

# Guidance for the estimation of project removals due to changes in soil organic carbon with the RothC model

## 1 Introduction

The SALM methodology<sup>1</sup> can be used to monitor and measure the GHG benefits of a range of project activities that increase carbon stocks in the agricultural landscape, in particular soil organic carbon (SOC) which is a major pool affected by climate smart agricultural practices.

The SALM methodology proposes to use a modeling approach by parameterizing a soil carbon model with existing datasets and to run the model with input values derived from the farm survey ABMS. The model proposed is the RothC carbon model. This model calculates the SOC stock changes due to changes of inputs of crop residues and manure in the soil. The increase or decrease of SOC is the result of the decomposition of the added organic materials.

The present version of the RothC model is a simplified version of the model developed by the Australian Greenhouse Office (2002) on the basis of the RothC-26.3 program<sup>2</sup>. It was modified by Joanneum Research and Unique forestry and land use for the BioCarbon Fund in the frame of the Kenya Agricultural Carbon Project (KACP). The model was enhanced with comments and automatic operations for the estimation in a simple manner of project removals due to changes in SOC according to the SALM methodology. This version can be used with Excel 2007 and 2010.

This guidance aims at supporting project developers using the SALM methodology in the estimation of project removals due to changes in SOC with the RothC model. It provides a step by step description based on the experiences of the KACP.

## 2 General guidance

Automatic operations require the use of macro. Usually a warning message appears on the top of the Excel file when opening it. The user should just click on *Options* and allow the use of macros.

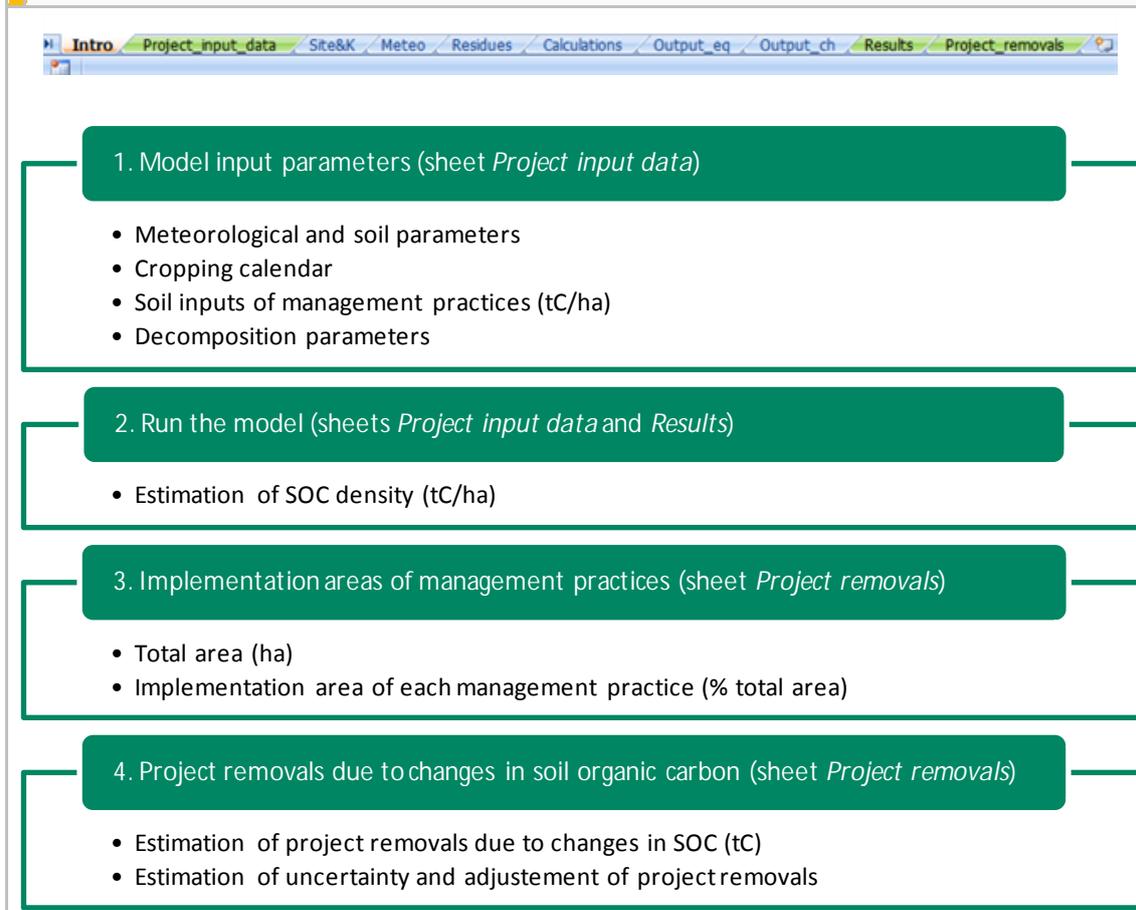
For the correct use of the model only yellow cells should be modified. The other cells are necessary for or resulting from automatic calculations and modifying them would lead to erroneous estimations. The user should pay special attention at the units for each parameter and the comments with additional guidance added in the model. The steps shown in the figure below and described in this document should be followed.

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<sup>1</sup> The SALM Methodology VM0017 Adoption of Sustainable Agricultural Land Management is the first ALM methodology approved for use under the Verified Carbon Standard. It was developed by the World Bank BioCarbon Fund based on the Kenya Agricultural Carbon Project implemented by Vi Agroforestry Programme. <http://v-c-s.org/sites/v-c-s.org/files/VM0017%20SALM%20Methodolgy%20v1.0.pdf>

<sup>2</sup> Coleman, K. and Jenkinson, D.S. (2007) RothC-26.3 – A model for the turnover of carbon in soil, Model description of user guide. [http://www.rothamsted.bbsrc.ac.uk/aen/carbon/mod26\\_3\\_dos.pdf](http://www.rothamsted.bbsrc.ac.uk/aen/carbon/mod26_3_dos.pdf)

Figure 1: Steps for the use of the RothC model



### 3 Model input parameters

#### 3.1 Data entry

The RothC model has several sheets where parameters and soil inputs need to be entered. In order to simplify data entry in this version of the model all necessary parameters are entered by the user in the sheet *Project input data*. Later when the model runs each parameter is automatically entered in the corresponding sheet and cell.

As indicated in the SALM methodology three types of input values are required for meteorological and soil parameters and for soil inputs of management practices:

- Area-weighted average values for the estimation of SOC density. These are referred as *Mean* in the RothC model.
- Values at the upper and lower confidence limit (see equations 12 and 13 of the SALM methodology) for the estimation of uncertainty in the model output and the subsequent adjustment of the resulting project removals due to changes in SOC. These values are referred as *Pmax* and *Pmin* in the RothC model.

## 3.2 Meteorological and soil parameters

Meteorological and soil parameters are necessary to parameterize the RothC model according to local conditions. The following information is required:

- The latitude corresponding to the project location in decimal degrees.
- Meteorological parameters<sup>3</sup> including:
  - Minimum temperature in °C for each month in the baseline and project scenario.
  - Maximum temperature in °C for each month in the baseline and project scenario.
  - Precipitation in mm for each month in the baseline and project scenario.
- Clay content<sup>4</sup> as % in the baseline and project scenario.

All yellow cells need to be filled in.

## 3.3 Cropping calendar

The cropping calendar defines when soil inputs from management practices happen. The following information is required:

- The month when the cropping year starts. Cropping years do not necessarily correspond to natural years and cropping seasons may expand over two different natural years.
- The existence or not of a second cropping season. If no information is given the model considers a single season as default.
- The month when each season starts (planting) and ends (harvesting). These are the months when soil inputs from management practices happen. The information for the second season is only required in case a second season is actually considered.

The duration of the complete cropping year should never exceed one year. Before running the model check the calendar and make sure all the information is correct.

## 3.4 Soil inputs of management practices

Soil inputs define the amount of material applied to the soil for each management practice. The current version of the model can be used for three different management practices:

- Residues management such as mulching or cover crops. Up to 3 different crops per season and per scenario can be modeled.
- Input from manure or composted manure.

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<sup>3</sup> Meteorological data can be derived from local weather stations or from online databases, such as the Climate Information Portal (<http://cip.csag.uct.ac.za/webclient/map>) or the website of the National Oceanic and Atmospheric Administration (NOAA) (<http://www.climate.gov/#dataServices>).

<sup>4</sup> Data on the soil type and its clay content can be derived from local soil information or from online databases such as the Harmonized World Soil Database (<http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/>)

- Residues from agroforestry.

Only the information for relevant management practices needs to be filled in. For example, in case no manure management is done during the first cropping season in the project scenario, the cells H101:K101 should be left empty or indicated as 0.

For each considered management practice the following information is required:

- Input values in tC/ha.
- Whether soil input happens at the start or at the end of the cropping season. If no information is given the model considers as default the end of the season for residues management and the start of the season for manure and agroforestry.

#### Estimation of input values from residues management

The calculation of residues inputs from crops is based on yield data collected from farms in the ABMS. The harvest fresh yield in tons per ha is converted to amount of residues produced in tons dry matter per ha on the basis of the equations reported in Table 11.2 in Volume 4 of the 2006 IPCC Guidelines<sup>5</sup>. The amount of aboveground residues is equal to:

$$R = a * b * Y + c$$

Where:

- R Aboveground residues in tdm/ha
- Y Harvest fresh yield for each crop in tfm/ha. Since farmers normally report their crop yields in local units such as bags or tins, these units need to be converted into standard kg units. The local units are usually regional or country specific.
- a Dry matter fraction of harvest product
- b Slope of the equation
- c Intercept of the equation

The amount of carbon of crop residues is finally calculated by multiplying the amount of aboveground residues (R) with a default carbon fraction. The IPCC default value of 0.4 can be used (see Example 1 at the end of the document).

#### Estimation of input values from manure

The calculation of manure inputs is based on information on the amount and types of livestock animals in each farm collected in ABMS. The factors from Tables 10A-4 to 10A-9 in Volume 4 of the 2006 IPCC Guidelines<sup>6</sup> are used to calculate the amount of manure produced by animal type (see Example 2 at the end of the document).

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<sup>5</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_11\\_Ch11\\_N2O&CO2.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf)

<sup>6</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_10\\_Ch10\\_Livestock.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf)

## Estimation of input values from composted manure

The estimation of composted manure available at each farm is based on several assumptions about the composting of manure and residues which need to be surveyed on a farm level (see Example 2 at the end of the document).

### 3.5 Decomposition parameters

Decomposition parameters determine how materials applied to the soil decompose. This will have a direct impact on the amount of soil organic carbon density resulting from soil inputs.

The following information is required in this version of the RothC model:

- DPM / RPM for crops
- DPM / RPM for agroforestry

As this information is not easily available some usual values are indicated and can be used:

- 1.44 for most agricultural crops and improved grassland
- 0.67 for unimproved grassland and scrub (including Savanna)
- 0.25 for deciduous and tropical woodland

All yellow cells need to be filled in.

## 4 Run the model

By clicking on the button the RothC model runs automatically using model input parameters entered by the user as described in the section above. The model runs for all soil input values (each value corresponding to a specific management practice, cropping season and scenario) using the following combination of parameters:

- *Mean* values of soil inputs with *Mean* values of meteorological data and clay content for the estimation of SOC density.
- *Pmin* values of soil inputs with *Pmax* values of meteorological data and *Pmin* values of clay content for the estimation of the minimum SOC density at the 95 % confidence interval (see equation 14 of the methodology).
- *Pmax* values of soil inputs with *Pmin* values of meteorological data and *Pmax* values of clay content for the estimation of the maximum SOC density at the 95 % confidence interval (see equation 14 of the methodology).

The resulting SOC density over 20 years is recorded for each case in the sheet *Results*. As indicated in the SALM methodology 20 years is considered as the period required for SOC to be at equilibrium after a change in management practice.

Every time model input parameters are modified the model should run in order to update the results.

## 5 Implementation areas of management practices

Implementation areas of management practices are the areas where soil inputs happen. The following information is required:

- Total area in ha
- Implementation areas of each considered management practice as % of total area

Only the information for relevant management practices needs to be filled in.

## 6 Project removals due to changes in soil organic carbon

Project removals due changes in SOC ( $PRS_t$ ) are estimated using the following equation:

$$PRS_t = \frac{1}{20} * (PS_{equil,t} - PS_{equil,t-20}) * \frac{44}{12}$$

This equation is the result of combining equations 5 and 6 of the SALM methodology. For the first 20 years of the project it is equivalent to the following equation that was applied in the RothC model:

$$PRS_t = \frac{1}{20} * (PS_{equil,t} - BS_{equil,0}) * \frac{44}{12}$$

The SOC density values obtained from the RothC model are multiplied by the corresponding implementation areas (implementation area in % \* total area in ha) to estimate  $PS_{equil,t}$  and  $BS_{equil,0}$  according to equations 1 and 4 of the methodology. The RothC model shows directly the  $PRS_t$  value resulting from the equation above. Results are presented for each cropping season and for the cropping year.

The same estimation is done using SOC density values obtained with  $P_{min}$  and  $P_{max}$  input values in order to estimate  $PRS_{min,t}$  and  $PRS_{max,t}$  and calculate uncertainty according to equation 15 of the methodology.  $PRS_t$  is then adjusted according to uncertainty:

- In case uncertainty  $\leq 15\%$  no adjustment is done.
- In case uncertainty  $> 15\%$  and  $\leq 30\%$  the value is adjusted according to equations 16 and 17 of the methodology.
- In case uncertainty  $> 30\%$  the user will get an error message.

### Example 1

Calculate the amount of carbon from residue biomass input to the field in the case of a farmer in Kenya who has a farm with 2 ha of cropland and 2013 produced 44 bags of maize in 2013.

1. What is the yield of maize per ha produced by the farmer?

A bag of maize in Kenya is equal to 90 kg then  $44 \times 90 = 3,960 \text{ kg} = 3.96 \text{ tfm}$ . The yield per ha is  $3.96 / 2 = 1.98 \text{ tfm/ha}$ .

2. How much is the dry weight of this yield?

According to Table 11.2 factor a for maize is 0.87 then  $1.98 \times 0.87 = 1.72 \text{ tdm/ha}$ .

3. What is the aboveground residue dry matter in tons per ha?

According to Table 11.2 factor b is 1.03 and factor c is 0.61 for maize then  $R = 1.72 \times 1.03 + 0.61 = 2.38 \text{ tdm/ha}$ .

4. What is the aboveground residue dry matter in tons carbon per ha?

By using IPCC default value of 0.4 the aboveground residue is  $2.38 \times 0.4 = 0.95 \text{ tC/ha}$ .

### Example 2

A farmer has 5 cows on 0.89 hectare of cropland. He is composting the manure and applying the composted manure to the cropland. The following assumptions are made for the farm:

- All the manure produced in the farm is collected during 3 months
- Fresh residues are added to the manure in a dry matter ratio of 3 manure : 2 residues
- The carbon fraction of manure is 0.4 and of residues is 0.47
- The mixed materials decompose during 2 months
- The amount of composted manure after the maturation period (decomposition) is estimated based on an equation obtained in a study on smallholder crop – livestock systems developed in Kenya<sup>7</sup>

$$Y_t = Y_0 + \text{EXP}(-2.22 * t^{0.53})$$

where:

$Y_t$  Composted manure resulting after t years (tC)

$Y_0$  Initial amount of manure + residues (tC)

t Composting period (years)

1. How much is the total dry matter from manure in the farm per day?

The manure produced per day by a cow in Africa is 1.9 kg dm according to Table 10A-4. Then 5 cows produce  $5 \times 1.9 = 9.5 \text{ kg} = 0.0095 \text{ tdm/day}$ .

2. Based on the assumptions above the farmer collects manure for 90 days for each application on the farm. How much manure is collected for each application?

$0.0095 \times 90 = 0.855 \text{ tdm}$  of manure are collected for each application.

3. The compost ratio of manure/plant residues is 3:2. How much residue input is needed for each application?

$0.855 \times 2 / 3 = 0.57 \text{ tdm}$  of residues are added to the manure for each application.

4. How much carbon content is in this composting pile?

<sup>7</sup> Tittonell, P., Rufino, M.C., Janssen, B.H. and Giller, K.E. (2010) Carbon and nutrient losses during manure storage under traditional and improved practices in smallholder crop-livestock systems – evidence from Kenya. *Plant Soil* 328: 253-269

Using carbon fractions  $0.855 \times 0.4 + 0.57 \times 0.47 = 0.6099$  tC enters the composting pile.

5. After two months (= 0.17 year) of ongoing decomposition, how much composted carbon input is available for each application?

Using the decomposition equation  $0.6099 + \text{EXP}(-2.22 * 0.17^{0.53}) = 1.03$  tC of composted manure for each application

6. How much is total composted manure input per hectare?

$1.03 / 0.89 = 1.16$  tC/ha of composted manure for each application.