Gold Standard

Gold Standard Agriculture Methodology

Increasing Soil Carbon Through Improved Tillage Practices

Valid since **March 2015**

Version **0.9 (for road-testing)**

This methodology of the Gold Standard is subject to *road-testing*. This means that during the road-testing phase experiences from the projects that apply this methodology will be collected and incorporated into version 1.0.

Version 0.9 is fully approved to create validated and verified CO_2-certificates. CO_2-certificates that are generated with this version are valid under future versions.

Applicability **Gold Standard for the Global Goals (LU&F Activity Requirements)**

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Gold Standard

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Development

This standalone methodology may later be integrated into an overall 'Gold Standard Land Use & Forests Methodology Toolbox' covering activities such as improved fertilizer management, livestock management, crop management, tillage practices. Until approval of such an integrated toolbox this standalone methodology can be used and applied by any project covering improved tillage practices.

How to Read the Document

- Dashed underlined words are defined in the section '1. Definitions' or in the 'Agriculture Requirements'.
- **Shall** indicates requirements that must be followed in order to conform.
- **Should** indicates that a certain course of action is preferred but not necessarily required.
- **May** indicates a course of action is permissible but not compulsory.
- **Can** is used for statements of possibility and capability.

This document features three different types of boxes:

Clear boxes l The information in the *clear boxes* is to assist in using the document and to introduce procedures.

Green boxes l *Green boxes* indicate that the project owner shall provide evidence to show compliance with the requirements through submitting the *project documentation* and *supporting documents*. (Note: If the document is printed in black and white, the *green boxes* are identified as the *grey* boxes without borders.)

Grey boxes with a border l *Grey boxes with a border* indicate requirements that must be followed, but which do not require documentary evidence from the project owner unless otherwise noted.

1. Definitions

Conservation tillage l Conservation tillage includes any form of minimum or reduced tillage, where residue, mulch, or sod is left on the soil surface to protect soil and conserve moisture. After planting, at least 30 percent of the soil surface remains covered by residue to reduce soil erosion by water.

Conventional tillage l Seedbed preparation using cultivation instruments such as harrows, mouldboard ploughs, offset harrows, subsoilers, and rippers. Conventional tillage methods, involving extensive seedbed preparation, cause the greatest soil disturbance and leave little plant residues on the surface.

Cropping system l The term cropping system refers to the crops, crop sequences and the management techniques used on a particular field over a period of years.

Cropland l (Source IPCC GPG for LULUCF) Cropland includes all arable and tillage land, and agro-forestry systems where vegetation falls below the threshold used for the forest land category, consistent with the selection of national definitions.

Tillage l Tillage is the agricultural preparation of soil by mechanical agitation of various types, such as digging, stirring, and overturning.

No tillage l No till farming (also called zero tillage) is a way of growing crops or pasture without tillage (no turning of topsoil), minimizing soil disturbance.

Project scenario l Project scenario describes the activities that occur in the proposed project.

Soil Organic Carbon (SOC) l Carbon (C) occurring in the soil in SOM.

Soil Organic Matter (SOM) l Organic constituents in the soil such as tissues from dead plants and animals, products produced as these decompose and the soil microbial biomass.

2. References

This methodology is based on the following key sources:

Aynekulu et al. (2011): A protocol for modeling, measurement and monitoring soil carbon stocks in agricultural landscapes, version 1.1. World Agroforestry Centre (ICRAF), Nairobi. (http://www.samples.ccafs.cgiar.org/uploads/2/6/8/2/26823384/icraf.pdf)

European Soil Data Centre (2014): Soil data and information systems (http://eusoils.jrc.ec.europa.eu/). Also contains information on non-European soils.

FAO (2006): World reference base for soil resources 2006: A framework for international classification, correlation and communication (ftp://ftp.fao.org/agl/agll/docs/wsrr103e.pdf).

Mangalassery et al (2014): To what extent can zero tillage lead to a reduction in greenhouse gas emissions from temperate soils? Scientific Reports 4, article number 4586. (http://www.nature.com/srep/2014/140404/srep04586/full/srep04586.html).

Hengl et al (2014): SoilGrids1km — Global Soil Information Based on Automated Mapping. PLOS ONE, DOI: 10.1371/journal.pone.0105992 (http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0105992).

IPCC (2006a): Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use, Chapter 5 Cropland (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf).

IPCC (2006b): Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use, Chapter 2 Generic Methodologies Applicable to Multiple Land-Use Categories (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html).

ISRIC (2014): World Soil Information (http://www.isric.org/content/data). Several global soil maps are available, e.g. 1 km soil grids (http://soilgrids.org/).

Lichtfouse (Editor; 2011): Genetics, Biofuels and Local Farming Systems. Springer, Sustainable Agriculture Reviews 7.

The Gold Standard 'Agriculture Requirements' v0.9 (for road testing) Dec 2014.

VCS Methodology VM0017 v 1.0 (2011): Adoption of Sustainable Agricultural Land Management. Developed by BioCarbon Fund, World Bank. http://www.v-c-s.org/methodologies/adoption-sustainable-agricultural-land-management-v10

VCS Module VMD0021 v1.0 (2011): Module VMD0021 Estimation of Stock in the Soil Carbon Pool. (http://www.v-c-s.org/methodologies/estimation-stocks-soil-carbon-pool-v10)

West and Post (2002): Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation: A Global Data Analysis. Soil Sci. Soc. Am. J. 66:1930–1946.

3. Summary Description

The aim of this methodology is to reduce greenhouse gas (GHG) emissions from agriculture by changing soil tillage practices within agricultural systems. Activities can achieve prevention of emissions as well as sequestration of carbon in the soil, both of which result in increased soil organic carbon (SOC) content.

This methodology provides a framework to incentivize and capture benefits from tillage improvements. It is applicable for a wide area of technological levels, from low tech land use to industrialized land management, using a variety of improved tillage techniques. As tillage techniques and scientific knowledge of their impact are constantly changing, the methodology does not require a specific approach but provides flexibility to apply the most current and best-fit systems. Where local information is unavailable, project owners may use data or models from other scientific sources. A high-level overview and a selection of potential scientific sources is listed in this methodology's Appendix A. Nevertheless, this methodology provides guidance to ensure that quality and quantification of benefits correspond to the high level expected in the Gold Standard.

A recently published study (Mangalassery et al, 2014) summarizes the importance of agricultural land use and tillage with regards to climate change as follows: "Globally, agriculture accounts for 10 - 12% of total anthropogenic emissions of greenhouse gases (GHGs) estimated to be 5.1 - 6.1 Gt CO2-eq yr^{-1} in 2005. Conservation tillage is one among many different mitigation options suggested to reduce GHG emissions from agriculture. Conservation tillage practices such as reduced/minimum/no tillage, direct drilling and strip cropping are also widely recommended to protect soil against erosion and degradation of structure, create greater aggregate stability, increase soil organic matter content, enhance sequestration of carbon, mitigate GHG emissions and improve biological activities."

In many countries conventional tillage methods are still in use today applying instruments such as harrows, mouldboard ploughs, offset harrows, subsoilers, and rippers for extensive seedbed preparation. Conventional tillage methods cause great soil disturbance such as soil compaction, loss of organic matter, degradation of soil aggregates, death or disruption of soil microbes and other organisms including mycorrhiza, arthropods, and earthworms, and soil erosion where topsoil is washed or blown away[1]. Also it leaves little plant residues on the surface and thus lead to not only greenhouse gas emissions but also moisture loss/imbalances and in many cases nutrient efflux. It is thus essential that – while ensuring food security and sustainability – incentives are provided to improve the relevant practices.

Under this methodology, conservation tillage methods are introduced to project areas previously under more conservative management. This includes forms of minimum or reduced impact tillage which causes less soil disturbance than conventional forms of tillage and where residue, mulch, or sod is left on the soil surface to protect soil and conserve moisture. After planting, at least 30 percent of the soil surface remains covered by residue to reduce soil erosion by water (compare applicability chapter).

[1] Various authors in Lichtfouse (Editor; 2011)

4. Applicability

The project shall meet all of the requirements listed below for this methodology to be applicable.

Geographic location

- Projects are eligible in all countries.

Project area

- Project area(s) shall not be on wetlands.
- The parcel of land on which the baseline crops are grown shall be the same parcel of land on which the project crops are grown.

Soil type

- Proposed projects on sites with organic soils (Histosols), as defined by the *FAO's World Reference Base for Soil Resources*[2], are ineligible. Only mineral soil types are eligible.

Site preparation

- No biomass burning for site preparation is allowed in the project scenario.
- Project activities shall not include changes in surface and shallow (<1m) soil water regimes through flood irrigation, drainage or other significant anthropogenic changes in the ground water table.

Cropping system

- Managed cropping systems (e.g. single crop or crop rotation) have been in place for at least 5 years prior to project implementation, i.e. the project does not lead to land use change.

Tillage practice

- Under this methodology, conservation tillage methods are applied meaning forms of minimum or reduced tillage, where residue, mulch, or sod is left on the soil surface to protect soil and conserve moisture. After planting, at least 30 percent of the soil surface remains covered by residue to reduce soil erosion by water. Due to the uncertainty associated with the carbon benefits of no-tillage techniques, this methodology is not applicable to no tillage techniques, including strip tillage and direct drill practices.

Food security

- No reduction in crop yield which can be attributed to the project activity shall be allowed. Activities in the project area shall deliver a yield at least equivalent to the baseline yield (five year average, prior to project start). If regional crop productivity changes (e.g. due to climatic factors), yield in project area shall not decrease significantly more than regional yield.

Permanence

- Project participants shall demonstrate other motivations to participate in the project than generating CO_2-certificates.

[2] FAO's World Reference Base for Soil Resources I ftp://ftp.fao.org/agl/agll/docs/wsrr103e.pdf

5. Project Boundaries

Spatial boundary
The spatial boundary encompasses the results of activities that are under the project owner's control. Activities in the project area result in sequestration of carbon in the soil, which result in an increased soil organic carbon (SOC) content.

Any areas leaving the project during the project duration are conservatively considered full reversals (i.e. loss of all carbon sequestered). According to the 'Gold Standard Agriculture Requirements' Section 7, Requirements 1 and 2, the project owner is responsible to maintain or compensate carbon loss to the level of CO_2-certificates already issued. If new areas are added to the project, they have to be documented and audited according to the 'New Area Certification' procedures described in the 'Gold Standard Agriculture Requirements'.

Temporal boundary
According to the 'Gold Standard Agriculture Requirements' the duration of the crediting period is specified on methodology level. This methodology therefore uses results from key peer reviewed scientific papers as guidance for temporal boundary demarcation[3].

The project crediting period shall be fixed to 10 years and cannot be renewed.

For retroactive submission of projects the *'Land Use & Forests Retroactive Guideline'*[4] shall be followed.

Carbon Pools
The table below summarizes the carbon pools included in projects using this methodology.

Pools	Includes	Project	Baseline	Leakage
Aboveground (tree and non-tree biomass)	Stem, branches, bark, grass, herbs, etc.	No	No	No
Belowground (tree and non-tree biomass)	Roots of grass, trees, herbs	No	No	No
Deadwood	Standing and lying deadwood	No	No	No
Litter	Leaves, small fallen branches	No	No	No
Soil organic carbon	Organic material	Yes	Yes	No
Wood products	Furniture, construction material, etc.	No	No	No

[3] Mangalassery et al (2014) found that increases in soil organic matter occurred within five years following conversion from conventional tillage to zero tillage: http://www.nature.com/srep/2014/140404/srep04586/full/srep04586.html). West and Post (2002) in similar work recorded a large increase in soil between 5–10 years.
[4] Gold Standard 'Land Use & Forests Retroactive Guideline' I www.goldstandard.org/wp-content/uploads/2015/02/LUF_Guidelines_-_Retroactive.pdf

6. Calculation of CO2-Certificates

Greenhouse gas benefits from improved tillage activities are calculated as the net changes in the soil organic carbon pool as depicted below. Consequently, the CO2 equivalent to the increase in SOC minus project emissions and potential emissions leakage effects is considered the greenhouse gas benefit attributable to the project activity. From these benefits, a fixed percentage of the CO_2 certificates shall be transferred into the Gold Standard 'Compliance Buffer'.

$$CO_2Certificates_{t-0} = \left[\left(\Delta C_{SOC,t-0} \times \frac{44}{12}\right) - PE_{t-0} - LK_{t-0}\right] \times (1 - BUF) \qquad (1)$$

Where:

CO_2 *Certificates*$_{t-0}$ = *GS emissions reductions to be issued for the calculation period [tCO_2e]*

$\Delta C_{SOC,t-0}$ = *change in carbon stocks in mineral soils in the calculation period [tC]*

$\frac{44}{12}$ = *C to CO2 molecular mass ratio [tCO2e tC^{-1}]*

PE_{t-0} = *additional emissions due to project activity in the calculation period [tCO_2e]*

LK_{t-0} = *leakage of emissions due to project activity in the calculation period [tCO_2e]*

BUF = *compliance buffer fraction [dimensionless]; please refer to the 'Gold Standard Agriculture Requirements' for the default percentage.*

Changes in SOC between two points in time (calculation period) are determined as the difference between SOC stocks at each point:

$$\Delta C_{SOC,t-0} = (SOC_t - SOC_0) \times (1 - UD) \qquad (2)$$

Where:

$\Delta C_{SOC,t-0}$ = *change in soil organic carbon stocks in the calculation period [tC]*

SOC_0 = *soil organic carbon stock at the beginning of the calculation period [tC]*

SOC_t = *soil organic carbon stock at the end of the calculation period [tC]*

UD = *uncertainty deduction [dimensionless]*

Note: For the first calculation period after project start, SOC_0 is equal to SOC_{BL}; for subsequent periods, SOC_0 refers to the previous period's SOC_t.

Approaches for baseline and project activity quantification

To accommodate that soil measurements are not always available to projects, especially for small community-based activities, this methodology incorporates three approaches to baseline and project activity quantification:

Approach 1

Approach 1 requires on-site measurements to directly document pre-project and project SOC stocks.

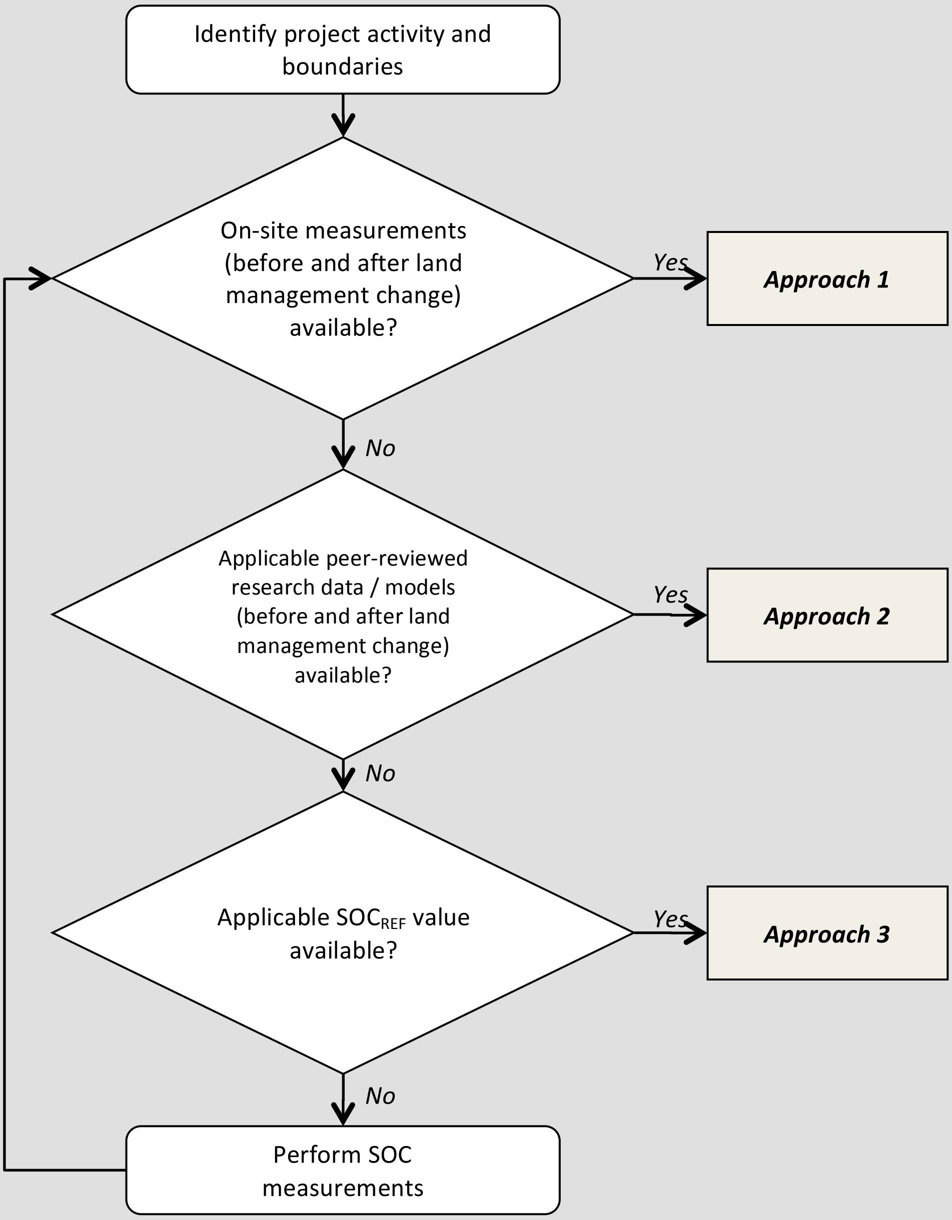
Approach 2

Approach 2 uses peer-reviewed publications to quantify pre-project SOC stocks and project impact. Project owners need to prove that the research results are conservative and applicable to the project site and management practice.

Approach 3

Approach 3 applies default factors to quantify SOC changes from improved tillage, relating to the general methodology described in the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC 2006a). However, instead of IPCC default SOC reference values (SOC_{REF}), a project-oriented SOC_{REF} value shall be used in connection with IPCC impact factors.

Generally, project owners shall use the most specific approach possible with the data available, giving preference to local data sources and models. A decision tree to determine an eligible approach is supplied in the figure below. Further requirements for each approach and its application are given in the baseline and project scenario chapters.



Uncertainty

The project owner shall use a precision of 20% of the mean at the 90% confidence level as the criteria for reliability of sampling efforts. This target precision shall be achieved by selecting appropriate parameters, sampling and measurement techniques.

Step 1: Calculate upper and lower confidence limits for all input parameters

Calculate the mean $\bar{X}_p$, and standard deviation σ_p, for each parameter used in stock calculations[5]. The standard error of the mean is then given by

$$SE_p = \frac{\sigma_p}{\sqrt{n_p}} \tag{3}$$

Where:

SE_p	*= standard error in the mean of parameter p*
σ_p	*= standard deviation of the parameter p*
n_p	*= number of samples used to calculate the mean and standard deviation of parameter p*

If SE_p (mean standard error) is available directly from the parameter source (e.g. literature, metadata) it may be used directly in the following calculations (without the use of Equation 3).

Assuming that values of the parameter are normally distributed about the mean, values for the upper and lower confidence intervals for the parameters are given by

$$\text{Lower}_p = \bar{X}_p - t_{np} \times SE_p \tag{4}$$
$$\text{Upper}_p = \bar{X}_p + t_{np} \times SE_p$$

Where:

$Lower_p$	*= value at the lower end of the 90% confidence interval for parameter p*
$Upper_p$	*= value at the upper end of the 90% confidence interval for parameter p*
$\bar{X}_p$	*= mean value for parameter p*
SE_p	*= standard error in the mean of parameter p*
t_{np}	*= t-value for the cumulative normal distribution at 90% confidence interval for the number of samples n_p for parameter p (apply table on the next page below).*

[5] For IPCC default factors used in this methodology (approach 3 only), a nominal error of ±90% is given (shown in Table 7-1). According to the table footnotes, this corresponds to 2*¶$_p$,. and thus to a sample size of 5 , which shall be assumed in this case.

t-values (t_{np}) applicable in equation (4). Select appropriate t_{np} value depending on the number of samples (n_p) measured for parameter *p*.

n_p	t_{np}	n_p	t_{np}	n_p	t_{np}	n_p	t_{np}
		51	1.6759	101	1.6602	151	1.6551
		52	1.6753	102	1.6601	152	1.6550
3	2.9200	53	1.6747	103	1.6599	153	1.6549
4	2.3534	54	1.6741	104	1.6598	154	1.6549
5	2.1319	55	1.6736	105	1.6596	155	1.6548
6	2.0150	56	1.6730	106	1.6595	156	1.6547
7	1.9432	57	1.6725	107	1.6593	157	1.6547
8	1.8946	58	1.6720	108	1.6592	158	1.6546
9	1.8595	59	1.6715	109	1.6591	159	1.6546
10	1.8331	60	1.6711	110	1.6589	160	1.6545
11	1.8124	61	1.6706	111	1.6588	161	1.6544
12	1.7959	62	1.6702	112	1.6587	162	1.6544
13	1.7823	63	1.6698	113	1.6586	163	1.6543
14	1.7709	64	1.6694	114	1.6585	164	1.6543
15	1.7613	65	1.6690	115	1.6583	165	1.6542
16	1.7530	66	1.6686	116	1.6582	166	1.6542
17	1.7459	67	1.6683	117	1.6581	167	1.6541
18	1.7396	68	1.6679	118	1.6580	168	1.6540
19	1.7341	69	1.6676	119	1.6579	169	1.6540
20	1.7291	70	1.6673	120	1.6578	170	1.6539
21	1.7247	71	1.6669	121	1.6577	171	1.6539
22	1.7207	72	1.6666	122	1.6575	172	1.6538
23	1.7172	73	1.6663	123	1.6574	173	1.6537
24	1.7139	74	1.6660	124	1.6573	174	1.6537
25	1.7109	75	1.6657	125	1.6572	175	1.6537
26	1.7081	76	1.6654	126	1.6571	176	1.6536
27	1.7056	77	1.6652	127	1.6570	177	1.6536
28	1.7033	78	1.6649	128	1.6570	178	1.6535
29	1.7011	79	1.6646	129	1.6568	179	1.6535
30	1.6991	80	1.6644	130	1.6568	180	1.6534
31	1.6973	81	1.6641	131	1.6567	181	1.6534
32	1.6955	82	1.6639	132	1.6566	182	1.6533
33	1.6939	83	1.6636	133	1.6565	183	1.6533
34	1.6924	84	1.6634	134	1.6564	184	1.6532
35	1.6909	85	1.6632	135	1.6563	185	1.6532
36	1.6896	86	1.6630	136	1.6562	186	1.6531
37	1.6883	87	1.6628	137	1.6561	187	1.6531
38	1.6871	88	1.6626	138	1.6561	188	1.6531
39	1.6859	89	1.6623	139	1.6560	189	1.6530
40	1.6849	90	1.6622	140	1.6559	190	1.6529
41	1.6839	91	1.6620	141	1.6558	191	1.6529
42	1.6829	92	1.6618	142	1.6557	192	1.6529
43	1.6820	93	1.6616	143	1.6557	193	1.6528
44	1.6811	94	1.6614	144	1.6556	194	1.6528
45	1.6802	95	1.6612	145	1.6555	195	1.6528
46	1.6794	96	1.6610	146	1.6554	196	1.6527
47	1.6787	97	1.6609	147	1.6554	197	1.6527
48	1.6779	98	1.6607	148	1.6553	198	1.6526
49	1.6772	99	1.6606	149	1.6552	199	1.6526
50	1.6766	100	1.6604	150	1.6551	≥200	1.6525

Step 2: Calculate SOC change (ΔCSOC,t-0) with the lower and upper confidence interval values of the input parameters

Apply the *Lower* and *Upper* parameter values in the models for $\Delta C_{SOC,t\text{-}0}$, i.e. equations for SOC_{BL} and SOC_t, to achieve a lower and upper value for ΔC_{SOC}

$$\mathrm{Lower}_{\Delta CSOC} = \mathrm{Model}_{SOC}\{\mathrm{Lower}_p\} \quad (5)$$
$$\mathrm{Upper}_{\Delta CSOC} = \mathrm{Model}_{SOC}\{\mathrm{Upper}_p\}$$

Where:

$Lower_{\Delta CSOC}$	*= lower value of SOC change at a 90% confidence interval*
$Upper_{\Delta CSOC}$	*= upper value of SOC change at a 90% confidence interval*
$Model_{SOC}$	*= calculation models for SOC_t, SOC_0, SOC_{BL}*
$Lower_p$	*= values at the lower end of the 90% confidence interval for all parameters p*
$Upper_p$	*= values at the upper end of the 90% confidence interval for all parameters p*

Step 3: Calculate the uncertainty in the model output

The uncertainty in the output model is given by

$$\mathrm{UNC} = \frac{|\mathrm{Upper}_{\Delta CSOC} - \mathrm{Lower}_{\Delta CSOC}|}{2 \times \Delta C_{SOC}} \quad (6)$$

Where:

UNC	*= model output uncertainty [%]*
$Lower_{\Delta CSOC}$	*= lower value of SOC change at a 90% confidence interval [tC]*
$Upper_{\Delta CSOC}$	*= upper value of SOC change at a 90% confidence interval [tC]*
ΔC_{SOC}	*= change in soil organic carbon stocks [tC]*

Step 4: Adjust the estimate of SOC change (ΔCSOC,t-0) based on the uncertainty in the model output

If the uncertainty of SOC change models is less than or equal to 20% of the mean SOC change value then the project owner may use the estimated value without any deduction for uncertainty, i.e. *UD* = 0 in Equation 2. If the uncertainty of soil models is greater than 20% of the mean value, then the project owner shall use the estimated value subject to an uncertainty deduction (*UD*) in Equation 2, calculated as

$$\mathrm{UD} = \mathrm{UNC} - 20\% \quad (7)$$

Where:

UD	*= uncertainty deduction [%]*
UNC	*= model output uncertainty (>20%) [%]*

7. Baseline Scenario

Under this methodology's 'Additionality' and 'Applicability conditions', the relevant baseline scenario is the continuation of the historical cropping practices where, in the absence of the project activity, conventional tillage is done in a business as usual (BAU) manner.

To determine the baseline of the eligible project area the land shall be stratified into modelling units (MU) according to

- mineral soil type
- climate zone
- tillage practices
- cropping system
- input levels (e.g. fertilization)

For each stratum (MU), SOC measurements have to be performed (*Approach 1*) and/or model parameters identified and verified (*Approach 2 or 3*).

Baseline Calculations

For all of the eligible project area, baseline SOC stocks are calculated as the sum of stocks in each stratum multiplied by the stratum area:

$$SOC_{BL} = \sum_{y=1}^{n} \left(SOC_{BL,y} \times A_y \right) \qquad (8)$$

Where:

SOC_{BL} = *soil organic carbon in the eligible project area before project start [tC]*

$SOC_{BL,y}$ = *soil organic carbon in stratum y before project start [tC ha^{-1}]*

A_y = *area of stratum y before project start [ha]*

For each stratum in the eligible project area, baseline SOC stocks shall be quantified using any of the three general approaches. Different approaches may be used for different strata.

Approach 1

$SOC_{BL,y}$ is measured in an adequate number of soil profiles with each stratum. Measurement of soil carbon content (SOC) shall follow accepted sampling and analysis protocols. Currently, accepted protocols are the *ICRAF protocol*[6] and the *VCS SOC Module*[7]. As these protocols require a certain measure of field and laboratory technology, alternate protocols may be proposed by the project owner. However, any deviations from the protocols listed (or use of alternate protocols) are subject to review and decision by the Gold Standard.

[6] ICRAF protocol — Aynekulu, E. Vagen, T-G., Shephard, K., Winowiecki, L. 2011. A protocol for modeling, measurement and monitoring soil carbon stocks in agricultural landscapes. Version 1.1. World Agroforestry Centre (ICRAF), Nairobi. (http://www.samples.ccafs.cgiar.org/uploads/2/6/8/2/26823384/icraf.pdf)

[7] VCS SOC Module — Verified Carbon Standard (VCS) 2011. Module VMD0021 Estimation of Stock in the Soil Carbon Pool (Version 1.0). (http://www.v-c-s.org/methodologies/estimation-stocks-soil-carbon-pool-v10)

Approach 2

$SOC_{BL,y}$ is derived from data published in peer-reviewed literature. Evidence for applicability of the literature values to the project site has to be provided with respect to climate factors (e.g. precipitation levels and seasonal distribution), soil and vegetation types as well as current and historic management systems (crops, tillage techniques, fertilization). Direct application of literature values is only permitted if the source conditions match the project environment, evidence of which shall be provided as described in section 0 (Montioring). Furthermore, literature values shall only be applied within the spatial and temporal dimensions analysed in the original source (e.g. SOC depth, timespan for which changes are documented). If a range of parameter values is given in a source or data is aggregated across various factor levels (e.g. average SOC in a region, across a range of soil types), the most conservative value shall be applied.

Alternatively, SOC values from literature may be verified by comparing them to measurements in a set of sample sites within the respective project stratum to indicate conservativeness of the parameter values applied. Such measurements are required if evidence for applicability (as listed above) of literature values is deemed insufficient by an auditor.

Approach 3

If no data for $SOC_{BL,y}$ is available, it may be modelled using equation 9. The calculation follows the approach documented in IPCC 2006 but allows for baseline management practices to be in place less than the estimated time to equilibrium (i.e. in case of IPCC default factors, less than 20 years).

$$SOC_{BL,y} = SOC_{REF,y} \times \left(1 + \left(F_{LU,y} \times F_{MG,BL,y} \times F_{I,BL,y} - 1\right) \times \frac{T_{BL}}{D_{BL}}\right) \quad (9)$$

Where:

$SOC_{BL,y}$ = *soil organic carbon before project start in stratum y [tC ha^{-1}]*
$SOC_{REF,y}$ = *reference soil organic carbon stock under natural vegetation in stratum y [tC ha^{-1}]*
$F_{LU,y}$ = *land use factor in stratum y [dimensionless]*
$F_{MG,BL,y}$ = *tillage factor before project start in stratum y [dimensionless]*
$F_{I,BL,y}$ = *input factor before project start in stratum y [dimensionless]*
D_{BL} = *time dependency of $F_{MG,BL}$ and $F_{I,BL}$ factors*[8] *[yr]*
T_{BL} = *number of years since introduction of baseline practice; maximum T_{PR} = D [yr]*

In this approach, $SOC_{REF,y}$ shall be selected from an appropriate scientific source[9] or measurements, applicability of which in the project stratum shall be documented. This must include evidence that the SOC_{REF} value stems from a comparable climatic, soil and vegetation environment, as described in section 0 (Monitoring). If evidence provided for applicability of SOC_{REF} is deemed insufficient by an auditor, appropriate measurements are required.

For $F_{LU,BL,y}$, $F_{MG,BL,y}$ and $F_{I,BL,y}$ factors, default values from the IPCC 2006 guidelines may be applied within a given temperature and moisture regime (see table on the next page), referring to the management before project start. If national or regional factors are available (IPCC Tier 2 or Tier 3 data) these should be used instead.

[8] For IPCC 2006 default factors, *D* equals 20 years
[9] Publications, verifiable local research results, soil databases e.g. ISRIC (http://www.isric.org/content/data), Hengl et al (2014), or the European Soil Portal (http://eusoils.jrc.ec.europa.eu/; also provides information on non-European soils).

Extract from IPCC relative stock change factors (F_{LU}, F_{MG}, F_I) for different management activities on cropland.

Relative stock change factors (F_{LU},$F_{MG,}$ and F_I) (over 20 years) for different management activities on cropland						
Factor value type	**Level**	**Temperature regime**	**Moisture regime[1]**	**IPCC defaults**	**Error[2,3]**	**Description**
Land use (F_{LU})	Long-term cultivated	Temperate/ Boreal	Dry	0.80	±9%	Represents area that has been continuously managed for >20yrs, to predominantly annual crops. Input and tillage factors are also applied to estimate carbon stock changes. Land-use factor was estimated relative to use of full tillage and nominal ('medium') carbon input levels.
			Moist	0.69	±12%	
		Tropical	Dry	0.58	±61%	
			Moist/wet	0.48	±46%	
		Tropical montane[4]	n/a	0.64	±50%	
Tillage (F_{MG})	Full	All	Dry and Moist/wet	1.00	NA	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (e.g. <30%) of the surface is covered by residues.
	Reduced	Temperate/ Boreal	Dry	1.02	±6%	Primary and/or secondary tillage but with reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with>30% coverage by residues at planting.
			Moist	1.08	±5%	
		Tropical	Dry	1.09	±9%	
			Moist/wet	1.15	±8%	
		Tropical montane[4]	n/a	1.09	±50%	
	No-till	No till practices are not eligible under this methodology				
Input (F_I)	Low	Temperate/ Boreal	Dry	0.95	±13%	Low residue return occurs when there is due to removal of residues (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g. vegetables, tobacco, cotton), no mineral fertilisation or N fixing crops.
			Moist	0.92	±14%	
		Tropical	Dry	0.95	±13%	
			Moist/wet	0.92	±14%	
		Tropical montane[4]	n/a	0.94	±50%	
	Medium	All	Dry and Moist/wet	1.00	NA	Representative for annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g. manure) is added. Also requires mineral fertilisation or N fixing crop in rotation.

[1] Where data were sufficient, separate values were determined for temperate and tropical temperature regimes, and dry, moist and wet moisture regimes. Temperate and tropical zones correspond to those defined in Chapter 3; wet moisture regime corresponds to the combined moist and wet zones in the tropics and moist zone in temperate regions.

[2] ± two standard deviations, expressed as a percentage of the mean, where sufficient studies were not available for statistical analysis to derive a default, uncertainty was assumed to be ±50% based on expert opinion. NA denotes 'Not Applicable', where factor values constitute defined reference values, and the uncertainties are reflected in the reference C stocks and stock change factors for land use.

[3] This error range does not include potential systematic error due to small sample sizes that may not be representative of the true impact for all regions of the world.

[4] There were not enough studies to estimate stocks change factors for mineral soils in the tropical montane climate region. As an approximation the average stock change between the temperate and tropical regions was used to approximate the stock change for the tropical montane climate.
Note: See Annex 5A.1 for the estimation of default stock change factors for mineral soil C emissions/removals for Cropland.

Source: IPCC 2006: Guidelines for National Greenhouse Gas Inventories, Volume 4 Agriculture, Forestry and Other Land Use, Chapter 5 Cropland, table 5.5. on page 5.17.
(www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf)

8. Project Scenario

Under the project scenario, conservation tillage practices are applied in the project area.
As with the baseline, the eligible project area shall be stratified into modelling units (MU) according to

- mineral soil type
- climate zone
- tillage practices
- cropping systems
- input levels (e.g. fertilization)

For each stratum (MU), SOC measurements have to be performed (*Approach 1*) and/or modelling parameters identified (*Approach 2 or 3*).

Project Scenario Calculations

For all of the eligible project area, SOC stocks at time *t* are calculated as the sum of stocks in each stratum multiplied by the stratum area:

$$SOC_t = \sum_{y=1}^{n}(SOC_{t,y} \times A_y) \quad (10)$$

Where:

SOC_t = *soil organic carbon in the eligible project area at time t [tC]*
$SOC_{t,y}$ = *soil organic carbon in stratum y at time t [tC ha^{-1}]*
A_y = *area of stratum y at time t [ha]*

For each stratum in the eligible project area, SOC stocks are quantified using any of the three approaches. If a different approach is used for baseline and project scenarios in a stratum, conservativeness and comparability have to be ensured. Specifically, soil depth reflected in SOC calculations / measurement shall match for both approaches, e.g. if only top 30 cm are considered in baseline estimations using approach 3, project scenario calculations shall apply same depth restriction, even if SOC levels are measured in deeper soil layers.

Approach 1

$SOC_{t,y}$ is measured in an adequate number of soil profiles with each stratum. Currently accepted protocols are the *ICRAF protocol*[10] and the *VCS SOC Module*[11]. As these protocols require a certain measure of field and laboratory technology, alternate protocols may be proposed by the project owner. However, any deviations from the protocols listed (or use of alternate protocols) are subject to review and decision by the Gold Standard.

For ex-ante calculations, literature references or an accepted soil carbon model shall be used, following Approach 2 below.

[10] Aynekulu, E. Vagen, T-G., Shephard, K., Winowiecki, L. 2011. A protocol for modeling, measurement and monitoring soil carbon stocks in agricultural landscapes. Version 1.1. World Agroforestry Centre (ICRAF), Nairobi. (http://www.samples.ccafs.cgiar.org/uploads/2/6/8/2/26823384/icraf.pdf)
[11] Verified Carbon Standard (VCS) 2011. Module VMD0021 Estimation of Stock in The Soil Carbon Pool (Version 1.0). (http://www.v-c-s.org/methodologies/estimation-stocks-soil-carbon-pool-v10)

Approach 2

$SOC_{t,y}$ is derived from data published in peer-reviewed literature or accepted soil carbon models[12]. Evidence for applicability of the literature values and model parameters to the project site has to be provided concerning climate factors (e.g. precipitation levels and seasonal distribution), soil and vegetation types as well as current and historic management systems (crops, tillage techniques, fertilization). Direct application of literature values is only permitted if the source conditions match the project environment, evidence of which shall be provided as described in section 0 (Monitoring). Furthermore, literature values shall only be applied within the spatial and temporal dimensions analysed in the original source (e.g. SOC depth, timespan for which changes are documented). If a range of parameter values is given in a source or data is aggregated across various factor levels (e.g. average SOC in a region, across a range of soil types), the most conservative value shall be applied.

Alternatively, the SOC values from literature may be verified by comparing them to measurements in a set of sample sites within the respective project stratum to indicate conservativeness of the parameter values applied. Such measurements are required if evidence for applicability (as listed above) of literature values or model parameters is deemed insufficient by an auditor.

Approach 3

If no data for $SOC_{BL,y}$ is available, it may be modelled using the approach documented in IPCC 2006. The land use factors F_{LU}, F_{MG} and F_I used in this approach have a time dependency based on the estimated time to reach an equilibrium state after a management change (for IPCC 2006a defaults factors, this is 20 years). Equation 11 below provides an approach to account for shorter crediting periods and shall thus be applied.

$$SOC_{t,y} = SOC_{BL,y} + \Delta SOC_{t,y}$$
$$\Delta SOC_{t,y} = SOC_{REF,y} \times F_{LU,y} \times \left(F_{MG,PR,y} \times F_{I,PR,y} - F_{MG,BL,y} \times F_{I,BL,y}\right) \times \frac{T_{PR}}{D_{PR}} \qquad (11)$$

Where:

$SOC_{t,y}$	=	*soil organic carbon in stratum y at time t [tC ha^{-1}]*
$SOC_{BL,y}$	=	*soil organic carbon in stratum y before project start (see equation 9) [tC ha^{-1}]*
$\Delta SOC_{t,y}$	=	*change in soil organic carbon since project start in stratum y at time t [tC ha^{-1}]*
$SOC_{REF,y}$	=	*reference soil organic carbon stock under natural vegetation in stratum y [tC ha^{-1}]*
$F_{LU,y}$	=	*land use factor in stratum y [dimensionless]*
$F_{MG,BL,y}$	=	*tillage factor before project start in stratum y [dimensionless]*
$F_{I,BL,y}$	=	*input factor before project start in stratum y [dimensionless]*
$F_{MG,PR,y}$	=	*tillage factor under the project scenario in stratum y [dimensionless]*
$F_{I,PR,y}$	=	*input factor under the project scenario in stratum y [dimensionless]*
D_{PR}	=	*time dependency of $F_{MG,PR}$ and $F_{I,PR}$ factors[13] [yr]*
T_{PR}	=	*number of years since project start at time t; maximum T_{PR} = D [yr]*

Under the applicability conditions of this methodology, no land use change is taking place and thus the $SOC_{REF,y}$ and $F_{LU,y}$ values are identical to the respective baseline values.

For $F_{MG,PR,y}$ and $F_{I,PR,y}$ factors, default values from the IPCC 2006 guidelines may be applied within a given temperature and moisture regime as in the baseline scenario (see Table 7-1), but now referring to the management and input levels under the project scenario. Note that the same climate zone and soil type as for baseline calculations shall be used. If national or regional factors are available (IPCC Tier 2 or Tier 3 data) these should be used instead. In such cases, time dependency *D* also has to be matched to the respective source.

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[12] Such as RothC (http://www.rothamsted.ac.uk/sustainable-soils-and-grassland-systems/rothamsted-carbon-model-rothc) or Century (http://www.nrel.colostate.edu/projects/century/) soil carbon models

[13] For IPCC 2006 default factors, *D* equals 20 years

9. Other Emissions

Significant additional greenhouse gas emissions due to the project activity need to be accounted for. This explicitly includes emissions from increased fertilizer input and fossil fuel combustion.

$$PE_{t-0} = \Delta FE_{t-0} + \Delta FU_{t-0} + \Delta AE_{t-0} \quad (12)$$

Where:

$PE_{t\text{-}0}$	=	*emissions from project activities in the calculation period [tCO_2e]*
$\Delta FE_{t\text{-}0}$	=	*emissions from increased fertilizer use in the calculation period [tCO2e]*
$\Delta FU_{t\text{-}0}$	=	*emissions from increased fuel and electricity use in the calculation period [tCO2e]*
$\Delta AE_{t\text{-}0}$	=	*other agrochemical emissions in the calculation period [tCO2e]*

Increased N Fertilizer Input

Emissions from increased nitrogen (N) fertilizer input in project scenario as compared to the baseline scenario are calculated as follows. No differentiation is made between synthetic and organic N fertilizer. Note that this formula is not applicable for decreases in N fertilizer input, in which case $\Delta FE_{t\text{-}0,y}$ is considered 0. To account for reductions in fertilizer input (and the respective GHG emissions reductions), a separate Gold Standard methodology may be applied.

$$\Delta FE_{t-0} = 0.01 \times \sum_{a=1}^{T} \left(FE_{PR,a} - FE_{BL} \right) \quad (13)$$

Where:

$\Delta FE_{t\text{-}0}$	=	*emissions from increased fertilizer use in the calculation period [tCO2e]*
$FE_{PR,a}$	=	*N fertilizer input under the project scenario in year a of the calculation period [kgN]*
FE_{BL}	=	*mean annual N fertilizer input under the baseline scenario [kgN]*
T	=	*number of years in the calculation period [yr]*
0.01	=	*Default conversion factor*[14] *for emissions from N fertilizer [tCO_2e kgN]*

FE_{PR} and FE_{BL} shall be documented by the project owner. For FE_{BL}, mean annual input is calculated based on respective management records for 5 years prior to project start. If no adequate documentation can be provided, FE_{BL} shall be no more than 50% of FE_{PR}.

Increased Combustion of Fossil Fuels and Electricity Use

Additional CO_2 emissions from use of fossil fuel and electricity in project activities (e.g. fuel used by farm machines due to needs for stronger tractors or additional passes to close/treat the surface, or fuel/electricity for irrigation pumps) need to be accounted for, unless project owner can demonstrate that fossil fuel/electricity used in the project scenario is less than or does not differ significantly from fossil fuel/electricity used in the baseline, in which case $\Delta FU_{t\text{-}0}$ is considered 0.

$$\Delta FU_{t-0} = \sum_{a=1}^{T} \left(FU_{PR,a} - FU_{BL} \right) + \left(EU_{PR,a} - EU_{BL} \right) \quad (14)$$

Where:

$\Delta FU_{t\text{-}0}$	=	*emissions from increased fossil fuel and electricity use in the calculation period [tCO_2e]*
$FU_{PR,a}$	=	*emissions from use of fossil fuels under the project scenario in year a of the calculation period [tCO_2e]*
FU_{BL}	=	*mean annual emissions from use of fossil fuels under the baseline scenario [tCO_2e]*
$EU_{PR,a}$	=	*emissions from use of electricity under the project scenario in year a 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]*

[14] IPCC 2006, Vol 4 AFOLU, Table 11.1

FU_{PR} and FU_{BL} 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.

$$FU_{i,a} = \sum_{MT} FUL_{i,MT,a} \times FEF_{i,MT} \quad (15)$$

Where:

- $FU_{i,a}$ = *emissions from use of fossil fuels in year a [tCO₂e ha⁻¹]*
- $FUL_{i,MT,a}$ = *fuel consumption by the machinery type MT used in year a [litres]*
- $FEF_{i,MT}$ = *emissions factor for the fuel used in machinery MT [tCO_2e $litres^{-1}$]*
- MT = *machinery type (gasoline two-stroke, gasoline four-stroke, diesel)*
- i = *formula used for baseline (i=BL) as well as project scenario (i=PR)*

For FU_{BL}, mean annual emissions are calculated based on respective management records for 5 years prior to project start. If this is not available, the amount of fuel combusted can be estimated using fuel efficiency (for example l/100 km, l/t-km, l/hour) of the vehicle and the appropriate unit of use for the selected fuel efficiency (for example km driven if efficiency is given in l/100 km). If no adequate documentation can be provided, FU_{BL} shall be no more than 50% of FU_{PR}.

Non-CO_2 green-house-gas emissions caused by the use of fossil fuel from project activities (management operations, machinery, etc.) are insignificant and may thus be neglected.

EU_{PR} and EU_{BL} shall be documented by the project owner and generally calculated with the equation below, based on electricity consumption by appliance and respective emission factor. If electricity is generated on-site using fossil fuels (e.g. in diesel generators for irrigation pumps), emissions from fuel combustion should be calculated instead, following the approach described above.

$$EU_{i,a} = \sum_{SE} EUW_{i,SE,a} \times EEF_{i,SE} \quad (16)$$

Where:

- $EU_{i,a}$ = *emissions from use of fossil fuels in year a [tCO_2e ha^{-1}]*
- $EUW_{i,SE,a}$ = *electricity consumption from source SE in year a [kWh]*
- $EEF_{i,SE}$ = *emissions factor for the electricity used in source SE [tCO_2e kWh^{-1}]*
- SE = *electricity source type (grid, fossil fuel generator, etc)*
- i = *formula used for baseline (i=BL) as well as project scenario (i=PR)*

For EU_{BL}, mean annual emissions are calculated based on respective management records for 5 years prior to project start. If no adequate documentation can be provided, EU_{BL} shall be no more than 50% of EU_{PR}.

Other Agrochemical Emissions

Additional agrochemical emissions (*AE*) related to the project activities from increased use of agrochemicals, especially pesticides or non-N fertilizers need to be accounted for, unless the project owner can demonstrate that agrochemicals used in the project scenario are less than or do not differ significantly from agrochemicals used in the baseline, in which case $\Delta AE_{t\text{-}0}$ is considered 0.

If use of agrochemicals (herbicides, pesticides) or non-N fertilizer is significantly higher in the project than in the baseline scenario, the project owner shall calculate respective emissions by using specific amounts and emission factors. Emission factors applied shall be based on manufacturer information or scientific sources.

$$\Delta AE_{t-0} = \sum_{a=1}^{T}\left(AE_{PR,a} - AE_{BL}\right) \qquad (17)$$

Where:

$\Delta AE_{t\text{-}0}$	=	*additional emissions from project activity in the calculation period [tCO_2e]*
$AE_{PR,a}$	=	*other emissions under the project scenario in year a of the calculation period [tCO_2e]*
AE_{BL}	=	*other emissions (annual mean) under the baseline scenario [tCO_2e]*
T	=	*number of years in the calculation period [yr]*

AE_{PR} and AE_{BL} shall be documented for each emitter type (agrochemical) by the project owner and calculated with the equation below, based on emission type, underlying quantity and respective emission factor.

$$AE_{i,a} = \sum_{ET} AQ_{i,ET,a} \times AEF_{i,ET} \qquad (18)$$

Where:

$AE_{i,a}$	=	*emissions from use of other agrochemicals in year a [$tCO2e\ ha^{-1}$]*
$AQ_{i,ET,a}$	=	*quantity of agrochemicals for emitter type ET applied in year a [kg]*
$AEF_{i,ET}$	=	*emissions factor of the agrochemical used (for emitter type ET) [$tCO2e\ kg^{-1}$]*
ET	=	*emitter type (specific pesticide, fertilizer, or other agrochemical)*
i	=	*formula used for baseline (i=BL) as well as project scenario (i=PR)*

For AE_{BL}, mean annual emissions are calculated based on respective management records for 5 years prior to project start. If no adequate documentation can be provided, AE_{BL} shall be no more than 50% of AE_{PR}.

10. Leakage

Leakage is defined as an increase in GHG emissions outside the project area as a result of project activities. In the context of this methodology, leakage could occur in relation to shift of crop production to other lands to compensate for yield reductions or to emissions from increased C runoff.
Under this methodology's applicability conditions, projects are not allowed on wetlands, where C runoff could be an issue. Leakage from C runoff is thus considered 0.

And, as the project site is being actively maintained for commodity production during the project-crediting period, yield-related leakage risks are relatively small. Crop producers are commonly risk averse and are unlikely to intentionally suffer reduced crop yields. Moreover, under the Gold Standard 'Agriculture Requirements', projects shall not lead to a decrease in agricultural productivity, thus all projects shall be set up to maintain or increase yield. Accordingly, this methodology's applicability conditions do not allow yield reduction.

For initial project calculations, LK_{t-0} is thus considered equal 0.

Nevertheless, if a reduction in yield is detected in a performance certification, it is assumed that the lost production capacity will have to be made up for on land outside the project area. Emissions caused by such a shift have to be accounted for as leakage.

Equation 19 is applied to calculate the carbon losses resulting from a reduction in crop yield (*CY*) and activity shift to a non-project land (leakage area) in a specific calculation period. In order to avoid undue accounting for leakage after temporary yield increases (i.e. no additional losses compared to the baseline yield), reduction in crop yield is always calculated against the lowest yield in the project area since project start.

$$\mathrm{LK}_{t-0} = \frac{CY_{min} - CY_t}{CY_{BL}} \times A \times \left(\Delta \mathrm{BC}_{LA} + \Delta SOC_{LA,t-0} + \Delta FE_{LA,t-0} + \Delta FU_{LA,t-0}\right) \quad (19)$$

Where:

LK_{t-0}	=	*leakage of emissions due to project activity in the calculation period [tCO_2e]*
CY_t	=	*crop yield in the project area at time t (5 year average) [$kg\ ha^{-1}$]*
CY_{min}	=	*lowest crop yield in the project area in any calculation period since project start (5 year average) [$kg\ ha^{-1}$]*
CY_{BL}	=	*crop yield in the project area under the baseline scenario (5 year average) [$kg\ ha^{-1}$]*
A	=	*total eligible project area [ha]*
ΔBC_{LA}	=	*change in biomass carbon stocks in leakage area [$tCO_2e\ ha^{-1}$]*
$\Delta SOC_{LA,t-0}$	=	*change in soil organic carbon stocks in leakage area [$tCO_2e\ ha^{-1}$]*
$\Delta FE_{LA,t-0}$	=	*change in emissions from use of fertilizer in leakage area [$tCO_2e\ ha^{-1}$]*
$\Delta FU_{LA,t-0}$	=	*change in emissions from fuel use in leakage area [$tCO_2e\ ha^{-1}$]*

CY_t, CY_{min} and CY_{BL} are based on project owner's documentation. For each point in time, the previous five years' average is used as yield quantity. Note that for the first calculation period CY_{min} equals CY_{BL}.

ΔBC_{LA}, ΔSOC_{LA}, ΔFE_{LA}, ΔFU_{LA} are calculated as the difference between respective carbon stocks on the land to which the activity would most likely be shifted (i.e. the pre-shift vegetation cover and land use) and the long-term biomass carbon stock under the baseline cropping system.

For ΔBC_{LA} biomass carbon stocks according to IPCC (2006)[15] or applicable local literature values are compared to the respective stocks under the baseline cropping system. All other parameters are calculated according to the approaches described in this methodology, taking into account the situation in the leakage area (i.e. use of appropriate parameters for different soils or management practices).

[15] IPCC 2006 GL: Vol 4 AFOLU, table 4.7 (forests), table 4.8 (plantations), chapter 5.2.1 (cropland), chapter 6.2.1 (grassland).

11. Project Buffer

According to Gold Standard's Agriculture Requirements, a fixed percentage of the validated and verified CO_2 certificates shall be transferred into the Gold Standard 'Compliance Buffer'. The buffer is non-refundable, though the project owner may transfer CO_2 certificates from other Gold Standard certified projects to the Gold Standard 'Compliance Buffer' in lieu of the CO_2 certificates from the project.

12. Additionality

All Gold Standard projects are required to demonstrate that they would not have been implemented without the benefits of carbon certification. Specific rules and guidelines on how to assess additionality can be found in the 'Additionality' section of Gold Standard's 'Agriculture Requirements'.

13. Do-No-Harm

Please refer to the current version of the Gold Standard 'Agriculture Requirements' regarding 'Do-No-Harm' requirements. No additional requirements are defined in this methodology.

14. Sustainable Development

Please refer to the current version of the Gold Standard 'Agriculture Requirements' regarding 'Sustainable Development' requirements. No additional requirements are defined in this methodology.

15. Monitoring

Monitoring frequency and performance reviews
The project owner shall submit a monitoring report annually, containing at least the information listed in the Gold Standard 'Agriculture Requirements' and those labelled annually in the table on the next page.

At least every 5 years, the project owner shall undergo a performance review according to the Gold Standard 'Agriculture Requirements'.

Assessment of data and model applicability
At initial certification, the project owner shall document applicability of parameters and models used in Approach 2 or Approach 3 based on field assessments. For each stratum, a representative number of small temporary soil pits (area of 50 by 50 cm) shall be dug to a depth of 50 cm. The resulting soil profiles are assessed against the following criteria:

1) Soil type and soil depth: verify that the soil type and depth match data source's conditions.
2) Inorganic soil contents (rock, sand, clay etc.): verify that portion of inorganic soil contents, match the data source's conditions. Especially increased presence of rocks or rock aggregates may require conservative adaptation of literature data and models (reduction of active soil components, density corrections, etc.).
3) Organic matter: assess the presence of (pre-project) organic matter such as large diameter root residues (indicating e.g. previous woody crops or plantation use). If such residues are present, the project's pre-project soil carbon stock may be considerably higher than a C-depleted soil. The resulting reduction of potential SOC increase may require model adaptation or exclusion of areas from project.
4) Evidence for tillage history: assess soil structure for evidence of previous tillage intensity and depth. Soil structure (e.g. upper soil horizons, porosity/compaction, disturbance depth, etc.) shall be in line with historic tillage and literature source's practices.

The number of pits used for this assessment shall be adequate for the project situation and equally distributed across the project area. In heterogeneous areas , e.g. with highly varying soils, land use history (e.g. fragmented historic deforestation) and/or management activities, the number of samples will have to be large enough to represent the variation and confirm the stratification.

The soil pits shall remain open until after the project initial certification audit. The auditor shall assess the adequacy of the sampling and shall revisit a series of soil pits to verify the project owner's assessment.

The assessments described above are explicitly also required for projects claiming retrospective crediting. Despite the project activities having already taken place at initial certification, the above criteria will indicate applicability and adequacy of data/model choice.

Data and parameters collected for baseline calculation

Description	Parameter	Data unit	Recording frequency	Source of data
Total project area	A	ha	Project start	Project owner records
Area per stratum y	A_y	ha	Project start	Project owner records
Agrochemical quantity applied by emitter type for baseline activities	$AQ_{BL,ET,a}$	kg	Annually	Project owner records (5year pre-project average current)
Crop yield: harvested annual dry matter yield for each crop	CY_{BL}	kg/ha	Project start	Project owner records or county level data (for both approaches 5year pre-project average)
Soil organic carbon density at equilibrium per stratum y	$SOC_{BL,y}$	tC/ha	Project start	Project owner records (approach 1), from literature (approach 2) or modelled (approach 3)
Soil organic carbon reference density (under natural vegetation) at equilibrium per stratum y	$SOC_{REF,y}$	tC/ha	Project start	values from literature / local studies (approach 3 only)
land use factor in stratum y	$F_{LU,y}$	[dimensionless]	Project start	IPCC defaults or national / local studies (preferred)
tillage factor before project start in stratum y	$F_{MG,BL,y}$	[dimensionless]	Project start	IPCC defaults or national / local studies (preferred)
input factor before project start in stratum y	$F_{I,BL,y}$	[dimensionless]	Project start	IPCC defaults or national / local studies (preferred)
mean annual N fertilizer input under the baseline scenario	FE_{BL}	kg	Project start, if applicable	Project owner records (5year pre-project average)
Fossil fuel consumed recorded by vehicle and fuel type for baseline activities	$FUL_{BL,MT}$	litres	Project start, if applicable	Project owner records or modelling (5year pre-project average)
electricity consumed by source for baseline activities	$EUW_{BL,SE}$	kWh	Project start, if applicable	Project owner records (5year pre-project average)

Data and parameters monitored

Description	**Parameter**	**Data unit**	**Recording frequency**	**Source of data**
Total project area	*A*	ha	Annually	Project owner records
Area per stratum y	A_y	ha	Annually	Project owner records
Agrochemical quantity by emitter type applied in year a	$AQ_{PR,ET,a}$	kg	Annually	Project owner records (current)
Crop yield: harvested annual dry matter yield per crop	CY_t	kg/ha	Annually	Project owner records
Soil organic carbon density at equilibrium per stratum y	$SOC_{t,y}$	tC/ha	At each performance certification	Project owner records (approach 1), from literature (approach 2) or modelled (approach 3)
Soil organic carbon reference density (under natural vegetation) at equilibrium per stratum y	$SOC_{REF,y}$	tC/ha	Project start	Same as in baseline
land use factor in stratum y	$F_{LU,y}$	[dimensionless]	Project start	Same as in baseline
tillage factor before project start in stratum y	$F_{MG,PR,y}$	[dimensionless]	Annually	IPCC defaults or national / local studies (preferred)
input factor before project start in stratum y	$F_{I,PR,y}$	[dimensionless]	Annually	IPCC defaults or national / local studies (preferred)
N fertilizer input under the project scenario in year a	$FE_{PR,a}$	kg	Annually, if applicable	Project owner records (current)
Fossil fuel consumed recorded by vehicle and fuel type in year a	$FUL_{PR,MT,a}$	litres	Annually, if applicable	Project owner records (current)
electricity consumed by source in year a	$EUW_{PR,SE,a}$	kWh	Annually, if applicable	Project owner records (current)

In addition to the parameters listed above, the project owner shall collect and document evidence that the methodology's applicability conditions are met at all times, especially that

- measures are taken to prevent soil erosion,
- adequate input of organic crop residue, mulch, sod or other organic C source is applied to the project area fields.