

# Process-Based Modelling for N<sub>2</sub>O emission estimation at the field-scale in Atlantic Canada

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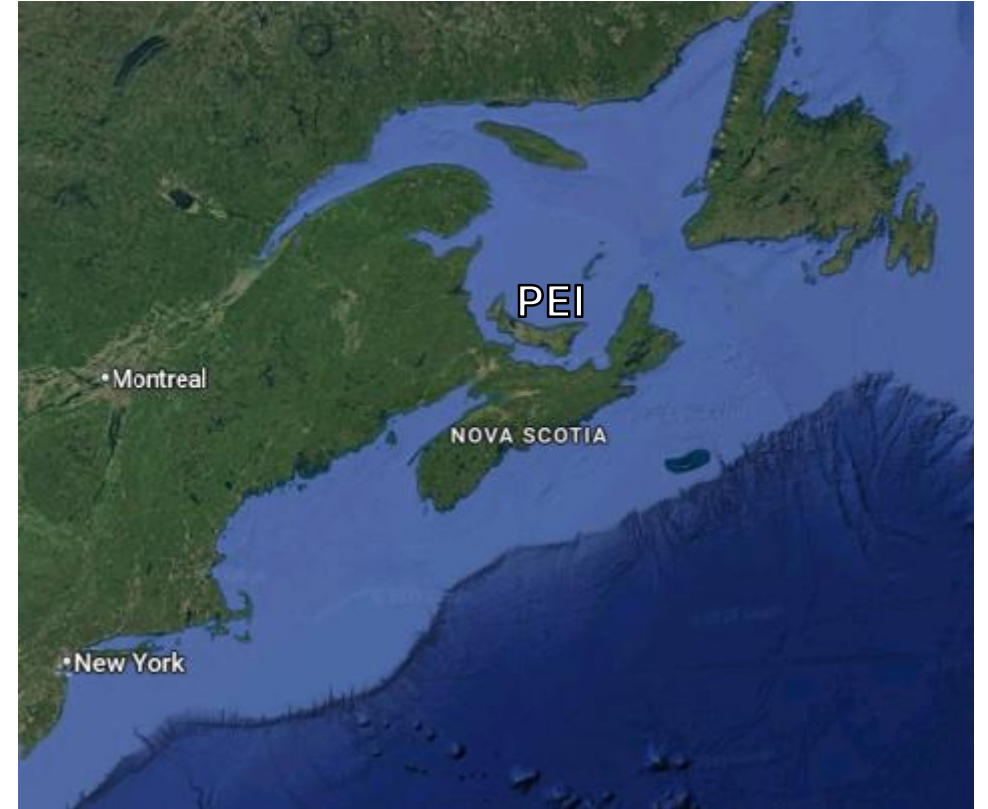


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# Mountain Gem Russet

- Increasingly popular in Prince Edward Island (PEI)
- Good disease resistance
- 15% higher yields than Russet Burbank
- 13% less nitrogen



Imagery ©2025 Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat / Copernicus, Map data ©2025 Google, INEGI 200 km

(Stark et al., 2016, USDA, 2020)

# Objectives

1. Calibrate and evaluate the STICS crop model on
  - Biomass (plant, tuber, roots)
  - N uptake
  - LAI
  - N<sub>2</sub>O emissions

2. Determine crop specific emission factors (EF)

<b>Urea 170 kg N</b>	Barley/Clover/Potato
	Corn/Sudan Grass/Potato
	Soybean/Mustard Potato
<b>Reduced Urea 120 kg N</b>	Barley/Clover/Potato
	Corn/Sudan Grass/Potato
	Soybean/Mustard Potato

X 3 reps

X 3 reps

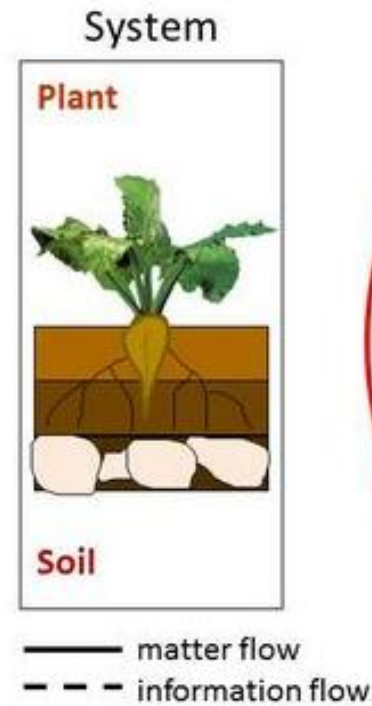
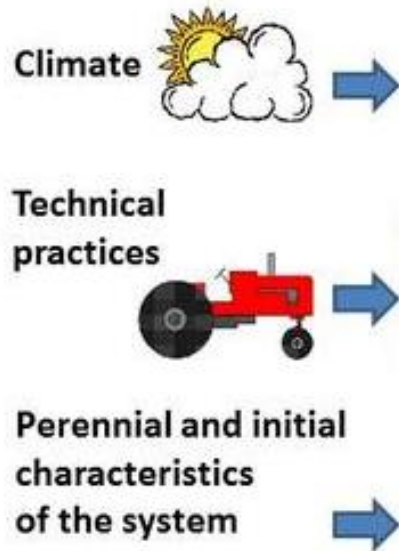
18 subplots



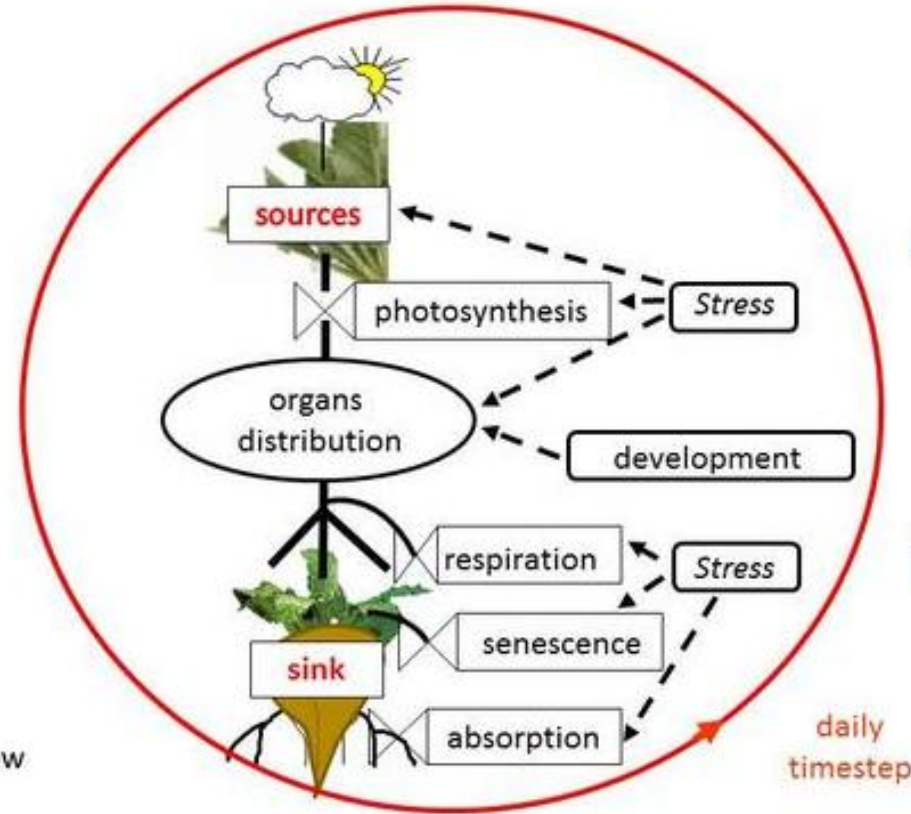
# STICS

Simulateur multIdisciplinaire pour les Cultures Standard / Multidisciplinary Simulator for Standard Crops

## Inputs



## System - process



Farming variables

Environmental variables

(Brisson et al. 2003)



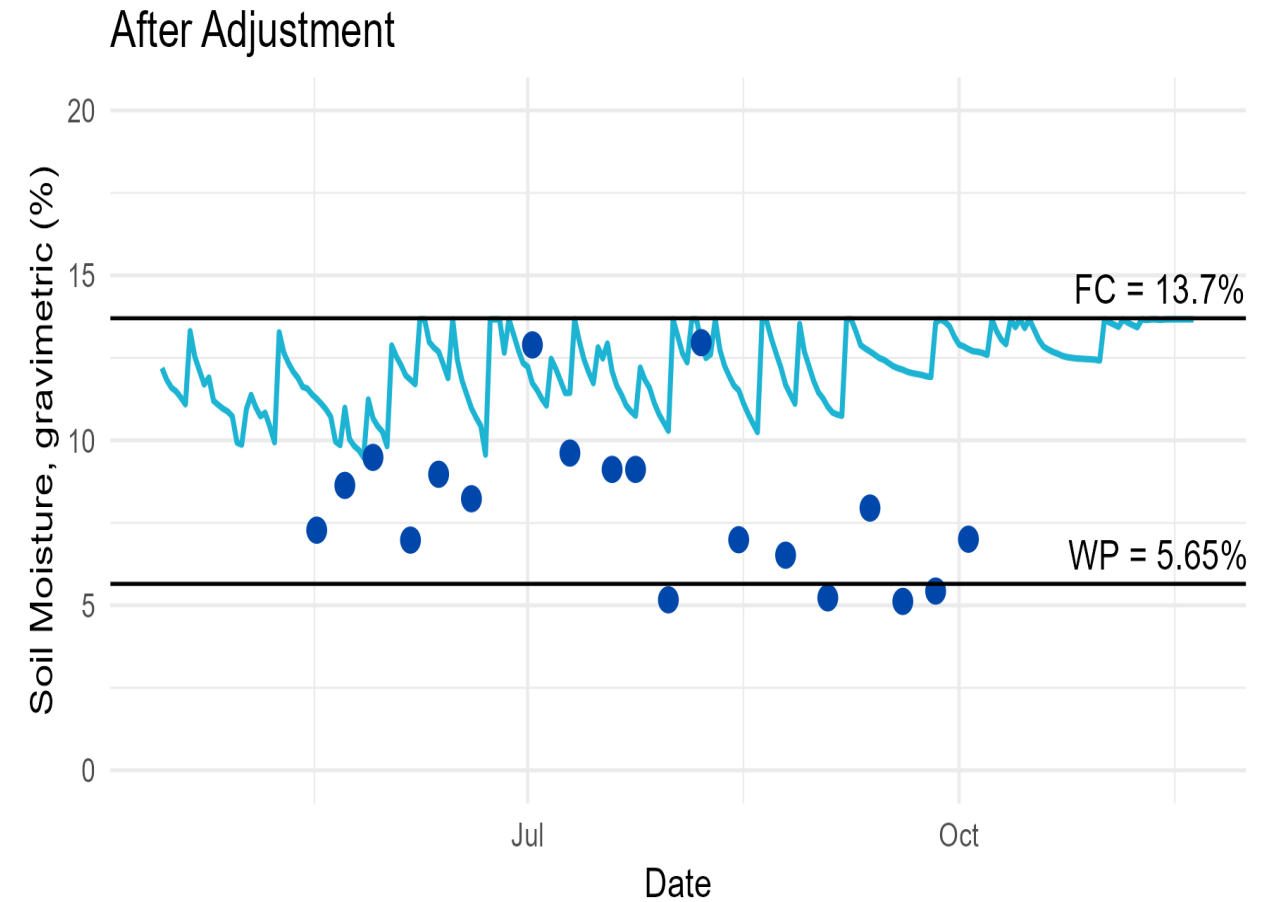
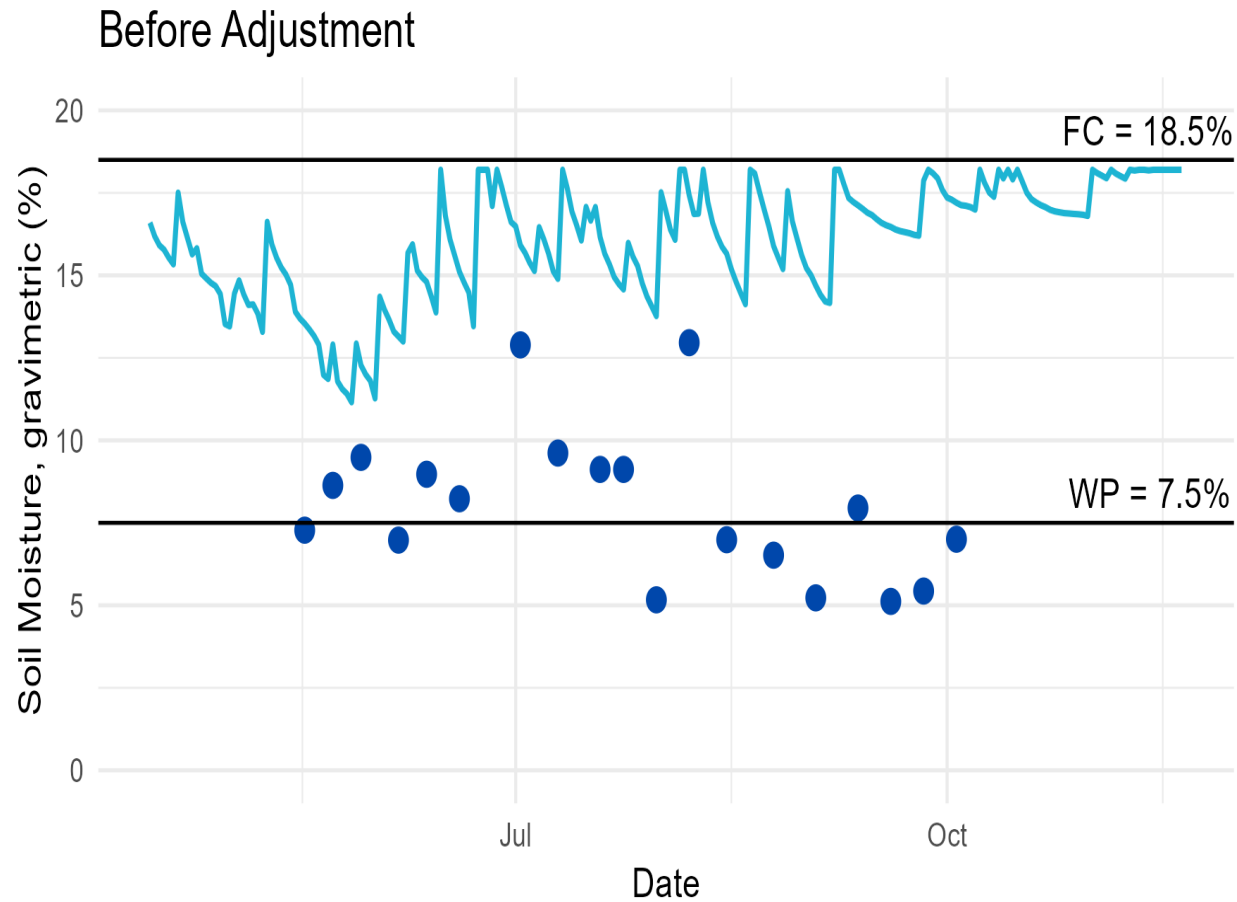
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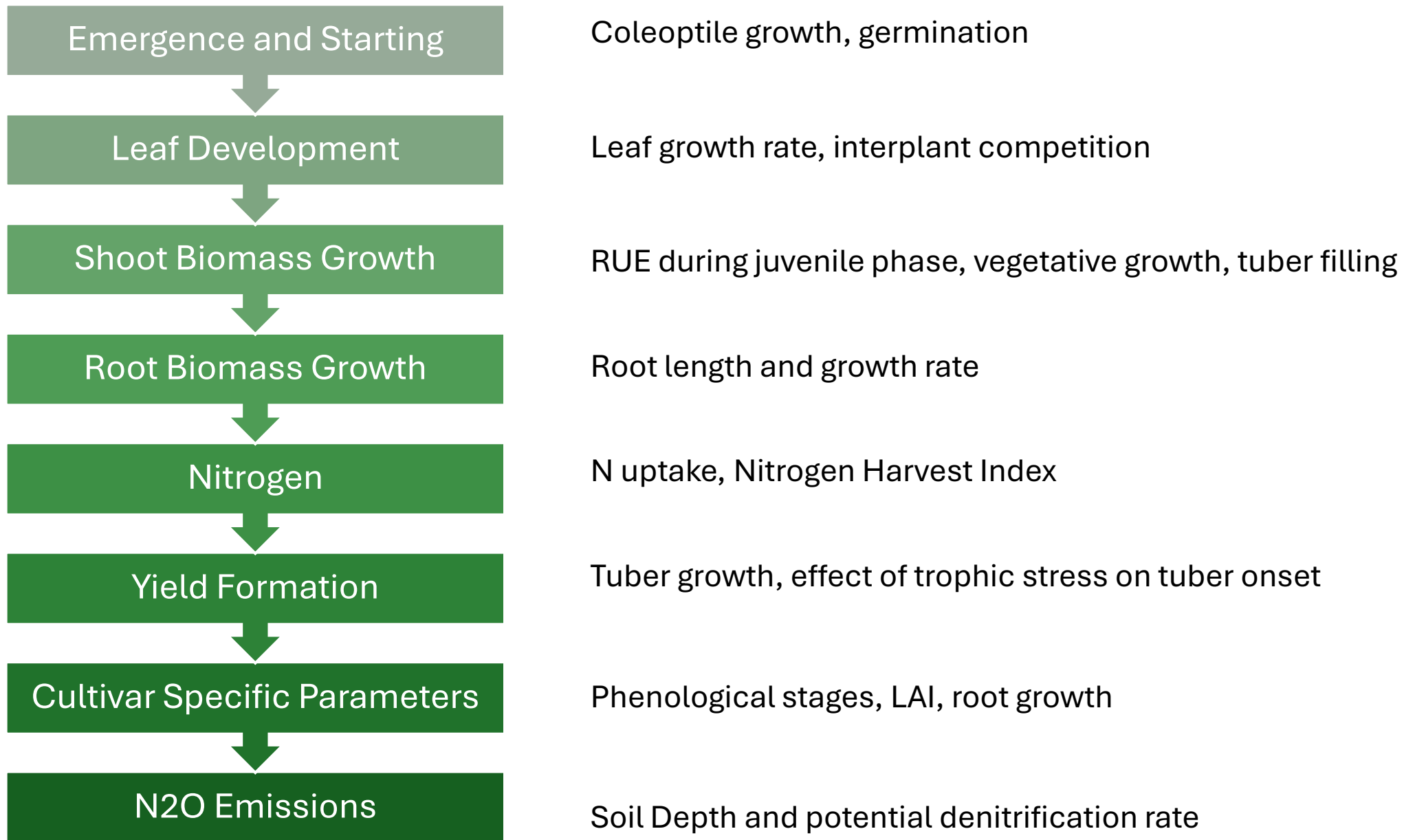
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# Soil Moisture (%) - Top 15cm, Hills



● Observed — Simulated



# Statistical Criteria

Bias

$$RMSEs = \sqrt{\frac{1}{n} \sum_{i=1}^n (\bar{S}_i - O_i)^2}$$

Data Dispersion

$$RMSEu = \sqrt{\frac{1}{n} \sum_{i=1}^n (S_i - \bar{S}_i)^2}$$

$\bar{S}_i$  = linear regression between observed and simulated values

$O$  = observed values

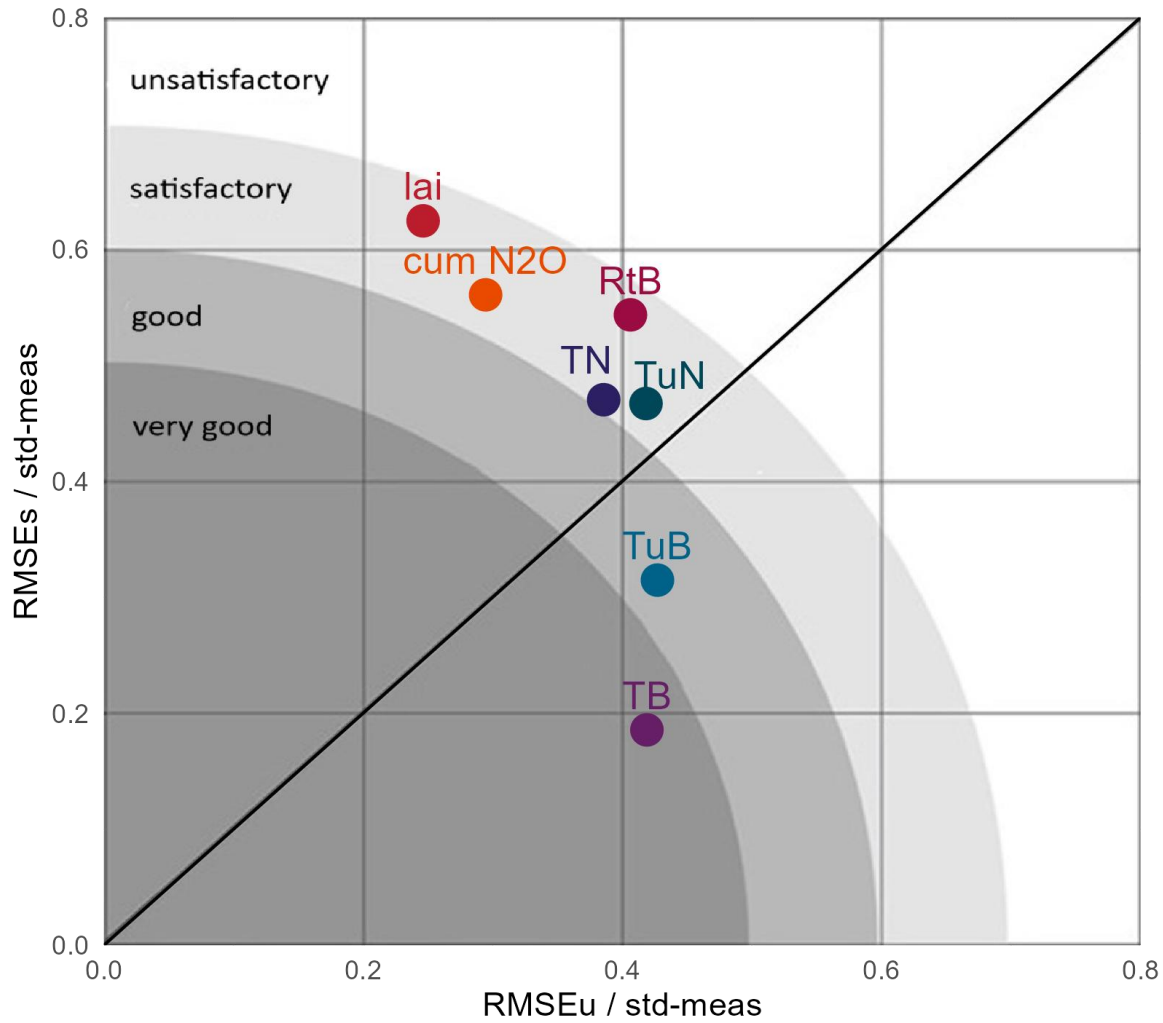
$S$  = simulated values

$n$  = number of measurements

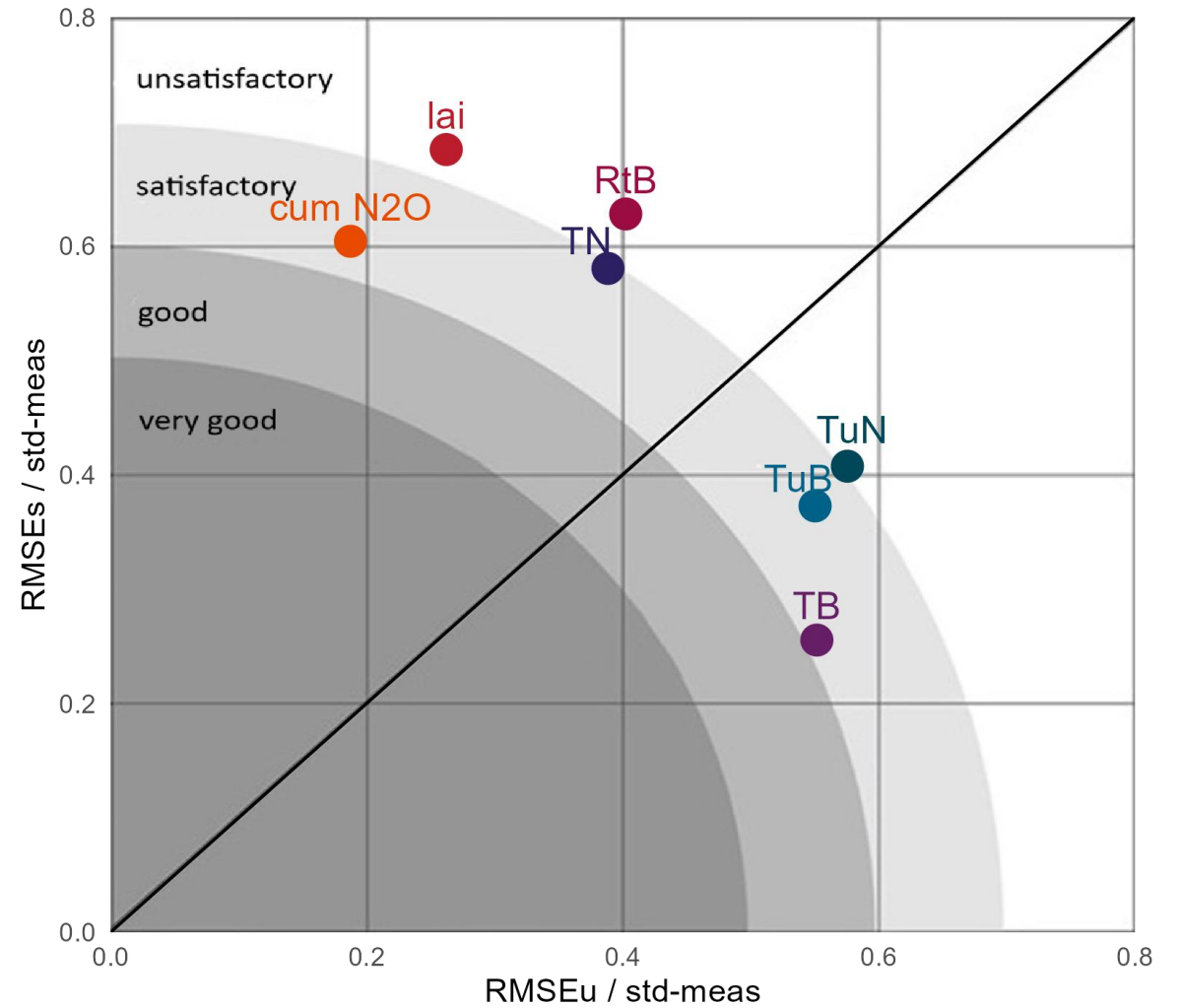
(Moriasi et al., 2007, Morissette et al., 2016, Willmott, 1981)



### Calibration

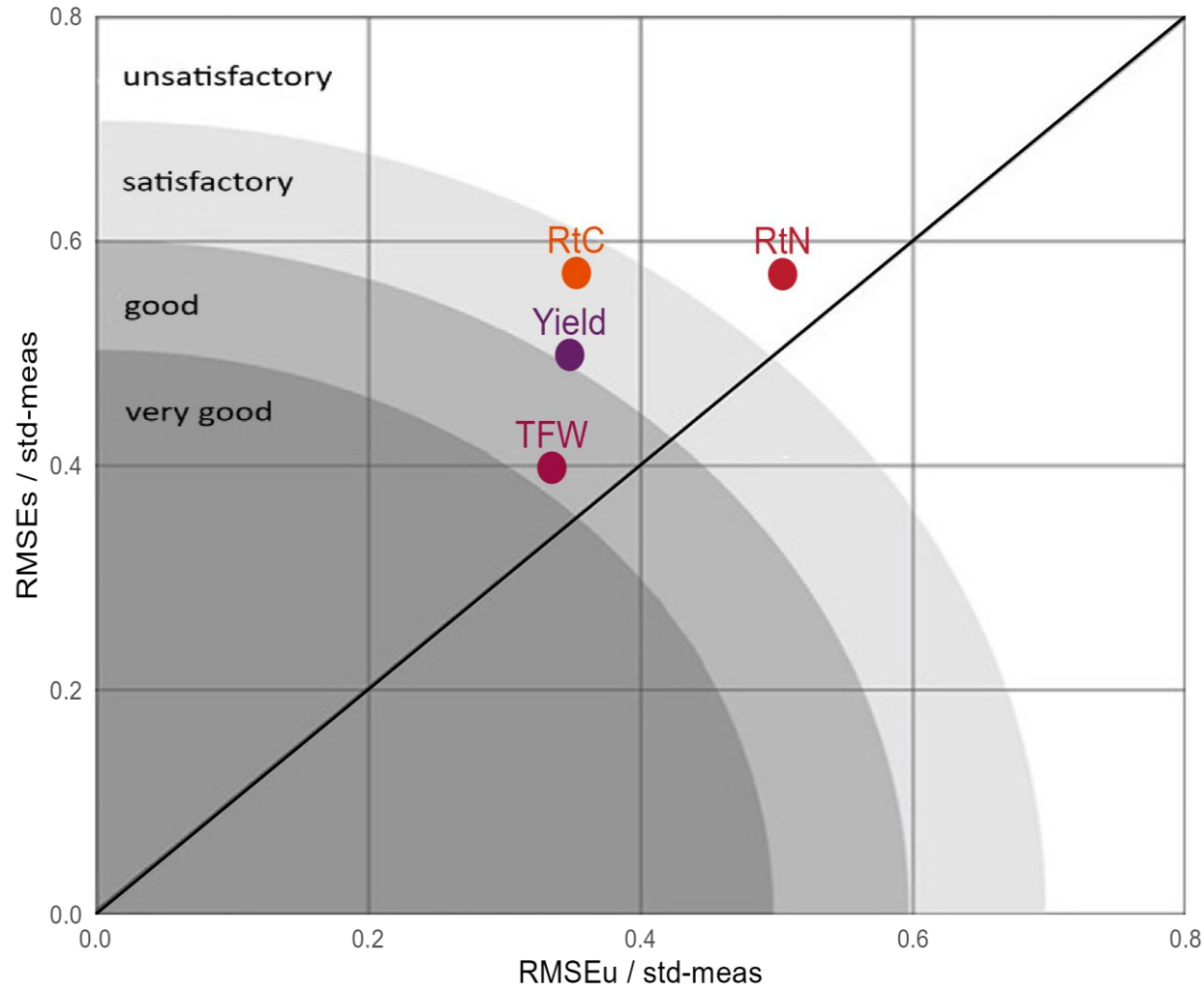


### Evaluation

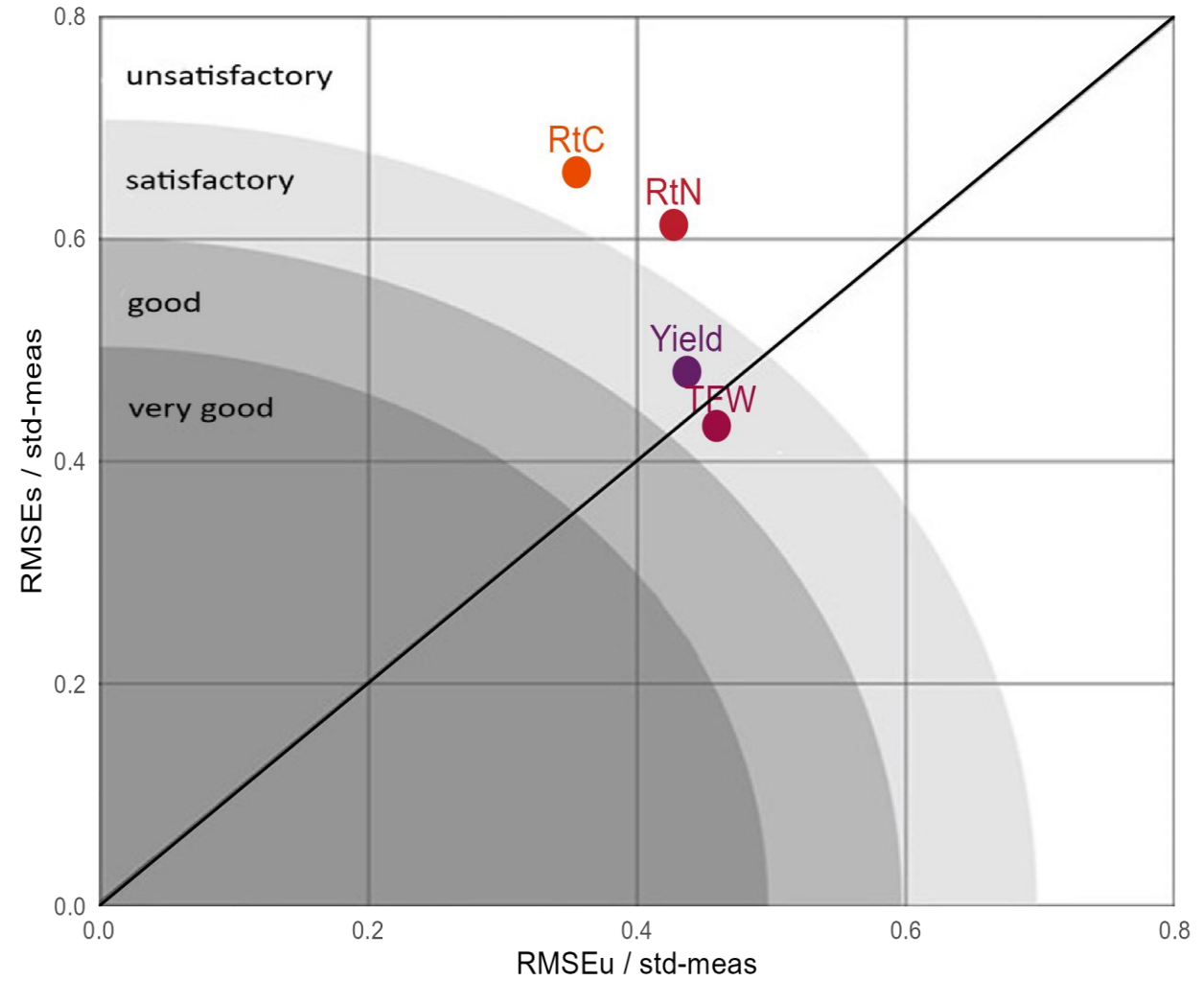


- cum N2O - Cumulative N2O emissions
- LAI
- RtB - Root Biomass
- TN - Total Biomass
- TN - Total N
- TuB - Tuber Biomass
- TuN - Tuber N

Calibration - Additional

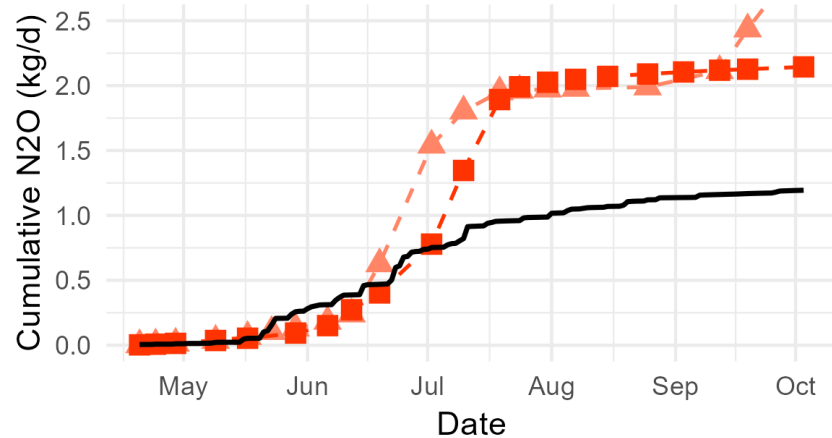


Evaluation - Additional



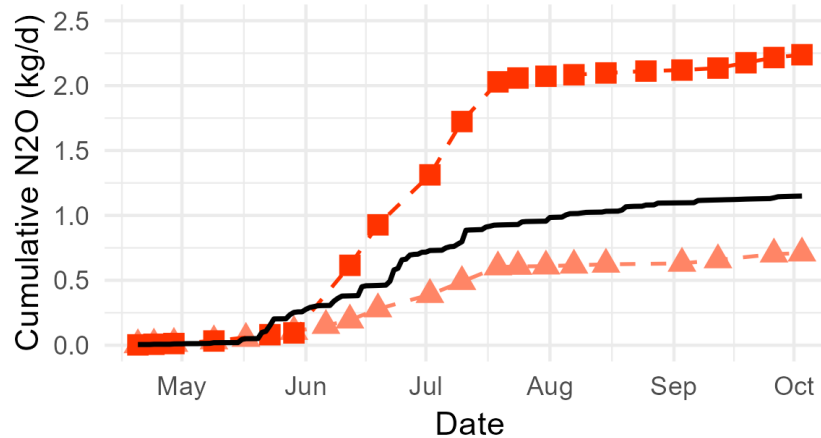
- RtC - Root C
- RtN - Root N
- Yield
- TFW - Fresh Weight

Barley/Clover/Potato - N170



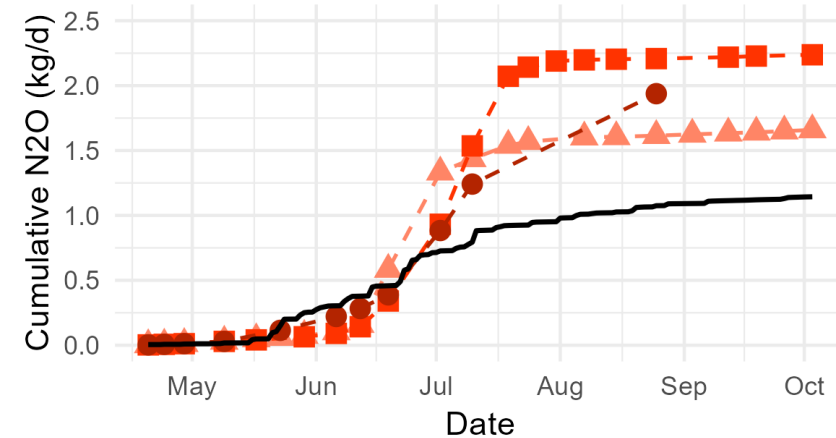
▲ Plot 2B ■ Plot 5B — Simulated

Corn/Grass/Potato - N170



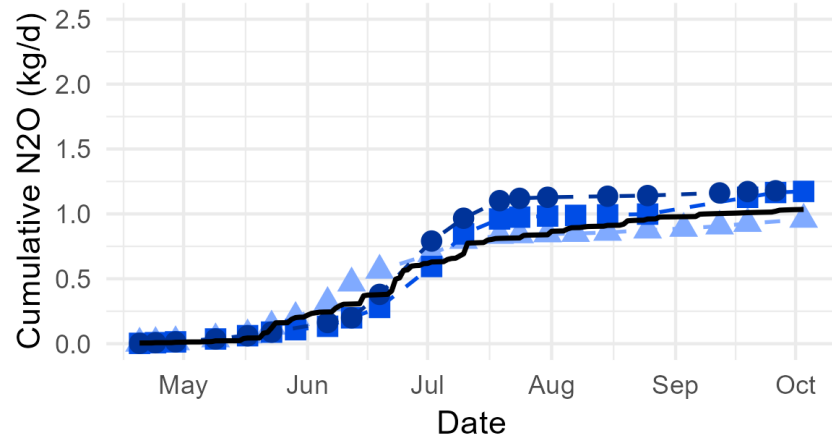
▲ Plot 1A ■ Plot 6A — Simulated

Soybean/Mustard/Potato - N170



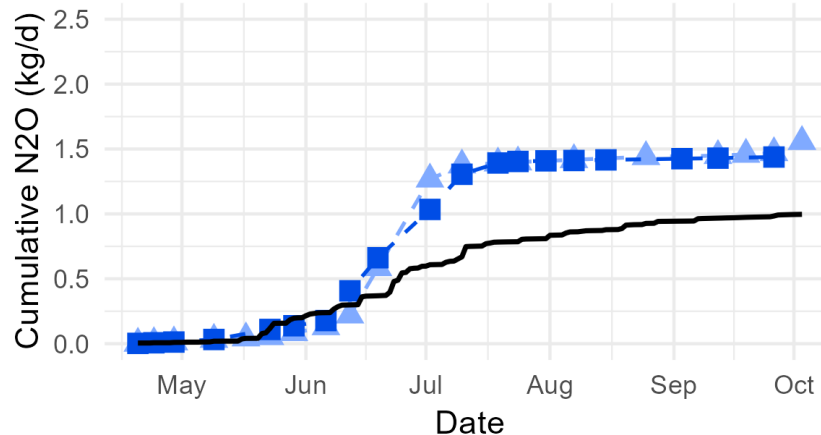
▲ Plot 3A ■ Plot 8A ● Plot 4B — Simulated

Barley/Clover/Potato - N120



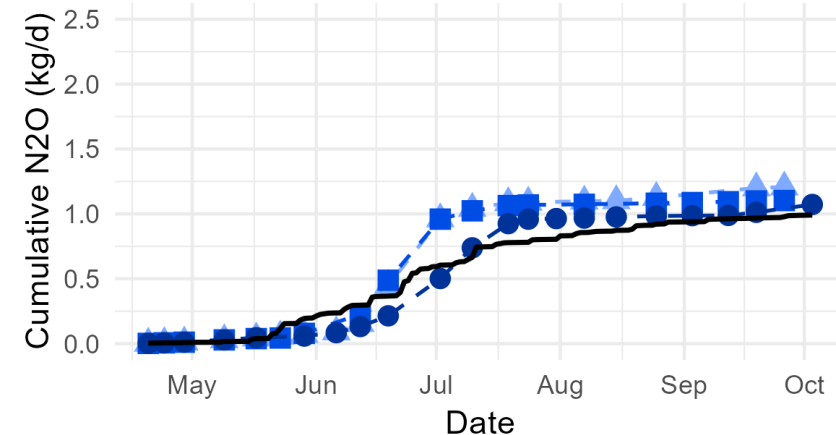
▲ Plot 2A ■ Plot 5A ● Plot 9A — Simulated

Corn/Grass/Potato - N120



▲ Plot 1B ■ Plot 6B — Simulated

Soybean/Mustard/Potato - N120



▲ Plot 4A ■ Plot 3B ● Plot 8B — Simulated



# Emission Factors, Hills

Treatment	Observed		Simulated	
	Cum. N2O (kg/ha.)	EF	Cum. N2O (kg/ha.)	EF
Barley/Clover/Potato X N120	1.18	1.0	1.09	0.9
Barley/Clover/Potato X N170	2.30	1.8	1.25	0.7
Corn/Grass/Potato X N120	1.56	1.3	1.05	0.9
Corn/Grass/Potato X N170	2.24	1.3	1.20	0.7
Soybean/Mustard/Potato X N120	1.21	1.0	1.04	0.9
Soybean/Mustard/Potato X N170	2.24	1.3	1.19	0.7

## IPCC EF for Canada

General	1%
Humid Environment	1.6%
Eastern Canada	1.2%

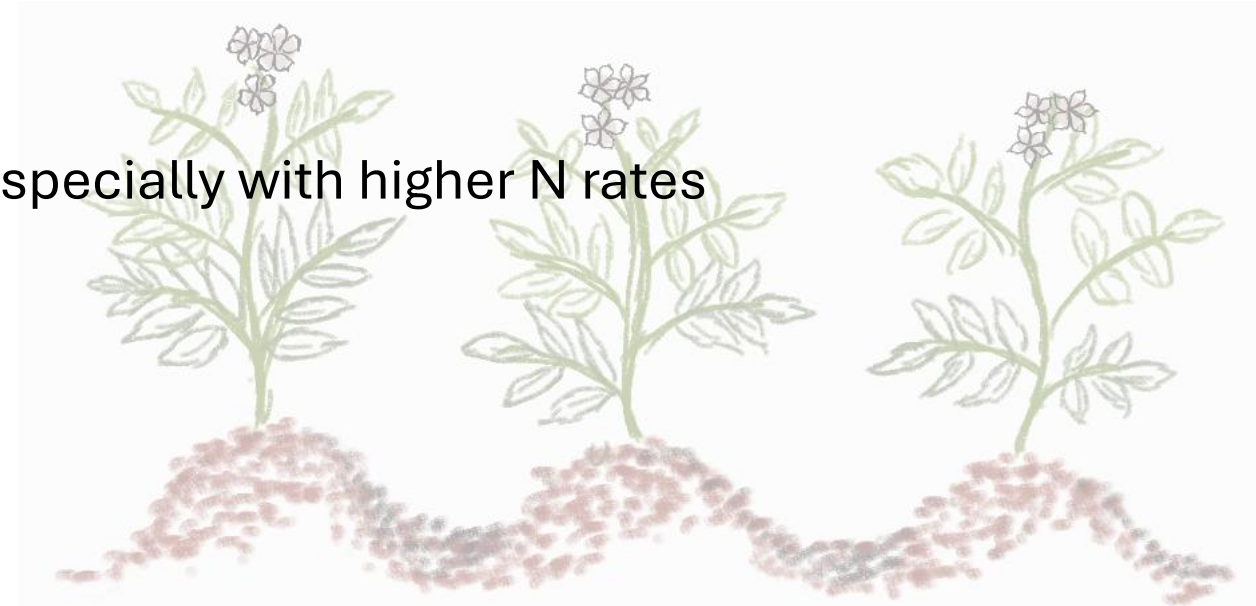


# Summary

- Considerations for potato's unique growing conditions
- Satisfactory model performance for RMSEs and RMSEu
- Root parameters and LAI poor in evaluation
- Model error generally due to bias

## Next Steps

- Improve N<sub>2</sub>O and soil moisture simulations, especially with higher N rates
  - Incorporate additional year of data
  - Simulate N<sub>2</sub>O contributions from furrows
- Evaluate impacts from conventional farms



# Acknowledgments

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	Name	Definition	Russet Value	Mtn. Gem	Variables	Calibration Method
Emergence	belong	Effect on coleoptile elongation, °C d	0.007	0.005	Total Biomass	Opt.
	celong	Parameter of the plantlet elongation curve	1	5	Total Biomass	Opt.
	elmax	Maximum elongation of the coleoptile in darkness condition	20	12	Total Biomass	Opt.
	tgmin	Minimum temperature below which emergence is stopped, °C	3	-0.63	Total Biomass	Opt.
Leaves	innturgmin	N stress function active on leaf expansion	0	0.4	LAI	Opt.
	laicomp	LAI above which competition b/t plants starts, m <sup>2</sup> leaf m <sup>-2</sup> soil	0.6	3	LAI	Opt.
	pentlaimax	Effect on the logistic curve of LAI growth	3.5	5.5	LAI	Opt.
	vlaimax	Physiological time when leaf growth rate begins to slow	2.0	2.4	LAI	Opt.
Shoot Biomass Growth	efcoijuv	Max. radiation use efficiency during the juvenile phase, g Mj <sup>-1</sup>	2.2	1.7	Total Biomass, Nitrogen	Opt.
	efroirepro	Max. radiation use efficiency during the tuber filling phase, g Mj <sup>-1</sup>	3.2	3.7	Total Biomass, Nitrogen	Opt.
	efcroiveg	Max. radiation use efficiency during the vegetative stage, g Mj <sup>-1</sup>	3.8	4.2	Total Biomass, Nitrogen	Opt.
Root Biomass Growth	sensrsec	Index of root sensitivity to drought		0.83	Root Biomass	Opt.
	draclong	Maximum rate of root length production per plant, cm plant <sup>-1</sup> °C d <sup>-1</sup>		311	Root Biomass	Opt.
	lvfront	Root density at the root apex, cm cm <sup>-3</sup>		0.44	Root Biomass	Opt.
	debsenrac	Thermal time units defining the beginning of root senescence (root life time), °C d		1163	Root Biomass	Opt.
	longsperac	Specific root length, cm g <sup>-1</sup>		18965	Root Biomass	Opt.

	Name	Definition	Russet Value	Mtn. Gem	Variables	Calibration Method
Nitrogen	Vmax2	Max. N uptake rate with high affinity transport system, $\mu\text{mol cm}^{-1} \text{h}^{-1}$	0.07	0.12	Total Biomass, Nitrogen	Opt.
	INNimin	Min possible value of INNi	0	-0.35	Total Biomass, Nitrogen	Opt.
	inngrain1	Lower threshold of INNS during tuber filling	0.95	0.1	Total Nitrogen	Opt.
	inngrain2	Upper threshold of INNS during tuber filling	1.05	2	Total Nitrogen	Opt.
	adil	Critical dilution curve parameter, %N	4.57			Lit.
	bdil	Critical dilution curve parameter	0.42			Lit.
	adilmax	Max. dilution curve parameter, %N	6.86			Lit.
	bdilmax	Max. dilution curve parameter	0.42			Lit.
Yield Formation (Indeterminate Crop)	nboite	No. of age classes of tubers for calculation of tuber growth	6	10	Tuber Biomass	Opt.
	allocfrmax	Max. daily growth allocation to tuber	0.6	1	Tuber Biomass	Opt.
	afpf	Relative tuber age at which growth is maximal	0.6	0.49	Tuber Biomass	Opt.
	bfpf	Max. growth rate relative to max. tuber weight	6	9.3	Tuber Biomass	Opt.
	spfrmin	Min. value allowing trophic stress calculation for tuber onset	0.2	0.64	Tuber Biomass	Opt.
	spfrmax	Max. value allowing trophic stress calculation for tuber onset	1	2	Tuber Biomass	Opt.
	splaimin	Min. value allowing trophic stress calculation for leaf growth	0.1	0.39	LAI	Opt.
	splaimax	Max. value allowing trophic stress calculation for leaf growth	1	1.3	LAI	Opt.



	Name	Definition	Russet Value	Mtn. Gem	Variables	Calibration Method
Leaves (Cultivar)	adens	Interplant competition parameter	-0.1	-0.01	LAI	Opt.
	bdens	Min. density above above which interplant competition starts, plants m <sup>-2</sup>	2	10	LAI	Opt.
	dlaimaxbrut	Max rate of the setting up of LAI, m <sup>2</sup> leaf plant <sup>-1</sup> (°C d <sup>-1</sup> )	0.0037	0.0034	LAI	Opt.
	durvieF	Max. lifespan of an adult leaf	225	215	LAI	Opt.
	innsen	N stress function active on senescence	0.55	0.74	LAI	Lit.
	stamflax	GDD between the emergence and the max. leaf growth rate, °C d	750	963	LAI	Lit.
	stlevamf	GDD between emergence and the max. leaf growth rate, °C d	200	294	LAI	Lit.
Root (cultivar)	croirac	Elongation rate of the root apex, cm C d <sup>-1</sup>		0.15	Root Biomass	Opt.
Yield (cultivar)	vitirazo	Rate of increase of the N harvest index vs. time, g tuber g <sup>-1</sup> plant <sup>-1</sup>	0.011	0.0087	Tuber Nitrogen	Opt.
Yield – Indeterminate (cultivar)	stdrpnou	GDD between start of tuber filling and setting, °C d	150	168	Tuber Biomass	Opt.
	dureefruit	GDD between the tuber setting and maturity, °C d	1450	1086	Tuber Biomass	Opt.
	pgrainmaxi	Max. dry weight of a single tuber, g	50 g	69 g	Tuber Biomass	Lit.
	stlevdrp	GDD between the emergence and beginning of tuber filling, °C d	400	500	Tuber Biomass	Opt.
	stdrpdcs	GDD between beginning of tuber filling onset of water dynamics		698	Tuber Biomass	Opt.
N2O emissions	profdenit	Soil depth at which denitrification is active, cm	20	10	Cum. N2O	Grid Search
	vpodenit	Potential rate of denitrification, kg ha <sup>-1</sup> d <sup>-1</sup>	2	2	Cum. N2O	Grid Search

# Calibration

variable	n_obs	sd_obs	sd_sim	RMSE	nRMSE	rRMSE	MAE	Bias	EF	RMSEs	RMSEu	RMSEs_sd	RMSEu_sd
CNgrain	36	0.349772	0.505072	0.294514	20.03801	0.20038	0.247267	-0.15663	0.27075	0.184204	0.229799	0.526639	0.656997
CNplante	45	1.399732	1.97407	0.7796	23.12705	0.231271	0.600543	0.080087	0.682741	0.474009	0.618944	0.338643	0.442188
HR_1	170	3.943834	0.86905	4.267539	40.67741	0.406774	3.493321	1.241096	-0.17782	4.179053	0.864527	1.059642	0.21921
QCrac	45	51.06089	28.45379	34.28357	29.03695	0.290369	28.75663	-3.99023	0.538942	29.16188	18.02631	0.57112	0.353036
QNgrain	36	34.11621	25.0486	21.39064	42.96666	0.429667	15.48643	-8.49425	0.595647	15.93408	14.27111	0.467053	0.418309
QNplante	45	64.2403	45.92505	39.07363	27.6471	0.276471	31.60882	-16.2633	0.621634	30.21473	24.77537	0.470339	0.385667
QNracs	45	2.886727	1.990005	2.197287	30.6352	0.306352	1.833273	0.604196	0.407454	1.645667	1.455971	0.570081	0.504368
Qem_N2O	164	0.723359	0.421013	0.458184	60.12447	0.601245	0.289316	-0.18784	0.596328	0.405634	0.213059	0.560764	0.294541
lai_n	36	1.392396	0.636302	0.934818	30.78717	0.307872	0.740821	-0.19466	0.536378	0.869629	0.342974	0.624556	0.246319
mafraiss	45	22.62633	19.26364	11.76766	28.74446	0.287445	9.51628	-7.55128	0.723362	9.000897	7.580351	0.397806	0.335023
mafruit	36	2.841425	2.294692	1.507738	39.0625	0.390625	1.08831	-0.06385	0.71039	0.894475	1.21375	0.314798	0.427162
masec_n	45	3.889717	3.583847	1.782684	31.46392	0.314639	1.197028	-0.17954	0.785181	0.722168	1.629857	0.185661	0.419017
msrac_n	45	0.122703	0.074877	0.083265	28.07243	0.280724	0.06731	0.003598	0.529047	0.06669	0.049856	0.543504	0.406314
pdsfruitfrais	45	14.84303	10.39887	9.021769	37.34685	0.373468	6.808925	-4.60483	0.622168	7.395533	5.16705	0.49825	0.348113

# Evaluation

variable	n_obs	sd_obs	sd_sim	RMSE	nRMSE	rRMSE	MAE	Bias	EF	RMSEs	RMSEu	RMSEs_sd	RMSEu_sd
CNgrain	35	0.39354	0.492677	0.307799	20.40218	0.204022	0.247748	-0.21218	0.370284	0.217091	0.218201	0.551636	0.554456
CNplante	44	1.49809	1.987299	0.885551	25.59578	0.255958	0.706682	-0.02315	0.642451	0.298901	0.833582	0.199522	0.55643
HR_1	171	4.463284	0.87443	4.542518	39.81193	0.398119	3.314608	0.330216	-0.04191	4.458064	0.871859	0.998831	0.19534
QCrac	45	57.48426	28.45397	43.05638	35.96394	0.359639	34.23552	-5.64222	0.426231	37.90679	20.41879	0.659429	0.355207
QNgrain	35	30.99437	25.82601	21.85495	48.493	0.48493	14.75529	-2.44369	0.488173	12.62798	17.83741	0.407428	0.575505
QNplante	44	80.46488	48.40587	56.19389	39.13455	0.391345	38.46469	-17.4439	0.500943	46.69577	31.26113	0.580325	0.388507
QNracs	45	3.389327	1.986444	2.530509	34.6078	0.346078	2.078197	0.450561	0.429903	2.074673	1.448864	0.61212	0.427478
Qem_N2O	131	0.759329	0.41067	0.480258	59.96864	0.599686	0.308601	-0.26713	0.596895	0.458688	0.142314	0.604071	0.18742
lai_n	36	1.543204	0.64463	1.130814	36.93348	0.369335	0.781694	-0.22643	0.447706	1.055961	0.404584	0.684265	0.262171
mafraiss	44	24.81245	19.31695	15.6378	39.95045	0.399505	10.69575	-5.46926	0.59356	10.70816	11.39631	0.431564	0.459298
mafruit	35	2.610432	2.247015	1.73491	49.84281	0.498428	1.170231	0.399587	0.545307	0.972995	1.436382	0.372733	0.550247
masec_n	44	3.867045	3.596298	2.350831	43.41714	0.434171	1.544874	0.133232	0.621846	0.9878	2.133227	0.25544	0.551643
msrac_n	45	0.13699	0.074878	0.102168	34.09469	0.340947	0.083467	0.000549	0.431136	0.086024	0.055119	0.627958	0.402357
pdsfruitfrais	44	14.42477	10.13506	9.367507	41.9184	0.419184	7.20035	-2.45677	0.568466	6.9257	6.307525	0.480126	0.437271