Approved VCS Methodology
VM0017

Version 1.0
Sectoral Scope 14

Adoption of Sustainable Agricultural Land Management

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Section I: Summary and applicability of the baseline and monitoring methodology

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I.1 Brief description

This methodology proposes to estimate and monitor greenhouse gas emissions of project activities that reduce emissions in agriculture through adoption of sustainable land management practices (SALM) in the agricultural landscape. In this methodology, SALM is defined as any practice that increases the carbon stocks on the land. Examples of SALM are (but are not limited to) manure management, use of cover corps, and returning composted crop residuals to the field and the introduction of trees into the landscape. The methodology is applicable to areas where the soil organic carbon would remain constant or decrease in the absence of the project.

The methodology in its current form is applicable only for use of Roth-C model. The estimates of uncertainty and Activity Baseline and Monitoring Survey (ABMS[a]) in the current methodology are adapted for the Roth-C model only. Application of the methodology for use of other models will require at a minimum, revisions to estimates of uncertainty and ABMS specific to the model applied. If however, the parameters used by another model correspond to some or all parameters included in this methodology, then the methodology is applicable, provided applicability conditions of the methodology are met.

This methodology is based on the project “Western Kenya Smallholder Agriculture Carbon Finance project” in Kenya. The baseline study, monitoring and project document are being prepared by the Foundation Vi Planterar trad (“We plant trees”) with assistance from Unique Forestry Consultants ltd., the Swedish International Agency (Sida) and the International Bank for Reconstruction and Development as Trustee of the Biocarbon Fund.

I.2 Applicability conditions

This methodology is applicable to projects that introduce sustainable agriculture land management practices (SALM) into an agricultural landscape subject to the following conditions:

a) Land is either cropland or grassland at the start of the project;
b) The project does not occur on wetlands;
c) The land is degraded and will continue to be degraded or continue to degrade;
d) The area of land under cultivation in the region is constant or increasing in absence of the project;
e) Forest land, as defined by the national CDM forest definition, in the region is constant or decreasing over time;
f) There must be studies (for example: scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate that the use of the Roth-C model[1] is appropriate for: (a) the IPCC climatic regions of 2006 IPCC AFOLU

[1] For ROTH-C see http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm.

Guidelines[b,] or (b) the agroecological zone (AEZ) in which the project is situated, using one of options presented below:[2]

Option 1: The studies used in support of the project should meet the guidance on model applicability as outlined in IPCC AFOLU 2006 guidelines in order to show that the model is applicable for the relevant IPCC climatic region. The guidance notes that an appropriate model should be capable of representing the relevant management practices and that the model inputs (i.e., driving variables) are validated from country or region-specific locations that are representatives of the variability of climate, soil and management systems in the country.

Option 2: Where available, the use of national, regional or global[3] level agroecological zone (AEZ) classification is appropriate to show that the model has been validated for similar AEZs. It is recognized that national level AEZ classifications are not readily available; therefore this methodology allows the use of the global and regional AEZ classification[4].

Where a project area consists of multiple sites, it is recognized that studies demonstrating model validity using either Option 1 or Option 2 may not be available for each of the sites in the project area. In such cases the study used should be capable of demonstrating that the following two conditions are met:

(i) The model is validated for at least 50% of the total project area where the project area covers up to 50,000 ha[5]; or at least 75% of the total project area where project area covers greater than 50,000 ha; and

(ii) The area for which the model is validated generates at least two-thirds of the total project emission reductions.

Explanation / justification

Applicability conditions (a) - (d) allow for the simplification of the baseline. With these conditions we conservatively assume that the lands of a given land use type are degrading in absence of the project.

Specifically it is likely that:

a) if the land is cropland, then it will remain cropland in absence of the project; otherwise
b) the land is grasslands that will remain grassland or be converted to croplands in absence of the project.

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[2] The IPCC climatic regions are shown in Figure 3A.5.1 page 3.38.
[3] The agro-ecological zone (AEZ) methodology is standardized framework for the characterization of climate, soil and terrain conditions relevant to agricultural production. Crop modelling and environmental matching procedures are used to identify crop-specific limitations of prevailing climate, soil and terrain resources, under assumed levels of inputs and management conditions.
[4] The details of global agroecological zones classification outlined by Food and Agricultural Organization of United Nations (FAO), Rome, Italy and International Institute for Applied Systems Analysis, Laxenburg, Austria are available at: http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm
[5] The project area of 50,000 ha is reasonable taking into account the wide range of soil carbon sequestration rates, which depend on climate, soil and land use characteristics. The project area is also influenced by the rates of SALM adoption that are in turn influenced by factors such as farmer awareness to SALM, institutional support and extension systems. Assuming a conservative soil sequestration rate of 0.5 tC/ ha/ yr applied in CDM A/R methodologies, a project of 50, 000 ha is likely to generate 25,000 tC/ ha/yr, and is considered reasonable taking into account the implementation, monitoring and verification costs.

Degradation shall be demonstrated using the latest version of the CDM EB approved tool *Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities*.[c]

Applicability condition (e) ensures that, in absence of the project, the land would likely not have been:

a) abandoned and allowed to naturally regenerate to forest, or
b) afforested or reforested.

With these applicability conditions we can conservatively assume that the soil organic carbon would remain constant or decrease with time in absence of the project.

Finally, the methodology relies on modelled soil organic carbon. To assure that the model results are reasonable, there must be studies (for example; scientific journals, university theses, local research studies or work carried out by the project proponent) that demonstrate the use of the selected model is valid for the project region. This is fulfilled with applicability condition (f) in accordance with the VCS guidance included in Section 2.3 of the VCS Standard Version 3.1 on quantification of GHG emissions and/or removals related to the methodology.

I.3 Selected carbon pools and emission sources

Table 1: Selected carbon pools

Carbon pools	Selected (answer with Yes or No)	Explanation / justification
Above ground	Yes	A carbon pool covered by SALM practices. The increase in above ground biomass of woody perennials planted as part of the SALM practices is part of the methodology. The increase in above ground biomass of annual crops is not considered since in the IPCC accounting system, annual crops are ignored. The above ground biomass is calculated using the CDM A/R Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*[d] and *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on grasslands or croplands* AR-AMS0001[e]
Below ground	Yes	Below-ground biomass stock is expected to increase due to the implementation of the SALM activities. The increase in below ground biomass of woody perennials planted as part of the SALM practices is part of the methodology. The increase in below ground biomass of annual crops is not considered since in the IPCC accounting system, annual crops are ignored. The below ground biomass is calculated using the CDM A/R Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*[d] and *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on*

		grasslands or croplands AR-AMS0001[e]
Dead wood	No	None of the applicable SALM practices decrease dead wood. It can be conservatively ignored.
Litter	No	None of the applicable SALM practices decrease the amount of litter. It can be conservatively ignored.
Soil organic carbon	Yes	A major carbon pool covered by SALM practices.
Wood products	No	None of the applicable SALM practices decrease the amount of wood products. It can be conservatively ignored.

Table 2: Emissions sources included in or excluded from the project boundary

Sources	**Gas**	**Included/ excluded**	**Explanation / justification**
Use of fertilizers	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Main gas for this source. These are calculated using the CDM A/R Tool *Estimation of direct nitrous oxide emission from nitrogen fertilization (version 01)*[f]
Use of N-fixing species	CO_2	Excluded	Not applicable
	CH_4	Excluded	Not applicable
	N_2O	Included	Main gas for this source. These are calculated using the tool *Estimation of direct nitrous oxide emission from N-fixing species and crop residues* (Section VI.1)
Burning of biomass	CO_2	Excluded	However, carbon stock decreases due to burning are accounted as a carbon stock change
	CH_4	Included	Non-CO_2 emissions from the burning of biomass. These are calculated using the tool *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3)
	N_2O	Included	Non-CO_2 emissions from the burning of biomass. These are calculated using *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3)
Burning of fossil fuels	CO_2	Included	CO_2 and non-CO_2 emissions are calculated using the tool *Estimation of emissions from the use of fossil fuels in agricultural management*
	CH_4	Included	
	N_2O	Included	

I.4 Summary description of major baseline and project methodological steps

I.4.1 Baseline methodology

The baseline emissions and removals are estimated using the following steps:

1. Identify and delineate the project boundary;

2. Identify the baseline scenario and demonstrate additionality;
3. Estimate the annual emissions from the use of synthetic fertilizers;
4. Estimate the annual emissions from the use of N-fixing species;
5. Estimate the annual emissions from the burning of agricultural residues;
6. Estimate the annual removals from existing woody perennials;
7. Estimate the annual emissions from the use of fossil fuels for agricultural management; and
8. Estimate the equilibrium soil organic carbon in the baseline assuming no changes in agricultural management or agricultural inputs.

I.4.2 Project methodology

The project emissions and removals are estimated using the following steps:

1. Estimate the annual emissions from the use of synthetic fertilizers;
2. Estimate the annual emissions from the use of N-fixing species;
3. Estimate the annual emissions from the burning of agricultural residues;
4. Estimate the annual emissions and removals from woody perennials;
5. Estimate the annual emissions from the use of fossil fuels for agricultural management;

Using the model estimate the parameters in 6, 7 and 8 below:

6. Estimate the equilibrium soil organic carbon in the project based on estimated or measured changes in agricultural management or agricultural inputs;
7. Convert the equilibrium soil organic carbon in the project to transient soil organic carbon assuming a linear transition period;
8. Estimate the annual emissions and removals from soil organic carbon; and
9. Estimate leakage from the increase in the use of non-renewable biomass that occurs from the displacement of biomass used for energy to agricultural inputs.

I.4.3 Monitoring methodology

The following steps are required as part of the monitoring methodology:

1. Record the amount of fossil fuels used in the project;
2. Record the amount of synthetic fertilizers used in the project;
3. Estimate the amount of production of biomass by N-fixing species in the project;
4. Estimate the amount of agricultural residues burnt in the project;
5. Record the production from areas of various types of agricultural land management;
6. Measure the changes in biomass in woody perennials;
7. Estimate the reduction in the amount of biomass used for energy that is a result of the project.

The summary description of major baseline and project methodological steps noted above has been elaborated in the sections II, III and IV of the methodology.

Section II: Baseline methodology description

II.1 Project boundary

The "project boundary" geographically delineates all lands that are under the control of the project proponent for the proposed sustainable agricultural land management (SALM) activities[6].

The SALM project activities may contain more than one discrete area of land.

II.2 Procedure for selection of most plausible baseline scenario

The baseline scenario is identified as existing or historical land management practices. The project proponent shall use the most recent version of the *Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities*[g], *mutatis mutandis*.

II.3 Additionality

The project proponent shall use the most recent version of the *Combined tool to identify the baseline scenario and demonstrate the additionality in A/R CDM project activities, mutatis mutandis*.

II.4 Estimation of baseline GHG emissions and removals

II.4.1 Baseline emissions due to fertilizer use

The baseline emissions from synthetic fertilizer use, BEF_t, are calculated using the latest version of the CDM A/R Tool *Estimation of direct nitrous oxide emission from nitrogen fertilization*[f].

Emissions from manure application are not expected to change with the project, as the project activity does not result in a change in animal population. For this reason the baseline emissions from manure application can be ignored.

II.4.2 Baseline emissions due to the use of N-fixing species

The baseline emissions from the use of N-fixing species, BEN_t, are not calculated, but the project proponent shall record the area under N-fixing species prior to project implementation.

II.4.3 Baseline emissions due to burning of biomass

The baseline emissions due to burning of biomass, $BEBB_t$, are calculated using the tool *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3).

II.4.4 Baseline removals from existing woody perennials

The baseline removals from woody perennials, $BRWP_t$, are calculated using the latest version of the CDM A/R Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities*[d].

II.4.5 Baseline emissions from use of fossil fuels in agricultural management

The baseline emissions due to combustion of fossil fuels in agricultural management in baseline, $BEFF_t$, is calculated using the tool *Estimation of emissions from combustion the use of fossil fuels in agricultural management* (Section VI.2).

[6] In accordance with the VCS rules.

II.4.6 Equilibrium soil organic carbon density in management systems

Using an analytic model that has been accepted in scientific publications (for example: Roth-C soil organic carbon model[h]) estimate the soil organic carbon (SOC) density to a depth of 30 cm, at equilibrium in identified management practices on cropland and grassland. Soil carbon modelling should count only biomass inputs to soil from within the project boundary.

The SOC density should be estimated using area-weighted average values of model input parameters for each management practice identified in Step 4 under uncertainty analysis.

The baseline soil organic carbon at equilibrium can be estimated using:

$$BS_{equil,t} = \sum_{m_C} BA_{C,m_C,t} \bullet SOC_{C,m_C} + \sum_{m_G} BA_{G,m_G,t} \bullet SOC_{G,m_G} \qquad 1$$

Where:

$BS_{equil,t}$	Baseline SOC in equilibrium year t, tC
$BA_{C,m_C,t}$	Baseline areas in cropland with management practice, m_C, year t, ha
SOC_{C,m_C}	Soil organic carbon density at equilibrium for cropland with management practice, m_C, tC/ha
m_C	An index for cropland management types, unit less
$BA_{G,m_G,t}$	Baseline areas in grassland with management practice, m_G, year t, ha
SOC_{G,m_G}	Soil organic carbon density to a depth of 30 cm, at equilibrium for grassland with management practice, m_G, tC/ha
m_G	An index for grassland management types, unit less

II.4.7 Baseline removals due to changes in soil organic carbon

Since the applicability conditions limit the project to lands that are under agricultural pressure and are degrading, it can be conservatively assumed that the baseline removals due to changes in SOC are zero. Therefore

$$BRS_t = 0 \qquad 2$$

Where:

BRS_t	Baseline removals due to changes in soil organic carbon in year t, t CO_2e.

II.4.8 Total baseline emissions and removals

The total baseline emissions and removals are given by:

$$BE_t = BEF_t + BEFF_t + BEBB_t - BRWP_t \qquad 3$$

Where:

BE_t	Baseline emissions in year t, t CO_2e
BEF_t	Baseline emissions due to nitrogen fertilizer use in year t, t CO_2e.

$BEFF_t$	Baseline emissions due to use of fossil fuels in agricultural management in year t, t CO_2e.
$BEBB_t$	Baseline emissions due to biomass burning in year t, t CO_2e.
$BRWP_t$	Baseline removals due to changes in woody perennials in year t, t CO_2e.

Section III: Project methodology description

III.1 Estimation of project GHG emissions and removals

Where the sum of increase in greenhouse gas emissions from each of the identified emission sources in the methodology and leakage due to displacement of renewable biomass is insignificant these can be ignored[7].

III.1.1 Project emissions due to fertilizer use

The project emissions from synthetic fertilizer use, PEF_t, are calculated using the latest version of the CDM A/R Tool *Estimation of direct nitrous oxide emission from nitrogen fertilization (version 01)*[f.]

Emissions from manure application are not expected to change with the project, as the project activity does not result in a change in the animal population. For this reason the project emissions from manure application can be ignored.

III.1.2 Project emissions due to the use of N-fixing species

Only the emissions due to increased area under N-fixing species shall be accounted.

If the area cropped with N-fixing species in the project is more than 50% larger than the area under N-fixing species in the baseline then the project emissions from the use of N-fixing species, PEN_t, are calculated using the tool *Estimation of direct nitrous oxide emission from N-fixing species and crop residues* (Section VI.1).

In all other cases estimation of emissions from N-fixing species is not required.

This differentiation is based on the assumption that:

a) the project does not occur on wetlands;

b) the project occurs on degraded lands so that the lands are likely nitrogen deficient.

These assumptions mean that the nitrogen emissions tend to be smaller than estimated by the Tier 1 IPCC estimation methodology.

III.1.3 Project emissions due to burning of biomass

The project emissions due to burning of biomass, $PEBB_t$, are calculated using the tool *Estimation of non-CO2 emissions from the burning of crop residues* (Section VI.3).

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[7] Significance is defined so that the sum of increase in greenhouse gas emissions from the displacement of renewable biomass and each of emission sources identified in the methodology is less than 5% of the emission reductions by the project. The significance of the emission will be tested using the latest version of the CDM EB approved *Tool for testing significance of GHG emissions in A/R CDM project activities* (http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf

III.1.4 Project removals from woody perennials

The project removals from woody perennials, $PRWP_t$, are calculated using portions of CDM A/R *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on grasslands or croplands* AR-AMS0001e.

III.1.5 Project emissions due to use of fossil fuels for agricultural management

The project emissions due to the use of fossil fuels for agricultural management, $PEFF_t$, are calculated using the tool *Estimation of emissions from the use of fossil fuels in agricultural management* (Section VI.2)

III.1.6 Project equilibrium soil organic carbon density in management systems

Undertake an Activity Baseline and Monitoring Survey (ABMS) to identify the dominant agricultural management practices for croplands and grasslands. The ABMS should estimate or record details of each management practice. For example when using the Roth-C model, one should record;

1. its area;
2. the average annual biomass production from within the project boundary;
3. the average biomass left on site or input;
4. the average number and type of grazing animals;
5. the amount of manure input; and
6. the amount of nitrogen fertilizers input.

Using an analytic model that has been accepted in scientific publications and validated for the project region (for example: Roth-C soil organic carbon model[i]) estimate the soil organic carbon (SOC) density, to a depth of 30 cm, at equilibrium in each of the identified management practices in each of the land use categories (cropland and grassland). The soil carbon modelling should count only biomass inputs to soil from within the project boundary.

The details of each management practice that are recorded will depend on the choice of soil model selected and the type of activity being promoted. For example, if the activity is improving the use of crop residues then for use with the Roth-C model, the ABMS should record:

- Area of each crop (ha)
- Productivity of each crop (kg/ha)
- The amount of crop residues (kg/ha)[8]
- Existing crop residue management practices and their frequency
- Future crop residue management practices that will be implemented with the project

If the project activity includes improving the management of manure, then for use with the Roth-C model, the ABMS should also record:

- Area of grazing (ha)
- The number of livestock per animal type
- The amount of manure produced (kg/ha or kg/an)[9]
- Existing manure management practices and their frequency

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[8] Amount of crop residues need not be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines

[9] Amount of manure need not be measured directly. It can also be estimated from the number and type of animal using values from Table 10A-4 in Chapter 10 of the 2006 IPCC Guidelines.

- Future manure management practices that will be implemented with the project

If the project activity includes improved tillage practices, then for use with the Roth-C model, the ABMS should record:

- Area under tillage (ha)
- Type and depth of tillage
- Existing tilling practices and their frequency
- Future tilling practices that will be implemented with the project

If the project activity includes agroforestry, then, for use with the Roth-C model, the ABMS should record:

- Area of agroforestry (ha)
- Number and species of trees used
- Diameter at breast height (DBH) of trees
- Future numbers of trees that will be implemented with the project

The applicability of the selected model and parameters recorded for the various activities, and soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project description.

The SOC density should be estimated using area-weighted average values of model input parameters for each management practice identified.

The project soil organic carbon at equilibrium can be estimated using:

$$PS_{equil,t} = \sum_{m_C} PA_{C,m_C,t} \bullet SOC_{C,m_C,t} + \sum_{m_G} PA_{G,m_G,t} \bullet SOC_{G,m_G,t} \qquad 4$$

Where:

$PS_{equil,t}$	Project SOC in equilibrium year t, tC
$PA_{C,m_C,t}$	Project areas in cropland with management practice, m_C, year t, ha
$SOC_{C,m_C,t}$	Soil organic carbon density at equilibrium for cropland, to a depth of 30 cm, with management practice, m_C, at year *t*, tC/ha
m_C	An index for cropland management types, unit less
$PA_{G,m_G,t}$	Project areas in grassland with management practice, m_G, year t, ha
$SOC_{G,m_G,t}$	Soil organic carbon density at equilibrium, to a depth of 30 cm, for grassland with management practice, m_G, at year *t*, tC/ha
m_G	An index for grassland management types, unit less

III.1.7 Project estimate of soil organic carbon with transitions

The estimate of soil organic carbon with transitions can be estimated using:

$$PS_t = \frac{1}{D} \sum_{t-D+1}^{t} PS_{equil,t} \bullet \Delta t \qquad 5$$

Where:

PS_t	Estimate of the project SOC in year t, tC
$PS_{equil,t}$	Estimate of the project SOC in equilibrium year t, tC
D	The transition period required for SOC to be at equilibrium after a change in land use or management practice, year
Δt	Time increment = 1 year

For values of t-D+1 less than zero (the start of the project) assume that $PS_{equil,t} = BS_{equil,t=0}$.

These values are required if one is trying to estimate the absolute soil organic carbon in the baseline. Since the ultimate goal of the methodology is the increase or decrease in SOC with the project these values are not required since they appear in both the baseline and project estimation technique.

Value of D may be chosen from published data from local or regional studies or the modelling exercise. In absence of such data, the IPCC Tier 1 methodology default factor of 20 years may also be used.

III.1.8 Estimate of project removals due to changes in soil organic carbon

The estimate of project removals due to changes in soil organic carbon is given by:

$$PRS_t = (PS_t - PS_{t-1}) \bullet \frac{44}{12} \qquad 6$$

Where:

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PS_t	Estimate of the project SOC in year t, tC
PS_{t-1}	Estimate of the project SOC in year t-1, tC

III.1.9 Actual net GHG emissions and removals by sinks

The actual net GHG emissions and removals by sinks are given by:

$$PE_t = PEF_t + PEFF_t + PEN_t + PEBB_t - PRWP_t - PRS_t \qquad 7$$

Where:

PE_t	Estimate of actual net project GHG emissions and removals by sinks in year t, t CO_2e
PEF_t	Estimate of project emissions due to nitrogen fertilizer use in year t, t CO_2e.
$PEFF_t$	Estimate of project emissions due to burning of fossil fuels for agricultural management in year t, t CO_2e.
PEN_t	Estimate of project emissions due to the increase use of N-fixing species in year t, t CO_2e.
$PEBB_t$	Estimate of project emissions due to biomass burning in year t, t CO_2e.
$PRWP_t$	Estimate of project removals due to changes in biomass of woody perennials in year t, t CO_2e.

PRS_t Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

III.2 Estimation of leakage

The one potential source of leakage is an increase in the use of fuel wood and/or fossil fuels from non-renewable sources for cooking and heating purposes due to the decrease in the use of manure and/or residuals as an energy source.

Leakage due to the increase in the use of fuel wood from non-renewable sources for cooking and heating purposes may be a significant source of leakage if manure or other agricultural residuals used for cooking and heating are transferred to the fields as part of the project. In the project, this could be minimized by the introduction of woody perennials for fuel in the landscape and/or improvement of energy efficiency of biomass for cooking and heating. In situations of this form of leakage, the leakage from a switch to non-renewable biomass use, $LNRB_t$, is calculated in accordance with Section IV.2.6 (which is adapted from the small scale methodology AMS-I.E. *Switch from Non-Renewable Biomass for Thermal Applications by the User* [j].)

However, where this is significant, leakage due to switch to fossil fuels (LFF_t) shall be estimated in accordance with Equation 11 in Section IV.2.6.

Table 3: Emissions sources included in or excluded from leakage

Sources	**Gas**	**Included/ excluded**	**Justification / Explanation of choice**
Soil organic carbon stock changes	CO_2	Excluded	Applicability condition
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable
Increase fossil fuel for cooking	CO_2	Included	
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable
Increase non-renewable biomass for cooking	CO_2	Included	
	CH_4	Excluded	Not applicable
	N_2O	Excluded	Not applicable

III.3 Estimation of net anthropogenic GHG emissions and removals

The estimation of net anthropogenic GHG removal by sinks is made using:

$$\Delta R_t = BE_t - PE_t - LHE_t \quad (8)$$

Where:

ΔR_t Estimate of net anthropogenic GHG emissions and removals in year t, t CO_2e

PE_t Estimate of actual net project GHG emissions and removals in year t, t CO_2e

BE_t	Baseline emissions and removals in year t, t CO_2e
LHE_t	The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO_2e

Section IV: Monitoring methodology description

IV.1 Baseline GHG emissions and removals

IV.1.1 Sampling design

The project proponent shall use the CDM EB approved *General Guidelines For Sampling And Surveys For Small-Scale CDM Project Activities*[k] for sampling and survey design. At the start of the project, the project proponent shall undertake an Activity Baseline and Monitoring Survey (ABMS) to identify the dominant agricultural management practices for croplands and grasslands. The ABMS should estimate or record details of each management practice. For example when using the Roth-C model, one should record;

1. its area;
2. the annual biomass production from within the project boundary;
3. the annual biomass left on the fields;
4. the number and type of grazing animals;
5. the amount of manure input;
6. the amount of nitrogen fertilizers input;
7. the amount of N-fixing species;
8. the amount of biomass burnt; and
9. the existence and amount of woody perennials (trees and bushes).

The information recorded will depend on the choice of soil model selected and the type of activity being promoted. For example, if the project activity is improving the use of crop residues then for use with the Roth-C model, the ABMS should record in the baseline:

- Area of each crop (ha)
- Productivity of each crop (kg/ha)
- The amount of crop residues (kg/ha)[10]
- Existing crop residue management practices and their frequency
- Future crop residue management practices that will be implemented with the project

If the project activity includes improving the management of manure, then for use with the Roth-C model, the ABMS should record in the baseline:

- Area of grazing (ha)
- The number of livestock per animal type
- The amount of manure produced (kg/ha or kg/an)[11]

[10] Amount of crop residues need not be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines.
[11] Amount of manure need not be measured directly. It can also be estimated from the number and type of animal using values from Table 10A-4 in Chapter 10 of the 2006 IPCC Guidelines.

- Existing manure management practices and their frequency
- Future manure management practices that will be implemented with the project

If the project activity includes improved tillage practices, then for use with the Roth-C model, the ABMS should record in the baseline:

- Area under tillage (ha)
- Type and depth of tillage
- Existing tilling practices and their frequency
- Future tilling practices that will be implemented with the project

If the project activity includes agroforestry, then for use with the Roth-C model, the ABMS should record in the baseline:

- Area of agroforestry (ha)
- Number and species of trees used
- Diameter at breast height (DBH) of trees
- Future numbers of trees that will be implemented with the project

The applicability of the selected model and parameters recorded for the various activities, and soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project description.

Other model input parameters that may be required by the selected model, such as climatic data, clay content and texture of soils[l] can be acquired from global or national data sets and do not need to be measured by the project proponent. The project proponent may use climatic data collected by the meteorological station/s in proximity to the project area or use published data and determine the relevance of this data to the project in the following ways:

- The data being applied to the project has been obtained from one or more meteorological station/s whose meteorological coverage includes the project area.

- The data being applied to the project has been obtained from one or more meteorological station/s whose meteorological coverage can be shown to be applicable to the project area based on expert opinion.

- Where data from a meteorological station/s is not available, project entities may use published climatic data by demonstrating that such data is applicable to the project area, using expert opinion.

It is recommended that the project proponent stratifies by crop system, tillage system, use of crop residues, application of manure and clay content of soils and relevant climatic variables as a minimum.

IV.1.2 Data to be collected and archived for baseline GHG emissions and removals

Section	Data / Parameter	Unit	Description	Recording frequency	Source
II.4.1	$BSN_{t=0}$	kg	Synthetic fertilizer use	Project start	ABMS
II.4.2	$Crop_{i,t=0}$	kg d.m./ha	Harvested annual dry matter yield for crop *i*	Project start	ABMS
II.4.2	$Area_{i,t=0}$	ha	total annual area harvested of crop *i* or N-fixing trees *i*	Project start	ABMS
II.4.2	$Areaburnt_{i,t=0}$	ha	annual area of crop *i* or N-fixing trees *i* burnt	Project start	ABMS

II.4.3	$MB_{C,t=0}$	t d.m.	Mass of crop residues burnt	Project start	ABMS
II.4.3	$MB_{G,t=0}$	t d.m.	Mass of grasslands residues burnt	Project start	ABMS
II.4.3	C_F	unitless	Combustion factors that depend on vegetation type	Project start	National or regional studies
II.4.4	See A/R Methodological Tool *Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities* [d] for a complete list of data and parameters collected and archived.				
II.4.5	$FC_{j,t}$	Litres	Fossil fuel consumed in vehicle or equipment recorded by vehicle and fuel type	Project start	ABMS
II.4.6	$BA_{C,m_C,t=0}$	ha	Baseline areas in cropland with management practice, m_C	Project start	ABMS
II.4.6	$SOC_{C,m_C,t=0}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for cropland with management practice, m_C	Project start	Modelled
II.4.6	$BP_{C,m_C,t=0}$	t/ha/month	Baseline production in cropland per month with management practice from within the project , m_C	Project start	ABMS
II.4.6	$BR_{C,m_C,t=0}$	t/t prod/ month	Baseline fraction of production returned as residues per month (calculated from $BP_{C,m_C,t=0}$) in cropland with management practice, m_C	Project start	ABMS
II.4.6	$BM_{C,m_C,t=0}$	t/ha/month	Baseline manure input in cropland per month with management practice, m_C	Project start	ABMS
II.4.6	$BCC_{C,m_C,t=0}$		Baseline cover crop flag per month in cropland per month with management practice, m_C	Project start	ABMS
II.4.6	$BA_{G,m_G,t=0}$	ha	Baseline areas in grassland with management practice, m_G,	Project start	ABMS
II.4.6	$SOC_{G,m_G,t=0}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for grassland with management practice, m_G	Project start	Modelled

II.4.6	$BP_{G,m_G,t=0}$	t/ha/month	Baseline production in grassland per month with management practice from within the project, m_G	Project start	ABMS
II.4.6	$BR_{G,m_G,t=0}$	t/t prod/ month	Baseline fraction of production returned as residuals per month (calculated from $BP_{G,m_G,t=0}$) in grassland with management practice, m_G	Project start	ABMS
II.4.6	$BM_{G,m_G,t=0}$	t/ha/month	Baseline manure input in grassland per month with management practice, m_G	Project start	ABMS
II.4.6	$BCC_{G,m_G,t=0}$		Baseline cover crop flag per month in grassland per month with management practice, m_G	Project start	ABMS
II.4.6	$\overline{Temp}_m$	°C	Average temperature per month	Project start	Data relevant to the project* area
II.4.6	$\overline{Prec}_m$	mm	Average precipitation per month	Project start	Data relevant to the project*area
II.4.6	$\overline{Evap}_m$	mm/day	Average evapotranspiration per month	Project start	Data relevant to the project area*

*IV.2 *Ex-ante and ex-post net anthropogenic GHG emissions and removals*

IV.2.1 Data to be collected and archived for *ex-ante* project GHG emissions and removals

Record all assumptions and sources of assumptions.

IV.2.2 Data to be collected and archived for *ex-ante* leakage

The only source of leakage possible as a result of the project is the leakage from a switch to non-renewable biomass use or fossil fuels. Procedures to estimate leakage have been included ex-post; the ex-ante estimate of leakage is zero.

IV.2.3 Monitoring of project implementation

The project proponent should record when each farmer within the project area enters into agreement to adopt sustainable agricultural land management practices.

Each farmer should be given a unique ID. Their name, location of their lands, and date of entering into the agreement and leaving the agreement should be recorded.

IV.2.4 Sampling design

The project proponent shall use the CDM EB approved *General Guidelines For Sampling And Surveys For Small-Scale CDM Project Activities*[m] for sampling and survey design. They should undertake an Activity Baseline and Monitoring Survey (ABMS) on a regular basis (annually or bi-annually) to identify the actual agricultural management practices adopted on croplands and grasslands. The ABMS should estimate or record details of each management practice. For example when using the Roth-C model, one should record;

1. its area;
2. the annual biomass production;
3. the annual biomass left on the fields;
4. the number and type of grazing animals;
5. the amount of manure input;
6. the amount of nitrogen fertilizers input;
7. the amount of N-fixing species;
8. the amount of biomass burnt; and
9. the biomass of woody perennials (trees and bushes).

The following parameters need to be recorded annually.

1. Regional total biomass production;
2. Annual temperature, precipitation and evapotranspiration and
3. Fertilizer price.
4. The amount of fossil fuel used for agricultural management

The information recorded will depend on the choice of soil model selected and the type of activity being promoted. For example, if the activity is improving the use of crop residues then for use with the Roth-C model, the ABMS should record:

- Area of each crop (ha)
- Productivity of each crop (kg/ha)
- The amount of crop residues (kg/ha)[12]
- Existing crop residue management practices and their frequency
- Future crop residue management practices that will be implemented with the project

If the project activity includes improving the management of manure, then for use with the Roth-C model, the ABMS should record:

- Area of grazing (ha)
- The number of livestock per animal type
- The amount of manure produced (kg/ha or kg/an)[13]
- Existing manure management practices and their frequency
- Future manure management practices that will be implemented with the project

If the project activity includes improved tillage practices, then for use with the Roth-C model, the ABMS should record:

- Area under tillage (ha)
- Type and depth of tillage
- Existing tilling practices and their frequency
- Future tilling practices that will be implemented with the project

[12] Amount of crop residues need not be measured directly. It can also be estimated from the crop production using equations listed in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines.
[13] Amount of manure need not be measured directly. It can also be estimated from the number and type of animal using values from Table 10A-4 in Chapter 10 of the 2006 IPCC Guidelines.

If the project activity includes agroforestry, then for use with the Roth-C model, the ABMS should record:

- Area of agroforestry (ha)
- Number and species of trees used
- Diameter at breast height (DBH) of trees
- Future numbers of trees that will be implemented with the project

It is recommended that the project proponent stratifies the project area by crop system, tillage system, use of crop residues, application of manure and clay content of soils and relevant climatic variables as a minimum.

The applicability of the selected model and parameters recorded for the various activities, and soil and climate types are dependent on the actual project. Since these are project specific and not methodology specific, they should be discussed in detail in the project description.

Other model input parameters that may be required by the selected model, such as climatic data, clay content and texture of soils[1] can be acquired from global or national data sets and do not need to be measured by the project proponent.

IV.2.5 Data to be collected and archived for project GHG emissions and removals

Section	Data / Parameter	Unit	Description	Recording frequency	Source
III.1.1	PSN_t	kg/year	Synthetic fertilizer use per year	Annually	ABMS
III.1.1	$PA_{C,t}$	ha/year	Areas in cropland	Annually	ABMS
III.1.1	$PA_{G,t}$	ha/year	Areas in grassland	Annually	ABMS
III.1.1	PF_t	USD/kg	the price of inorganic fertilizer	Annually	National or regional studies
III.1.2	$Crop_{i,t}$	kg d.m./ha	Harvested annual dry matter yield for crop *i*	Annually	ABMS
III.1.2	$Area_{i,t}$	Ha/year	total annual area harvested of crop *i* or N-fixing trees *i*	Annually	ABMS
III.1.2	$Areaburnt_{i,t}$	Ha/year	annual area of crop *i* or N-fixing trees *i* burnt	Annually	ABMS
III.1.3	$MB_{C,t}$	t d.m./year	Mass of crop residues burnt	Annually	ABMS
III.1.3	$MB_{G,t}$	t d.m./year	Mass of grasslands residues burnt	Annually	ABMS
III.1.3	C_F	unitless	Combustion factors that depend on vegetation type	Project start	National or regional studies
III.1.4	See *Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on grasslands or croplands* AR-AMS0001e for a complete list of data and parameters collected and archived.				
III.1.5	$FC_{j,t}$	Litres	Fossil fuel consumed in	Annually	ABMS

			vehicle or equipment recorded by vehicle and fuel type		
III.1.6	$PA_{C,m_C,t}$	ha	Project areas in cropland with management practice, m_C	Annually	ABMS
III.1.6	$SOC_{C,m_C,t}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for cropland with management practice, m_C	Every five years	Modelled
III.1.6	$PP_{C,m_C,t}$	t/ha/month	Production in cropland per month with management practice from within the project, m_C	Annually	ABMS
III.1.6	$PR_{C,m_C,t}$	t/t prod/ month	Project fraction of production returned as residues per month (calculated from $PP_{C,m_C,t}$) in cropland with management practice, m_C	Annually	ABMS
III.1.6	$PM_{C,m_C,t}$	t/ha/month	Project manure input in cropland per month with management practice, m_C	Annually	ABMS
III.1.6	$PCC_{C,m_C,t}$		Project cover crop flag per month in cropland per month with management practice, m_C	Annually	ABMS
III.1.6	$PA_{G,m_G,t}$	ha	Project areas in grassland with management practice, m_G	Annually	ABMS
III.1.6	$SOC_{G,m_G,t}$	tC/ha	Soil organic carbon density, to a depth of 30 cm, at equilibrium for grassland with management practice, m_G	Every five years	Modelled
III.1.6	$PP_{G,m_G,t}$	t/ha/month	Production in grassland per month with management practice, from within the project, m_G	Annually	ABMS
III.1.6	$PR_{G,m_G,t}$	t/t prod/ month	Project fraction of production returned as residuals per month (calculated from $PP_{G,m_G,t}$) in grassland with management practice, m_G	Annually	ABMS

III.1.6	$PM_{G,m_G,t}$	t/ha/month	Project manure input in grassland per month with management practice, m_G	Annually	ABMS
III.1.6	$PCC_{G,m_G,t}$		Project cover crop flag per month in grassland per month with management practice, m_G	Annually	ABMS
III.1.6	$\overline{Temp}_m$	°C	Average temperature per month	Over the previous five years	Data relevant to the project area
III.1.6	$\overline{Prec}_m$	mm	Average precipitation per month	Over the previous five years	Data relevant to the project area
III.1.6	$\overline{Evap}_m$	mm/day	Average evapotranspiration per month	Over the previous five years	Data relevant to the project area
III.1.6	D	Years	Transition period	Every five years	National or regional studies

IV.2.6 Data to be collected and archived for leakage

The only source of leakage possible as a result of the project is the leakage from a switch to non-renewable biomass use attributable to the project. If the project plan includes the diversion of biomass used for cooking and heating to the fields (for example, manure or agricultural residuals) then the project proponent should estimate the possible leakage.

The project proponent should record the amount of biomass used for cooking and heating purposes that is diverted to the agricultural system. It is conservatively assumed that this is replaced by non-renewable biomass or locally used fossil fuels.

The ABMS survey is expected to provide information to assess whether or not non-renewable biomass from outside the project or fossil fuels are used for the purpose of cooking or heating by the surveyed project households to replace the biomass diverted to agricultural fields. If the ABMS survey data shows that 10% or fewer project households use non-renewable biomass from outside the project or fossil fuels to replace the biomass diverted to agricultural fields, then the leakage is considered insignificant and ignored.

In situations where ABMS survey data shows that more than 10% of the project households use non-renewable biomass from outside the project or fossil fuels to replace the biomass diverted to agricultural fields, then the leakage is considered significant and shall be estimated based on the household energy use information collected through the ABMS Survey to calculate the leakage.

$$LHE_t = LNRB_t + LFF_t \qquad 9$$

Where:

LHE_t	The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO2e
$LNRB_t$	Leakage from a switch to non-renewable biomass use in year t, , t CO_2e

LFF_t Leakage from switch to fossil fuel in year t , t CO_2e

$$LNRB_t = B_{biomass,t} * fNRB * NCV_{biomass} * EF_{fossil\ fuel} \qquad (10)$$

$LNRB_t$ Leakage from a switch to non-renewable biomass use in year t, t CO_2e

$B_{biomass,t}$ Quantity of biomass from outside the project that replaces biomass used for cooking/heating diverted to agricultural system in year t, tonnes

$fNRB$ Fraction of non-renewable biomass from outside the project in year t

$NCV_{biomass}$ Net calorific value of the non-renewable biomass from outside the project

$EF_{fossil\ fuel}$ Emission factor of fossil fuel as substitute for non-renewable biomass

$$LFF_t = B_{fossil\ fuel\ t} * NCV_{fossil\ fuel} * EF_{fossil\ fuel} \qquad (11)$$

$B_{fossilfuel,\ t}$ Quantity of fossil fuel that replaces the biomass used for cooking/heating diverted to agricultural system in year t, tonnes

$NCV_{fossil\ fuel}$ Net calorific value of the fossil fuel that is substituted

$EF_{fossil\ fuel}$ Emission factor of fossil fuel as a substitution for non-renewable biomass

Section	Data / Parameter	Unit	Description	Recording frequency	Source
III.2	$B_{biomass,t}$ $B_{fossilfuel,\ t}$	tonnes/ year	Quantity of biomass from outside the project or fossil fuel used in place of the amount of biomass used in cooking and heating diverted to the agricultural system in the project	Annually	ABMS

III.2	$f_{NRB,t}$	dimension less	Fraction of biomass that comes from non-renewable sources	Start of the project	If the data on $f_{NRB,t}$ is available, it is calculated as per the procedure of AMS I.E methodology. For situations, where the data on $f_{NRB,t}$ is not available $fNRB_{,t}$ =1 shall be used (i.e., $fNRB_{,t}$ value is fixed at 1), which is conservative.
III.2	$NCV_{biomass}$/ $NCV_{fossil\ fuel}$	TJ/ tonne	Net calorific value of the non-renewable biomass or fossil fuel substituted	Start of the project	IPCC defaults, National or regional studies
III.2	$EF_{fossilfuel}$	tCO2/ TJ	Emission factor for the projected fossil fuel consumption	Start of the project	Default value of 81.6 tCO2/TJ I as per AMS I.E

IV.2.7 Conservative approach

Since emissions reduced are calculated as the baseline emissions minus project emissions, an approach that:

1) ignores emissions in the baseline; and/or
2) ignores emission removals (sequestration) in the project

is conservative. Ignoring either of these two items will mean that emission reductions are underestimated.

The methodology uses a conservative approach because applicability conditions limit its use to:

a) Land is either cropland or grassland at the start of the project
b) The project does not occur on wetlands
c) The land is degraded and will continue to be degraded or continue to degrade
d) The area of land under cultivation is constant or increasing in absence of the project
e) Forest land, as defined by the national CDM forest definition, in the area is constant or decreasing over time

With these assumptions the methodology conservatively ignores emissions from SOC in the baseline.

The methodology uses a conservative approach because it assumes that leakage caused by the displacement of biomass used for cooking and heating purposes to the fields as the result of the project, causes an increase in the use of non-renewable biomass or fossil fuels.

IV.2.8 Uncertainty analysis

The project proponent shall use the CDM EB approved *General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities*[o] with a view to reducing uncertainty of model input parameters. The generation of model parameters follows the standard procedures on surveys and quality assurance in the collection and organization of data.

The project proponent will estimate the uncertainty of the agricultural input parameters to the soil organic model using the ABMS as required under Section 4.1 of VCS standard v3.1.

If the project area is stratified, the sampling effort should represent the relevant strata in the sample frame. Where there is no specific survey guidance from national institutions, the project proponent shall use a precision of 15% at the 95% confidence level as the criteria for reliability of sampling efforts. This reliability specification shall be applied to determine the sampling requirements for assessing parameter values. The sampling intensity could be increased to ensure that the model parameters estimated from the ABMS lead to the achievement of a desired precision of 15% at the 95% confidence level) for the estimate of greenhouse gas emission reductions from the project. The project proponent should calculate the soil model response using the model input parameters with the upper and lower confidence levels. The range of model responses demonstrates the uncertainty of the soil modelling.

Step 1: Calculate the values for all input parameters at the upper and lower confidence limit.

Calculate the mean, X_p and standard deviation, ∂_p for all parameters measured in ABMS, and then the standard error in the mean is given by:

$$SE_p = \frac{\partial_p}{\sqrt{n_p}} \qquad 12$$

Where:

SE_p	Standard error in the mean of parameter, *p* in year *t*
∂_p	The standard deviation of the parameter p in year t
n_p	Number of samples used to calculate the mean and standard deviation of parameter p

Assuming that values of the parameter are normally distributed about the mean, the minimum and maximum values for the parameters are given by.

$$P_{\min} = \overline{X_p} - 1.96 * SE_p$$
$$P_{\max} = \overline{X}_p + 1.96 * SE_p \qquad 13$$

Where:

$P_{\min}$	The minimum value of the parameter at the 95% confidence interval
$P_{\max}$	The maximum value of the parameter at the 95% confidence interval
SE_p	Standard error in the mean of parameter, *p* in year *t*
1.96	The value of the cumulative normal distribution at 95% confidence interval

Step 2: Calculate the project removals due to changes in soil organic carbon with the minimum and maximum values of the input parameters

The project removals due to changes in soil organic carbon using the minimum and maximum values of the parameters is given by

$$PRS_{\min,t} = Model(P_{\min}, Temperature_{\max}, \Pr ecipitation_{\max}, ClayContent_{\min})$$
$$PRS_{\max,t} = Model(P_{\max}, Temperature_{\min}, \Pr ecipitation_{\min}, ClayContent_{\max}) \quad 14$$

Where:

$PRS_{\min,t}$	The minimum value of project removals due to changes in soil organic carbon at the 95% confidence interval
$PRS_{\max,t}$	The maximum value of project removals due to changes in soil organic carbon at the 95% confidence interval

Step 3: Calculate the uncertainty in the model output

The uncertainty in the output model is given by:

$$UNC_t = \frac{\left| PRS_{\max,t} - PRS_{\min,t} \right|}{2 * PRS_t} \quad 15$$

Step 4: Adjust the estimate of soil sequestration based on the uncertainty in the model output

If the uncertainty of soil models is less than or equal to 15% of the mean value then the project proponent may use the estimated value without any deduction for conservativeness or increase in sampling.

If the uncertainty of soil models is greater than 15% but less than or equal to 30% of the mean value, then the project proponent may use the estimated value subject to a deduction calculated as

$$PRS_{Deduction,t} = PRS_t * (UNC_t - 15\%) \quad 16$$

And the following term will be used in equation 7 in place of PRS_t

$$PRS_{Adj,t} = PRS_t - PRS_{Deduction,t} \quad 17$$

Where:

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PRS_{Unc}	Estimate of uncertainty in the mean of changes in soil organic carbon in year t, t CO_2e.
$PRS_{Deduction,t}$	A calculated deduction to the estimate of the change in soil organic removals year t, t CO_2e.
$PRS_{Adj,t}$	An adjusted estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

In this way, when the uncertainty is 15% or less than 15% there is no deduction and when the uncertainty is between 15 and 30% a deduction as calculated in Step 4 above will apply.

If the uncertainty of soil models is greater than 30% of the mean value then the project proponent should increase the sample size of the input parameters until the soil model uncertainty is better than ± 30%.

IV.2.9 Other information

Every five years the means of parameters will be tested for significant difference using t-tests. If the means are significantly different then the soil model shall be updated based on the new data and relevant data such as studies conducted in the region. It is not incumbent that the project proponent shall undertake such studies as part of the project activity but shall make use of data generated elsewhere as part of ongoing research/other efforts in the region for updating the model. Such data can be used to refine the model over time and decrease uncertainty.

Section V: Lists of variables, acronyms and references

V.1 Variables used in equations

Equation 1

$BS_{equil,t}$	Baseline SOC in equilibrium year t, tC
$BA_{C,m_C,t}$	Baseline areas in cropland with management practice, m_C, year t, ha
SOC_{C,m_C}	Soil organic carbon density at equilibrium for cropland with management practice, m_C, tC/ha
m_C	An index for cropland management types, unit less
$BA_{G,m_G,t}$	Baseline areas in grassland with management practice, m_G, year t, ha
SOC_{G,m_G}	Soil organic carbon density at equilibrium for grassland with management practice, m_G, tC/ha
m_G	An index for grassland management types, unit less

Equation 2

BRS_t	Baseline removals due to changes in soil organic carbon in year t, t CO_2e.

Equation 3

BE_t	Baseline emissions in year t, t CO_2e
BEF_t	Baseline emissions due to nitrogen fertilizer use in year t, t CO_2e.
$BEFF_t$	Baseline emissions due to use of fossil fuels in agricultural management in year t, t CO_2e.
BEN_t	Baseline emissions due to the use of N-fixing species in year t, t CO_2e.
$BEBB_t$	Baseline emissions due to biomass burning in year t, t CO_2e.
$BRWP_t$	Baseline removals due to changes in woody perennials in year t, t CO_2e.

Equation 4

$PS_{equil,t}$	Project SOC in equilibrium year t, tC
$PA_{C,m_C,t}$	Project areas in cropland with management practice, m_C, year t, ha
$SOC_{C,m_C,t}$	Soil organic carbon density at equilibrium for cropland with management practice, m_C, at year *t*, tC/ha
m_C	An index for cropland management types, unit less
$PA_{G,m_G,t}$	Project areas in grassland with management practice, m_G, year t, ha
$SOC_{G,m_G,t}$	Soil organic carbon density at equilibrium for grassland with management practice, m_G, at year *t*, tC/ha
m_G	An index for grassland management types, unit less

Equation 5

PS_t	Project estimate of the project SOC in year t, tC
$PS_{equil,t}$	Project estimate of the project SOC in equilibrium year t, tC
D	The transition period required for SOC to be at equilibrium after a change in land use or management practice, year
Δt	Time increment = 1 year

Equation 6

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PS_t	Estimate of the project SOC in year t, tC

Equation 7

PE_t	Estimate of actual net GHG emissions and removals by sinks in year t, t CO_2e
PEF_t	Estimate of project emissions due to nitrogen fertilizer use in year t, t CO_2e.
$PEFF_t$	Estimate of project emissions due to burning of fossil fuels for agricultural management in year t, t CO_2e.
PEN_t	Estimate of project emissions due to the use of N-fixing species in year t, t CO_2e.
$PEBB_t$	Estimate of project emissions due to biomass burning in year t, t CO_2e.
$PRWP_t$	Estimate of project due to changes in biomass of woody perennials in year t, t CO_2e.
PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

Equation 8

ΔR_t	Estimate of net anthropogenic GHG emissions and removals in year t, t CO_2e
PE_t	Estimate of actual net GHG emissions and removals in year t, t CO_2e
BE_t	Baseline emissions and removals in year t, t CO_2e
LHE_t	The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO_2e

Equation 9

LHE_t	The leakage from a switch to non-renewable biomass or fossil fuel in place of the biomass used for cooking/heating diverted to agricultural system in year t, t CO2e
$LNRB_t$	Leakage from a switch to non-renewable biomass use in year t, , t CO_2e
LFF_t	Leakage from switch to fossil fuel in year t , t CO_2e

Equation 10

$LNRB_t$	Leakage from a switch to non-renewable biomass use in year t, t CO_2e
$B_{biomass,t}$	Quantity of biomass from outside the project used in place of the biomass used for cooking/heating diverted to agricultural system in year t, tonnes
$fNRB$	Fraction of non-renewable biomass from outside the project in year t
$NCV_{biomass}$	Net calorific value of the non-renewable biomass from outside the project
$EF_{fossil\ fuel}$	Emission factor of fossil fuel as substitute for non-renewable biomass

Equation 11

$B_{fossilfuel,t}$	Quantity of fossil fuel used in place of the biomass used for cooking/heating diverted to agricultural system in year t, tonnes
$NCV_{fossil\ fuel}$	Net calorific value of the fossil that is substituted
$EF_{fossil\ fuel}$	Emission factor of fossil fuel as a substitution for non-renewable biomass

Equation 12

SE_p	Standard error in the mean of parameter, *p* in year *t*
∂_p	The standard deviation of the parameter p in year t
n_p	Number of samples used to calculate the mean and standard deviation of parameter p

SE_p	Standard error in the mean of parameter, *p* in year *t*

Equation 13

$P_{\min}$	The minimum value of the parameter at the 95% confidence interval
$P_{\max}$	The maximum value of the parameter at the 95% confidence interval
SE_p	Standard error in the mean of parameter, *p* in year *t*
1.96	The value of the cumulative normal distribution at 95% confidence interval

Equation 14, 15

$PRS_{\min,t}$	The minimum value of project removals due to changes in soil organic carbon at the 95% confidence interval
$PRS_{\max,t}$	The maximum value of project removals due to changes in soil organic carbon at the 95% confidence interval

Equation 16, 17

PRS_t	Estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.
PRS_{Unc}	Estimate of uncertainty in the mean of changes in soil organic carbon in year t, t CO_2e.
$PRS_{Deduction,t}$	A calculated deduction to the estimate of the change in soil organic removals year t, t CO_2e.
$PRS_{Adj,t}$	An adjusted estimate of project removals due to changes in soil organic carbon in year t, t CO_2e.

V.2 Acronyms

A/R	Afforestation / reforestation
CDM	Clean Development Mechanism
ABMS	Activity Baseline and Monitoring Survey
SALM	sustainable agricultural land management
SOC	soil organic carbon

Section VI: Tools

VI.1 Estimation of direct nitrous oxide emission from N-fixing species and crop residues

This tool can be used for both ex ante and ex post estimation of the nitrous oxide emissions from the use of nitrogen fixing species and crop residues within the boundary of a VCS project. For *ex post* estimation purposes, activity data (quantities of crop residues) are monitored or estimated.

It is important to note that for the project emissions, it is only the new area under N-fixing crop that is input to the formulae.

As the project proponent may use various N-fixing species, it is important to identify and record the species type and estimate the amount of inputs from each species. The direct nitrous oxide emissions from the use of nitrogen-fixing species and crop residues can be estimated using equations as follows:

$$N_2O_{direct-N,t} = F_{CR,t} \cdot EF_1 \cdot MW_{N_2O} \cdot GWP_{N_2O} \cdot 10^{-3} \quad 18$$

$$F_{CR,t} = \sum_{i=1}^{I} Crop_{i,t} \cdot \left(Area_{i,t} - Areaburnt_{i,t} \cdot C_f\right) \cdot Frac_{Renew} \cdot \left[R_{AG,i,t} \cdot N_{AG,i,t} \cdot \left(1 - Frac_{Removed}\right) + R_{BG,i,t} \cdot N_{BG,i,t}\right] \quad 19$$

Where:

$N_2O_{direct-N,t}$	Direct N_2O emission as a result of nitrogen application within the project boundary, t-CO_2-e in year t
$F_{CR,t}$	Amount of N in crop residues (above and below ground), including N-fixing crops returned to soils annually, kg N yr^{-1} in year t
EF_1	Emission Factor for emissions from N inputs, tonne-N_2O-N (tonne-N input)$^{-1}$ As noted in IPCC 2006 Guidelines (table 11.1), the default emission factor (EF_1) is 1% of applied N, and this value should be used when country-specific factors are unavailable. The project proponent may use emission factors from the peer reviewed scientific literature that are specific for the project area.
MW_{N_2O}	Ratio of molecular weights of N_2O and N (44/28), tonne-N_2O (t-N)$^{-1}$
GWP_{N2O}	Global Warming Potential for N_2O, kg-CO_2-e (kg-N_2O)$^{-1}$ (IPCC default = 310, valid for the first commitment period).
$Crop_{i,t}$	Harvested annual dry matter yield for crop i in year t, kg d.m. ha^{-1} For N-fixing trees use the above ground biomass.
$Area_{i,t}$	total annual area harvested of N-fixing crop i or trees i in year t, ha yr^{-1}
$Areaburnt_{i,t}$	annual area of N-fixing crop i or trees burnt in year t, ha yr^{-1}
C_f	combustion factor (dimensionless) (see *2006 IPCC Guidelines*, Table 2.6)
$Frac_{Renew}$	fraction of total area under crop that is renewed annually. For countries where pastures are renewed on average every X years, $Frac_{Renew}$ = 1/X. For annual crops $Frac_{Renew}$ = 1. For N-fixing trees assume that they shed their

	leaves every year are similar to annual crops
$R_{AG,i,t}$	ratio of above-ground residues dry matter ($AG_{DM,i,t}$) to harvested yield for crop i in year t ($Crop_{i,t}$), kg d.m. (kg d.m.)$^{-1}$ (see *2006 IPCC Guidelines*, Table 11.2) For NB-fixing trees use the ratio of leaf biomass to above ground biomass. For deciduous trees 0.02 is a reasonable value
$N_{AG,i,t}$	N content of above-ground residues for crop i, kg N (kg d.m.) $^{-1}$ (see *2006 IPCC Guidelines*, Table 11.2) For N-fixing trees assume 0.027 (default value for N-fixing forages) This value should be used when country-specific factors are unavailable.
$Frac_{Removed}$	Fraction of above-ground residues of crop i removed annually for purposes such as feed, bedding and construction, kg N (kg crop-N)$^{-1}$. Survey of experts in country is required to obtain data. If data for $Frac_{Removed}$ are not available, assume no removal.
$R_{BG,i,t}$	Ratio of below-ground residues to harvested yield for crop i, kg d.m. (kg d.m.)$^{-1}$. (see *2006 IPCC Guidelines*, Table 11.2) For N-fixing trees assume 0.01 (assumes that fine roots are 7% of total root biomass, that total root biomass is 25% of above ground biomass and there is a 50% fine root turnover). This value should be used when country-specific factors are unavailable.
$N_{BG,i,t}$	N content of below-ground residues for crop i, kg N (kg d.m.)$^{-1}$. (see *2006 IPCC Guidelines*, Table 11.2) For N-fixing trees assume 0.022 (default value for N-fixing forages) This value should be used when country-specific factors are unavailable.

VI.2 Estimation of emissions from the use of fossil fuels in agricultural management

The following tool is derived from the A/R Methodological Tool *Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities*[n]. The CO_2 emissions are calculated using the following equations:

$$EFF_t = \sum_{j=1J} ET_{j,t} \quad (20)$$

Where:

EFF_t Emissions due to the use of fossil fuels in agricultural management, t CO_2e
Note: in the methodology there is a prefix B or P depending on whether they are baseline or project emissions

$ET_{j,t}$ Emission from fossil fuel combustion in vehicle/equipment type *j* during year *t*, t CO_2e/yr

j Type of vehicle/equipment

J Total number of types of vehicle/equipment used in the project activity

It is assumed that the amount of fuel combusted is available. The method may be used in estimating vehicle/equipment emission, when the vehicle/equipment is captive (i.e. controlled by the project proponent) and the entire fuel consumptions can be monitored. 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). The equation is as follows.

$$ET_{j,t} = FC_{j,t} \cdot EF_{CO2,j}$$

Where:

$ET_{j,t}$	Emission from fossil fuel combustion in vehicle/equipment type *j* during year *t*, t CO_2e/yr
$FC_{j,t}$	Consumption of fossil fuel in vehicle/equipment type *j* during year *t*, litres/yr
$EF_{CO2,j}$	Emission factor for the type of fossil fuel combusted in vehicle or equipment, *j*
	For gasoline EF_{CO2e} = 0.002810 t per litre. For diesel EF_{CO2e} = 0.002886 t per litre[14]
j	Type of vehicle/equipment
J	Total number of types of vehicle/equipment used in the project activity

VI.3 Estimation of non-CO_2 emissions from the burning of crop residues

The CO_2 emissions from the burning of crop residues and grasslands are not included in the methodology as per IPCC convention. The non-CO_2 emissions burning this biomass, EBB_t are calculated using the following equations:

$$EBB_t = \begin{bmatrix} MB_{C,t} \bullet C_F \bullet (2.7 \bullet GWP_{CH4} + 0.07 \bullet GWP_{N2O}) \\ + MB_{G,t} \bullet C_F \bullet (2.3 \bullet GWP_{CH4} + 0.21 \bullet GWP_{N2O}) \end{bmatrix} \bullet 10^{-3} \qquad 20$$

Where:

EBB_t	Emissions due to biomass burning in year t, t CO_2e
$MB_{C,t}$	Mass of crop residues burnt in year t, tonnes
2.7, 0.07	Emissions factors for the burning of cropland, g CH_4 / kg and g N_2O / kg, respectively From Table 2.5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories
$MB_{G,t}$	Mass of grasslands residues burnt in year t, tonnes
2.3, 0.21	Emissions factors for the burning of grassland, g CH_4 / kg and g N_2O / kg, respectively
	From Table 2.5, 2006 IPCC Guidelines for National Greenhouse Gas Inventories
GWP_{CH4}	Global warming potential of CH_4 (IPCC default: 21 for the first commitment period of the Kyoto Protocol); t CO_2e / t $_{CH4}$
C_F	Combustion factors that depend on vegetation type (see Table 4), unit less

[14] These values calculated from IPCC 2006 Table 3.3.1 assuming 2-stroke gasoline engine for gasoline combustion and default values for energy content of 47.1 GJ/t and 45.66 GJ/t for gasoline and diesel respectively (IEA. 2004. Energy Statistics Manual. http://www.iea.org/stats/docs/statistics_manual.pdf)

Table 4: Combustion factor values for fires in a range of vegetation types

Vegetation type	Subcategory	Mean Value
Savanna Grasslands/ Pastures (early dry season burns)	Tropical/sub-tropical grassland	0.74
	Grassland	-
All savanna grasslands (early dry season burns)		**0.74**
Savanna Grasslands/ Pastures (mid/late dry season burns)*	Tropical/sub-tropical grassland	0.92
	Tropical pasture~	0.35
	Savanna	0.86
All savanna grasslands (mid/late dry season burns)		**0.77**
Other vegetation types	Peatland	0.50
	Tropical Wetlands	0.70
Agricultural residues (Post harvest field burning)	Wheat residues	0.90
	Maize residues	0.80
	Rice residues	0.80
	Sugarcane	0.80

From Table 2.6, 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Section VII: References

[a] ABMS: Crop production and Activity baseline and Monitoring Survey Guideline for Sustainable Agricultural Land Management practices (SALM)

[b] IPCC. 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry, and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

[c] A/R methodological Tool "Tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities" (Version 01) EB 41, Annex 15. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-13-v1.pdf

[d] A/R Methodological Tool "Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities (Version 02.1.0) EB 60, Annex 13. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v2.1.0.pdf

[e] AR-AMS0001 "Simplified baseline and monitoring methodologies for small-scale A/R CDM project activities implemented on grasslands or croplands with limited displacement of pre-project activities (Version 6.0)". http://cdm.unfccc.int/methodologies/DB/91OLF4XK2MEDIRIWUQ22X3ZQAOPBWY

[f] A/R Methodological tool "Estimation of direct nitrous oxide emission from nitrogen fertilization" (Version 01) EB 33, Annex 16. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-07-v1.pdf

[g] A/R Methodological tool "Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities" (Version 01) EB 35, Annex 19. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-02-v1.pdf

[h] K Coleman & DS Jenkinson (2008) ROTHC-26.3 - a model for the turnover of carbon in soil. http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm

[i] K Coleman & DS Jenkinson (2008) ROTHC-26.3 - a model for the turnover of carbon in soil. http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm

[j]AMS-I.E.: Switch from Non-Renewable Biomass for Thermal Applications by the User (Version 4.0). http://cdm.unfccc.int/filestorage/M/I/6/MI6Z47XJAVRTKN3BWSQ1Y8FD2E9ULG/EB60_repan20_%20AMS-I.E_ver04.pdf?t=eG58bHdnOWkyfDDxWVo4h67XHCltxDQuoxY7

[k] General guidelines for sampling and surveys for small-scale CDM project activities (Version 1) EB 50, Annex 30. http://cdm.unfccc.int/EB/050/eb50_repan30.pdf

[l] FAO/IIASA/ISRIC/ISSCAS/JRC, 2009. Harmonized World Soil Database (version 1.1). FAO, Rome, Italy and IIASA, Laxenburg, Austria http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/index.html

[m] General guidelines for sampling and surveys for small-scale CDM project activities (Version 1) EB 50, Annex 30. http://cdm.unfccc.int/EB/050/eb50_repan30.pdf

[n] A/R Methodological Tool "Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities" (Version 01) EB 33 Annex 14. http://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-05-v1.pdf