Step-by-Step User's Manual, Version 5.1

A Location-Based Model of Organic Matter Fate within the Sand-Based Surface Layer of a Putting Green

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Model Description and Application

This model estimates future Soil Organic Matter (SOM) contents within the surface, 12.5 cm (ca. 5-in) depth of a putting green subject to various SOM control measures. The model operates on a monthly time step and the surface layer is subdivided into 2.5 cm (ca. 1-in) increments. The model is location-based through user input of local, long-term monthly high and low air temperatures, easily accessible on the web. SOM accumulation from turfgrass growth and natural SOM decay are also considered through user input of accumulation and decay factors. Version 5.1 provides the application of 2, user designed SOM diluting mixes, each containing up to 2 components, such as unamended sand, a sand/Profile mix, or a sand/Peat mix. The different mixes can then be assigned to individual SOM control measures.

Various SOM Management Options and their occurrences in the course of a year can be chosen by the user; including such operations as routine topdressing (TD), hollow-tyne (HT) aeration, solid-tyne (ST) aeration, direct injection (DI) and deep verticutting (DV). Also, the Operational Details of control operations such as TD depths; HT tube diameters, spacing & depth of coring; ST & DI hole diameters, spacing & depths; and DV blade widths & depth, all may be adjusted by the user.

The model operates on a scenario basis whereby the user specifies a given scenario and results of the model calculations are generated. Output includes plots of monthly (for 60 months) and yearly (for 15 years), spatial mean % by wt. organic matter for each of the 5 depth increments. These results are as if a large diameter core (such as a cup cutter) sample was withdrawn for testing. In addition, yearly volumes (cubic ft per 1000 sq ft green area) of each mix and for each Management Option are calculated. The model is designed for planning purposes whereby the user can run different SOM management scenarios and observe the efficacy of SOM control. This will provide superintendents a decision support tool to better manage organic matter within their putting greens.

Step 1. Location & Climate Information

Open the Excel file "Greens Organic Matter Mgmt Tool Ver 5.1" and navigate to I-O Page 1.

To make this management tool Location Specific one needs to specify the Location, Long-Term Mean Monthly Air Temperatures, & whether Cool or Warn Season turfgrass is being grown each month.

First Google "City State Climate." Topping the list of search hits is the information you are seeking. Then on this search item choose graphs and Fahrenheit (F). An example of the information you need to enter into the spreadsheet for Hatboro, PA is shown in **Fig. 1.**

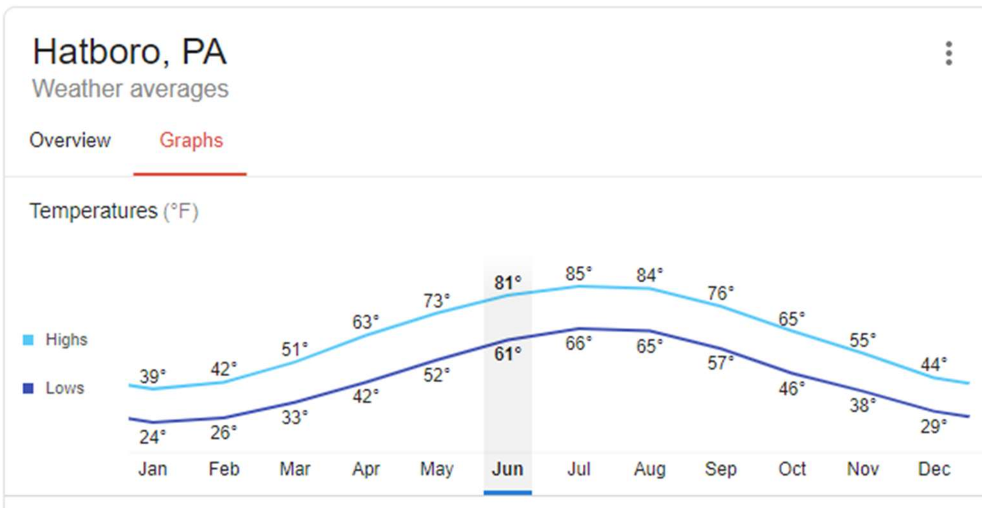

Fig. 1. Long-term average, monthly high and low air-temperatures for Hatboro, PA, USA.

On I-O Page 1 of the spreadsheet enter the city & state and transfer the monthly high & low air-temperatures where indicated in **Green**. The example for Hatboro is shown in **Fig 2.** You will note in **Fig. 2** that the mean monthly high & low air-temperatures are used to calculate the mean monthly air-temperature shown in **Black**. Throughout this analysis, values shown in **Black** are calculated results and should not be changed. Also, indicate in column G whether cool (c) or warm (w) season grasses are grown each month. *[According to Toy et al. (1977), mean monthly air-temperatures are a good approximation of mean monthly soil-temperatures at 2-inchs depth, approximately mid-way through the total soil depth of this analysis.]*

The graph on I-O Page 1 (**Fig. 2**) shows the monthly Accumulation & Decay temperature factors which in this case are for Hatboro, PA. SOM accumulation occurs optimally when monthly temperatures for turfgrass growth (either cool or warm season grasses) are near their optimum. If monthly temperatures are below the optimum then SOM accumulation will be less.

Also, if temperatures are above the optimum then SOM accumulation will be less as well. For Hatboro, PA, near optimal SOM accumulation temperatures occurs in June and September.

The optimum temperature for SOM decay is, interestingly, near 95 to 100 °F. Mean monthly temperatures above or below this optimum will reduce SOM decay rates. Decay can, however, continue slowly even when soils are cold. For Hatboro, PA, these factors result in optimum decay rates in July and slow decay all winter.

Location: Hatboro, PA

Month	numeric Month	Mean Hi Temp. (F)	Mean Low Temp. (F)	Mean Temp. (F)	Indicate Months of Cool (c) or Warm (w) Season Grass Growth.
Jan	1	39	24	32	c
Feb	2	42	26	34	c
Mar	3	51	33	42	c
Apr	4	63	42	53	c
May	5	73	52	63	c
Jun	6	81	61	71	c
Jul	7	85	66	76	c
Aug	8	84	65	75	c
Sep	9	76	57	67	c
Oct	10	65	46	56	c
Nov	11	55	38	47	c
Dec	12	44	29	37	c

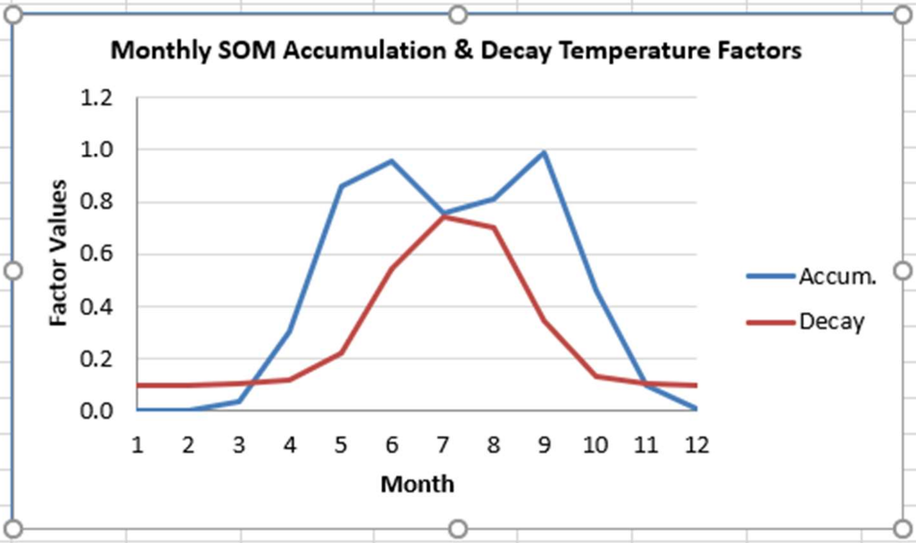

Fig. 2. Example of I-O Page 1 showing entered data & results for Hatboro, PA.

Step 2. Depth Distribution of SOM Accumulation & Decay

Navigate to I-O Page 2.

This page includes inputs to calculate the monthly rates and depth distribution of SOM Accumulation & Decay. SOM Accumulation results from turfgrass growth that is strongly influenced by monthly temperature where, as mentioned previously, maximum accumulation occurs at optimum growth temperatures for either cool or warm season grasses. Cold winter temperatures severely limit SOM accumulation. Further, results from model calibration studies indicate that most SOM accumulation occurs in the surface, 0 to 2.5 cm depth increment.

SOM Decay results from natural, soil microbial processes, is temperature dependent, occurs through the entire 12.5 cm depth and is also dependent on the monthly SOM content of a given soil layer. That is, if a given soil layer has a greater SOM content, then the SOM decay rates will be greater, for a given temperature, than if a soil layer has a smaller SOM content. *[Soil scientists say that SOM decay is universally a first-order process.]*

The user's choices on I-O Page 2 are values of the SOM Accumulation and Decay Rates (as used in this analysis). For "average" turfgrass growth condition calibration studies recommend a SOM Accumulation Rate of 3.5. For growth conditions with frequent irrigation, High N levels, aggressive cultivars, or acidic soil pH; consider a SOM Accumulation Rate up to 4.5. And for turfgrass management to limit growth, consider a SOM Accumulation Rate as low as 2.5. These suggested rates are for cool season grass as no calibration studies are available for warm season grasses.

Calibration studies examining SOM Decay fairly consistently center on a SOM Decay Rate value of 0.025.

Enter your SOM Accumulation and Decay Rates where indicated in **Green** (**Fig. 3**).

The graphs below show the depth distribution of Yearly SOM Accumulation & Decay for Hatboro, PA and using the indicated SOM Accumulation & Decay Rates.

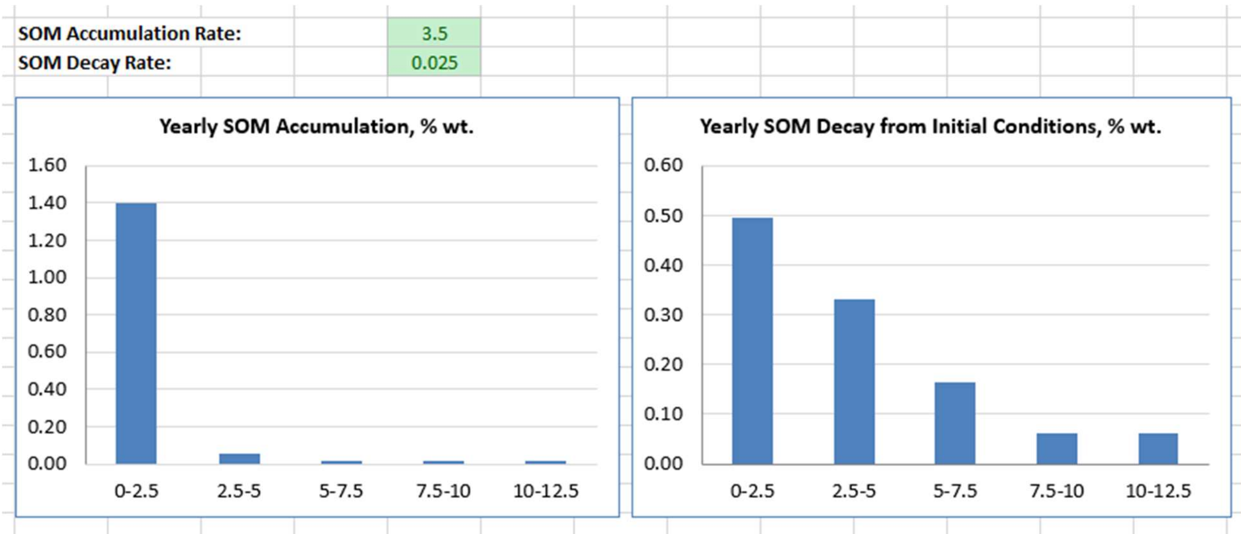

Fig. 3. Entered values for SOM Accumulation and Decay Rates and graphs for the yearly depth distribution of SOM Accumulation & Decay for Hatboro, PA. In this case, the initial conditions, as entered on I-O Page 3 for depth increments 1 to 5, were 60, 40, 20, 7.5 and 7.5 g/kg, yielding progressively less SOM Decay at deeper depths.

Step 3. Properties of the Mix Components, the Mixes Themselves & Initial Conditions

Navigate to I-O Page 3.

Two mixes (Mix 1 & Mix 2) can be designed for use in SOM Management. The different mixes can then be assigned to individual SOM control operations. For example, as shown in the Hatboro scenario of this document, the user can choose unamended sand for all routine topdressing operations, yet also choose a sand/15% Profile mix for the solid-tyne, hollow-tyne and direct injection operations of the yearly management plan. Only mixes containing up to 2 components are allowed. That is, the user could choose to use unamended sand (a 1 component "mix"), or sand/Profile, or sand/Peat (both 2 component mixes); but not a sand/Profile/Peat combination. The user can also choose the volume %'s of the amendment component of the mix.

The mix design protocol uses 2 component properties: Bulk Density (kg/m3) and Organic Matter Content (g/kg). *[To convert Bulk Density from the typical units of g/cm3 to kg/m3, multiply by 1000, and to convert Organic Matter from units of % by wt. to g/kg, multiply by 10.]*

To design the Mixes, enter the Mix Components Bulk Density (kg/m3) and Mix Components Organic Matter Content (g/kg) where indicated in **Green** (**Fig. 4**). Then specify the Amendment Type (correct spelling required) and Amendment % by Volume where indicated in **Green** (**Fig.**

4). The terms "**none**", "**Profile**" and "**Peat**" are presently the only terms that can be used to describe an amendment (see the Amendments Tab). Otherwise an error will occur.

Then to get the calculations started enter values of the Initial Depth Distribution of SOM (g/kg) and Profile (g/kg) where indicated in **Green** (**Fig. 4**). For a newly constructed green initial SOM values could be very low (eg. 7.5 g/kg) and consistent with depth. For a more mature green as shown in this example (**Fig. 4**) it is common to observe larger values at the surface and smaller values with depth. Of course, if measured values are known from greens testing, then those would be preferred. The same can be said for initial values for Profile. In this example we have assumed that Profile amendment has never been applied to this green.

Mix Components Bulk Density			
SOM Bulk Density	220	kg/m3	existing SOM
sand Bulk Density	1570	kg/m3	
Profile Bulk Density	660	kg/m3	
Peat Bulk Density	100	kg/m3	sphagnum
Mix Components Organic Matter Content			
Sand Organic Matter	0	g/kg	
Soil Organic Matter	See Initial Conditions		existing SOM
Profile Organic Matter	0	g/kg	
Peat Organic Matter	950	g/kg	sphagnum

Mix Properties **Mixes include: unammended sand, sand/Profile & sand/Peat**

	Amendment Type	**Vol % Amdt**	Vol % Sand	Mix OM (g/kg)	Mix Profile (g/kg)	Mix BD (kg/m3)
Mix 1	none	0	100	0.00	0.00	1570
Mix 2	Profile	15	85	0.00	69.06	1434

Initial Depth Distribution of SOM & Profile

Increment	Depth (mm)	SOM g/kg	SOM %	Profile g/kg	Profile %
1	0-25	60.00	6.00	0	0.00
2	25-50	40.00	4.00	0	0.00
3	50-75	20.00	2.00	0	0.00
4	75-100	7.50	0.75	0	0.00
5	100-125	7.50	0.75	0	0.00

Fig 4. Values of Mix Component Bulk Density and Mix Component Organic Matter Content as entries into the model. The Amendment Type and Volume % of Amendment is also entered. Mix properties of Vol % sand, Mix OM Mix Profile and Mix Bulk Density are then calculated. The entry space for the Initial Depth Distribution of SOM & Profile is shown on the right. The conversion to % by wt. is automatically performed.

One may want to consider using other types of amendments than Profile and (sphagnum) Peat. The information on the **Amendments Tab** provides properties of some common Organic and Inorganic Amendments, as found in the turfgrass literature This tab is editable so the user may add amendments and their corresponding properties to this library.

If using some other Organic Amendment, replace the Mix Component values for Peat on I-O Page 3 with those of the alternative Organic Amendment. The term "Peat" should be retained or errors will occur. Also, if using some other Inorganic Amendment, replace the Mix

Component values for Profile on I-O Page 3 with those of the alternative Inorganic Amendment. The term "Profile" should be retained or errors will occur.

Finally, to acknowledge that organic amendments change when added to soil, once Peat is added to the rootzone it automatically takes on the bulk density values of the existing SOM.

Step 4. The Management Options & Their Operation Details

Navigate to I-O Page 4. This is the page where most of the user's time will be spent.

The Management Options available include the SOM Control Operations of: Routine Topdressing, Hollow-Tyne Aeration, Solid-Tyne Aeration, Direct Injection & Deep Verticutting; and the number of these operations to be performed each month over the course of a year (**Fig 5**). This information is specified in the two tables of (**Fig. 5**), the first table is for **Mix 1** & the Second Table is for **Mix 2**.

Select which month and how many SOM control applications are to be applied for each Mix as shown in **Green** (**Fig. 5**). Check to ensure that there are no Management Options with non-zero entries for both mixes in the same month (see Warning tab).

Management Options (Mixs 1 & 2):													
	Number of Mix 1 (		none	0	% Amdment)		Operations per Month.						Yearly
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Operations
Month (numeric)	1	2	3	4	5	6	7	8	9	10	11	12	
Topdressings (TD) (Mix 1)	0	0	0	0	2	2	1	1	2	0	0	0	8
Direct Injections (DI) (Mix 1)	0	0	0	0	0	0	0	0	0	0	0	0	0
Hollow-Tyne (HT) Aeration (Mix 1)	0	0	0	0	0	0	0	0	0	0	0	0	0
Solid-Tyne (ST) Aeration (Mix 1)	0	0	0	0	0	0	0	0	0	0	0	0	0
Deep Verticutting (DV) (Mix 1)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of Mix 2 (		Profile	15	% Amdment)		Operations per Month.						
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 (TD) (Mix 2)	0	0	0	0	0	0	0	0	0	0	0	0	0
Direct Injections (DI) (Mix 2)	0	0	0	0	0	1	0	0	0	0	0	0	1
Hollow-Tyne (HT) Aeration (Mix 2)	0	0	0	0	0	0	0	0	0	1	0	0	1
Solid-Tyne (ST) Aeration (Mix 2)	0	0	0	1	0	0	0	0	0	0	0	0	1
Deep Verticutting (DV) (Mix 2)	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 5. The Management Options for Mixes 1 & 2 as separate tables. The columns of each table are months of the year and the rows are various SOM Control Operations. Selection of the number of applications per month for a given Control Operation means that those operations will be repeated each year for the duration of the calculation period (at least for this Version 5.1). *[The entries shown on this figure are not the authors' recommendations, but are for demonstration purposes only.]*

The Operation Details include such aspects as Topdressing Depth, Depth & Spacings of operations like Direct Injection, Hollow-Tyne Aeration & Solid-Tyne Aeration and also Deep Verticutting Blade Thickness (**Fig. 6**). The final Operational Detail is the unavoidable topdressing that would accompany HT, ST & DV Operations. This is often a heavier topdressing. *[Topdressing depths in Fig. 6 generally follows Whitlark and Thompson. 3 May 2019. USGA Green Section Record 57:1-8]*

Enter the Operation Details for the methods & implements you will or may employ to control SOM (in cm & mm) as shown in **Green** (**Fig 6**). Check the provided Notes following each Operation Detail entry.

Operation Details:					**Notes:**	
Topdress Depth	0.03			cm	0.03 = 1 ft3/M	
Direct Injection Hole Diam.	1.05			cm	from DryJect Inc.	
Direct Injection Spacing	7.5	by	5.0	cm		
Direct Injection Depth	7.5			cm	in 2.5 cm increments	
Hollow-Tyne Diameter	1.27			cm		
Hollow-Tyne Aeration Spacing	7.5	by	5.0	cm		
Hollow-Tyne Aeration Depth	7.5			cm	in 2.5 cm increments	
Solid-Tyne Diameter	1.27			cm		
Solid-Tyne Aeration Spacing	7.5	by	5.0	cm		
Solid-Tyne Aeration Depth	7.5			cm	in 2.5 cm increments	
DV Blade Thickness	2.0			mm	use 2 mm for 5/64"	use 3.6 mm for 9/64"
DV Depth	2.0			cm	does not exceed 2.5 cm	
HT, ST & DV Topdressing Depth	0.06			cm	a heavier topdressing	

Fig 6. The Operational Details that accompany each SOM control operation. This is for the example Hatboro PA scenario. The operational detail values will only enter into the calculations if a corresponding Management Option is entered into the tables of **Fig 5**. Otherwise the values can be left as is.

The **Warning Tab** points out that if there is a non-zero (1,2,3,…) entry for a given Management Option for either Mix 1 or Mix 2, that there **should not** be a non-zero entry for the other Mix during the same Month and the same Management Option.

An example of what to avoid is shown by the non-zero entries within the red circles. In this case, 2 ST Aerations occur in April, one using Mix 1 and the other using Mix 2. You should choose one Mix or the other with either a single or multiple ST Aerations. That is, one of the corresponding entries should be zero. If the situation shown occurs for any Management Option and Month then the computation will be incorrect. It is also rather impractical to be performing the same Management Option on a putting green in the same Month using different Mixes.

The remaining information on I-O Page 4 is the output of the calculations. To the right are the Yearly Mix Volumes used in the scenario for both Mixes and for each SOM control operation. Thus, as shown for the Hatboro scenario (**Fig. 7**) the Yearly Total Mix 1 Volume is 7.87 ft3/1000 sq ft consisting entirely of routine topdressing. The Yearly Total Mix 2 Volume is 26.24 ft3/1000 sq ft contributed by the DI, HT and ST operations each year.

Also shown (**Fig. 7**) are the Yearly Volumes of Profile (an inorganic amendment) and Peat (an organic amendment) contributed by each operation.

Yearly Mix & Amendment Volumes			
Mix 1	**Total**		
	Mix	**Profile**	**Peat**
	ft3/M	ft3/M	ft3/M
Yearly TD Volume	7.87	0.00	0.00
Yearly DI Volume	0.00	0.00	0.00
Yearly HT Volume	0.00	0.00	0.00
Yearly ST Volume	0.00	0.00	0.00
Yearly DV Volume	0.00	0.00	0.00
Yearly HT, ST & DV Volume	0.00	0.00	0.00
Yearly Total Mix 1 Volume	7.87	0.00	0.00
Mix 2	**Total**		
	Mix	**Profile**	**Peat**
	ft3/M	ft3/M	ft3/M
Yearly TD Volume	0.00	0.00	0.00
Yearly DI Volume	5.68	0.85	0.00
Yearly HT Volume	8.31	1.25	0.00
Yearly ST Volume	8.31	1.25	0.00
Yearly DV Volume	0.00	0.00	0.00
Yearly HT, ST & DV Volume	3.94	0.59	0.00
Yearly Total Mix 2 Volume	26.24	3.94	0.00
Yearly Total Mix 1 + Mix 2	34.12	3.94	0.00

Fig. 7. The yearly mix and amendment volumes for Mixes 1 & 2 and for each SOM Control Operation. This output is for the example Hatboro PA scenario. Results will be different for any other scenario.

Also shown on I-O Page 4 are the Results at a Glance tables for SOM (% wt.) and Profile (% wt.) within the 5 depth increments and at the end of years 5 and 15. Results of any added organic amendment are not shown because it is assumed that this organic amendment has become part of the SOM content of the root zone.

Finally shown on I-O Page 4 are graphs of the spatial mean SOM (% wt.) and Profile (% wt.) at each depth increment, monthly for 60 months and yearly for 15 years.

Scenario Print Tab

The Greens SOM Management Tool was designed for planning purposes whereby the user can run different SOM management scenarios and observe the efficacy of SOM control. To aid in comparison among scenarios, the scenario print tab is included in the program. To print the results for a scenario, go to the Scenario Print tab and click on the Name Box. Select Print Area. Then Print the area. I would choose Landscape printing and Shrink to 1 Page. Do not make any changes to the values on this page as you will break the link between this page and any future results. **Return to I-O Page 4 to set-up the next scenario.**

This will then print the results of the scenario. Another scenario can then be set-up, run and printed for comparison and planning.

Lastly, please leave the Calculations page alone.