad \text{equation 23}$$

where:

$\Delta CO_2e_{60\ PA}$ is the value for $\Delta CO_2e_{60\ PA}$, in tonnes of CO_2-e, given by equation 22.

Note: The 0.5 is a temporary discount to the creditable amount of change in carbon stock due to the use of only 2 sampling rounds.

10.3.2 Where 3 or more sampling rounds are conducted

This subdivision applies to the calculation of $\Delta CO_2e_{60\,PA\,(RP)}$ if the baseline sampling round and 2 or more subsequent sampling rounds have been conducted in relation to the project area.

10.3.2.1 Median day of a sampling round

In this Subdivision, the ***median day*** of a sampling round is:

(a) if the sampling was conducted on a single day—that day; or

(b) if the sampling was conducted over an odd number of days counting from the first to last day—the middle day; or

(c) if the sampling was conducted over an even number of days counting from the first to last day—the second of the two middle days.

10.3.2.2 Average project duration

Calculate the average project duration between all completed sampling rounds (the $\overline{PD}$), in years, using the following equation:

$$\overline{PD} = \frac{\sum_{t=0}^{T} PD_t}{T} \qquad \text{equation 24}$$

where:

PD_t is the duration of the project associated with each sampling round *t* calculated as the time, in decimal years, between the median day of sampling round and the median day of the baseline sampling round.

T is the number of sampling rounds completed (including the baseline sampling round).

10.3.2.3 Average carbon stock across all completed sampling rounds

Calculate the average carbon stock across all completed sampling rounds (the $\overline{SOC_{CEA_{(t_0-t_x)}}}$), in tonnes of soil organic carbon per CEA, using the following equation:

$$\overline{SOC_{CEA_{(t_0-t_x)}}} = \frac{\sum_{t0}^{T} SOC_{CEA_t}}{T} \qquad \text{equation 25}$$

where:

SOC_{CEA_t} is the value for SOC_{CEA} for the sampling round, in tonnes of soil organic carbon per CEA, given by equation 14.

T is the number of sampling rounds completed (including the baseline sampling round).

10.3.2.4 Average rate of change in carbon stock across all completed sampling rounds (slope of linear regression)

Calculate the average rate of change of carbon stock across all completed sampling rounds (the b_1), in tonnes of soil organic carbon per CEA per year, using the following equation:

$$b_1 = \frac{\sum_{t=1}^{T} (PD_t - \overline{PD}) \times (SOC_{CEA_t} - \overline{SOC_{CEA_{(t_0-t_x)}}})}{\sum_{t=1}^{T} (PD_t - \overline{PD})^2} \quad \text{equation 26}$$

where:

PD_t is the duration of the project associated with each sampling round *t* calculated as the time, in decimal years, between the median day of sampling round and the median day of the baseline sampling round.

$\overline{PD}$ is the value of $\overline{PD}$, in years, given by equation 24.

SOC_{CEA_t} is the value for SOC_{CEA} for the sampling round, in tonnes of soil organic carbon per CEA, given by equation 13.

$\overline{SOC_{CEA_{(t_0-t_x)}}}$ is the value for $\overline{SOC_{CEA_{(t_0-t_x)}}}$, in tonnes of soil organic carbon per CEA, given by equation 25.

$\boldsymbol{T}$ is the number of sampling rounds completed (including the baseline sampling round).

10.3.2.5 Y-intercept of linear regression (line of best fit)

Calculate the y-intercept of the linear regression (the b_0), in tonnes of soil organic carbon per hectare, using the following equation:

$$b_0 = \overline{SOC_{CEA_{(t_0-t_x)}}} - b_1 \times \overline{PD} \quad \text{equation 27}$$

where:

$\overline{SOC_{CEA_{(t_0-t_x)}}}$ is the value for $\overline{SOC_{CEA_{(t_0-t_x)}}}$, in tonnes of soil organic carbon per CEA, given by equation 25.

b_1 is the value of b_1, in tonnes of soil organic carbon per CEA per year, given by equation 26.

$\overline{PD}$ is the value of $\overline{PD}$, in years, given by equation 24.

10.3.2.6 Predicted soil organic carbon stock from linear regression

Calculate the predicted soil organic carbon stock of the CEA from the linear regression (the $PredictedSOC_{CEA}$), in tonnes of soil organic carbon per CEA, using the following equation:

$$PredictedSOC_{CEA} = b_0 + b_1 \times PD_t$$ equation 28

where:

b_0 is the value of b_0, in tonnes of soil organic carbon per hectare, given by equation 27.

b_1 is the value of b_1, in tonnes of soil organic carbon per CEA per year, given by equation 26.

PD_t is the duration of the project associated with the last completed sampling round t calculated as the time, in decimal years, between the median day of sampling round and the median day of the baseline sampling round.

$\boldsymbol{T}$ is the number of sampling rounds completed (including the baseline sampling round).

10.3.2.7 Alpha value for student's t test

Calculate the alpha value α for the one-tail student's t test in equation 35, using the following equation:

$$\alpha = \frac{(100 - probability\ of\ exceedance)}{100}$$ equation 29

where:

$probability\ of\ exceedance$ is deemed to be 60, based on a conservative estimate of the probability that the true soil organic carbon stock value will exceed the calculated value.

10.3.2.8 Degrees of freedom for students t test

Calculate the degrees of freedom $\boldsymbol{df}$ to use the one-tail student's t test in equation 35, using the following equation:

$$df = T - 2$$ equation 30

where:

$\boldsymbol{T}$ is the number of sampling rounds completed (including the baseline sampling round).

10.3.2.9 Standard error of slope of linear regression

Calculate the standard error of the slope of the linear regression b_1 (the SE_{b_1}) using the following equation:

$$SE_{b_1} = \frac{= \sqrt{\frac{\sum_{t=0}^{T} (SOC_{CEA_t} - PredictedSOC_{CEA_t})^2}{df}}}{\sqrt{\sum_{x=1}^{T} (PD_t - \overline{PD})^2}}$$ equation 31

where:

SOC_{CEA_t} is the value for SOC_{CEA} for the sampling round, in tonnes of soil organic carbon per CEA, given by equation 14.

$PredictedSOC_{CEA_t}$ is the value for $PredictedSOC_{CEA_t}$ for the sampling round, in tonnes of soil organic carbon per CEA, given by equation 28.

df is the value of df given by equation 30.

PD_t is the duration of the project associated with the last completed sampling round *t* calculated as the time, in decimal years, between the median day of sampling round and the median day of the baseline sampling round.

$\overline{PD}$ is the value of $\overline{PD}$, in years, given by equation 24.

$\boldsymbol{T}$ is the number of sampling rounds completed (including the baseline sampling round).

10.3.2.10 Rate of change in carbon stock for a CEA with 60% probability of exceedance

Calculate the rate of change in soil organic carbon stock for the CEA between the baseline sampling round and the last sampling round associated with a 60% probability of exceedance (th**e** $\Delta SOC_{60\ CEA}$), in tonnes of carbon per CEA per year, using the following equation:

$$\Delta SOC_{60\ CEA} = b_1 + SE_{b_1} \times t_{\alpha(df)}$$ equation 32

where:

b_1 is the value of b_1, in tonnes of soil organic carbon per CEA per year, given by equation 26.

SE_{b_1} is the value for SE_{b_1} given by equation 31.

$t_{\alpha(df)}$ is the t value derived from a one-tailed student's t-distribution with the value for alpha α given by equation 32 and the degrees of freedom df given by equation 30.

10.3.2.11 Total change in carbon stock for a CEA with 60% probability of exceedance

Calculate the total change in soil organic carbon stock for the CEA between the baseline sampling round t_0 and the last sampling round t_x associated with a 60% probability of exceedance (th**e** $\Delta SOC_{60\ CEA\,(t_0 - t_x)}$), in tonnes of carbon per CEA, using the following equation:

$$\Delta SOC_{60\ CEA\ (t_0 - t_x)} = \Delta SOC_{60\ CEA} \times PD_t \qquad \text{equation 33}$$

where:

$\Delta SOC_{60\ CEA}$ is the value for $\Delta SOC_{60\ CEA}$ given by equation 32.

PD_t is the duration of the project associated with the last completed sampling round t calculated as the time, in decimal years, between the median day of sampling round and the median day of the baseline sampling round.

10.3.2.12 Change in carbon stock for a project area with 60% probability of exceedance

Calculate the change in soil organic carbon stock for a project area between the baseline sampling round and the last sampling round associated with a 60% probability of exceedance (the $\Delta SOC_{60\ PA}$), in tonnes of carbon per project area, using the following equation:

$$\Delta SOC_{60\ PA} = \sum_{CEA=1}^{n_{CEA}} \Delta SOC_{60\ CEA\ (t_0 - t_x)} \qquad \text{equation 34}$$

where:

$\Delta SOC_{60\ CEA\ (t_0 - t_x)}$ is the value for $\Delta SOC_{60\ CEA\ (t_0 - t_x)}$, in tonnes of soil organic carbon per CEA, given by equation 33.

n_{CEA} is the number of CEAs in the project area.

10.3.2.13 Carbon dioxide equivalence of change carbon stock for a project area with 60% probability of exceedance

Calculate the carbon dioxide equivalence of the change in soil organic carbon stock for a project area between the baseline sampling round and the last sampling round associated with a 60% probability of exceedance (the $\Delta CO_2e_{60\ PA\ (t_0 - t_x)}$), in tonnes of CO_2-*e*, using the following equation:

$$\Delta CO_2e_{60\ PA\ (t_0 - t_x)} = \Delta SOC_{60\ PA} \times \frac{44}{12} \qquad \text{equation 35}$$

where:

$\Delta SOC_{60\ PA}$ is the value for $\Delta SOC_{60\ PA}$, in tonnes of soil organic carbon per project area, given by equation 34.

Note: The value $\frac{44}{12}$ converts tonnes of carbon to tonnes of CO_2-*e*.

10.3.2.14 Creditable change in soil organic carbon for a project area for a reporting period

The $\Delta CO_2e_{60\ PA\ (RP)}$, in tonnes of CO_2-e, is given by the following equation:

$$\Delta CO_2e_{60\ PA\ (RP)} = \Delta CO_2e_{60\ PA\left(t_0 - t_x\right)} - \left(\sum_{RP=1}^{n_{RP}} \Delta CO_2e_{60\ PA\ (pRP)}\right) \qquad \text{equation 36}$$

where:

$\Delta CO_2e_{60\ PA\left(t_0 - t_x\right)}$ is the value for $\Delta CO_2e_{60\ PA\left(t_0 - t_x\right)}$, in tonnes of CO_2-e, given by equation 35.

n_{RP} is the number of previous reporting periods.

$\Delta CO_2e_{60\ PA\ (pRP)}$ is the value for $\Delta CO_2e_{60\ PA\ (RP)}$, in tonnes of CO_2-e, given by equation 36 or equation 23 for the project area for each previous reporting period *pRP*, in tonnes of CO_2-e.

11 . Calculation of Emissions

This Schedule provides for the calculation of the baseline and project emissions. During the first sampling round projects are only discounted average project emissions that exceed average baseline emissions. During the following sampling rounds, projects are expected to be a net carbon sink, this means total project emissions are discounted from their total creditable change in soil carbon.

Project emissions are calculated on a yearly basis, based on farmer reporting and evidence. This section follows procedures suggested by Australian Carbon Credits, but calculations are based on refined IPCC Guidelines (2019).[16]

11.1 Summary of sources of emissions considered in this protocol

Table 4 summarizes the sources used to calculate the average emissions for a project area.

Table 4: Emission sources and calculation methods.

Source	GHC	Emission Factor	Level	Source
Livestock	CH4	Enteric Fermentation	Tier 1a	IPCC 2019
		Methane from Manure	Tier 1a	IPCC 2019
	N2O	NO2 from dung and urine	Tier 1a	IPCC 2019
		Indirect emissions(Volat/lixiv)	Tier 1a	IPCC 2019
Synthetic Fertilizers	CO2	Direct emissions from urea aplications	Tier 1	IPCC 2019
	N2O	Direct emissions from synthetic fertilizers	Tier 1a	IPCC 2019
		Indirect emissions(Volat/lixiv)	Tier 1a	IPCC 2019
Lime application	CO2	Direct emissions from lime application	Tier 1a	IPCC 2019
Tillage and crop residues	N2O	Emissions from crop residues	Tier 1a	IPCC 2021
		Pasture tillage events	Tier 1a	IPCC 2019
		Secondary emissions from fuel and agrochemicals	Tier 1a	IPCC 2019
Prescribed burning	CO	Direct emissions from grassland and savanna burning	Tier 1a	IPCC 2019
	N2O	Direct emissions from grassland and savanna burning	Tier 1a	IPCC 2019
	CH4	Direct emissions from grassland and savanna burning	Tier 1a	IPCC 2019

For more detail about emissions factors used see Annex A.

11.2 Calculating average annual baseline emissions for a project area

The annual average emissions for the baseline period (BP) for a project area (the $\boldsymbol{E_{allBP,PA}}$), in tonnes of CO_2-e per year, must be calculated and is given by the following equation:

$$E_{allBP,PA} = E_{LS,BP,PA} + E_{SF,BP,PA} + E_{L,BP,PA} + E_{Res,BP,PA} + E_{PB,BP,PA} \qquad \text{Equation 37}$$

equation 50.

$E_{PB,BP,PA}$ is the average total emissions from prescribed burning events in project area PA during the baseline period, in tonnes of CO_2-e per year, given by equation 56 where:

[16] 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

$E_{LS,BP,PA}$ is the average **total emissions from livestock** for the project area *PA*,during the baseline period, in tonnes of CO_2-*e* per year, given by equation 38.

$E_{SF,BP,PA}$ is the **average total emissions from synthetic fertiliser** applied to project area *PA* during baseline period, in tonnes of CO_2-*e* per year, given by equation 45.

$E_{L,BP,PA}$ is the average **total carbon dioxide emissions from lime** applied in the baseline period to project area *PA*, in tonnes of CO_2-*e* per year, given by equation 48.

$E_{Res,\,BP,PA}$ is the average total emissions from all tillage events in project area *PA* during the baseline period, in tonnes of CO_2-*e* per year, given by

11.2.1 Livestock emissions - If historical stock rate is known

This section applies if the project proponent is able to access stocking rate records for baseline calculation

For equation 37 , ELS,BP,PA is given by the following equation:

$$E_{LS,BP,PA} = \sum_{g=1}^{k} (E_{EF,\,g,\,i} + E_{DU,\,g,\,i} + N_{D,\,g,\,i} + N_{I,\,g,\,i}) \qquad \text{equation 38}$$

where:

k is the number of livestock categories during year i for the project area PA.

$E_{EF,\,g,\,i}$ is the average methane emissions from enteric fermentation from livestock group *g* during the baseline period BP for the project area *PA*, in tonnes of CO_2-*e*, given by equation 39.

$E_{DU,\,g,\,i}$ are the average methane emissions from manure decomposition from livestock group *g* during baseline period for the project area *PA*, in tonnes of CO_2-*e*, given by equation 40.

$N_{D,\,g,\,i}$ are average direct Nitrous oxide emissions from manure and urine from livestock group *gijk* during year i for the project area *PA*, in tonnes of CO_2-*e*, given by equation 42.

$N_{I,\,g,\,i}$ are average indirect emissions from volatilization and lixiviation from manure and urine, from livestock group *g* during year i for the project area *PA,* in tonnes of CO_2-*e*, given by equation 44.

(2) For equation 38, Eef is given by the following equation:

$$E_{EF,\,g,\,i} = 1/n * \sum(Q_{LS_g,i,PA} \times D_{LS_g,,PA} / 365 \times \frac{EF_{ef_g}}{1000}) \quad \text{equation 39}$$

where:

n= number of years of Baseline period

$Q_{LS_{g,}i,PA}$ is the number of animals in livestock group *g* within project area *PA* during year i, in livestock head.

$D_{LS,g,i,PA}$ is the number of days during year i that livestock group *g* was within the project area *PA*, in days.

EF_{ef_g} is the emission factor for methane emissions of the livestock group g, as set out in the Annex A; in kilograms of CO_2-e per livestock head per year. Source: Tier 1a, Table 10 A.3. IPCC 2019

(3) For equation 38, Edu is given by the following equation:

$$E_{DU,\,g,\,i} = 1/n * \sum(Q_{LS,g\ ,i,PA} \times D_{LS,g,,i,PA} / 365 * VSg \times \frac{EF_{du}}{1000}) \quad \text{equation 40}$$

where
VSg = annual average excretion per head of group g expressed in kg VS animal^{-1}yr^{-1} as calculated by equation 41

VSg = VS * TAM /1000 equation 41

where VS is the Tier 1 a average excretion factor as shown in Table 10.13 of IPCC (2019)
TAM is the average live weight of group g

EF_{du_g} is the emission factor for methane emissions from manure management for livestock group g, in kilograms of CO_2-e per livestock head per year as shown in Table 10.14

(4) For equation 38, Nd is given by the following equation:

$$N_{D,\,g,\,i} = 1/n * \left\{ \sum(Q_{LS_g,i,PA} \times D_{LS_g,i,PA} / 365 * N_{EX,\,g}\, x\, \frac{EFNd}{1000}) \right\} * 44/28 \quad \text{equation 42}$$

$N_{EX,\,g}$ is the nitrogen excretion rate of each livestock group g, expressed in kg N. head-1. yr- 1 calculated by equation 43

$N_{EX,\,g\,=}$ N rate * TAM/1000*365 equation 43

Where N rate is the default excretion rate, kgN (1000 kg/animal mass)-1 day-1 for animal group g, using Tier 1a, as shown in table 10.19 IPCC 2019.

TAM is average live weight of group g

EFnd is the factor for direct emissions of nitrous oxide from dung and urine, as proposed by IPCC 2019, Table 10.19

(5) For equation 38, Ni is given by the following equation:

equation 44

$$N_{I,\,g,i} = 1/n * \sum (Q_{LS_g,i,PA} \times D_{LS_g,i,PA} / 365 * N_{EX,\,g}\ x \frac{EF4Ni}{1000})*44/28$$

where

EFni is the emission factor for indirect N2O emissions (EF 4, Table 11.3; IPCC 2019)

11.2.2 Livestock emissions - If historical stock rate is unknown

If there are no records of historical emissions available for the project area, Year 1 emissions calculated following the procedures described in section 11.2.1. will be considered the baseline for Emission change calculations.

11.2.3 Synthetic fertiliser emissions

(1) For equation 40, $E_{SF,i,PA}$ is given by the following equation:

$$E_{Si,PA} = 1/n * \sum(E_{SF_{direct},i,PA} + E_{SF_{indirect},i,PA} + E\ urea, i, PA\ )$$ equation 45

where:

$E_{SF_N\ direct\ ,i,PA}$ is the average direct nitrous oxide emissions from synthetic fertiliser applied to project area *PA* in tonnes of CO_2-e, given by equation 46

$E_{SF_{indirect},i,PA}$ is the average indirect nitrous oxide emissions from synthetic fertiliser applied to project area *PA* in tonnes of CO_2-e, given by equation 47

E urea is the average CO2 emissions from urea applied to project area PA in tonnes of CO2 equivalent, given by equation, given by equation 48

(2) For equation 48, $E_{SF_{N\,direct},i,PA}$ is given by the following equation:

$$E = 1/n * \sum(\sum_{(all\ groups\ fij)} G_{SF_{fij},i,PA} \times P_f \times EF1 \times 298) \qquad \text{equation 46}$$

where:

$G_{SF_{fij},i,PA}$ is the quantity of synthetic fertiliser group *fij* applied to project area *PA* during year i, in tonnes of fertiliser.

P_f is the percentage nitrogen content of fertiliser f in synthetic fertiliser group *fij*, as provided by the manufacturer, in tonnes of Nitrogen per tonne of fertiliser.

EF_1 is the emission factor for synthetic fertiliser group *fij* as set out in Annex A, in tonnes of CO_2-eq per tonne of fertiliser, following Table 11.1 of IPCC 2019

(3) For equation 48, $E_{SF_{N\,indirect},i,PA}$ is given by the following equation:

$$E_{SF_{Nindirect},i,PA} = \sum_{(all\ groups\ fij)} (G_{SF_{fij},i,PA} \times P_f \times EF4 + G_{SF_{fij},i,PA} \times P_f \times E.) \times 298 \qquad \text{equation 47}$$

where:

$G_{SF_{fij},i,PA}$ is the quantity of synthetic fertilizers group *fij* applied to project area *PA* during year i, in tonnes of fertiliser.

P_f is the percentage nitrogen content of fertilizer f in synthetic fertilizers group *fij*, as provided by the manufacturer, in tonnes of Nitrogen per tonne of fertiliser.

EF_4 is the emission factor for indirect emissions due to volatilization of synthetic fertilizers group *fij* as set out in the Annex A, in tonnes of CO_2-e per tonne of fertilizer, following Table 11.3 of the IPCC 2019 Guidelines

EF_5 is the emission factor for indirect emissions due to lixiviation of synthetic fertilizers group *fij* as set out in theAnnex A, in tonnes of CO_2-e per tonne of fertiliser, following Table 11.3 of the IPCC 2019 Guideline.

For Equation 45, $E\ urea, i, PA$ is given by the following equation:

$$E\ urea, i, PA = \sum \text{G urea x EF x } 44/28 \qquad \text{equation 48}$$

where G urea is the quantity of urea applied to project area during year i

EF is emission factor for urea according to IPCC 2006 (0.20)

11.2.4 Lime emissions

(1) For equation 37, $E_{L,i,PA}$ is given by the following equation:

$$E_{L,i,PA} = 1/n * \sum(Q_{L,i,PA} \times EF_{L})\times 44/28 \qquad \text{equation 49}$$

where:

$Q_{L,i,PA}$ is the quantity of carbonates ($CaCO_3$) of each lime type applied during year i to the project area, in tonnes,

EF_{L} is the default emission factor according to IPCC 2006 (0.12 for limestone; 0,13 for dolomite)

11.2.5 Residue, tillage and soil landscape modification emissions

(1) For equation 37, $E_{Res,i,PA}$ is given by the following equation:

$$E_{Res,i,PA} = 1/n * \sum(E_{F,i,PA} + E_{R,i,PA} + E_{P,i,PA}\ ) \qquad \text{equation 50}$$

where:

$E_{F,i,PA}$ is the secondary emissions from diesel fuel and irrigation energy used for cropping during year i in project area *PA,* in tonnes of CO_2-*e*, given by equation 51**.**

$E_{R,i,PA}$ is the emissions from the residues of all crop types during year i in project area *PA,* in tonnes of CO_2-*e*, given by equation 52.

$E_{P,i,PA}$ is the emissions from pasture tillage events during year i in project area *PA,* in tonnes of CO_2-*e*, given by equation 53.

(2) For equation 50, $E_{F,i,PA}$ is given by the following equation:

$$E_{F,i,PA} = \left(\sum_{g=1}^{n} Fuel_{i}\ *\ 0,0000344\ *\ EFf/1000\right) + \left(\sum_{g=1}^{n} Irr_{i}\, x\, EFi/1000\right) \qquad \text{equation 51}$$

where:

n is the number of gas types.

$Fuel_{i}$ is the amount of gasoil , expressed in liters/year for the year i.

0,0000344 is a conversion factor from liters of gasoil to TJ (Terajoules per liter)

EFf is the emission factor for gasoil following tables 3.2.1 (CO2) and 3.2.2.(CH4 and N2O) IPCC 2019

Irr is the amount of energy used for irrigation, expressed in kilowatts. hour per year for year i.

EFi is the emission factor for electricity coming from the public grid. Based on Wang (2007), quoted by Jacobo et al 2020

(3) For equation 50, $E_{R,i,PA}$ is given by the following equation:

$$E_{R,i,PA} = \sum_{v=1}^{n} E_{R,v,i,,PA} \quad \text{equation 52}$$

where:

$E_{R,v,i,PA}$ is the emissions from the residues of crop type *v* during year i in project area *PA,* in tonnes of CO_2-e, given by equation 56.

n is the number of crops grown in the reporting period in the project area *PA*.

v is the crop type as specified in the Annex A.

(4) For equation 52, $E_{R,v,i,PA}$ is given by the following equation:

$$E_{R,v,i,PA} = \sum A_{v,i}\, x\, [(Frac_v\, x\, Agdm_{v,i}\, x\, Nag_v) + (Rbg_v\, x\, Agdm_{v,i}\, x\, N /1000]\, x\, 44/28 \quad \text{equation 53}$$

where:

$A_{v,i}$ is the area of each crop type v during year i, expressed in hectares

$Frac_v$ is the fraction of the crop that is renewed each year (0-1) according with table 11.2 of IPCC 2006

$Agdm_{v,i}$ is the estimated aerial biomass of crop residues (tn/ha) for crop type v during year i calculated following equation 54

Nag_v is the Nitrogen content of crop residues for crop type v, according with table 11.1a of IPCC 2019

Rbg_v is the ratio between crop yield and belowground biomass for crop type v, according with table 11.1a of IPCC 2019

Nbg_v is the nitrogen content of belowground biomass (tn N /ha) for crop type v, according with table 11.1a of IPCC 2019

(5) For equation 53, Agdm is given by the following equation:

$$Agdm_{v,i} = (Crop_{v,i} \text{ x } Dry_{v,i} \text{x } Slope_v) + Intercept_v \quad \text{equation 54}$$

where:

$Crop_{v,i}$ is crop yield of crop type v during year i expressed in Kg /ha

$Dry_{v,i}$ is the % of dry matter of the crop fresh material for crop type v during year i according to Table 11.1a of IPCC 2019

$Slope_{v}$ is the increment in dry matter for crop residues, for each crop type v, according with table 11.1a of IPCC 2019 (kg/ha/th dry harvest)

$Intercept_{v}$ is the value from Table 11.1a IPCC 2019, that reflects the value for CROP =0. (kg/ha)

For equation 50 $E_{P,i,PA}$ is given by the following equation:

$$E_{P,i,PA} = A_{till,i} \text{ x } \left[(Frac_{v}\ x\ Yield\ x\ Nag_{v}) + (Rbg_{v}\ x\ Agdm_{v,i}\ x\ Nbg_{v})/1000\right] \text{ x } 44/28 \quad \text{equation 55}$$

where:

$Yield_{i}$ is annual dry matter yield for pasture as set out in the Annex, in tonnes per hectare.

$A_{till,\,i}$ is the tilled area for pasture establishment or renovation during year i in project area *PA*, in hectares.

The rest of the terms correspond to those in equation 53.

11.2.6 Emissions from prescribed burning of grasslands

For equation 37, $E_{PB,BP,PA}$ is given by the following equation as indicated by equation 2.27 in IPCC 2019:

$$E_{PB,BP,PA} = A * M_B * C_F * Gef * 10^{-3} \quad \text{Equation 56}$$

Where:

A = Area burnt, ha
M_{B}= mass of fuel available for combustion, tonnes ha-1. This includes only aboveground biomass.
C_F = combustion factor, dimensionless, (default values in Table 2.6 IPCC 2019)

Gef = emission factor, g kg^{-1} dry matter burnt (Default values in Table 2.5, IPCC 2019) for CO; NO_2 and CH_4

11.3 Calculating average annual project emissions for a project area

The annual average emissions for the reporting period for a project area (the $\bar{E}_{allRP,PA}$), in tonnes of CO2-e per year, must be calculated and is given by the following equation:

$$E_{allRP,PA} = E_{LS,RP,PA} + E_{SF,RP,PA} + E_{L,RP,PA} + E_{Res,RP,PA} + E_{PB,RP,PA} \quad \text{Equation 57}$$

where:

$E_{LS,RP,PA}$ is the average **total emissions from livestock** for the project area *PA*,during the reporting period, in tonnes of CO_2-*e* per year calculated using equation 38.

$E_{SF,RP,PA}$ is the **average total emissions from synthetic fertiliser** applied to project area *PA* during the reporting period, in tonnes of CO_2-*e* per year, calculated using equation 45.

$E_{L,RP,PA}$ is the average **total carbon dioxide emissions from lime** applied in the reporting period to project area *PA*, in tonnes of CO_2-*e* per year,calculated using equation 48.

$E_{Res,\,RP,PA}$ is the average total emissions from crop residues and tillage events in project area *PA* during reporting period, , in tonnes of CO_2-*e* per year, given by equation 50.

$E_{PB,RP,PA}$ is the average total emissions from prescribed burning in Project area (PA) during reporting period, in tonnes of CO_2-*e* per year, given by equation 56

11.4 Estimating emissions discount

11.4.1 Where only baseline and 1 subsequent sampling round conducted

The difference between the emissions in the current reporting period RP and the baseline period (the $\Delta \boldsymbol{E_{allRP,PA}}$) in tonnes of CO2-e, is given by the following equation:

$$\Delta \boldsymbol{E_{allRP,PA}} = (E_{allRP,PA} - E_{allBP,PA}) * \text{years RP} \quad \text{Equation 58}$$

where:

$\boldsymbol{E_{allRP,PA}}$ is the average annual emissions from all sources during the reporting period RP for the project area PA, in tonnes of CO2-e, given by equation 57.

$\boldsymbol{EallBP}$,$\boldsymbol{PA}$ is the average annual emissions from all sources during the baseline period BP for the project area PA, in tonnes of CO2-e, given by equation 37.
y$\boldsymbol{earsRP}$ is the number of years in the reporting period, in years.

11.4.2 Where 3 or more sampling rounds are conducted

The total net emissions for the reporting period T$\boldsymbol{EallRP}$,$\boldsymbol{PA}$ in tonnes of CO2-e, is given by the following equation:

$$\mathrm{T}\boldsymbol{EallRP}\mathrm{t},\boldsymbol{PA} = \left(\sum_{t=1}^{n} Eall_{RPt\ PA}\right) - \left(\sum_{RP=1}^{n_{RP}} EA_{pRPPA}\right) \qquad \text{Equation 58}$$

where:
$\boldsymbol{Eall}$RP,$\boldsymbol{PA}$ is the average annual emissions from all sources during year t for the project area PA, in tonnes of CO2-e, given by equation 57.

n is the total number of years between the reporting period and the baseline

EA_{pRPPA} is the emissions adjustments for the previous reporting periods for the project area PA, in tonnes of CO2-e,, given by equation 3.

n_{RP} is the number of previous reporting periods.

ANNEX A: Emission factors utilized

Source: IPCC (2019)

TABLE 10A.3 (NEW)
DATA FOR ESTIMATING TIER 1A ENTERIC FERMENTATION CH4 EMISSION FACTORS, VOLATILE SOLID AND NITROGEN EXCRETION RATES AND N RETENTION FRACTION FOR OTHER CATTLE

Regions[4]	Weight, kg	Weight gain, kg/day	Feeding Situation	Milk yield, kg/day[1]	Fat content of milk, %	Protein content of milk, %	Work, hrs/day	Pregnant, %	Digestibility of feed, %	CP in diet, %	CH4 Conversion, %[2]	Day weighted population mix %[3]	Enteric fermentation EF, CH4 kg/head/yr	VS (1000 kg animal mass^{-1}) day^{-1}	Nex (1000 kg animal mass^{-1}) day^{-1}	Nretention fraction, (kg N retained/animal/day) (kg N intake/animal/day)$^{-1}$
Latin America																
High productivity systems												23[3]				
Mature Females	490		Pasture/Range	2.7	4.2	3.2		78	61	11.2	7.0	33	89	8.4	0.35	0.07
Mature Males	595		Pasture/Range						61	11.2	7.0	1	79	6.2	0.28	0.00
Growing heifers/steers	240	0.50	Pasture/Range						63	11.8	6.3	22	45	9.2	0.40	0.13
Replacement/growing	350	0.50	Pasture/Range						61	11.0	7.0	16	70	9.3	0.38	0.08
Calves on milk	82	0.50	Pasture/Range						95	9.5	0.0	12	0	1.9	0.18	0.49
Calves on forage	200	0.50	Pasture/Range						63	12.3	7.0	12	44	10.8	0.50	0.11
Feedlot cattle	460	0.90	Stall Fed						74	14.0	4.0	4	39	4.8	0.35	0.10
Low productivity systems												77[3]				
Mature Females	420		Pasture/Range	1.8	4.3	3.2		59	59	9.1	7.0	37	79	9.2	0.30	0.07
Mature Males	580		Pasture/Range						59	9.6	7.0	2	81	6.8	0.25	0.00
Growing heifers/steers	240	0.30	Pasture/Range						60	9.2	7.0	22	47	9.3	0.30	0.10
Replacement/growing	290	0.30	Pasture/Range						60	9.3	7.0	19	54	8.9	0.30	0.08
Calves on milk	60	0.30	Pasture/Range						95	9.5	0.0	10	0	1.7	0.16	0.50
Calves on forage	145	0.30	Pasture/Range						60	9.2	7.0	10	35	11.7	0.37	0.14

TABLE 10.10 (UPDATED)[2,3] ENTERIC FERMENTATION EMISSION FACTORS FOR TIER 1 METHOD (KG CH_4 HEAD^{-1} YR^{-1})			
Livestock	**High Productivity Systems[1]**	**Low Productivity Systems**	**Liveweight[7]**
Sheep	9	5	40 kg – high productivity systems[6] 31 kg – low productivity systems
Swine	1.5	1	72 kg - high productivity systems[6] 52 kg - low productivity systems
Goats	9	5	50 kg – high productivity systems[5] 28 kg – low productivity systems
Horses	18		550 kg
Camels	46		570 kg
Mules and Asses	10		245 kg
Deer	20		120 kg
Ostrich[4]	5		120 kg
Poultry	Insufficient data for calculation		
Llamas and Alpacas	8		65 kg
Other (e.g., bison)	To be determined		
All estimates have an uncertainty of $\pm$30-50%.			

TABLE 10.13A (NEW) DEFAULT VALUES FOR VOLATILE SOLID EXCRETION RATE (KG VS (1000 KG ANIMAL MASS)-1 DAY^{-1})																			
Category of animal	**Region**																		
	North America	**Western Europe**	**Eastern Europe**	**Oceania[7]**	**Latin America**			**Africa[6]**			**Middle East[6]**			**Asia**			**India sub-continent**		
					Mean	**High PS[1]**	**Low PS[1]**	**Mean**	**High PS**	**Low PS**	**Mean**	**High PS**	**Low PS**	**Mean**	**High PS**	**Low PS**	**Mean**	**High PS**	**Low PS**
Dairy cattle[4]	9.3	7.5	6.7	6.0	7.9	9.0	7.1	18.2	21.7	15.2	10.7	8.4	11.8	9.0	8.1	9.2	14.1	9.1	16.1
Other cattle[4]	7.6	5.7	7.6	8.7	8.5	8.1	8.6	12.0	10.2	12.7	14.1	10.5	16.8	9.8	6.8	10.8	12.2	13.5	12.0
Buffalo[4]	NA	7.7	6.2	NA	11.2	NE		12.9	NE		9.8	NE		13.5	NE			NE	
Swine[3]	3.3	4.5	4.0	4.0	5.0	3.3	8.3	7.2	4.3	8.7	4.3	3.9	7.2	5.8	4.3	7.1	7.7	5.5	8.7
Finishing	3.9	5.3	4.9	5.6	6.4	4.3	10.0	8.2	5.3	9.4	4.9	4.4	7.8	6.8	5.1	8.1	8.6	6.5	9.5
Breeding	1.8	2.4	2.0	2.1	2.7	1.7	4.8	4.4	2.4	6.0	2.5	2.3	4.6	3.4	2.3	4.3	4.6	3.0	5.5
Poultry[3]	14.5	12.3	12.6	15.4	13.5	13.3	15.7	12.6	12.3	13.0	14.2	14.1	16.5	11.2	10.6	14.3	14.9	14.3	15.7
Hens ±1 yr	9.4	8.6	9.4	8.6	10.1	9.3	14.7	10.2	8.0	11.6	9.0	8.4	15.8	9.3	8.5	12.8	13.2	11.6	14.6
Pullets	5.9	5.3	5.9	6.2	7.6	5.7	18.5	12.0	5.8	16.5	6.8	5.6	18.5	7.5	5.4	17.7	13.2	6.8	18.9
Broilers	16.8	16.1	16.0	18.3	15.6	15.5	17.8	15.9	16.0	15.4	17.7	17.7	17.9	15.7	15.6	17.1	17.7	17.6	18.2
Turkeys[8]	10.3																		
Ducks[8]	7.4																		
Sheep[3]	8.2				8.3														
Goats[5]	9				10.4														
Horses[8]	5.65				7.2														
Mules/ Asses[8]	7.2																		
Camels[8]	11.5																		

Table 10.14 (Updated) (Continued) Methane Emission Factors by animal category, manure management system and climate zone (g CH_4 kg VS^{-1}) [7]					
Livestock species	**Productivity Class**	**Manure Storage System[4]**	**Cool**	**Temperate**	**Warm**
Camels	High productivity	Solid storage	3.5	7.0	8.7
		Dry lot	1.7	2.6	0.0
	Low productivity	Solid storage	2.8	5.6	7.0
		Dry lot	1.4	2.1	2.8
Horses	High productivity	Solid storage	4.0	8.0	10.1
		Dry lot	2.0	3.0	4.0
	Low productivity	Solid storage	3.5	7.0	8.7
		Dry lot	1.7	2.6	3.5
Mules/ Asses	High productivity	Solid storage	4.4	8.8	11.1
		Dry lot	2.2	3.3	4.4
	Low productivity	Solid storage	3.5	7.0	8.7
		Dry lot	1.7	2.6	3.5
All Animals	High and Low Productivity	Pasture Range and Paddock	0.6		

All values are calculated based on MCFs and B_0s reported in Tables 10.17 and 10.16, respectively, using the equation MCF*B_0*0.67.

[1] For the application of Tier 1, for all regions other than North America, Europe and Oceania the Tier 1 default values are the low productivity EFs. Pasture range and paddock emission factors are based on observation in updated version of Cai et al. (2017) database (see Annex 10B.6). No differences were observe for animal type, region or productivity class and are therefore reported as a constant for all animal and productivity categories.

[2] Temp. is an abbreviation for temperate

[3] Composting is the biological oxidation of organic material

[4] Definitions of manure management systems can be found in Table 10.18

[5] Emissions for liquid systems are calculated from manure management systems with a 6 month retention time.

[6] Buffalo emission factors are equivalent to low productivity non dairy animals.

[7] Uncertainty is ±30% consisten with the *2006 IPCC Guidelines*

[8] Anaerobic digestion for high productivity used emission estimates from high quality gas-tight digesters and average MCFs for storage whereas, low quality used high digester leakage rates and average MCFs for storage leakage rates. Countries should consider the type and quality of digesters used in their individual countries in evaluating what emission factors they choose to employ as opposed to the level of productivity for anaerobic digesters only.

Table 10.19 (Updated)
Default values for Nitrogen excretion rate (kg N (1000 kg animal mass)$^{-1}$ day^{-1})

Category of animal	Region																		
	North America	Western Europe	Eastern Europe	Oceania	Latin America			Africa			Middle East			Asia			India sub-continent		
					Mean	High PS[1]	Low PS[1]	Mean	High PS	Low PS	Mean	High PS	Low PS	Mean	High PS	Low PS	Mean	High PS	Low PS
Dairy cattle[3]	0.60	0.50	0.42	0.72	0.39	0.60	0.28	0.44	0.41	0.45	0.50	0.49	0.51	0.44	0.55	0.41	0.65	0.51	0.70
Other cattle[3]	0.40	0.42	0.47	0.46	0.31	0.36	0.29	0.44	0.42	0.45	0.55	0.51	0.58	0.38	0.36	0.38	0.44	0.63	0.40
Buffalo[3]	NA	0.45	0.35	NA	0.41			0.41			0.39			0.44			0.57		
Swine[4]	0.39	0.65	0.63	0.54	0.59	0.55	0.67	0.44	0.33	0.49	0.66	0.67	0.56	0.61	0.54	0.67	0.68	0.63	0.71
Finishing	0.46	0.76	0.77	0.72	0.73	0.69	0.80	0.49	0.39	0.54	0.73	0.75	0.60	0.70	0.63	0.76	0.76	0.74	0.76
Breeding	0.24	0.38	0.36	0.31	0.35	0.32	0.43	0.29	0.21	0.35	0.40	0.41	0.37	0.37	0.32	0.43	0.43	0.37	0.47
Poultry[4]	1.45	0.99	0.96	1.42	1.20	1.13	2.14	1.29	1.16	1.44	1.29	1.27	1.79	1.10	1.00	1.62	1.62	1.48	1.83
Hens >/= 1 yr	1.13	0.87	0.81	1.04	1.17	1.02	2.01	1.20	0.99	1.34	1.11	1.06	1.70	1.00	0.89	1.50	1.65	1.60	1.70
Pullets	0.77	0.58	0.58	0.76	0.95	0.68	2.50	1.29	0.70	1.72	0.85	0.74	2.03	0.83	0.60	1.91	1.63	0.98	2.20
Broilers	1.59	1.14	1.12	1.59	1.23	1.21	2.39	1.40	1.34	1.58	1.43	1.42	1.95	1.35	1.31	1.84	1.58	1.47	2.11
Turkeys[12]	0.74																		
Ducks[12]	0.83																		
Sheep[4]	0.35	0.36	0.36	0.43	0.32														
Goats[5]	0.46	0.46	0.44	0.42	0.34														
Horses and mules and asses[12]	0.30	0.26	0.30	0.30	0.46														

TABLE 11.1 (UPDATED)
DEFAULT EMISSION FACTORS TO ESTIMATE DIRECT N_2O EMISSIONS FROM MANAGED SOILS

Emission factor	Aggregated		Disaggregated		
	Default value	Uncertainty range	Disaggregation[4]	Default value	Uncertainty range
EF_1 for N additions from synthetic fertilisers, organic amendments and crop residues, and N mineralised from mineral soil as a result of loss of soil carbon[1] [kg N_2O–N (kg $N)^{-1}$]	0.010	0.001 – 0.018	Synthetic fertiliser inputs[5] in wet climates	0.016	0.013 – 0.019
			Other N inputs[6] in wet climates	0.006	0.001 – 0.011
			All N inputs in dry climates	0.005	0.000 – 0.011
EF_{1FR} for flooded rice fields[2,7] [kg N_2O–N (kg $N)^{-1}$]	0.004	0.000 – 0.029	Continuous flooding	0.003	0.000 – 0.010
			Single and multiple drainage	0.005	0.000 – 0.016
$EF_{3PRP, CPP}$ for cattle (dairy, non-dairy and buffalo), poultry and pigs[3] [kg N_2O–N (kg $N)^{-1}$]	0.004	0.000– 0.014	Wet climates	0.006	0.000 – 0.026
			Dry climates	0.002	0.000 – 0.006
$EF_{3PRP, SO}$ for sheep and 'other animals'[3] [kg N_2O–N (kg $N)^{-1}$]	0.003	0.000 – 0.010	-	-	-

Sources:

[1] Stehfest & Bouwman 2006; van Lent et al. 2015; Grace et al. 2016; van der Weerden et al. 2016; Albanito et al. 2017; Cayuela et al. 2017; Liu et al. 2017; Rochette et al. 2018.

[2] Akiyama et al. 2005; Albanito et al. 2017; Cayuela et al. 2017.

[3] Yamulki et al. 1998; Galbally et al. 2000; Liebig et al. 2008; Cai & Akiyama 2016; Cardenas et al. 2016; Di et al. 2016; Hoogendoorn et al. 2016; Hyde et al. 2016; Krol et al. 2016; Li et al. 2016; Luo et al. 2016; Marsden et al. 2016; Misselbrook et al. 2016; Nichols et al. 2016; O'Connor et al. 2016; Owens et al. 2016; Pelster et al. 2016; Ward et al. 2016; Balvert et al. 2017; Byrnes et al. 2017; Forrestal et al. 2017; Marsden et al. 2017; Owens et al. 2017; Thomas et al. 2017a, b; Tully et al. 2017; van der Weerden et al. 2017; Cardoso et al. 2018; Chadwick et al. 2018; Nichols et al. 2018.

Notes:

EF_1: Uncertainty range of disaggregated EF_1 based on the 95% confidence interval of fitted values. Uncertainty range of aggregated EF_1 is based on the 2.5th to 97.5th percentile of the dataset (See methods, data and results in Annex 11A.2).

EF_{1FR}: Uncertainty range is based on the 2.5th to 97.5th percentile (See methods and data in Annex 11A.3).

$EF_{3PRP, CPP}$ and $EF_{3PRP, SO}$: Uncertainty range is based on the 2.5th to 97.5th percentile (See methods and data in Annex 11A.4).

For EF_2, see guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: Wetlands, Chapter 2, Table 2.5.

[4] Disaggregation of EF_1 and $EF_{3PRP, CPP}$ by climate (based on long-term averages): Wet climates occur in temperate and boreal zones where the ratio of annual precipitation: potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climate occur in temperate and boreal zones where the ratio of annual precipitation: potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm (cf. Figure 3.A.5.1 in Chapter 3 of Vol. 4 provides a map subdividing wet and dry climates based on these criteria). In wet climates, the EF_1 is further disaggregated by synthetic fertiliser N inputs and other N inputs.

[5] This emission factor should be used for synthetic fertiliser applications, and fertiliser mixtures that include both synthetic and organic forms of N.

[6] Other N input refers to organic amendments, animal manures (e.g. slurries, digested manures), N in crop residues and mineralised N from soil organic matter decomposition.

[7] Disaggregation of EF_{1FR}: Single and multiple drainage also include alternate wetting and drying. Disaggregated EF_{1FR} for rain-fed and deep-water systems not provided due to lack of data. The EF_1 should be used for upland rice.

TABLE 11.3 (UPDATED) DEFAULT EMISSION, VOLATILISATION AND LEACHING FACTORS FOR INDIRECT SOIL N_2O EMISSIONS					
Emission factor	**Aggregated**		**Disaggregated**		
	Default value	**Uncertainty range**	**Disaggregation**	**Default value**	**Uncertainty range**
EF_4 [N volatilisation and re-deposition][1], kg N_2O–N (kg NH_3–N + NO_X–N volatilised)$^{-1}$	0.010	0.002 - 0.018	Wet climate	0.014	0.011 – 0.017
			Dry climate	0.005	0.000 – 0.011
EF_5 [leaching/runoff][2], kg N_2O–N (kg N leaching/runoff)$^{-1}$	0.011	0.000 - 0.020	-	-	-
$Frac_{GASF}$ [Volatilisation from synthetic fertiliser][3], (kg NH_3–N + NOx–N) (kg N applied)$^{-1}$	0.11	0.02 - 0.33	Urea	0.15	0.03 – 0.43
			Ammonium-based	0.08	0.02 – 0.30
			Nitrate-based	0.01	0.00 – 0.02
			Ammonium-nitrate-based	0.05	0.00 – 0.20
$Frac_{GASM}$ [Volatilisation from all organic N fertilisers applied, and dung and urine deposited by grazing animals][4], (kg NH_3–N + NOx–N) (kg N applied or deposited)$^{-1}$	0.21	0.00 - 0.31	-	-	-
$Frac_{LEACH-(H)}$ [N losses by leaching/runoff in wet climates][5], kg N (kg N additions or deposition by grazing animals)$^{-1}$	0.24	0.01 – 0.73	-	-	-

TABLE 3.2.1
ROAD TRANSPORT DEFAULT CO_2 EMISSION FACTORS AND UNCERTAINTY RANGES [a]

Fuel Type	Default (kg/TJ)	Lower	Upper
Motor Gasoline	69 300	67 500	73 000
Gas/ Diesel Oil	74 100	72 600	74 800
Liquefied Petroleum Gases	63 100	61 600	65 600
Kerosene	71 900	70 800	73 700
Lubricants [b]	73 300	71 900	75 200
Compressed Natural Gas	56 100	54 300	58 300
Liquefied Natural Gas	56 100	54 300	58 300

Source: Table 1.4 in the Introduction chapter of the Energy Volume.

Notes:

[a] Values represent 100 percent oxidation of fuel carbon content.

[b] See Box 3.2.4 Lubricants in Mobile Combustion for guidance for uses of lubricants.

TABLE 3.2.2
ROAD TRANSPORT N_2O AND CH_4 DEFAULT EMISSION FACTORS AND UNCERTAINTY RANGES [(a)]

Fuel Type/Representative Vehicle Category	CH_4 (kg /TJ)			N_2O (kg /TJ)		
	Default	Lower	Upper	Default	Lower	Upper
Motor Gasoline -Uncontrolled [(b)]	33	9.6	110	3.2	0.96	11
Motor Gasoline –Oxidation Catalyst [(c)]	25	7.5	86	8.0	2.6	24
Motor Gasoline –Low Mileage Light Duty Vehicle Vintage 1995 or Later [(d)]	3.8	1.1	13	5.7	1.9	17
Gas / Diesel Oil [(e)]	3.9	1.6	9.5	3.9	1.3	12
Natural Gas [(f)]	92	50	1 540	3	1	77
Liquified petroleum gas [(g)]	62	na	na	0.2	na	na
Ethanol, trucks, US [(h)]	260	77	880	41	13	123
Ethanol, cars, Brazil [(i)]	18	13	84	na	na	na

Sources: USEPA (2004b), EEA (2005a), TNO (2003) and Borsari (2005) CETESB (2004 & 2005) with assumptions given below. Uncertainty ranges were derived from data in Lipman and Delucchi (2002), except for ethanol in cars.

(a) Except for LPG and ethanol cars, default values are derived from the sources indicated using the NCV values reported in the Energy Volume Introduction chapter; density values reported by the U.S. Energy Information Administration; and the following assumed representative fuel consumption values: 10 km/l for motor gasoline vehicles; 5 km/l for diesel vehicles; 9 km/l for natural gas vehicles (assumed equivalent to gasoline vehicles); 9 km/l for ethanol vehicles. If actual representative fuel economy values are available, it is recommended that they be used with total fuel use data to estimate total distance travelled data, which should then be multiplied by Tier 2 emission factors for N_2O and CH_4.

(b) Motor gasoline uncontrolled default value is based on USEPA (2004b) value for a USA light duty gasoline vehicle (car) – uncontrolled, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(c) Motor gasoline – light duty vehicle oxidation catalyst default value is based on the USEPA (2004b) value for a USA Light Duty Gasoline Vehicle (Car) – Oxidation Catalyst, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(d) Motor gasoline – light duty vehicle vintage 1995 or later default value is based on the USEPA (2004b) value for a USA Light Duty Gasoline Vehicle (Car) – Tier 1, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(e) Diesel default value is based on the EEA (2005a) value for a European heavy duty diesel truck, converted using values and assumptions described in table note (a).

(f) Natural gas default and lower values were based on a study by TNO (2003), conducted using European vehicles and test cycles in the Netherlands. There is a lot of uncertainties for N_2O. The USEPA (2004b) has a default value of 350 kg CH_4/TJ and 28 kg N_2O/TJ for a USA CNG car, converted using values and assumptions described in table note (a). Upper and lower limits are also taken from USEPA (2004b)

(g) The default value for methane emissions from LPG, considering for 50 MJ/kg low heating value and 3.1 g CH_4/kg LPG was obtained from TNO (2003). Uncertainty ranges have not been provided.

(h) Ethanol default value is based on the USEPA (2004b) value for a USA ethanol heavy duty truck, converted using values and assumptions described in table note (a).

(i) Data obtained in Brazilian vehicles by Borsari (2005) and CETESB (2004 & 2005). For new 2003 models, best case: 51.3 kg THC/TJ fuel and 26.0 percent CH_4 in THC. For 5 years old vehicles: 67 kg THC/TJ fuel and 27.2 percent CH_4 in THC. For 10 years old: 308 kg THC/TJ fuel and 27.2 percent CH_4 in THC.

TABLE 11.1A (NEW) (CONTINUE) DEFAULT VALUES FOR $N_{AG(T)}$, $N_{BG(T)}$, $R_{AG(T)}$, $RS_{(T)}$ AND DRY TO BE USED IN EQUATIONS 11.6 AND 11.7					
Crops	**N content of above-ground residues** ($N_{AG(T)}$)[a]	**N content of below-ground residues** ($N_{BG(T)}$)[a]	**Ratio of above-ground residue dry matter to harvested yield** ($R_{AG(T)}$)[b]	**Ratio of below-ground biomass to above-ground biomass** ($RS_{(T)}$)[a]	**Dry matter fraction of harvested product** (DRY)[a]
Grasses and Forages					
Alfalfa	0.027 (± 75%)[d]	0.019 (± 75%)[d]	-[e]	0.40 (± 50%)[g]	0.90
Non-legume hay	0.015 (± 75%)[d]	0.012 (± 75%)[d]	-[e]	0.54 (± 50%)[g]	0.90
N-fixing forages	0.027 (± 75%)[d]	0.022 (± 75%)[d]	0.3	0.40 (± 50%)	0.90
Non-N-fixing forages	0.015 (± 75%)[d]	0.012 (± 75%)[d]	0.3	0.54 (± 50%)	0.90
Perennial Grasses	0.015 (± 75%)[d]	0.012 (± 75%)[d]	0.3	0.80 (± 50%)h	0.90
Grass-Clover Mixtures	0.025 (± 75%)[d]	0.016 (± 75%)[d]	0.3	0.80 (± 50%)[h]	0.90

Sources:

a Literature review by Stephen A. Williams, Natural Resource Ecology Laboratory, Colorado State University. A list of the original references is given in Annex 11A.1.

b 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 4 for R AG(T) except forages, grasses and grass-clover mixes, which are from the 2006 IPCC Guidelines, Chapter 11, and the generic value for all crops, which is the expert opinion of authors.

Notes:

c It is assumed here that grass dominates the system by 2 to 1 over legumes.

d No uncertainty is provided in the original study. This uncertainty is expert-based judgment.

e No estimate is available. The most appropriate generic value can be used based on expert judgment, in absence of more specific information available to develop a country-specific value.

f This is an estimate of non-tuber roots based on the root:shoot values found for other crops. If unmarketable tuber yield is returned to the soil then data are derived from Vangessel & Renner 1990 (see Annex 11A.1) (unmarketable yield = 0.08 * marketable yield = 0.29 * above-ground biomass) suggest that the total residues returned might then be on the order of 0.49 * above-ground biomass. Default s.d.

g This is an estimate of root turnover in perennial systems. Default s.d.

h Estimate of root turnover to above-ground production based on the assumption that in natural grass systems below-ground biomass is approximately equal to twice (one to three times) the above-ground biomass and that root turnover in these systems averages about 40% (30% to 50%) per year. Default s.d.

Table 11.2 (Updated) Alternative method and data for estimating above-ground residue ($AG_{DM(T)}$) a					
Crop	**Above-ground residue dry matter $AG_{DM(T)}$ (kg d.m. ha^{-1}):** $AG_{DM(T)} = Crop_{(T)} \bullet Slope_{(T)} + Intercept_{(T)}$				
	$Slope_{(T)}$	**± 2 s.d. as % of mean**	***$Intercept_{(T)}$***	**± 2 s.d. as % of mean**	**R^2 adj.**
Major crop types					
Grains	1.09	± 2%	0.88	± 6%	0.65
Beans & pulses[b]	1.13	± 19%	0.85	± 56%	0.28
Tubers[c]	0.10	± 69%	1.06	± 70%	0.18
Root crops, other[d]	1.07	± 19%	1.54	± 41%	0.63
N-fixing forages	0.3	± 50% default	0	-	-
Non-N-fixing forages	0.3	± 50% default	0	-	-
Perennial grasses	0.3	± 50% default	0	-	-
Grass-clover mixtures	0.3	± 50% default	0	-	-
Individual crops					
Maize	1.03	± 3%	0.61	± 19%	0.76
Wheat	1.51	± 3%	0.52	± 17%	0.68
Winter wheat	1.61	± 3%	0.40	± 25%	0.67
Spring wheat	1.29	± 5%	0.75	± 26%	0.76
Rice	0.95	±19%	2.46	± 41%	0.47
Barley	0.98	± 8%	0.59	± 41%	0.68
Oats	0.91	± 5%	0.89	± 8%	0.45
Millet	1.43	± 18%	0.14	± 308%	0.50
Sorghum	0.88	± 13%	1.33	± 27%	0.36
Rye[e]	1.09	± 50% default	0.88	± 50% default	-
Soybean[f]	0.93	± 31%	1.35	± 49%	0.16
Dry bean[g]	0.36	± 100%	0.68	± 47%	0.15
Potato[h]	0.10	± 69%	1.06	± 70%	0.18
Peanut (w/pod)[i]	1.07	± 19%	1.54	± 41%	0.63
Alfalfa	0.29[j]	± 31%	0	-	-
Non-legume hay	0.18	± 50% default	0	-	-

Sources:

[a] Literature review by Stephen A. Williams, Natural Resource Ecology Laboratory, Colorado State University. A list of the original references is given in Annex 11A.1.

Notes:

[b] The average above-ground residue:grain ratio from all data used was 2.0 and included data for soya bean, dry bean, lentil, cowpea, black gram, and pea.

[c] Average of other crops.

[d] Modelled after peanuts.

[e] No data for rye. Slope and intercept values are those for all grain. Default s.d.

[f] The average above-ground residue:grain ratio from all data used was 1.9.

[g] Ortega, 1988 (see Annex 11A.1). The average above-ground residue:grain ratio from this single source was 1.6. default s.d. for root:AGB.

[h] The mean value for above-ground residue: tuber ratio in the sources used was 0.27 with a standard error of 0.04.

[i] The mean value for above-ground residue: pod yield in the sources used was 1.80 with a standard error of 0.10.

[j] This is the average above-ground biomass reported as litter or harvest losses. This does not include reported stubble, which averaged 0.165 x Reported Yields. Default s.d.

Table 9: Agriculture lime application parameters

	Emission factor (t C/t $CaCO_3$ or t $CaMg(CO_3)_2$
Dolomite	0.13
Limestone	0.12

TABLE 2.5

EMISSION FACTORS (g kg^{-1} DRY MATTER BURNT) FOR VARIOUS TYPES OF BURNING. VALUES ARE MEANS ± SD AND ARE BASED ON THE COMPREHENSIVE REVIEW BY ANDREAE AND MERLET (2001)

(To be used as quantity 'G_{ef}' in Equation 2.27)

Category	CO_2	CO	CH_4	N_2O	NO_X
Savanna and grassland	1613 ± 95	65 ± 20	2.3 ± 0.9	0.21 ± 0.10	3.9 ± 2.4
Agricultural residues	1515 ± 177	92 ± 84	2.7	0.07	2.5 ± 1.0
Tropical forest	1580 ± 90	104 ± 20	6.8 ± 2.0	0.20	1.6 ± 0.7
Extra tropical forest	1569 ± 131	107 ± 37	4.7 ± 1.9	0.26 ±0.07	3.0 ± 1.4
Biofuel burning	1550 ± 95	78 ± 31	6.1 ± 2.2	0.06	1.1 ± 0.6

Note: The "extra tropical forest' category includes all other forest types.

Note: For combustion of non-woody biomass in Grassland and Cropland, CO_2 emissions do not need to be estimated and reported, because it is assumed that annual CO_2 removals (through growth) and emissions (whether by decay or fire) by biomass are in balance (see earlier discussion on synchrony in Section 2.4.

TABLE 2.6 (UPDATED) (CONTINUED) COMBUSTION FACTOR VALUES (PROPORTION OF PREFIRE FUEL BIOMASS CONSUMED) FOR FIRES IN A RANGE OF VEGETATION TYPES (Values in column 'mean' are to be used for quantity C_f in Equation 2.27)				
Vegetation type	**Subcategory**	**Mean**	**SD**	**References**
Shrublands	Shrubland (general)	0.95	-	44
	Calluna heath	0.71	0.30	26, 56, 39
	Fynbos	0.61	0.16	70, 44
All shrublands		**0.72**	**0.25**	
Savanna woodlands (early dry season burns)*	Savanna woodland	0.22	-	28
	Savanna parkland	0.73	-	57
	Other savanna woodlands	0.37	0.19	22, 29
All savanna woodlands (early dry season burns)		**0.40**	**0.22**	
Savanna woodlands (mid/late dry season burns)*	Savanna woodland	0.72	-	66, 57
	Savanna parkland	0.82	0.07	57, 6, 51
	Tropical savanna	0.73	0.04	52, 73, 66, 12
	Other savanna woodlands	0.68	0.19	22, 29, 44, 31, 57
All savanna woodlands (mid/late dry season burns)*		**0.74**	**0.14**	
Savanna Grasslands/ Pastures (early dry season burns)*	Tropical/sub-tropical grassland	0.74	-	28
	Grassland	-	-	48
All savanna grasslands (early dry season burns)*		**0.74**	-	
Savanna Grasslands/ Pastures (mid/late dry season burns)*	Tropical/sub-tropical grassland	0.92	0.11	44, 73, 66, 12, 57
	Tropical pasture~	0.35	0.21	4, 23, 38, 66
	Savanna	0.86	0.12	53, 5, 56, 42, 50, 6, 45, 13, 44, 65, 66
All savanna grasslands (mid/late dry season burns)*		**0.77**	**0.26**	
Other vegetation types	Peatland	0.50	-	20, 44
	Tropical Wetlands	0.70	-	44
Agricultural residues (Post-harvest field burning)	Wheat residues	0.90	-	see Note b
	Maize residues	0.80	-	see Note b
	Rice residues	0.80	-	see Note b
	Sugarcane a	0.80	-	see Note b
	Other Crops	0.85	-	see Note b

[*] Surface layer combustion only; ~ Derived from slashed tropical forest (includes unburned woody material); [a] For sugarcane, data refer to burning before harvest of the crop; [b] Expert assessment by authors.

ANNEX B: Pre-sampling for number of soil samples calculation

Number of samples required for an error of 10%

Following Carter and Gregorich, chapter 3 page 28

	Rincon de Corrientes	La Adela	SMRecuerdo all	SMRecuerdo ST1	SMRecuerdo ST2	Numancia All	Numancia Strata 1	Numancia Strata 2
Average	38	123,7	90	74	97	89	112	74
Stand. Dev	3	20,1	20	5	17	22	16	9
Variance	9	404,9	419	21	300	493	245	77
% CV	8%	16%	23%	6%	18%	25%	14%	12%
n sample	12	12	12	4	8	20	8	12
t 0.95	1,7959	1,7959	1,7959	2,3534	1,8946	1,7291	1,8946	1,7959
n req 0.95	2	9	17	2	11	18	7	4

Number of soil samples for contrasting environments. Rincón de Corrientes located at Corrientes. La Adela: Entre Ríos. SM Recuerdo: Saladillo, Buenos Aires, and Numancia: SW Chubut. Data from GRASS database. Note that in Santa María del Recuerdo and Numancia, processing all the samples as a single strata (all) gave a high %CV, but when stratification is done, total number of samples required are below 15. Data suggests that 18-20 samples would allow precise estimation of the Soil C Average under a wide range of environmental conditions.

ANNEX C: Contrasting Management Subprotocol.

The following guidelines will be used to create a valid baseline under the Contrasting Management approach.

Location:

BAU sites can be defined inside the property, when Project Area is a fraction of the total area. If the management practice has been applied leaving a valid control area, that can be used as a baseline

Neighbour farms: Adjacent areas from neighbour farms can be used, provided that the other two conditions are met (soil type and previous management)

BAU sites location will need to be defined by kmz /kml files.

Topographic position /soil type
Developers will need to provide the following evidence:

1. Cartographic location of soil sampling sites in project area and BAU area (kmz/kml file)
2. If available, soil map showing soil series and determining that there are the same mapping units
3. Soil profile photograph and description, using GRASS form 13
4. Comparable topographic position: height, slope. This can be assessed by using digital images of digital elevation models (DEM) (e.g. ASTER GDEM)

Land use history

Previous land use of BAU areas must be similar to the project area. If project area was used for cropping before the start of the project, BAU area should be a cropping area. If project area was permanently used for grazing operation, BAU area should be a comparable piece of land having the same land use and management practices.

Evidence for land use history

1. Farmers declaration of land use history
2. Remote sensing series starting at least 5 years prior to project starting date. Comparison of selected spectral indexes time series (e.g. normalized difference in vegetation index- NDVI; Normalized difference water index - NDWI, bare soil index - BSI) from BAU and project areas (should include a comparison prior to project implementation and after project implementation)