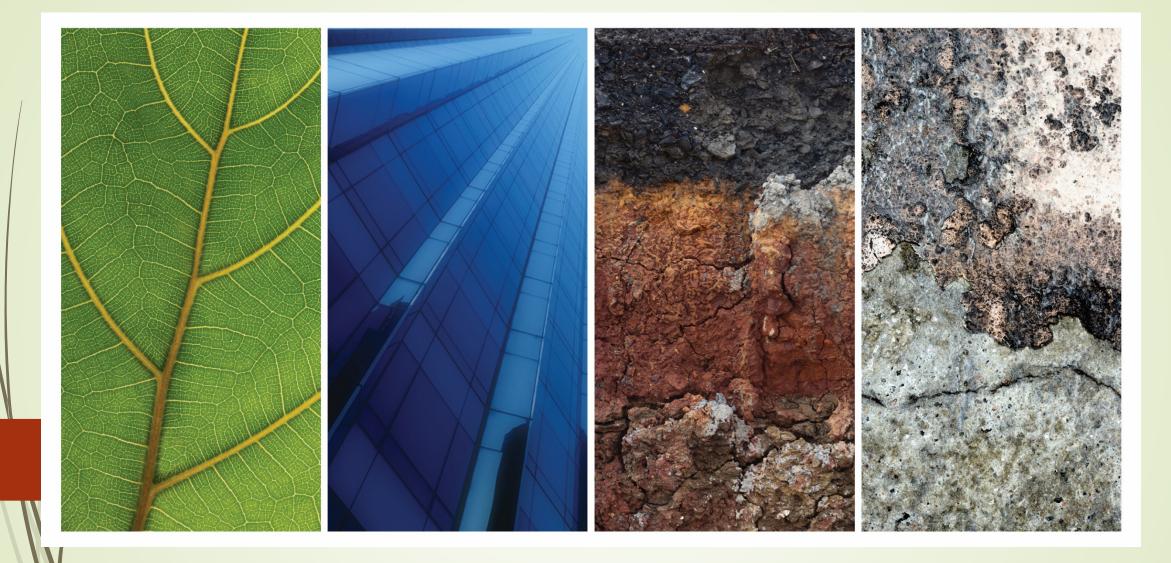
Highway Agronomy



Requirements for establishing vegetation on disturbed soils



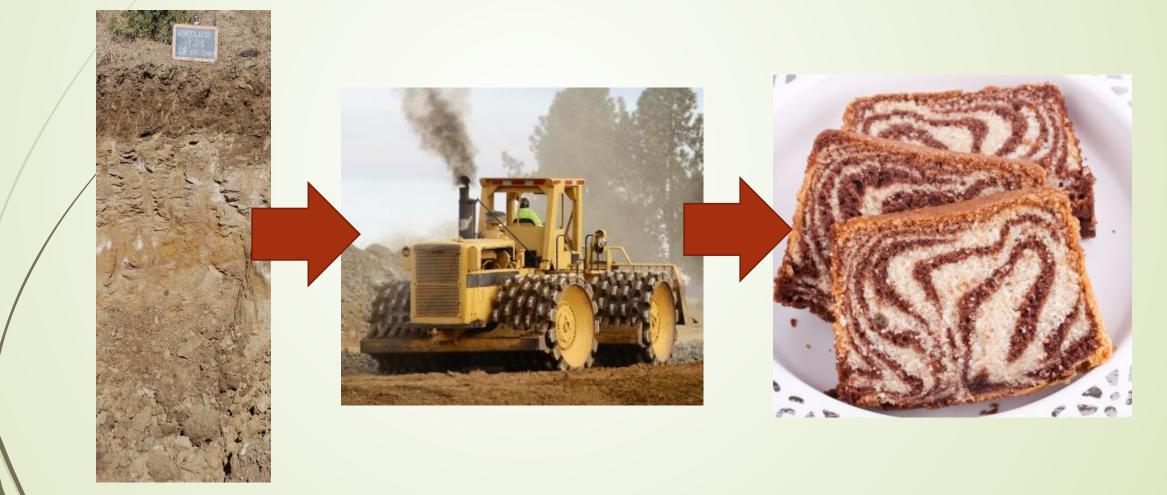
Terracon Consultants, Inc.

There is more to stormwater management than erosion control

- As we impact the land surface we disrupt the mechanisms that have evolved over geologic time.
- Land disturbance can disconnect the natural systems that are needed to buffer and stabilize surface water.
 - Agricultural tile drains;
 - Surface mining spoils;
 - Highway embankment soils.

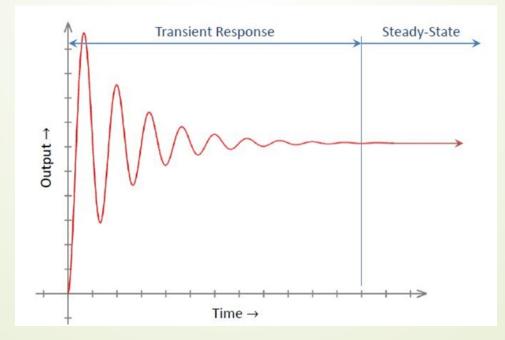


Why doesn't one size fit all?



Steady State Energy

- How do you re-establish the natural steady state?
 - A system in a steady state has a higher level of energy than its surroundings.



Soil is a complex living system



But simply stated: Soil is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life.

We know a lot

We have an extensive technical understanding of the soil's processes and mechanisms.

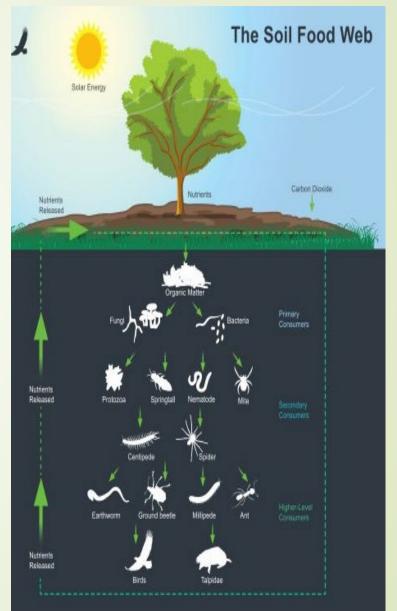
Not sure why we don't always apply what we know.

Everything should be made as simple as possible but not simpler. Albert Einstein

Soil is a complex living system

Soil genesis (formation);

- climate, organisms, relief, parent material, and time.
- Soil physical and chemical properties;
 - texture, structure, mineralogy, consistency, density, porosity, color;
- Soil/water management;
 - soil compression, compaction and consolidation.



How do we restore or replace soil once it is severely disturbed?

Simple approach

- Grade the site to drain
- Prepare the completed surface grades
- Apply Lime, Fertilizer, Seed and Mulch
 Add a little Water









Real world: Construction site DAY 1

The contract documents clearly require site preparation to include stripping and stockpiling of all available topsoil.

"There is no topsoil"... and "we need to get going on the 200,000 cubic yards of dirt we gotta move"



Prescriptive vs. Performance

- Doesn't the designer have some responsibility to identify the location, describe the consistency and estimate the volume of on-site topsoil resources?
- "Strip and stockpile all topsoil available on site."
 ...The contract also includes a pay item to bring in topsoil from off site (if needed).

Prescriptive vs. Performance

The performance clause – "Final Seeding"

"Contractor is responsible for providing a permanent stand of perennial grasses and legumes."

OR

"The contractor is required to provide 70% perennial grass cover prior to contract completion."

This is an equation for arguments, diminished quality and regulatory compliance headaches...



Real world: Construction site Day 100

- Ok, we just gotta seed and weer dun!
- What topsoil? I told you there was no topsoil... I can bring in some topsoil but it is expensive!
 - ...Let me get Bob. He uses that triple
 16 and... man, stuff really grows!
- Don't worry, I got a seed mix that will grow grass on a stop sign...no, really...

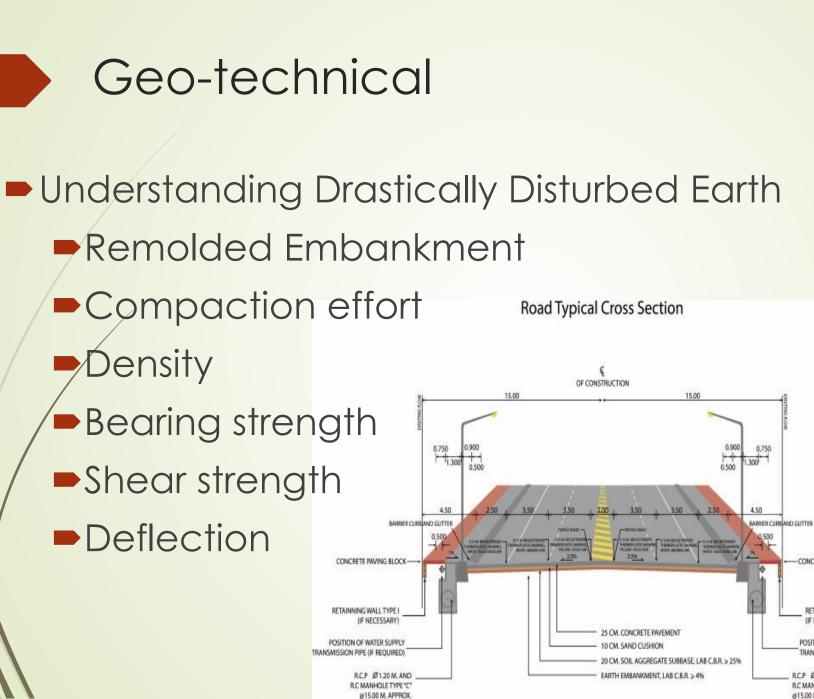


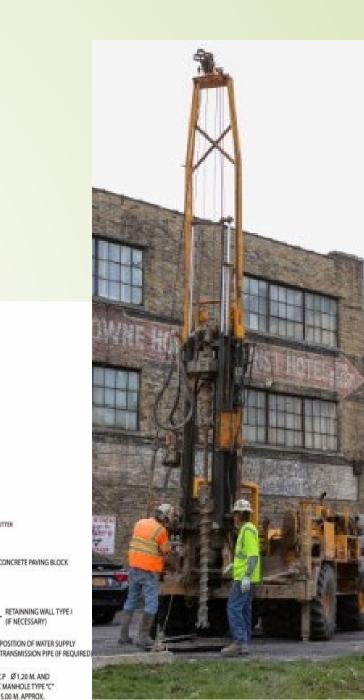
Final finishes

Any final finish is a difficult task
End of the job
Budgets and profits are under the microscope
What is the reasonable science based approach to vegetative restoration?

END OF RANT

- Lets talk about how we can better understand how plant/soil systems work.
- Maybe develop an appreciation for what we are asking for.
- Then apply that to what is needed to achieve the "permanent vegetative cover".
- It isn't simple and it isn't cheap.





- CONCRETE PAVING BLOCK

(IF NECESSARY)

R.C.P. Ø1.20 M. AND

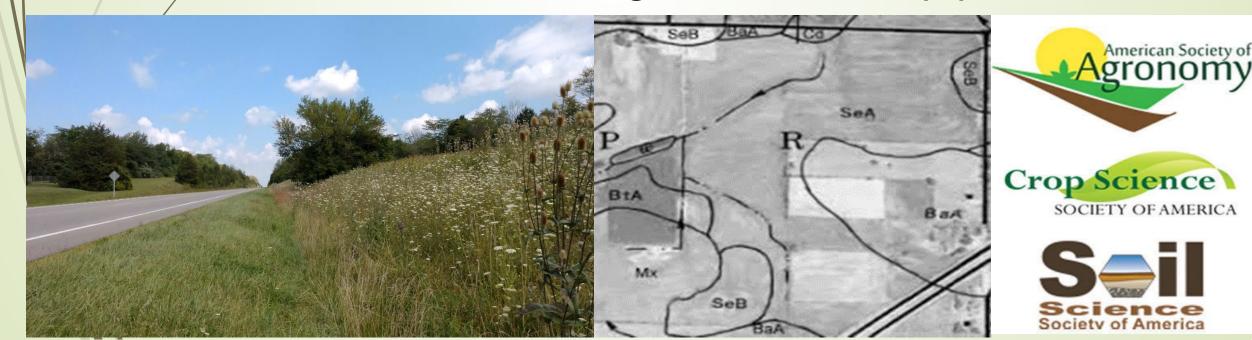
R.C. MANHOLE TYPE 'C'

@15.00 M. APPROX

Agronomy



The science of soil management and crop production.



Chemical and physical soil considerations



- The near surface soil needs to be a reservoir of readily available nutrients.
- Hospitable environment that promotes germination and plant growth.

A closer look at soil amendments

Key players: lime



modifies pH

fertilizer

retained nutrients are held on the soil complex primarily by electrochemical matrix

seed

embryonic nutrients, moisture

mulch

moisture retention, raindrop splash impact

pH- negative log of the Hydrogen ion concentration

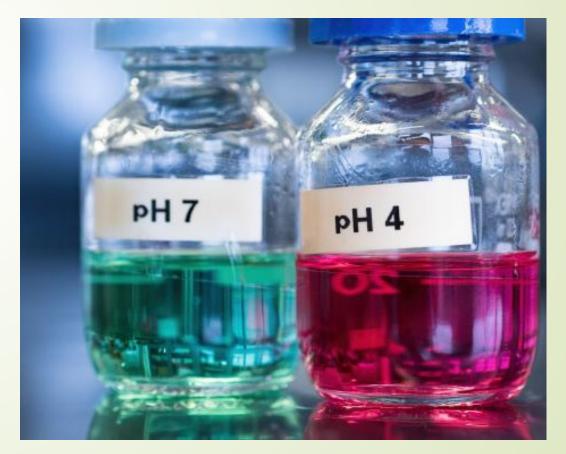


pH is a measure of the hydrogen ion concentration of a solution. Solutions with a high concentration of hydrogen ions have a
 Iow **pH** and solutions with a low concentrations of H+ ions have a high **pH**.

pH 4 is ten times more acidic than **pH** 5 and 100 times (10 times 10) more acidic than **pH** 6.

Soil is a buffer

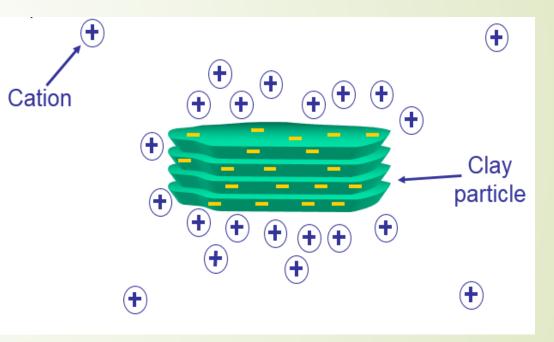
 Buffers resist change
 Basically, buffers resist changes in pH as acids or bases are added to the solution.



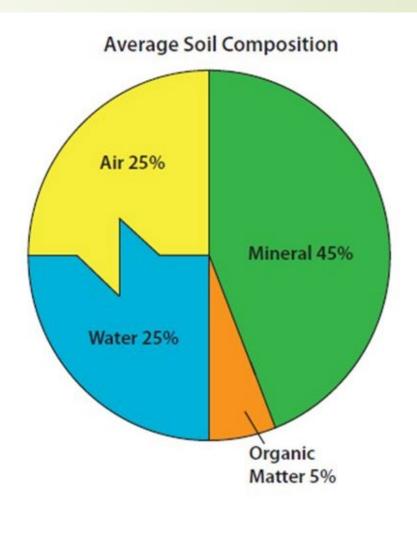
Cation Exchange Capacity

Soil buffer capacity

Controls how certain nutrients are retained or lost from the soil



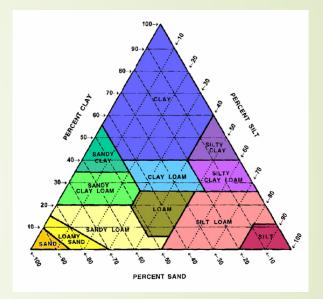




How plants extract nutrients from soil

Cation Exchange Capacity Sand ■ Silt Clay Organic Matter Soil gas Soil solution







How plants extract nutrients from soil

- Cations are electrostatically held on the soil matrix.
 Cations (+) stick to negatively charged clay particles and long chain organic molecules.
- Moisture films on the soil particles create the medium for the plant root to exert an electrochemical force that pulls the nutrients from the soil cation exchange complex to the membranes in the root that have a cation exchange complex of their own.

BRILLIANT!



- Healthy soil has the ability to barely hold nutrients
- Plants expend barely enough energy to extract the nutrients from the soil
- How can we apply this concept to severely disturbed soil systems?
- Difficult task in our marble cake world.

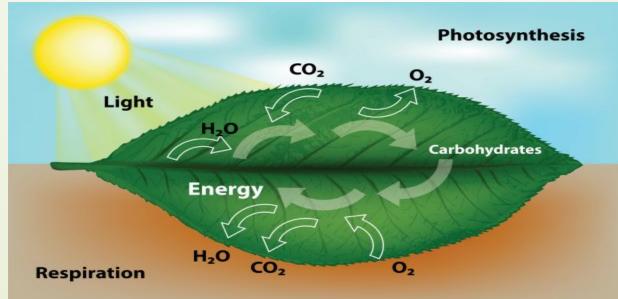


Photosynthesis and Respiration



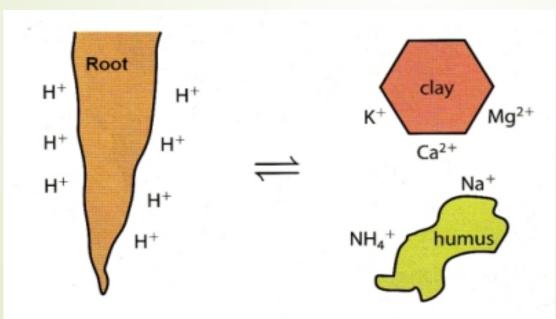
Photosynthesis captures energy and produces carbohydrate

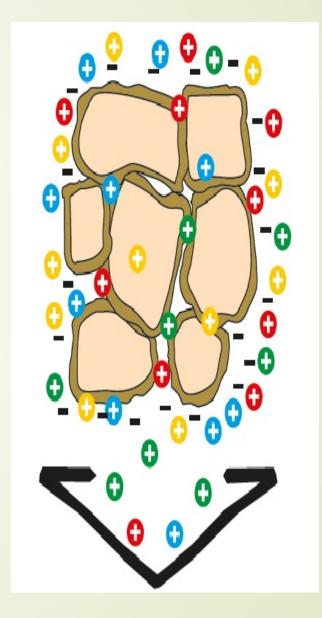
- Sunlight + 6H2O + 6CO2 → C6H12O6 + 6O2
- Respiration generates ATP and spills H+
 - $-C6H12O6 + 6O2 \rightarrow 6H2O + 6CO2 + energy$



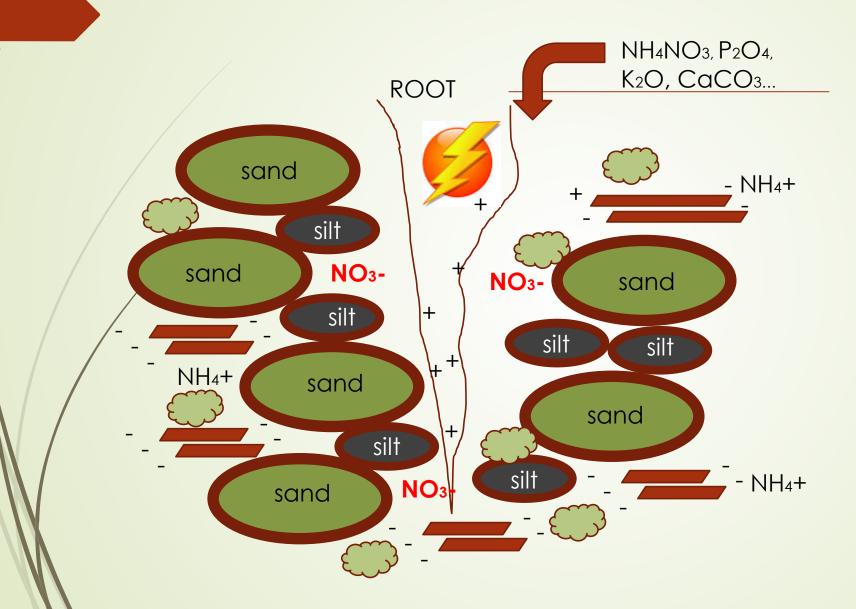
cation-exchange capacity

CEC is the number of exchangeable cations that a soil is capable of holding, at a given pH value, <u>AND</u> available for exchange with the soil water solution.



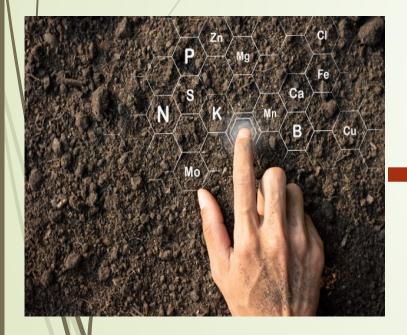


How plants extract nutrients from soil





Common soil nutrient ions



The most common soil cations:

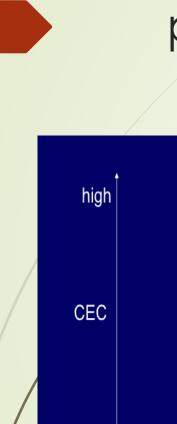
- calcium (Ca⁺⁺), magnesium (Mg⁺⁺), potassium (K+), ammonium (NH₄+), hydrogen (H⁺) and sodium (Na⁺).
- Common soil anions:
 - chlorine (Cl⁻), nitrate (NO₃⁻), sulfate (SO₄⁼) and phosphate (PO₄³⁻).



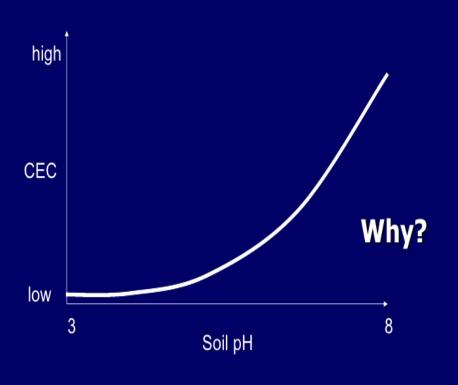
pH influences CEC

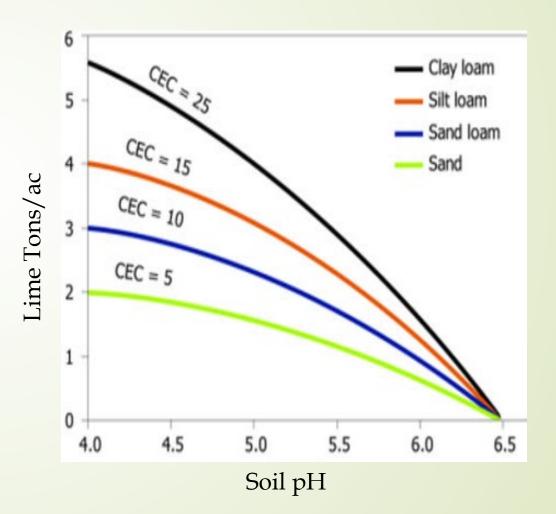


- Adding limestone replaces the acidic hydrogen and aluminum cations with basic calcium and magnesium cations, which increases the base saturation and raises the pH.
- If the pH is too low, the available nutrients go into solution and cannot be held on the soil complex.
- If the pH is too high, the nutrients are held tightly to the soil complex and not released into the soil solution.
- As the pH goes up so does the CEC



pH influences CEC





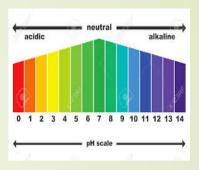
Why is this important?

The lime and fertilizer amendments need to be closely prescribed to the soil characteristics namely, OM content, texture, pH and CEC.

This is the only way that the nutrients will be reasonably available to the plant.

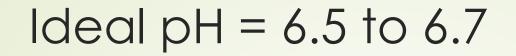
So, Bob's triple 16 fertilizer only fits a very narrow range of soil conditions that aren't apparent with out testing. It is likely that much of the application leaches out of the profile or runs off in our surface waters.

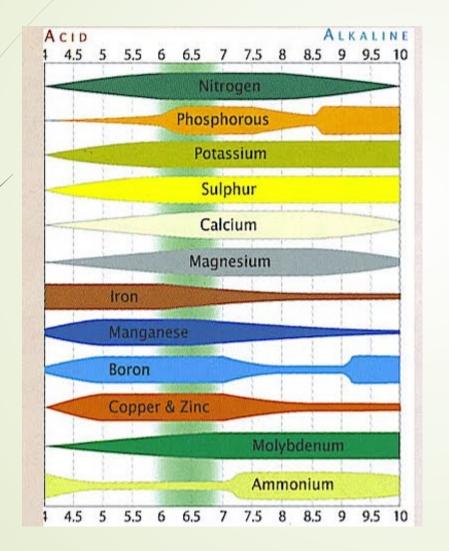










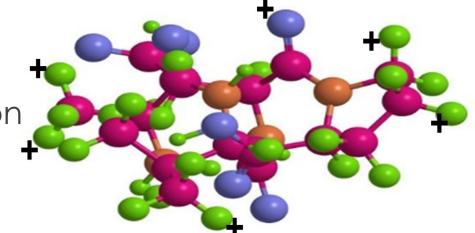


The pH range where most plants can regulate nutrient intake from the soil solution.

Managing retained Organic Matter

Primary CEC players are Clay and OM

- Clay is a very stable mineral that has electrostatic sites that can retain nutrient ions that contribute to the nutrient flow through the soil solution.
- So what about Organic Matter?
 - (1) electrostatic long chain attraction
 - (2) complex formation
 - (3) water retention

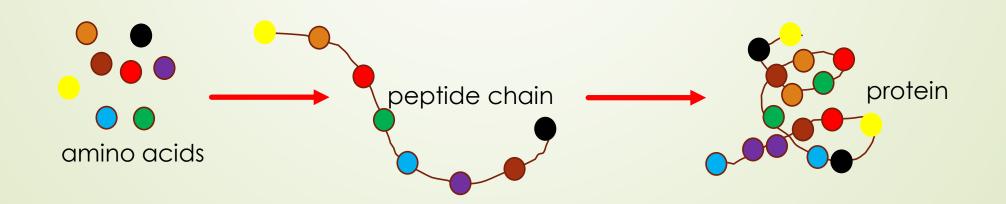


BLA BLA BLA.... How do you increase the OM in a soil system to create a sustainable stand of perennial vegetation?



Nitrogen...amine...amino acid ...protein...tissue

- Both Nitrogen and Carbon have to be in reasonable abundance.
 - Animal waste Nitrogenous wastes
 - Plant residue high in cellulose is high in carbon
 - Oak leaves, wheat straw, corn trash etc.
- Microbes break down the cellulose and take nitrogen from the soil solution to operate their life cycle (aka protein synthesis).



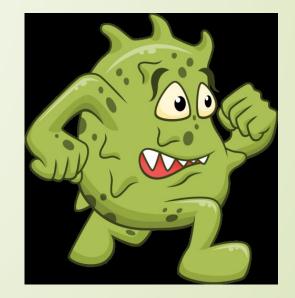
Microbes are mobile, plants are not

Good news

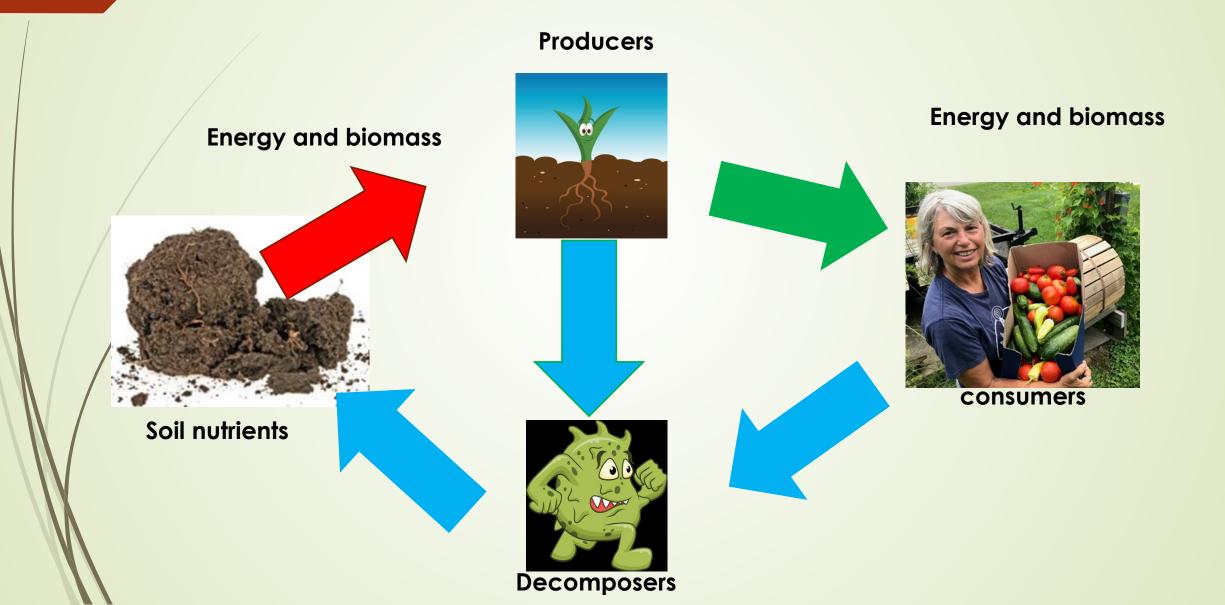
Digested cellulose is in a form that enhances the CEC and can enhance soil productivity.

- Bad News
 - Microbes are mobile and can move to the nitrogen they need. Plants cannot spatially compete.
- You have to balance the availability of the Carbon and Nitrogen resources so the plant can benefit from the organic matter that is present in the soil profile.





Carbon cycle and nitrogen cycle



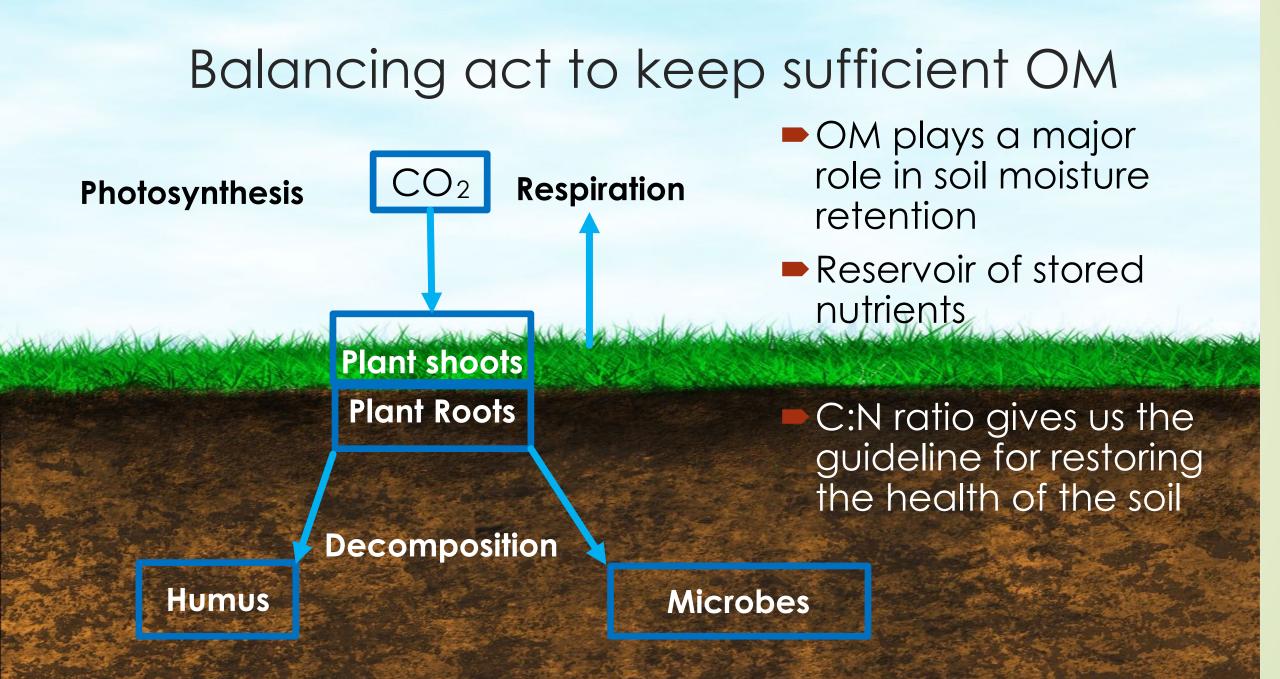
Balancing the Carbon to Nitrogen Ratio

Ag system optimum C:N ratio is 24:1 for ideal decomposition of crop residue.

Microbe's body tissue is comprised of about 8 parts.

Microbes need an additional 16 parts of carbon for energy synthesis.

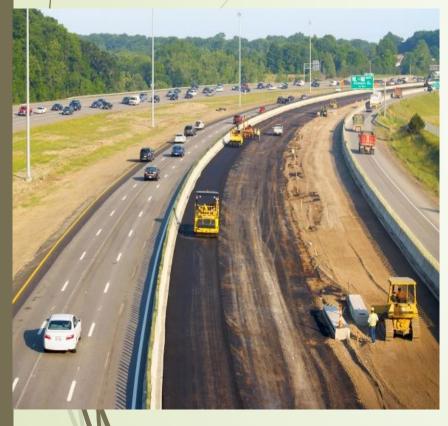
REELE



Lets just say...

- We have a highly engineered, reinforced stable embankment.
- Optimum compaction
- Graded to drain
- AND
- We also have a highly desirable stockpile of topsoil
 - ► pH 6.7, CEC 15, coarse silt loam, 6% OM

Spring construction delay results in the contractor requesting to seed before the July 4th weekend



- The stockpiles have been sampled
- The distribution of the re-soiling materials are planned
- pH has been adjusted per soil test
- Fertilizer analysis and application rate has been accurately developed
- Site specific seed mix and seed rates have been selected
- Lets waive the contractual seeding date

Timeliness of seeding

- In the state of Ohio, planting coolseason grass seed in early fall or spring.
- Sowing or over-seeding is best done when soil temperatures range between 50 and 65 degrees Fahrenheit.
- September is the best time for grass seeding, close second is mid-February to late March, depending on the weather.
 - Snow, mud, site accessibility





Preparing the seed bed

The characteristics of a good seedbed:
soil depth minimum of 4 inches
soil moisture
weed free







Managing sustainable nutrient equilibrium in soil to optimize plant growth

Even though a field could be within recommended ranges for nutrients, the soil physical structure or soil food web could be the primary constraint to production.

Ohio Agronomy Guide 15th Edition, Bulletin 472



Exercise care when planting

- Proper seed depth.
 - Typically less that 1/4"
 - Good soil-seed contact



Cultipacking crushes dirt clods and firms the seedbed. It improves uniform shallow seed placement and increases seed-to-soil contact.



Mulch

- Protects the exposed soil surface from splash impact
- Protects against surface crusting
- Protects the fertilizer from volatilizing
- High cellulose, High Carbon, OM precursor
- Ohio disturbed sites:
 - 2-3 tons per acre
 Crimped in place





Remember the "Simple Approach"?

Simple approach

Grade the site to drain and be physically stable

Prepare the completed surface grades

Apply Lime, Fertilizer, Seed and Mulch

Add a little Water



Remember the "Simple Approach"?

- Not so simple approach
 - Grade the site to drain with stable slopes
 - Prepare the completed surface grades
 - Condition the organic matter content in the re-soiling material (stockpiled "topsoil")
 - Spread/apply re-soiling material
 - Determine the Amendment application rates by soil testing
 - Test pH Reserve acidity
 - Fertilizer N-P-K amendment that is right for the soil's CEC
 - Prepare the seed bed
 - Seed Correct species, placement, dates and rates
 - Mulch sufficient cover to enhance moisture retention and prevent raindrop impact/crusting

How does any of this apply to a roadway project?

- We need to be site location specific
 - Designers need to call out incremental LFSM areas on the project site.
 - Incremental testing needs to be built into the work.
 - DON'T waive the seeding dates!
 - Yes, it is expensive
 - Yes, it may delay completion
 - Yes, you will get what you pay for.

Popular Construction Guidance Manual: Seeding and Mulching -

"Because of the straight forward nature of this item of work, no detailed explanation of the work is required in the Manual."

> "In our attempt to make conservation easy, we have made it trivial." - Aldo Leopold, 1949

Thank you for your attention. Any questions?



