Brookside LABS / Amplify

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Existing Root-zone Physical Testing

> "Anything worth doing, is worth doing right"
>
> Hunter S Thompson

The saying "Anything worth doing, is worth doing right" surely applies when it comes to proper sampling to ensure accurate data. Collecting a truly representative sample utilizing the best methods and subjecting those samples to the proper analytical procedures is a critical step to understanding greens performance and evaluating the effectiveness of cultural practices. If you have been challenged with trying to design or better understand your cultural practices around highly variable and incongruent test results, then review your sampling procedures. Like soil nutrient samples, **more than one core should be collected from a golf course green to obtain accurate and representative data.**

The sand, silt, clay, organic matter, and sand particle distributions (partial physical analysis) are the "meat and potatoes" of the physical report. If these levels are desirable, then the moisture measurements are most likely going to be within an acceptable range. Although undisturbed core samples might seem to be the best method of analysis, it is impossible to collect a sample that is truly "undisturbed." If small cores are used, then multiple cores will need to be collected to provide sufficient sample to meet the requirements for accurate laboratory analysis of factors such as particle size distribution and organic matter content.

In this article, the recommended number of samples, sample size and volume are discussed. Most importantly, I **do not recommend the use of a single core per green** to be representative of an entire green. In addition, I recommend that percolation rates be conducted in the field using an infiltrometer because there are no "undisturbed" samples. There will always be some disruption during sampling, shipping and handling in a laboratory that likely impact hydraulic conductivity. By following the steps outlined in this article you can help ensure that you obtain representative samples and accurate data from the laboratory to make management decisions related to root zone physical conditions.

Organic Matter Challenges: Unexplainable swings in organic matter content from one year to the next or even within the same growing season (Table 1. Data from a single 2-inch core) are common. There are many different ways to sample and analyze organic matter in existing root-zones; however, when done properly, there is typically no more than 0.2% to 0.75% change within twelve months for cool season turf. Like the USGA quality control confidence interval for organic matter, I suggest that a change of <0.2% is not a significant change as there may be this much variability in testing the same sample. If you are seeing changes >1% within a year on mature cool season turf putting greens (without highly aggressive cultural practices), then I suggest having the sample re-checked, utilize a more representative sampling method or seeking an alternative source for the data.

Table 1.	Organic Matter%		
Date	November 2011	March 2011	March 2010
Green 10 (0-1")	2.84%	3.57%	2.04%

Data from a single 2-inch core (**Not** Brookside Labs data)

Infiltration Challenges:

Infiltration/ Hydraulic Conductivity readings are another parameter that have caused concern for testing accuracy. It is challenging to replicate this "real world" physical property, but typically when the organic matter increases in a high sand content root-zone, the infiltration reading should decrease. Increase in organic matter/ thatch reduces macropore space and causes a decline in infiltration (Carrow, et al 2002). Significant fluctuations in infiltration readings have been seen from year to year in single core samples, and they have shown to decrease significantly when organic matter remains the same or supposedly decreases. A decrease in thatch/ organic matter would normally result in increased infiltration assuming the sand particles and silt/clay levels are constant. Table 2. is an example demonstrating this lack of correlation seen when testing a single 2-inch core. Silt/Clay and Sand particle sizes also impact infiltration readings, but these levels have not been significantly different to explain the large swings in infiltration readings of the single core samples.

Table 2.				
Date	December 2020	March 2020	April 2019	
Green #9 (.25-1")	2.39%	1.67%	2.38%	OM%
	5.08 in./hr.	17.88 in./hr.	23.23 in./hr.	Infiltration

Data from a single 2-inch core (**Not** Brookside Labs data)

Unfortunately, even in laboratory settings the Saturated Hydraulic Conductivity (SHC) method utilized for USGA/A2LA testing (ASTM D2434 & ASTM 1815-97) is typically not representative of the in-field perc rates for a mature upper root-zone. Samples are compacted according to protocol in effort to simulate on-site conditions. This method works very well for samples containing limited silt/clay (<2% combined) and organic matter (<1.5%), but most existing root-zone samples contain >2% silt/clay and organic matter (turf removed 360 C°). This results in excessively compacting the samples and greatly reduced SHC compared to on-site readings.

Other test methods such as the Drop Test (McIntyre, Jakobsen, "Practical Drainage…") in the lab or on-site Double Ring Infiltrometer (Turf-Tec International) readings may be more accurate. On-site readings are subject to variables like soil moisture content, wetting agent applications, recent cultural practices, etc. However, they are easily re-checked/ repeated if there are significant differences from one year to the next. If the single core samples submitted have been dissected, then there is no chance of having those results re-checked. The Drop Test can be re-checked at the lab if enough sample has been submitted. Remember that the Sand, Silt, Clay, and Organic Matter percentages along with Sand Particle Distribution/ Characteristics tend to dictate moisture measurements in the root-zone. If these parameters are desirable, then the moisture readings should follow. If you see conflicting results, then it is time to ask for re-checks or utilize another source for your data.

"Data is only as good as the system (or process) that collects it." Anon.

Sample Collection:

If your existing root-zone physical data is based on a single core 2-3 inches in diameter, then you have most likely seen these significant swings in results. This is especially true if the sample is dissected into 1-inch increments (0-1", 1-2", 2-3", etc.). The data on the small sample may be accurate for that sample, but the sample is most likely not representative of an entire green. Furthermore, a 0.5" aeration hole filled with sand in a 2-inch core can have a significant impact on the results as it represents 25% of the sample area.

When submitting samples for USGA/A2LA accredited testing where results are based on the average of duplicate analysis, a minimum of 0.5 gallons (2200 grams) of material is required. This amount of sample is needed to accurately measure the parameters for a Complete Physical Analysis. It is highly recommended to submit extra material if there is a need to re-check any of the parameters. In order to obtain representative samples for an existing green (approximately 5,000 ft^2) collect:

1. **Complete Physical Analysis**: 6 cup-cutter sized plugs per area to be sampled cut into 1-inch increments (Clay, Silt, Sand, Organic Matter, Sand Particle Sizes, Saturated Hydraulic Conductivity, Moisture Retention, Air Filled/ Capillary Pore Spaces, Bulk Density, Particle Density, and Visual Classification) Example:

Date	Sample ID	Clay (%)	Silt (%)	Sand (%)	Organic Matter (%)	Fine Gravel - 2 mm (%)	Very Coarse Sand - 1 mm (%)	Coarse Sand - 0.5 mm (%)	Medium Sand - 0.25 mm (%)	Fine Sand - 0.15 mm (%)	Very Fine Sand - 0.106 mm (%)	Very Fine Sand - 0.053 mm (%)	Saturated Conductivity (in/hr)	On-Site Infiltration (in/hr)	30cm Moisture Retention (%)	Air Filled Pore Space (%)	Capillary Pore Space (%)	Total Pore Space (%)	Bulk Density (g/cc)	Particle Density (g/cc)	pH	Visual Classification
	USGA Guide	*<=3*	*<=5*		**2-3*	*<=3*	*<=10*	*>=60*		*<=20*	*<=5*		*>6*	*>6**		*15-30*	*15-25*	*35-55*	**1.5-1.7*			
9/21/16	#1-G (0-1")	0.6	2.2	96	1.8	0.8	3.8	31.4	44	12	3.6	1.3	3.1	18.8	19.8	9.9	31	41.2	1.59	2.7	7.7	edium sphericity/subangular to subrounde
9/23/15	#1-G (0-1")	0.5	2	97	2.35	0.5	5.1	32.6	44	11	3.2	1.3	2.1	18.4	22	9.9	33	43	1.51	2.64	7.1	edium sphericity/subangular to subrounde
9/19/14	#1-G (0-1")	0.2	2.5	97	1.7	0.3	6	35.4	42	10	2.5	1.1	1.5	15.8	21.6	10.8	33	43.5	1.51	2.67	7.6	edium sphericity/subangular to subrounde
9/12/13	#1-G (0-1")	0.2	2.2	96	1.4	0.4	5.4	33.3	41	12	3	1.2	4	23.5*	18.2	16.8	27	44	1.5	2.68	7.8	edium sphericity/subangular to subrounde
9/13/12	#1-G (0-1")	0.2	2.5	97	1	0.3	5.6	33	42	12	3.1	1.3	8.7	15.6*	14.5	20.1	22	42.3	1.54	2.67	7.2	edium sphericity/subangular to subrounde
9/1/11	#1-G (0-1")	0.5	0.9	98	0.6	0.2	5.3	34	43	12	3	1.2	12	30.8	12.7	20	20	40.3	1.6	2.68	7.7	edium sphericity/subangular to subrounde
6/30/10	Mix Pile #4	0.8	0.8	98.3	0.6	0.1	4.6	32.1	44	13	3.4	1.3	24.6		12.8	19.2	20	39.6	1.6	2.65	7.5	edium sphericity/subangular to subrounde

(6 cup-cutter plug samples) Analytical Services Provided by Brookside Labs.

2. **Partial Physical Analysis:** 3-4 cup-cutter sized plugs per area to be sampled cut into 1-inch increments. (Clay, Silt, Sand, Organic Matter and Sand Particle Sizes) Example:

Date	Sample ID	Clay (%)	Silt (%)	Sand (%)	Organic Matter (%)	Fine Gravel - 2 mm (%)	Very Coarse Sand - 1 mm (%)	Coarse Sand - 0.5 mm (%)	Medium Sand - 0.25 mm (%)	Fine Sand - 0.15 mm (%)	Very Fine Sand - 0.106 mm (%)	Very Fine Sand - 0.053 mm (%)	Saturated Conductivity (in/hr)	On-Site Infiltration (in/hr)
	USGA Guide	*<=3*	*<=5*		*2-3%*	*<=3*	*<=10*	*>=60*		*<=20*	*<=5*		*>6*	*>10*
8/19/20	16-G (0-1")	1.6	4.3	94	2.85	0	4.8	36.4	42	8.2	1.8	0.9	< 1.0	9.8
11/11/19	16-G (0-1")	1.6	2.4	96	2.70	0.2	3.7	36.1	46	8.1	1.6	0.7		14
10/1/19	16-G (0-1")	0.8	1.5	97	2.49	0.4	4.3	36.3	46	8.4	1.7	0.7		14
8/15/19	16-G (0-1")	1.2	2.5	96	2.59	0.4	4	36.6	45	8.3	1.5	0.7		21
7/23/18	16-G (0-1")	0.6	2	97	2.48	0.1	3.5	37.1	47	8.3	1.4	0.4		28
8/14/17	16-G (0-1")	0.3	3.1	97	2.48	0.1	2.4	31.7	50	10	1.8	0.9		38
8/29/16	16-G (0-1")	1.3	4.9	93	1.2	0.4	3.8	35	42	9.1	1.8	1.4		31
2015	Mix Average	5.18		94	0.9	0.1	3.6	35.2	44	8.9	1.6	0.93	14.3	

(4 cup-cutter plug samples) Analytical Services Provided by Brookside Labs.

Ideally the cores would be dissected prior to shipping. If you would like information on how to construct a miter box like the one pictured above, please contact Mavis Consulting. If you are submitting the entire core, then secure them in plastic wrap to retain moisture and keep the cores in-tact. Be sure to package them tightly.

3. **Organic Matter Analysis:** If the goal is to evaluate Organic Matter only, then collect 15 soil probe (0.75 – 1 inch diameter) cores cut into 1inch increments. This can also be substituted with seven plugs (2 inch diameter) or possibly soil profiler (3-inches wide by 1-inch deep) plugs all cut into 1-inch increments. Again, err on the high side for sample collection to ensure sufficient material for testing and increasing area representation. The advantage of the soil probe plugs is that they can be easily repaired with a ball mark tool. The depth of layers to be

tested and number of layers can be determined based on site specific conditions. However, I recommend testing layers no greater than 1 inch or 2 cm (as suggested by some) in depth to detect changes sooner than later.

Green #18 Organic Matter Content (360 Deg C LOI)						Turf Removed		
	5/24/19	8/31/18	10/3/17	9/29/16	10/6/15	9/16/14	10/1/13	10/3/12
0-1"	2.85	2.59	2.15	2.5	2.25	2.04	1.87	1.98
1-2"	2.11	1.8	1.59	1.73	1.42	1.75	1.89	1.48
2-3"	1.36	1.45	1.38	1.58	1.64	1.73	1.43	1.35
3-4"	1.18							0.52
Avg.	**1.88**	**1.95**	**1.71**	**1.94**	**1.77**	**1.84**	**1.73**	**1.33**

(15 Soil Probe or 6 Cup Cutter Plug samples) Analytical Services Provided by Brookside Labs.

Organic Matter (0-1")			
360 Degree Ash Test (Turf			
Green	10/13/20	10/21/19	10/19/18
1	2.36		2.4
2		2.85	2.48
3	2.16		2.33
4			2.97
5	2.33		2.25
6		2.43	2.63
7	2.45		2.70
8		2.95	2.52
9	2.11		2.22
10		2.83	2.57
11	2.16		2.44
12		2.98	2.19
13	2.69		2.78
14		2.89	2.33
15	3.24	3.23	2.90
16			2.43
17	2.61	2.90	2.68
18		2.70	2.85
Avg	2.46	2.86	2.54

(15 soil probe samples) (Turf Removed) Analytical Services Provided by Brookside Labs.

Testing:

There are numerous physical tests that can be conducted on existing root-zones. If testing organic matter only, then the decision needs to be made on whether to include the turf in the testing or not. As expected there is a significant increase in organic content if the turf is left on the sample (approximately 1-2%) as compared to removing the upper 0.125-0.25 inches. To date I have experienced more variability when including the turf in the testing and results that do not reflect significant changes in cultural practices. However, other independent agronomists are finding that including the turf has been repeatable and representative. The majority of the samples Mavis Consulting submits for Soil Profile Assessment (SPA) request the turf be removed from the sample at the lab for these reasons as well as the ability to also analyze sand particle distribution and moisture measurements. I will continue to evaluate samples where the turf is included in the organic matter analysis.

Table 4. Organic %		
360 avg without turf	360 avg with turf	440 avg with turf
3.43%	5.04%	5.77%
(0-1" Samples from the same greens)		

Analytical Services Provided by Brookside Labs.

1. **Organic Matter Testing:**

The next decision is which organic matter test to run (360, 440, 550, 360&440, Walkley Black, etc.). The 360 C° ash test is utilized to determine organic matter content when conducting USGA/A2LA accredited root-zone mix testing. Keep in mind that the USGA confidence interval for organic matter testing is ± 0.2%. Therefore, I would suggest that <0.2% differences are not significant, especially with organic matter readings >2%. The USGA/A2LA accredited 360 C° ash test is utilized by Mavis Consulting for SPA samples the same as greens mix testing, and protocol requires turf to be removed. Average organic matter content in the upper inch (0.125-1") ranges from 2.5-4.5% when the turf is removed (cool season turf PG). Table 4. indicates the average for some of the possible differences within the same putting greens based on different test methods and whether or not the turf is removed.

2. **Sand Fraction Testing:**

Sand particle size distribution testing seems to be fairly consistent from lab to lab if they utilize the same sieves. Unfortunately, the same sieves are not always utilized, which can add a slight challenge when trying to compare results. Some calculations may need to be made if different sieves are added or data is reported as a percent retained vs. passing to determine if the results are similar. Some industries typically report data as a percent passing, while others like the USGA guidelines utilize percent retained.

Summary

The sand, silt, clay, organic matter, and sand particle distributions (partial physical analysis) are the "meat and potatoes" of the physical report. If these levels are desirable, then the moisture measurements are most likely going to be within an acceptable range. Keep in mind that when testing mature root-zones, the moisture measurements (Saturated Hydraulic Conductivity, Moisture Retention, Air Filled/ Capillary Pore Spaces) will most likely **not** meet USGA guidelines if utilizing the same test methods as new root-zone mixes (USGA/A2LA Accredited). This is due to the higher organic matter (>2%) of existing root-zones that is typically present in the upper profile. However, the information may be very useful for yearly comparison, especially if not conducting on-site infiltration readings.

In summary, ensure that you are collecting representative samples to accurately evaluate existing root-zone physical conditions. If you are tired of trying to design your cultural practices around incongruent results, then review your sampling procedures. **More than one core should be collected from a golf course green to obtain accurate and representative data.** If you are not currently utilizing data to develop and evaluate cultural practices and fertility programs, then consider starting as soon as possible to avoid blindly walking off the edge of a "cliff".

Brian Mavis is an independent agronomist and owner of Mavis Consulting, Ltd. (established in 2000).

References

Carrow, R., P. O'Brien, and C. Hartwiger. 2002.Why Putting Greens Sometimes Fail. Unpublished manuscript.

McIntyre, Jakobsen, 2000 "Practical Drainage for Golf, Sportsturf, and Horticulture"