

## Spreadsheets to model counterfactual tropical forest losses (1990-2019) for Brazil, Democratic Republic of Congo and Indonesia

18 spreadsheets cover a period of five years each and have been used to simulate the counterfactual forest losses underlying the publication:

“Trends in tropical forest loss and the social value of emission reductions: harnessing market-driven counterfactual land-use simulation,”

by Thomas Knoke, Nick Hanley, Rosa Maria Roman-Cuesta, Ben Groom, Frank Venmans and Carola Paul

The spreadsheets are based on the dynamic robust multifunctional land-use allocation program described in ref.<sup>1</sup>. A static version to simulate land-use allocation for land rehabilitation initiatives is provided by ref.<sup>2</sup> and by ref.<sup>3</sup> as a version programmed in R. However, the new spreadsheets are enhanced by Monte-Carlo simulation-optimization programs, where multiple individual land manager groups are characterized by stochastic profit scenarios to simulate heterogeneous expectations of decision makers. The simulation is conducted by solving multiple linear programs, each of which uses randomly different hypothetically expected profit scenarios for land manager groups.

All spreadsheets have the same structure, but differ concerning the initial landscape composition (B23:H23, examples from Brazil, spreadsheet “Brazil spreadsheet 1990\_1994”),

A. Formulation of initial landscape state						
Start landscape composition in %						
Other land	Planted forest	Arable	Permanent cropland	Permanent pasture	New deforestation	Naturally regenerated forest
1,4%	0,4%	5,7%	1,1%	21,3%	0,0%	70,0%

the considered uncertainty intervals (AF46 and AG46),

Level of uncertainty (m)		
Upside	Downside	
1,0	2,0	x sd

the expected profit coefficients (sheet “Profit coefficients from FAO”),

1. Period (1990). Coefficients for Land-use/land-cover types									Estimate of uncertainty, STD							
Decision c	Direction	Land-uses							Decision c	Land-uses						
		Other land	Planted forest	Cropland	Permanent forest	Permanent forest	New deforestation	Naturally regenerated forest		Other land	Planted forest	Cropland	Permanent forest	Permanent forest	New deforestation	Naturally regenerated forest
Net revenue	more is better	0	98	331	46	96	96	30	Net revenue	0,0	39,2	53,0	4,6	3,8	48,0	9,0
									Variation coefficient	0,00	0,40	0,16	0,10	0,04	0,50	0,30

and the associated ranges of the random profit scenarios (generated in BB1056:MU2055, only part of which is seen below).

Generation of new random profit scenarios								
Farmer		Planted fores	Arable	Permanent cr	Permanent pa	New deforest	Naturally regenerated fores	
1		63,3	306,2	40,3	92,5	81,4	21,4	66,7
2		121,6	329,1	48,9	92,3	63,4	32,8	88,0
3		116,9	318,9	40,4	96,5	36,0	23,8	37,8
4		33,0	363,9	39,5	96,0	26,1	17,3	103,1
5		104,3	341,8	45,3	94,2	50,4	33,3	51,7
6		30,6	381,7	44,6	89,5	130,1	37,3	92,3
7		58,8	274,4	42,4	94,5	94,0	35,0	72,9
8		124,1	346,0	47,4	95,6	137,9	15,2	62,9
9		88,8	286,1	49,1	93,5	30,9	23,9	80,8
10		26,4	293,1	39,5	90,5	143,9	12,2	48,7
11		125,8	293,1	42,7	97,1	40,3	17,0	120,4
12		69,0	343,6	45,0	96,2	109,4	24,6	79,4
13		112,1	348,2	48,4	92,0	78,6	31,5	86,8
14		121,7	329,5	38,5	88,7	30,2	22,1	70,6
15		92,5	352,4	42,9	88,4	17,3	12,9	98,3
16		113,8	377,3	43,5	90,2	84,4	20,4	23,0
17		29,1	291,1	41,6	91,5	76,6	18,6	41,3
18		106,4	254,5	47,0	93,7	1,9	15,0	20,0

Note that the initial landscape composition is also a random outcome from 1995 onwards, consisting of the resulting landscape composition of a previous simulation period. For each period, counterfactual simulations have been repeated five times and the initial landscape composition of the subsequent period consists of their average land-cover proportions.

For a new simulation run, one has to paste newly simulated random profit scenarios copied from the matrix BB1056:MU2055 (which simulates random profits) into BB53:MU1052 and then start a sequence of 50 simulation runs, using Frontline Analytic Solver Optimization plus Simulation® (V2022.5) standard Linear Programming/Quadratic Engine.

PsiOptParam(...;...) in AA46 then generates 50 index numbers,

PsiOpt Index
0

which inform the lookup functions in AA53:AF1052 about where to read the matrix BB53:MU1052 to obtain corresponding random profit coefficients.

Uncertainty adjusted Indicator (+/- m × sd)						
Other land	Planted fores	Arable	Permanent cr	Permanent p	New deforest	Naturally regene
0	43	262	49	91	101	19
0	39	365	42	93	113	39
0	95	228	49	99	3	21
0	85	376	40	89	117	13
0	75	333	45	96	123	18
0	62	333	50	93	68	13
0	59	251	46	91	49	24
0	44	248	41	92	14	37
0	117	312	50	90	29	31
0	49	241	47	98	34	36
0	126	377	50	99	10	22
0	96	329	50	89	7	18
0	95	340	42	99	36	20
0	24	369	50	98	70	36
0	38	307	43	92	12	14
0	111	315	46	96	139	27

One robust optimization program is then solved for each index number and the resulting landscape composition at the end of the considered period is written into the cells Y2:AP26, using PsiOptValue(...;...) functions. The numbers are the shares of land covered by a land-use/land-cover type in a specific scenario.

PsiOptValues		Other land	Planted fores	Arable	Permanent c	Permanent p	New deforest	Naturally reg	Deforestation r
	1	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,01084746	0,68947582	0,003097843
	2	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,03185251	0,66847077	0,009096516
	3	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,01291973	0,68740354	0,003689649
	4	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,03123182	0,66909146	0,008919257
	5	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00559405	0,69472923	0,001597561
	6	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,02082461	0,67949867	0,005947141
	7	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00744691	0,69287636	0,002126708
	8	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00350875	0,69681453	0,001002037
	9	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00610184	0,69422143	0,001742579
	10	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,03014741	0,67017586	0,008609571
	11	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,03785797	0,6624653	0,010811571
	12	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,04844577	0,65187751	0,01383526
	13	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,02368554	0,67663773	0,006764174
	14	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00142658	0,6988967	0,000407406
	15	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,0370739	0,66324938	0,010587653
	16	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,0377605	0,66256278	0,010783734
	17	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,02478889	0,67553439	0,007079269
	18	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,01144297	0,68888031	0,003267909
	19	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,01258199	0,68774129	0,003593194
	20	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00652495	0,69379833	0,00186341
	21	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,02001344	0,68030984	0,005715485
	22	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00832018	0,6920031	0,002376096
	23	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,00389457	0,6964287	0,001112222
	24	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,0058218	0,69450147	0,001662605
	25	0,03214764	0,00571369	0,06013659	0,00908894	0,19258986	0,03703272	0,66329056	0,010575893

50 stored example landscape compositions at the end of the considered period are displayed in AS2:BI26.

## References

1. Knoke, T. *et al.* Accounting for multiple ecosystem services in a simulation of land-use decisions: Does it reduce tropical deforestation? *Glob. Chang. Biol.* **26**, 2403–2420;

10.1111/gcb.15003 (2020).

2. Knoke, T. *et al.* Compositional diversity of rehabilitated tropical lands supports multiple ecosystem services and buffers uncertainties. *Nat. Commun.* **7**, 11877; 10.1038/ncomms11877 (2016).
3. Husmann, K. *et al.* optimLanduse : A package for multiobjective land-cover composition optimization under uncertainty. *Methods Ecol Evol* **13**, 2719–2728; 10.1111/2041-210X.14000 (2022).