Title: Soil organic carbon dynamics in semi-arid irrigated cropping systems

Authors:

Removed for Review

Supplemental Material

(S1): Denitrification decomposition (DNDC) model goodness of fit statistics for biomass carbon, Mg ha^{-1}, as run in a "Default" and "Calibrated" capacity for each treatment of 3 simulated research locations. Fit statistics were recalculated considering all treatments for the values next to each location.[c b]

(S2): Denitrification decomposition (DNDC) model goodness of fit statistics for soil organic carbon, Mg ha^{-1}, as run in a "Default" and "Calibrated" capacity for each treatment of 3 simulated research locations. Fit statistics were recalculated considering all treatments for the values next to each location. [c b]

(S3): Denitrification decomposition (DNDC) model goodness of fit statistics for cumulative nitrogen mineralization, kg ha^{-1}, as run in a "Default" and "Calibrated" capacity for each treatment of 3 simulated research locations. Fit statistics were recalculated considering all treatments for the values next to each location. [c b]

(S4): Denitrification decomposition (DNDC) model goodness of fit statistics for soil water contents, cm^3 cm^{-3} or Θ_v, as run in a "Default" and "Calibrated" capacity for each treatment of 3 simulated research locations. Fit statistics were recalculated considering all treatments for the values next to each location. [c b]

(S5): Denitrification decomposition (DNDC) model goodness of fit statistics for estimated actual evapotranspiration, mm water, as run in a "Default" and "Calibrated" capacity for each treatment of 3 simulated research locations. Fit statistics were recalculated considering all treatments for the values next to each location. [c b]

(S6): Denitrification decomposition (DNDC) modeled biomass carbon, kg ha^{-1}, relative to observed values at the CoverCrop location. Bars without the triticale indicator represent corn silage. The DNDC model was run in the "Default" capacity without calibration. Error bars indicate 1 standard error of the observed mean.

(S7): Denitrification decomposition (DNDC) modeled biomass carbon, kg ha^{-1}, relative to observed values at the CoverCrop location. Bars without the triticale indicator represent corn silage. The DNDC model was run in the "Calibrated" capacity. Error bars indicate 1 standard error of the observed mean.

(S8): Denitrification decomposition (DNDC) modeled soil organic carbon, Mg ha^{-1}, relative to observed values at the CoverCrop location. The DNDC model was run in the "Default" capacity without calibration. Error bars indicate 1 standard error of the observed mean.

(S9): Denitrification decomposition (DNDC) modeled soil organic carbon, Mg ha^{-1}, relative to observed values at the CoverCrop location. The DNDC model was run in the "Calibrated" capacity. Error bars indicate 1 standard error of the observed mean.

(S10): Denitrification decomposition (DNDC) modeled cumulative nitrogen mineralization, kg ha^{-1}, relative to observed values at the CoverCrop location. The DNDC model was run in the "Default" capacity without calibration.

(S11): Denitrification decomposition (DNDC) modeled cumulative nitrogen mineralization, kg ha^{-1}, relative to observed values at the CoverCrop location. The DNDC model was run in the "Calibrated" capacity.

(S12): Denitrification decomposition (DNDC) modeled soil water contents, $cm^3\ cm^{-3}$ or Θ_v, relative to observed values at the CoverCrop location. The DNDC model was run in the "Default" capacity without calibration.

(S13): Denitrification decomposition (DNDC) modeled soil water contents, $cm^3\ cm^{-3}$ or Θ_v, relative to observed values at the CoverCrop location. The DNDC model was run in the "Calibrated" capacity.

(S14): Denitrification decomposition (DNDC) modeled crop actual evapotranspiration, mm water, relative to observed values at the CoverCrop location. The DNDC model was run in the "Default" capacity without calibration.

(S15): Denitrification decomposition (DNDC) modeled crop actual evapotranspiration, mm water, relative to observed values at the CoverCrop location. The DNDC model was run in the "Calibrated" capacity.

(S16): Denitrification decomposition (DNDC) modeled biomass carbon, kg ha^{-1}, relative to observed values at the GRACEnet location. The DNDC model was run in the "Default" capacity without calibration. Error bars indicate 1 standard error of the observed mean.

(S17): Denitrification decomposition (DNDC) modeled biomass carbon, kg ha^{-1}, relative to observed values at the GRACEnet location. The DNDC model was run in the "Calibrated" capacity. Error bars indicate 1 standard error of the observed mean.

(S18): Denitrification decomposition (DNDC) modeled soil organic carbon, Mg ha^{-1}, relative to observed values at the GRACEnet location. The DNDC model was run in the "Default" capacity without calibration. Error bars indicate 1 standard error of the observed mean.

(S19): Denitrification decomposition (DNDC) modeled soil organic carbon, Mg ha^{-1}, relative to observed values at the GRACEnet location. The DNDC model was run in the "Calibrated" capacity. Error bars indicate 1 standard error of the observed mean.

(S20): Denitrification decomposition (DNDC) modeled cumulative nitrogen mineralization, kg ha^{-1}, relative to observed values at the GRACEnet location. The DNDC model was run in the "Default" capacity without calibration.

(S21): Denitrification decomposition (DNDC) modeled cumulative nitrogen mineralization, kg ha^{-1}, relative to observed values at the GRACEnet location. The DNDC model was run in the "Calibrated" capacity.

(S22): Denitrification decomposition (DNDC) modeled soil water contents, $cm^3\ cm^{-3}$ or Θ_v, relative to observed values at the GRACEnet location. The DNDC model was run in the "Default" capacity without calibration.

(S23): Denitrification decomposition (DNDC) modeled soil water contents, $cm^3\ cm^{-3}$ or Θ_v, relative to observed values at the GRACEnet location. The DNDC model was run in the "Calibrated" capacity.

(S24): Denitrification decomposition (DNDC) modeled crop actual evapotranspiration, mm water, relative to observed values at the GRACEnet location. The DNDC model was run in the "Default" capacity without calibration.

(S25): Denitrification decomposition (DNDC) modeled crop actual evapotranspiration, mm water, relative to observed values at the GRACEnet location. The DNDC model was run in the "Calibrated" capacity.

(S26): Denitrification decomposition (DNDC) modeled biomass carbon, kg ha^{-1}, relative to observed values at the LT Manure location. The DNDC model was run in the "Default" capacity without calibration. Error bars indicate 1 standard error of the observed mean.

(S27): Denitrification decomposition (DNDC) modeled biomass carbon, kg ha^{-1}, relative to observed values at the LT Manure location. The DNDC model was run in the "Calibrated" capacity. Error bars indicate 1 standard error of the observed mean.

(S28): Denitrification decomposition (DNDC) modeled soil organic carbon, Mg ha^{-1}, relative to observed values at the LT Manure location. The DNDC model was run in the "Default" capacity without calibration. Error bars indicate 1 standard error of the observed mean.

(S29): Denitrification decomposition (DNDC) modeled soil organic carbon, Mg ha^{-1}, relative to observed values at the LT Manure location. The DNDC model was run in the "Calibrated" capacity. Error bars indicate 1 standard error of the observed mean.

(S30): Denitrification decomposition (DNDC) modeled cumulative nitrogen mineralization, kg ha^{-1}, relative to observed values at the LT Manure location. The DNDC model was run in the "Default" capacity without calibration.

(S31): Denitrification decomposition (DNDC) modeled cumulative nitrogen mineralization, kg ha^{-1}, relative to observed values at the LT Manure location. The DNDC model was run in the "Calibrated" capacity.

(S32): Denitrification decomposition (DNDC) modeled soil water contents, $cm^3\ cm^{-3}$ or Θ_v, relative to observed values at the LT Manure location. The DNDC model was run in the "Default" capacity without calibration.

(S33): Denitrification decomposition (DNDC) modeled soil water contents, $cm^3\ cm^{-3}$ or Θ_v, relative to observed values at the LT Manure location. The DNDC model was run in the "Calibrated" capacity.

(S34): Denitrification decomposition (DNDC) modeled crop actual evapotranspiration, mm water, relative to observed values at the LT Manure location. The DNDC model was run in the "Default" capacity without calibration.

(S35): Denitrification decomposition (DNDC) modeled crop actual evapotranspiration, mm water, relative to observed values at the LT Manure location. The DNDC model was run in the "Calibrated" capacity.

(S36): Denitrification decomposition (DNDC) model prediction of soil organic carbon (SOC) stocks, Mg ha^{-1}, under "high" and "low" emission projections for the 52A treatment at the LT manure location until 2100. The model was forecast in the "Calibrated" state.

(S1)

	PBIAS		NSE		MAE	
	Default	Calibrate	Default	Calibrate	Default	Calibrate
	Biomass Carbon (yield), Mg ha-1					
CoverCrop	4.1	5.0	0.84	0.92	0.99	0.58
CT-M-F	15.7	4.7	-2.53	0.03	1.26	0.60
CT-M-T	0.7	2.2	0.70	0.98	1.33	0.33
CT-NM-F	-5.6	2.6	0.45	0.24	0.46	0.55
CT-NM-T	-0.5	6.1	0.95	0.88	0.69	0.92
MT-M-F	15.4	3.9	-3.10	0.11	1.25	0.51
MT-M-T	3.8	5.9	0.72	0.97	1.35	0.37
MT-NM-F	-2.2	5.7	-0.25	-0.32	0.48	0.48
MT-NM-T	5.4	9.6	0.91	0.89	0.89	0.84
GRACEnet	-32.6	8.3	-0.69	0.70	2.62	1.13
Control	-43.3	-11.1	-0.33	0.61	2.94	1.10
Fall compost	-25.6	11.5	-1.11	0.75	2.45	1.06
Fall manure	-29.6	5.5	-0.91	0.84	2.61	0.77
Spr manure	-24.9	11.2	-1.25	0.76	2.44	0.99
Spr super-U	-34.8	-2.8	-0.59	0.98	2.57	0.37
Spr Urea	-36.5	-5.2	-0.46	0.94	2.70	0.61
LT Manure	-14.4	-4.4	0.73	0.85	0.67	0.49
18A	-13.4	-4.5	0.77	0.81	0.63	0.54
18B	-13.6	-4.2	0.79	0.96	0.62	0.32
36A	-8.4	0.6	0.87	0.90	0.45	0.38
36B	-14.0	-4.9	0.78	0.89	0.68	0.47
52A	-4.2	3.6	0.83	0.96	0.61	0.33
52B	-11.4	-1.8	0.84	0.74	0.52	0.56
Control	-30.1	-19.5	0.40	0.47	0.94	0.93
Fertilizer	-22.6	-6.9	0.57	0.93	0.89	0.41

[b] **Cover Crop treatments:** CT-M-F, conventional tillage-manure application-fallow; CT-M-T, conventional tillage-manure application-triticale; CT-NM-F, conventional tillage-no manure-fallow; CT-NM-T, conventional tillage-no manure-triticale; MT-M-F, Minimum-till-manure application-fallow; MT-M-T, Minimum-till-manure application-triticale; MT-NM-F, Minimum-till-no manure-fallow; MT-NM-T, Minimum-till-no manure-triticale. Treatments with manure were applied annually at a target rate of 52 Mg ha^{-1} on a dry weight basis. **GRACEnet treatments:** Control, no synthetic fertilizer or manure; Fall compost, composted dairy manure applied in the Fall; Fall manure, dairy manure applied in the Fall; Spr manure, dairy manure applied in the Spring; Spr super-U, Super-U applied annually in the spring based on soil test N; Urea, Urea applied annually in the spring based on soil test N. Compost and manure applications were made on a dry weight basis according to crop rotation at target application rates of 33 Mg ha^{-1} and 52 Mg ha^{-1}, respectively. **LT manure treatments:** 18A, dairy manure applied annually at a rate of 18 Mg ha^{-1}; 18B, dairy manure applied biennially at a rate of 18 Mg ha^{-1}; 36A, dairy manure applied annually at a rate of 36 Mg ha^{-1}; 36B, dairy manure applied biennially at a rate of 36 Mg ha^{-1}; 52A, dairy manure applied annually at a rate of 52 Mg ha^{-1}; 52B, dairy manure applied biennially at a rate of 52 Mg ha^{-1}; Control, no synthetic fertilizer or manure; Fertilizer, synthetic fertilizer. All target manure application rates are on a dry weight basis.

[c] **Percent bias:** PBIAS, the tendency of simulated values to be larger or smaller than corresponding observed values; the optimal PBIAS value is 0 with positive and negative values indicating overestimation or underestimation bias, respectively. **Nash-Sutcliffe model efficiency coefficient:** NSE, describes the predictive accuracy of a model ranging from negative infinity to 1, a perfect model; when NSE is equal to 0 the model has the same predictive ability as the mean of observations. **Mean absolute error:** MAE, the calculated average of absolute errors between simulated and observed values.

(S2)

	PBIAS		NSE		MAE	
	Default	Calibrate	Default	Calibrate	Default	Calibrate
	Soil Organic Carbon, Mg ha-1					
CoverCrop	-9.8	-14.4	0.59	0.48	5.08	6.06
CT-M-F	-9.3	-14.4	0.75	0.55	4.80	6.88
CT-M-T	-7.5	-11.1	0.78	0.67	3.74	5.26
CT-NM-F	1.5	-4.7	0.59	0.13	1.60	1.78
CT-NM-T	1.2	-4.1	0.71	0.38	1.26	1.56
MT-M-F	-22.2	-27.0	0.16	-0.15	11.01	13.07
MT-M-T	-27.1	-30.4	0.05	-0.08	15.01	16.44
MT-NM-F	0.6	-4.5	0.57	0.08	1.47	1.75
MT-NM-T	2.9	-1.5	0.59	0.51	1.73	1.74
GRACEnet	-6.9	-3.9	0.45	0.76	4.74	2.75
Control	-6.7	-3.3	-6.85	-1.18	4.30	2.24
Fall compost	-6.8	-3.4	-2.04	0.37	4.54	1.68
Fall manure	-5.6	-3.3	0.39	0.60	5.75	4.09
Spr manure	-9.2	-6.7	-0.14	0.38	5.66	4.31
Spr super-U	-6.6	-3.4	-3.66	-0.45	4.34	2.40
Spr Urea	-6.0	-2.8	-6.02	-0.47	3.88	1.81
LT Manure	0.6	2.9	0.74	0.73	4.12	4.36
18A	1.4	4.4	0.26	0.21	4.7	4.92
18B	1.7	5.0	-0.08	-0.16	3.18	3.72
36A	1.3	3.0	0.43	0.46	5.19	5.26
36B	3.8	6.3	-0.1	-0.07	3.33	3.51
52A	-0.8	0.2	0.71	0.71	5.96	5.44
52B	-4.3	-2.6	0.40	0.41	6.44	6.46
Control	2.3	5.0	-0.27	-0.74	2.25	3.01
Fertilizer	1.3	4.4	-0.05	-0.70	1.89	2.55

[b] **Cover Crop treatments:** CT-M-F, conventional tillage-manure application-fallow; CT-M-T, conventional tillage-manure application-triticale; CT-NM-F, conventional tillage-no manure-fallow; CT-NM-T, conventional tillage-no manure-triticale; MT-M-F, Minimum-till-manure application-fallow; MT-M-T, Minimum-till-manure application-triticale; MT-NM-F, Minimum-till-no manure-fallow; MT-NM-T, Minimum-till-no manure-triticale. Treatments with manure were applied annually at a target rate of 52 Mg ha^{-1} on a dry weight basis. **GRACEnet treatments:** Control, no synthetic fertilizer or manure; Fall compost, composted dairy manure applied in the Fall; Fall manure, dairy manure applied in the Fall; Spr manure, dairy manure applied in the Spring; Spr super-U, Super-U applied annually in the spring based on soil test N; Urea, Urea applied annually in the spring based on soil test N. Compost and manure applications were made on a dry weight basis according to crop rotation at target application rates of 33 Mg ha^{-1} and 52 Mg ha^{-1}, respectively. **LT manure treatments:** 18A, dairy manure applied annually at a rate of 18 Mg ha^{-1}; 18B, dairy manure applied biennially at a rate of 18 Mg ha^{-1}; 36A, dairy manure applied annually at a rate of 36 Mg ha^{-1}; 36B, dairy manure applied biennially at a rate of 36 Mg ha^{-1}; 52A, dairy manure applied annually at a rate of 52 Mg ha^{-1}; 52B, dairy manure applied biennially at a rate of 52 Mg ha^{-1}; Control, no synthetic fertilizer or manure; Fertilizer, synthetic fertilizer. All target manure application rates are on a dry weight basis.

[c] **Percent bias:** PBIAS, the tendency of simulated values to be larger or smaller than corresponding observed values; the optimal PBIAS value is 0 with positive and negative values indicating overestimation or underestimation bias, respectively. **Nash-Sutcliffe model efficiency coefficient:** NSE, describes the predictive accuracy of a model ranging from negative infinity to 1, a perfect model; when NSE is equal to 0 the model has the same predictive ability as the mean of observations. **Mean absolute error:** MAE, the calculated average of absolute errors between simulated and observed values.

(S3)

	PBIAS		NSE		MAE	
	Default	Calibrate	Default	Calibrate	Default	Calibrate
	Nitrogen Mineralization, kg ha-1					
CoverCrop	-10.0	20.2	0.37	0.13	51	61
CT-M-F	27.0	46.5	0.68	0.11	41	71
CT-M-T	26.6	61.0	0.61	-0.73	39	89
CT-NM-F	-79.8	-50.8	-0.84	0.17	60	38
CT-NM-T	-81.3	-53.1	-1.17	-0.04	73	50
MT-M-F	-	-	-	-	-	-
MT-M-T	-	-	-	-	-	-
MT-NM-F	-20.0	102.7	0.42	-0.15	19	27
MT-NM-T	-270.2	-533.1	-8.75	-33.45	38	74
GRACEnet	-42.4	-33.7	0.33	0.54	59	48
Control	-65.7	-57.7	-0.90	-0.44	76	66
Fall compost	-	-	-	-	-	-
Fall manure	-20.8	-11.6	0.79	0.91	38	25
Spr manure	-34.8	-26.1	0.53	0.72	54	43
Spr super-U	-	-	-	-	-	-
Spr Urea	-62.0	-53.6	-0.71	-0.25	68	59
LT Manure	-30.9	6.2	0.70	0.92	121	59
18A	-36.4	0.3	0.52	0.99	144	23
18B	-34.6	26.6	0.51	0.68	82	67
36A	-13.3	16.2	0.92	0.89	68	81
36B	-41.5	-5.5	0.38	0.94	172	59
52A	-2.3	21.1	0.98	0.82	37	130
52B	-33.5	-2.5	0.57	0.96	164	51
Control	-73.3	-14.1	-1.06	0.89	172	34
Fertilizer	-69.5	-8.8	-0.74	0.90	134	28

[b] **Cover Crop treatments:** CT-M-F, conventional tillage-manure application-fallow; CT-M-T, conventional tillage-manure application-triticale; CT-NM-F, conventional tillage-no manure-fallow; CT-NM-T, conventional tillage-no manure-triticale; MT-M-F, Minimum-till-manure application-fallow; MT-M-T, Minimum-till-manure application-triticale; MT-NM-F, Minimum-till-no manure-fallow; MT-NM-T, Minimum-till-no manure-triticale. Treatments with manure were applied annually at a target rate of 52 Mg ha^{-1} on a dry weight basis. **GRACEnet treatments:** Control, no synthetic fertilizer or manure; Fall compost, composted dairy manure applied in the Fall; Fall manure, dairy manure applied in the Fall; Spr manure, dairy manure applied in the Spring; Spr super-U, Super-U applied annually in the spring based on soil test N; Urea, Urea applied annually in the spring based on soil test N. Compost and manure applications were made on a dry weight basis according to crop rotation at target application rates of 33 Mg ha^{-1} and 52 Mg ha^{-1}, respectively. **LT manure treatments:** 18A, dairy manure applied annually at a rate of 18 Mg ha^{-1}; 18B, dairy manure applied biennially at a rate of 18 Mg ha^{-1}; 36A, dairy manure applied annually at a rate of 36 Mg ha^{-1}; 36B, dairy manure applied biennially at a rate of 36 Mg ha^{-1}; 52A, dairy manure applied annually at a rate of 52 Mg ha^{-1}; 52B, dairy manure applied biennially at a rate of 52 Mg ha^{-1}; Control, no synthetic fertilizer or manure; Fertilizer, synthetic fertilizer. All target manure application rates are on a dry weight basis.

[c] **Percent bias:** PBIAS, the tendency of simulated values to be larger or smaller than corresponding observed values; the optimal PBIAS value is 0 with positive and negative values indicating overestimation or underestimation bias, respectively. **Nash-Sutcliffe model efficiency coefficient:** NSE, describes the predictive accuracy of a model ranging from negative infinity to 1, a perfect model; when NSE is equal to 0 the model has the same predictive ability as the mean of observations. **Mean absolute error:** MAE, the calculated average of absolute errors between simulated and observed values.

(S4)

	PBIAS		NSE		MAE	
	Default	Calibrate	Default	Calibrate	Default	Calibrate
	Soil Water, Θv					
CoverCrop	34.1	27.9	-4.72	-3.49	0.09	0.08
CT-M-F	48.6	45.4	-7.83	-6.97	0.12	0.11
CT-M-T	29.1	24.4	-3.41	-2.75	0.08	0.07
CT-NM-F	19.6	15.3	-2.23	-1.76	0.06	0.06
CT-NM-T	11.9	3.0	-1.82	-1.14	0.06	0.05
MT-M-F	52.6	46.8	-8.34	-6.69	0.13	0.12
MT-M-T	39.3	34.1	-4.79	-3.54	0.10	0.08
MT-NM-F	36.3	27.5	-4.61	-2.43	0.09	0.07
MT-NM-T	34.2	25.4	-4.94	-2.74	0.09	0.07
GRACEnet	46.1	9.4	-2.03	-0.03	0.11	0.06
Control	41.7	6.3	-1.36	0.18	0.10	0.05
Fall compost	49.7	12.1	-2.32	-0.09	0.11	0.06
Fall manure	53.3	16.5	-2.84	-0.39	0.13	0.07
Spr manure	46.1	9.5	-2.34	-0.16	0.12	0.06
Spr super-U	42.5	5.7	-1.65	0.13	0.10	0.05
Spr Urea	43.0	5.9	-1.78	0.10	0.10	0.05
LT Manure	14.3	4.2	-0.73	-1.07	0.08	0.09
18A	12.0	4.7	-0.77	-1.09	0.08	0.09
18B	14.1	-3.2	-0.64	-1.38-	0.08	0.10
36A	18.3	2.0	-1.12	-1.69	0.09	0.11
36B	11.3	4.0	-0.80	-1.07	0.08	0.09
52A	18.8	10.0	-1.13	-1.38	0.09	0.10
52B	14.0	-2.3	-0.86	-1.54	0.08	0.10
Control	22.3	14.5	-0.36	-0.29	0.07	0.07
Fertilizer	5.0	-4.5	-0.39	-0.90	0.07	0.09

[b] **Cover Crop treatments:** CT-M-F, conventional tillage-manure application-fallow; CT-M-T, conventional tillage-manure application-triticale; CT-NM-F, conventional tillage-no manure-fallow; CT-NM-T, conventional tillage-no manure-triticale; MT-M-F, Minimum-till-manure application-fallow; MT-M-T, Minimum-till-manure application-triticale; MT-NM-F, Minimum-till-no manure-fallow; MT-NM-T, Minimum-till-no manure-triticale. Treatments with manure were applied annually at a target rate of 52 Mg ha^{-1} on a dry weight basis. **GRACEnet treatments:** Control, no synthetic fertilizer or manure; Fall compost, composted dairy manure applied in the Fall; Fall manure, dairy manure applied in the Fall; Spr manure, dairy manure applied in the Spring; Spr super-U, Super-U applied annually in the spring based on soil test N; Urea, Urea applied annually in the spring based on soil test N. Compost and manure applications were made on a dry weight basis according to crop rotation at target application rates of 33 Mg ha^{-1} and 52 Mg ha^{-1}, respectively. **LT manure treatments:** 18A, dairy manure applied annually at a rate of 18 Mg ha^{-1}; 18B, dairy manure applied biennially at a rate of 18 Mg ha^{-1}; 36A, dairy manure applied annually at a rate of 36 Mg ha^{-1}; 36B, dairy manure applied biennially at a rate of 36 Mg ha^{-1}; 52A, dairy manure applied annually at a rate of 52 Mg ha^{-1}; 52B, dairy manure applied biennially at a rate of 52 Mg ha^{-1}; Control, no synthetic fertilizer or manure; Fertilizer, synthetic fertilizer. All target manure application rates are on a dry weight basis.

[c] **Percent bias:** PBIAS, the tendency of simulated values to be larger or smaller than corresponding observed values; the optimal PBIAS value is 0 with positive and negative values indicating overestimation or underestimation bias, respectively. **Nash-Sutcliffe model efficiency coefficient:** NSE, describes the predictive accuracy of a model ranging from negative infinity to 1, a perfect model; when NSE is equal to 0 the model has the same predictive ability as the mean of observations. **Mean absolute error:** MAE, the calculated average of absolute errors between simulated and observed values.

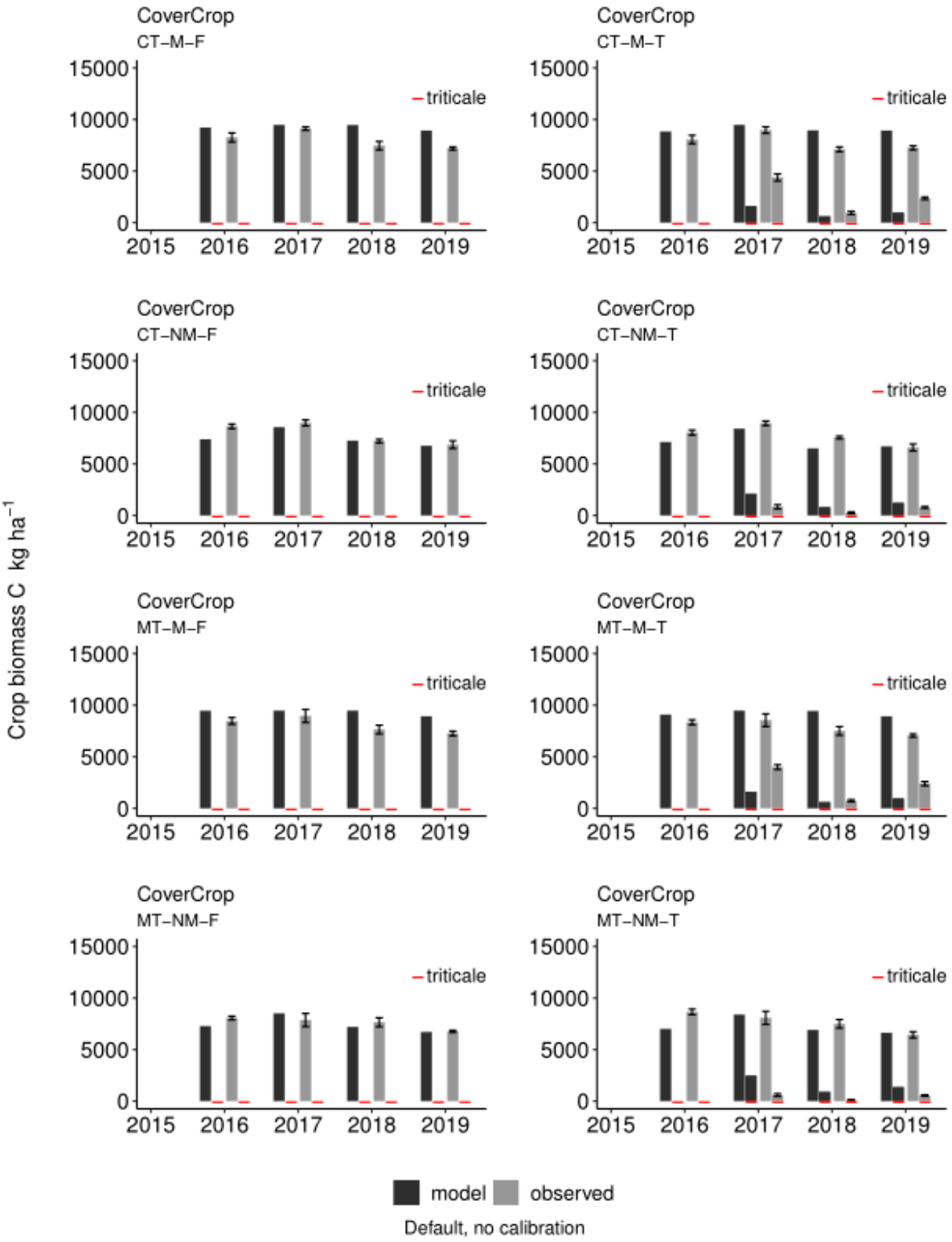
(S5)

	PBIAS		NSE		MAE	
	Default	Calibrate	Default	Calibrate	Default	Calibrate
	Estimated Actual Evapotranspiration, mm					
CoverCrop	-44.5	-43.7	-1.17	-1.11	244	240
CT-M-F	-21.4	-22.9	0.55	0.49	118	127
CT-M-T	-61.7	-58.0	-2.56	-2.17	377	318
CT-NM-F	-27.2	-24.4	0.27	0.42	152	136
CT-NM-T	-51.2	-54.7	-1.50	-1.86	282	301
MT-M-F	-25.5	-27.8	0.38	0.27	139	151
MT-M-T	-71.3	-68.3	-3.71	-3.32	387	371
MT-NM-F	-36.1	-29.8	-0.27	0.14	200	166
MT-NM-T	-61.7	-64.0	-2.57	-2.84	339	352
GRACEnet	-37.4	-34.0	-1.92	-1.55	303	275
Control	-38.9	-35.8	-1.91	-1.64	316	291
Fall compost	-36.8	-33.2	-1.93	-1.53	299	269
Fall manure	-36.5	-32.7	-1.86	-1.47	296	265
Spr manure	-36.8	-33.3	-1.88	-1.49	298	270
Spr super-U	-37.7	-34.4	-1.98	-1.58	306	279
Spr Urea	-37.8	-34.4	-1.99	-1.58	307	279
LT Manure	-14.3	-7.9	0.25	0.59	150	80
18A	-12.0	-6.0	0.17	0.67	121	74
18B	-12.5	-6.8	0.21	0.68	119	74
36A	-11.4	-5.6	0.21	0.69	118	72
36B	-12.0	-6.6	0.22	0.70	118	72
52A	-10.3	-5.2	0.22	0.68	118	72
52B	-11.8	-6.3	0.23	0.71	117	71
Control	-34.4	-19.0	-1.71	-0.04	225	126
Fertilizer	-16.5	-8.0	-0.18	0.64	143	80

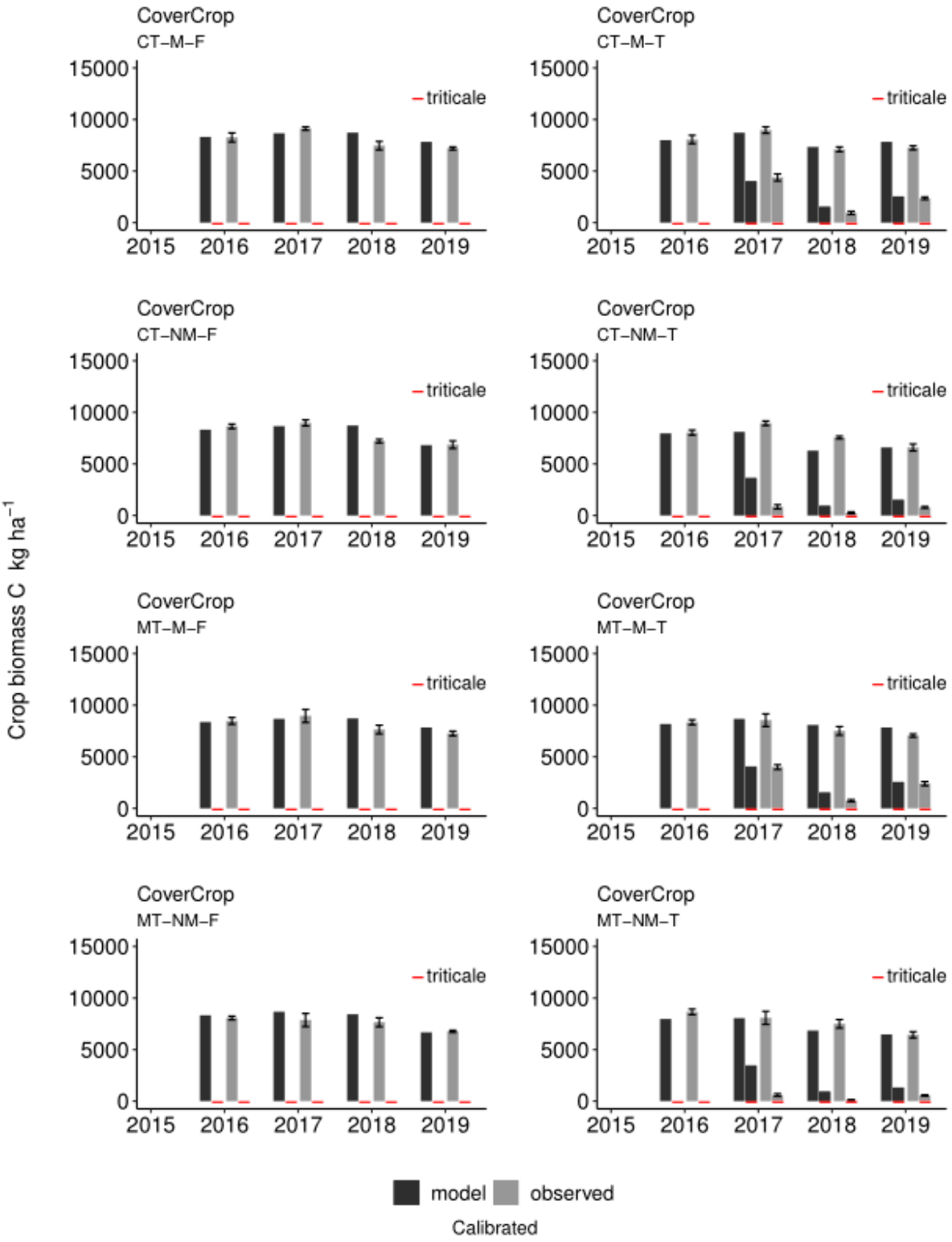
[b] **Cover Crop treatments:** CT-M-F, conventional tillage-manure application-fallow; CT-M-T, conventional tillage-manure application-triticale; CT-NM-F, conventional tillage-no manure-fallow; CT-NM-T, conventional tillage-no manure-triticale; MT-M-F, Minimum-till-manure application-fallow; MT-M-T, Minimum-till-manure application-triticale; MT-NM-F, Minimum-till-no manure-fallow; MT-NM-T, Minimum-till-no manure-triticale. Treatments with manure were applied annually at a target rate of 52 Mg ha^{-1} on a dry weight basis. **GRACEnet treatments:** Control, no synthetic fertilizer or manure; Fall compost, composted dairy manure applied in the Fall; Fall manure, dairy manure applied in the Fall; Spr manure, dairy manure applied in the Spring; Spr super-U, Super-U applied annually in the spring based on soil test N; Urea, Urea applied annually in the spring based on soil test N. Compost and manure applications were made on a dry weight basis according to crop rotation at target application rates of 33 Mg ha^{-1} and 52 Mg ha^{-1}, respectively. **LT manure treatments:** 18A, dairy manure applied annually at a rate of 18 Mg ha^{-1}; 18B, dairy manure applied biennially at a rate of 18 Mg ha^{-1}; 36A, dairy manure applied annually at a rate of 36 Mg ha^{-1}; 36B, dairy manure applied biennially at a rate of 36 Mg ha^{-1}; 52A, dairy manure applied annually at a rate of 52 Mg ha^{-1}; 52B, dairy manure applied biennially at a rate of 52 Mg ha^{-1}; Control, no synthetic fertilizer or manure; Fertilizer, synthetic fertilizer. All target manure application rates are on a dry weight basis.

[c] **Percent bias:** PBIAS, the tendency of simulated values to be larger or smaller than corresponding observed values; the optimal PBIAS value is 0 with positive and negative values indicating overestimation or underestimation bias, respectively. **Nash-Sutcliffe model efficiency coefficient:** NSE, describes the predictive accuracy of a model ranging from negative infinity to 1, a perfect model; when NSE is equal to 0 the model has the same predictive ability as the mean of observations. **Mean absolute error:** MAE, the calculated average of absolute errors between simulated and observed values.

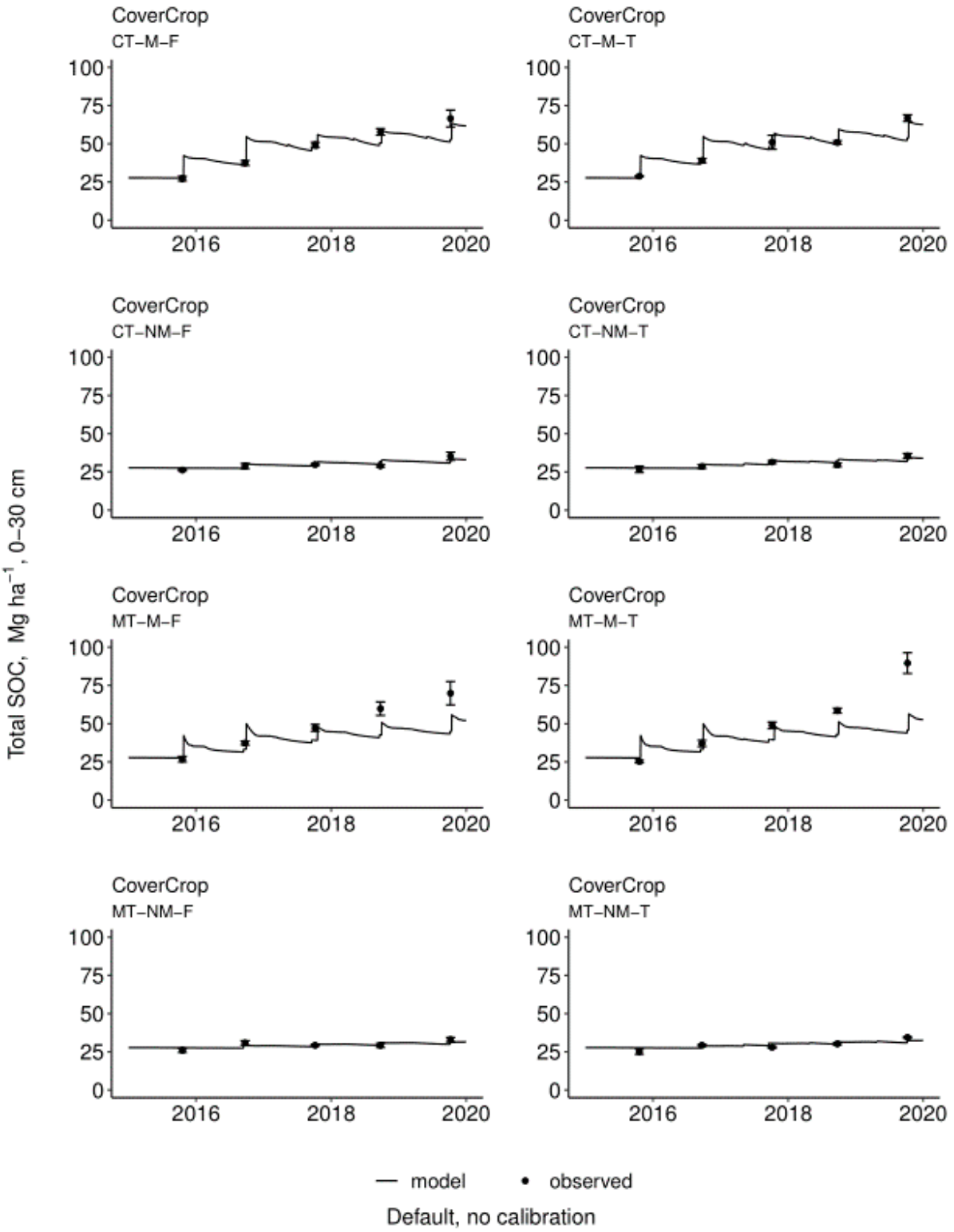
(S6)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
triticale
15000
10000
5000
0
2015
2016
2017
2018
2019
Crop biomass C kg ha^{-1}
model
observed
Default, no calibration

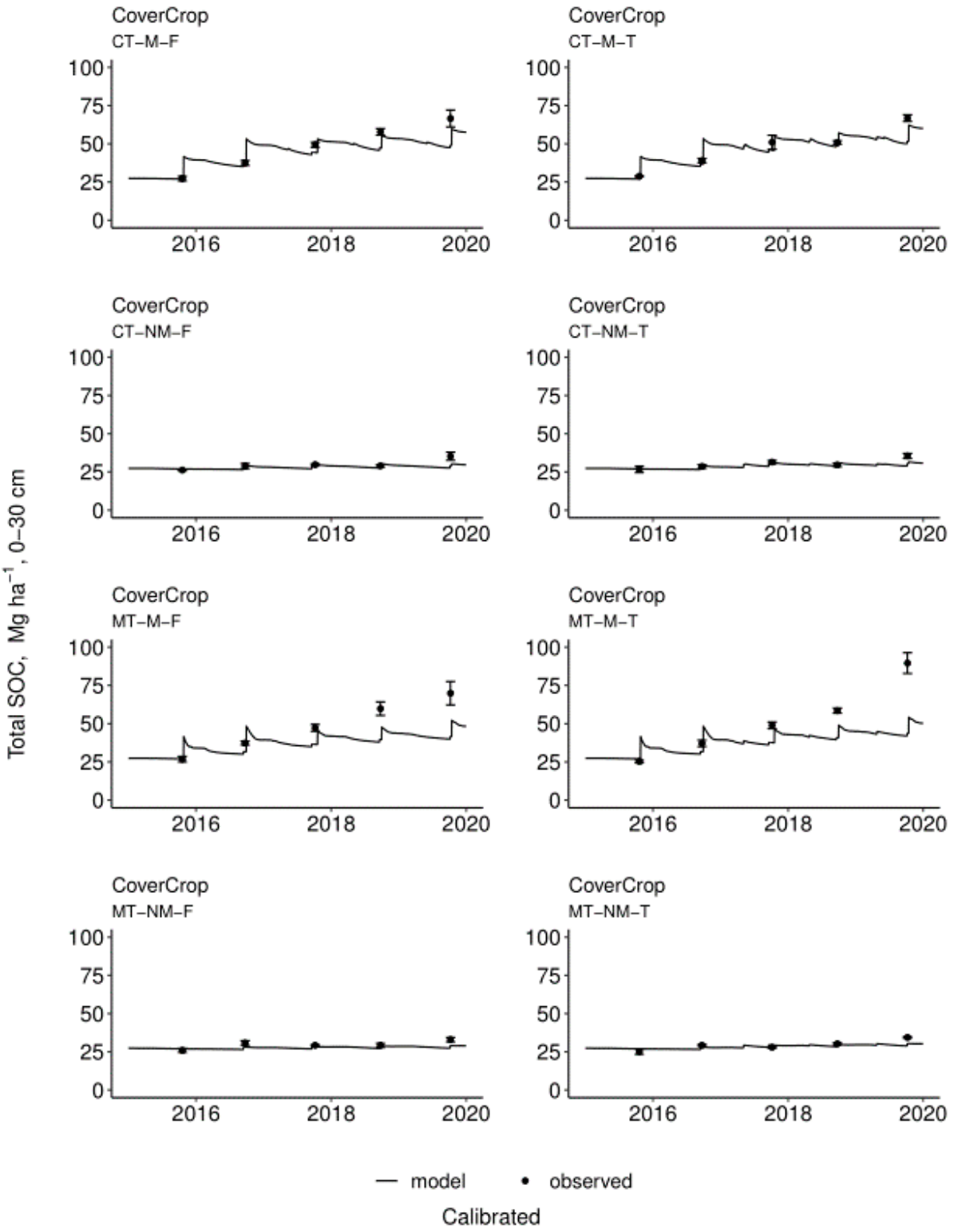
(S7)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
triticale
15000
10000
5000
0
2015
2016
2017
2018
2019
Crop biomass C kg ha^{-1}
model
observed
Calibrated

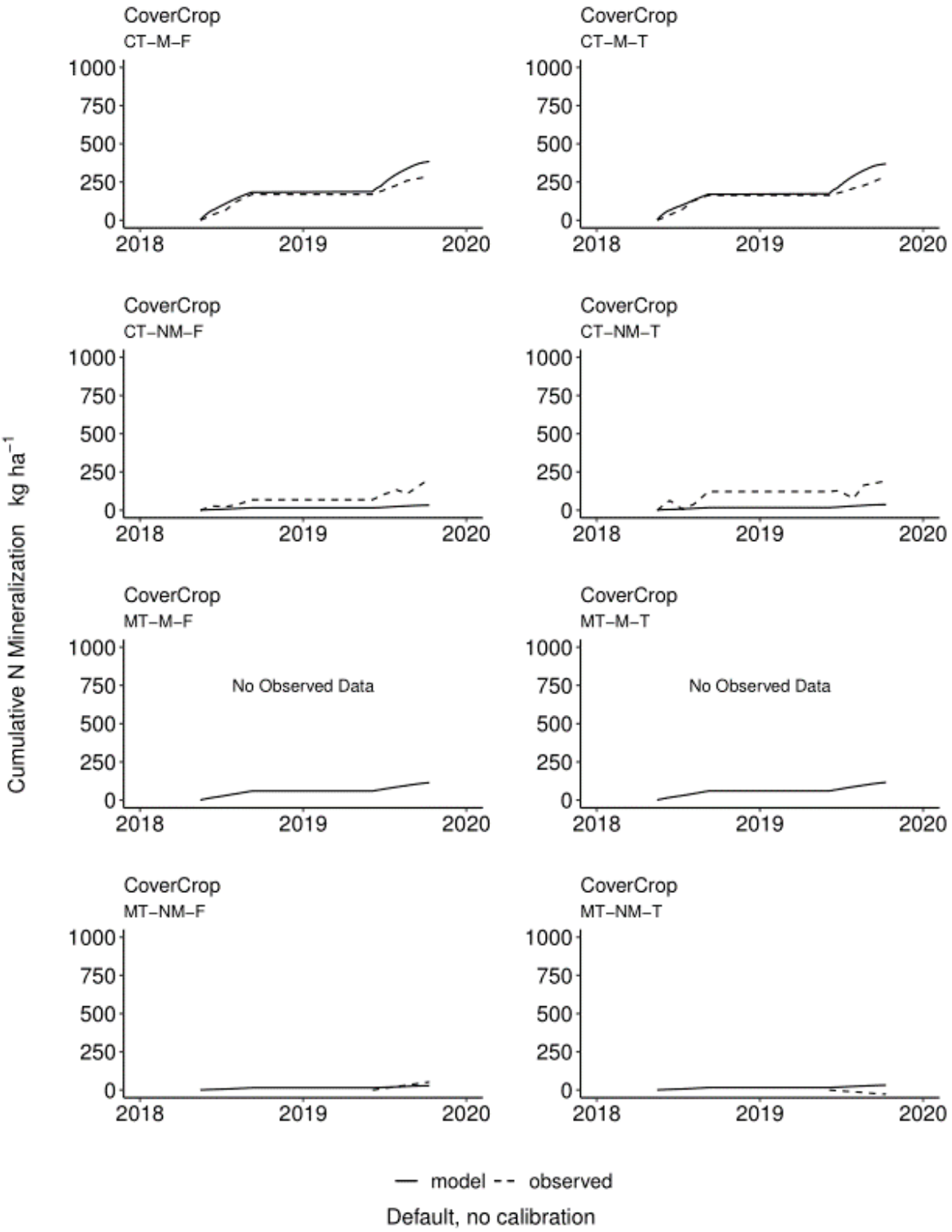
(S8)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
Total SOC, Mg ha^{-1}, 0–30 cm
0
25
50
75
100
2016
2018
2020
model
observed
Default, no calibration

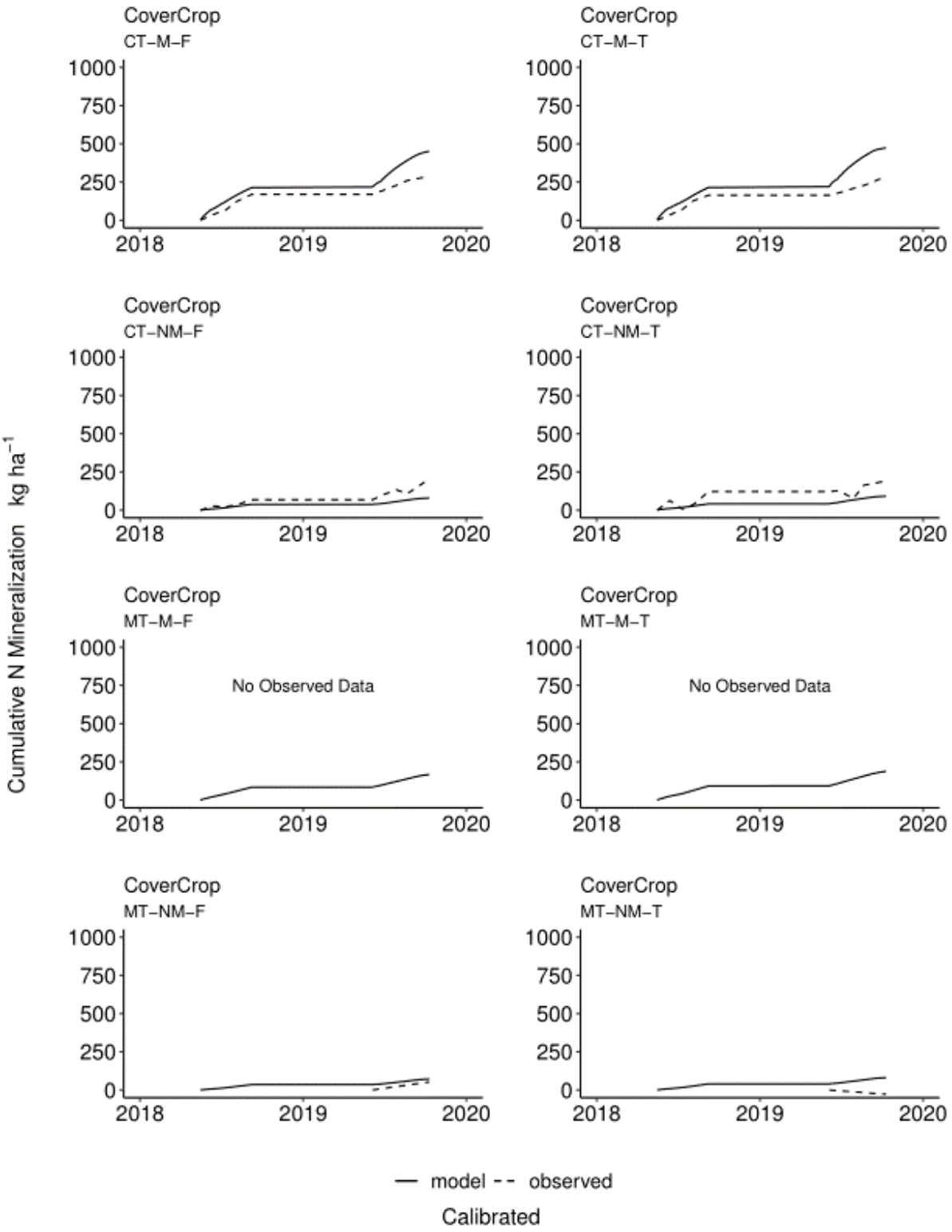
(S9)


CoverCrop
CT–M–F
CT–M–T
CT–NM–F
CT–NM–T
MT–M–F
MT–M–T
MT–NM–F
MT–NM–T
Total SOC, Mg ha^{-1}, 0–30 cm
100
75
50
25
0
2016
2018
2020
model
observed
Calibrated

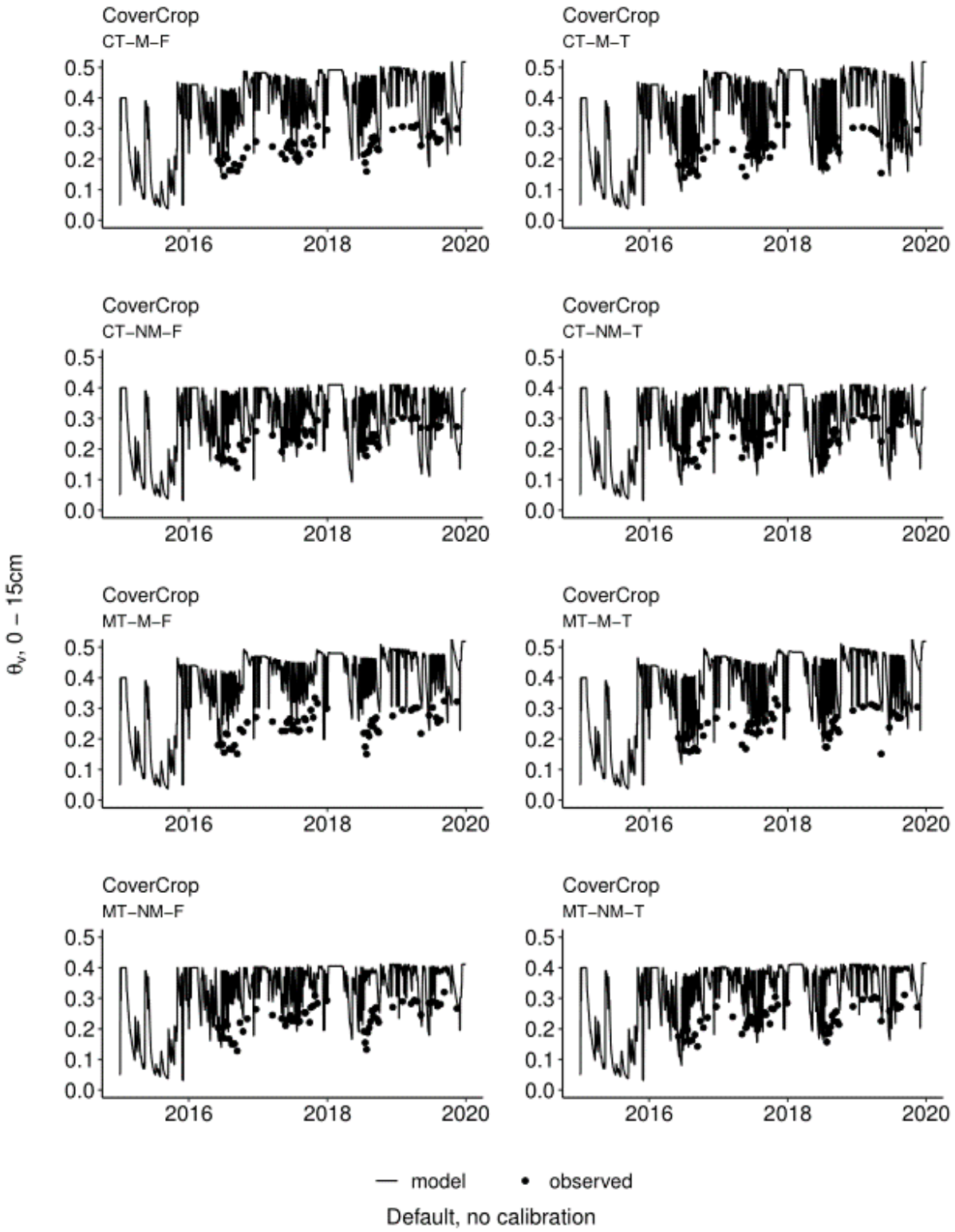
(S10)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
No Observed Data
CoverCrop
MT–M–T
No Observed Data
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
Cumulative N Mineralization kg ha^{-1}
0
250
500
750
1000
2018
2019
2020
model
observed
Default, no calibration

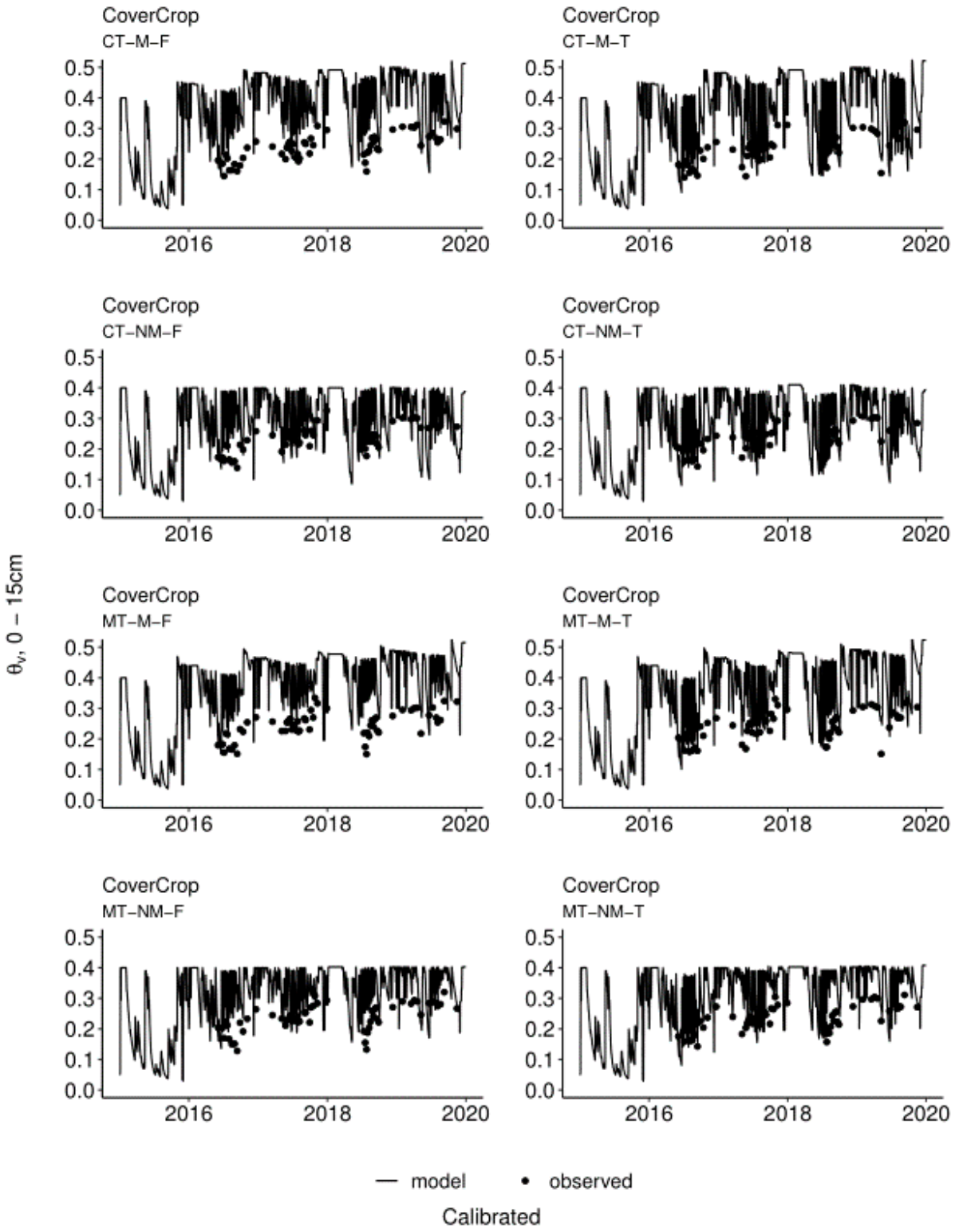
(S11)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
No Observed Data
CoverCrop
MT–M–T
No Observed Data
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
Cumulative N Mineralization kg ha^{-1}
1000
750
500
250
0
2018
2019
2020
model
observed
Calibrated

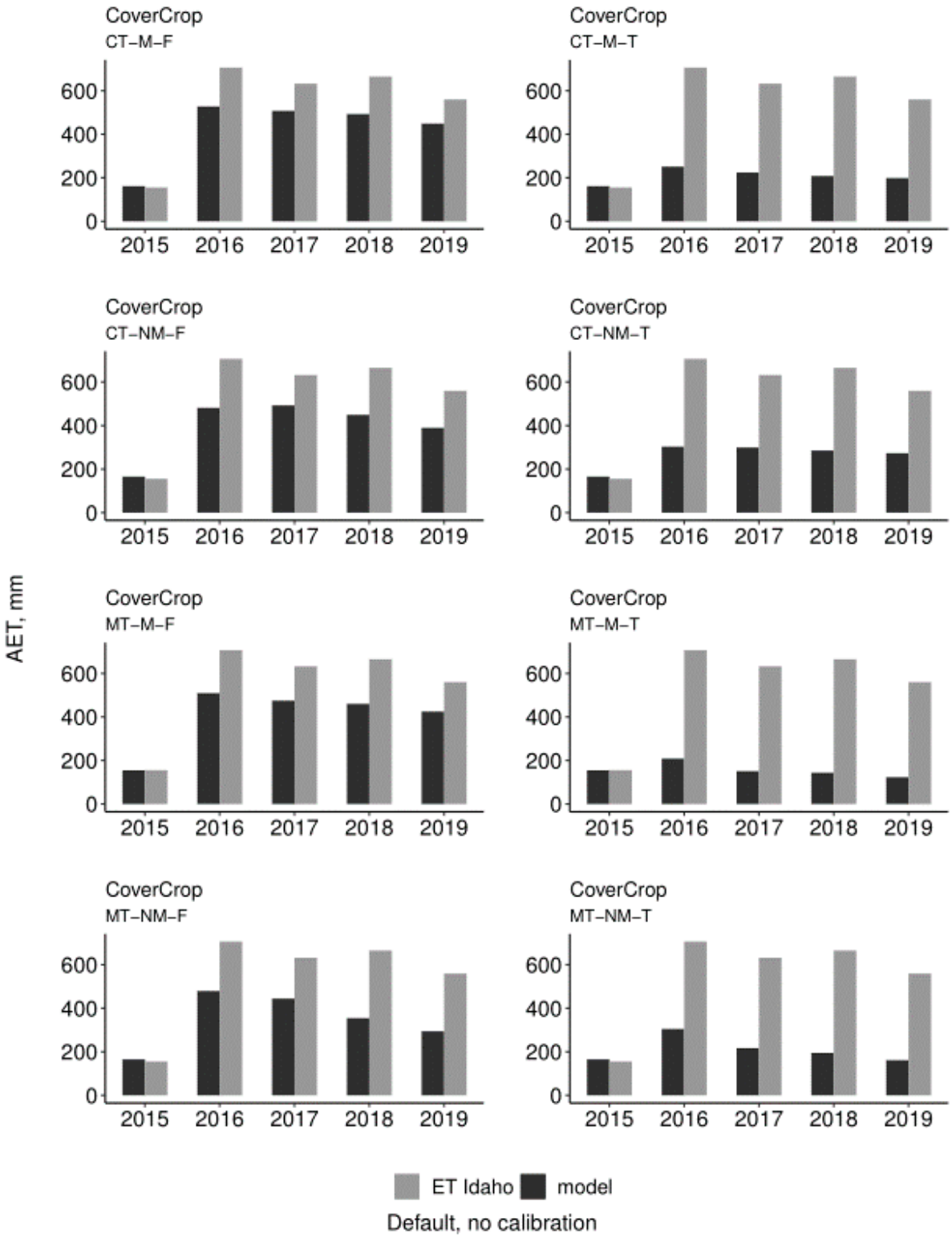
(S12)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
θv, 0 – 15cm
0.0
0.1
0.2
0.3
0.4
0.5
2016
2018
2020
model
observed
Default, no calibration

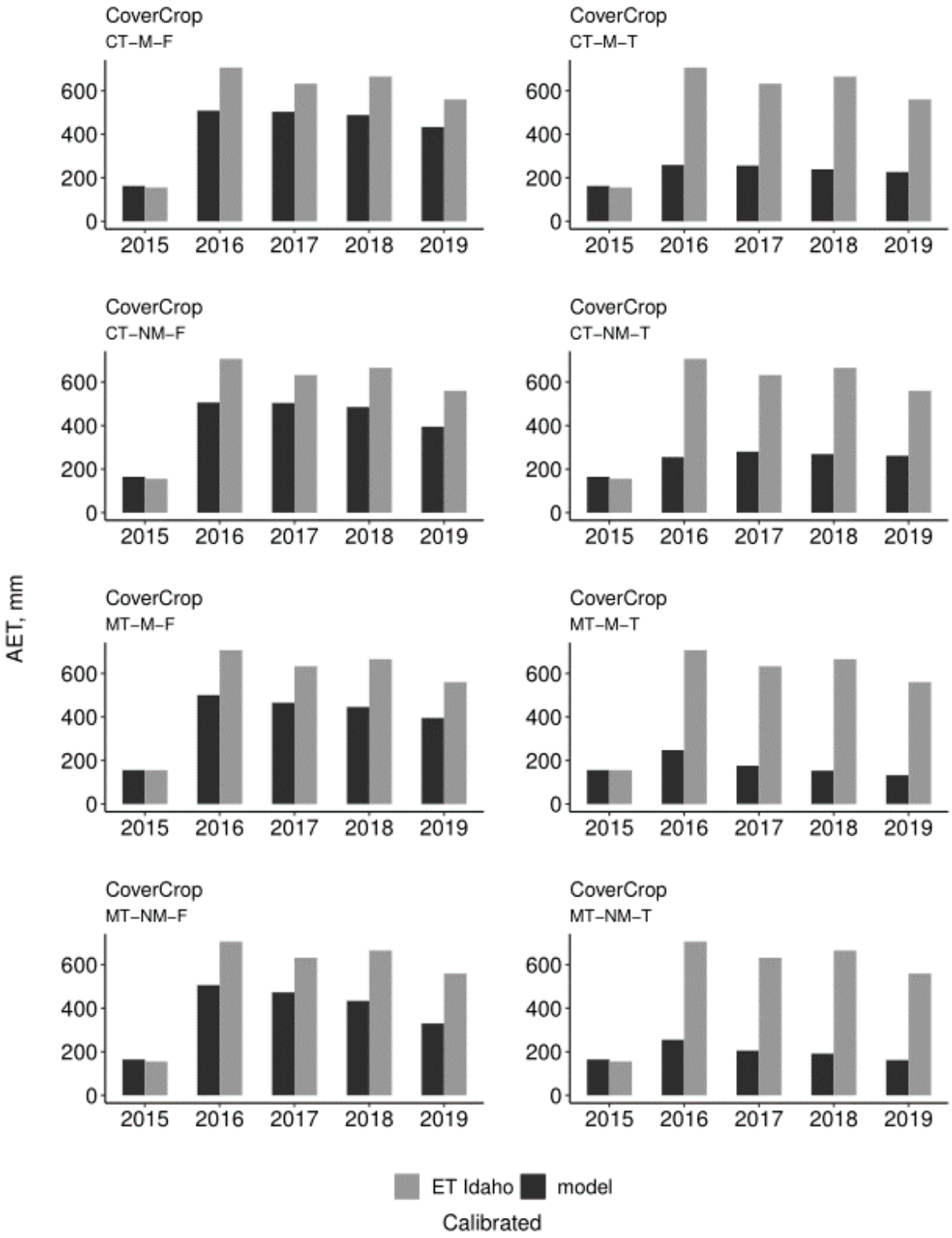
(S13)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
θv, 0 – 15cm
0.0
0.1
0.2
0.3
0.4
0.5
2016
2018
2020
model
observed
Calibrated

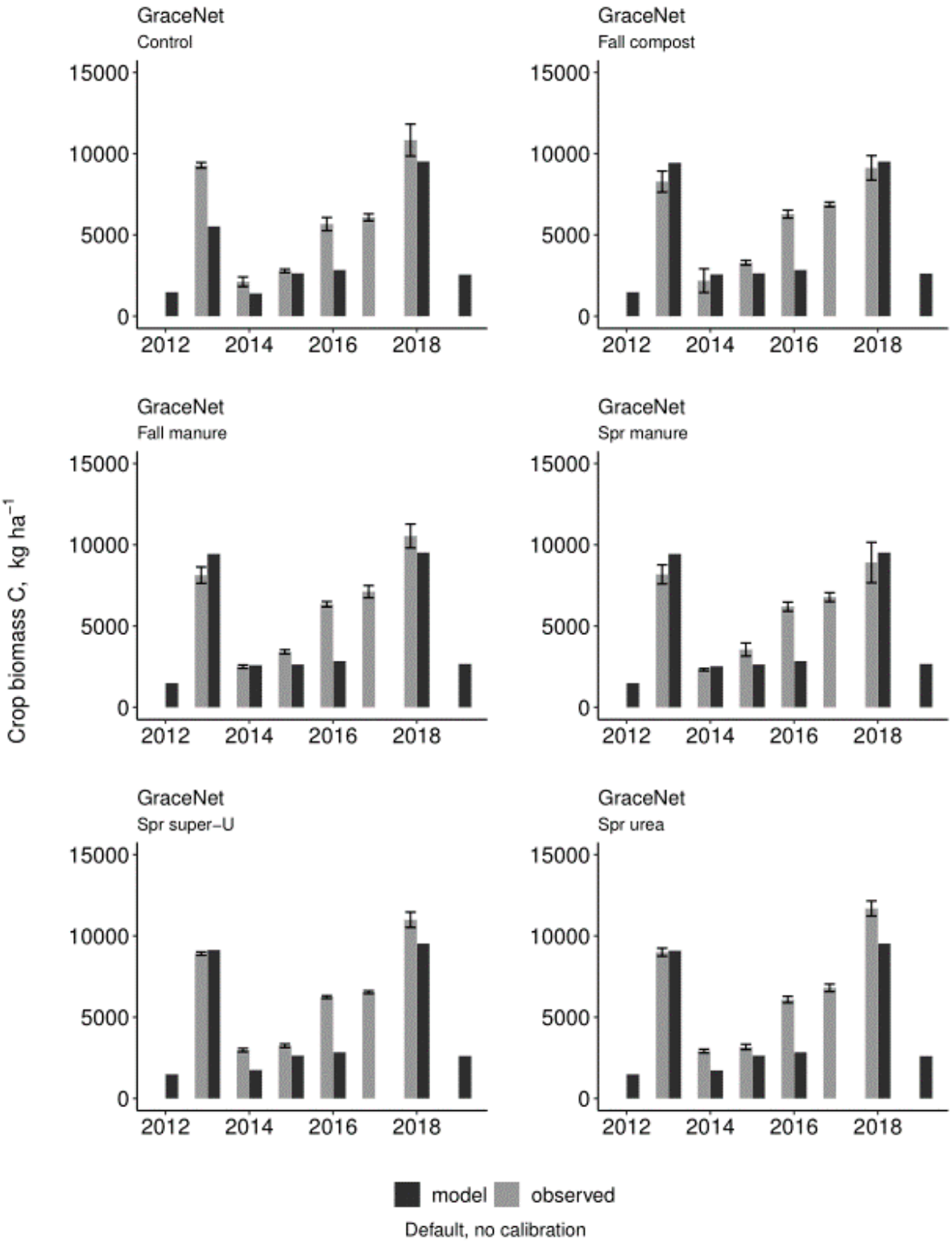
(S14)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
AET, mm
0
200
400
600
2015
2016
2017
2018
2019
ET Idaho
model
Default, no calibration

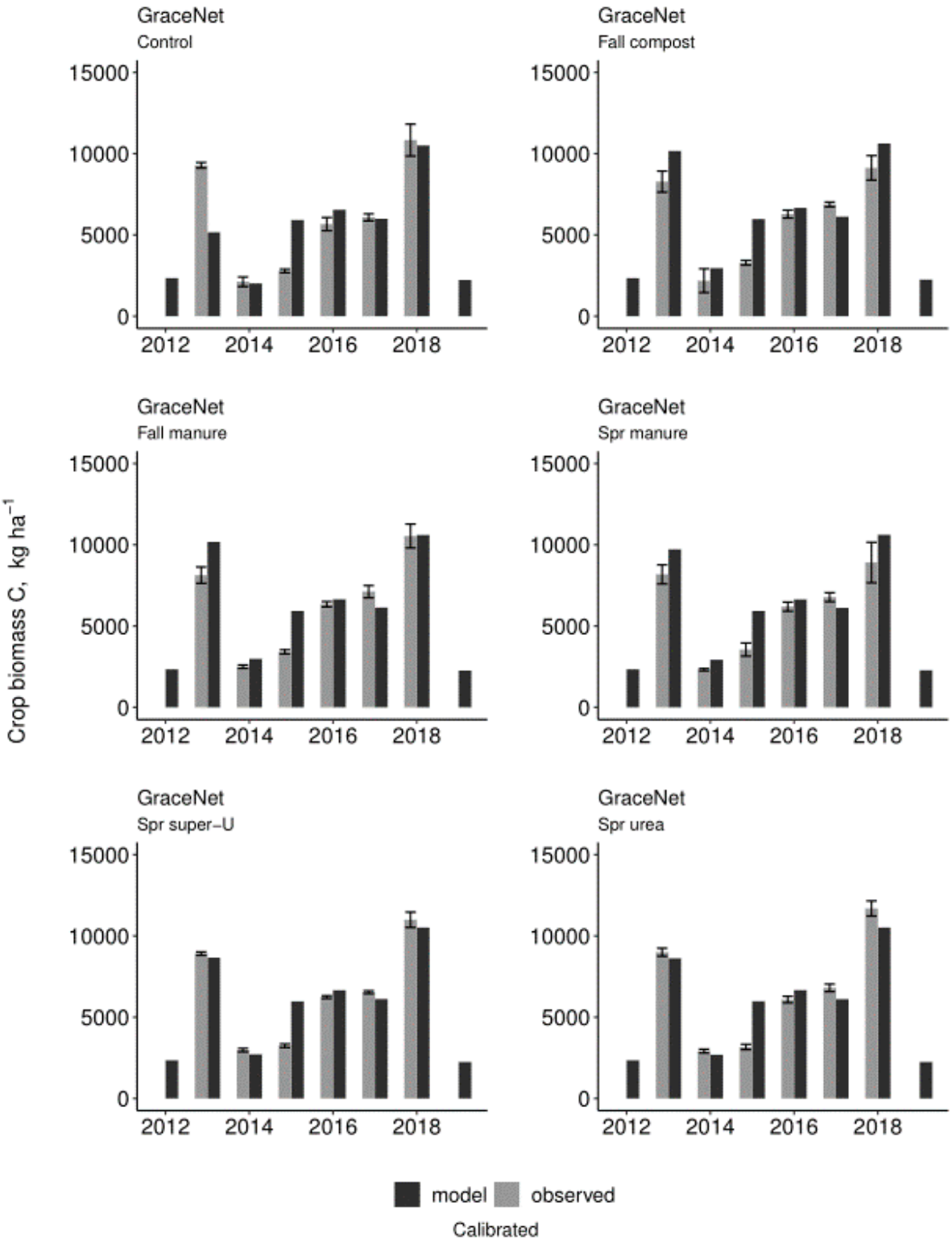
(S15)


CoverCrop
CT–M–F
CoverCrop
CT–M–T
CoverCrop
CT–NM–F
CoverCrop
CT–NM–T
CoverCrop
MT–M–F
CoverCrop
MT–M–T
CoverCrop
MT–NM–F
CoverCrop
MT–NM–T
AET, mm
0
200
400
600
2015
2016
2017
2018
2019
ET Idaho
model
Calibrated

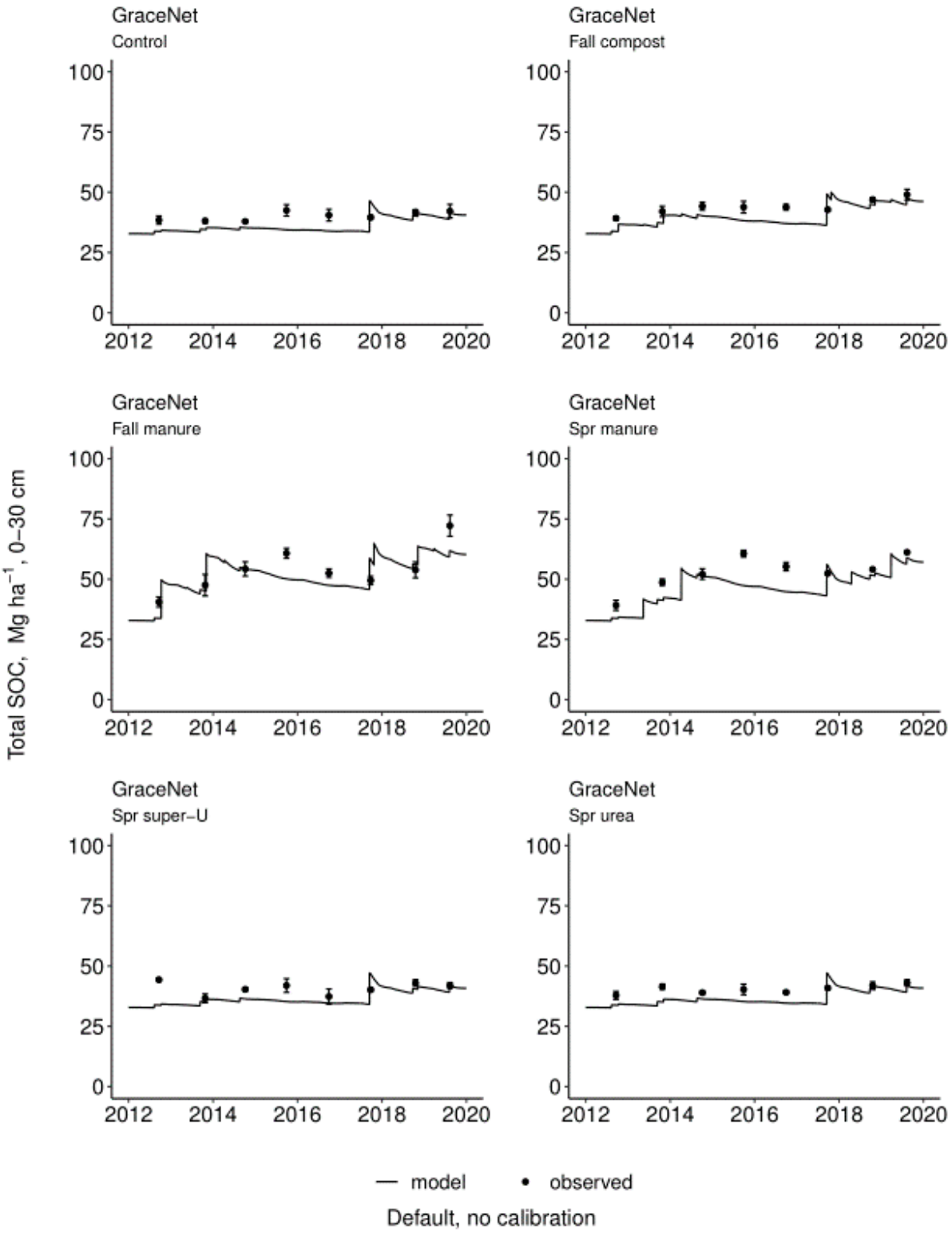
(S16)


GraceNet
Control
GraceNet
Fall compost
GraceNet
Fall manure
GraceNet
Spr manure
GraceNet
Spr super−U
GraceNet
Spr urea
Crop biomass C, kg ha−1
15000
10000
5000
0
2012
2014
2016
2018
model
observed
Default, no calibration

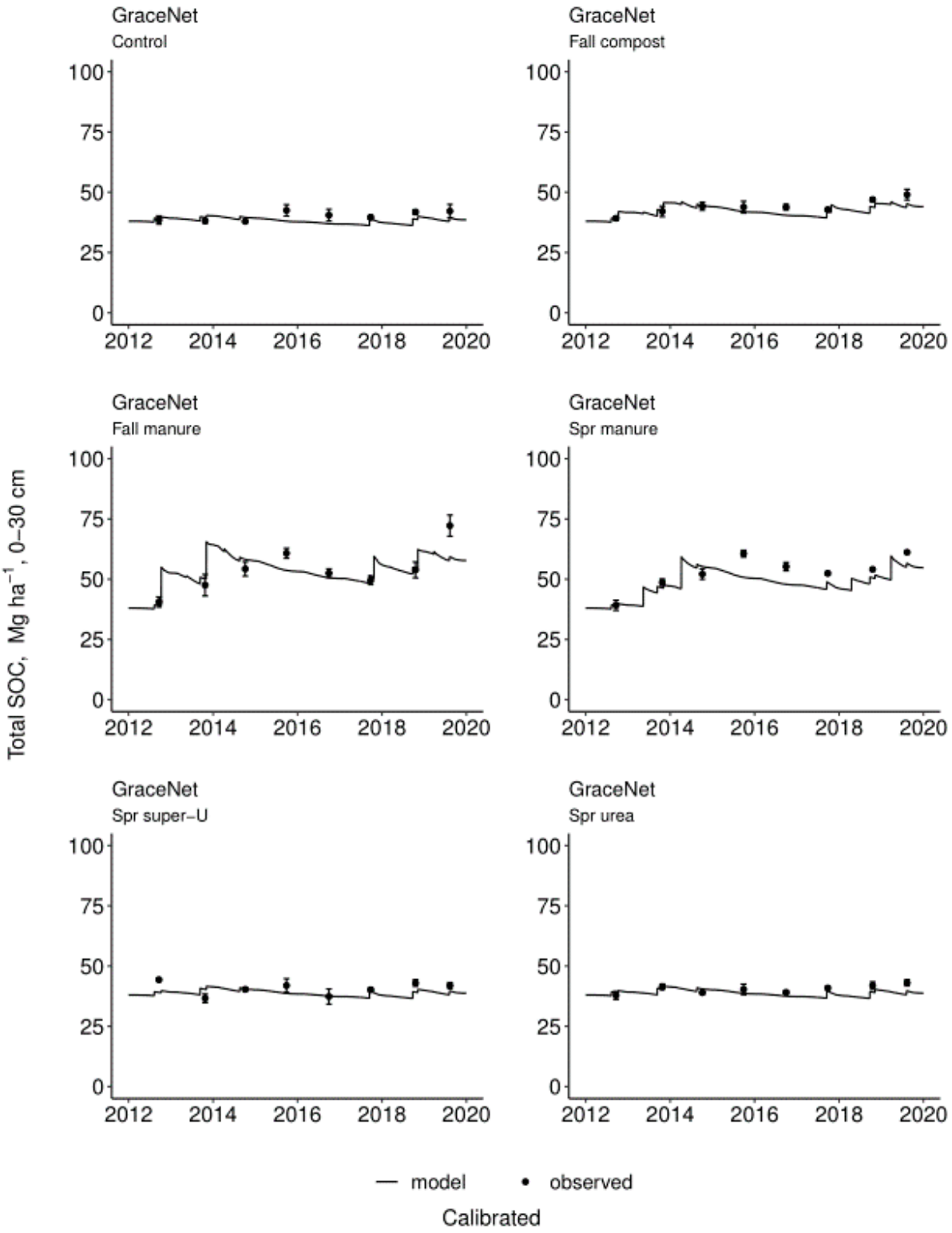
(S17)


GraceNet
Control
GraceNet
Fall compost
GraceNet
Fall manure
GraceNet
Spr manure
GraceNet
Spr super−U
GraceNet
Spr urea
Crop biomass C, kg ha−1
15000
10000
5000
0
2012
2014
2016
2018
model
observed
Calibrated

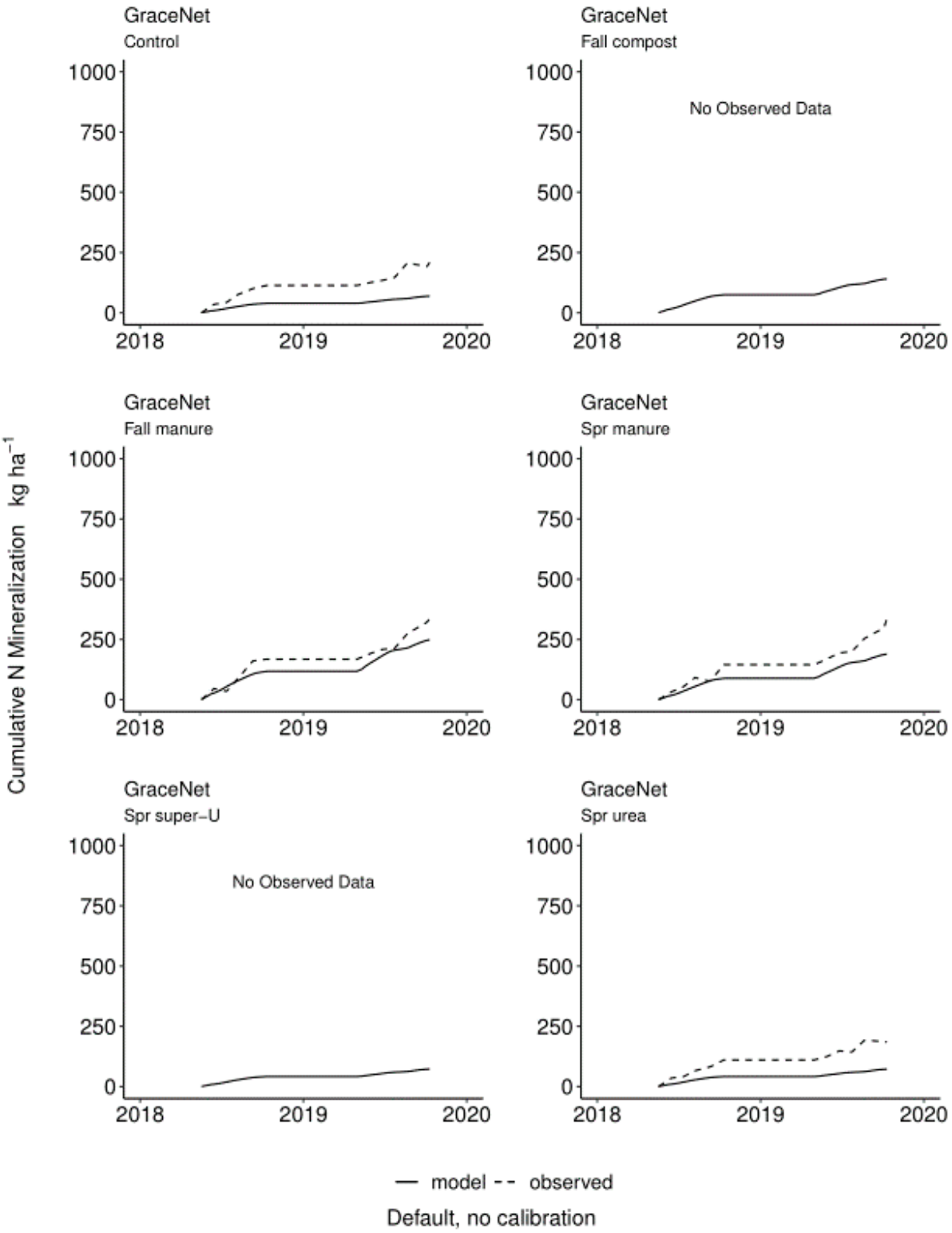
(S18)


GraceNet
Control
GraceNet
Fall compost
GraceNet
Fall manure
GraceNet
Spr manure
GraceNet
Spr super−U
GraceNet
Spr urea
Total SOC, Mg ha^{-1}, 0–30 cm
100
75
50
25
0
2012
2014
2016
2018
2020
model
observed
Default, no calibration

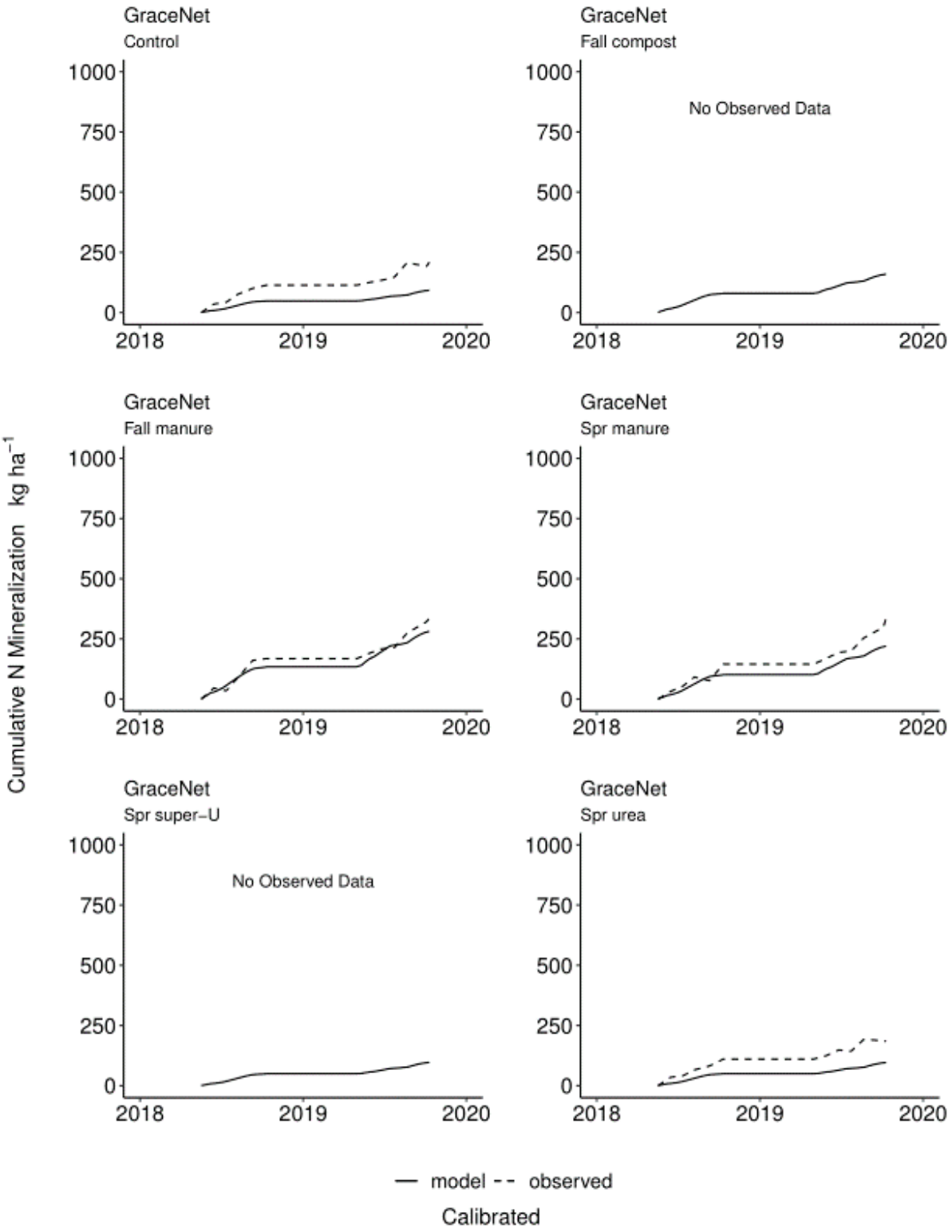
(S19)


GraceNet
Control
GraceNet
Fall compost
GraceNet
Fall manure
GraceNet
Spr manure
GraceNet
Spr super−U
GraceNet
Spr urea
Total SOC, Mg ha^{-1}, 0–30 cm
100
75
50
25
0
2012
2014
2016
2018
2020
model
observed
Calibrated

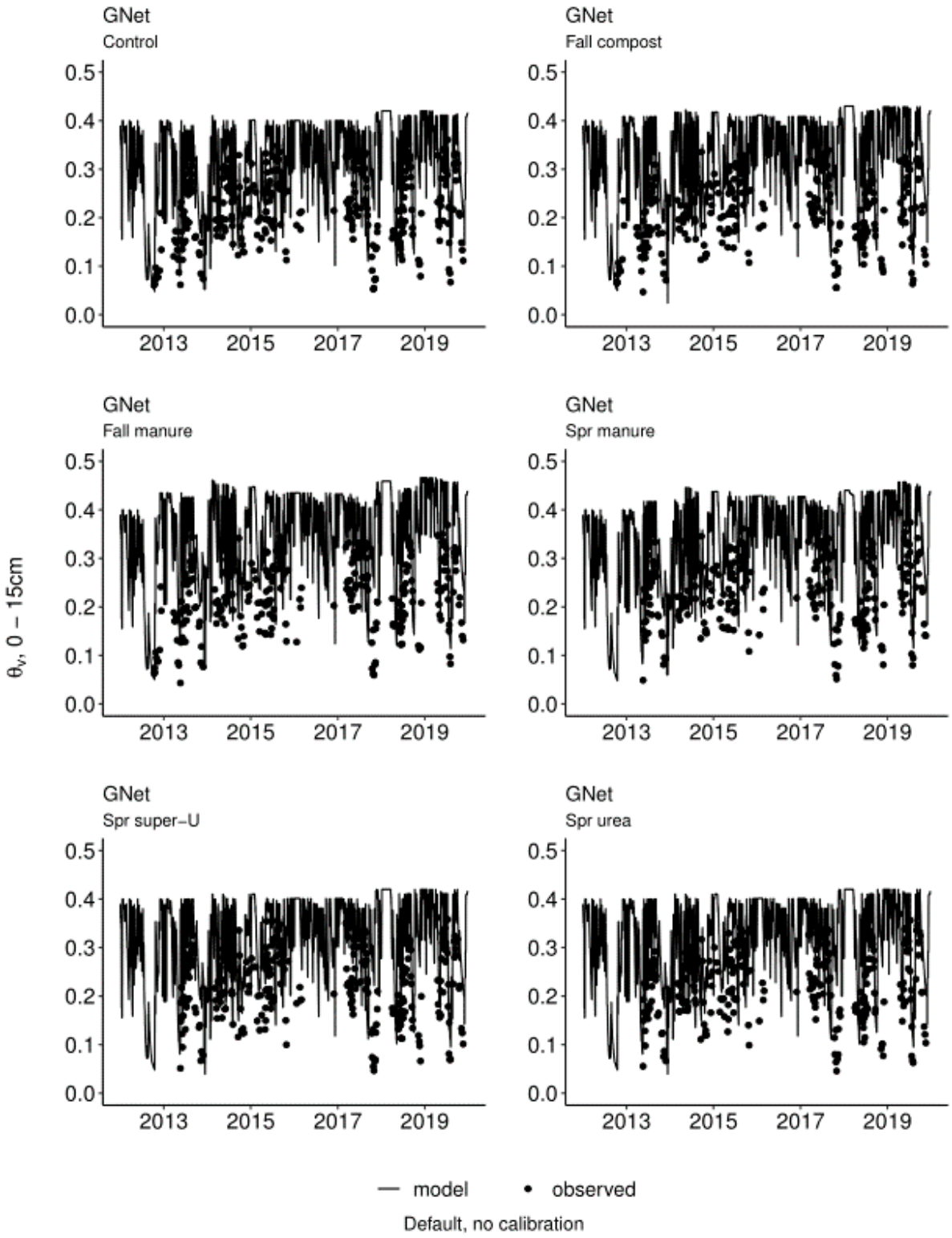
(S20)


GraceNet
Control
GraceNet
Fall compost
No Observed Data
GraceNet
Fall manure
GraceNet
Spr manure
GraceNet
Spr super−U
No Observed Data
GraceNet
Spr urea
Cumulative N Mineralization kg ha−1
1000
750
500
250
0
2018
2019
2020
model observed
Default, no calibration

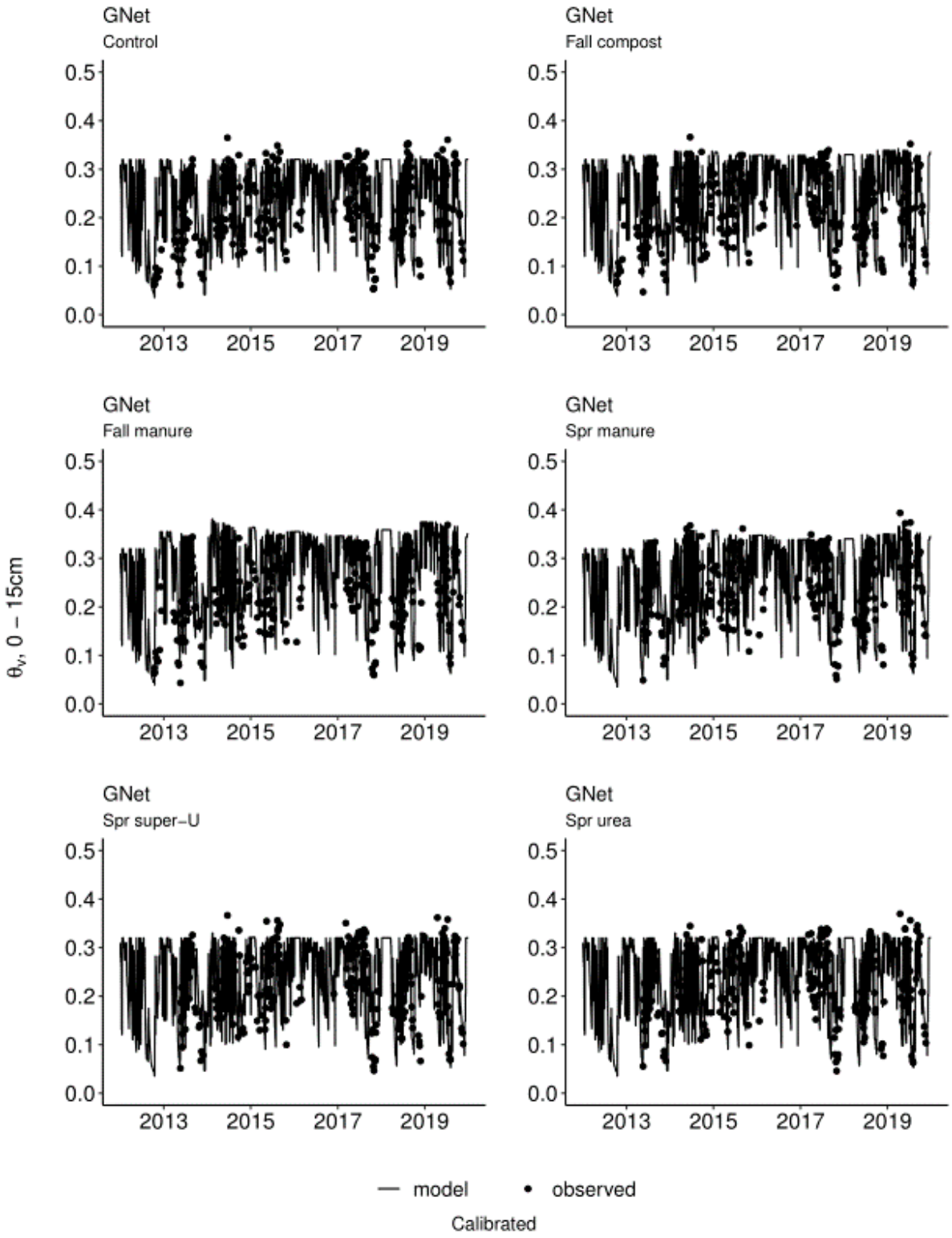
(S21)


GraceNet
Control
GraceNet
Fall compost
No Observed Data
GraceNet
Fall manure
GraceNet
Spr manure
GraceNet
Spr super−U
No Observed Data
GraceNet
Spr urea
Cumulative N Mineralization kg ha−1
1000
750
500
250
0
2018
2019
2020
model observed
Calibrated

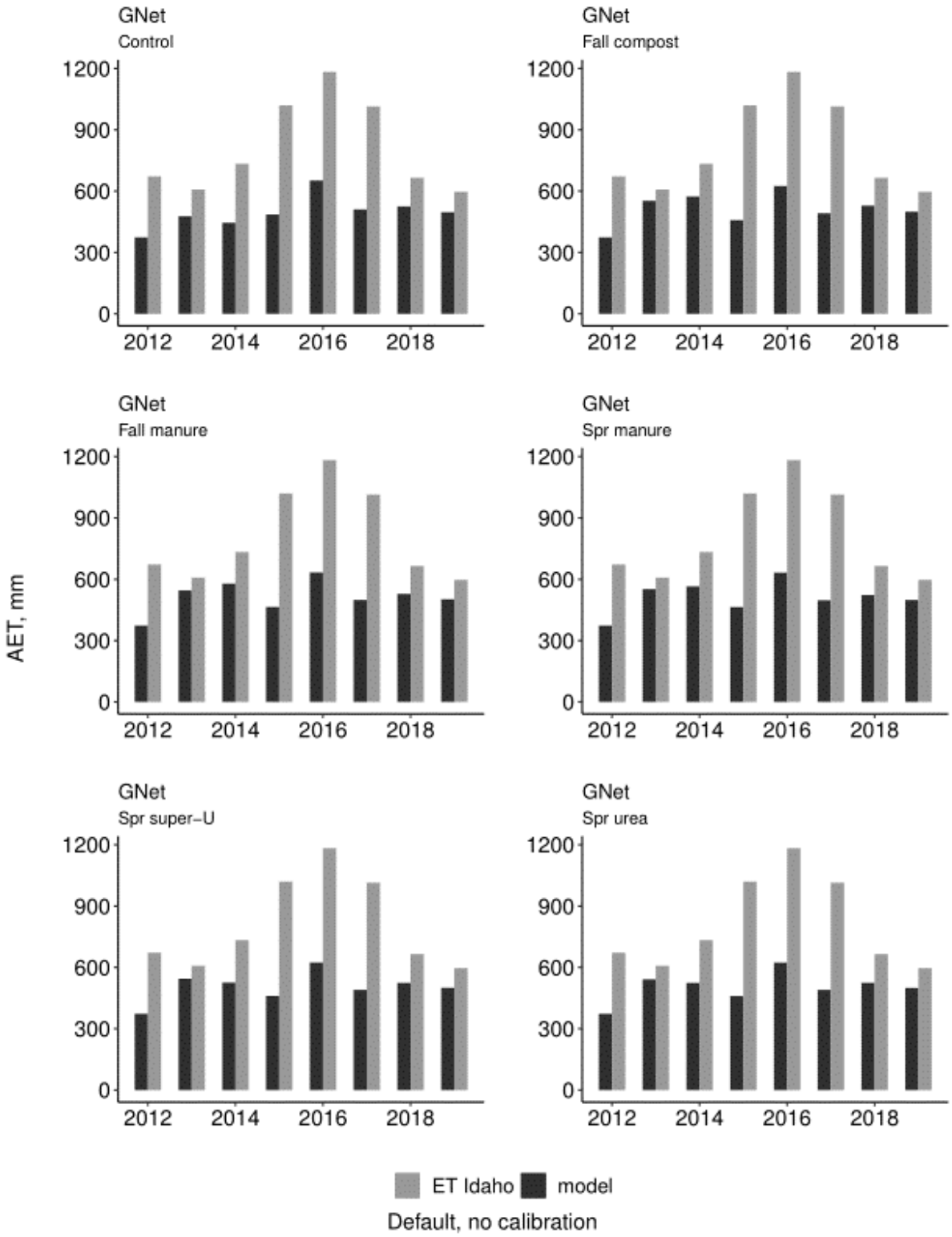
(S22)


GNet
Control
GNet
Fall compost
GNet
Fall manure
GNet
Spr manure
GNet
Spr super−U
GNet
Spr urea
θv, 0 − 15cm
0.0
0.1
0.2
0.3
0.4
0.5
2013
2015
2017
2019
model
observed
Default, no calibration

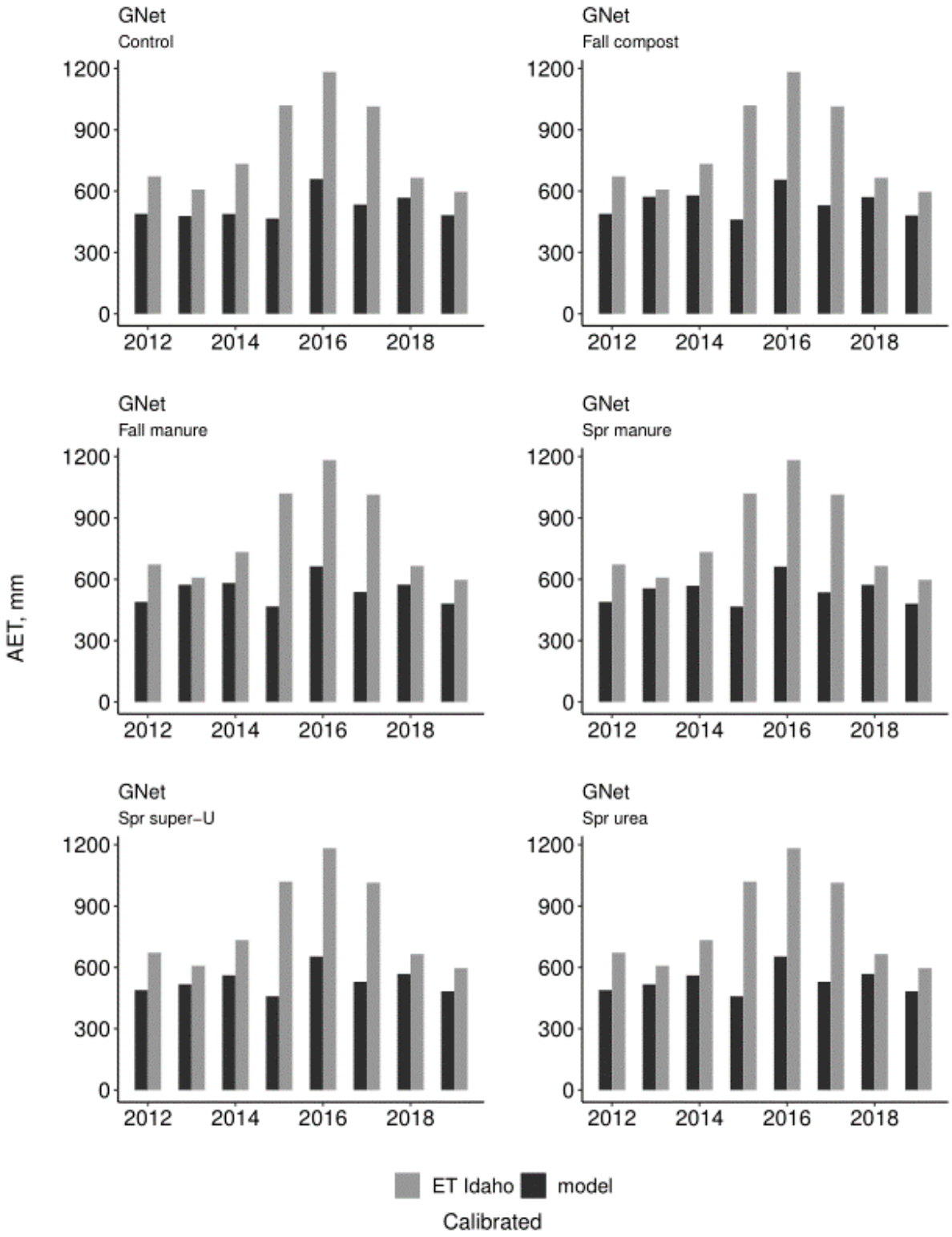
(S23)


GNet
Control
GNet
Fall compost
GNet
Fall manure
GNet
Spr manure
GNet
Spr super−U
GNet
Spr urea
θv, 0 − 15cm
0.0
0.1
0.2
0.3
0.4
0.5
2013
2015
2017
2019
model
observed
Calibrated

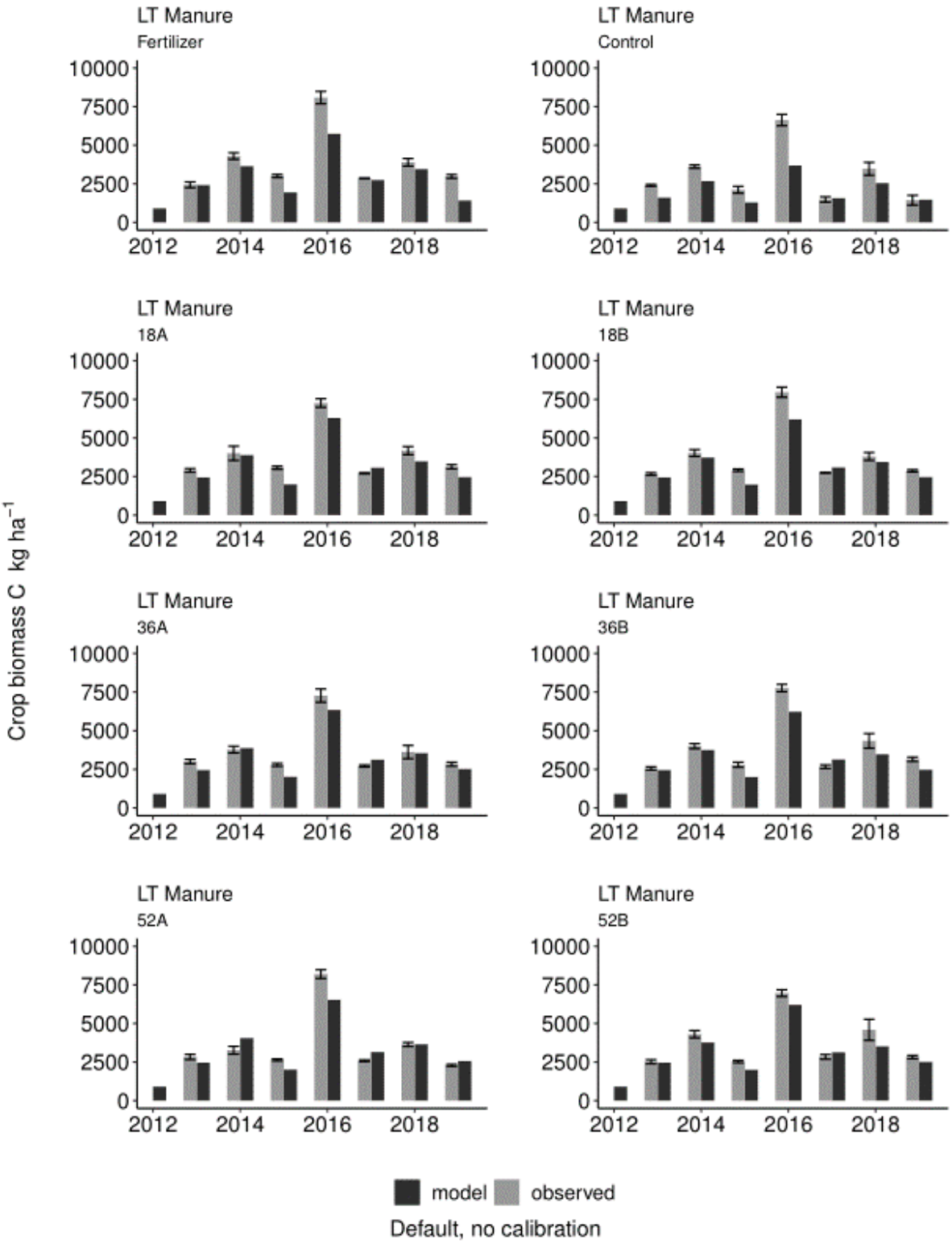
(S24)


GNet
Control
GNet
Fall compost
GNet
Fall manure
GNet
Spr manure
GNet
Spr super−U
GNet
Spr urea
AET, mm
0
300
600
900
1200
2012
2014
2016
2018
ET Idaho
model
Default, no calibration

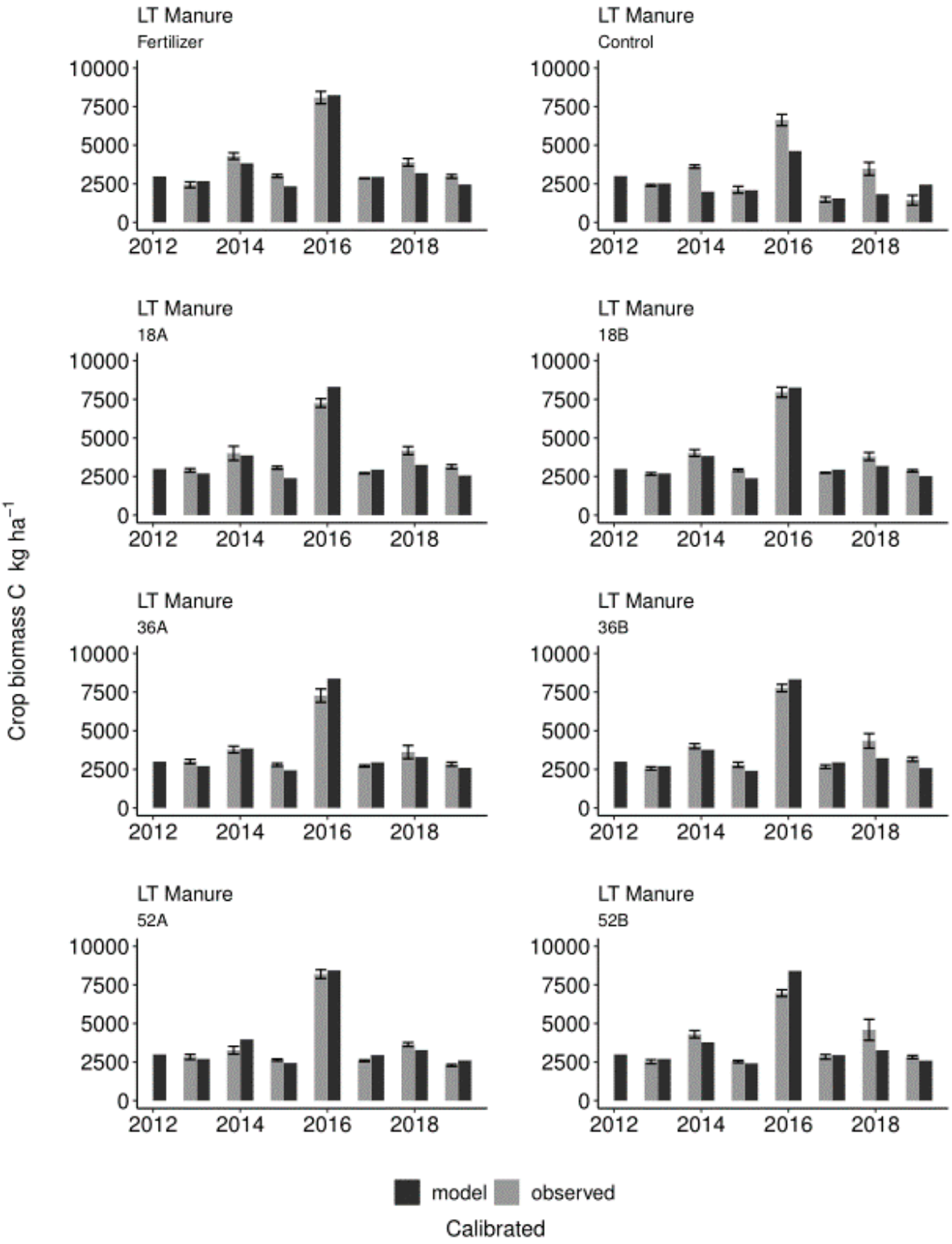
(S25)


GNet
Control
GNet
Fall compost
GNet
Fall manure
GNet
Spr manure
GNet
Spr super−U
GNet
Spr urea
AET, mm
0
300
600
900
1200
2012
2014
2016
2018
ET Idaho
model
Calibrated

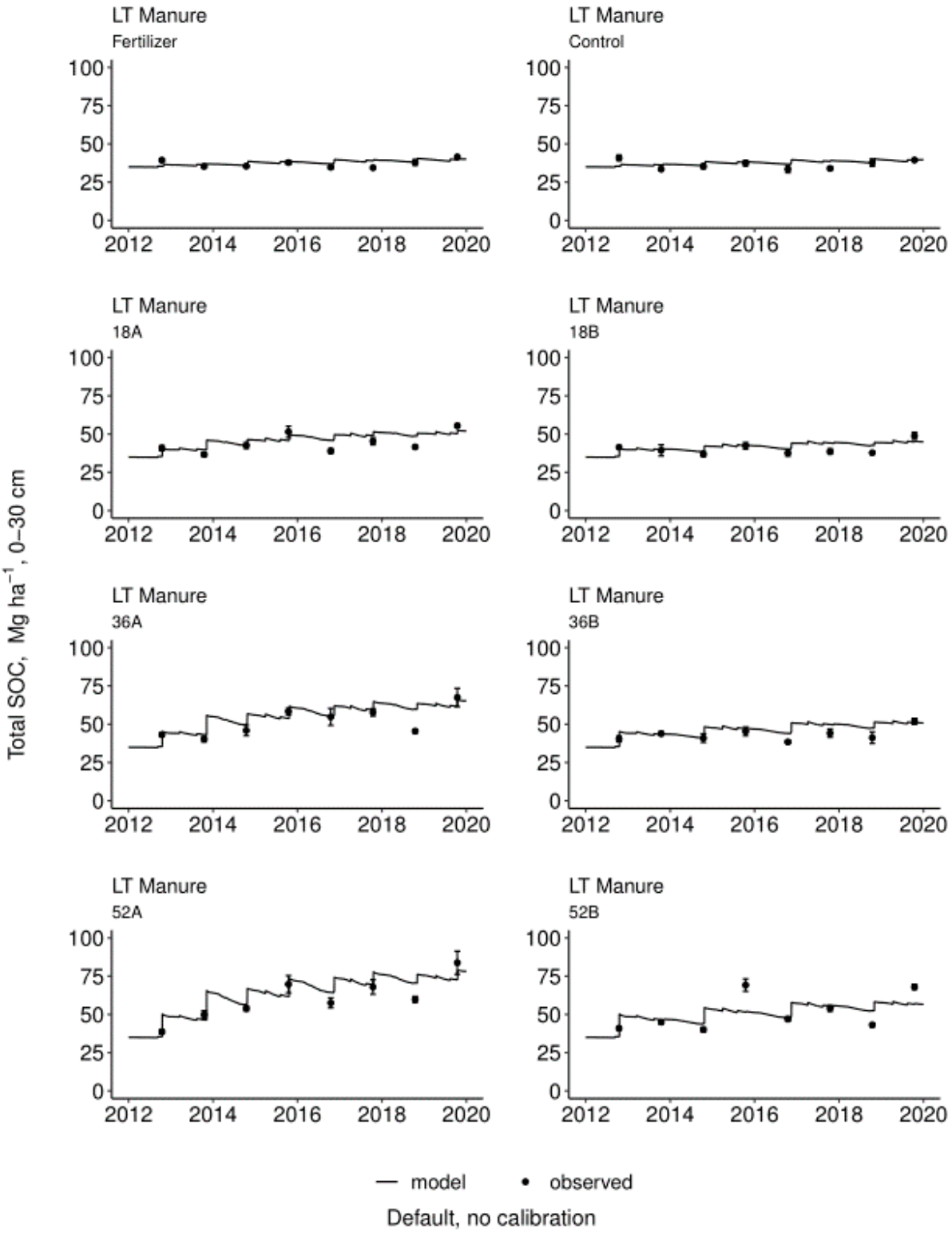
(S26)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Crop biomass C kg ha^{-1}
0
2500
5000
7500
10000
2012
2014
2016
2018
model
observed
Default, no calibration

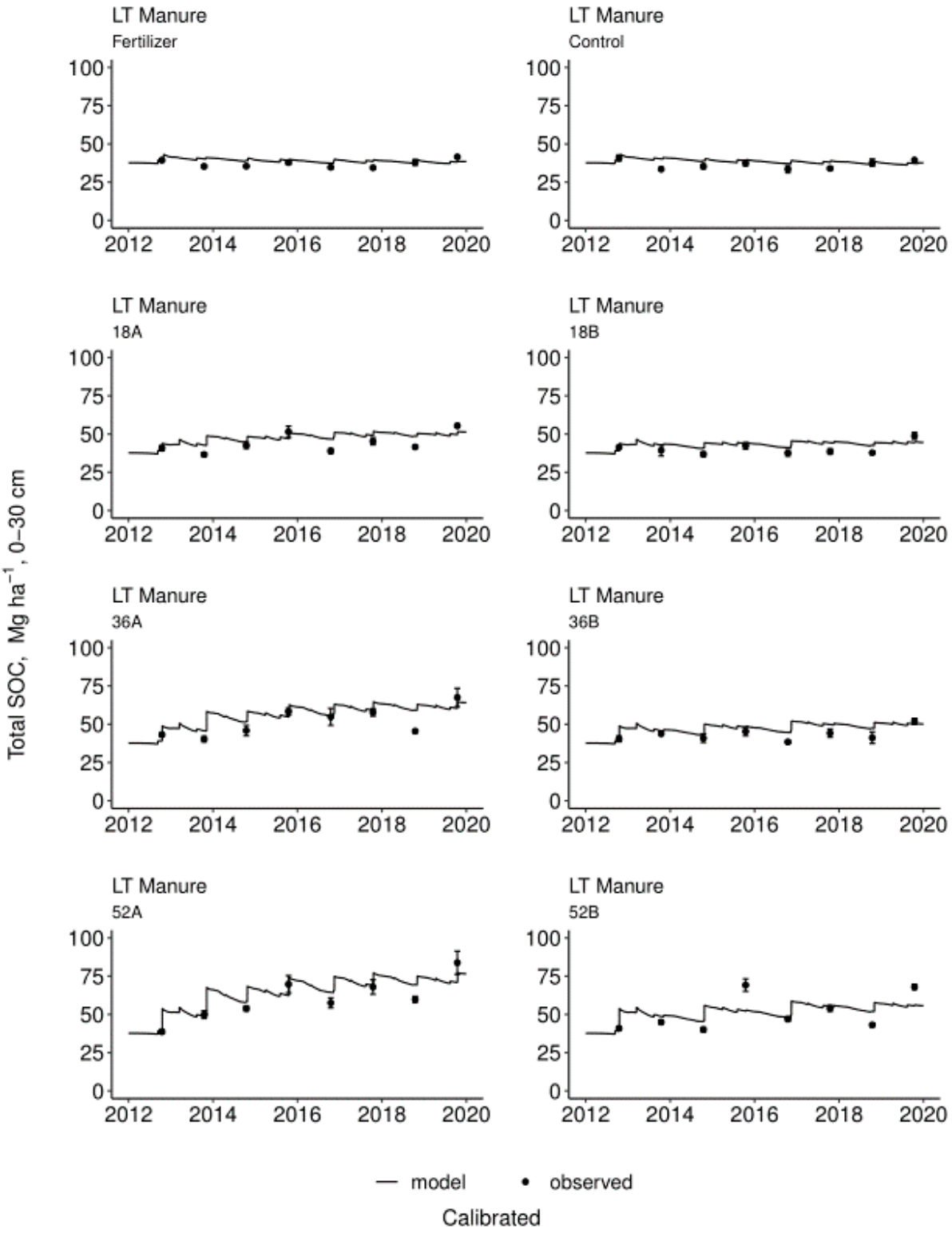
(S27)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Crop biomass C kg ha^{-1}
10000
7500
5000
2500
0
2012
2014
2016
2018
model
observed
Calibrated

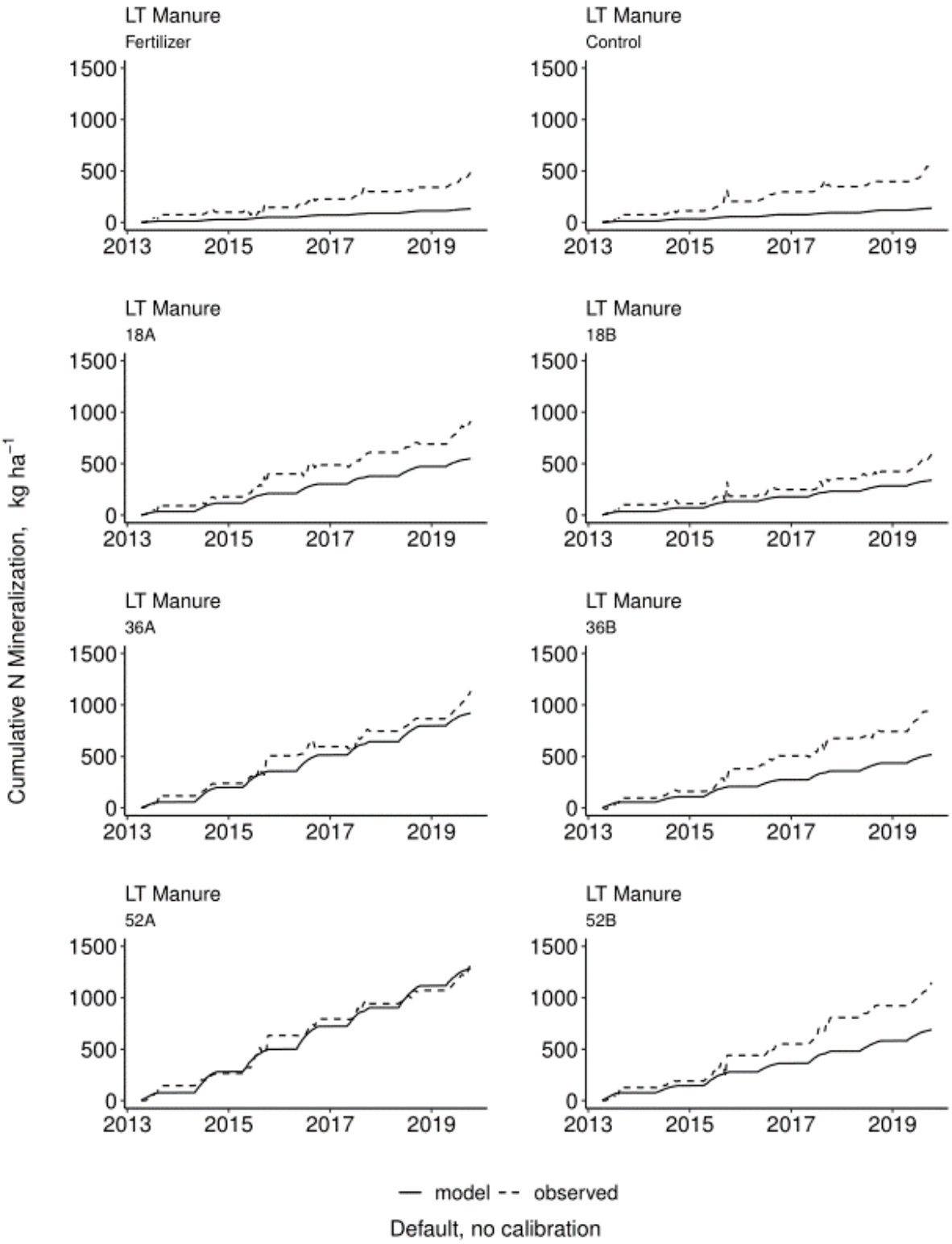
(S28)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Total SOC, Mg ha^{-1}, 0–30 cm
0
25
50
75
100
2012
2014
2016
2018
2020
model
observed
Default, no calibration

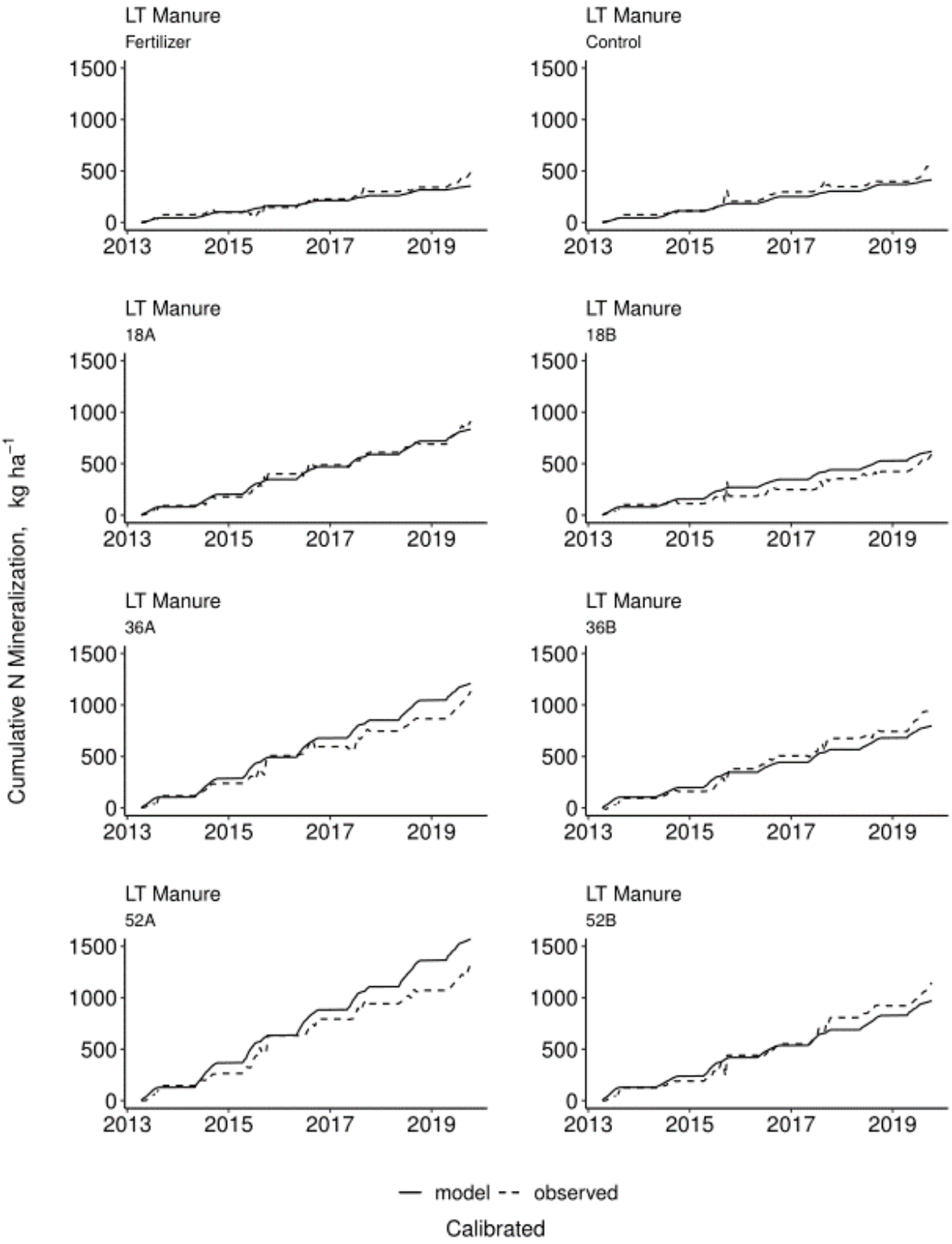
(S29)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Total SOC, Mg ha^{-1}, 0–30 cm
100
75
50
25
0
2012
2014
2016
2018
2020
model
observed
Calibrated

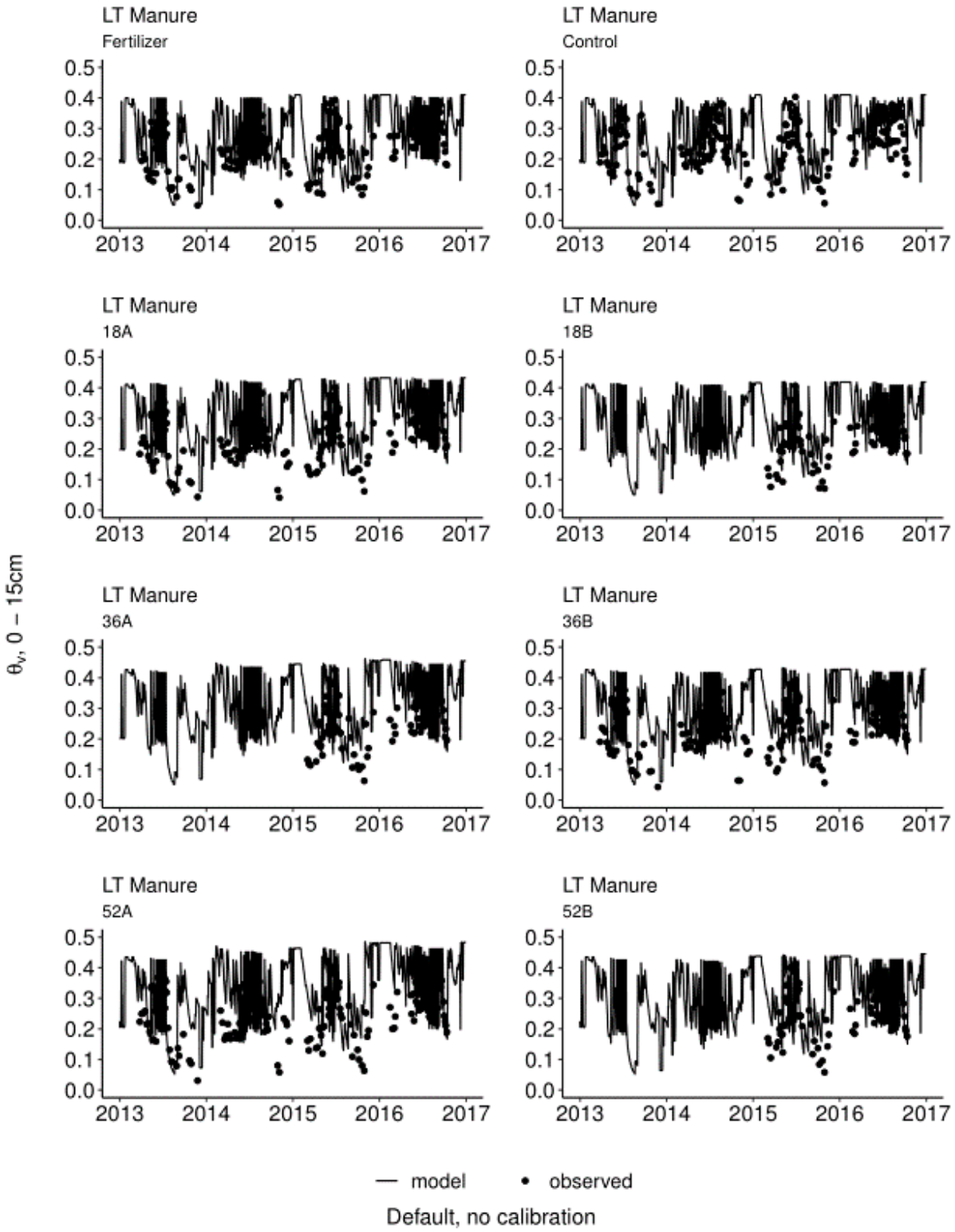
(S30)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Cumulative N Mineralization, kg ha^{-1}
0
500
1000
1500
2013
2015
2017
2019
model
observed
Default, no calibration

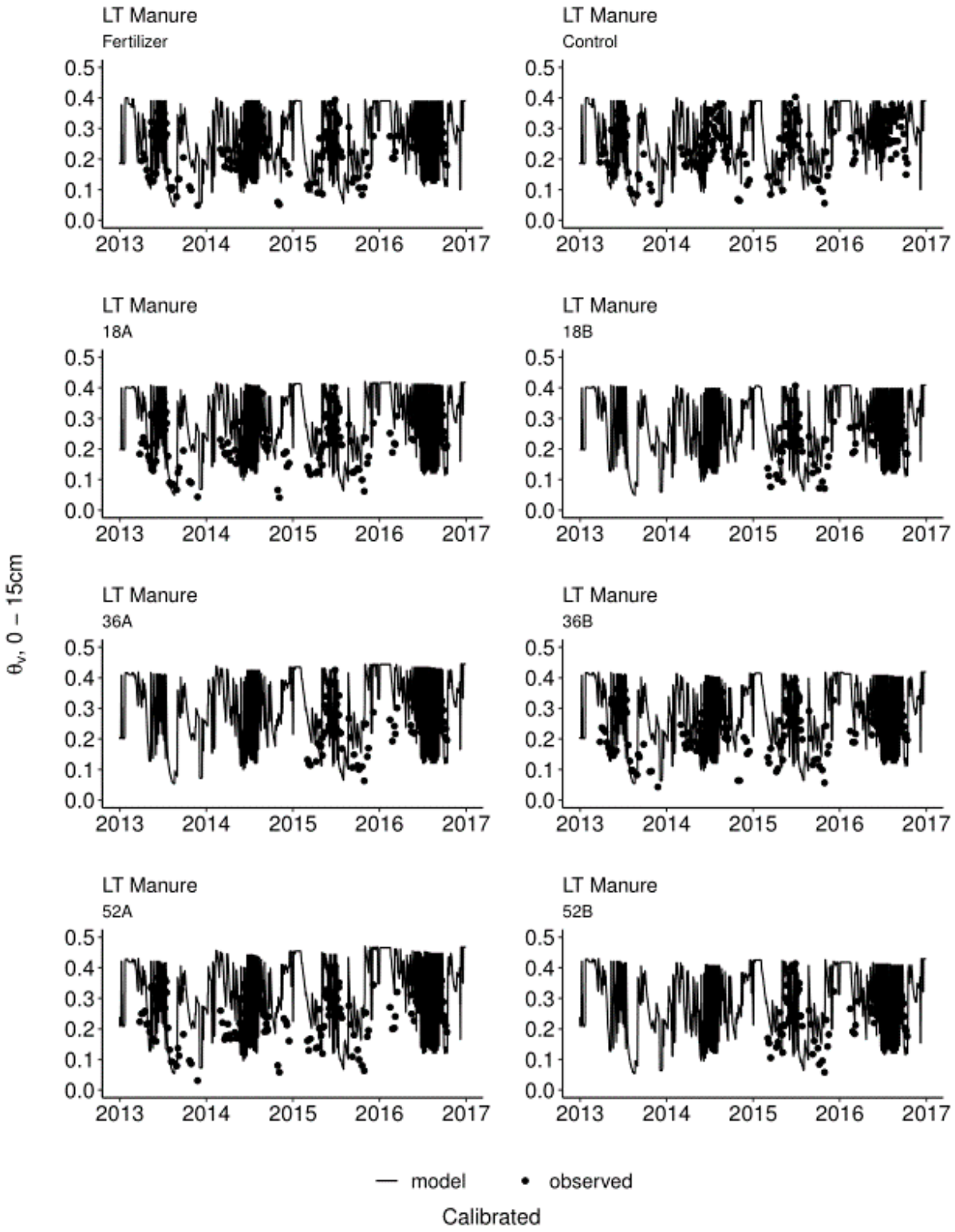
(S31)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Cumulative N Mineralization, kg ha^{-1}
0
500
1000
1500
2013
2015
2017
2019
model
observed
Calibrated

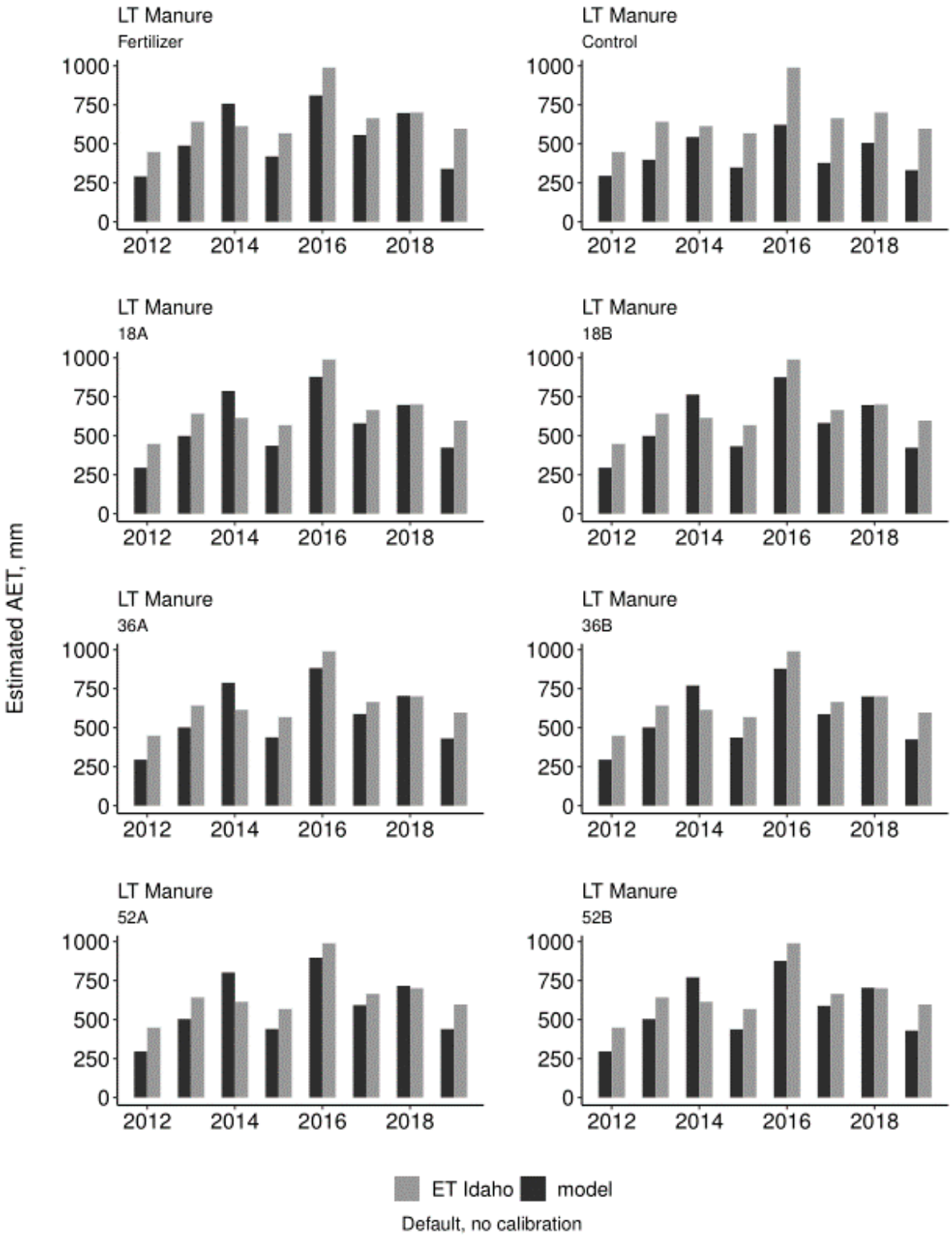
(S32)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
θv, 0 – 15cm
0.0
0.1
0.2
0.3
0.4
0.5
2013
2014
2015
2016
2017
model
observed
Default, no calibration

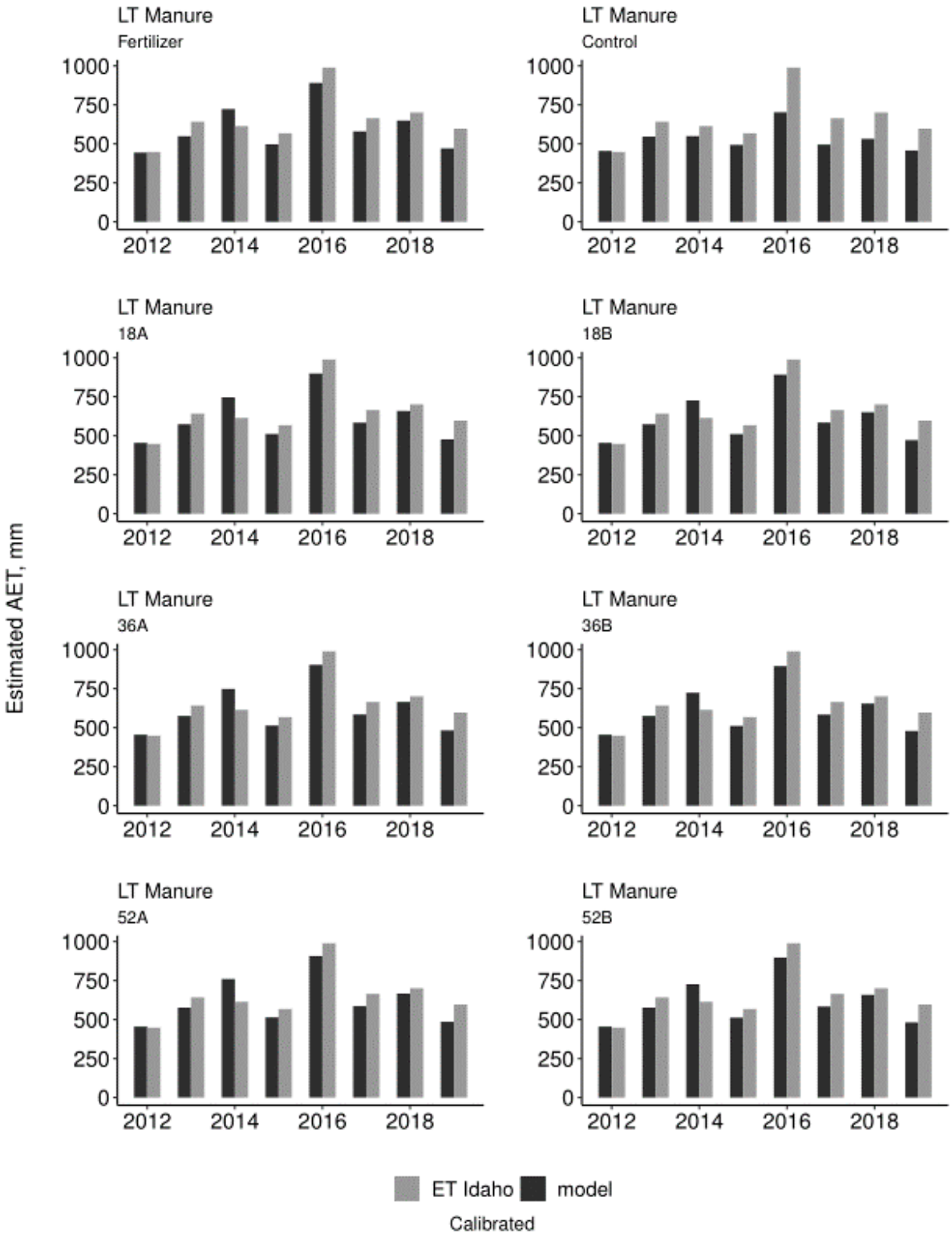
(S33)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
θv, 0 – 15cm
0.0
0.1
0.2
0.3
0.4
0.5
2013
2014
2015
2016
2017
model
observed
Calibrated

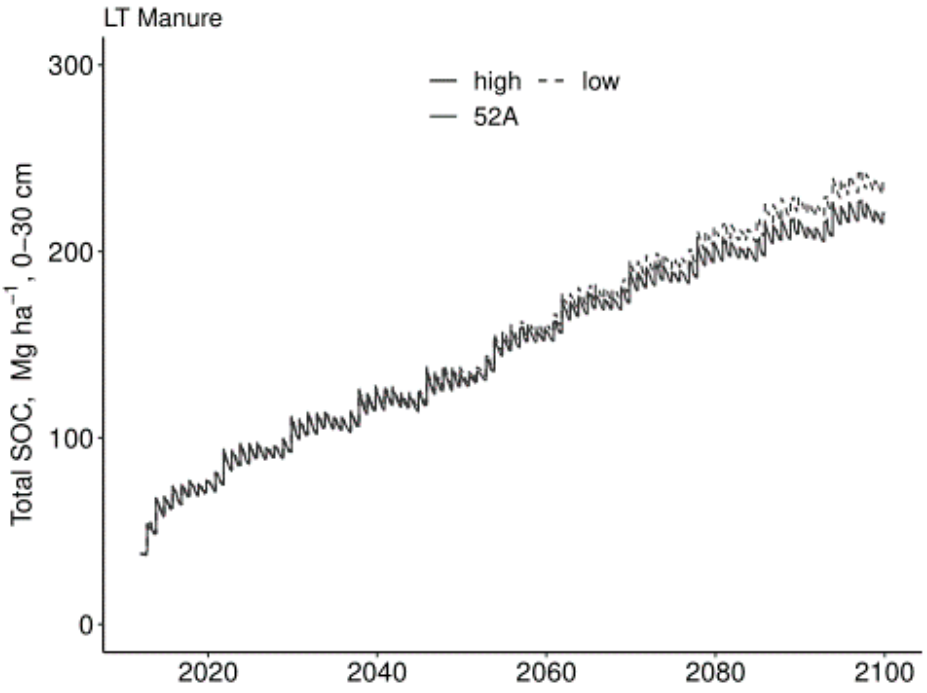
(S34)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Estimated AET, mm
0
250
500
750
1000
2012
2014
2016
2018
ET Idaho
model
Default, no calibration

(S35)


LT Manure
Fertilizer
LT Manure
Control
LT Manure
18A
LT Manure
18B
LT Manure
36A
LT Manure
36B
LT Manure
52A
LT Manure
52B
Estimated AET, mm
0
250
500
750
1000
2012
2014
2016
2018
ET Idaho
model
Calibrated

(S36)


LT Manure
high
low
52A
Total SOC, Mg ha^{-1}, 0–30 cm
300
200
100
0
2020
2040
2060
2080
2100