

{mocaredd}

Monte Carlo Simulations for REDD+ uncertainty analysis

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Lead partners



GFOI is a flagship of the  GROUP ON EARTH OBSERVATIONS

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Content

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 - Uncertainty requirements for REDD+ emissions and removals
- Current **challenges** for uncertainty reporting
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- Demo of the {mocaredd}



Context

Uncertainty requirements for REDD+ emissions and removals



IPCC Guidelines / High integrity standards

- IPCC offers uncertainty propagation formulas (approach 1)

EQUATION 3.1 (UPDATED)

COMBINING UNCERTAINTIES – APPROACH 1 – MULTIPLICATION

$$U_{total} = \sqrt{U_1^2 + \dots U_i^2 + \dots + U_n^2}$$

EQUATION 3.2 (UPDATED)

COMBINING UNCERTAINTIES – APPROACH 1 – ADDITION AND SUBTRACTION

$$U_{total} = \frac{\sqrt{(U_1 \bullet x_1)^2 + \dots + (U_i \bullet x_i)^2 + \dots + (U_n \bullet x_n)^2}}{|x_1 + \dots + x_i + \dots + x_n|}$$

"Approach 1 has limitations to the consideration of correlation as it only allows for full correlation or independency between the variables."

IPCC Guidelines / High integrity standards

- IPCC recommends Monte Carlo simulations

The Monte Carlo analysis is suitable for detailed category-by-category assessment of uncertainty, particularly where uncertainties are large, distribution is non-normal, the algorithms are complex functions and/or there are correlations between some of the activity sets, emissions factors, or both.

- Carbon fund requests simulations (Monte Carlo or bootstrap) and a sensitivity analysis

Criterion 9 of the FCPF Methodological Framework requires that the uncertainty of the estimate of Emission Reductions be quantified using Monte Carlo methods. The FCPF Guidelines on Uncertainty Analysis of Emission Reductions describe which sources of uncertainty to propagate and provide guidance for conducting Monte Carlo simulations.

([FCPF guidance note on MC based uncertainty](#))

IPCC Guidelines / High integrity standards

- ART/TREES requires Monte carlo simulations

Uncertainty shall be assessed on both activity data and emission factors. Errors shall be propagated between sources using Approach 2 (Monte Carlo simulation). Monte Carlo simulations shall use the 90% confidence interval and a simulation n of 10,000. The bootstrapping method may be used where the probability density function is unknown. The simulations will form the basis for estimations both of value and uncertainty at each step, as the simulated sum of components will be more accurate than an arithmetic approach. Thus, simulated values should replace arithmetic values in Section 10.²⁰

([TREES V2.0](#))

Challenges

For reporting simulation-based uncertainties



Spreadsheet workbooks

Often favored because capacities are in place both in countries and with reviewers, but:

- **Very hard to understand** and follow for anybody but their developers,
- Computation times are **slow** (esp. with sensitivity analysis),
- **Randomization** poorly handled,
- **License** barrier (MS Excel, ...),
- High chances of **mistakes**,
- **Carbon accounting calculation chain not obvious**

Proposed solution

Combining spreadsheet with statistical language



Combining spreadsheets with programming

- Spreadsheet for templating (but organized)
 - Split the data into
 - Customization options
 - Time periods
 - Land use change areas
 - Carbon elements
- Processing with R
 - Statistical libraries (truncated normal distributions)
 - Free and Open source
 - Local or cloud-based processing (no coding skill required)

In action

{mocaredd} template and tool in action



Screenshot - Template in action

Time periods

period_no	year_start	year_end	period_type
T1	2005	2014	REF
T2	2019	2019	MON1
T3	2020	2020	MON2
T4	2021	2021	MON2

One year
period



2nd monitoring period
regroups 2 time periods



Screenshot - Template in action

Activity data require time period, initial and final land use, area and their standard error for each land use change.

trans_period	lu_initial_id	lu_final_id	trans_area	trans_se	trans_pdf
T1	open	postdef_open	4,994.00	627.62	normal
T1	ev_wet_closed	postdef_ev_wet_closed	319	168.82	normal
T1	ev_moist_closed	postdef_ev_moist_closed	1,814.00	422.8	normal
T1	md_moist_closed_se	postdef_md_moist_closed_se	1,131.00	302	normal
T1	md_moist_closed_nw	postdef_md_moist_closed_nw	1,230.00	279.14	normal
T1	ev_upland	postdef_ev_upland	168	52.42	normal
T2	open	postdef_open	2020	1165.9	normal
T2	ev_wet_closed	postdef_ev_wet_closed	0	0	normal
T2	ev_moist_closed	postdef_ev_moist_closed	0	0	normal
T2	md_moist_closed_se	postdef_md_moist_closed_se	0	0	normal
T2	md_moist_closed_nw	postdef_md_moist_closed_nw	650	650.05	normal
T2	ev_upland	postdef_ev_upland	0	0	normal

Screenshot - Template in action

Carbon elements require the carbon element, time period, land use, value and standard deviation for all carbon pools and/or carbon fraction and/or degradation ratios.

c_period	c_element	c_lu_id	c_value	c_se	c_pdf
ALL	AGB	open	28.72	5.62	normal
ALL	AGB	ev_wet_closed	85.34	45.6	normal
ALL	AGB	ev_moist_closed	212.99	43.58	normal
ALL	AGB	md_moist_closed_se	105.48	37.05	normal
ALL	AGB	md_moist_closed_nw	79.71	11.55	normal
ALL	AGB	ev_upland	78.33	14.56	normal
ALL	BGB	open	10.89	1.94	normal
ALL	BGB	ev_wet_closed	11.03	5.24	normal
ALL	BGB	ev_moist_closed	28.12	5.84	normal
ALL	BGB	md_moist_closed_se	27.14	3.8	normal
ALL	BGB	md_moist_closed_nw	19.94	2.24	normal
ALL	BGB	ev_upland	25.29	2.47	normal

Screenshots - Loading data and checks

Basic info cards

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① Upload your data

{mocaredd} only accepts XLSX files that follow a specific template. Download the template here if you haven't converted your data yet.

Download the template

Once your data has converted to the app's template, you can upload your data here:

Browse... example1-4pools.xlsx

Upload complete

Data uploaded with correct tabs.

Run checks

② Create Monte Carlo Simulations

All checks passed.

Run simulations

③ Perform sensitivity analysis

Load template

Time periods

4 reporting periods

1 for reference
3 for monitoring

Land use transitions

48 land use transitions

6 land use categories
2 REDD+ activities: DF, DG

Carbon stock

4 Carbon pools

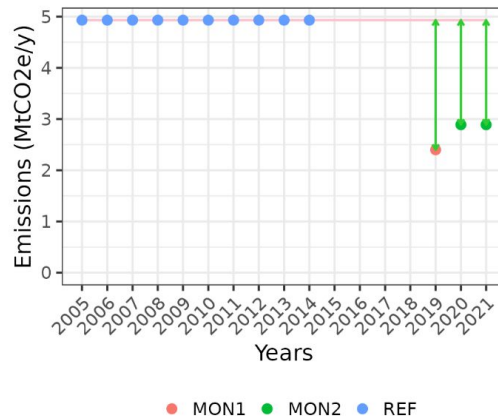
AGB, BGB, DW, LI
Degradation ratio applied to
AGB, BGB, DW

Check all column names are valid

Check	Status	Problems
column names	✓	
table sizes	✓	
column data types	✓	
category variables	✓	
unique IDs	✓	
matches between tables	✓	

Data checks

Arithmetic mean emission reductions per period (tCO₂e/y)



Arithmetic means

Screenshots - Results

Download results and simulations

Download the simulations and aggregated results

[Download the arithmetic mean ERs](#) [Download the simulated ERs](#) [Download all the ER simulations](#) [Download all the land use transition simulations](#)

Emission reductions details

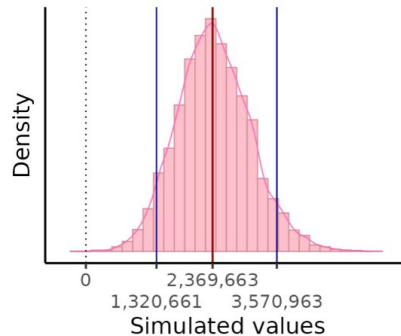
Time periods	Arithmetic mean		MCS results			
	(tCO2/y)	E (tCO2/y)	U (%)	CI (90%)		
REF	4,934,807	4,902,724	25%	(3,729,471 - 6,185,698)		
E-MON1	2,397,134	2,369,663	47%	(1,320,661 - 3,570,963)		
E-MON2	2,892,373	2,853,116	47%	(1,583,382 - 4,250,281)		
ER-MON1	2,537,673	2,523,248	56%	(1,133,105 - 3,980,631)		
ER-MON2	2,042,434	2,025,119	80%	(469,678 - 3,715,322)		

Emission reductions histogram

Select a period

E-MON1

Emissions for: MON1 (tCO2e/year)



Red: median
Blue: confidence interval
Dots: x=0

REDD+ Activity details

REDD+ activity histograms

Resources

Where to run the app and find documentation



Resources

The app is now ready to use and we will continue development in 2026!

- Run the app online: <https://openforis-shiny.shinyapps.io/mocaredd/>
- Documentation: <https://openforis.github.io/mocaredd/>
- Contact us: <https://forms.gle/5RjfuwEqtWD25N1L6>
 - Or scan the code



Thank you



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