ASES ON-CHAIN PROTOCOL

METHODOLOGY FOR GHG EMISSIONS REDUCTIONS FROM FERTILIZER USE AND FIXATION IN SOIL

IV. Methodologies V1.0

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On-Chain Protocol

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ACRONYMS

aOCP	ASES climate action on-chain protocol
GHG	Greenhouse gas
GSG	Global Stakeholder Consultation
SOC	Soil Organic Carbon
NPC	Nature Positive Credit
EP	Expert Panel
aOCP-Ve	ASES On-Chain Protocol Verifiers
aOCP-V	ASES On-Chain Protocol Validator
VBBC	Verified Biodiversity Based Credits
VCAC	Verified Climate Action Credits
VWC	Verified Water Credits

INTRODUCTION

The ASES climate action on-chain protocol is a blockchain-powered protocol that simplifies offsetting carbon emissions and supports high-quality carbon removal and biodiversity conservation projects to fight climate change. It helps to guarantee that the projects contribute the global fight against climate change, biodiversity loss and land degradation.

This methodology details the principles and requirements for determining baselines and monitoring, quantifying, and reporting project emissions.

It focuses on greenhouse gases, projects or activities based on the two GHG sectoral scopes (GHG-SS) which are:

- Afforestation and reforestation is covered by GHG Sectoral Scope 14
- Agriculture, GHG Sectoral Scope 15

These management projects that have a direct effect on the soil, specifically designed to reduce greenhouse gas emissions and/or improve the removal of greenhouse gases. It provides a basis for GHG projects to be verified and validated.

This Methodology Protocol is intended to provide a holistic assessment of multiple ecological state indicators for grasslands under the practice of prescribed grazing. It can be used by Project proponents and other stakeholders to obtain estimates of Soil Organic Carbon (SOC) stocks within a project area, and measure additional ecological co-benefits such as animal welfare, ecosystem health, and soil health.

I. DEFINITIONS

In addition to the definitions set out in the latest version of the Program Definitions, the following definitions apply to this methodology:

1. Soil Organic Carbon (SOC) is a major contributor to overall soil health, agriculture, climate change, and food solutions. It is a natural energy storage, derived from soil organic matter and considered a highly valued earth's biopolymer;
2. VBBC stands for the account holder's right to assert that the ecological community under assessment has achieved a 1 unit increase in the Shannon-Weiner Species Diversity Index in the account in which the unit is recorded (counted independently for each taxon targeted in the PSF);
3. VCAC stands for individual trees planted in urban areas, which although not enough to remove tons of CO2 should be recognized for their contribution to sustainable development;
4. "Methodology" refers to a methodology that has been approved in line with the aOCP's methodology development procedure (see: aOCP Procedures). A specific set of GHG emission reduction and biodiversity project activities fall under the purview of methodology, which primarily consists of steps for establishing the project's boundaries, baseline scenario, additionality, baseline emissions, project emissions, emission reductions, changes to biodiversity, non-monitored parameters, and monitored

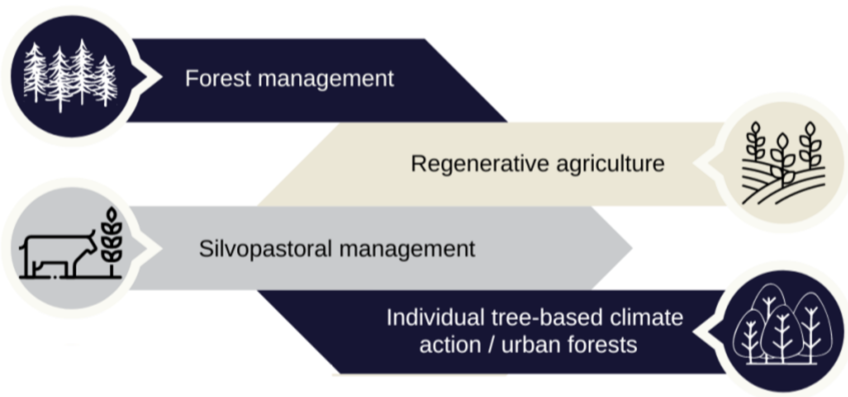
parameters. 15. Validation/Verification Services refers to the services of project validation and/or emission reduction verification by an aOCP Validator/Verifier, as per the aOCP Procedures and Procedure for Approval of aOCP Validators/Verifiers. An aOCP methodology also defines the relevant GHG sectoral scopes of its applicability as per the internationally recognized scopes defined in the Procedure for Approval of aOCP Validators/Verifiers;

5. The co-benefits are intended to allow for a holistic assessment of the project area beyond carbon sequestration. The soil health, ecosystem health, and animal welfare metrics are chosen based on their widespread use as known, reliable indicators sensitive to the changes in ecological state;
6. Ecosystem health is assessed holistically through the use of context-dependent indicators of ecosystem vigor, organization and resilience.

II. APPLICABILITY CONDITIONS

This methodology is applicable under the following conditions:

a) The type of Project is:



b) The Project complies with the standards of the aOCP Program;

c) The Project was developed less than 12 months ago;

d) If a project area does not meet requirement “e,” the project proponent must offer a technical reason arguing that ecological restoration is necessary because the area’s biodiversity and environmental services are vulnerable.

III. METHODOLOGICAL CONSIDERATION

III.1. APPLICATION OF METHODOLOGY

The following table identifies the types of projects that will be subject to the application of this methodology, which correspond to those that directly or indirectly will benefit ecosystems and therefore reduce carbon emissions.

TABLE 1. APPLICATION OF METHODOLOGY BY PROJECT

Type of project	Use of methodologies			
	Carbon in vegetation	GHG emission	Biodiversity	Water
Regenerative agriculture		✓		
Forest management		✓		
Silvopastoral		✓		
Urban forest		✓		
Water flow restoration				

III.2. METHODOLOGY PARAMETERS

The following table identifies the parameters of the methodology and the elements that will be considered in its use.

TABLE 2. PARAMETERS OF THE METHODOLOGY

Parameters	Index	Explanation
Soil	SOC (Soil Organic Carbon) stocks	SOC stock (i.e., **carbon stock expressed as Mg ha^{-1} or kg m^{-2}**) can be increased by enhancing biomass production and retaining crop residues as an effective mitigation action against climate change, as stated by the 4 per 1000 international initiative.

IV. PROJECT BOUNDARY

To calculate carbon stocks in the soil, it is necessary to delimit the study area. With the help of Geographic Information Systems, any road or building, woody vegetation, bodies of water, or any man-made object should be removed.

IV.1. SPATIAL BOUNDARIES

The spatial boundary encompasses all land on which the Project Proponent will undertake the Proposed Activity. Spatial boundaries defining the project area should be provided by the Project Proponent with any parcels or stratification schemes defined. Acceptable polygon data formats include ESRI shapefile OGC GeoPackage, KML/KMZ and GeoJSON.

V. BASELINE SCENARIO

Development of the schedule of activities in the base scenario

During the period prior to the project start date, SOC stock measurements should be made to get a clear picture of the current picture.

At the end of the establishment of the project, measurements of the variables are carried out again. The interval during which the evaluations will be carried out from the execution of the project will be annual.

VI. QUANTIFICATION

This methodology outlines two approaches for estimating carbon stocks. The first method is an innovative approach based on using remote sensing data to calibrate statistical models to estimate SOC (Soil Organic Carbon) stocks. This approach allows for a significant reduction in the number of soil samples that must be collected by the Project Proponent as compared to traditional sampling.

The second method adopts a traditional extrapolation approach in which SOC stocks are calculated using soil samples extracted during an intensive sampling effort.

The main ecological health indicator assessed in this methodology is:

- **Carbon sequestration**
    - Soil Organic Carbon (SOC) stocks and CO2 equivalents (CO2e)

Additional Co-Benefits assessed are:

- **Soil health**
    - pH

    Macronutrients

    - Nitrogen, Phosphorus, Potassium
    - Cation Exchange Capacity - CEC

    Minor nutrients:

    - Calcium, Magnesium, Potassium, Sodium, Aluminum

- **Animal welfare**

Measured using standards aligned with the project area locale

- **Ecosystem health**
  - Ecosystem Vigor
  - Normalized Difference Vegetation Index (NDVI)
  - Ecosystem Organization
  - Woody vegetation landscape metrics
  - Protected perimeter of wetlands and watercourses
  - Ecosystem Resilience
  - Bare Soil Estimation (BSI)

SAMPLE SIZE

The minimum number of project samples must be met to achieve a reliable and statistically valid level of rigor. For this, the use of the calculator developed by the RND scientific team is recommended.

For both the satellite calibration and spatial interpolation approaches, the number of samples required for soil sampling is the same and will be calculated using the Carbonplus Grasslands Sample Calculator V1.0 (Carbonplus V1.0.0.).

The Calculator only requires two inputs: the Project's net grassland area in hectares (ha) and the level of landscape conservation.

Main steps for estimating the sample size:

1. Load the online Carbonplus Grasslands Sample Calculator V1.0
2. Enter the net grassland area (ha) of the Project.
3. Determine the Landscape Variability Class:
   - **Low Variability:** If at least 4 proxies are ranked as Low, and not more than 1 proxy ranked as high.
   - **Moderate Variability:** If at least 3 proxies are ranked as Moderate, and not more than 1 proxy ranked as high.
   - **High Variability:** At least 2 proxies are ranked as High.
4. Set the final sample size between the minimum and the optimal numbers provided by the calculator:
   - The minimum number is the lowest sample size allowed.
   - The optimal number should be preferred, in particular for the first sampling round.

The following table presents the classification of the Landscape Variability of the project area.

TABLE 3. CLASSIFICATION OF THE LANDSCAPE VARIABILITY

Variation in soil carbon	✓	Landscape characteristics
High		Steep slopes (>20%) are present
		More than 3 soil types (suborder level)
		Diverse vegetation assemblages
		Adjacent / crossed by a waterbody
		Large area (>1,500 ha)
		The management history of parcels largely differs. This applies not only for the implementation of regenerative management, but also in the level of intensity of thee previous land use. Some areas may have been more degraded than others, and thus the starting point for each parcel differs greatly.
Medium		Moderate slopes (between 5 and 20%) across a majority of the project area
		2-3 soil types (suborder level)
		Similar vegetation assemblages, variable herbaceous species in different areas
		Not adjacent to a water body
		Medium sized area (500-1,500 ha)
		In some areas regenerative grazing management has beeen implemented before others. The land use history of the different parcels has been similar despite differences in stock density, frequency of rotation or dates of implementation. The previous land use was similar across paddocks/parcels.
Low		Flat area (slopes of less than 5%) across a majority of the project area
		1 soil type (suborder level)
		Uniform herbaceous vegetation (e.g. open grassland, same species across study area)
		Not adjacent to a water body
		Small area (<500 ha)
		The same management history has been implemented across the entire project area

Auxiliary data

If information on soil samples from areas adjacent to the project is available, these can be used in the study. The conditions that the auxiliary data must meet are the following:

- The sample dates for the project area and the sample dates for the farm providing the ancillary data must fall within one month of each other.

- The project area and the farm providing the ancillary data must be within the same climatic region according to the Köppen Climate Classification System.
- The project area and the farm providing the ancillary data must have been under the same management practices for at least 3 years.
- The project area and the farm providing the ancillary data must have similar soils, topography and vegetation cover, and must fall within the same landscape variability class.
- The sample extraction methods and sample analysis methods at the ancillary farm must match the protocols used for the primary farm

Stratification

In statistics, stratified sampling is a technique used to divide the population into subgroups or strata, based on similar characteristics. Stratification is recommended to increase precision.

Stratification should be applied particularly if:

1. The spatial boundaries provided include a large number of parcels and there is a need to add similar parcels.
2. If the Project area has a high variability of soils, humidity, vegetation cover, hydrological conditions, management history or other variables that could be affecting the SOC in the upper layer of the soil.

Variables correlated with soil organic carbon can be used as criteria to divide the project area into strata. Stratification should be applied particularly if:

1. The spatial boundaries provided include a large number of parcels and there is a need to add similar parcels.
2. The Project plots have a high variability of soils, humidity, vegetation cover, hydrological conditions, management history or other variables that could be affecting the SOC in the upper layer of the soil.

Some variables identified as good indicators of the spatial variability of SOC at the field scale include:

- Topography: elevation, slope, aspect, erosion, terrain roughness index (TRI) and multiple resolution valley, bottom flatness index (MrVBF)
- Land use (LULC): vegetation cover, aboveground biomass, land management history
- Satellite imagery: Multispectral satellite bands (eg Sentinel-2, Landsat TM), NDVI, BSI, NDWI, Tasseled Cap
- Hydrology: Topographic Moisture Index (TWI), catchment area, and Stream Power Index (SPI)
- Edaphology: soil types, clay content
- Other: Ph.

A geospatial file defining the stratified zones used for each round of monitoring must be provided with each report. Also, any additions or changes to sampling points between surveys must be clearly reported.

Useful Resources:

- cLHS - Conditioned Latin Hypercube Sampling
- QuickCarbon Stratifi
- Equal-range stratification
- k-means [20]
- A thorough review of variations on these methodologies authored by Biswas and Zhang (2018).

Geolocation of the sites to be sampled

Geolocations for soil test points should be randomly selected.

If stratified sampling is chosen, at least three soil samples per stratum should be included to ensure that variations in soil organic carbon are represented.

Sample collection

Regen Network recommends the following instructions to collect soil samples:

- Prior to core extraction, clear the sample location of living plants, plant litter and surface rocks.
- The minimum sampling depth is 10cm, but the recommended sampling depth is 30cm. Justification must be provided if sample depth is out of the 10-30cm range.
- The sampling depth must be the same at all sample locations in all given carbon estimation areas. Where the nominated sampling depth cannot be reached due to bedrock or impenetrable layers, the sampling point should be moved to a better spot within a 20m radius.
- The sampling depth must be consistent between all sampling rounds (i.e if samples are collected at 15cm for the baseline, samples must be collected at 15cm for following monitoring rounds).
- A GNSS receiver with a minimum accuracy of 4 meters must be used to record the sampling point in the field. The GNSS model must be reported in the monitoring report. If the minimum accuracy of 4 meters requirement is not met by the device, the Monitor should explore options like the point averaging method to improve accuracy.
- If subsamples are taken, please document the geometry of the sub-samples. Distance and direction from a reference point are recommended.
- If subsamples are taken more than 4 meters apart, the sample location for each subsample should be recorded using a GNSS receiver.
- Samples must be taken at least 10 meters away from any tree, shrub, structure, or body of water.
- If the soil profile is altered (incorporating substances external to the profile, or vertically altering the profile – eg. tilling, clay delving, water ponding) the sampling depth must be at least 10 cm below the depth of profile alteration.
- Report the day, month and year for each sample collected within the given sampling round.

- It is a requirement that all sampling rounds occur at least 6 months after the application of non-synthetic fertilizer.

Additionally, it is recommended to make a report including the following criteria.

- Tools and methods used to estimate number of samples
- Sample stratification method and stratification map
- Tool used to extract soil cores
    - If core sampler used, include tool diameter in mm
- GNSS coordinate for each sample location and sub-samples (if applicable)
- GNSS device used to record sample locations

Sampling analysis

To quantify SOC stocks, percent soil organic carbon and bulk density must be measured for each soil sample. Additional metrics to assess soil health are required from a smaller subset (30%) of the total number of samples.

- **All soil samples must be analyzed for:**
    1. Percent soil organic carbon
    2. Bulk density
    3. Gravel content (when relevant)
- **30% of the samples randomly chosen, will be also analyzed for:**
    1. pH
    2. Macronutrients
        a. Phosphorus
        b. Potassium
        c. Nitrogen (at least one of the following)
            i. Total Nitrogen
            ii. Nitrate Nitrogen
            iii. Ammonium Nitrogen

CEC (cation exchange capacity)

Minor nutrients: at least three (3) of the following:

d. Calcium
e. Magnesium
f. Potassium
g. Sodium
h. Aluminum

SOC STOCKS CALCULATIONS

Extracting spectral values at sampling points

Satellite imagery and other remote sensing data can be paired with percent soil organic carbon values from collected soil samples to train statistical models which can be used to estimate soil organic carbon stocks at unsampled locations. The GNSS coordinates recorded at soil sample locations tie the two datasets together. Imagery used for the remote sensing approach must have a spatial resolution of 20 meters or finer. Ancillary data, such as digital elevation models (DEMs), pedologic maps, and derived indices may also be used for analysis.

TABLE 4. EXTRACTING SPECTRAL VALUES

Band	Resolution	Central Wavelength	Description
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Red Edge 1
B6	20 m	740 nm	Red Edge 2
B7	20 m	783 nm	Red Edge 3
B8	10 m	842 nm	Near Infrared (NIR)
B8A	20 m	865 nm	Red Edge 4
B11	20 m	1375 nm	Short Wave Infrared 1 (SWIR 1)
B12	20 m	1610 nm	Short Wave Infrared 2 (SWIR 2)

TABLE 5. REMOTE SENSING INDICES, TOPOGRAPHIC VARIABLES AND SOIL DATA.

Name	Description	Data Used
Normalized Difference Vegetation Index (NDVI)	NDVI is a measure of vegetation health	Equation: $\frac{NIR-Red}{NIR+Red}$
Normalized Difference Moisture Index (NDMI)	NDMI is a measure of vegetation water content	Equation: $\frac{NIR-SWIR}{NIR+SWIR}$

Name	Description	Data Used
Bare Soil Index (BSI)	BSI identifies bare ground cover within a landscape	Equation: $\frac{((Red+SWIR) - (NIR+Blue))}{((Red+SWIR) + (NIR+Blue))}$
Normalized burn ratio 2 (NBR2)	NBR2 is used to detect burn scars on the landscape	Equation: $\frac{(SWIR1 - SWIR2)}{(SWIR1 + SWIR2)}$
Soil-adjusted Total Vegetation Index (SATVI)	SATVI is a vegetation index that reduces sensitivity to effects from soil	Equation: ((SWIR1-Red)/(SWIR1+Red+L)*(1+L) - (SWIR2/2) where L=1 (or 0.5)
Elevation	Elevation is a measure of the distance above sea level	Elevation
Slope	Slope represents the rate of elevation change from a digital elevation model	Elevation
Aspect	Aspect measures the slope direction	Elevation
Topographic Wetness Index (TWI)	TWI is a measure of topographic control on hydrological processes	TWI = ln(a/tan b) Where: a = upslope contributing area (m2) and b= slope in radians
Percent Silt	A measure of the composition of silt in the soil from 5-15cm and from 15-30cm	NA
Percent Clay	A measure of the composition of clay in the soil from 5-15cm and from 15-30cm	NA

Sentinel-2 surface reflectance (BOA) images (other high resolution images such as Planet Scope, Worldview or GeoEye may be used) with a date no more than 4 months similar to the date should be used to calculate SOC stocks. Of sampling.

Images should be free of clouds, as cloudy images often affect results, even if clouds do not directly cover the study area.

The auxiliary data does not have to be within the detection period of +/- 6 months, as long as there has not been a significant change in the variable.

The QGIS Point Sampling tool (or an analogous tool) could be used to extract remote sensing data at each sampling location. These data should be exported and combined with percentage soil organic carbon and bulk density values, or directly with SOC stocks per unit area (ton/ha), depending on the approach followed.

OPTION A. CORRELATION BETWEEN PERCENTAGE OF SOC AND REMOTE SENSING DATA

In this case, the remote sensing model is based on the relationship between the spectral data and the SOC% values at the sampling points, instead of using the stock values. The result is a SOC% map of the project grassland area that must be combined with a bulk density map to estimate SOC stocks.

Step 1) Creating the SOC% raster

The first step is to find the most accurate model to predict SOC% values based on the sampled data and the remote sensing data from the project area, for the corresponding sampling round.

Regression: Multiple linear regression and nonlinear regression models can be fitted to Sentinel-2 image bands and other predictor variables included in the analysis. Once the models for all bands have been generated, the accuracy of the model should be assessed using the exclusion cross-validation approach to calculate the R2 value, the root mean square error (RMSE), and the average normalized version of the RMSE. (nRMSE). Once all models have been scored, the model with the highest predictive accuracy should be selected to predict % SOC across the entire project area. Design Considerations:

- Outliers can be removed, but the methods used and a justification must be included in the report. Outlier removal should be performed using standard statistical techniques such as external standardized residuals, z-scores, or box plots. Removing too many outliers may result in overfitting and may compromise the size and reliability of the data set, so the removal of any outliers from the report should be justified.
- The maximum possible SOC % value of the output map should be trimmed to the maximum SOC % value of the project area samples. This is a conservative measure that avoids overestimations beyond the range of input values that were used to build the model.

Machine learning – Unlike simple regression models that rely on prior assumptions about the relationship between the predictor and response variable, machine learning does not require prior knowledge of the assumptions. These types of models can be useful in more complex areas of study by uncovering patterns that more basic regression models might miss. However, it is important to note that machine learning models tend to work better with large training data sets and this restriction will limit the cases where the use of machine learning models is justified. The accuracy of machine learning models can be assessed using a one-hold cross-validation approach, as outlined in the regression section above.

The selected model will be run based on the corresponding Sentinel-2 bands and/or ancillary data rasters from the entire project rangeland area to estimate the %SOC in the unsampled pixels. The raster output from this step is a map for the entire project area, where each pixel has a SOC% value.

Converting percent soil organic carbon to soil organic carbon stocks requires bulk density and soil depth measurements to incorporate soil volume into stock calculations (Equation 6). The soil depth is a constant value that corresponds to the depth of the soil samples taken.

Step 2) Creating the bulk density raster

Bulk density can be estimated using one of the following approaches:

Spatial interpolation: Spatial interpolation algorithms such as kriging, inverse distance weighting (IDW), or splines can be used to estimate bulk density values at unsampled locations. The resulting bulk density estimates should be scored and evaluated using methods such as cross-validation and other prediction error statistics. The monitor must specify the method of spatial interpolation used.

Pedotransfer functions: Pedotransfer functions (PTFs) that relate percent soil organic carbon to bulk density can be used as a method to generate a bulk density raster for the project area. The pedotransfer function used should be supported by peer-reviewed literature and evaluated by comparing PTF estimates with bulk density values collected during sampling.

Step 3) Creating the SOC Stocks raster

Soil organic carbon stocks are calculated through map algebra. The rasters are applied by applying the following equation for percent soil organic carbon and bulk density, using soil depth as a constant:

$$\textbf{Stock de SOC}\left(\frac{\textbf{ton}}{\textbf{ha}}\right) = \textbf{SOC\%} * \textbf{BD}\left(\frac{\textbf{g}}{\textbf{cm3}}\right) * \textbf{Profundidad del suelo}\ (\textbf{cm})$$

The raster output of this step is a SOC stock map for the entire project area, where each pixel has a SOC stock value in tonnes/ha.

For example, if the sampling depth was 30 cm, a pixel with a SOC% value of 4% and a bulk density of 1.3 g/cm3, then the SOC pool would be 156 ton/ha.

Option B. Correlation between SOC stocks and remote sensing data

In this case, the remote sensing model is based on the relationship between the spectral data and the SOC Stock values at the sampling points. The result is a SOC stock map that is used to estimate the total stock of the project rangeland area.

The first step is to estimate the SOC stocks per sampling point.[2]

The general equation for calculating SOC stocks is:

$$SOC\ STOCK\ \left(\frac{ton}{ha}\right) = SOC\% * BD\left(\frac{g}{cm^3}\right) * Soil\ Depth\ (cm)$$

For rocky soils (i.e., coarse weight > 15%), it is recommended that the equation include a coarse particle (CP) correction factor as follows:

$$SOC\ STOCK\ \left(\frac{ton}{ha}\right) = SOC\% * BD\left(\frac{g}{cm^3}\right) * Soil\ Depth\ (cm) * \left(1 - \frac{CP}{100}\right)$$

Based on the sampling depth and the % SOC and bulk density data provided by the laboratory, a stock SOC value can be calculated for each point.

Calculation of soil organic carbon stocks using a spatial interpolation approach

Kriging, Inverse Distance Weighting (IDW), or splining spatial interpolation methods can be used to estimate carbon stocks at unsampled locations.

The maximum possible SOC stock value (ton/ha) from the output map should be clipped to the maximum SOC stock value from the Project Area samples. This is a conservative measure that prevents overestimations beyond the range of input values that were used to build the model.

Uncertainty from the resultant SOC stock raster must be assessed using leave-one-out cross-validation or another approach supported by peer reviewed literature (Note that, for instance using a train-test split approach would require considering an additional % of samples collected during the sampling rounds for testing).

Final carbon calculation

To ensure that only grasslands are included in the final estimate of soil organic carbon stocks, the area of grasslands should be used to estimate the final stocks.

The QGIS zonal statistics tool (or an equivalent tool) can be used to sum all the pixels contained in the grasslands. The resulting number is the final estimate of the soil organic carbon stock for the monitoring round.

Note: A special attention must be paid to the units here, given that having ton/ha values at the pixel level can be confusing. Converting pixel values to ton/ pixel area can be a good step to avoid errors when calculating the total tons of SOC for the project area. Alternatively, please be sure to correct the spatial resolution of pixels to match units of tonnes per hectare before calculating the sum. Then just summing the pixels within the grasslands area provides the total SOC stocks, in tons.

Conversion of SOC stocks to CO2 equivalents

The conversion of soil organic carbon stocks to CO2 equivalent stocks can be done by multiplying the SOC stocks (in metric tons) by a conversion factor of 3.67:

CO2eq. (metric ton) = SOC (metric ton) * 3.67

CALCULATING THE GREENHOUSE GAS EMISSIONS

This methodology requires accounting for cattle GHG emissions, and any other emission sources that result in significant (>5%) GHG due to the project activity. For electricity and fuel usage, only the additional emissions from the baseline will be accounted for, whereas cattle and agrochemicals emissions will be considered as totals.

- **Emissions from livestock**

Livestock emissions must be calculated for each year of the project lifetime in accordance with IPCC or relevant national/state/regional scale factors. Equation shows how livestock emissions should be calculated using the number of animals present, the number of days the animals were located in the project area, and a default emission factor for the corresponding group of livestock. The livestock type, region, and the source of the emission factors must be cited in the report.

$$E_{liv} = Q \times D \times EF_{liv}/1{,}000$$

Where:

E_{liv} is the total emissions from livestock for a particular year for the project area, in metric tons of CO2e.

- $\boldsymbol{Q}$ is the number of animals within the project area in that year, in livestock head.
- $\boldsymbol{D}$ is the number of days in the reporting period that the livestock was within the project area. $\boldsymbol{E}$
- $\boldsymbol{F}_{liv}$ is the default emission factor for the livestock, according to its type, as set out for the particular region; in kilograms of CO2e per livestock head per day.

There are many ways livestock heads can be reported as per the Project Proponent. For example:

1. If total livestock head is reported for a monitoring year, use total livestock head for Q and the number of days in the project area for D.
2. If livestock head is provided in terms of opening and closing head for a given monitoring year, take the average between the two for Q and set the number of days in project area D, to 365.
3. If livestock head is recorded for each quarter of a monitoring year, take the average of the four quarters for Q, and set the number of days in project area D, to 365.

- **Emissions from fertilizer**

If fertilizers are used within the Project Area, the total Greenhouse Gas (GHG) emissions from fertilizers for the calculation year must be quantified, and used to calculate the creditable carbon change. No distinction is made between synthetic and organic N fertilizers. Calculations of fertilizer emissions must be performed in accordance with IPCC, relevant national/state/regional scale factors, or the following equation:

$$\boldsymbol{FE_{t-0}} = \sum_{x=1}^{t} (\boldsymbol{EF_{FE}} * \boldsymbol{FE_X})$$

Where:

FE_{t-0}= emissions (tCO2e) from fertilizer use during the whole calculation period

t **=** number of years in the calculation period (yr)

FE_x **=** N fertilizer input in year x (kgN)

EF_{FE} **=** Conversion factor for emissions from N fertilizer [tCO2e kg N-1].

The Project Proponent should provide fertilizer specific information as it relates to the project area including a) the type of fertilizer used and b) the mean annual fertilizer input during the monitoring period (often reported in kg). Conversion factors (often with units of tCO_2e/kg fertilizer), aligned with specific fertilizer types, are used to convert kg of fertilizer to annual emissions in tCO_2e. The fertilizer type, mean annual fertilizer input, conversion factor, and final emission quantification should be cited in the report. FEx will be documented by the project owner.

- **Fuel and electricity use emissions**

Direct and indirect emissions from increased fuel and electricity usage from the baseline to the calculation year must be accounted for by using the nest equation. This includes all fuel sources from stationary combustion, mobile combustion, and electricity.

$$\boldsymbol{\Delta FU_{t-o} = \sum_{x=1}^{t} (FU_{PRx} - FU_{BL}) + (EU_{PR\,x} - EU_{BL})}$$

Where:

ΔFU_{t-0} = emissions from increased fuel and electricity use in the calculation period [tCO2e]

$FU_{PR,x}$ **=**emissions from use of fuels under the project scenario in year a of the calculation period [tCO_2e]

FU_{BL} **=** mean annual emissions from use of fuels under the baseline scenario [tCO2e]

$EU_{PR,x}$ = emissions from use of electricity under the project scenario in year x of the calculation period [tCO_2e]

EU_{BL} **=**mean annual emissions from use of electricity under the baseline scenario [tCO_2e]

t= number of years in the calculation period [yr]

- **Fuel Emissions**

Emissions from the use of fossil fuels for a given year *x* (FU_x) shall be documented by the project owner and generally calculated with the equation below, based on fuel consumption by machine type and fuel emission factor:

$$FU_X = \sum_{MT} (FUL_{MT\,x} * FEF_{MT})$$

Where:

FU_x= emissions from use of fossil fuels in year x (tCO_2e ha-1)

$FUL_{MT,x}$ = fuel consumption by the machinery type (MT) used in year x (litres)

FEF_{MT} = emissions factor for the fuel used in machinery MT (tCO_2e litres-1)

MT = machinery type (gasoline two-stroke, gasoline four-stroke, diesel)

Electricity Use Emissions

Emissions from electricity use shall be calculated from the equation below, both for the baseline and for a given project year, based on electricity consumption by equipment type using the respective emission factor. If electricity is generated using fuel, emissions should be calculated from fuel combustion using the equation above, rather than electricity consumption.

$$EU_X = \sum_{SE=1}^{n} (EUW_{SE\ x} * EEF_{SE})$$

Where:

EU_x= emissions from use of electricity in year x [tCO_2e ha-1]

$EUW_{SE,\ x}$= electricity consumption from source SE in year x [kWh]

EEF_{SE} = emissions factor for the electricity used in source SE [tCO_2e kWh-1]

SE **=** electricity source type (grid, fossil fuel generator, etc)

For EU_{BL} input is calculated based on the mean of data for the prior 5 years to project start.

- **Additional agrochemical emissions**

Agrochemical emissions in the project activity in the calculation period will be documented by the project owner and for each emitter type (specific pesticide, fertilizer, or other agrochemical) and calculated using the equation below:

$$\boldsymbol{AE_{t-0}} = \sum_{x=1}^{t} ((\boldsymbol{AQ_{ET}} * \boldsymbol{AEF_{ET\ x}})$$

Where:

***AE_{t-0}*=** Agrochemical emissions in the project activity in the calculation period (tCO_2e)

***$AQ_{ET,x}$*=** quantity of agrochemicals for emitter type ET applied (kg)

***AEF_{ET}*=** emissions factor of the agrochemical used (for emitter type ET) (tCO_2e kg^{-1})

ET= emitter type

x= year of the calculation period (tCO_2e)

t **=** number of years in the calculation period (yr)

The *Project Proponent* should provide agrochemical specific information as it relates to the project area including a) quantity of agrochemical use, b) emitter type, or c) emission factors used.

- **Other Emissions**

Any other emission sources ($OE_{t\text{-}0}$ *, equation X*) that result in significant GHG due to the project activity that constitutes greater than 5% of the total CO_2 benefits generated by the project should be accounted for.

CHANGES IN CO2E BETWEEN REPORTING PERIODS

The change in SOC stocks between reporting periods is estimated as the difference between the total SOC stocks from the current monitoring period, minus total SOC stocks from the previous period.

$$\textbf{SOC stock change} = tSOC_{(t+1)} - tSOC_{t}$$

The same applies for estimating the change in the total SOC converted into CO2 equivalents between two sampling periods.

$$CO_2e\ \textbf{change} = CO_2e_{(t+1)} - CO2e_{t}$$

Net CO_2e reduction

The net CO_2e reduction in the project area for a given reporting period is calculated as the difference between the changes in SOC stocks, expressed as metric tons of CO_2e, minus the total GHG emissions, also in CO_2e units:

$$\textbf{net } co_2e\ \textbf{reduction} = CO_2e\ \textbf{change} - E_{liv} - E_{Fertilizer} - E_{Energy/\ Fuel} - E_{Agrochemicals}$$

CALCULATING THE SOIL HEALTH INDICATORS

The main soil health indicators for Grasslands projects are pH, macronutrients (Nitrogen, Phosphorus, and Potassium), cation exchange capacity (CEC), and other minor nutrients such as Calcium and Magnesium.

In order to assess the soil health of a pasture, the desired levels (i.e. benchmarks) of the most relevant soil health indicators for the Project Area must be established during the baseline period.

These levels will vary depending on soil types and ecoregion.

The soil indicators to be assessed in at least 30% of the samples will be chosen according to their relevance for assessing soil health in the Project Area, and must include at least the following:

- Soil pH
- Macronutrients: Phosphorous, Potassium and at least one Nitrogen parameter (i.e. Ammonia, Nitrate or Total Nitrogen).
- CEC (Cation Exchange capacity)
- Minor nutrients: at least three minor nutrients from the following list:
    - Calcium
    - Magnesium

- Potassium
- Sodium

CALCULATING THE ECOSYSTEM HEALTH INDICATORS

Ecosystem Vigor

Ecosystem vigor is widely used as a primary factor for quantifying ecosystem health. The vigor of a living system is a measure of its activity, metabolism and/or primary productivity

Vegetation index

The Normalized Difference Vegetation Index (NDVI) is a good indicator of plant vigor, and has been used in previous research for the assessment of grassland ecosystem health using remote sensing.

$$\boldsymbol{NDVI = \frac{NIR - Red}{NIR + Red}}$$

Ecosystem Organization

Ecosystem organization represents the structure of an ecosystem and describes the interactions among various components of the ecosystem . This depends on the landscape heterogeneity (LH) and landscape connectivity (LC). The LH can be represented by landscape diversity, which can be determined using the Shannon's diversity index. The LC depends on the overall connectivity of the landscape and that of important ecological patches, which can be assessed using landscape metrics.

Ecosystem Resilience

Resilience represents the ability for an ecosystem to maintain its structure and function in the presence of stress, and can be measured by the system's capacity to return its original state following perturbation.

Bare soil estimation

Bare soil (i.e. [1 - vegetation cover]) has been identified as a good indicator of ecosystems resilience and grasslands health. The Bare Soil Index (BSI) is a numerical indicator estimated from satellite imagery that combines blue, red, near infrared and short wave infrared spectral bands to capture soil variations.

$$BSI_{s2} = \frac{(Band11 + Band4) - (Band8 + Band2)}{(Band11 + Band4) + (Band8 + Band2)}$$

CALCULATING THE ANIMAL WELFARE RANKING

The Animal Welfare ranks within 4 possible categories

1. **Needs improvement:** <40% requirements are met.
2. **Fair:** Between 40% and 70% requirements are met.

3. **Good**: >70% requirements are met.
4. **Excellent**: 100% requirements met

OVERALL SCORING

1. SOC: Total tCO2e
2. CO-BENEFITS:

The following scoring system shall be followed, using Table 5 below as a template for the calculation of the final scores for the main Co-Benefits.

Partial and Final Scores

Each indicator within the Ecosystem Health and Soil health co-benefits, as well as the Animal Welfare ranking, will be assigned with points in Table 6, as follows:

- Needs Improvement point = 0.25
- Fair point = 0.50
- Good point = 0.75
- Excellent Point = 1

Final score = Sum of the indicators points / Total number of indicators

Calculation Example of the final score for Ecosystem Health

If the partial resulting scores for each indicator of Ecosystem health were:

- Organization = GOOD = 0.75
- Vigor = FAIR = 0.50
- Resilience = EXCELLENT = 1.00

Then the final average score for Ecosystem Health is estimated as :

Ecosystem Health = (0.75+0.5+1)/ 3 = 0.75 (GOOD

Ranking of Final Scores

According to the final Score, the Soil Health metrics and the Ecosystem Health metrics are ranked as follows:

- Final Score0.40 = NEEDS IMPROVEMENT
- 0.40 < Final Score 0.60 = FAIR
- 0.60 < Final Score 0.80 = GOOD
- Final Score > 0.80 = EXCELLENT

TABLE 6. TEMPLATE FOR THE CALCULATION OF THE PARTIAL AND TOTAL SCORES OF THE CO-BENEFITS.

Main Indicator	Partial Indicator	Rating (cross-check the corresponding rating)				Final score
		Needs Improvement	Fair	Good	Excellent	
Soil Health Indicator	pH					**Qualitative NI-F-G-E according to sum of weighted points**
	N					
	P					
	K					
	CEC					
Sum of points from the Soil Health Indicators						*Write here Final Score and Qualitative Result*
	Partial Indicator	**Needs Improvement**	**Fair**	**Good**	**Excellent**	
Ecosystem Health Indicator	Vigor					**Qualitative NI-F-G-E according to sum of weighted points**
	Organization					
	Resilience					
Sum of points from the Ecosystem Health indicators						*Write here Final Score and Qualitative Result*
Score for Animal Welfare						*Write here the*

Main Indicator	Partial Indicator	Rating (cross-check the corresponding rating)				Final score
		Needs Improvement	Fair	Good	Excellent	
						Qualitative Result

* NI=Needs Improvement; F=Fair; G=Good; E=Excellent

VII. REPORT

After each monitoring round, a report must be submitted to the Regen Registry including a description of the methods used for soil sampling, analysis of samples, as well as the equations and references used. The reported results for each section of this Methodology must be accompanied by all the information that supports them. In the case of GIS or remote sensing data, it is required that the maps are included as images within the report for illustrative purposes. The original vector and raster files must be kept by the Monitor. Any documentation containing calculations and statistical analysis should also be saved.

VIII. MONITORING

VIII.1. TEMPORALITY

TABLE 7. SCHEDULE OF ACTIVITIES

Activity	Temporality		
	Prior to the start of the Project	End of the Project activities	Annually during the life of the Project
Calculation of SOC stock	✓	✓	✓

IX. SECTORAL SCOPE APPLICABLE TO AOCP VALIDATOR/VERIFIER

The verifiers that will review and verify the impact results of the project will be those that comply with the competencies established in section VII.3.3. of the Procedure for the Approval of Validators and Verifiers aOCP, and specifically of those who comply with the Accreditation of our courses, especially those oriented to:

- Climate actions
- Urban forest
- Biodiversity and climate change
- Regenerative agriculture

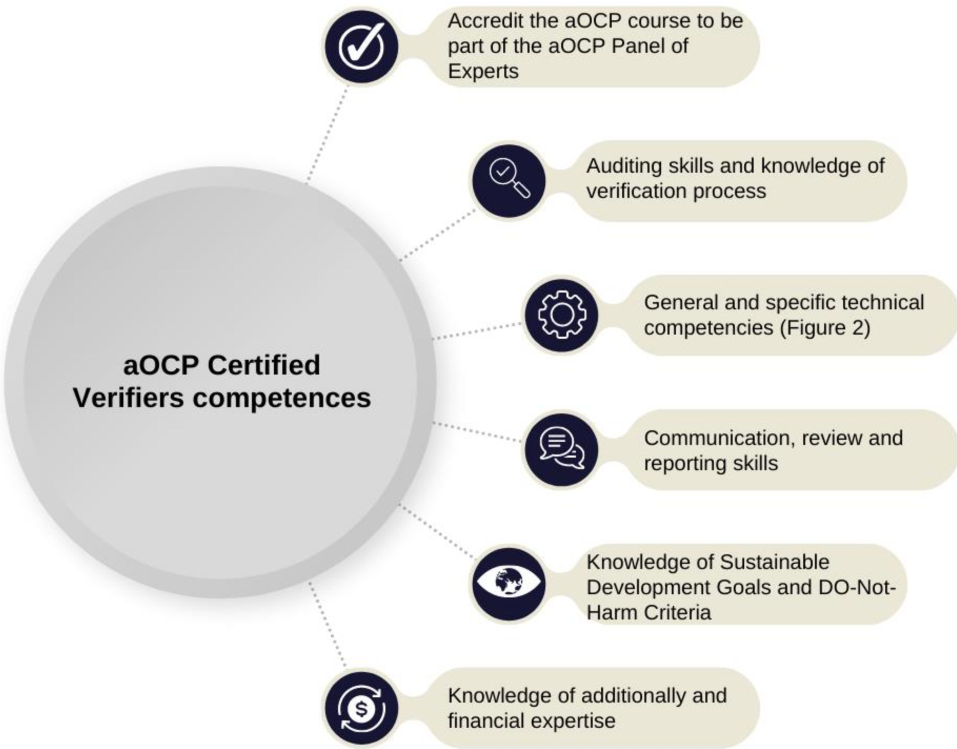


FIGURE 1. AOCP CERTIFIED VERIFIERS COMPETENCES

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