Empirical approach for developing production environment soil health goals, New York, USA

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March 16, 2023

Abstract

Defining quantitative soil health goals can support efforts to improve soil quality and meet broader ecosystem services goals, while simultaneously helping field-level benchmarking of soil health on farms. But soil health metrics in agricultural systems require edaphic context, notably climate, soil type (soil texture and classification), as well as cropping system. Soil samples (n=1,328) from New York State (USA) with Land Resource Regions (LRR), texture, and cropping system information were analyzed for eight physical and biological soil health indicators (soil organic matter, permanganate-oxidizable carbon, respiration, protein, available water capacity, wet aggregate stability, and penetration resistance from 0-15 and 15-45 cm), and population distribution functions were determined. Production environment soil health (PESH) goals were derived for four soil texture groups and six cropping systems by proposing the 75^{th} and 90^{th} percentile for each factorial class. Finer-textured soils and Pasture and Mixed Vegetable cropping systems generally had the highest values for soil health goals, followed by Dairy Crop and Orchard systems, then Annual Grain, and lastly Processing Vegetable systems. Long Island (LRR-S) had soil organic matter PESH goals that were on average 0.7 % lower than the rest of New York State (LRRs-L&R). This implies that regional PESH goals within a state or region may be warranted if edaphic context is considerably different.

Table 2. Mean values (standard deviation; SD) for biological and physical soil health indicators across four soil texture groups in NYS without Long Island (LRR-L&R). These mean and SD values are the parameters required for the cumulative normal distribution scoring functions specific to cropping system and soil texture (production environment).

Cropping System	n	SOM	Pred. SOC	POXC	Protein	Resp	WAS	AWC
		%	%	mg C/kg	mg/g	mg CO_2/g	%	g H_2O/g soil
Coarse-Textured								
Annual Grain	37	2.2 (0.6)	1.4 (0.4)	428 (143)	5.5 (1.6)	0.45 (0.16)	33.7 (17.0)	0.16 (0.03)
Processing Veg	20	1.9 (1.0)	1.3 (0.7)	363 (201)	5.0 (2.3)	0.37 (0.26)	25.1 (19.8)	0.17 (0.05)
Dairy Crop	29	2.8 (1.4)	1.9 (1.0)	551 (270)	6.7 (2.7)	0.54 (0.28)	39.9 (22.5)	0.16 (0.07)
Mixed Veg	29	3.4 (1.3)	2.3 (0.9)	579 (243)	9.8 (4.3)	0.57 (0.26)	43.6 (18.3)	0.18 (0.06)
Orchard	44	2.4 (0.8)	1.6 (0.6)	552 (231)	6.7 (3.0)	0.44 (0.21)	38.4 (19.2)	0.17 (0.05)
Pasture	16	3.1 (0.8)	2.1 (0.5)	531 (142)	7.8 (1.9)	0.62 (0.20)	63.8 (23.0)	0.20 (0.06)
All	175	2.6 (1.1)	1.8 (0.8)	506 (224)	6.9 (3.2)	0.49 (0.24)	39.3 (21.5)	0.17 (0.05)
Loam								
Annual Grain	209	2.8 (0.7)	1.7 (0.5)	545 (158)	5.5 (1.7)	0.53 (0.15)	26.4 (15.5)	0.20 (0.03)
Processing Veg	38	2.7 (0.7)	1.6 (0.6)	440 (124)	5.1 (1.4)	0.46 (0.17)	21.2 (17.5)	0.20 (0.03)
Dairy Crop	133	3.2 (1.0)	2.0 (0.7)	617 (154)	6.6 (2.1)	0.65 (0.19)	30.5 (20.6)	0.21 (0.03)
Mixed Veg	62	4.0 (1.4)	2.5 (1.0)	667 (217)	8.8 (4.0)	0.62 (0.27)	37.3 (17.7)	0.22 (0.03)
Orchard	51	2.7 (0.8)	1.7 (0.6)	543 (167)	6.5 (1.9)	0.50 (0.19)	33.5 (19.7)	0.20 (0.04)
Pasture	38	4.0 (1.0)	2.5 (0.7)	638 (200)	8.2 (2.6)	0.86 (0.33)	61.1 (20.0)	0.23 (0.03)
All	531	3.1 (1.0)	1.9 (0.7)	576 (176)	6.4 (2.5)	0.59 (0.22)	31.5 (20.2)	0.21 (0.03)
Silt Loam								
Annual Grain	79	3.6 (1.0)	2.2 (0.7)	618 (202)	7.6 (3.1)	0.65 (0.24)	36.9 (21.8)	0.23 (0.05)
Processing Veg	21	3.5 (1.1)	2.2 (0.8)	554 (166)	6.9 (2.6)	0.57 (0.27)	37.4 (26.7)	0.23 (0.05)
Dairy Crop	52	3.9 (1.1)	2.5 (0.8)	628 (168)	7.8 (2.4)	0.67 (0.19)	38.8 (23.2)	0.26 (0.05)
Mixed Veg	58	4.3 (1.1)	2.7 (0.8)	685 (187)	9.2 (2.9)	0.65 (0.23)	48.9 (23.6)	0.27 (0.05)
Orchard	48	3.7 (1.0)	2.3 (0.8)	633 (161)	8.7 (3.1)	0.70 (0.29)	46.5 (19.2)	0.27 (0.05)
Pasture	60	5.2 (1.1)	3.3 (0.8)	684 (164)	10.0 (2.5)	1.11 (0.38)	74.2 (17.0)	0.27 (0.05)
All	318	4.1 (1.2)	2.6 (0.9)	642 (181)	8.5 (3.0)	0.74 (0.32)	47.9 (25.3)	0.26 (0.05)
Fine-Textured								
Annual Grain	12	3.9 (0.8)	2.2 (0.5)	650 (150)	6.3 (1.0)	0.53 (0.20)	36.9 (21.8)	0.23 (0.04)
Processing Veg	*	3.9 (0.8)	2.3 (0.8)	650 (150)	6.3 (1.0)	0.53 (0.20)	31.1 (23.2)	0.23 (0.04)
Dairy Crop	23	4.3 (0.8)	2.5 (0.4)	730 (120)	6.7 (2.3)	0.60 (0.14)	38.8 (23.2)	0.23 (0.04)
Mixed Veg	*	4.2 (1.2)	2.5 (0.8)	730 (120)	6.7 (2.3)	0.60 (0.14)	38.6 (24.0)	0.23 (0.04)
Orchard	*	4.2 (1.0)	2.5 (0.6)	730 (120)	6.7 (2.3)	0.60 (0.14)	43.1 (20.5)	0.23 (0.04)
Pasture	4*	4.8 (1.7)	2.8 (0.9)	740 (210)	8.4 (2.6)	1.23 (0.18)	68.5 (22.9)	0.23 (0.04)
All	40	4.2 (0.9)	2.5 (0.6)	700 (145)	6.8 (2.1)	0.64 (0.24)	31.0 (21.2)	0.23 (0.04)

Table 3. Production environment soil health goals (Q75 and Q90 basis) by cropping system and soil texture for biological SH indicators for NYS without Long Island (LRR-L&R).

Cropping System	n	Q75 SOM	Q90 SOM	Q75 Pred. SOC	Q90 Pred. SOC	Q75 POXC	Q90 POXC	Q75 Protein	Q90 Protein	Q75 Resp	Q90 Resp
		%	%	%	%	mg C/ kg	mg C/ kg	mg/g	mg/g	mg CO_2/g	mg CO_2/g
Coarse-Textured											
Annual Grain	37	2.6	2.8	1.8	1.9	494	620	6.5	7.5	0.53	0.58
Processing Veg	20	2.2	2.8	1.5	1.9	509	603	6.7	7.7	0.42	0.60
Dairy Crop	29	3.7	4.3	2.5	3.1	668	954	8.5	9.4	0.63	0.85
Mixed Veg	29	4.6	5.0	3.0	3.4	790	900	12.5	15.0	0.65	1.00
Orchard	44	2.7	3.0	2.0	2.1	685	843	7.6	9.6	0.48	0.54
Pasture	16	3.4	4.2	2.3	2.9	575	735	9.0	9.6	0.75	0.87
All	175	3.1	4.2	2.1	2.9	629	836	8.1	11	0.58	0.78
Loam											
Annual Grain	209	3.2	3.7	2.0	2.3	651	757	5.9	7.2	0.61	0.69
Processing Veg	38	3.1	3.5	1.9	2.1	508	579	5.6	6.5	0.53	0.66
Dairy Crop	133	3.6	4.5	2.3	2.9	688	775	7.4	8.8	0.72	0.89
Mixed Veg	62	4.9	5.6	3.2	3.6	847	927	10.8	14.7	0.70	0.86
Orchard	51	3.2	3.7	2.1	2.3	617	731	7.2	9.0	0.58	0.76
Pasture	38	4.8	5.2	2.9	3.4	731	895	9.7	11.8	1.12	1.27
All	531	3.6	4.5	2.2	2.9	680	811	7.2	9.4	0.68	0.84
Silt Loam											
Annual Grain	79	4.2	5.2	2.7	3.3	758	856	8.7	11.4	0.72	0.87
Processing Veg	21	4.2	4.8	2.7	3.0	651	690	7.7	8.9	0.76	0.91
Dairy Crop	52	4.4	5.6	2.8	3.6	725	859	8.6	11.7	0.77	0.92
Mixed Veg	58	5.0	5.9	3.1	3.9	800	912	10.7	13.1	0.79	0.94
Orchard	48	4.5	4.8	2.8	3.1	746	834	9.7	12.1	0.89	1.08
Pasture	60	5.9	6.5	3.8	4.3	801	862	11.4	12.7	1.37	1.64
All	318	4.9	5.8	3.1	3.8	774	883	10.0	12.5	0.89	1.19
Fine-Textured											
Annual Grain	12	4.2	4.7	2.4	2.8	659	822	7.2	7.4	0.62	0.70
Processing Veg	*	4.2	4.7	2.4	2.8	659	822	7.2	7.4	0.62	0.70
Dairy Crop	23	4.7	5.1	2.8	3.3	784	924	7.9	8.8	0.69	0.80
Mixed Veg	*	4.7	5.1	2.8	3.3	784	924	7.9	8.8	0.69	0.80
Orchard	*	4.7	5.1	2.8	3.3	784	924	7.9	8.8	0.69	0.80
Pasture	4	5.9	6.5	3.8	4.2	797	857	11.3	12.6	1.37	1.63
All	37	4.6	5.2	2.8	3.1	777	913	7.8	8.9	0.70	1.06

*Groups with fewer than 10 in the fine-textured categories were interpolated based off silt loam values.

Table 4. Production environment soil health goals (Q75 and Q90 basis) by cropping system and soil texture for physical SH indicators for NYS without Long Island (LRR-L&R). Soil health goals for PR15 and PR45 are presented in the section 3.2.

Cropping System	n	Q75 WAS %	Q90 WAS %	Q75 AWC g H_2O/ g soil	Q90 AWC g H_2O/ g soil
Coarse-Textured					
Annual Grain	37	47.7	58.3	0.19	0.20
Processing Veg	20	28.0	43.9	0.21	0.23
Dairy Crop	29	49.7	71.6	0.21	0.24
Mixed Veg	29	57.7	69.1	0.22	0.24
Orchard	44	48.0	65.9	0.19	0.20
Pasture	16	84.5	86.1	0.23	0.28
All	175	52.4	72.2	0.20	0.23
Loam					
Annual Grain	209	34.5	44.5	0.22	0.24
Processing Veg	38	33.2	44.1	0.22	0.23
Dairy Crop	133	54.9	70.1	0.28	0.30
Mixed Veg	62	69.6	74.5	0.30	0.34
Orchard	51	42.9	68.3	0.22	0.23
Pasture	38	76.1	81.9	0.25	0.26
All	531	41.0	62.9	0.23	0.24
Silt Loam					
Annual Grain	79	54.7	70.1	0.26	0.30
Processing Veg	21	50.4	72.7	0.28	0.29
Dairy Crop	52	54.9	70.1	0.28	0.30
Mixed Veg	58	69.6	74.5	0.30	0.34
Orchard	48	59.1	72.3	0.31	0.34
Pasture	60	87.1	92.0	0.30	0.32
All	318	70.1	83.3	0.29	0.32
Fine-Textured					
Annual Grain	12	54.7	70.1	0.25	0.26
Processing Veg	*	50.4	72.7	0.25	0.26
Dairy Crop	23	54.9	70.1	0.25	0.26
Mixed Veg	*	69.6	74.5	0.25	0.26
Orchard	*	59.1	72.3	0.25	0.26
Pasture	4	87.1	92.0	0.25	0.26
All	40	70.3	84.0	0.25	0.26

*Cropping system goals in the fine-textured categories were assumed to be the same as the silt loam category for aggregate stability and the same as All fine-textured samples for AWC.

Table 5. Mean values (standard deviation; SD) and Production Environment Soil Health goals (Q75 and Q90 basis) by cropping system and soil texture for soil organic matter compared between Long Island (LRR-S) and the rest of NYS (LRR-L&R). Letters indicate differences in soil organic matter across regions within the same texture and cropping system categories (P<0.05).

	NYS (LRR-L&R)				Long Island (LRR-S)			
Cropping System	**n**	**Mean (SD) SOM**	**Q75 SOM**	**Q90 SOM**	**n**	**Mean (SD) SOM**	**Q75 SOM**	**Q90 SOM**
		%	%	%		%	%	%
Coarse								
Annual Grain	37	2.2 (0.6)	2.6	2.8	-	-	-	-
Processing Veg	20	1.9a (1.0)	2.2	2.8	25	1.7a (0.4)	2.1	2.2
Dairy Crop	29	2.8 (1.4)	3.7	4.3	-	-	-	-
Mixed Veg	29	3.4a (1.3)	4.6	5.0	46	3.3a (1.9)	4.0	6.3
Orchard	44	2.4b (0.8)	2.7	3.0	9*	3.3a (1.8)	4.1	5.5
Pasture	16	3.1a (0.8)	3.4	4.2	28	2.0b (0.7)	2.5	3.0
All	176	2.6 (1.1)	3.1	4.3	108	2.6 (1.5)	3.1	5.1
Loam								
Annual Grain	209	2.8 (0.7)	3.2	3.7	-		-	-
Processing Veg	38	2.7a (0.7)	3.1	3.5	10	2.2a (0.3)	2.5	2.6
Dairy Crop	133	3.2 (1.0)	3.6	4.5	-		-	-
Mixed Veg	64	4.0a (1.4)	4.9	5.6	26	2.6b (0.9)	2.9	3.5
Orchard	51	2.7a (0.8)	3.2	3.7	16	2.4a (0.7)	3.3	3.7
Pasture	38	4.0a (1.0)	4.8	5.2	8*	2.2b (0.6)	2.1	2.8
All	533	3.1 (1.0)	3.6	4.5	60	2.4 (0.7)	2.6	3.3
Silt Loam								
Annual Grain	79	3.6 (1.0)	4.2	5.2	-	-	-	-
Processing Veg	21	3.5a (1.1)	4.2	4.8	13	2.9a (1.0)	3.5	4.1
Dairy Crop	52	3.9 (1.1)	4.4	5.6	-	-	-	-
Mixed Veg	58	4.3a (1.1)	5.0	5.9	38	2.6b (0.7)	3.0	3.7
Orchard	48	3.7a (1.0)	4.5	4.8	25	2.8b (0.6)	3.1	3.7
Pasture	62	5.2a (1.1)	5.9	6.5	20	3.2b (0.8)	3.6	4.0
All	320	4.1 (1.2)	4.9	5.8	96	2.8 (0.8)	3.3	3.9

Figure 1: This is a caption

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