Supplement of Biogeosciences, 20, 15–26, 2023
https://doi.org/10.5194/bg-20-15-2023-supplement

Biogeosciences Open Access EGU

Supplement of

The paradox of assessing greenhouse gases from soils for nature-based solutions

Rodrigo Vargas and Van Huong Le

Correspondence to: Rodrigo Vargas (rvargas@udel.edu)

Supplementary Tables and Figures

Table S1. Statistical properties for automated measurements of soil CO_2 (F_A CO_2), soil CH_4 (F_A CH_4), and soil N_2O (F_A N_2O) fluxes, optimized samples (k=12, 28, 48) using a temporal univariate Latin Hypercube sampling (*tuLHs*), and fixed temporal stratification (k=12, 28, 48). Units for soil CO_2 fluxes are in μmol m^{-2} s^{-1}, and for soil CH_4 and N_2O fluxes in nmol m^{-2} s^{-1}.

	Number of measurements (k)	**1st. Quartile**	**Median**	**Mean**	**3rd. Quartile**	**Standard Deviation**
F_ACO_2	8259	2.81	5.03	5.87	8.65	3.85
tuLHs approach (**CO_2**)	12	3.19	5.30	6.25	8.88	4.06
	24	3.00	5.13	5.93	8.44	3.90
	48	2.84	4.97	5.88	8.54	3.87
Fixed temporal stratification (**CO_2**)	12	2.68	5.82	5.37	7.10	3.15
	24	2.69	5.66	5.50	7.07	3.24
	48	2.69	5.53	5.45	8.05	3.29
F_ACH_4	8259	-1.14	-0.92	-0.93	-0.67	0.36
tuLHs approach (**CH_4**)	12	-1.11	-0.89	-0.87	-0.66	0.33
	24	-1.14	-0.92	-0.94	-0.66	0.34
	48	-1.13	-0.91	-0.92	-0.66	0.35
Fixed temporal stratification (**CH_4**)	12	-1.01	-0.83	-0.83	-0.67	0.27
	24	-1.01	-0.89	-0.86	-0.68	0.26
	48	-1.10	-0.86	-0.88	-0.66	0.29
F_AN_2O	8259	-0.18	0.01	0.45	0.49	1.62
tuLHs approach (**N_2O**)	12	-0.18	-0.01	0.58	0.50	1.58
	24	-0.18	0.03	0.51	0.45	1.54
	48	-0.17	0.02	0.49	0.45	1.54
Fixed temporal stratification (**N_2O**)	12	-0.35	0.51	0.59	0.83	1.38
	24	-0.21	-0.08	0.61	0.36	1.97
	48	-0.31	0.00	0.25	0.53	0.91

Table S2. Comparison of errors between experimental variogram for automated measurements of soil greenhouse gases (F_A; k=8259) and experimental variograms for data using temporal univariate Latin Hypercube sampling (*tuLHs*) and fixed temporal stratification.

	Approach	**Number of measurements** (k)	**Error (Sum of absolute differences)**
Soil CO_2 fluxes	Fixed	12	69.31
		24	54.39
		48	49.42
	tuLHs	12	5.69
		24	1.99
		48	1.39
Soil CH_4 fluxes	Fixed	12	0.63
		24	0.68
		48	0.49
	tuLHs	12	0.06
		24	0.04
		48	0.02
Soil N_2O fluxes	Fixed	12	10.01
		24	12.25
		48	16.75
	tuLHs	12	0.82
		24	1.13
		48	3.57

Table S3. Cumulative sum and associated uncertainty of greenhouse gas (GHG) fluxes derived from automated measurements (F_A) and using an optimized sampling approach (*tuLHs*) or a fixed temporal stratification. The cumulative sum represents the total flux from available measurements derived from automated measurements for all GHG fluxes.

	Number of measurements (*k*)	**Cumulative Sum**	**Uncertainty 95% CI**		**Uncertainty Range**
F_ACO_2 ($g\ CO_2\ m^2$)	8259	5758	893	13860	12966
tuLHs approach ($g\ CO_2\ m^2$)	12	6130	1423	13218	11794
	24	5818	1046	13438	12391
	48	5766	946	13429	12482
Fixed temporal stratification ($g\ CO_2\ m^2$)	12	5273	1376	10117	8740
	24	5402	1196	11356	10160
	48	5351	1162	11621	10458
F_ACH_4 ($g\ CH_4\ m^2$)	8259	-0.33	-0.58	-0.14	0.44
tuLHs approach ($g\ CH_4\ m^2$)	12	-0.31	-0.49	-0.12	0.37
	24	-0.33	-0.57	-0.16	0.41
	48	-0.33	-0.56	-0.14	0.42
Fixed temporal stratification ($g\ CH_4\ m^2$)	12	-0.3	-0.45	-0.15	0.3
	24	-0.31	-0.46	-0.14	0.32
	48	-0.32	-0.51	-0.14	0.37
F_AN_2O ($g\ N_2O\ m^2$)	8259	0.44	-0.53	3.67	4.2
tuLHs approach ($g\ N_2O\ m^2$)	12	0.57	-0.48	4.19	4.67
	24	0.5	-0.43	4.35	4.78
	48	0.48	-0.5	3.58	4.08
	12	-0.3	-0.83	3.52	4.35
	24	-0.31	-0.43	4.86	5.29

Fixed temporal stratification (g N_2O m^2)	48	-0.32	-0.7	2.21		2.91

41
42

43

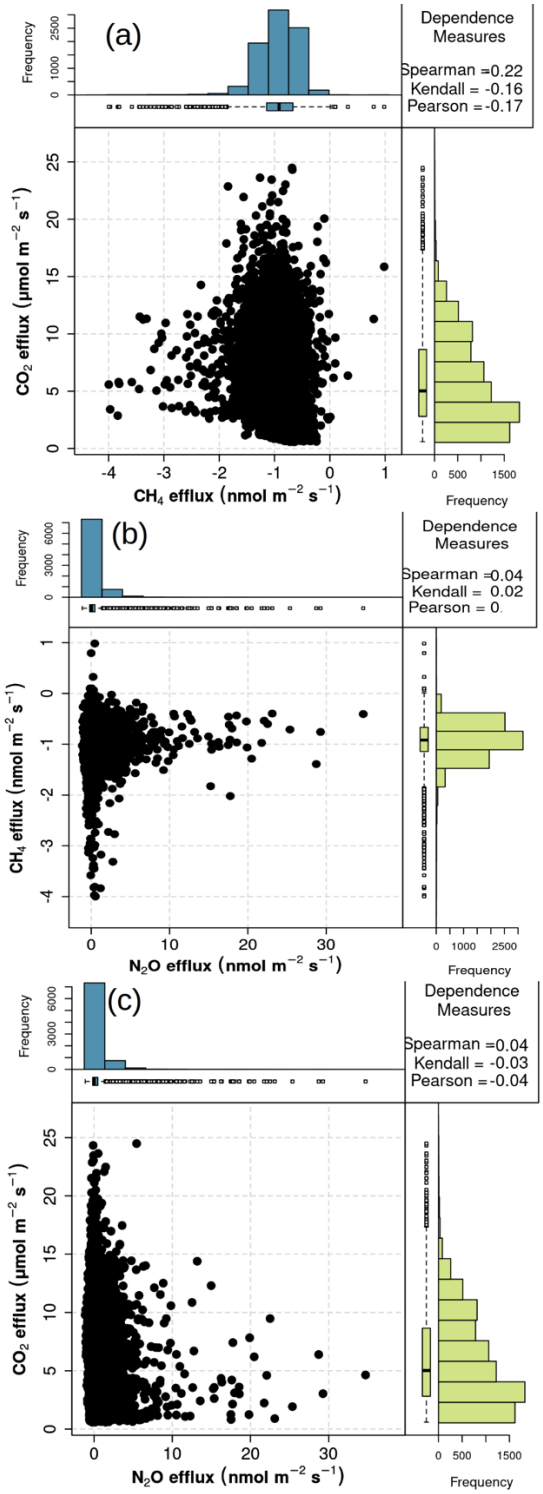

Figure S1. Relationships between soil CO_2 (F_A CO_2) with soil CH_4 (F_A CH_4) fluxes (a), soil CH_4 (F_A CH_4) with soil N_2O (F_A N_2O) fluxes (b), and soil CO_2 (F_A CO_2) with soil N_2O (F_A N_2O) fluxes. None of these relationships were significant at α=0.05. These relationships were derived using all available data from automated measurements (F_A) of soil greenhouse gas fluxes.

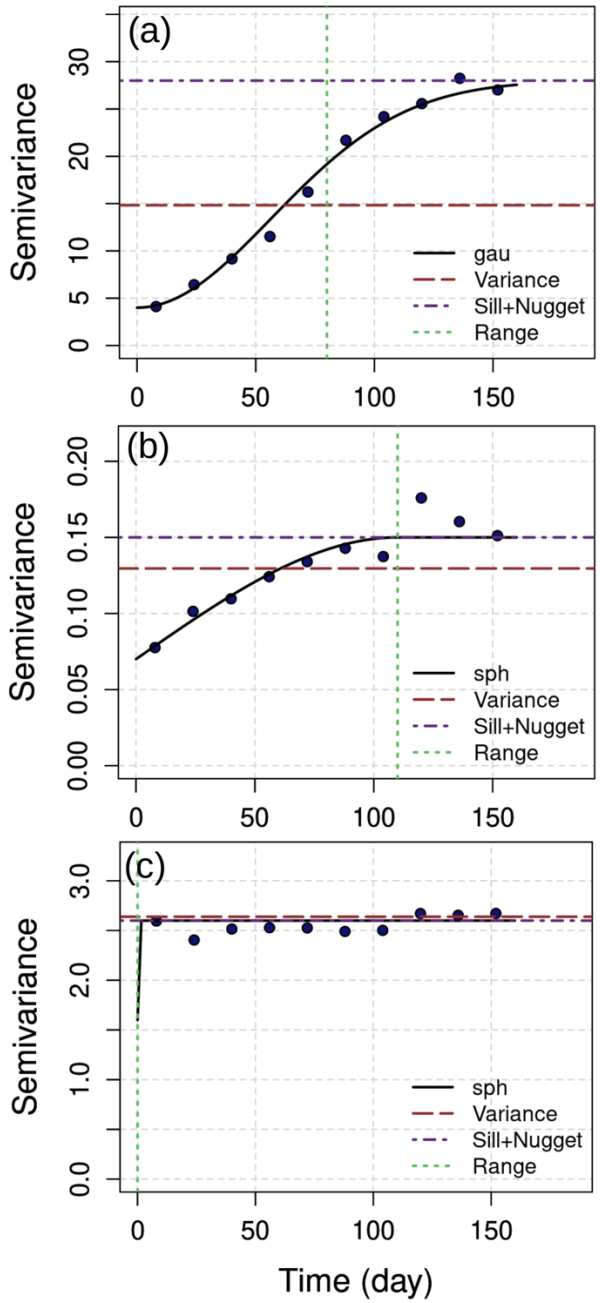

Figure S2. Semivariograms of soil CO_2 (F_A CO_2; a), soil CH_4 (F_A CH_4; b), and soil N_2O (F_A N_2O; c) fluxes. These semivariograms were derived using all available data from automated measurements (F_A) of soil greenhouse gas fluxes. Semivariogram fits were gaussian (Gau) or spherical (sph).

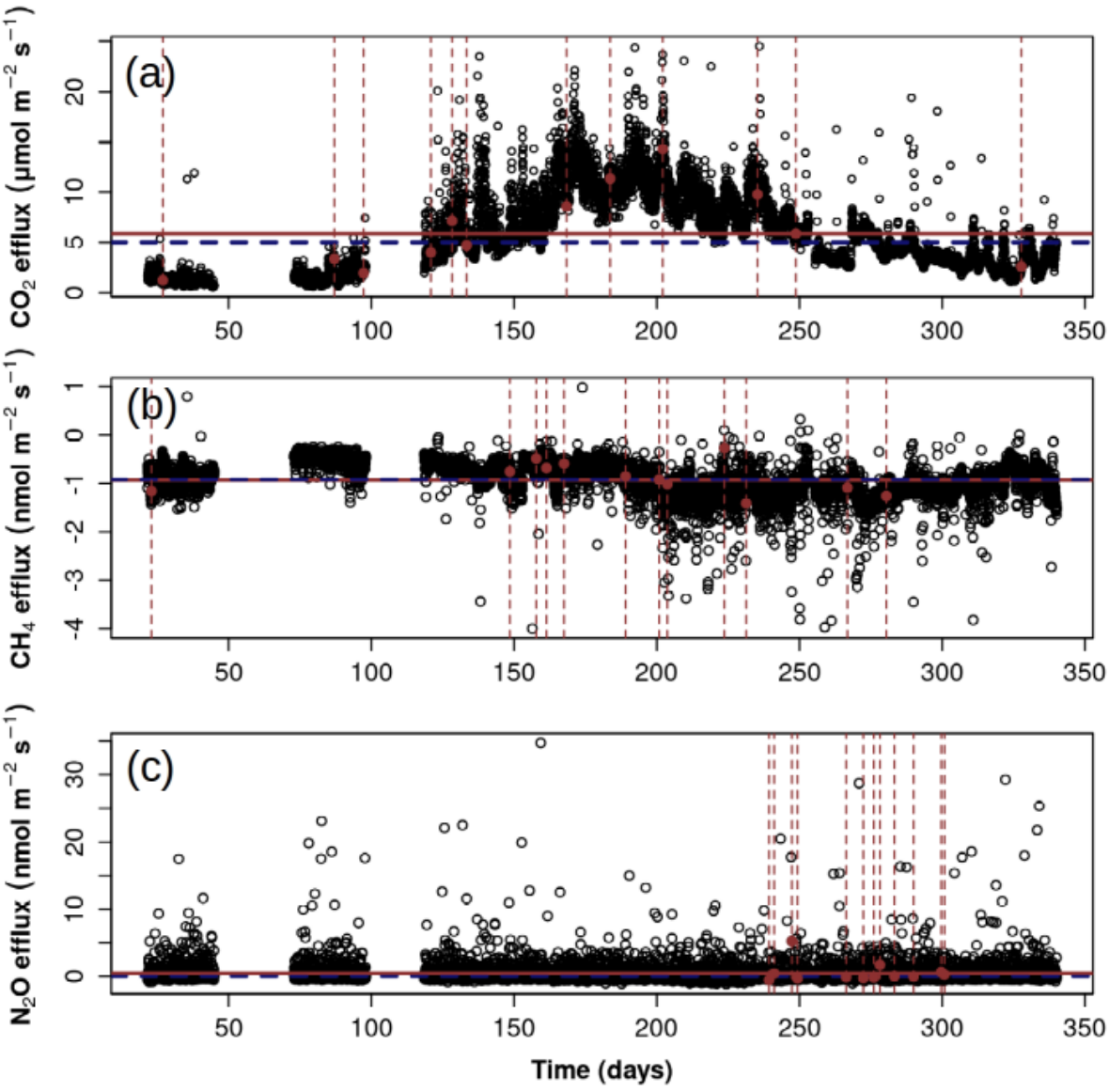

Figure S3. Time series of automated measurements (FA) of soil greenhouse gas fluxes (black circles) and optimized samples (k=12) using a temporal univariate Latin Hypercube sampling (*tuLHs*) approach for soil CO_2 (a), soil CH_4 (b) and soil N_2O (c) fluxes. The horizontal red line represents the mean, and the horizontal blue line is the median of each greenhouse gas flux derived from automated measurements. Time (x-axis) represents days from January 1 to December 31 of 2015.

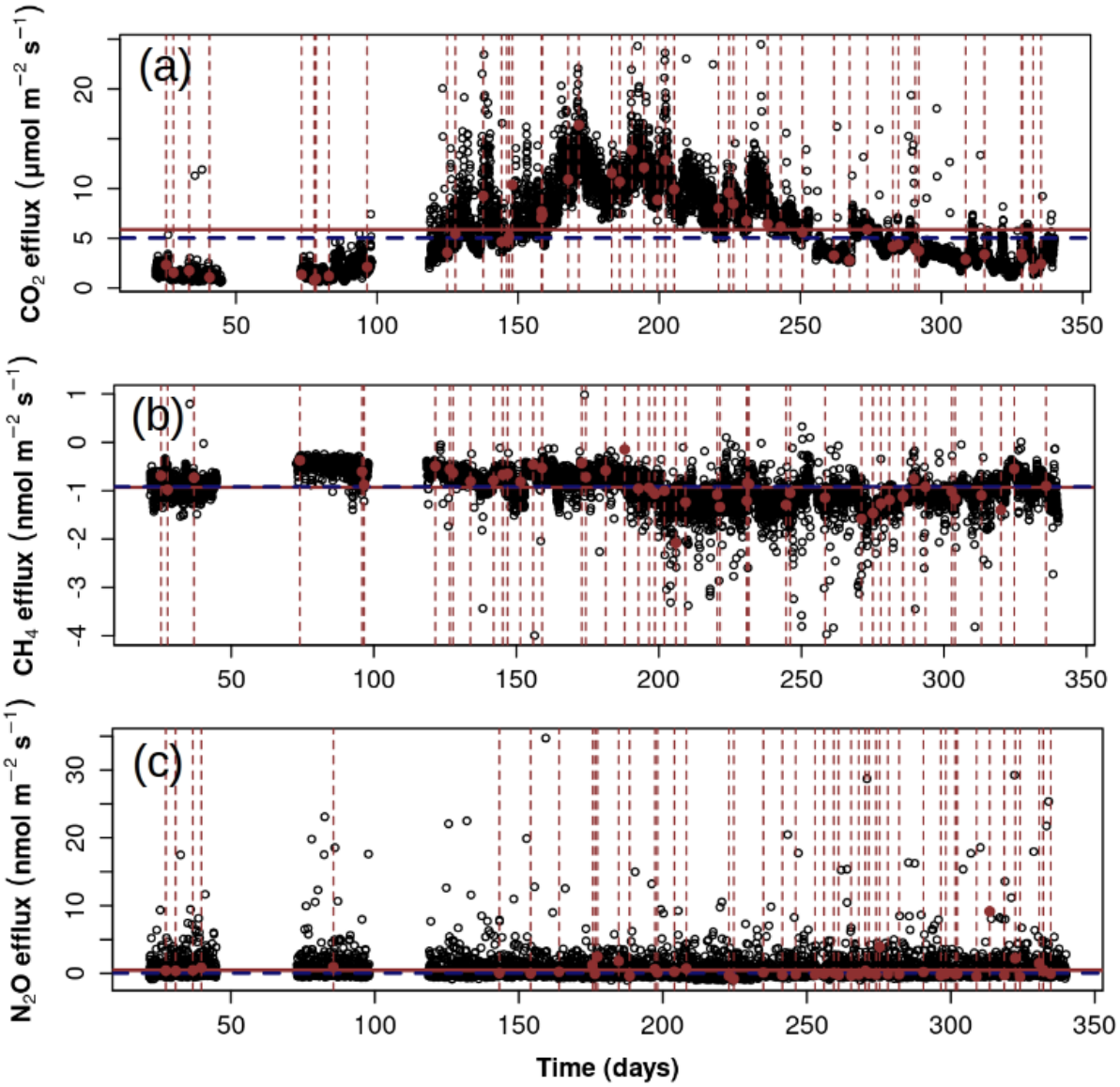

Figure S4. Time series of automated measurements (FA) of soil greenhouse gas fluxes (black circles) and optimized samples (*k*=48) using a temporal univariate Latin Hypercube sampling (*tuLHs*) approach for soil CO_2 (a), soil CH_4 (b) and soil N_2O (c) fluxes. The horizontal red line represents the mean, and the horizontal blue line is the median of each greenhouse gas flux derived from automated measurements. Time (x-axis) represents days from January 1 to December 31 of 2015.

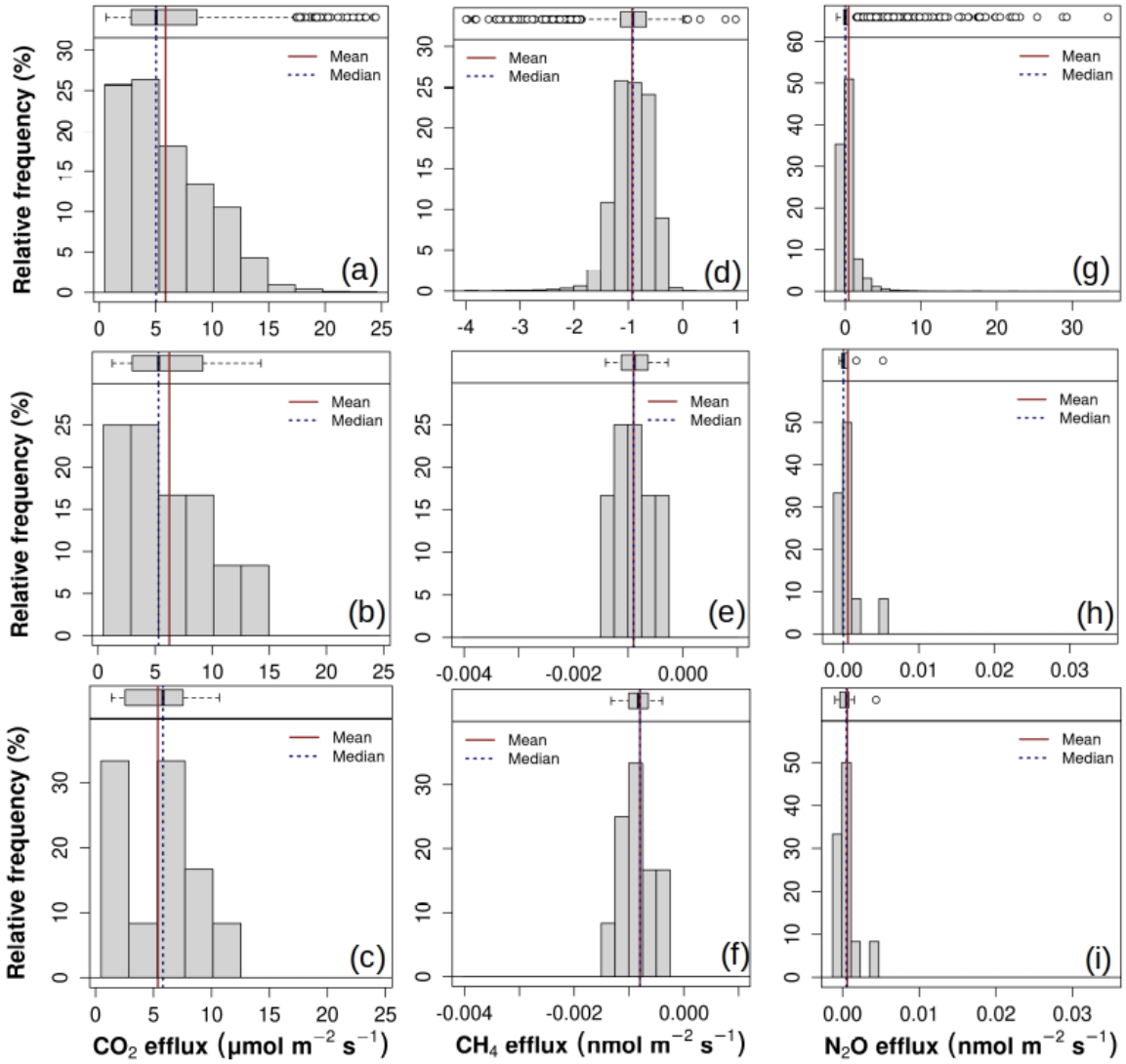

Figure S5. Histograms for automated measurements of soil CO_2 (F_A CO_2; a), soil CH_4 (F_A CH_4; d), and soil N_2O (F_A N_2O; g) fluxes. Histograms for optimized samples (k=12) using a temporal univariate Latin Hypercube sampling (*tuLHs*) approach for soil CO_2 (b), soil CH_4 (e), and soil N_2O (h) fluxes. Histograms for fixed temporal stratification (i.e., stratified manual sampling schedule; k=12) for soil CO_2 (c), soil CH_4 (f), and soil N_2O (i) fluxes.

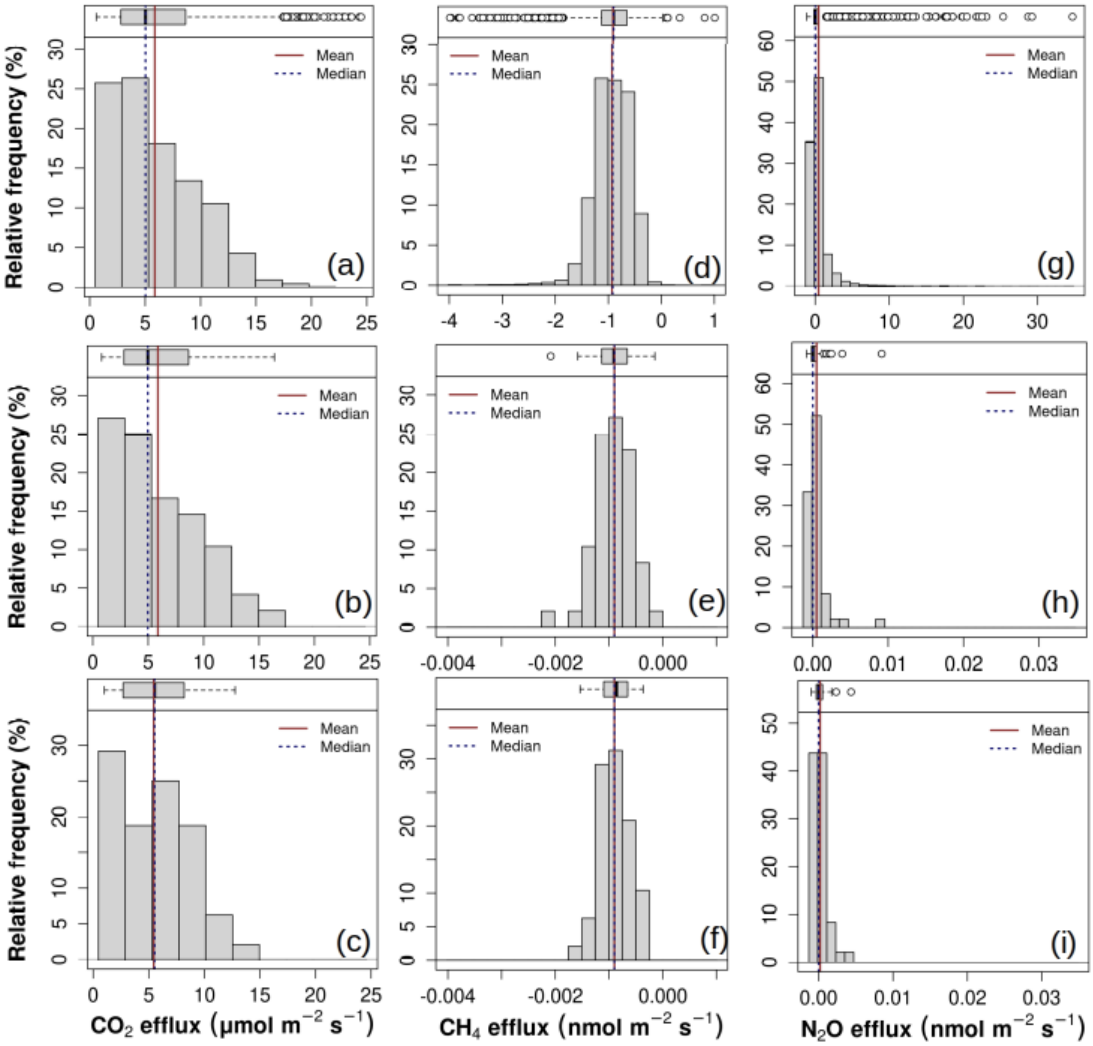

Figure S6. Histograms for automated measurements of soil CO_2 (F_A CO_2; a), soil CH_4 (F_A CH_4; d), and soil N_2O (F_A N_2O; g) fluxes. Histograms for optimized samples (k=48) using a temporal univariate Latin Hypercube sampling (*tuLHs*) approach for soil CO_2 (b), soil CH_4 (e), and soil N_2O (h) fluxes. Histograms for fixed temporal stratification (i.e., stratified manual sampling schedule; k=48) for soil CO_2 (c), soil CH_4 (f), and soil N_2O (i) fluxes.

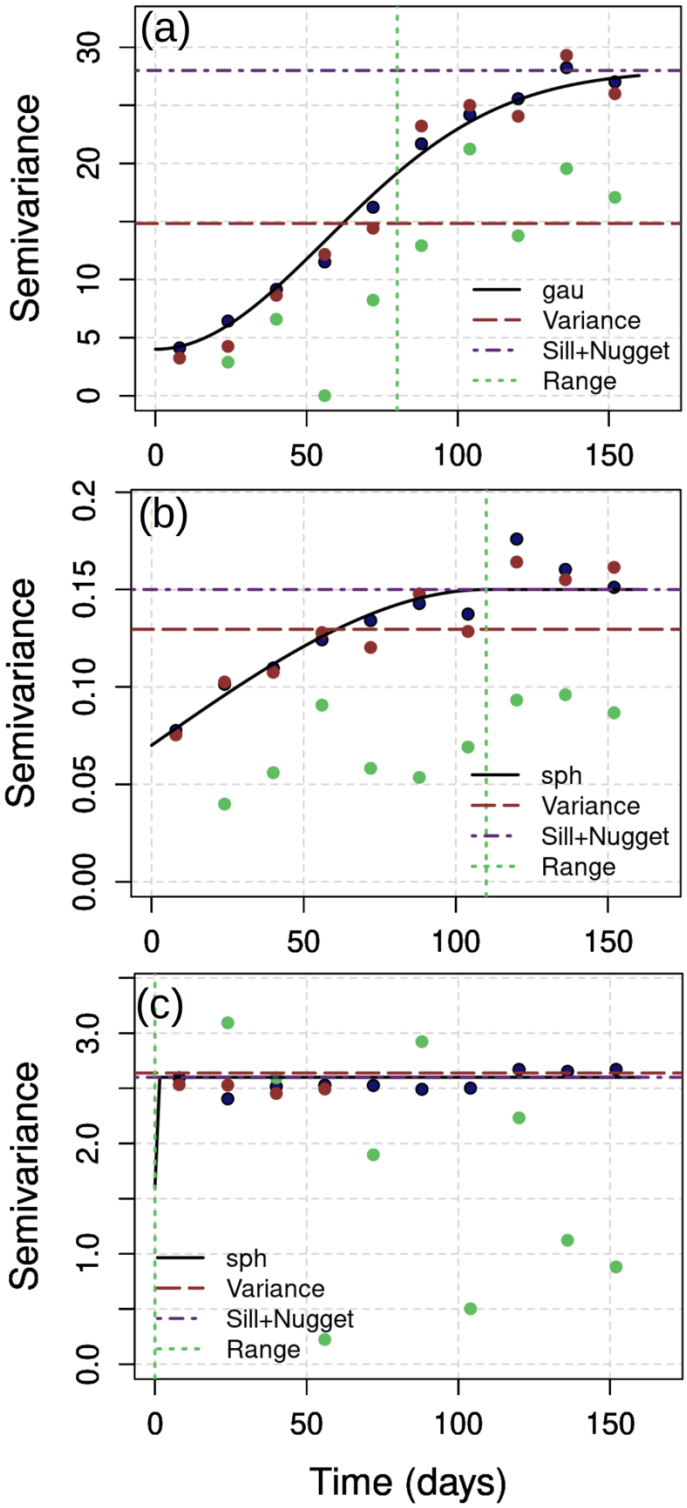

Figure S7. Comparison of semivariograms between automated measurements (F_A) of soil greenhouse gas fluxes (solid black line) and for optimized (red circles) or fixed temporal stratification (green circles) with k=12. Semivarograms are presented for soil CO_2 (a), CH_4 (d), and N_2O (c) fluxes. Semivariogram fits were gaussian (Gau) or spherical (sph).

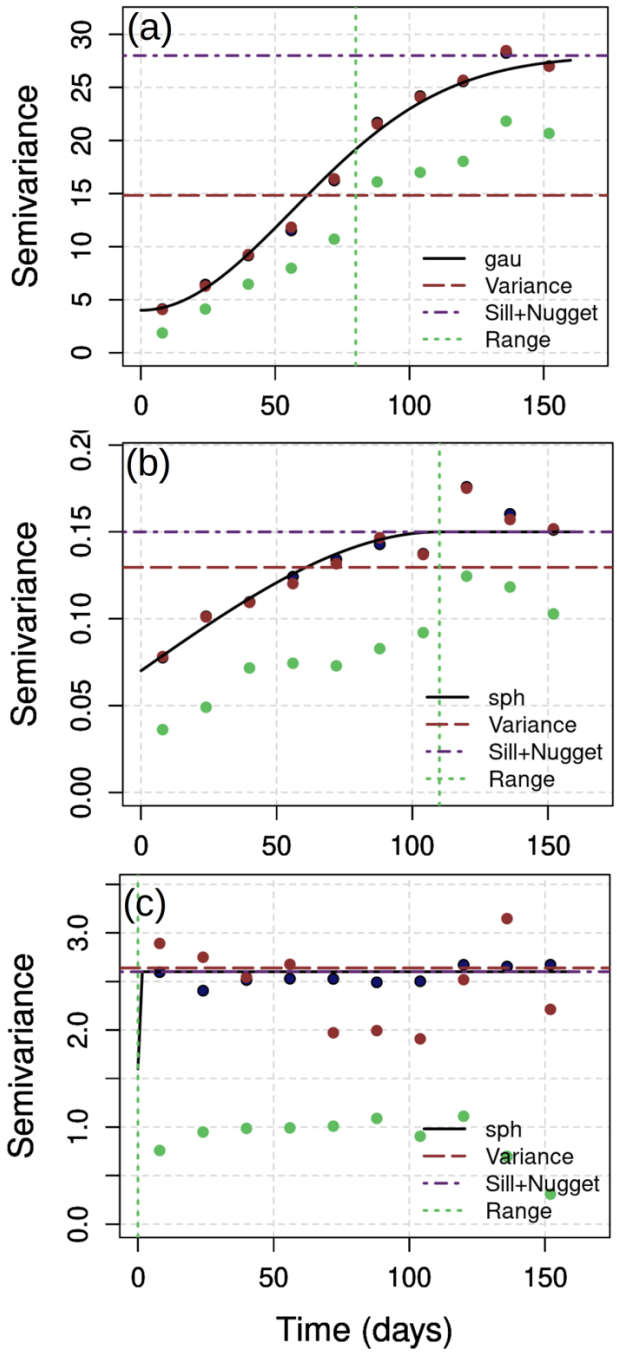

Figure S8. Comparison of semivariograms between automated measurements (F_A) of soil greenhouse gas fluxes (solid black line) and for optimized (red circles) or fixed temporal stratification (green circles) with k=48. Semivarograms are presented for soil CO_2 (a), CH_4 (d), and N_2O (c) fluxes. Semivariogram fits were gaussian (Gau) or spherical (sph).