

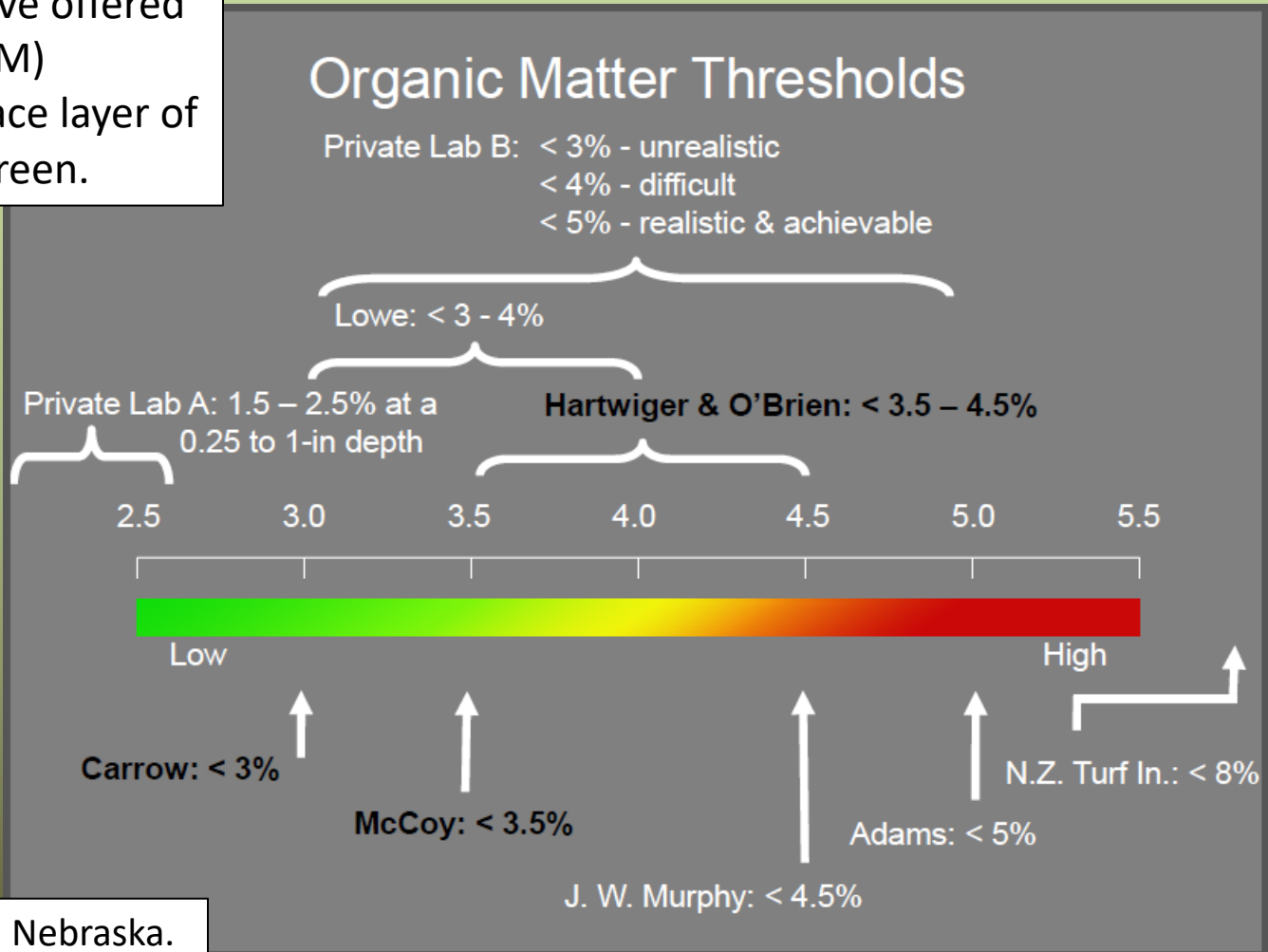
**Putting Greens Organic Matter  
Management:** via an Excel  
Simulation Tool, V 4.1

Ed McCoy, Ohio State University  
Jeff Broadbelt, DryJect, Inc.

Available at:  
<https://buckeyeturf.osu.edu/organicmattertool>  
<https://dryject.com/>



Multiple authorities have offered soil organic matter (SOM) thresholds for the surface layer of a sand-based putting green.



Credit: Roch Gaussoin, U. Nebraska.

## The Goal of this Model:

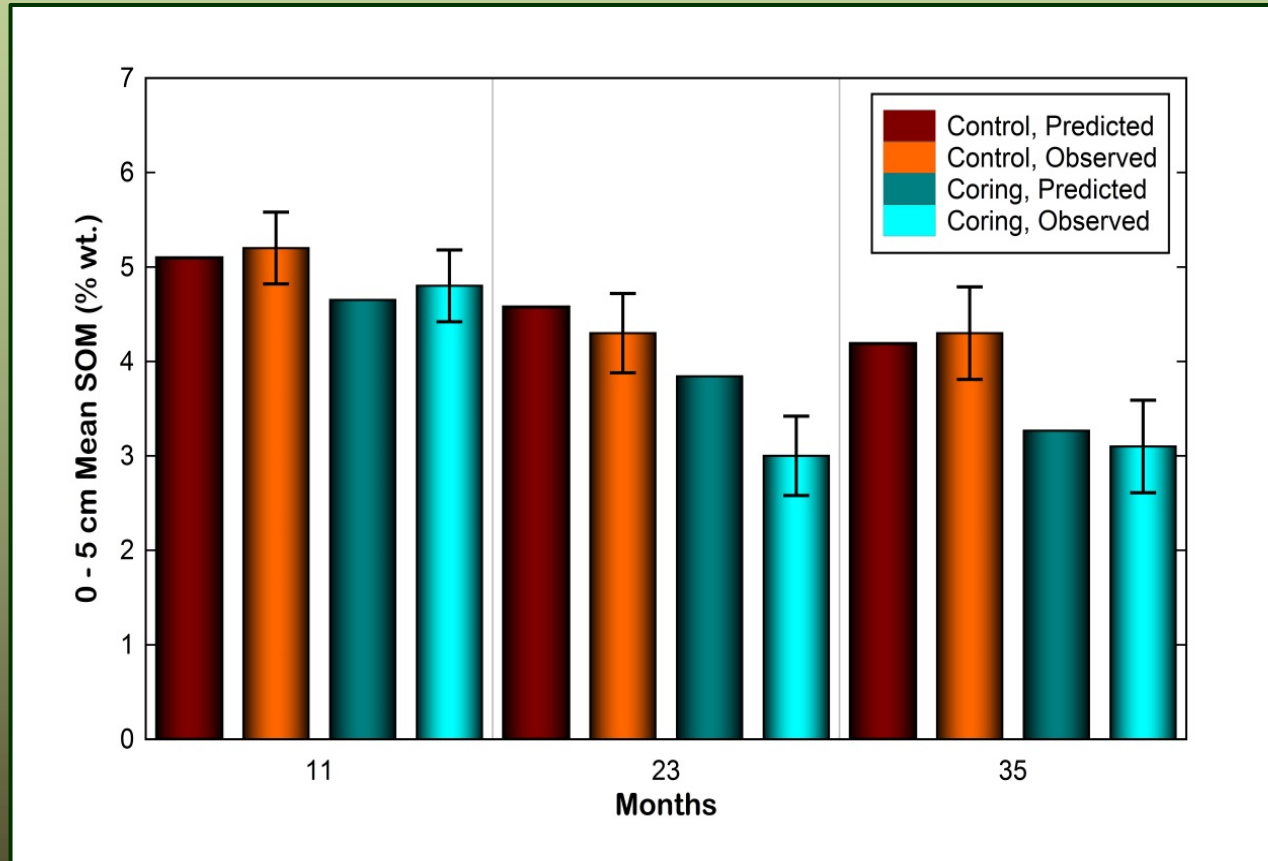
- 1) Calculate for a geographic location, monthly SOM values in the sand-based, surface 5-inch layer of a putting green that occur in response to:
  - Organic matter accumulation & decay each month.
  - Monthly operations that either dilute or remove soil organic matter.
- 2) Conform to conventional sampling and analysis of SOM in putting greens:
  - Only the surface layer is to be considered (i.e. top 5-inches).
  - The soil sample is subdivided into 1-inch increments.
  - Samples are sufficiently large or numerous to average across relict sand injection & core aeration holes.
- 3) Be accessible to interested users & equation based for transparency.

The model is based on a soil organic matter (SOM) mass balance equation that is calculated monthly for each of 5 depth intervals spanning 0 to 12.5 cm (0 to 5 in):

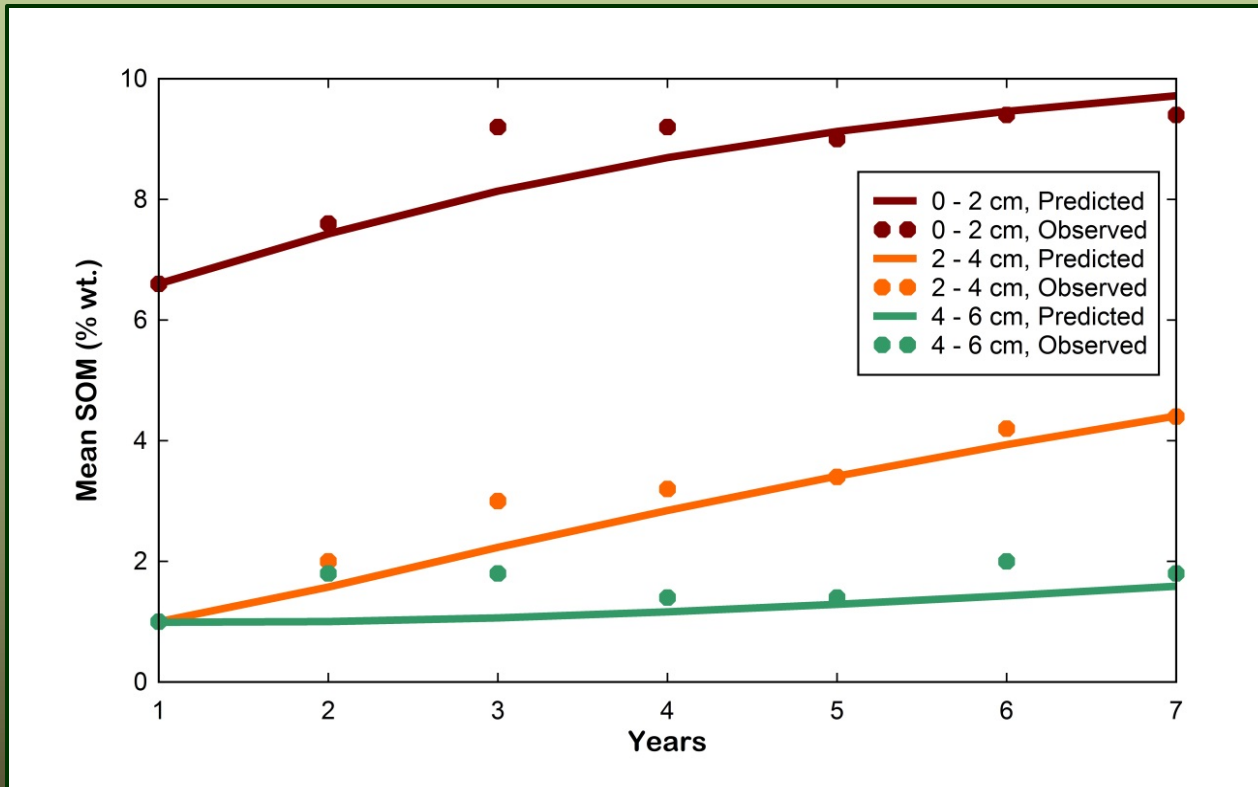
$$SOM_e = SOM_i + SOM_a - SOM_m - n_d \cdot SOM_d - n_r \cdot SOM_r$$

- $SOM_e$  is the soil organic matter at month's end ( $\text{g kg}^{-1}$ )
- $SOM_i$  is the month's beginning soil organic matter ( $\text{g kg}^{-1}$ )
- $SOM_a$  is the monthly accumulation of soil organic matter ( $\text{g kg}^{-1}$ )
- $SOM_m$  is the monthly natural decay of soil organic matter ( $\text{g kg}^{-1}$ )
- $n_d$  is the number of SOM dilution applications
- $SOM_d$  is the SOM reduction effect via dilution ( $\text{g kg}^{-1}$ )
- $n_r$  is the number of SOM removal applications
- $SOM_r$  is the SOM reduction effect via removal ( $\text{g kg}^{-1}$ )

Calibration Results: Using data from Ervin and Nichols (2011), comparing seasonal topdressing only (control) or seasonal topdressing plus twice yearly core aeration; model SOM accumulation and decay parameters were adjusted to best fit the observed data.



Calibration Results: using the data from Glasgow et al. (2005), where mean SOM was measured within 4 depth increments (3 shown here) for 7 putting greens built in successive years. For all times and all depths there was a good agreement between the observed and predicted values.



Baseline values of SOM accumulation and decay parameters for cool season turfgrass from the model calibration results (5 studies total).

Name	Symbol	Value	Units
Monthly Max. SOM Accumulation at z = 0	$AC_0$	3.0	$g\ kg^{-1}$
Monthly Max. SOM Accumulation at z = 125	$AC_{mx}$	0.03	$g\ kg^{-1}$
Depth of 1/2 Max. Accumulation	$z_h$	20	mm
Curve Shape Factor	s	10	-
Monthly Decay Rate Coefficient	$K_m$	0.025	-
Sand Bulk Density	$\rho_s$	1560	$kg\ m^{-3}$
Organic Matter Bulk Density	$\rho_{om}$	220	$kg\ m^{-3}$

## Monthly Max. SOM Accumulation at $z = 0$ .

- The baseline value of 3.0 g/kg is for average growing conditions.
- Consider larger values e.g. 4.0 g/kg for conditions of (Carrow, 2003):
  - ✓ Frequent irrigation.
  - ✓ High levels of N use.
  - ✓ Acidic, soil pH < 5.5.
  - ✓ Aggressive creeping bentgrass or bermudagrass cultivars.
- Consider smaller values e.g. 2.0 g/kg for management to limit growth.

The Monthly Decay Rate Coefficient is important for self-regulation of SOM accumulation.

Soil Organic Matter (SOM) in Putting Greens Monthly and with Depth to 125 mm (5 in).

E.L. McCoy, Ohio State University; J. Broadbelt, DryJet Inc, 2019.

SOM Accumulation & Decay Inputs in Red See goal & instructions below.

Monthly SOM Accumulation & Decay Temperature Function scaled [0 to 1]:

Location: **State College, PA**

Recommended Accumulation Temperatures, F: 68 for cool season, 88 for warm season.

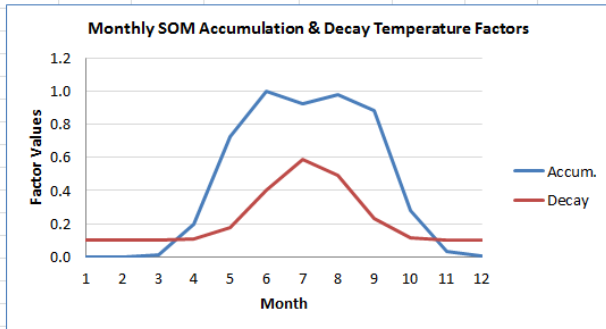
Cool Season = **68** Warm Season = **88**

Recommended Standard Deviation: 10 for cool season, 12 for warm season.

Cool Season = **10** Warm Season = **12**

Month	numeric Month	Mean Temp.* (F)	IndicateMonths of Cool (c) or Warm (w) Season Grass Growth.
Jan	1	28	c
Feb	2	29	c
Mar	3	38	c
Apr	4	50	c
May	5	60	c
Jun	6	68	c
Jul	7	72	c
Aug	8	70	c
Sep	9	63	c
Oct	10	52	c
Nov	11	42	c
Dec	12	32	c

\* <https://www.timeanddate.com/weather/usa/state-college/climate>



Depth Function of Monthly OM Accumulation:

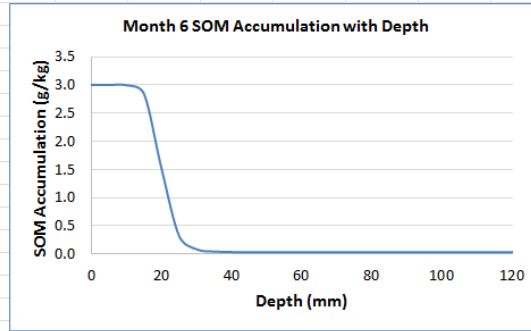
Overall Maximum SOM Accumulation at z = 0: **3** g/kg

Overall Maximum SOM Accumulation at z = zmax: **0.03** g/kg

Depth of 1/2 Maximum Accumulation: **20** mm

Shape Factor: larger steeper & vice versa **10**

Monthly Decay Rate Coefficient: **0.025**

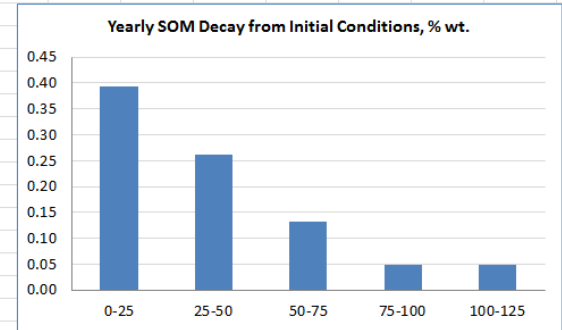
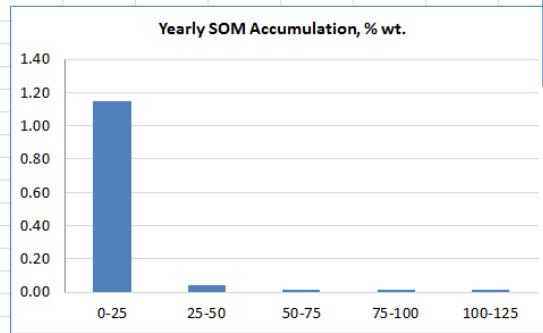
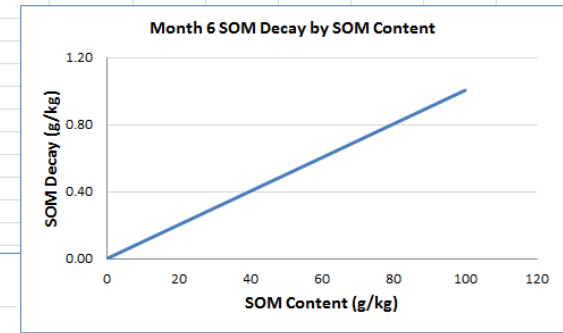


Sand Bulk Density **1560** kg/m3

SOM Bulk Density **220** kg/m3

SOM Initial Conditions

Increment	Depth (mm)	SOM g/kg	SOM %
1	0-25	60.00	6.00
2	25-50	40.00	4.00
3	50-75	20.00	2.00
4	75-100	7.50	0.75
5	100-125	7.50	0.75



Monthly SOM Accumulation & Decay Temperature Function scaled [0 to 1]:

Location: **State College, PA**

Recommended Accumulation Temperatures, F: 68 for cool season, 88 for warm.

Cool Season = **68**      Warm Season = **88**

Recommended Standard Deviation: 10 for cool season, 12 for warm season.

Cool Season = **10**      Warm Season = **12**

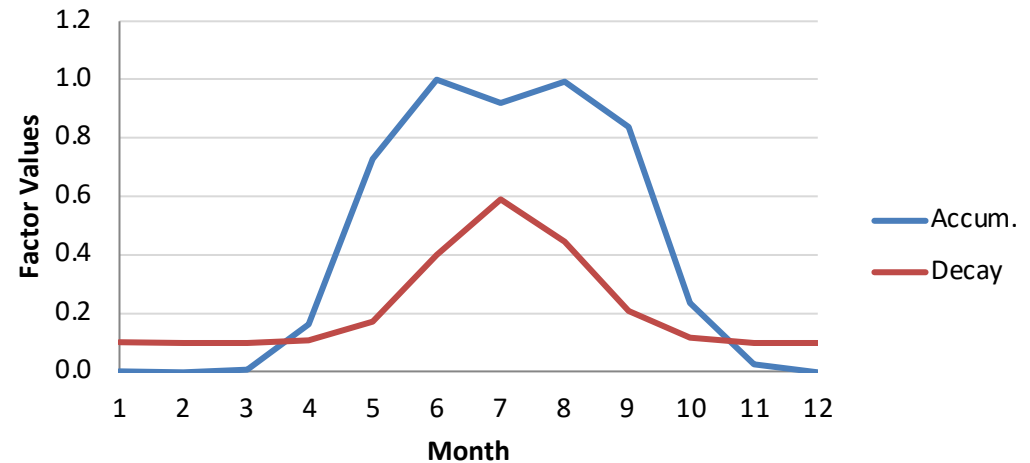
3		numeric	Mean	IndicateMonths of
4	Month	Month	Temp.*	Cool (c) or Warm (w) Season
5			(F)	Grass Growth.
6	Jan	1	28	c
7	Feb	2	29	c
8	Mar	3	38	c
9	Apr	4	50	c
10	May	5	60	c
11	Jun	6	68	c
12	Jul	7	72	c
13	Aug	8	70	c
14	Sep	9	63	c
15	Oct	10	52	c
16	Nov	11	42	c
17	Dec	12	32	c

\* <https://www.timeanddate.com/weather/usa/state-college>

The model is designed to be location specific.

Growth Potential Reference (GCSAA, 2010)

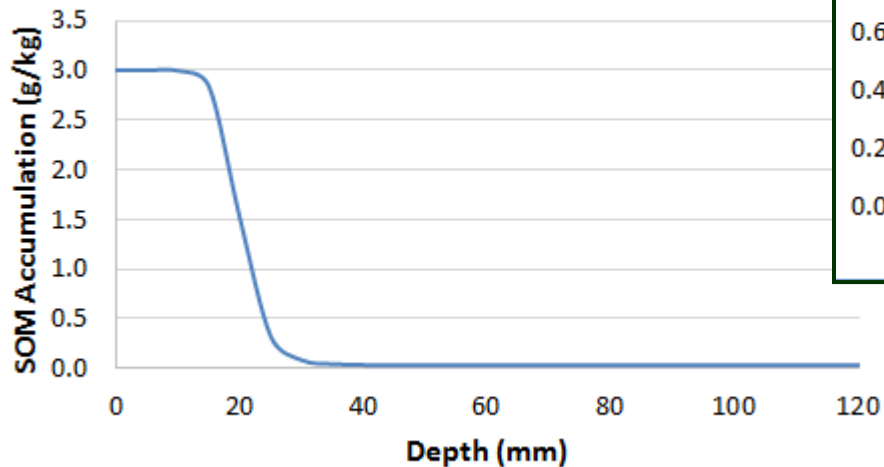
Monthly SOM Accumulation & Decay Temperature Factors



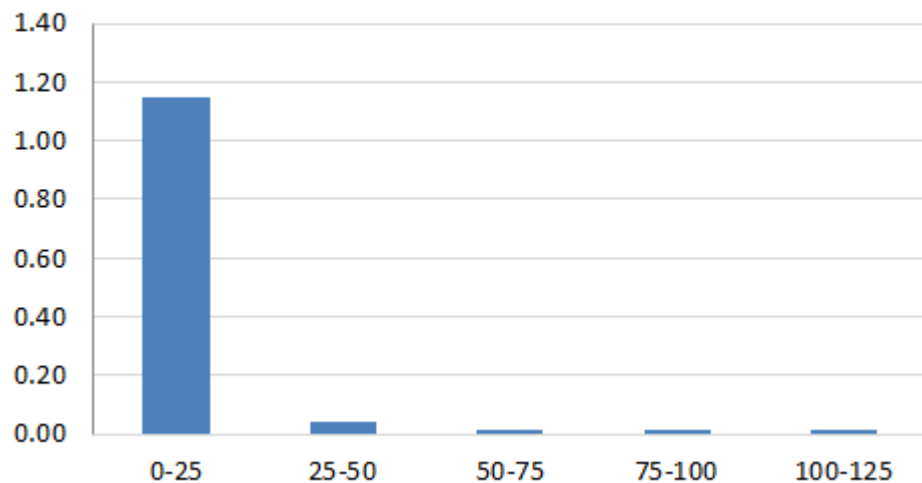
### Depth Function of Monthly OM Accumulation:

Overall Maximum SOM Accumulation at $z = 0$ :	3	g/kg
Overall Maximum SOM Accumulation at $z = z_{max}$ :	0.03	g/kg
Depth of 1/2 Maximum Accumulation:	20	mm
Shape Factor:	larger steeper & vice versa	10
Monthly Decay Rate Coefficient:	0.025	

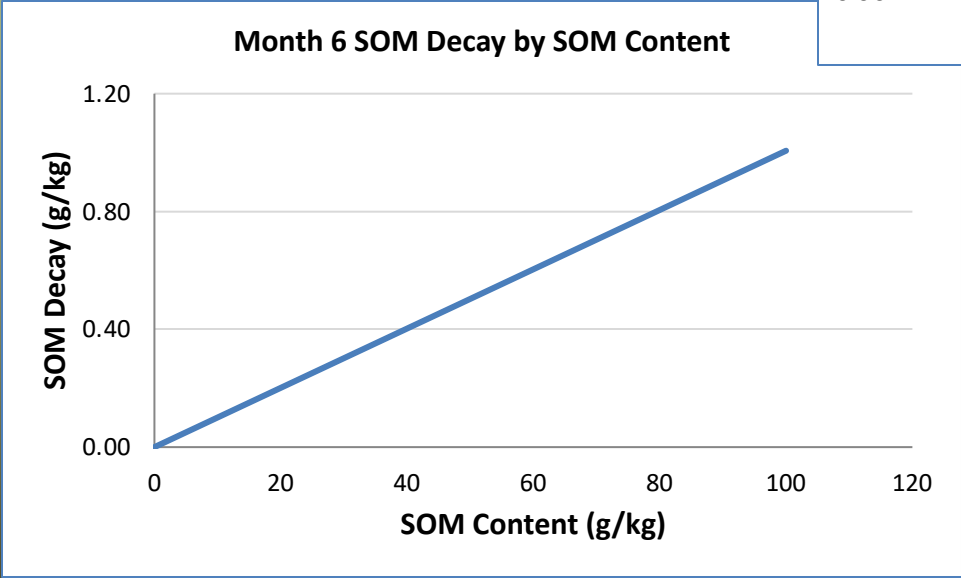
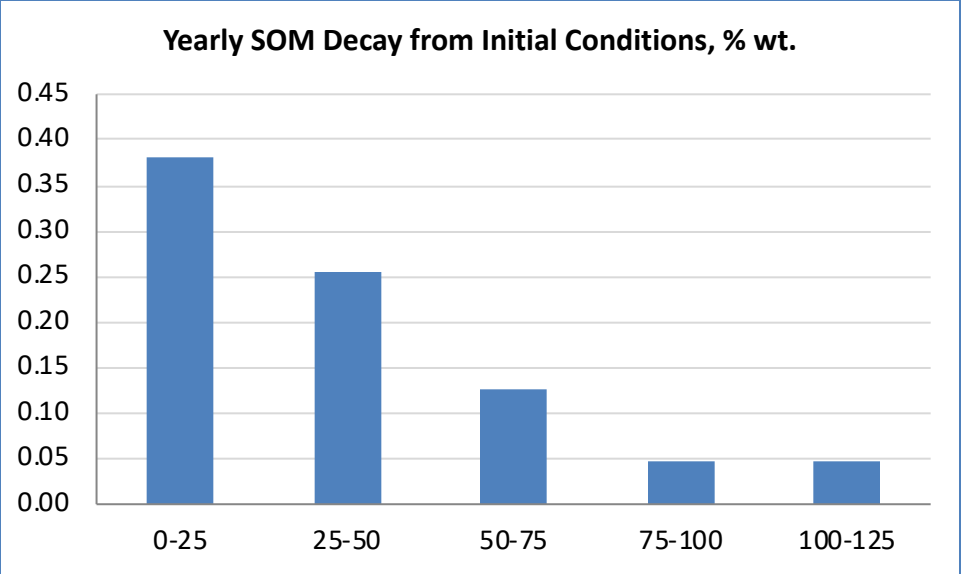
### Month 6 SOM Accumulation with Depth



### Yearly SOM Accumulation, % wt.



Sand Bulk Density	1560	kg/m <sup>3</sup>	
SOM Bulk Density	220	kg/m <sup>3</sup>	
SOM Initial Conditions			
Increment	Depth (mm)	SOM g/kg	SOM %
1	0-25	60.00	6.00
2	25-50	40.00	4.00
3	50-75	20.00	2.00
4	75-100	7.50	0.75
5	100-125	7.50	0.75





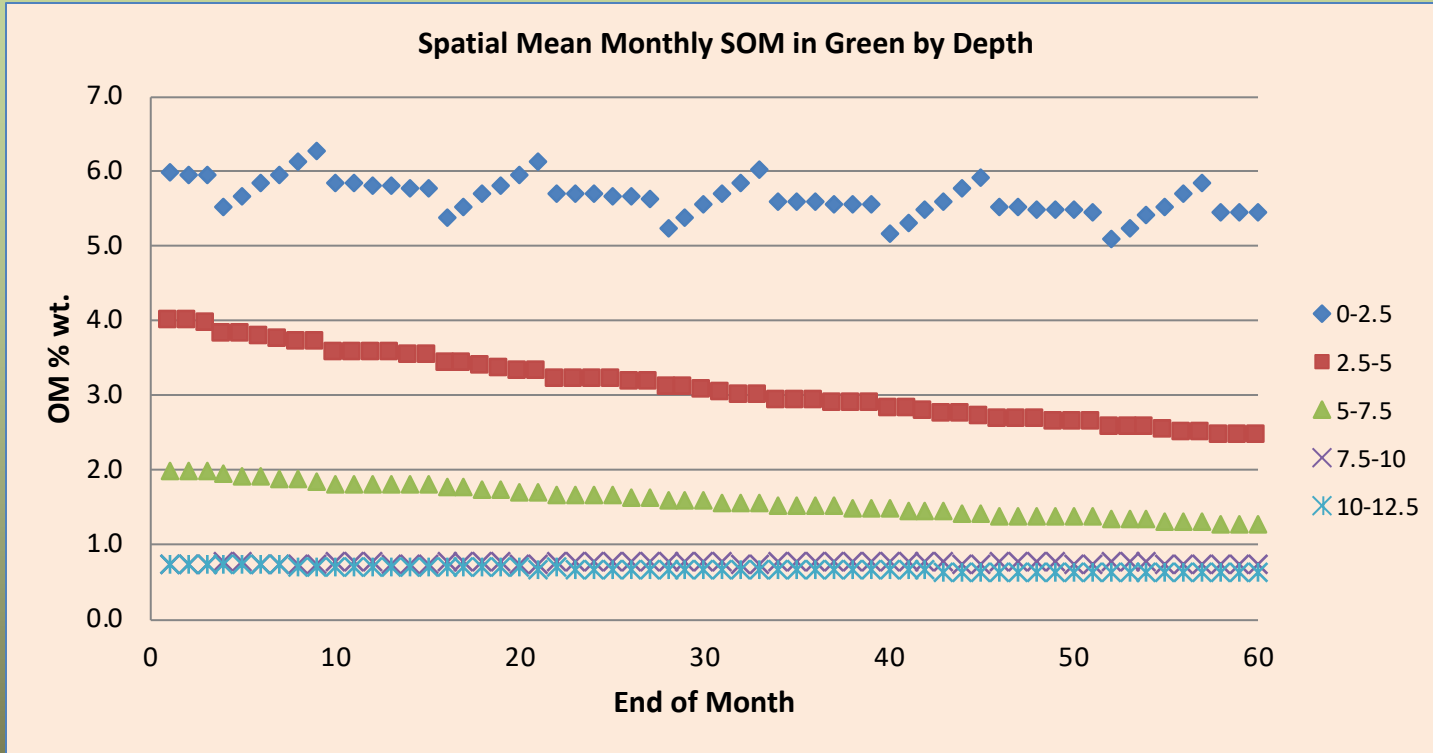
# Management Plan & Details: Twice Yearly ½-inch Hollow Tyne Aerations

Month	Number of Respective Operations per Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Month (numeric)	1	2	3	4	5	6	7	8	9	10	11	12
Topdressings	0	0	0	0	0	0	0	0	0	0	0	0
Sand Injections	0	0	0	0	0	0	0	0	0	0	0	0
Hollow-Tyne Aeration (HT)	0	0	0	1	0	0	0	0	0	1	0	0
Solid-Tyne Aeration (ST)	0	0	0	0	0	0	0	0	0	0	0	0
Deep Verticutting (DV)	0	0	0	0	0	0	0	0	0	0	0	0
HT, ST & DV Topdressing	0	0	0	1	0	0	0	0	0	1	0	0

Topdress Depth	0.03			cm
Sand Injection Hole Diam.	1.05			cm
Sand Injection Spacing	7.5	by	5.0	cm
Sand Injection Depth	7.5			cm
Hollow-Tyne Diameter	1.27			cm
Hollow-Tyne Aeration Spacing	7.5	by	5.0	cm
Hollow-Tyne Aeration Depth	7.5			cm
Solid-Tyne Diameter	1.27			cm
Solid-Tyne Aeration Spacing	7.5	by	5.0	cm
Solid-Tyne Aeration Depth	7.5			cm
DV Blade Thickness	2.0			mm
DV Depth	2.0			cm
HT, ST & DV Topdressing Depth	0.06			cm

Yearly Topdress Vol.	0.00	ft3	per 1000 ft2
Yearly Injection Vol.	0.00	ft3	per 1000 ft2
Yearly HT Vol.	16.62	ft3	per 1000 ft2
Yearly ST Vol.	0.00	ft3	per 1000 ft2
Yearly DV Vol.	0.00	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	20.56	ft3	per 1000 ft2

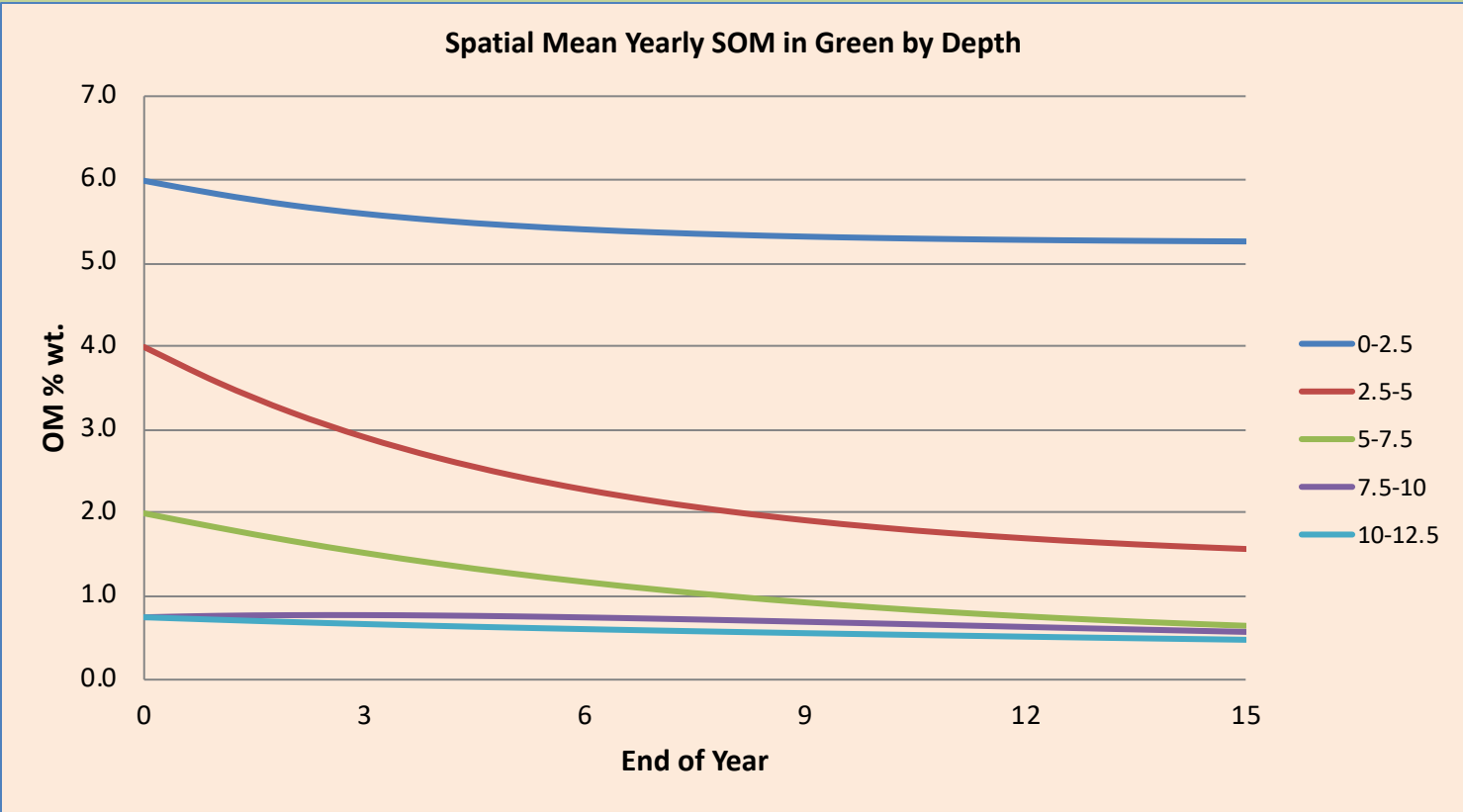
# 60 Month Results: Twice Yearly ½-inch Hollow Tyne Aerations



End of Year 5	
Depth	Organic
Increment	Matter
cm	% wt.
0-2.5	5.45
2.5-5.0	2.45
5.0-7.5	1.27
7.5-10.0	0.76
10.0-12.5	0.62

Seasonal SOM accumulation in the top 1-inch nearly negates the Hollow Tyne aeration.

# 15 Year Results: Twice Yearly ½-inch Hollow Tine Aeration



End of Year 15	
Depth	Organic
Increment	Matter
cm	% wt.
0-2.5	5.26
2.5-5.0	1.57
5.0-7.5	0.65
7.5-10.0	0.57
10.0-12.5	0.48

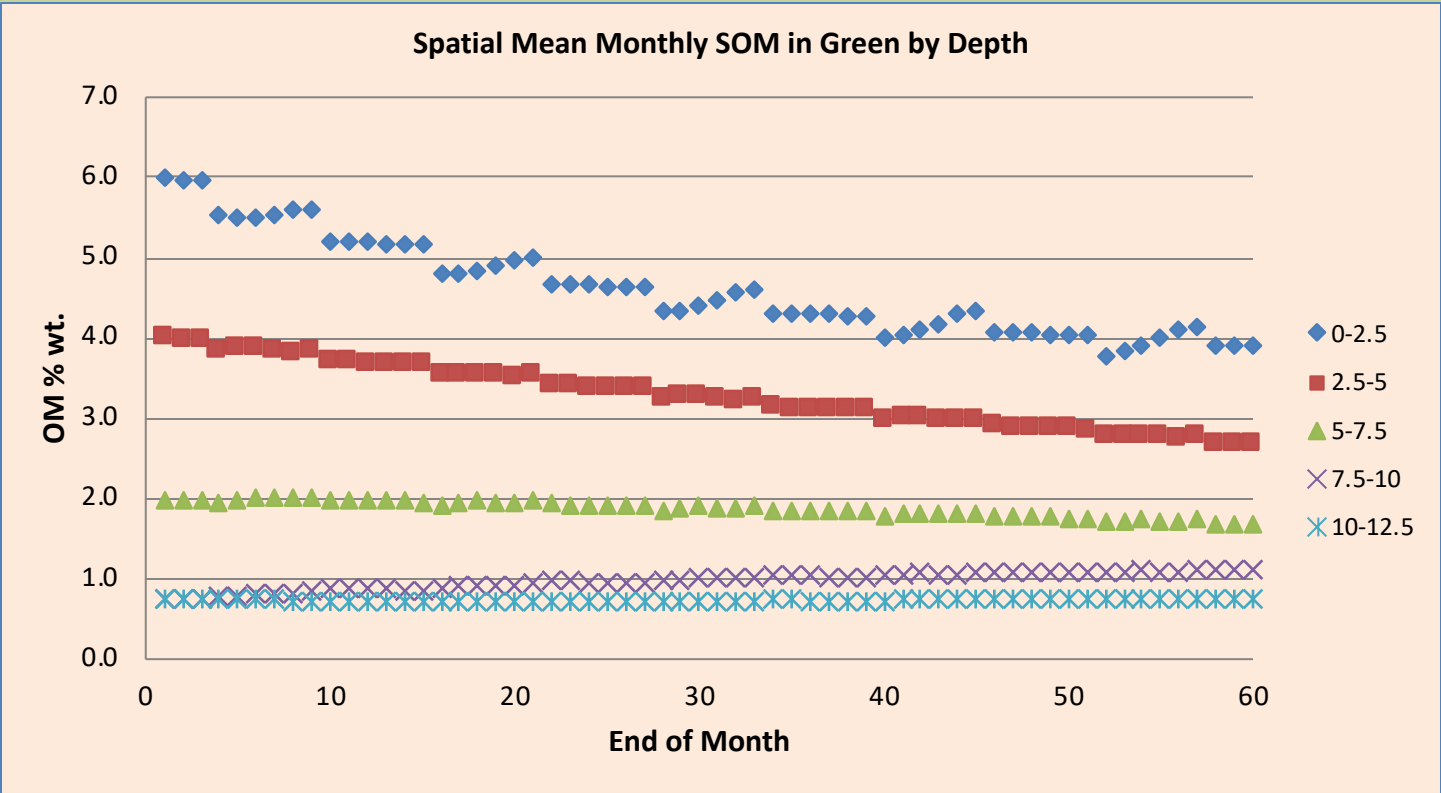
# Management Plan & Details: Twice Yearly Hollow Tyne + 8 Monthly Topdressings

Month	Number of Respective Operations per Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Month (numeric)	1	2	3	4	5	6	7	8	9	10	11	12
Topdressings	0	0	0	0	2	2	1	1	2	0	0	0
Sand Injections	0	0	0	0	0	0	0	0	0	0	0	0
Hollow-Tyne Aeration (HT)	0	0	0	1	0	0	0	0	0	1	0	0
Solid-Tyne Aeration (ST)	0	0	0	0	0	0	0	0	0	0	0	0
Deep Verticutting (DV)	0	0	0	0	0	0	0	0	0	0	0	0
HT, ST & DV Topdressing	0	0	0	1	0	0	0	0	0	1	0	0

Topdress Depth	0.03			cm
Sand Injection Hole Diam.	1.05			cm
Sand Injection Spacing	7.5	by	5.0	cm
Sand Injection Depth	7.5			cm
Hollow-Tyne Diameter	1.27			cm
Hollow-Tyne Aeration Spacing	7.5	by	5.0	cm
Hollow-Tyne Aeration Depth	7.5			cm
Solid-Tyne Diameter	1.27			cm
Solid-Tyne Aeration Spacing	7.5	by	5.0	cm
Solid-Tyne Aeration Depth	7.5			cm
DV Blade Thickness	2.0			mm
DV Depth	2.0			cm
HT, ST & DV Topdressing Depth	0.06			cm

Yearly Topdress Vol.	7.87	ft3	per 1000 ft2
Yearly Injection Vol.	0.00	ft3	per 1000 ft2
Yearly HT Vol.	16.62	ft3	per 1000 ft2
Yearly ST Vol.	0.00	ft3	per 1000 ft2
Yearly DV Vol.	0.00	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	28.44	ft3	per 1000 ft2

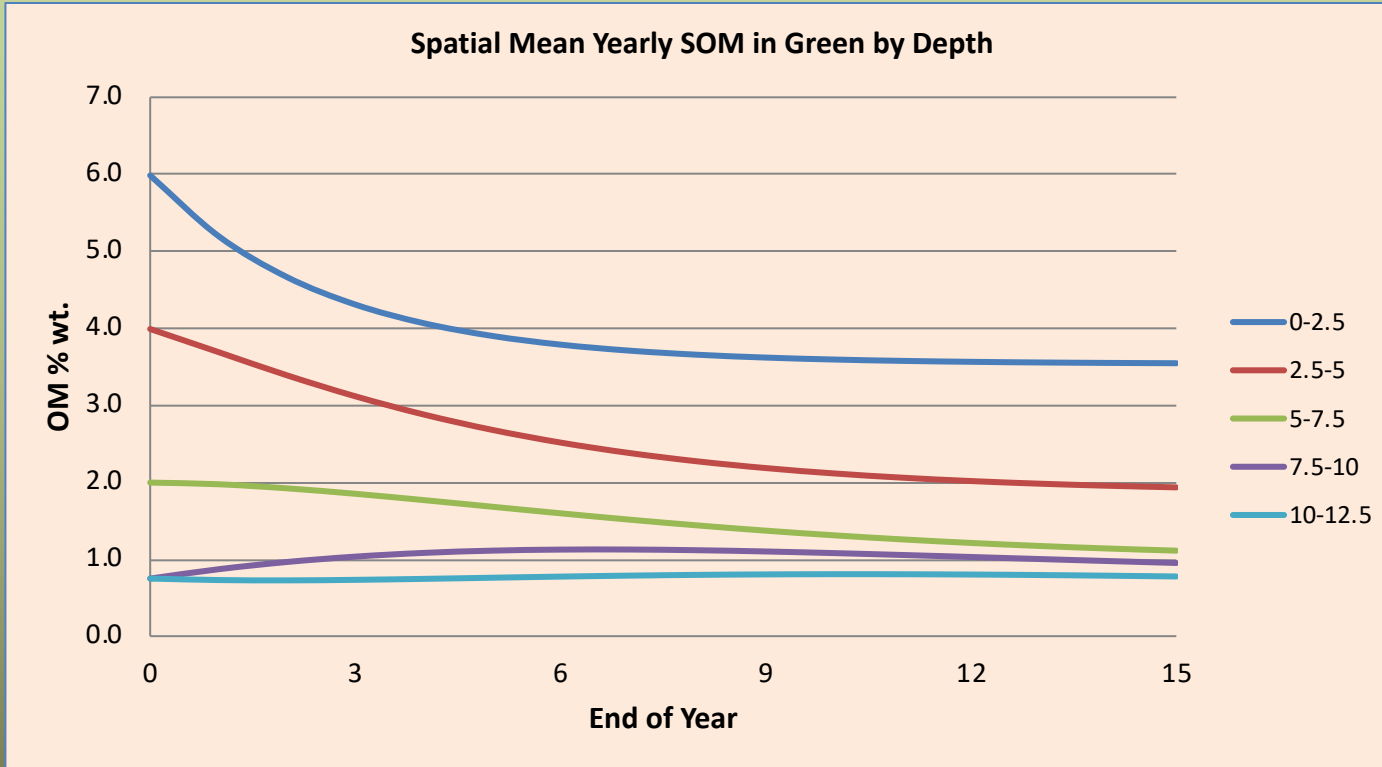
# 60 Month Results: Twice Yearly Hollow Tine + 8 Monthly Topdressings



End of Year 5	
Depth	Organic
Increment	Matter
cm	% wt.
0-2.5	3.90
2.5-5.0	2.68
5.0-7.5	1.68
7.5-10.0	1.11
10.0-12.5	0.76

Seasonal Topdressing needed to slow SOM accumulation.

# 15 Year Results: Twice Yearly Hollow Tyne + 8 Monthly Topdressings



End of Year 15	
Depth Increment cm	Organic Matter % wt.
0-2.5	3.55
2.5-5.0	1.93
5.0-7.5	1.11
7.5-10.0	0.95
10.0-12.5	0.78

# Comparing 1/2-inch Hollow Tine to 1/2-inch Solid Tine Each with 8 Monthly Topdressings

## Hollow Tine

Yearly Topdress Vol.	7.87	ft3	per 1000 ft2
Yearly Injection Vol.	0.00	ft3	per 1000 ft2
Yearly HT Vol.	16.62	ft3	per 1000 ft2
Yearly ST Vol.	0.00	ft3	per 1000 ft2
Yearly DV Vol.	0.00	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	28.44	ft3	per 1000 ft2

## Solid Tine

Yearly Topdress Vol.	7.87	ft3	per 1000 ft2
Yearly Injection Vol.	0.00	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	16.62	ft3	per 1000 ft2
Yearly DV Vol.	0.00	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	28.44	ft3	per 1000 ft2

End of Year 5		End of Year 15	
Depth	Organic	Depth	Organic
Increment	Matter	Increment	Matter
cm	% wt.	cm	% wt.
0-2.5	3.90	0-2.5	3.55
2.5-5.0	2.68	2.5-5.0	1.93
5.0-7.5	1.68	5.0-7.5	1.11
7.5-10.0	1.11	7.5-10.0	0.95
10.0-12.5	0.76	10.0-12.5	0.78

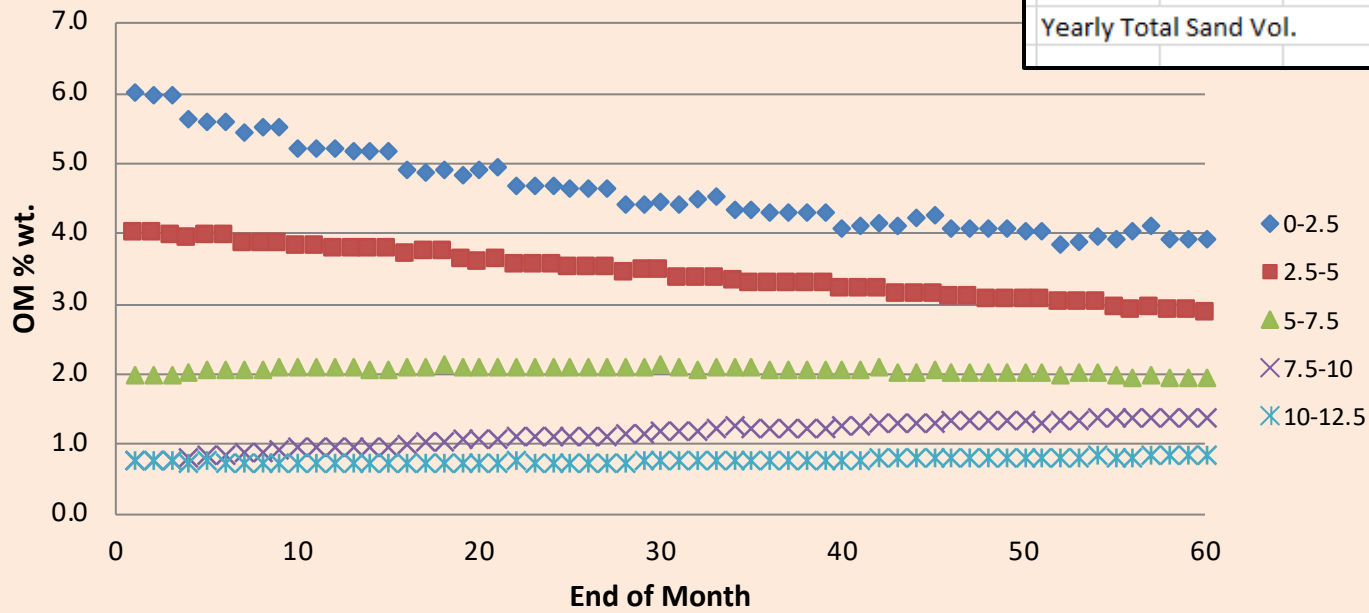
End of Year 5		End of Year 15	
Depth	Organic	Depth	Organic
Increment	Matter	Increment	Matter
cm	% wt.	cm	% wt.
0-2.5	3.93	0-2.5	3.57
2.5-5.0	2.91	2.5-5.0	2.25
5.0-7.5	1.96	5.0-7.5	1.44
7.5-10.0	1.37	7.5-10.0	1.24
10.0-12.5	0.84	10.0-12.5	0.96

SOM removal has only a small effect.

3, 0.42-inch diam. Sand Injections + 12 Topdressings Apr. to Oct.

Yearly Topdress Vol.	11.81	ft3	per 1000 ft2
Yearly Injection Vol.	17.05	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	0.00	ft3	per 1000 ft2
Yearly DV Vol.	0.00	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	0.00	ft3	per 1000 ft2
Yearly Total Sand Vol.	28.86	ft3	per 1000 ft2

Spatial Mean Monthly SOM in Green by Depth



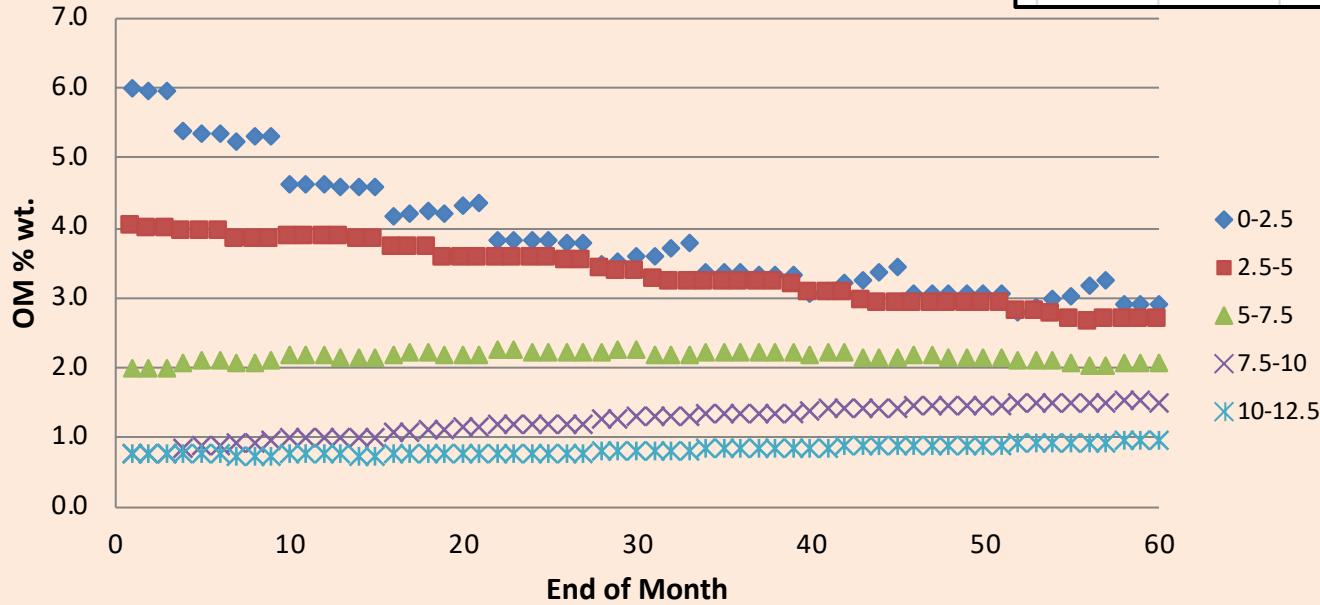
End of Year 15	
Depth	Organic
Increment	Matter
cm	% wt.
0-2.5	3.55
2.5-5.0	2.22
5.0-7.5	1.42
7.5-10.0	1.23
10.0-12.5	0.95

Very Similar Results as with Previous Hollow & Solid Tine Treatments.

1 Solid Tine (Apr.) + 1 Sand Injection (Jul.) + 1 Deep Verticut (Oct, 5/64") + 12 Topdressings (Apr. to Oct.)

Yearly Topdress Vol.	11.81	ft3	per 1000 ft2
Yearly Injection Vol.	5.68	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	8.31	ft3	per 1000 ft2
Yearly DV Vol.	5.17	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	34.91	ft3	per 1000 ft2

Spatial Mean Monthly SOM in Green by Depth

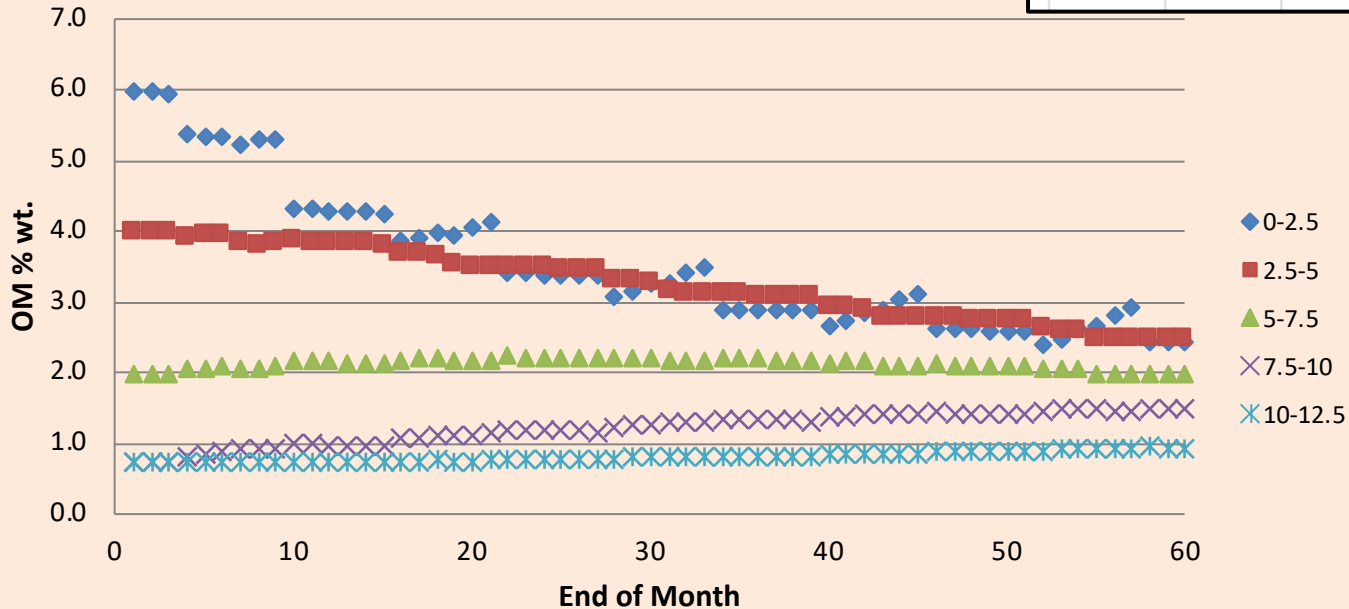


End of Year 15	
Depth	Organic
Increment	Matter
cm	% wt.
0-2.5	2.61
2.5-5.0	1.89
5.0-7.5	1.34
7.5-10.0	1.20
10.0-12.5	1.04

1 Solid Tine (Apr.) + 1 Sand Injection (Jul.) + 1 Deep Verticut (Oct, 9/64") + 12 Topdressings (Apr. to Oct.)

Yearly Topdress Vol.	11.81	ft3	per 1000 ft2
Yearly Injection Vol.	5.68	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	8.31	ft3	per 1000 ft2
Yearly DV Vol.	9.30	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	39.04	ft3	per 1000 ft2

Spatial Mean Monthly SOM in Green by Depth



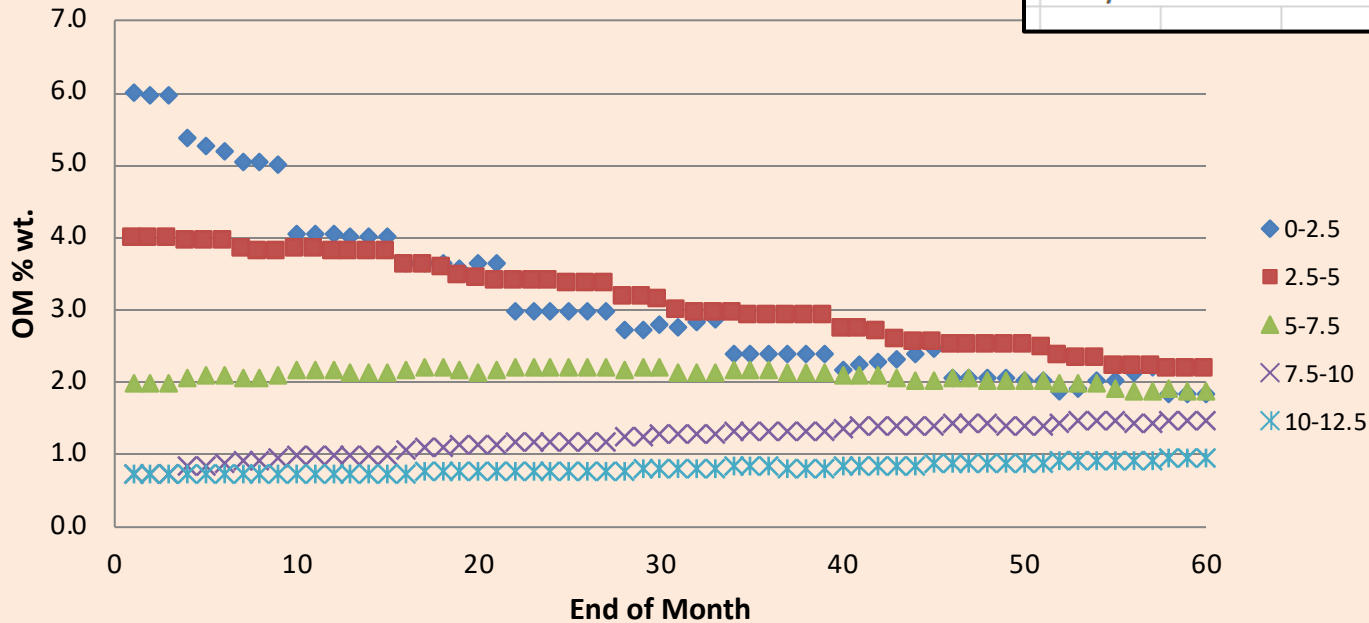
End of Year 15	
Depth Increment	Organic Matter % wt.
0-2.5	2.23
2.5-5.0	1.68
5.0-7.5	1.20
7.5-10.0	1.11
10.0-12.5	0.98

About 40 cu ft of Sand to Achieve 2.5% Surface SOM in 5-Years.

Same as Before Except Max SOM Accumulation = 2.0 g/kg.

Yearly Topdress Vol.	11.81	ft3	per 1000 ft2
Yearly Injection Vol.	5.68	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	8.31	ft3	per 1000 ft2
Yearly DV Vol.	9.30	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	39.04	ft3	per 1000 ft2

Spatial Mean Monthly SOM in Green by Depth

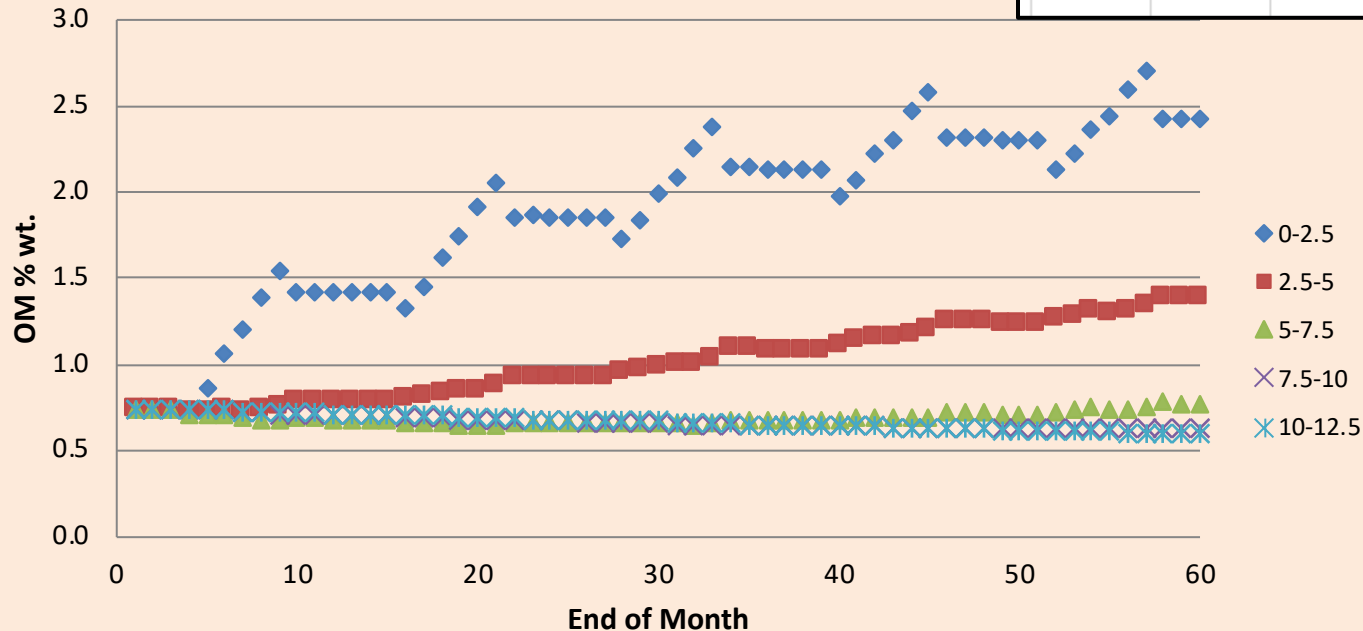


End of Year 15	
Depth Increment	Organic Matter % wt.
0-2.5	1.54
2.5-5.0	1.20
5.0-7.5	0.91
7.5-10.0	0.91
10.0-12.5	0.87

New Green: 1 Solid Tine (Apr.) + 1 Sand Injection (Jul.) + 1 Deep Verticut (Oct, 5/64") + 12 Topdressings (Apr. to Oct.)

Yearly Topdress Vol.	11.81	ft3	per 1000 ft2
Yearly Injection Vol.	5.68	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	8.31	ft3	per 1000 ft2
Yearly DV Vol.	5.17	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	34.91	ft3	per 1000 ft2

Spatial Mean Monthly SOM in Green by Depth

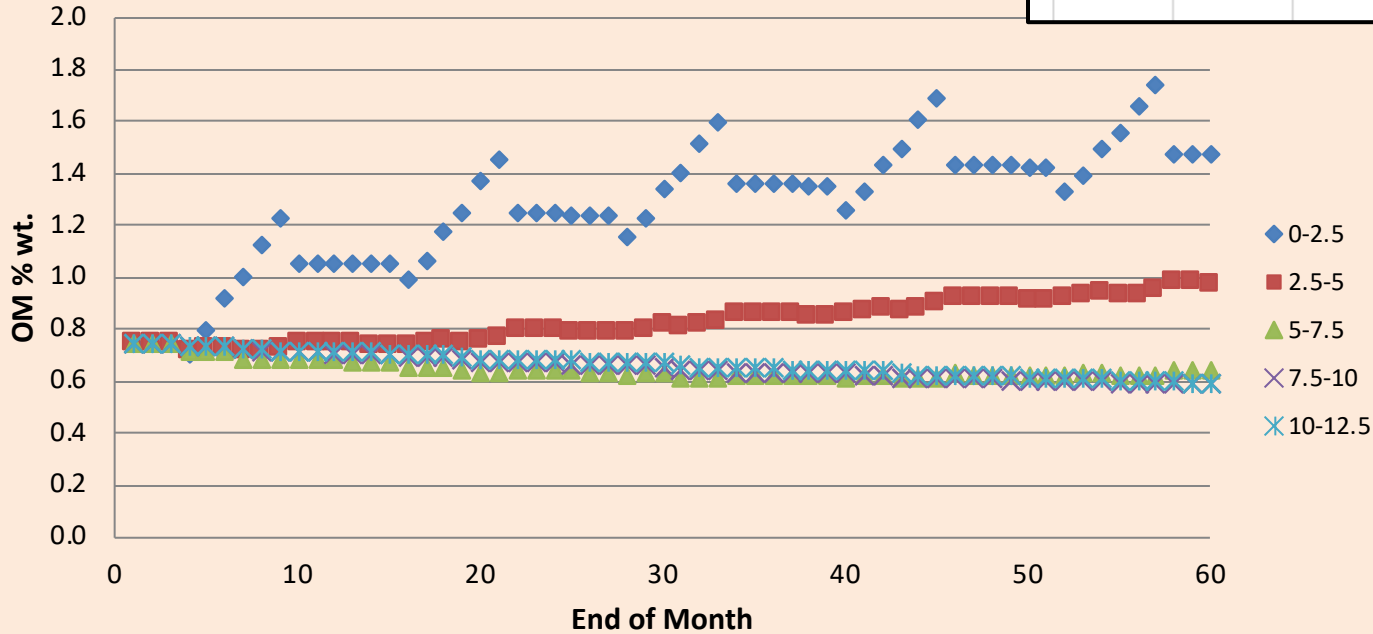


End of Year 15	
Depth	Organic
Increment	Matter
cm	% wt.
0-2.5	2.61
2.5-5.0	1.84
5.0-7.5	1.20
7.5-10.0	0.92
10.0-12.5	0.67

New Green: Same as Before Except Max SOM Accumulation = 2.0 g/kg & Deep Verticut (9/64")

Yearly Topdress Vol.	11.81	ft3	per 1000 ft2
Yearly Injection Vol.	5.68	ft3	per 1000 ft2
Yearly HT Vol.	0.00	ft3	per 1000 ft2
Yearly ST Vol.	8.31	ft3	per 1000 ft2
Yearly DV Vol.	9.30	ft3	per 1000 ft2
Yearly HT, St & DV Topdress Vo	3.94	ft3	per 1000 ft2
Yearly Total Sand Vol.	39.04	ft3	per 1000 ft2

Spatial Mean Monthly SOM in Green by Depth



End of Year 15	
Depth Increment	Organic Matter % wt.
0-2.5	1.54
2.5-5.0	1.16
5.0-7.5	0.79
7.5-10.0	0.64
10.0-12.5	0.53

Questions?

