SOIL TESTING AND AMENDMENTS FOR SUCCESSFUL REVEGETATION

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About the Presenter

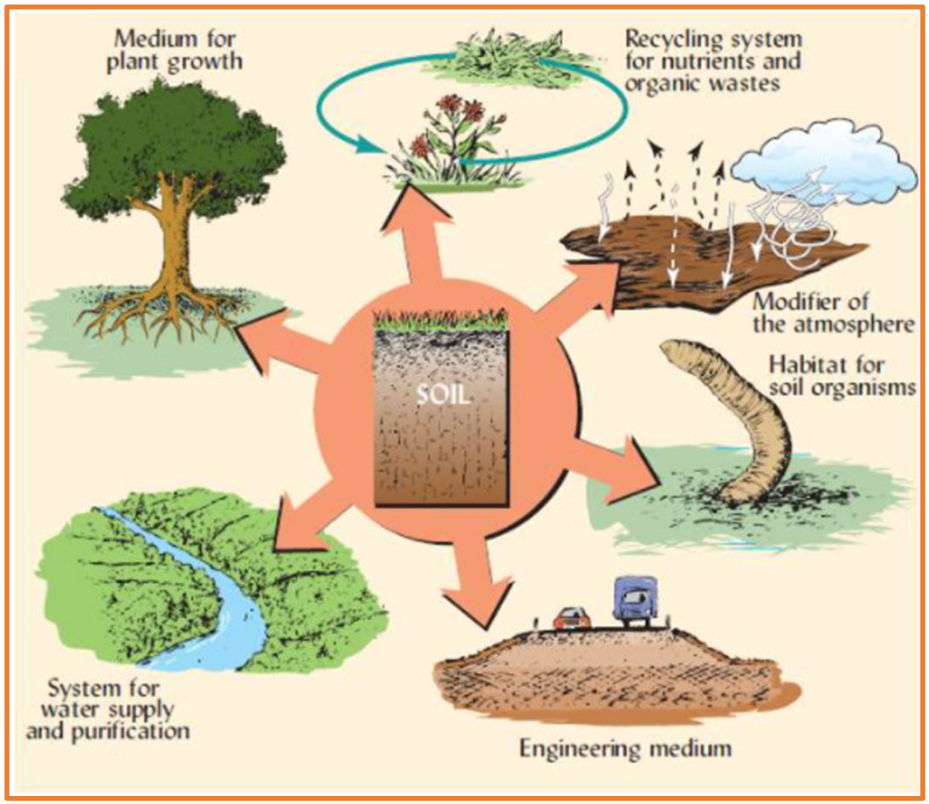
Overview

- What is soil?
- How to take a soil sample
- Soil deficiencies and remediations
  - pH
  - Nutrient imbalances
  - Salts
  - Organic matter
- Successful case histories
- Q & A

What is Soil?

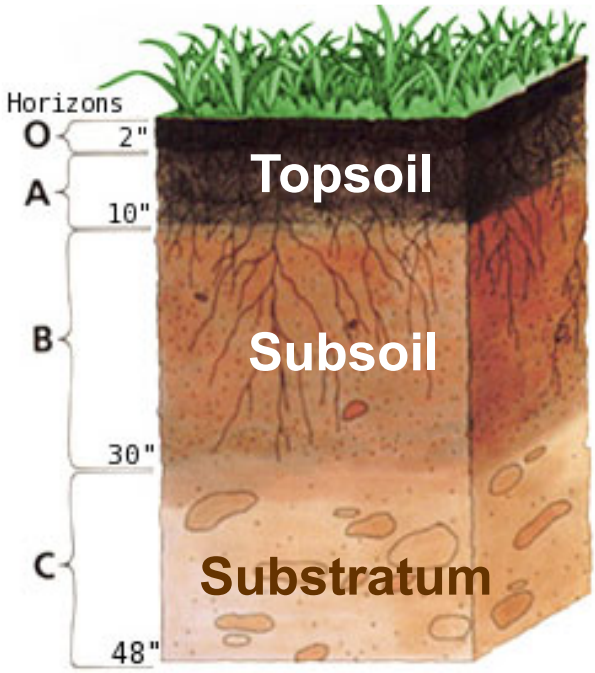
- Soil is a dynamic natural body composed of mineral and organic solids, gases, liquids and living organisms.

- Many functions, primarily focusing on its ability to serve as a medium for plant growth.

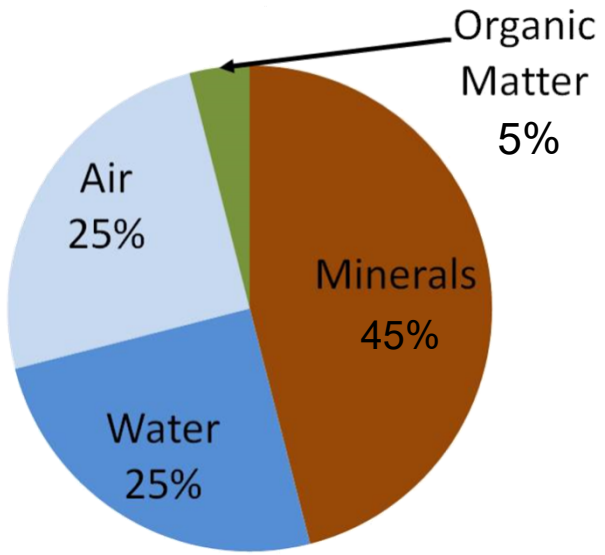


Brady, Nyle and Weil, Ray. *The Nature and Properties of Soils*. 14th edition

Ideal Soil Profile



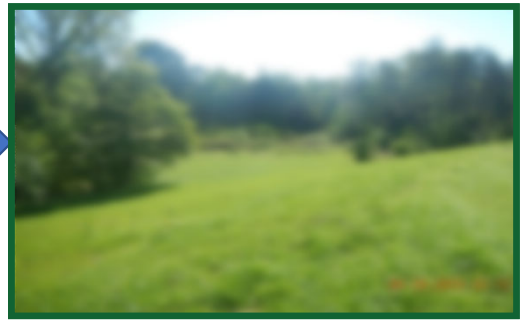
Ideal Topsoil Composition for the O/A Horizon



Soil Health is the Foundation of a Successful Project!

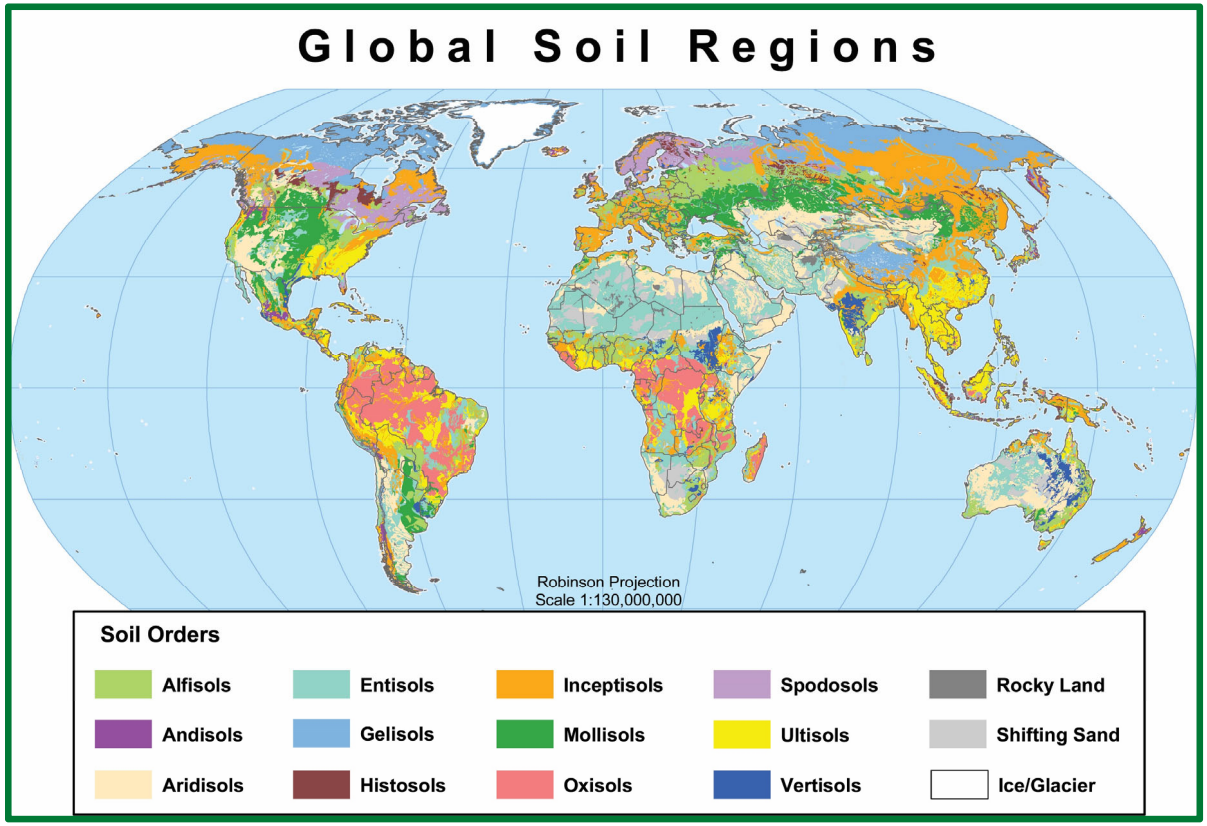
Healthy Soil

Sustainable Vegetation



Long-Term Erosion Control

Soils Are Unique



https://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1237749.pdf

How can you tell if your soil is healthy?

- Can you see if your soil has the right minerals?
- Contains sufficient organic matter?
- Can you see if your soil has a salt imbalance or a pH problem?
- Generally not, therefore…
- Test Your Soil!

Soil Sampling

- Composite Sampling
  - When the area is going to be managed the same.
- Zone Sampling
  - When different areas will be managed separately.
- Ideally, soils that are visually different should be managed differently.

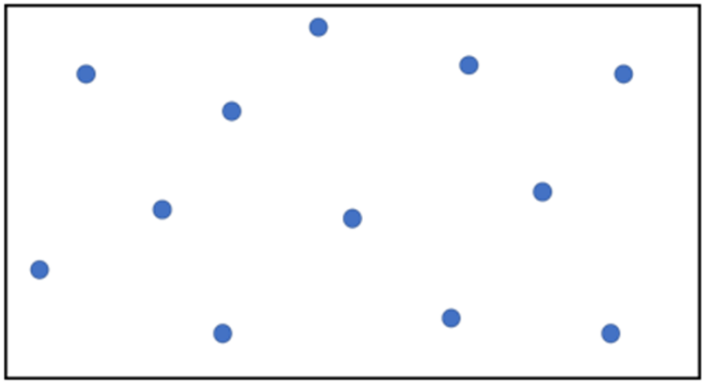


Figure 1: Composite Sampling

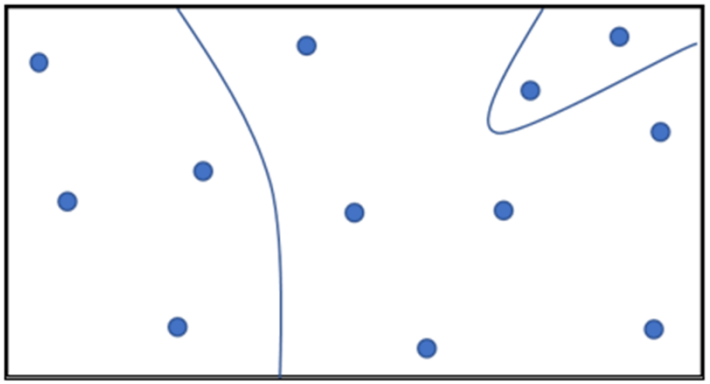


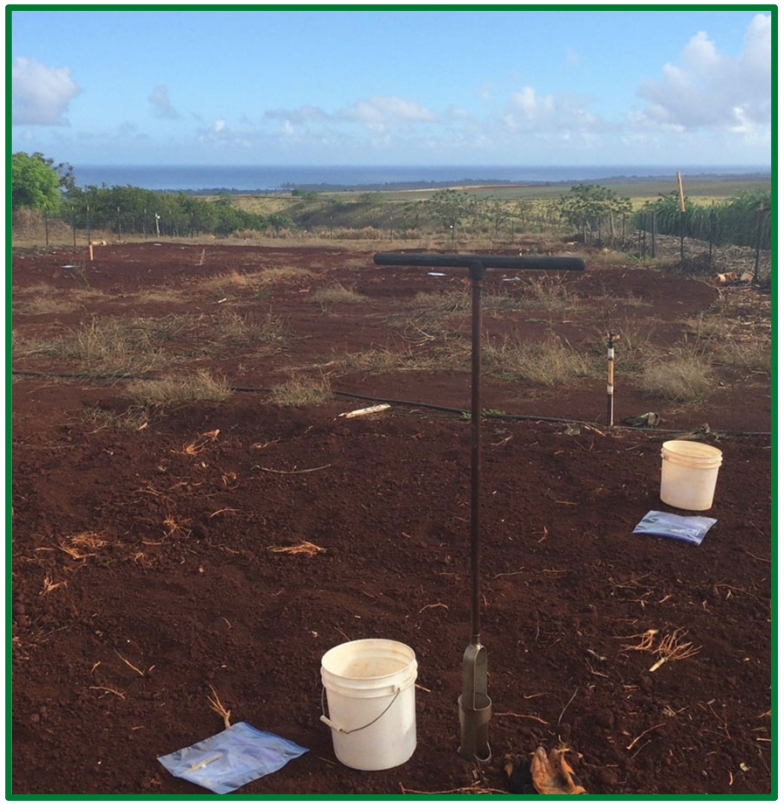
Figure 2: Zone Sampling

Soil Sampling

- Sampling equipment
  - Soil sampling probe or shovel
  - Stainless steel or plastic to avoid metal contamination
- Bucket
  - To mix the composite samples
  - Stainless steel or plastic preferred
- Bags
  - Plastic or plastic lined bags
  - Double bagging prevents bursting in transit

Soil Sampling

- Remove top layer of organic material like leaves, sticks, wood chips or grass
- Sample down to 3 inches (76.2mm)
- Take 10-15 subsamples per sample
- Remove large rocks from the sample
- Mix the subsamples well and take 2 cups (500mL) of it and transfer into a labeled plastic bag
  - If in doubt, more soil is better than less



Soil Analysis

SOIL ANALYSIS RESULTS (Optimal Plant Growth Conditions)

Sample	Nitrate N ppm	Phosphorus ppm	Potassium ppm	Magnesium ppm	Calcium ppm	Sulfur ppm	Zinc ppm	Manganese ppm	Copper ppm	Iron ppm	Boron ppm
1	18.8	28	109	407	2104	10	1.83	4.3	1.6	39.8	0.5
2	12.9	30	281	457	2011	6	1.64	1.7	1.5	30.9	0.6
	(10 - 30)	IF pH ≤ 7.1 (20-40) IF pH > 7.1 (10-25)	(150 - 250)	(60 - 300)	(≥ 400)	(5 - 20)	(1.3 - 3.0)	(4.1 - 12.0)	(1.0 - 2.0)	(7.1 - 20.0)	(< 2.0)

Sample	% Organic Matter	Soil Respiration mg CO2/kg soil/week[5]	Sand %	Silt %	Clay %	Texture USDA
1	2.7		47.2	34	18.8	Loam
2	2.8		35.2	46	18.8	Loam
	(> 5%)	(> 1,000)	(20 - 60%)	Silt & Clay (40 - 80%)		

Notes: 5. Soil Respiration ppm = mg/kg

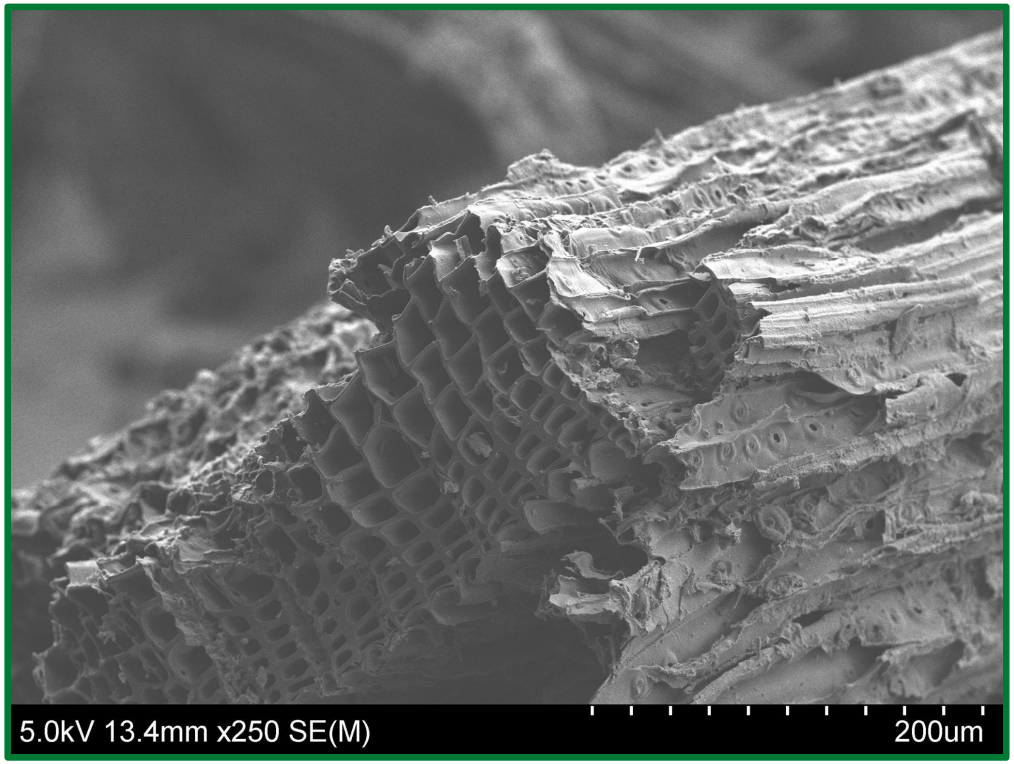
							Bulk Density	
Sample	Soil pH[6]	Buffer Index	TDS[7] ppm	Soluble Salts mmhos/cm	Sodium ppm	SAR[8]	g/cm^3	oz/in^3
1	7.8	7.5	211.2	0.33	28	0.47	1.17	0.68
2	7.8	7.5	288	0.45	14	0.2	1.09	0.63
	(6.3 - 7.3)		(<256)	(< 0.75)		(<2)		

Soil Amendments

- Common amendments
  - Fertilizer
  - Lime
  - Compost/Manure
  - Sulfur
  - Gypsum
- Lesser known amendments
  - Biochar
  - Humic Acid
  - Seaweed Extract
  - Endomycorrhizae

Biochar

- A recalcitrant material that is high in carbon created from combusting biomass in a low oxygen environment
- Helps increase soil cation exchange capacity (CEC)
  - Measurement of the total negative charges in a soil to adsorb plant nutrient cations like Ca^{2+}, Mg^{2+} and K^{+}
- Provides microbial habitat
- Increases soil carbon sequestration



Humic Acid

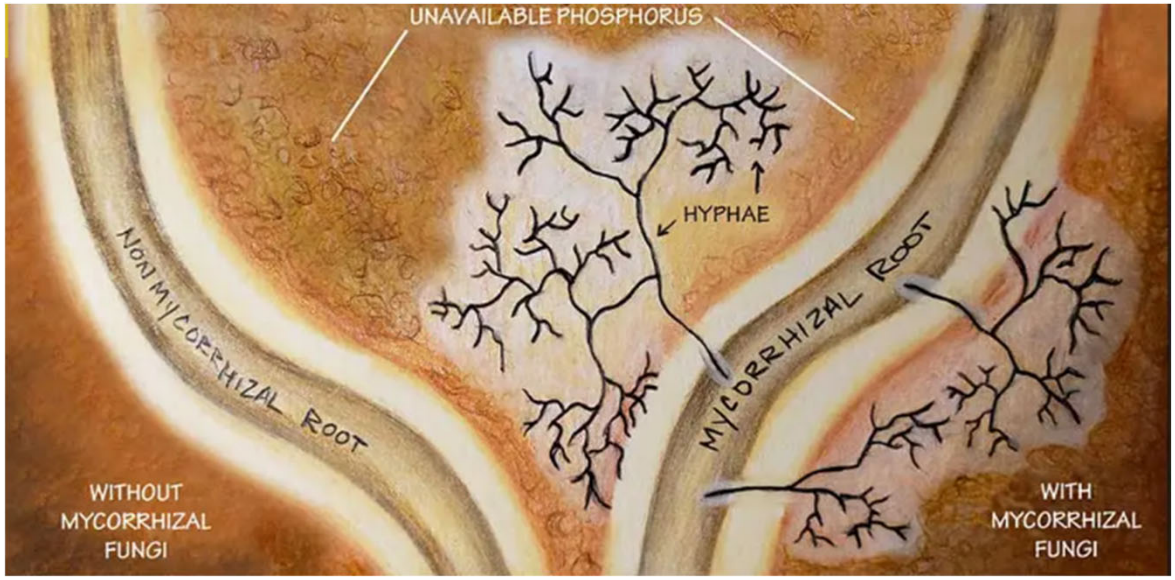
- Organic molecules that play essential roles in improving soil properties and plant growth
  - Helps break up clay and compacted soils
  - Enhances water retention, reducing soil solution evaporation
  - Improves root development and penetration through soil
  - Improves transfer of macro- and micro-nutrients
  - Stimulates development of micro-flora populations

Seaweed Extract

- Derived from marine plants like algae and kelp
- Contains plant hormones:
  - Cytokinins
  - Auxins
  - Gibberellic acid
- Plant hormones benefits:
  - Enhanced growth and root mass
  - Delay plant aging and enhance plant cell division
  - Excellent source of naturally occurring plant nutrients and minerals

Endomycorrhizae

- Fungi that live in the rhizosphere in a mutual association with root hairs
- Symbiotic relationship with the plant
  - The fungi source food, carbohydrates, vitamins, and amino acids from the plant
  - In exchange, the fungi supply water and macro- and micro-nutrients to the plant



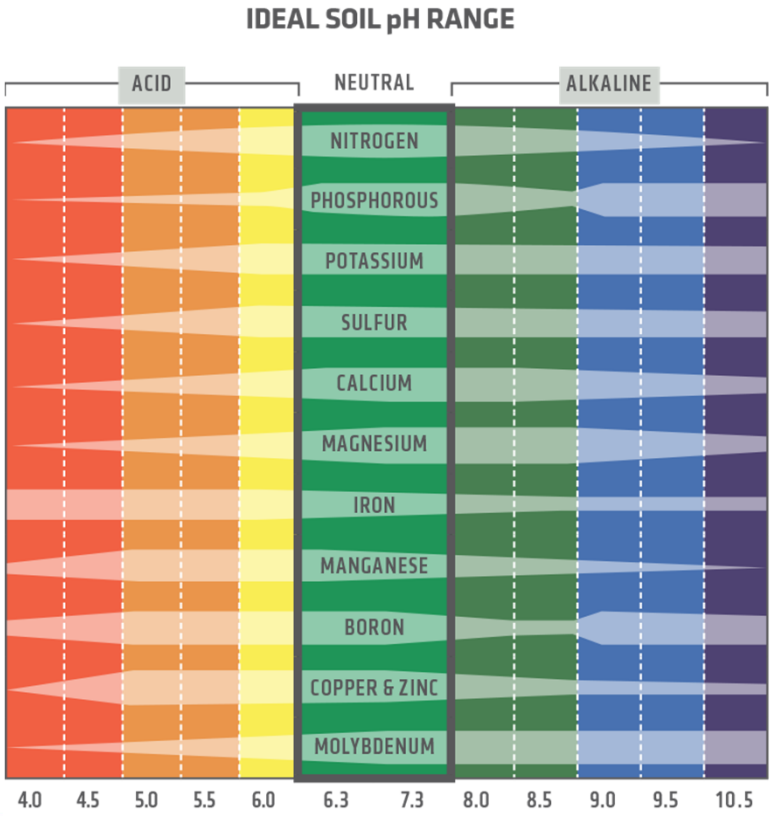
Soil Analysis

Soil pH[6]
7.8
7.8
(6.3 - 7.3)

Managing Soil pH

- Correcting the pH will:
  - Balance nutrient availability
  - Improve soil structure
  - Improve soil moisture infiltration and retention
  - Stimulate faster germination and growth
  - Improve long-term fertility and vitality of soils
- Which will lead to:
  - Denser vegetative cover
  - Increase erosion control effectiveness

Soil pH



PLANT NUTRIENT AVAILABILITY

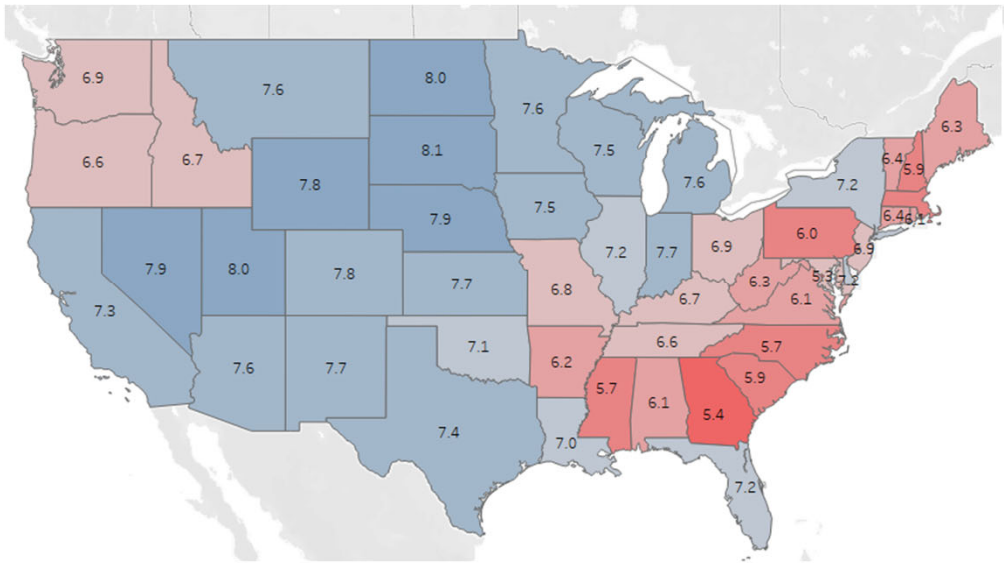
SOIL ACIDITY

4.0	10%	-90%
4.5	29%	-71%
5.0	46%	-54%
5.5	67%	-33%
6.0	80%	-20%
6.3	100%	0%
7.3	100%	0%
8.0	80%	-20%
8.5	67%	-33%
9.0	46%	-54%
9.5	29%	-71%
10.0	10%	-90%

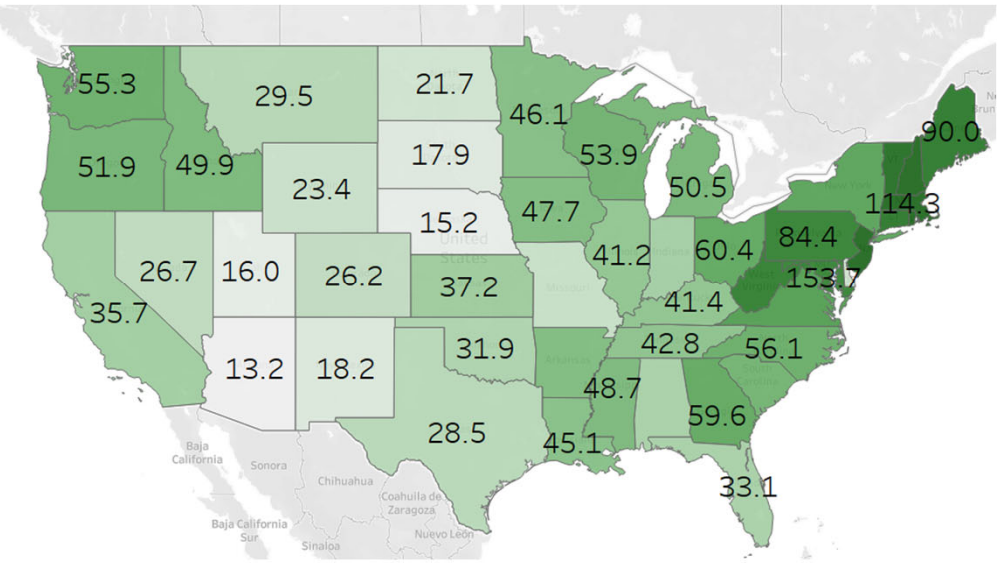
SOIL ALKALINITY

Iron and pH

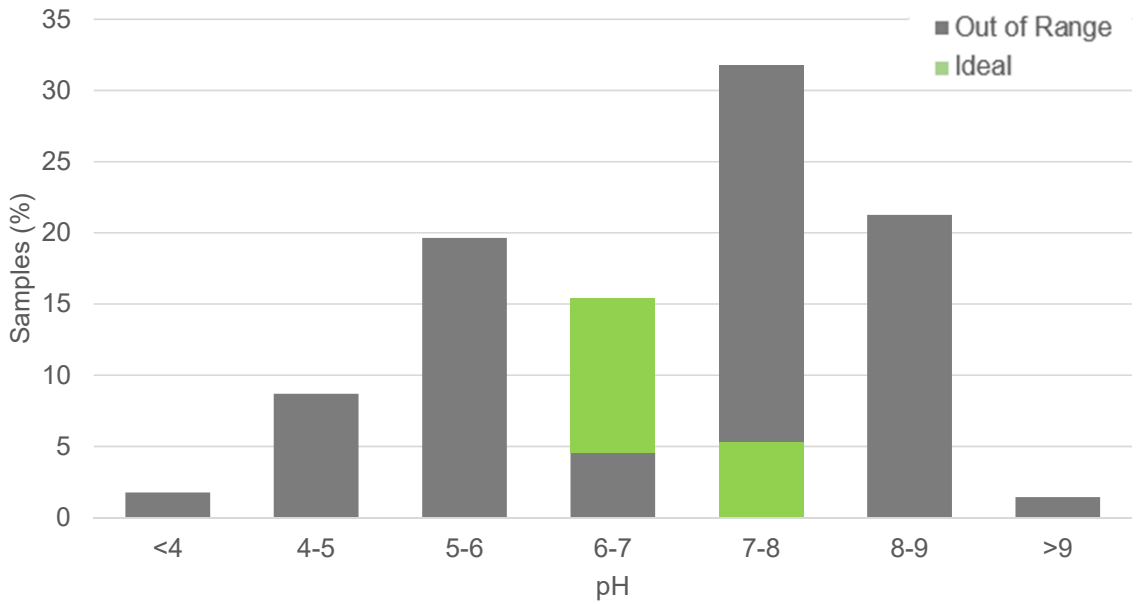
Soil pH



Soil Iron



pH


35
30
25
20
15
10
5
0
Samples (%)
Out of Range
Ideal
<4
4-5
5-6
6-7
7-8
8-9
>9
pH

Acidic Soil

- Acidic soil are those with a pH <7
- Causes include:
  - Rainfall and leaching
  - Acidic parent material
  - Management decisions
- Lime can applied to increase pH
  - High calcium lime (calcitic)
  - High magnesium lime (dolomitic)

Agricultural Lime

- Limestone is calcium carbonate – $CaCO_3$
  - Calcium Oxide- CaO
  - Calcium Hydroxide- $Ca(OH)_2$
- Agricultural lime (Ag Lime) coarse granules will require 4-10 months to activate and work best when incorporated into the soil
- Rate determined by buffer pH, not soil pH
  - Well buffered soils require large rates of lime
  - Poorly buffered soils only need small amounts of lime

Fast Acting Lime

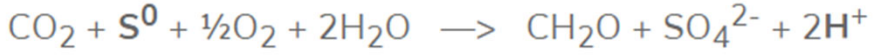
- Fast-acting Calcium Carbonate ($CaCO_3$)
  - Liquid or micronized powder
- Works in 3-10 days to raise pH
- Lasts up to 6-18 weeks
- Mixes easily in hydroseeder tank

Alkaline Soils

- pH > 7
- Elemental sulfur can be applied to decrease pH
- Calcareous soils (high levels of calcium carbonate) may require multiple applications
- Alkaline soils can also have issues with high sodium levels
  - typical of arid, semi arid and coastal regions

Elemental Sulfur

- Elemental sulfur can be used to add sulfur to deficient soils or to lower soil pH.
  - Soil bacteria convert the sulfur to sulfate and hydrogen.



  - Pros:
    - Generally safer than applying acids
    - Can add sulfur to deficient soils
  - Cons:
    - Not the most cost-effective practice
    - The conversion is slow
    - Requires the appropriate bacteria to be present in the soil

Soil Analysis

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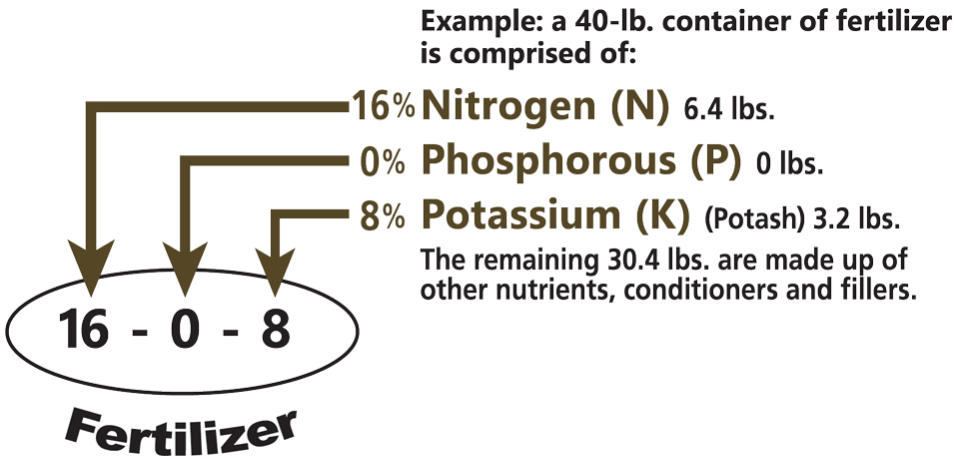
Soil Nutrients

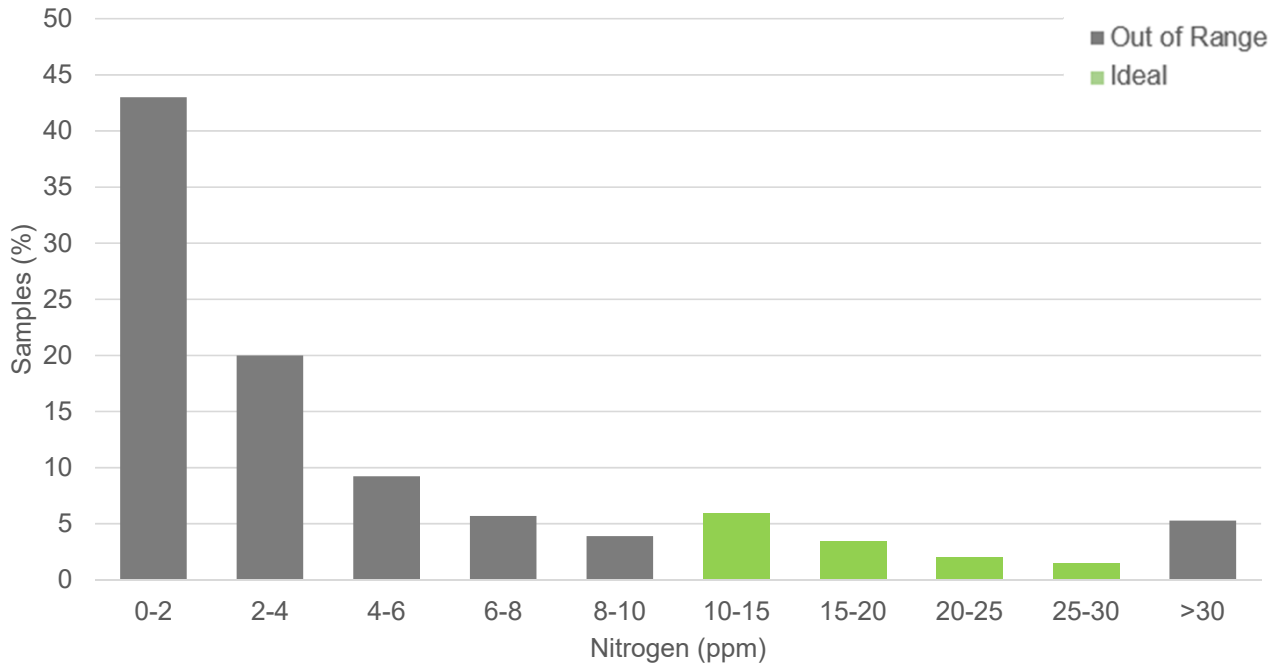
- Macronutrients
  - Nitrogen (N), Phosphorus (P), Potassium (K)
- Secondary Nutrients
  - Calcium (Ca), Magnesium (Mg), Sulfur (S)
- Micronutrients
  - Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn), Boron (B), Chloride (Cl)
- Other
  - Sodium



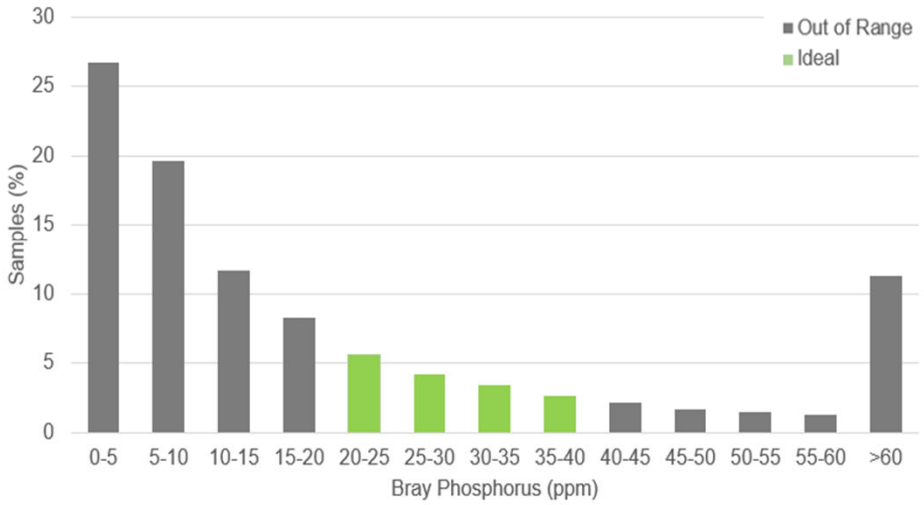
Fertilizers

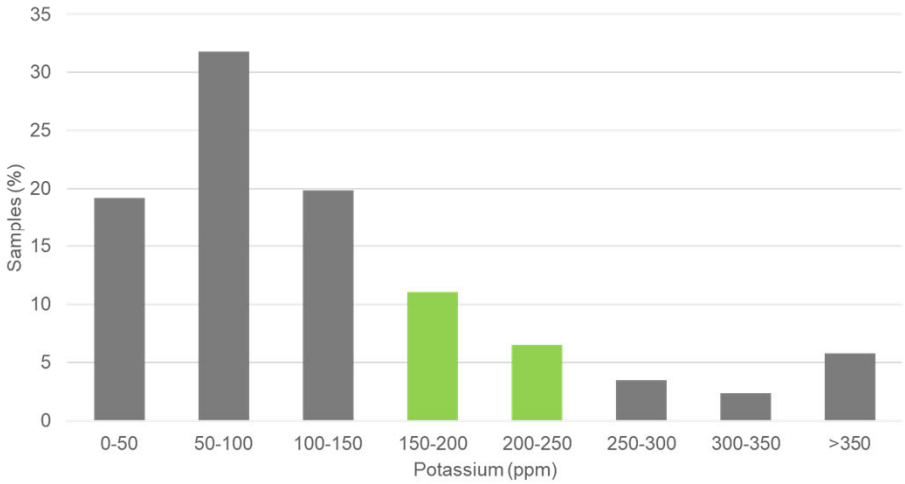
- Two types
  - Organic (derived from living things)
  - Inorganic (synthetically derived chemicals)
- Two forms
  - Granular
  - Liquid
- Different formulations

Nitrogen (N)

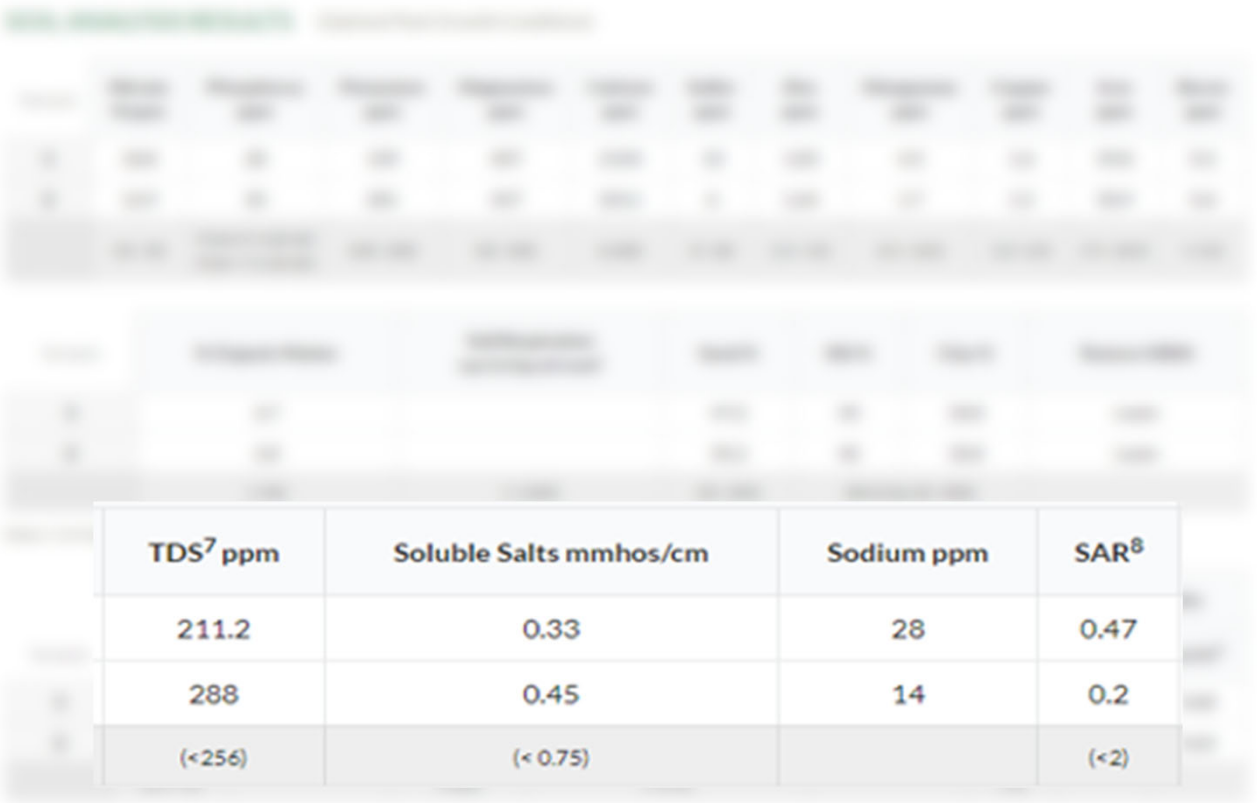

Out of Range
Ideal
Samples (%)
50
45
40
35
30
25
20
15
10
5
0
0-2
2-4
4-6
6-8
8-10
10-15
15-20
20-25
25-30
>30
Nitrogen (ppm)

Phosphorus (P) and Potassium (K)





Soil Analysis



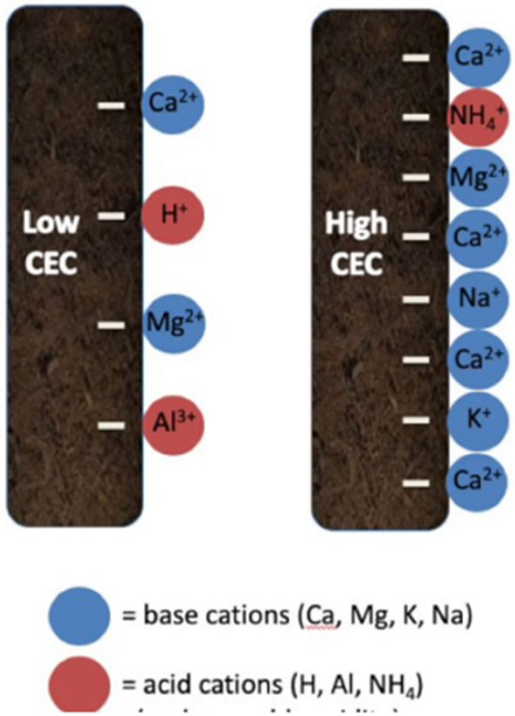
TDS[7] ppm	Soluble Salts mmhos/cm	Sodium ppm	SAR[8]
211.2	0.33	28	0.47
288	0.45	14	0.2
(<256)	(< 0.75)		(<2)

Salt Impacts

- Soluble Salts (SS) or Electrical Conductivity (EC)
  - Ions in solution conduct electricity, so the total amount of soluble ions can be estimated by measuring the solutions ability to conduct electricity
- Sodium Adsorption Ratio (SAR)
  - The ratio of ‘bad’ to ‘good’ flocculators
  - Na ions compared to Ca and Mg
  - Higher values are worse, with values > 7.0 often having detrimental effects

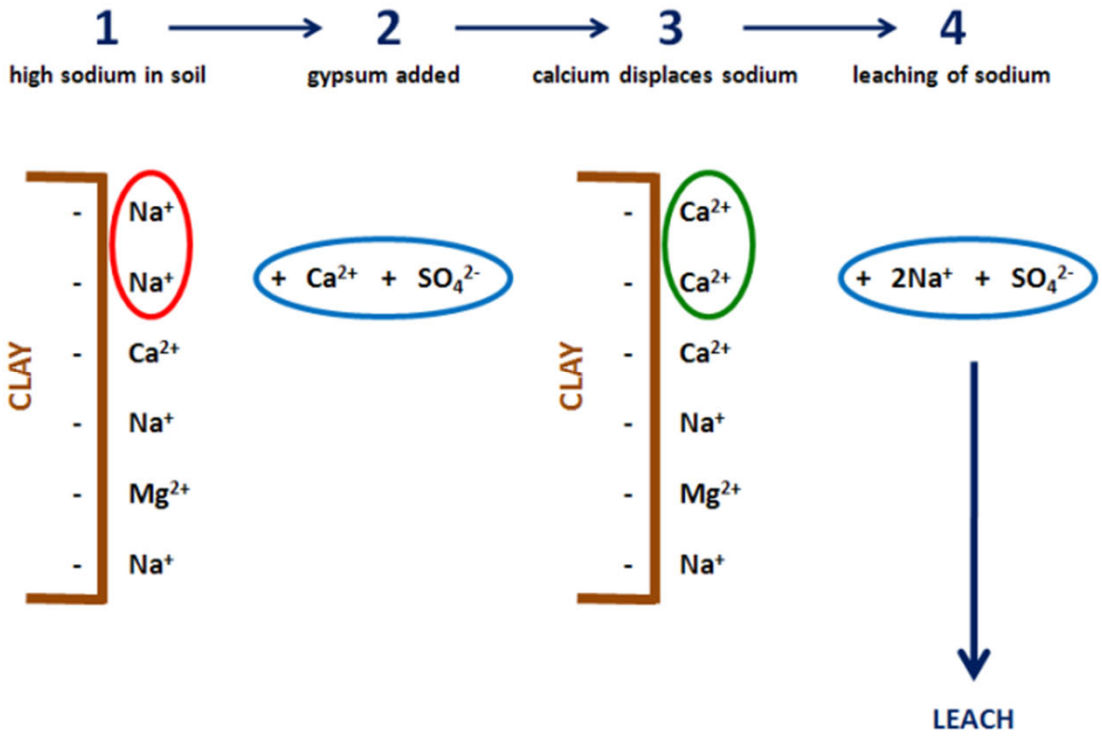
Salt Impacts

- Cation Exchange Capacity (CEC):
  - The ability of a soil to hold exchangeable cations
  - (Ca^{2+} ,Mg^{2+} ,Na^{+} ,K^{+} ,H^{+})
  - Measures negative surface charges
- CEC varies with soil pH
  - CEC is lowest in acidic soils, highest in alkaline soils
- CEC varies with soil texture
  - CEC is highest in clay soils, lowest in sandy soils
- Buffering
  - High CEC soils are well buffered
  - Low CEC soils are not well buffered



Gypsum

- Calcium sulfate ($CaSO_4$)
- Displaces sodium with calcium
- Sodium can then leach away from the root zone

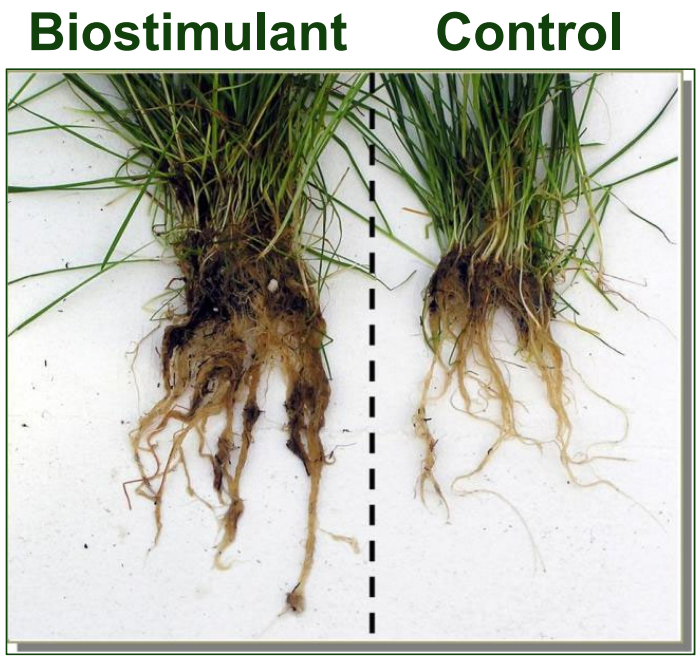


Biostimulants

- Work synergistically to improve short-and long-term plant establishment
- Enhance plant resistance to stress
- Enhance growth and root mass
- Accelerate decomposition of organic materials
- Improve water infiltration
- Reduce soil compaction and salinity
- May contain beneficial bacteria

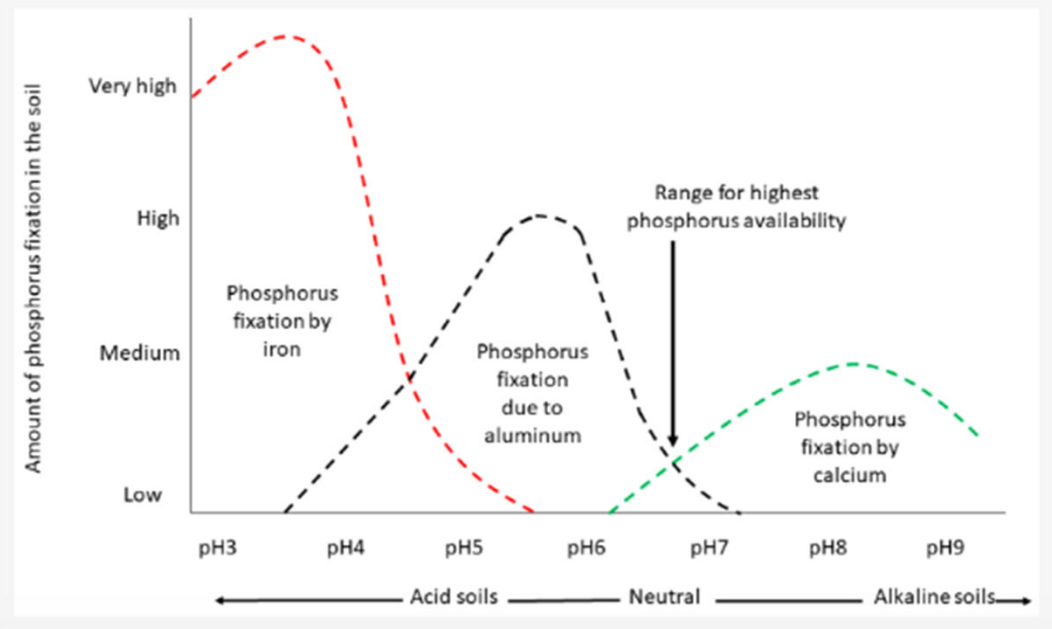
Biostimulant

- Auburn University
- Bluegrass
- Both received an application of complete fertilizer.
- 60 day harvest



Other issues

- Boron toxicity can occur when boron levels are >2 ppm
- Manganese, iron, aluminum can available in concentrations high enough to be toxic in soils with a pH <5



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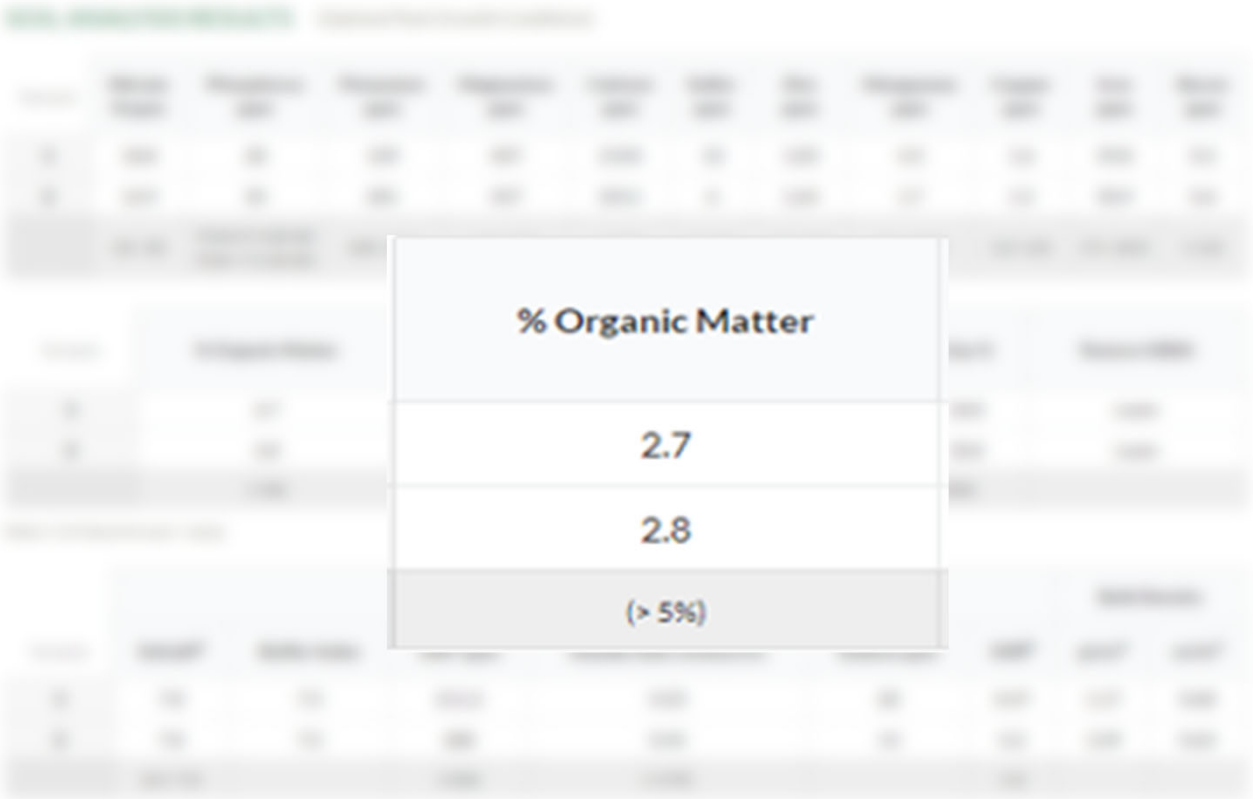
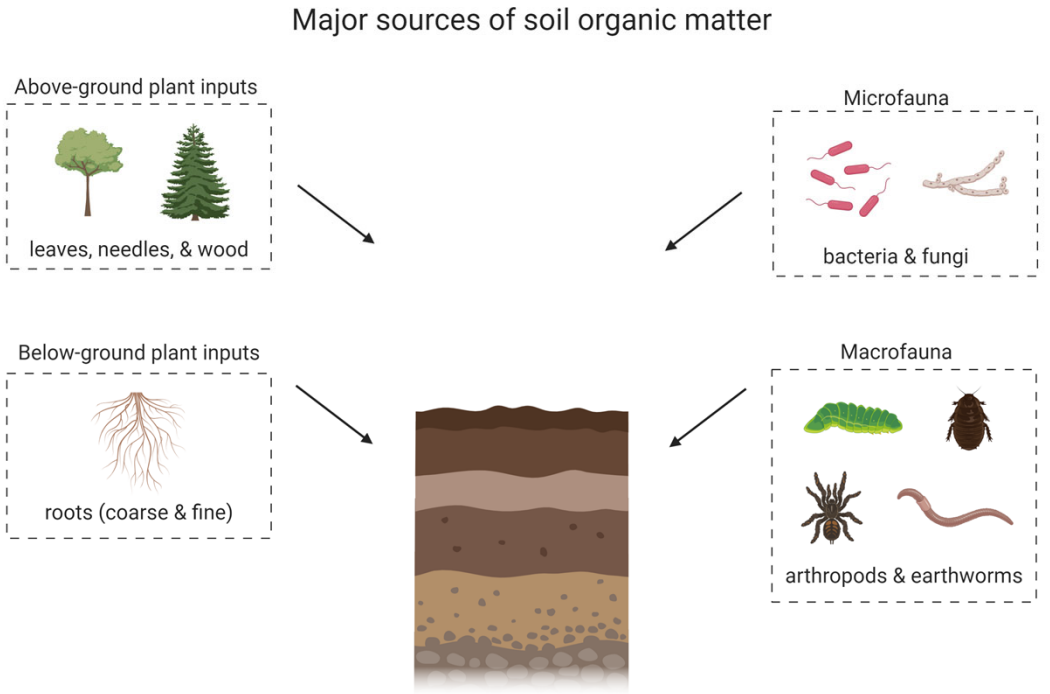


% Organic Matter
2.7
2.8
(> 5%)

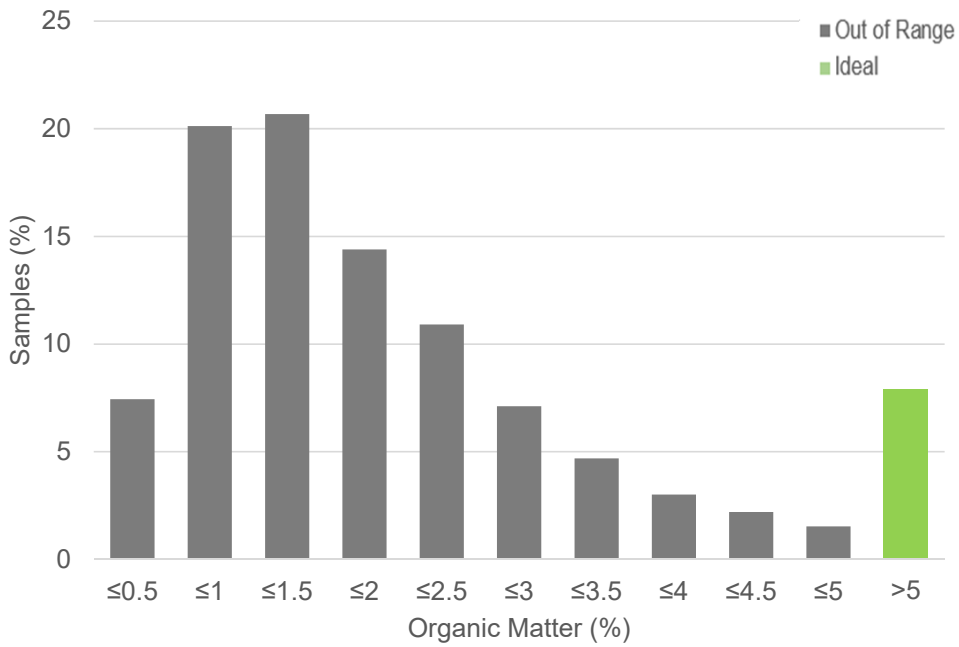
Soil Organic Matter

- Soil organic matter in soil comes from the from leaves, grass, roots, other organic material and microbial biomass
- Macrofauna and microfauna then decompose these materials, turning them into beneficial organic matter the soil
  - OM reduces compaction and improves soil structure
  - OM improves the ability of soil to store water, nutrients, and carbon
  - Provides a store of nutrients that are slowly released back into the soil



Organic Matter

- Ideally, we want organic matter to be >5%
- Regional differences in targets and the ability of soil to reach certain levels etc.
- Typical "construction" (disturbed) soils <1% OM
- This can take truckloads of topsoil, compost, or other sources of organic material hauled to jobsites to get to 5%



Topsoil

- The uppermost layer of soil
- Contains a high concentration of organic matter and microorganisms
- High concentration of roots due to high nutrient availability
- Current use and subsequent erosion of topsoil currently outpaces it's natural generation

Topsoil - Potential Issues

- Topsoil can introduce unwanted items:
  - Pesticides
  - Herbicides
  - Invasive species
  - Heavy metals
- If stockpiled, the topsoil conditions may have been incompatible with the microbial communities, resulting in biologically unhealthy soil

Compost

- A mixture of organic matter, that has decayed or has been digested by organisms to the point that none of the original components are identifiable
- Benefits:
  - Improve soil structure
  - Provide nutrients
  - Improve moisture retention
  - Increase biological activity

Compost – Potential Issues

- Quality compost is oftentimes an oxymoron
  - Plastic contamination
    - United States Composting Council (USCC) allows up to 1% of physical contaminants, including plastic, glass and metal
  - PFAS (per- and poly-fluoroalkyl substances)
    - Forever chemicals that readily mobilize in water, bioaccumulate, and are associated with a variety adverse health affects
  - Herbicides
    - Chemicals used to manipulate or control undesirable vegetation
    - Can be found in the green waste used in compost

Topsoil and Compost Problems

- Poor topsoil or compost specifications
- Steep slopes
- Cost and environmental impact of hauling
- Safety concerns – hauling and onsite
- Quality topsoil and compost – scarce and expensive
- What can we do?

Topsoil and Engineered Soil Amendment

- ASTM D5268-19 is a specification for “Topsoil Used for Landscaping and Construction Purposes.”
- Exhaustive third-party testing, research, and case studies on various Hydraulic Biotic Soil Amendments (HBSAs) were presented to the ASTM D18.22 Technical Subcommittee.
- Through the meticulous ASTM peer-review process a new category of topsoil alternative products called “Engineered Soil Amendments” was formed.

Biotic Soil Technology

- Benefits:
  - Development of soils with low OM
  - Rapid establishment and sustained growth of vegetation
  - Replacement of costly or difficult to obtain topsoil
  - Replacement of compost, peat, manure or other sources of OM
  - Installed beneath HECP or RECPs are a growing media

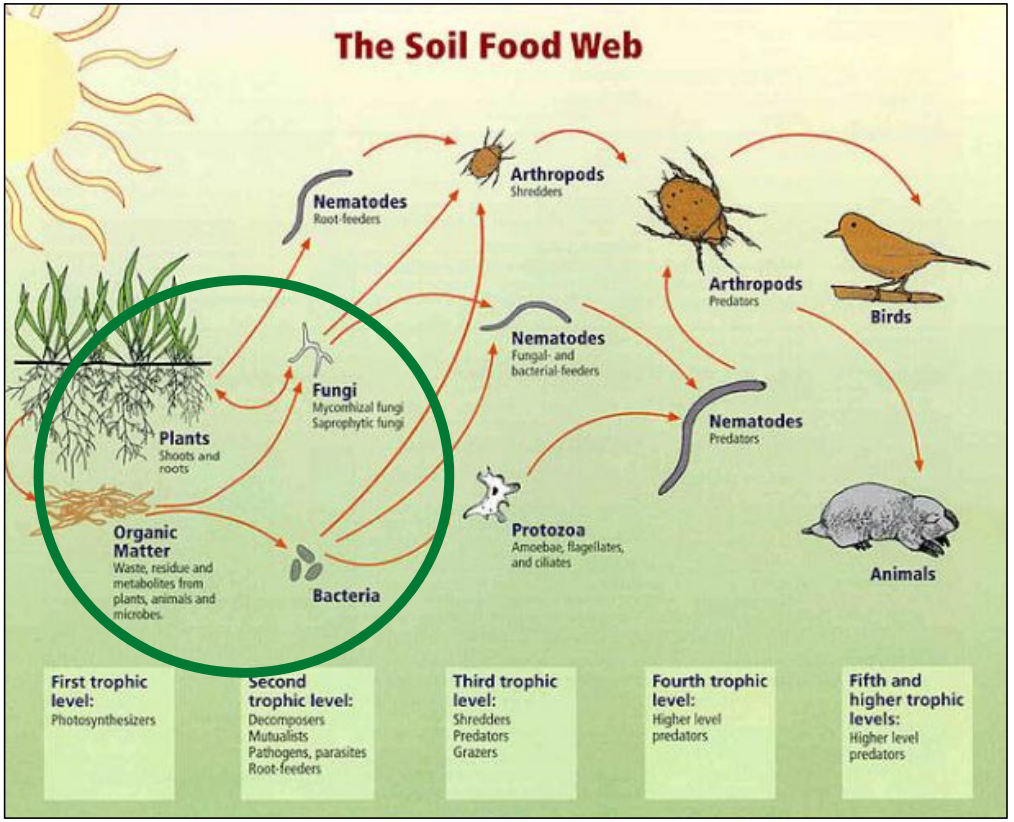
Biotic Soil Technology vs Topsoil and Compost

CONSIDERATIONS	BST	Topsoil	Compost
Consistent Product	✓	?	?
Decreased Hauling Costs	✓	X	X
Readily Available / Easy Delivery	✓	?	?
Easy On-Site Storage	✓	?	?
Fast, Uniform Application	✓	X	X
No Substrate Mixing Required	✓	✓	?

CONSIDERATIONS	BST	Topsoil	Compost
Safe for Steep Slope Applications	✓	X	X
Introduces Organic and Biological Elements	✓	?	✓
From Renewable Sources	✓	X	✓
Wet or Frozen Conditions	✓	X	X
Weed Seed and Pathogen Free	✓	?	?
No Potential Harm to Human Health	✓	?	X

How Does BST Work?

- Soil chemistry
  - Increased organic matter and biological activity
  - Results in plant establishment and subsequent nutrient cycling
- While the soil chemistry is improving, the media provides an ideal growing environment
- Provides rapid growth establishment and sustained long-term vegetation

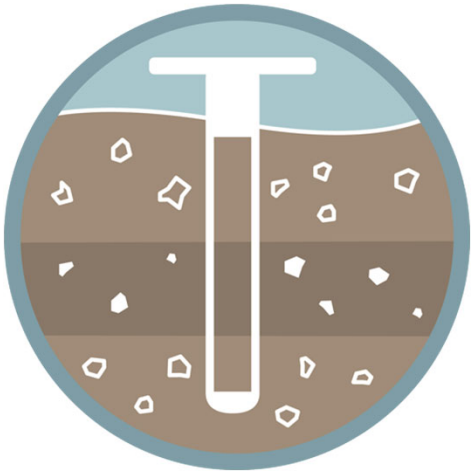


Typical BSM Application Rates

% Organic Matter	lb/ac	kg/ha
< 0.75	5,000	5,600
≥0.75 to <1.5	4,500	5,040
≥1.5 to <2.0	4,000	4,480
≥2.0 to <5.0	3,500	3,920

- Always conduct a soil test to determine agronomic needs.
- Soils with organic matter >5% typically do not require BST.
- *Depending on the test results, it is typically advisable to apply fertilizer, pH neutralizers and/or additional bio-stimulants with BST.*

Case Studies



South Wake Land Fill – North Carolina
Mine Reclamation – Georgia

Profile
Solutions for your Environment

South Wake Landfill Project

SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT SUMMARY

Challenges

- Landfill expansion
- Long interior slopes up to 150 ft (45.72 m) long
- Slope gradients up to 3H:1V
- Weekly rain events

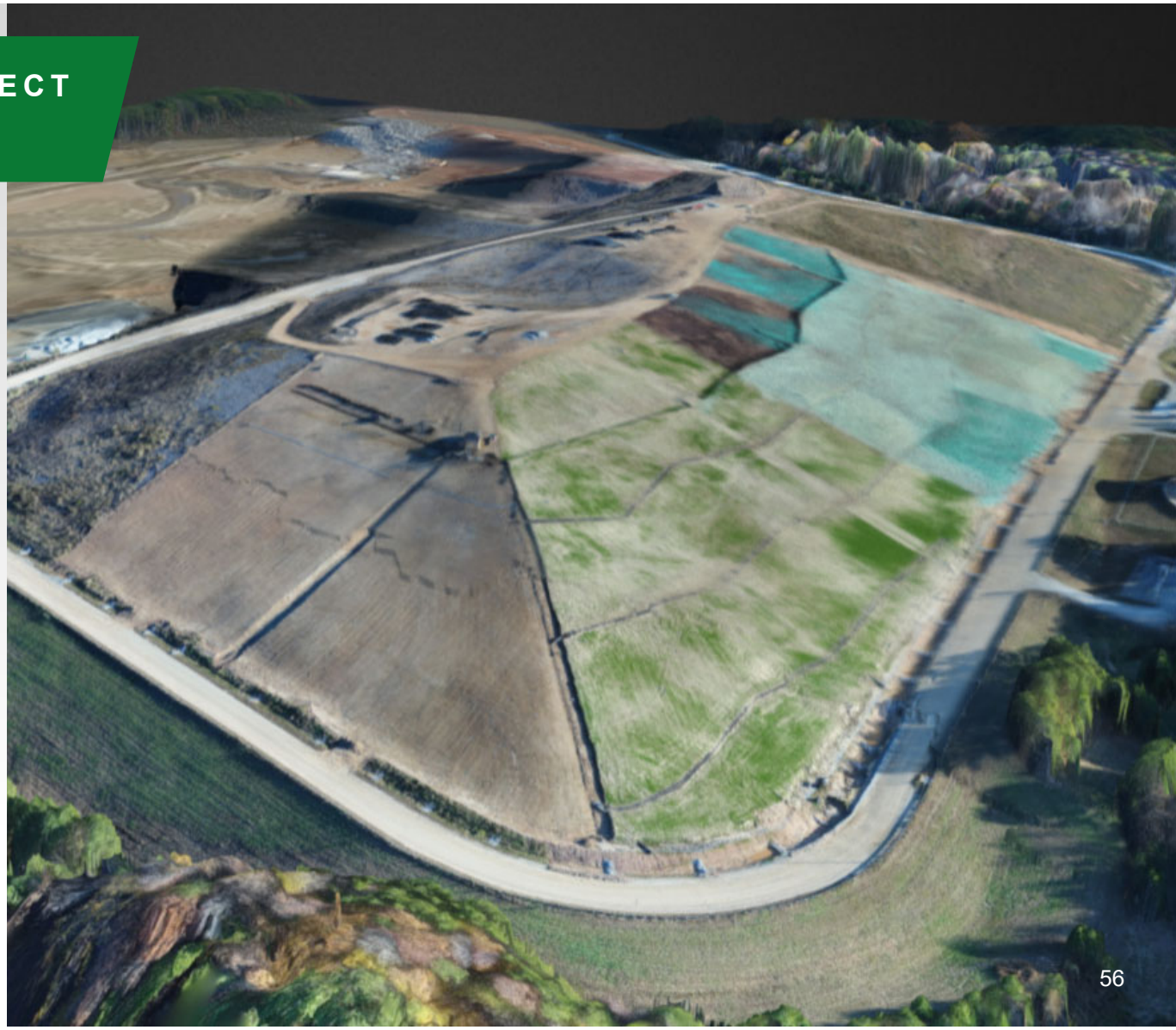
SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT SUMMARY

Challenges

- Phased construction
- Minimize seed and soil loss
- Wanted to use on-site soil for to reach their 24 inch (60.96cm) cover requirement



SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT SUMMARY

Soil Tests

- Acidic pH: 4.6-5.6
- Low OM: 1.2-3.9%
- High Mn: 7-99 ppm
- High Fe: 30-772 ppm

SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT INSTALLATION

Product Applications

- ProGanics: 4,000 lbs/acre (4483 kg/ha)
- JumpStart: 2.5 gal/acre (23 L/ha)
- BioPrime: 80 lbs/acre (89 kg/ha)
- 19-19-19 fertilizer
- NeutraLime: 80 lb/acre (89 kg/ha)
- Ag Lime: 6,500 lbs/acre (7286 kg/ha) incorporated to 6 inches (15.24 cm)
- Blend of warm and cool season grasses, including nitrogen fixers.

SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT INSTALLATION

Product Applications

- Flexterra: 3,000 lbs/acre (3363 kg/ha)

SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT RESULTS

Initial Germination

- 1 month later

SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT RESULTS

One year later

SOUTH WAKE LANDFILL PROJECT

Wake County, NC

PROJECT RESULTS

Two years later

Soil Results

Parameter	Initial	3 years
pH	4.6-5.6	6.0
OM (%)	1.2-2.2	4.6
Iron (ppm)	31-772	37
Manganese (ppm)	7-99	4

Mine Reclamation Project

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Challenges

- 44 acres with a 5 acre problem area
- Acidic soils
- Low organic matter

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Challenges

- Initial reclamation begin in 2003 (property acquired in 2008)
- Land and lakes reclamation process

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Challenges

- Erosion over 10 years
- Three failed reclamation attempts

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Challenges

- On Florida/Georgia Line
- **“Failure is Not an Option”**
- “Must gain bond release to open up additional mining sites”
- Must be done in 2016

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Soil Testing

December 2015

Sandy Clay Loam

- **Organic Matter – 0.4%**
- **pH – 4.8**
- **Very low in nutrients**

MINE RECLAMATION

Attapulgus, GA

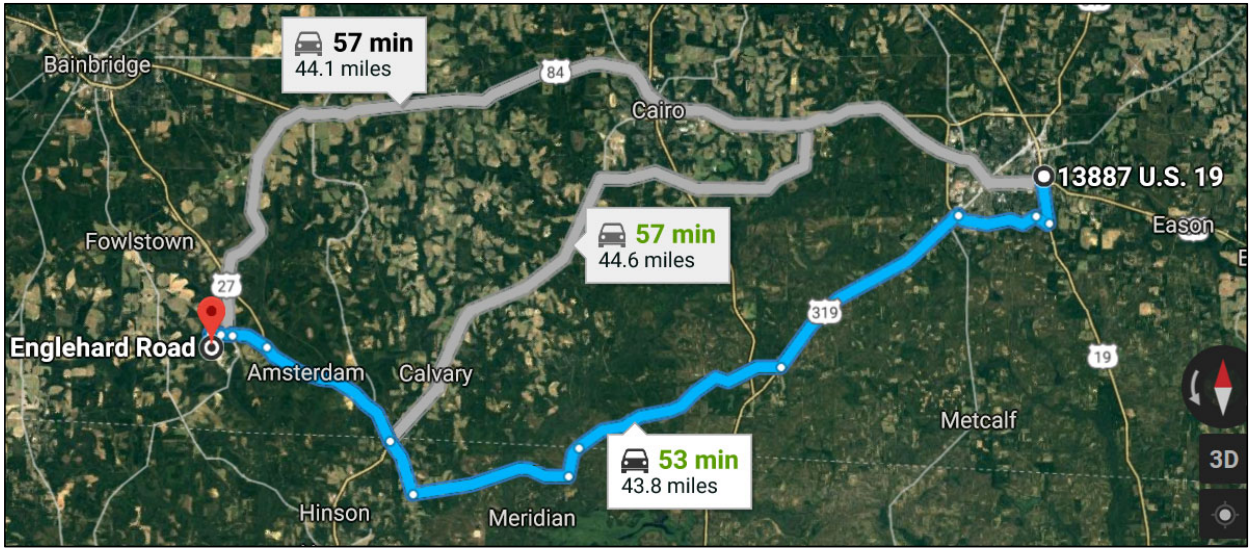
PROJECT SUMMARY

Site Preparation

Slopes were cat tracked to:

- Increase soil roughness
- Reduce erosion potential
- Create pockets for germination

The Nearest Topsoil that Meets Specification



- Topsoil Material Cost - $19.25/cubic yard
- Material Delivery - $75.00/hour (Min - 2 Hours/Load)
  - 14 cubic yard dump truck
- Estimated $11.00/cubic yard to Install

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

BSM Application

Per soil test recommendations installed:

- 5,000 lb/ac (5,600 kg/ha) of BSM
- Fast-Acting and Slow-Release Lime
- Slow-Release and Fast-Acting Biostimulant Additives

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Flexterra Application

Per soil test recommendations installed:

- 3,500 lb/ac (3,920 kg/ha) of HP-FGM

MINE RECLAMATION

Attapulgus, GA

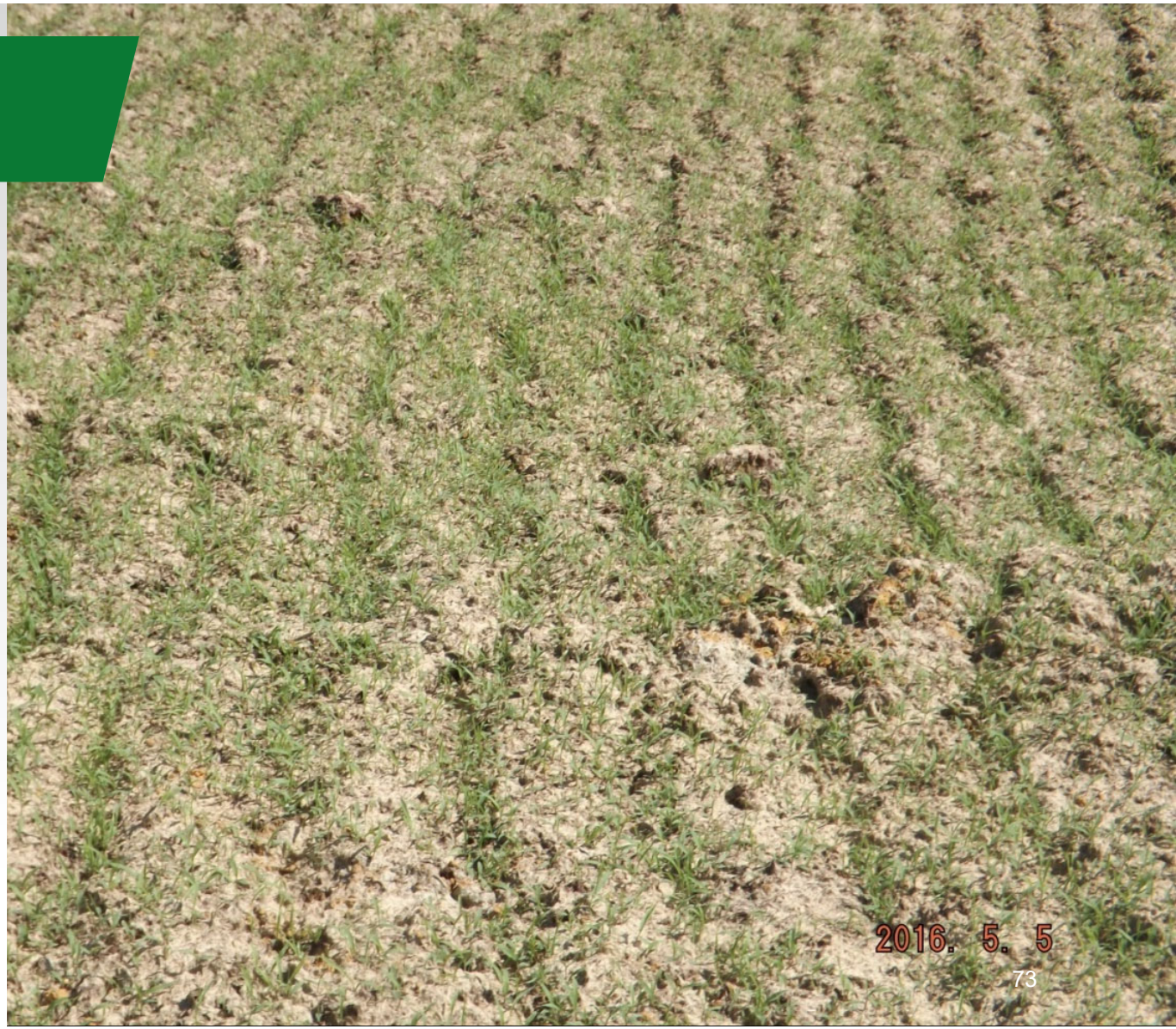
PROJECT SUMMARY

Vegetation Establishment

- 8 days post-seeding

Seed mix included:

- Bermuda grass (*Cynodon*)
- Bahia grass (*Paspalum*)
- Millet – nurse crop



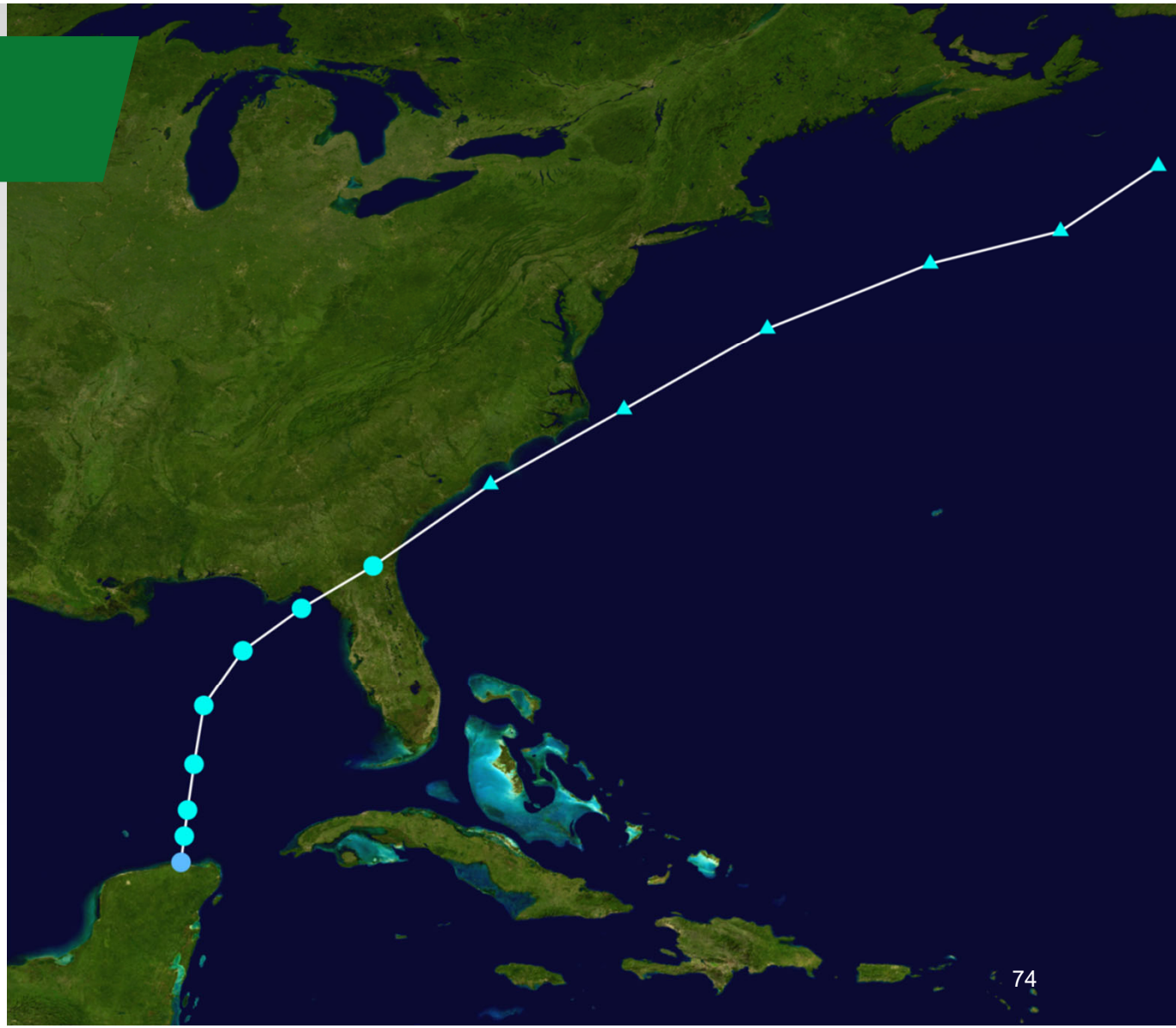
MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Vegetation Establishment

- Tropical Storm Colin
- June 5-6, 2016
- 5” of rain in 24 hours



MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Vegetation Establishment

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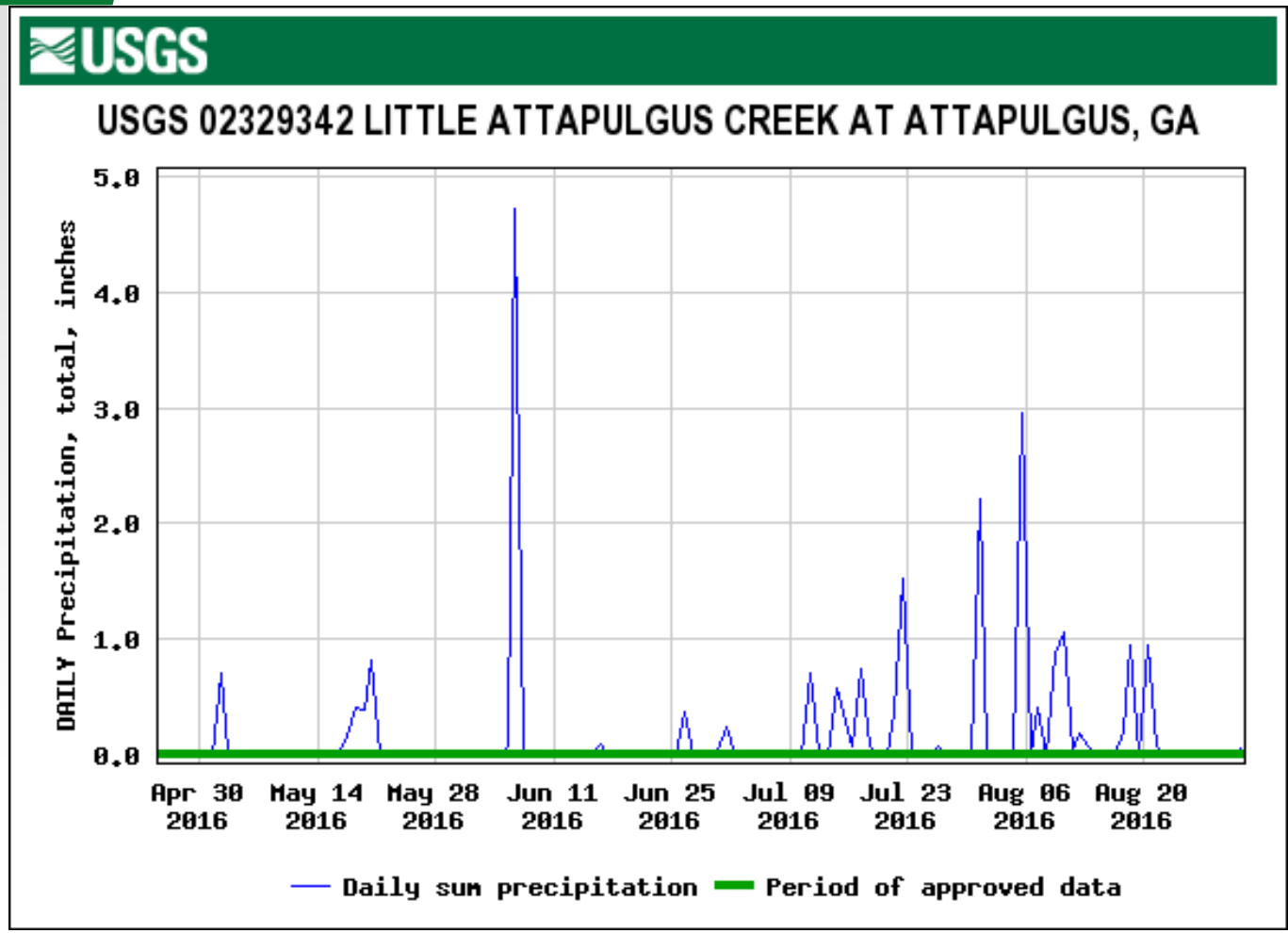

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Vegetation Establishment

- Tropical Storm Colin
- June 5-6, 2016
- 5” of rain in 24 hours
- One day after the storm passed

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Vegetation Establishment

- October 5, 2016

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Project Completion

- Initiated/Completed Final Design Jan/Feb 2016
- Completed Grading & re-Contouring & Application by end of April 2016
- Site inspection mid-August 2016 by Regulatory Agency
- Achieved Bond Release on September 1, 2016
- < 4 Months from Time of Installation until Release

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Follow up Visits

- September 2017

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Follow up Visits

- September 2017

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Follow up Visits

- December 2017

MINE RECLAMATION

Attapulgus, GA

PROJECT SUMMARY

Soil Test Results

December 2015	December 2017
Sandy Clay Loam • Organic Matter – 0.4% • pH – 4.8	Sandy Clay Loam • Organic Matter – 2.0% • pH – 5.3

Background Organic Matter is 1.5%

Georgia DOT and HECPs

716.3.05 Construction

The contractor may elect to use either Section 712 – Fiberglass Blanket, Section 713 – Organic and Synthetic Material Fiber Blanket (except do not use Type II Wood Fiber Blanket), or Section 714 – Jute Mesh Erosion Control on slopes. All of the materials, construction and measurement portions of the noted sections apply to the type mat (blanket) selected for use.

GDOT
Georgia Department of Transportation

Office of Materials and Testing
Qualified Products List

I Wood fiber blanket	Slopes Only
I Wood fiber blanket	Slopes Only
II Wood fiber blanket	Slopes & Shoulders
II Wood fiber blanket	Slopes & Shoulders
II Wood fiber blanket	Slopes & Shoulders
II Wood fiber blanket	Slopes & Shoulders
II Wood fiber blanket	Slopes & Shoulders
II Wood fiber blanket	Slopes & Shoulders
II Wood fiber blanket	Slopes & Shoulders

Following discussions with GDOT, **they have acknowledged the inaccuracy of the specification and clarified that Type II Wood Fiber Blankets are indeed approved for use on slopes**. GDOT is actively working to revise the 716.3.05 specification, reflecting the approval of these products for use on slopes.

Conclusion

- Soils are the foundation of a successful erosion control project
- Test your soils on erosion control projects
- Issues with pH, OM, salts, or other issues can make establishing vegetation difficult
- Amend the soils accordingly

Questions?

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