Tree-soil interactions 101:

How to make a soil map, and considerations for successful tree planting

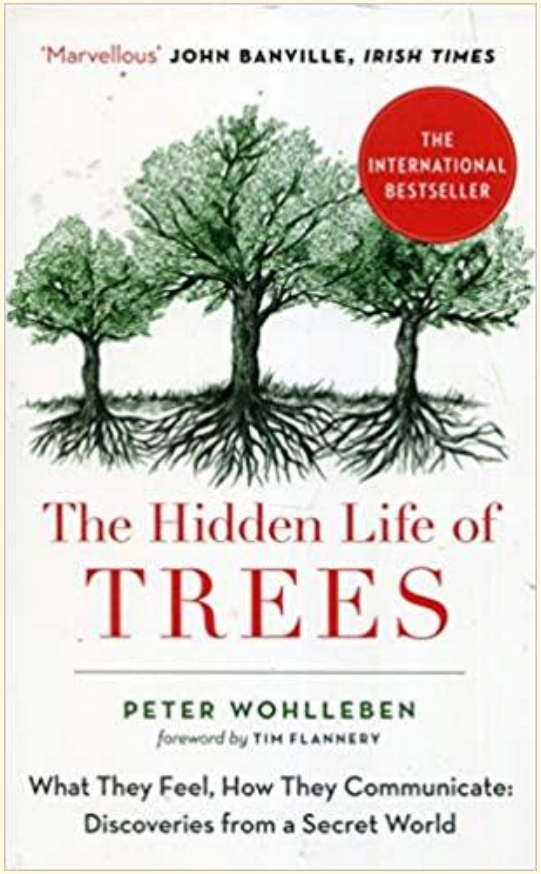
Joel Betts

Conservation Planner

Watershed Ecologist

The unseen half of trees

- There are more lifeforms in a handful of forest soil than humans on the planet!
- Up to half of the biomass of a forest is in the soil, with a tree's roots often spreading twice as far as its canopy.
- A tree can store up to 22 tons of carbon dioxide in the biomass of its shoots, trunk, and roots, and even more in the affiliated mycorrhizal fungal network underground.
  - Same as emitted by 2,246 gallons of gas burned (50,000 miles for a typical car)



Also see documentary "Intelligent Trees" made after the book (on Amazon)

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

The unseen half of trees

- Plant communities depend on and are largely determined by the characteristics of soil they are growing in, and what is growing in the soil with them.
- The characteristics of the soil are also dependent on and changed by and the plants growing in it.

Goals of this talk

- Understand the properties of soil and how the relate to trees/forests
  - Inherent (unchangeable)
    - parent material, texture, formation
    - USDA soil survey maps for MA
  - Dynamic (changeable)
    - pH, Bulk Density, Water holding capacity, nutrients, organic matter, soil health/life
    - Soil Testing
    - Forestry and soils (basics)
- Apply this knowledge for successful tree planting
  - Choosing the right tree for your soils
  - Changing your soils for the right tree

- Learn some cool tidbits about tree/soil interactions and the hidden ecology of the soil

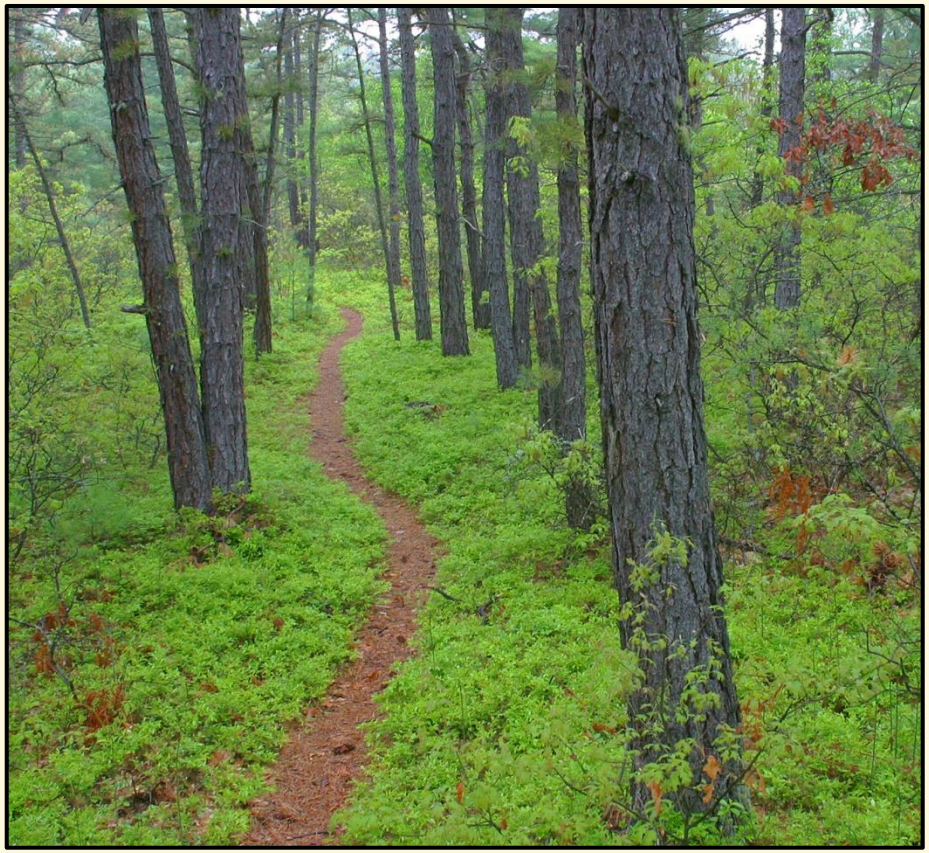
What we do…

Worcester County Conservation District

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

- **Planting trees** since the 1950's through our spring **Seedling Sale**!
- **Workshops** and **outreach** on soil health, sustainable agriculture practices, and wildlife habitat conservation
- **Soil Testing** and **technical assistance**
  - 75 site visits with landowners, >100 soil samples in 2020

What’s the difference between these forests?



https://www.maine.gov/dacf/mnap/features/commsheets.htm

What’s the difference between these forests?

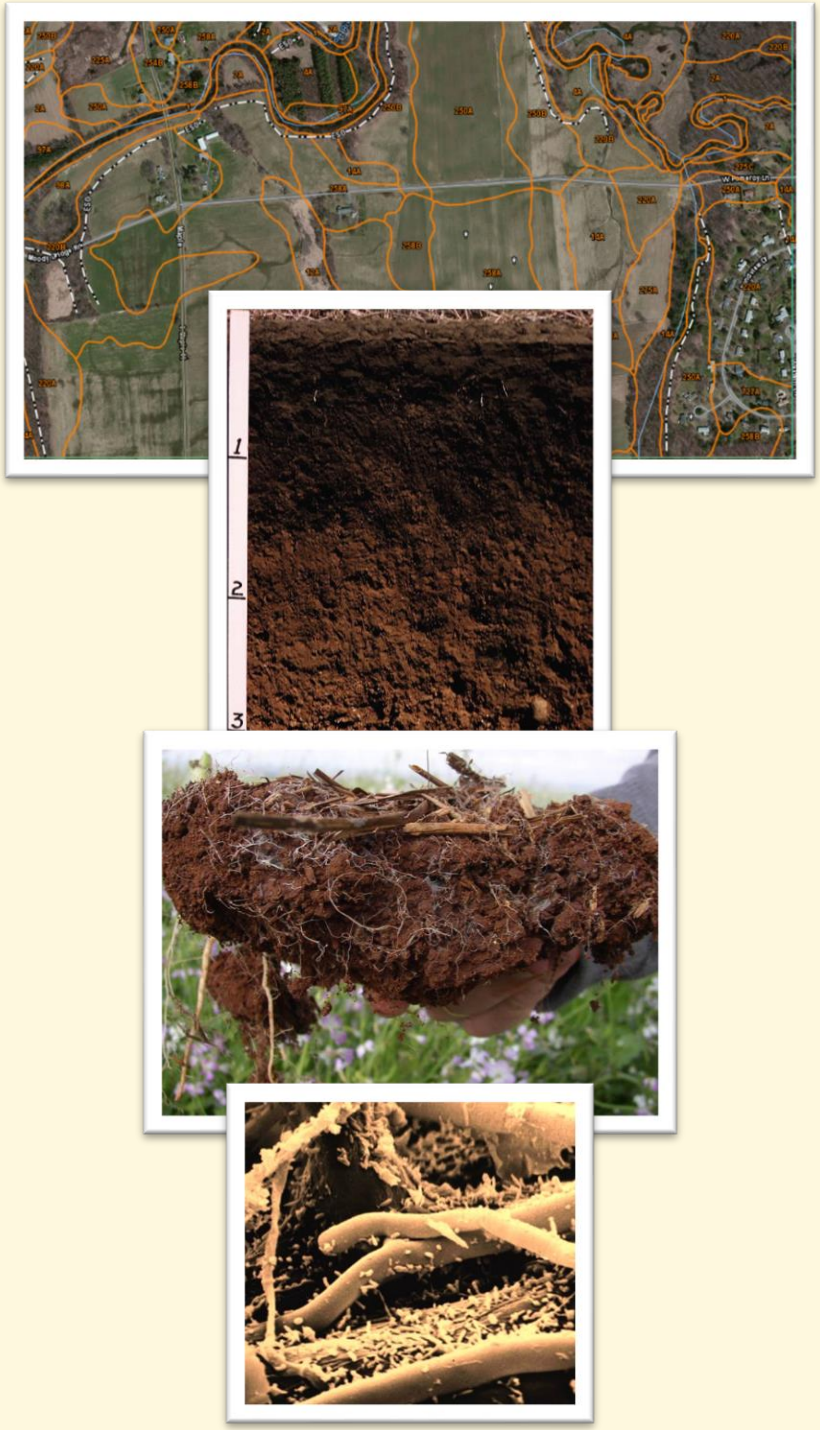
What determines the composition of a forest?

- **Temperature**
- **Moisture**
- Natural Disturbance Regime (Flooding, Fire, Hurricane)
- Land Use History
- Wildlife interactions
- **Soil qualities**

These same forces operate on a small scale

& may determine the success of a tree planting, depending on the species' adaptations

- **Inherent** soil properties (geologic timeframe; larger scale)
  - Parent material
  - Texture (sand, silt , clay)
  - Drainage class
    - Slope
    - Landscape position
  - Depth to bedrock or restrictive layer
- **Dynamic** soil properties (human timeframe; smaller scale)
  - pH
  - Organic Matter
  - Soil Life
  - Cation Exchange Capacity
  - Nutrients
  - Structure
  - Porosity



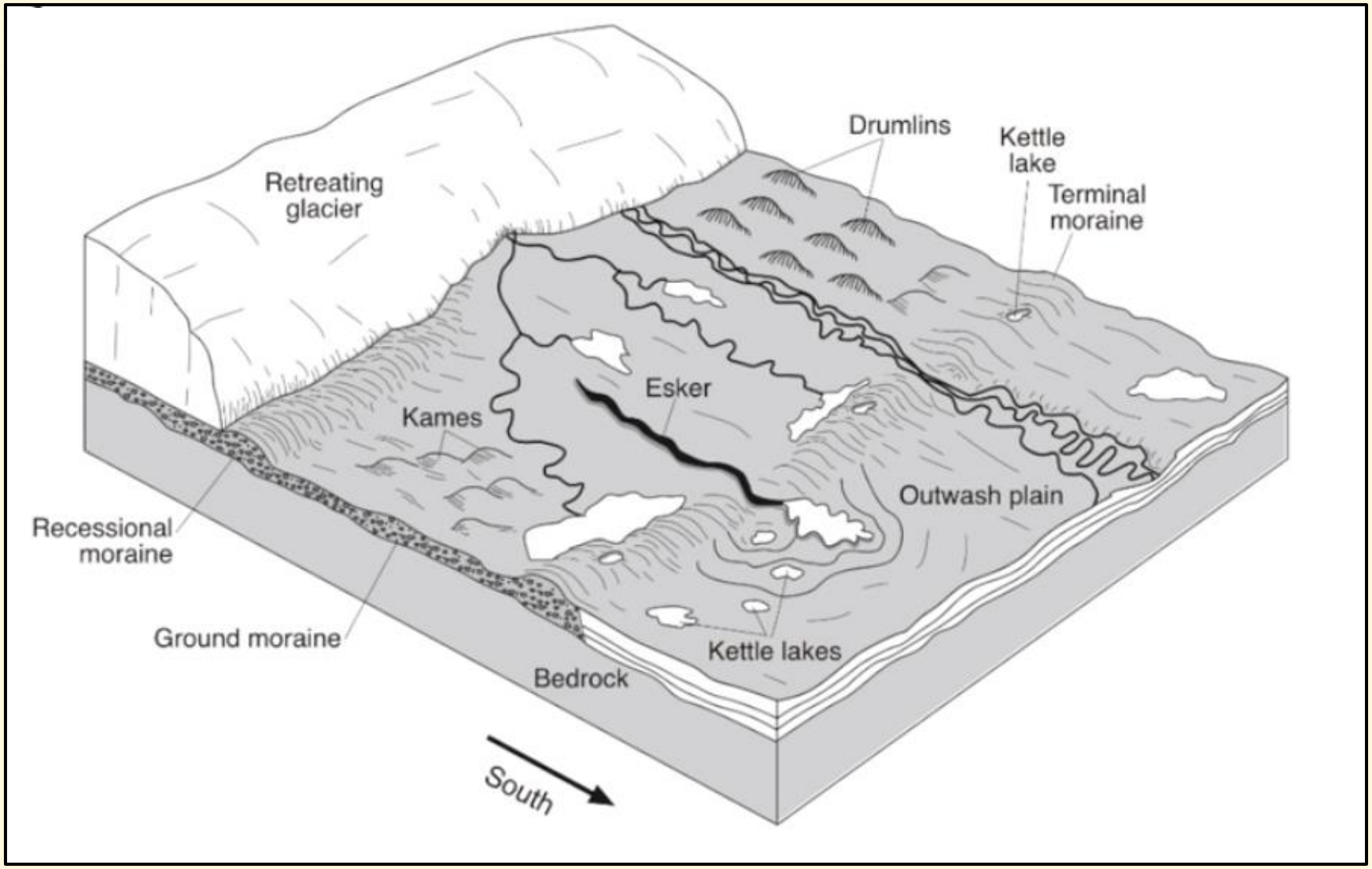
Parent Material

- The material in and from which soils form
- In the lower part of the soils
- May be relatively unchanged from when they were deposited by moving water, ice, or wind.

→ Depth to densic material


Sea ice surrounded Iceland.
The Bering Strait was a land bridge.
Continental glacier
Sea ice
Unglaciated land
Large lakes formed in the Basin and Range Province.
New York City was under ice.
500 mi
500 km

Glacial landforms determine parent material in Massachusetts



https://www.youtube.com/watch?v=HEStq4VYJ2Y

Types of transported parent material and associated modes of transportation and deposition

Mode of Transport	Resulting Parent Material
Water	• Alluvial or fluvial (deposited from flowing water) • Lacustrine (sediments in still water, especially lakes) • Marine (deposited in oceans or re-worked by oceans)
Water and Ice	• Glacial-fluvial (sediments deposited by glacial meltwater in a floodplain environment) • Glacial-lacustrine (sediments deposited by glacial meltwater in lake environment) • Glacial-marine (sediments deposited by glacial metlwater in an ocean environment)
Ice	• Till (sediment deposited directly by glacial ice)
Wind	• Loess (sediment composed primarily of silt-sized particles) • Volcanic tephra (sediment composed of volcanic erecta in a range of particle sizes) • Eolian sand (sediment composed primarily of sand-sized particles)
Gravity	• Colluvium (sediments found on steep slopes derived from local sources)

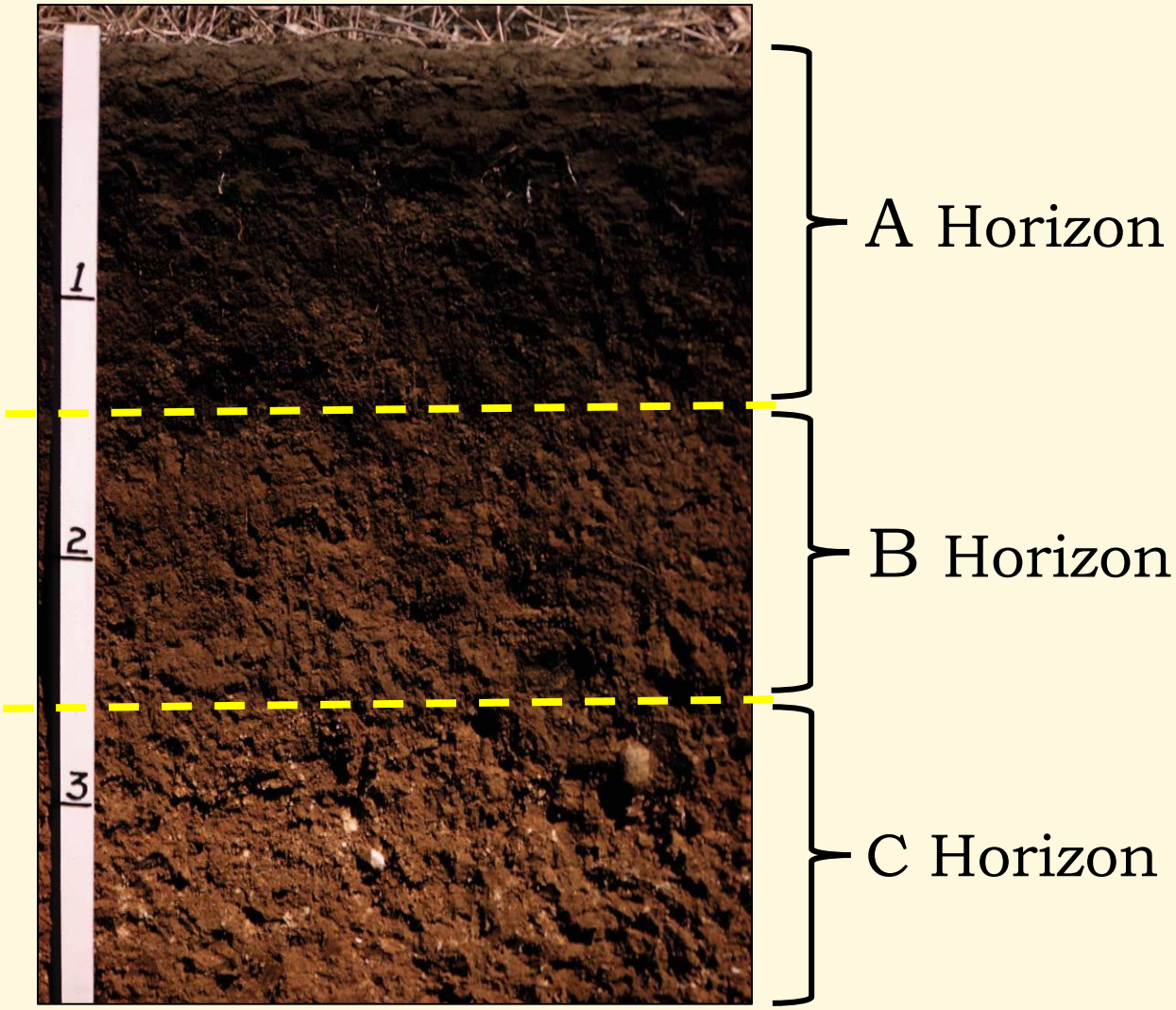
https://landscape.soilweb.ca/parent-material/

Soil Profile

Physical Characteristics

- Texture
- Structure
- Color

Determines soil type



Let's talk about soil texture…

- Mineral fraction – only!
  - Sand – gritty (0.5-2mm)
  - Silt – floury (0.002mm – 0.5mm)
  - Clay – sticky (<0.002mm)

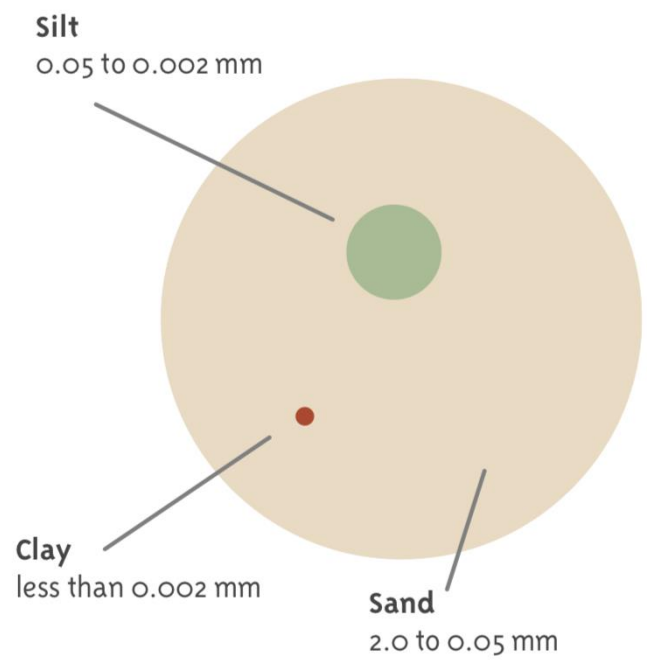
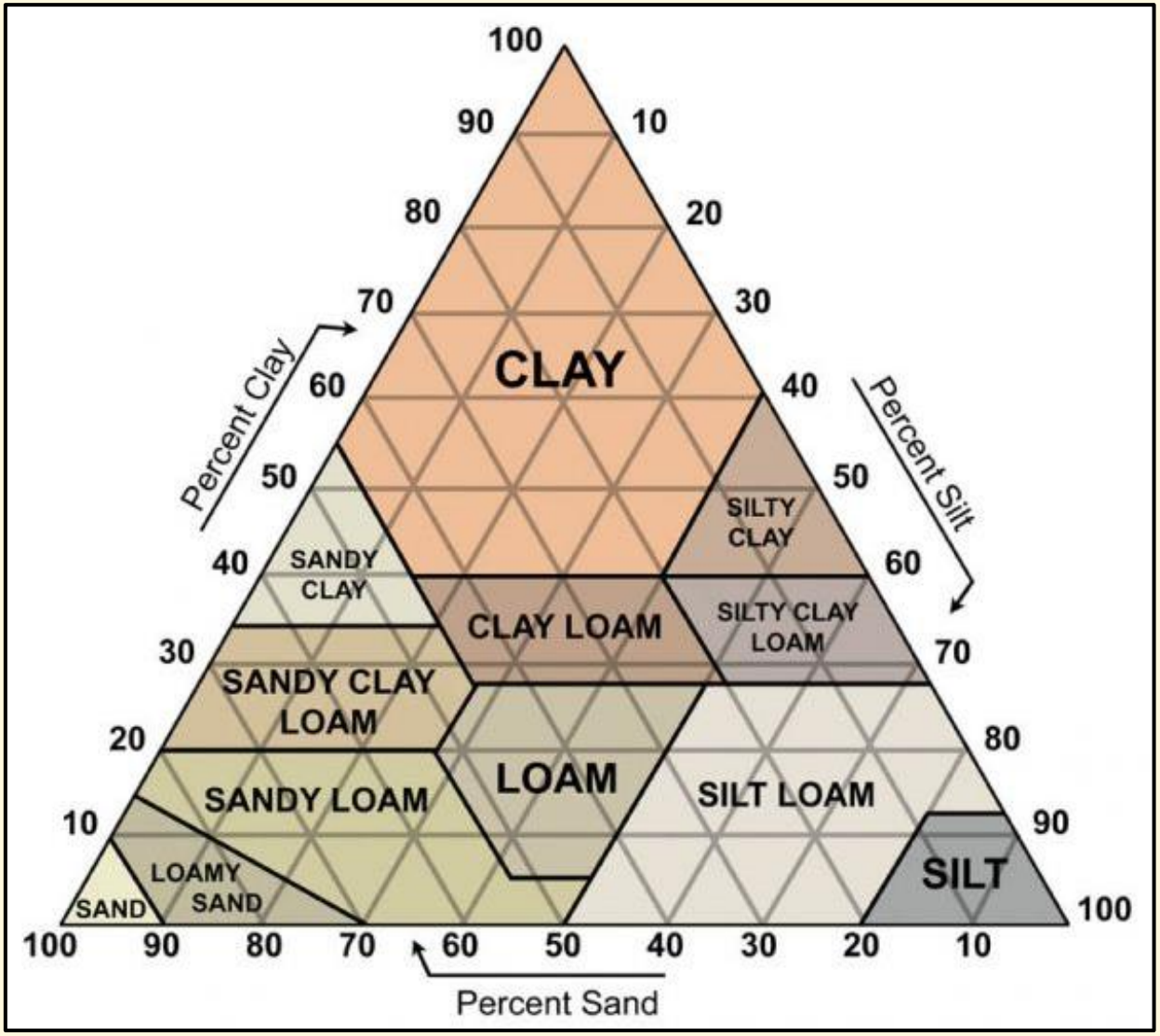


Fig. 1. Relative sizes of sand, silt and clay particles.

- Organic fraction (2-4% in most New England soils)

Soil Texture Triangle



Our current soils are a result of (Soil Formation)

- parent material (geologic and organic precursors to the soil)
- climate (precipitation, wind, and temperature)
- **topography** (shape of the land)
- biota (native vegetation, animals, and microbes)
- time (time that parent material is subject to soil formation processes)

Soil Moisture: Drainage

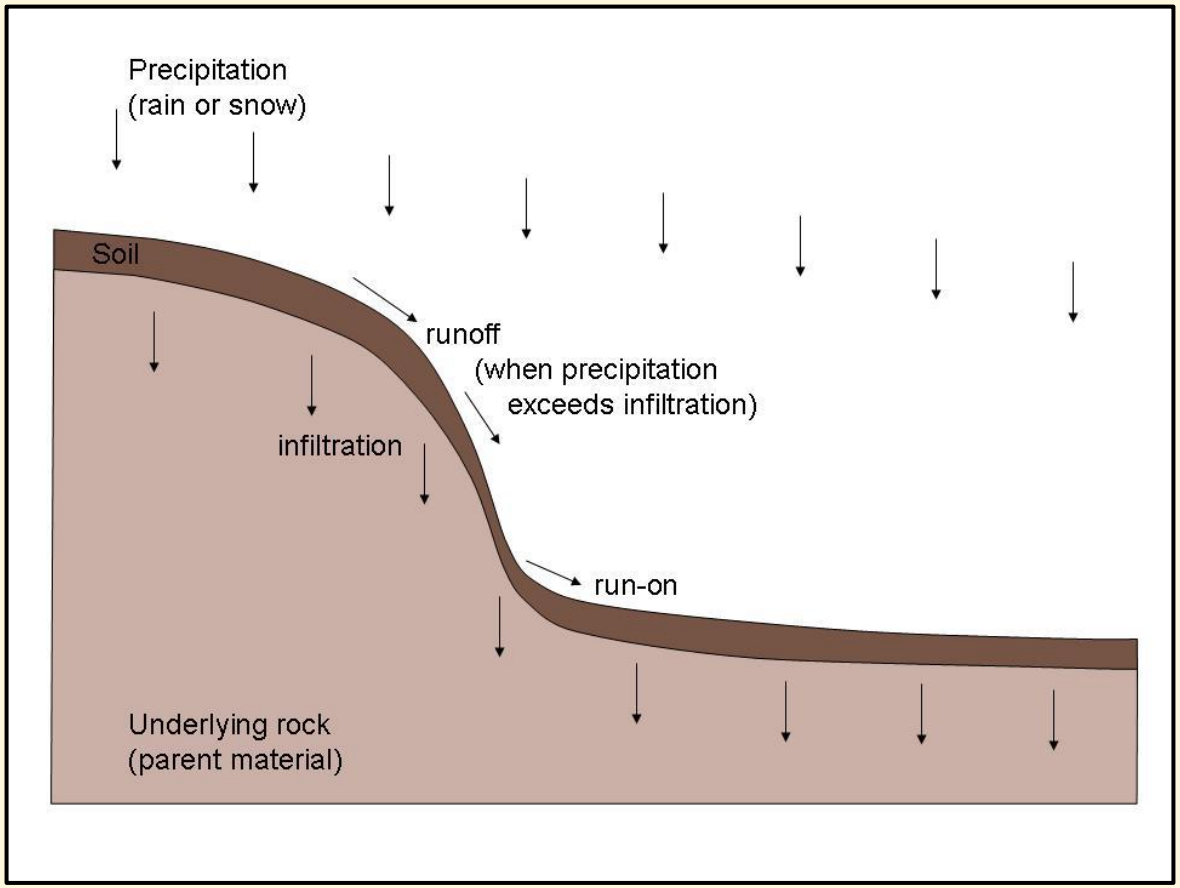
Particle size/composition

Larger particles (like sand) hold less water, create drier conditions

Finer particles (silts and clays) hold more water, create wetter conditions

Soil Moisture: Drainage

Slope



You find certain plant communities on certain soil types and certain drainage areas on the landscape

Soil Drainage Class

- **Excessively drained.** Water is removed very rapidly.
- **Somewhat excessively drained.** Water is removed from the soil rapidly.
- **Well drained.** Water is removed from the soil readily but not rapidly.
- **Moderately well drained.** Water is removed from the soil somewhat slowly during some periods of the year.
- **Somewhat poorly drained.** Water is removed slowly so that the soil is wet at a shallow depth for significant periods during the growing season.
- **Poorly drained.** Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods.
- **Very poorly drained.** Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season.

Choosing the right tree for your soils: Plant Adaptations (and how much to water)

Drier Soils, well-drained

Red Pine and Oak

- Hard, ‘waxy’ leaf (Thick leaf cuticle), limited water loss from evaporation

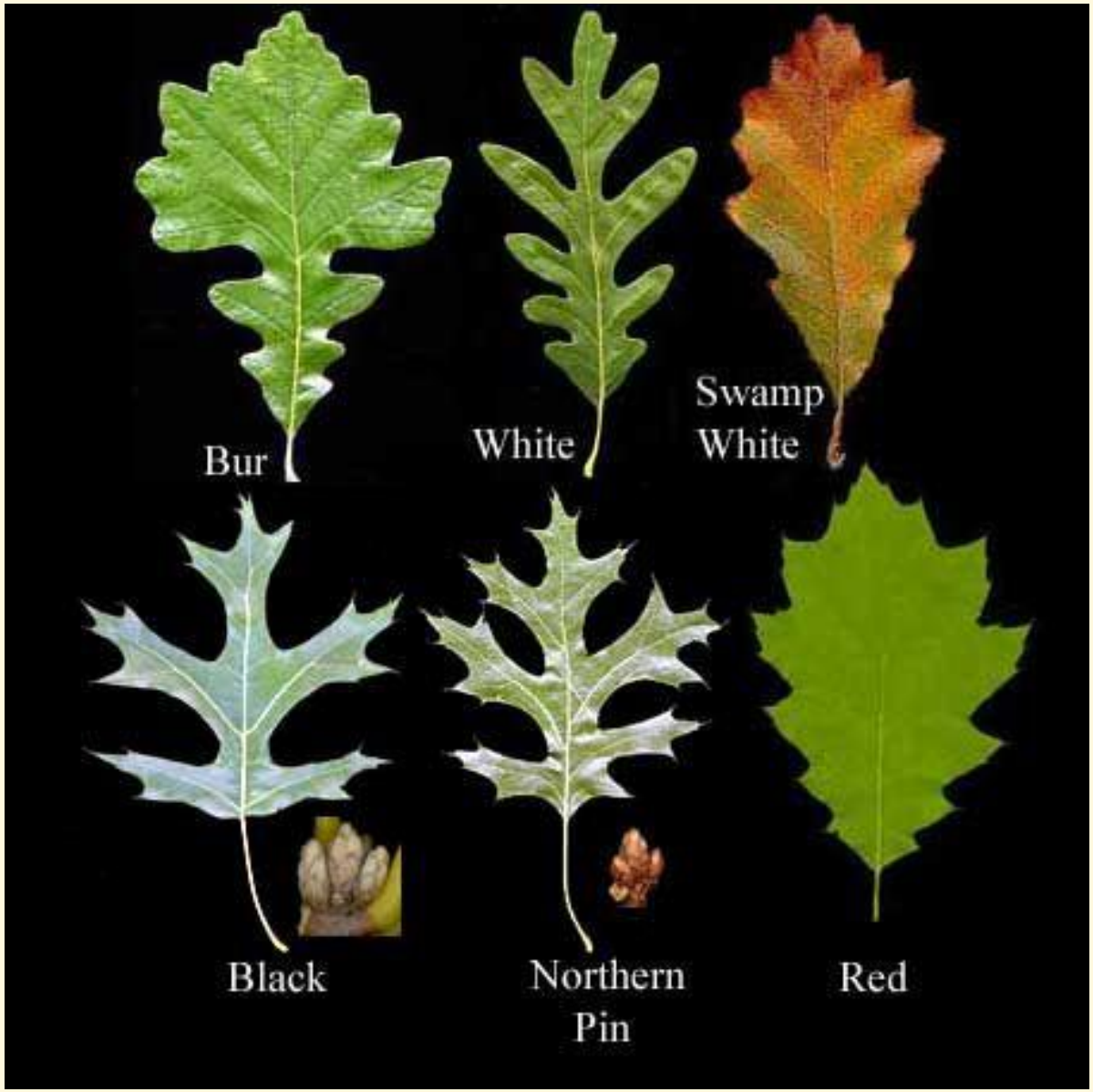
Wetter Soils, more poorly drained*

Sugar Maple and Ash

- Softer ‘smooth’ (less leaf cuticle), higher water loss from evaporation

Plant Adaptations: Oaks (Quercus spp.)

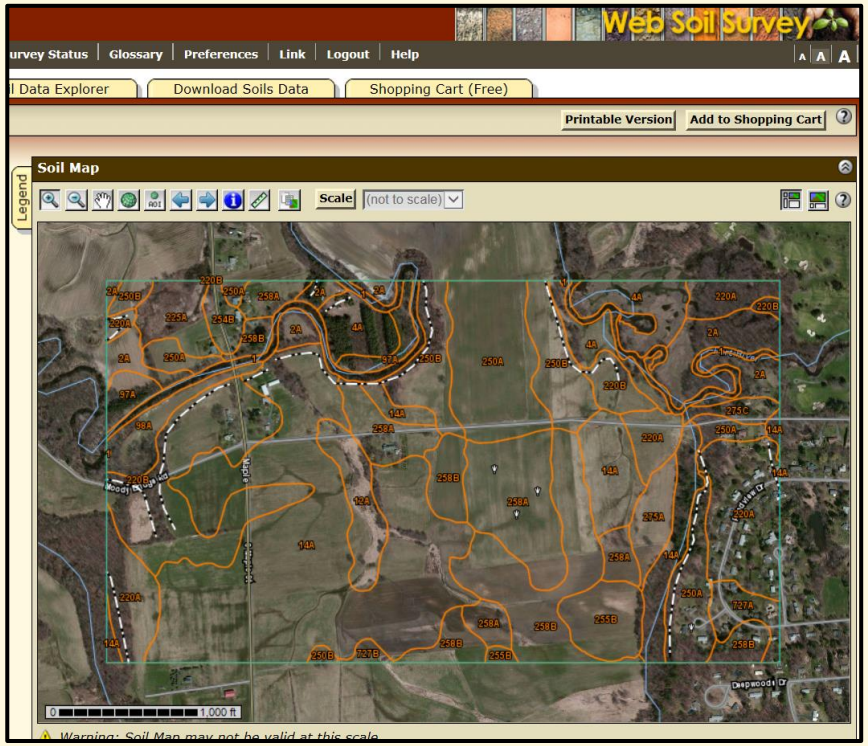
Wetter Soils, more poorly drained*



Drier Soils, well-drained

How to Create, Use, and Interpret Soil Maps: Web Soil Survey Exercise

- https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Example: Tower Hill Botanic Garden (11 French Dr, Boylston, MA 01505)



Implications for Tree Planting?

- Soil map and Ecological Site Description–only a place to start
- A tool to think about patterns on the landscape and narrow down options

BUT…

- Most yards are on a smaller scale than soil maps
  - Drainage pattern, microclimate, shade, soil quality vary
- You can CHANGE your soil or the growing conditions for your plant to an extent
  - *Planting success often comes down to soil moisture holding capacity and watering*

Dynamic Properties of Soil

Dynamic: properties that can be changed over a relatively short time period.

- pH (acidity)
- Macro and micronutrients
- Bulk Density (and porosity)
- Organic Matter (carbon)
- Cation Exchange Capacity
- Soil Structure
- **Soil Health**

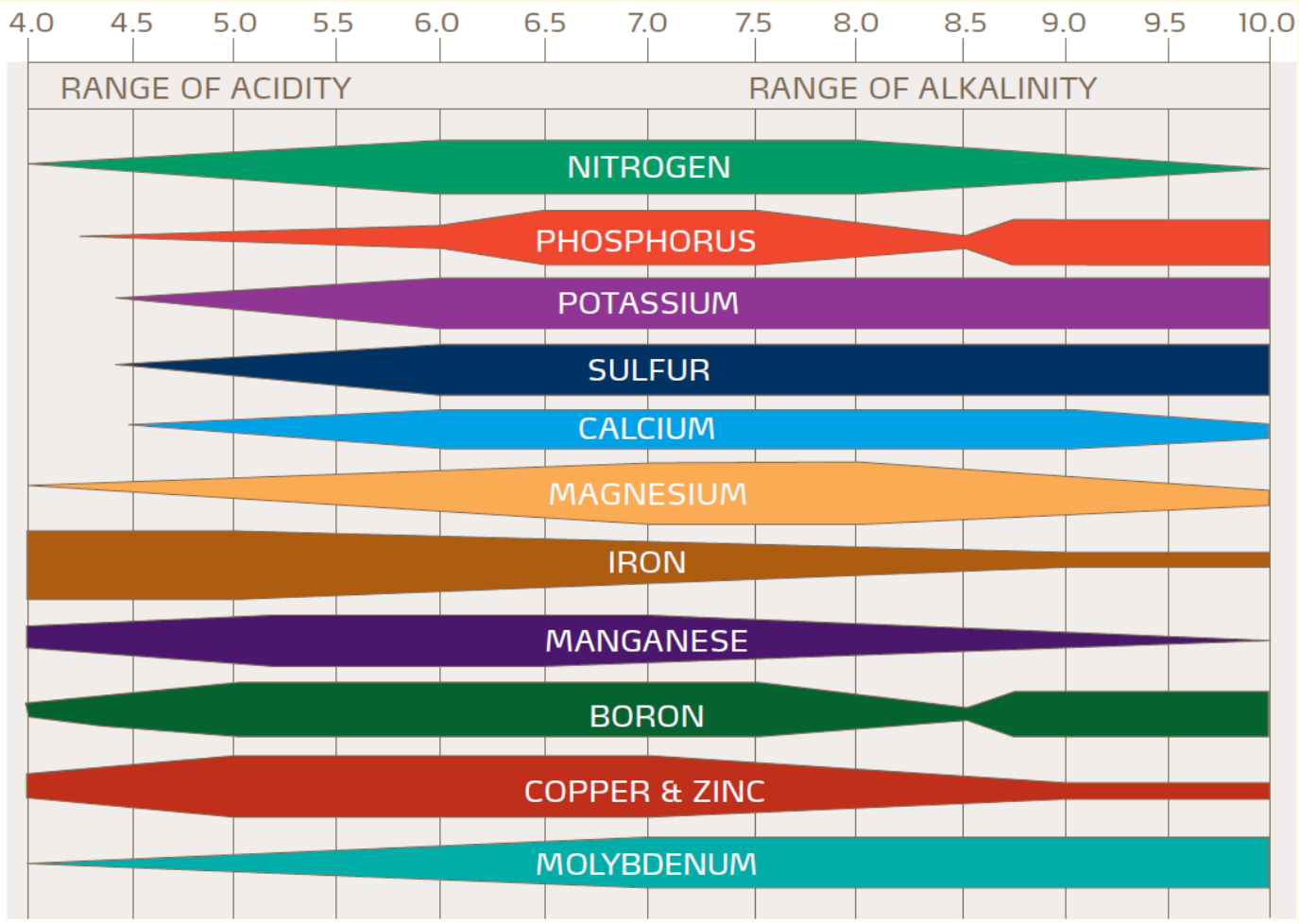
Dynamic Properties of Soil: pH

- Measure of the acidity or alkalinity of soils (H+ ions in soil solution
  - <7 – acidic
  - 7 – neutral
  - >7 – alkaline
- New England soils **tend** to be 4-7
  - This is easy to test, and easy to alter!
- Most deciduous trees and shrubs do best within a soil pH range of 5.5 to 6.8. Red maples, oaks, junipers and most conifers (pines, firs and hemlocks) prefer a pH of 5.5 to 6.0. Some conifers can tolerate higher levels; for example, yews and arborvitae prefer a pH of 6.0 to 7.0.

extension.unh.edu

https://stormwater.pca.state.mn.us/index.php/Tree_species_list_-_pH_and_moisture_ranges

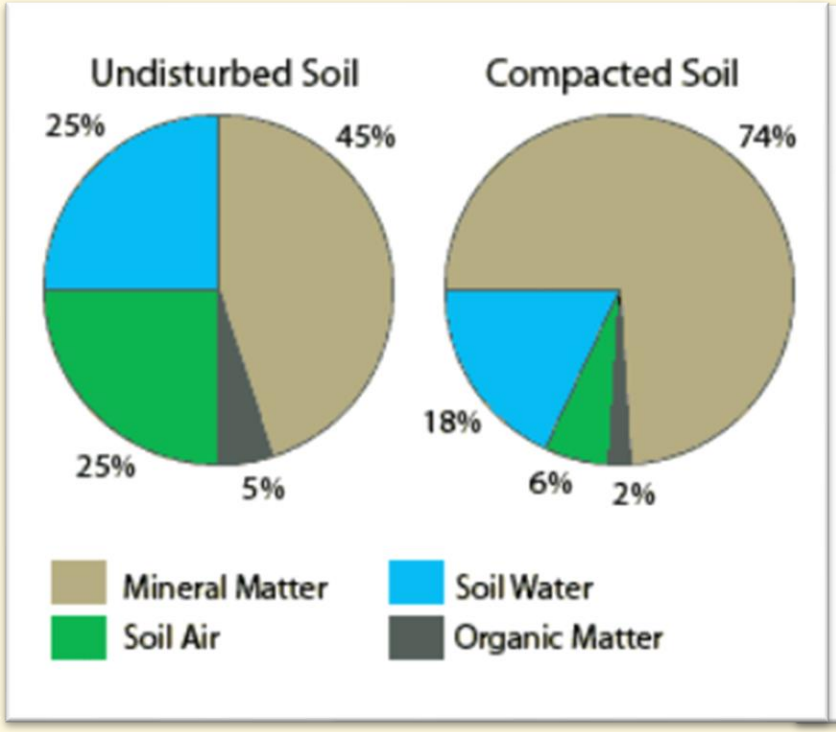
Effect of soil pH on nutrient availability

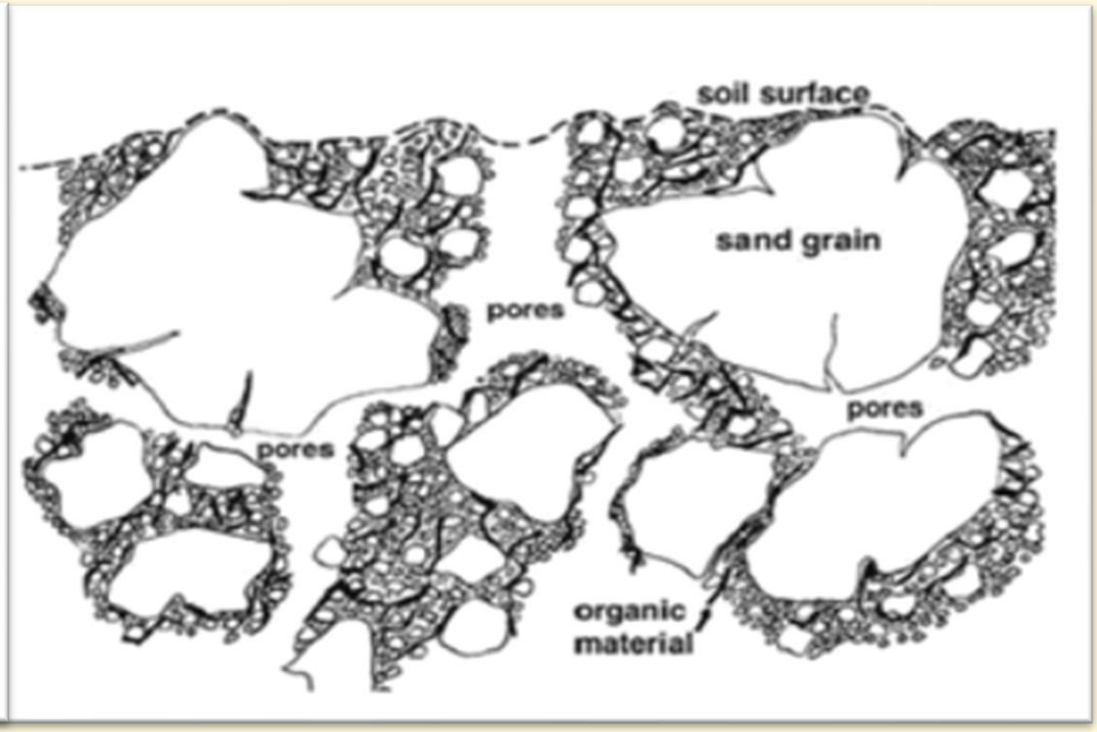


Dynamic Properties: Soil Nutrients

- Macronutrients
  - Nitrogen (especially dynamic)
  - Phosphorus
  - Potassium
  - Calcium
  - Sulfur
  - Magnesium
- Micronutrients
  - Iron
  - Zinc
  - Manganese
  - Boron
  - Copper

Bulk Density (The mass of dry soil per unit volume) and Compaction

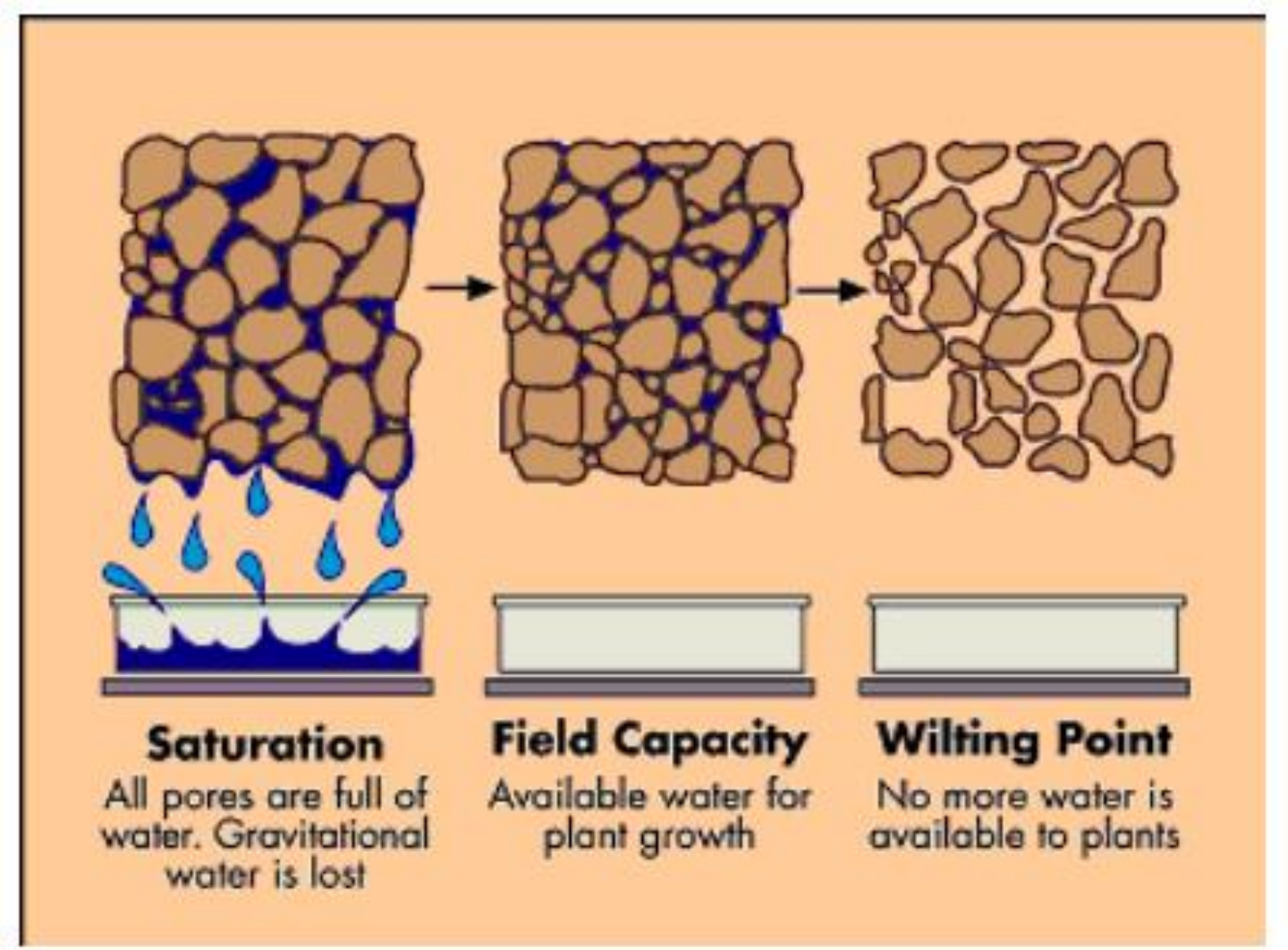




Bulk Density and Permeability

Permeability Measurements of Sampled Layers within 20 " of Soil Surface		
Site	Bulk Density (g/cm3)	Permeability (in/hr)
Woods	1.42	15
Pasture	1.47	9.9
Single House	1.67	7.1
Subdivision Lawn (1)	1.79	0.14
Garage Lawn	1.82	0.13
Cleared Woods	1.83	0.13
Subdivision Lawn (2)	2.03	0.03
Athletic field	1.95	0.01
Concrete	2.4	0.00

Available Water Holding Capacity



Dynamic Properties: Organic Matter

- 2-4% in New England soils
  - Tends toward the lower end in conventional agriculture, higher in forest, higher in pasture, and highest in wetlands
- Aids in soil aggregation
  - Resists compaction
  - Promotes soil aeration, drainage, and proper moisture retention
- Essential for nutrient cycling and microbial activity

Paradigm Shift

- Treating the soil like an ecosystem instead of a purely physical body

"Feed the subterranean herd"

Relative Amount of Microbes in Handful of Soil

Bacteria	**up to 50 billion**

Actinomycetes	**up to 2 billion**

Fungus	**up to 100 million (many miles)**

Protozoa	**up to 50 million**

Nematodes	**10,000**

Arthropods	**1000**

Earthworm	**0 to 2**

Rhizosphere

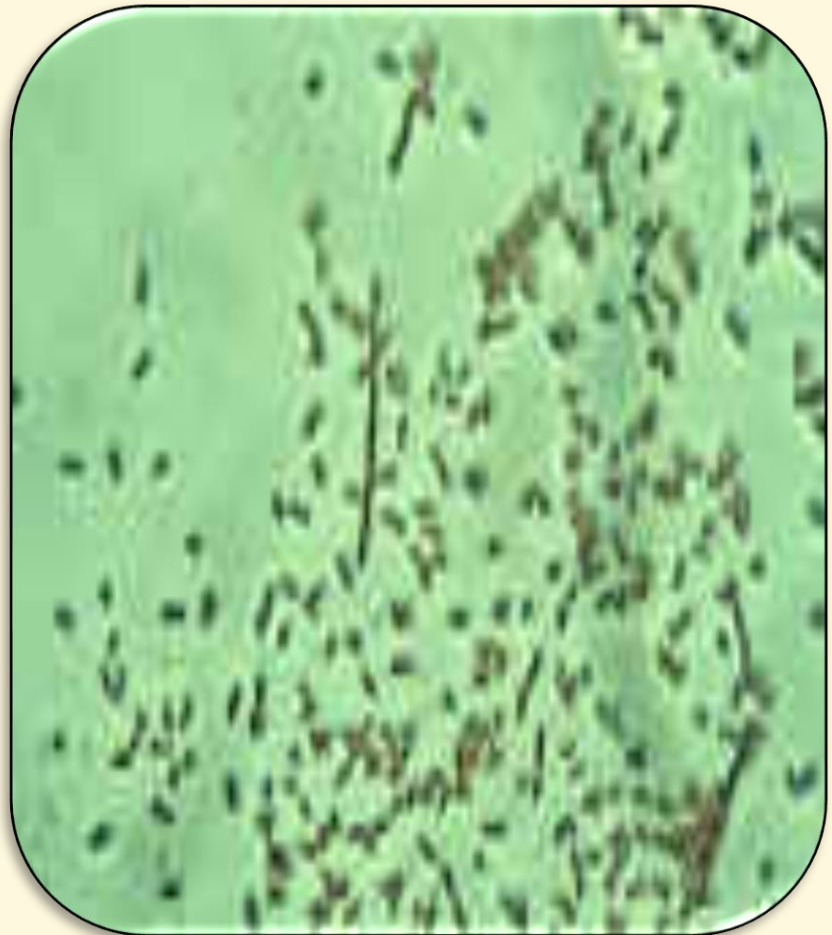
- Narrow region of soil directly around roots
- Living roots release many types of organic materials
- These compounds attract Bacteria that feed on the proteins & sugars

Rhizosphere

- Number of bacteria is from 5 to 2000 times larger than in the regular soil.
- Protozoa and Nematodes feed on the bacteria
- Nutrient cycling & disease suppression start right here

Bacteria

- Decomposition of OM
- Nutrient cycling
- Nitrogen fixation



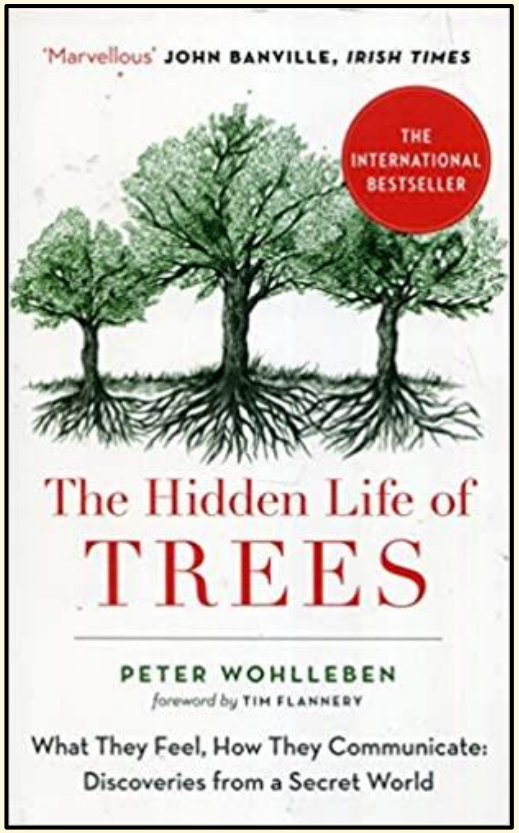
- Nitrification
- Denitrification
- Disease Suppression
- Breakdown of hard to decompose compounds

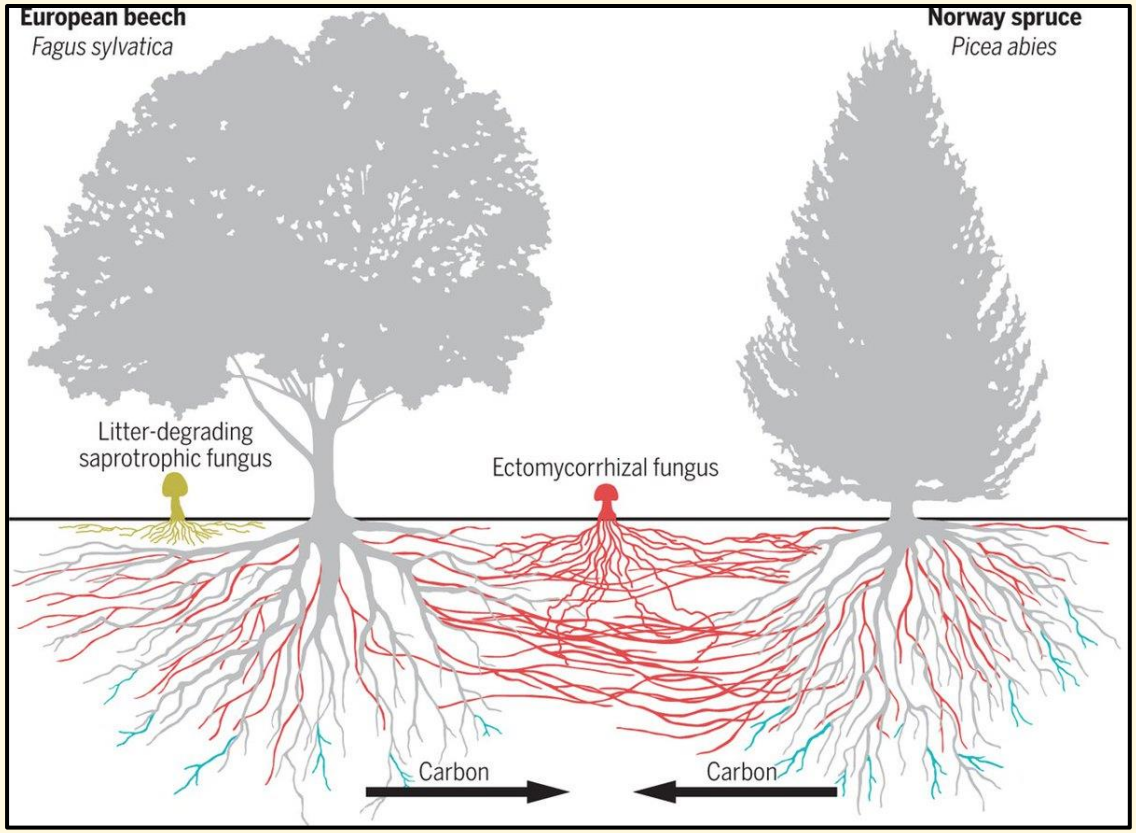
Fungi

- Decompose Organic Matter
- **Glomalin** secretion develops soil structure
    - Stable organic matter
- Extract nutrients
- Hold nutrients
- Many miles of hyphae in a teaspoon of soil!

Fungi

- Trees even use fungal hyphal networks to communicate via electrical and chemical signals!
- Warnings of impending insect damage, so neighbors can “arm” themselves with anti-herbivore chemicals like (tannins in oaks)



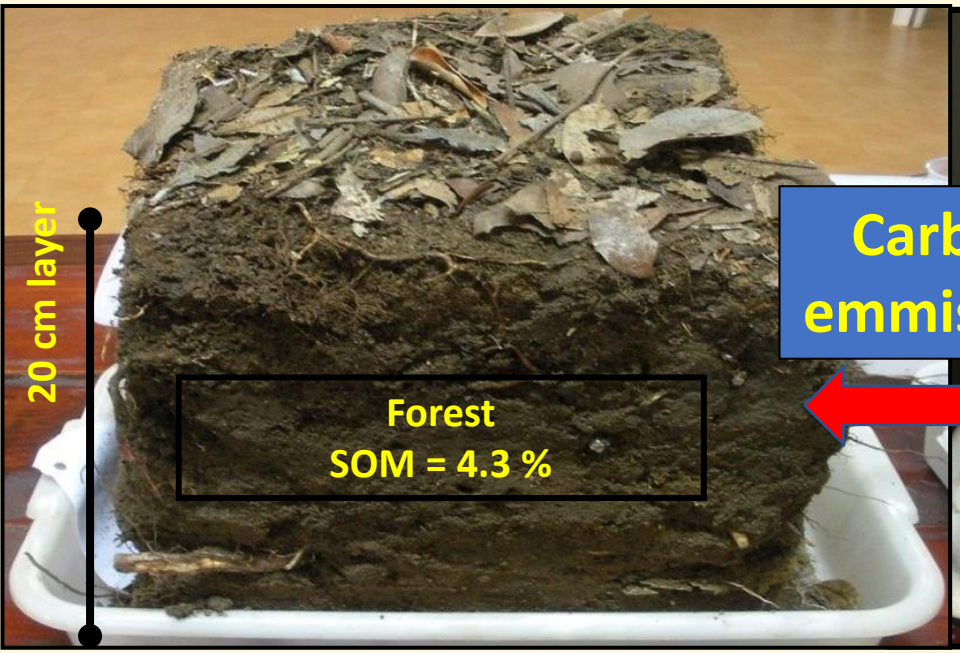


What is Soil Health?

The continued capacity of the <u>soil to function</u> as a vital living ecosystem that sustains plants, animals, and humans.

Same Soils: Dynamic Soil Properties Changed!

62.8% loss of SOM after 17 yr intensive tillage



Carbon emmisions

Forestry and Soil Health

- Prevent Soil Compaction
  - Minimize skid trails and equipment traffic areas
  - Don’t operate/harvest when the soil is wet/saturated
  - Restock quickly after a heavy cut, cut less often
- Give back to the soil
  - Leave debris on the site: the more debris left on the site the more organic matter and nutrients will recycle into the soil
- Prevent Erosion
  - Control for the flow of water, especially skid trails on slopes
  - Stabilize disturbed areas with vegetation/debris
  - Put in diversions to slow down runoff

***Use a forester who is conscious and an operator who is responsible.

Forest are good for the soil! They regenerate the soil naturally over time.

Understanding dynamic properties: Soil Testing

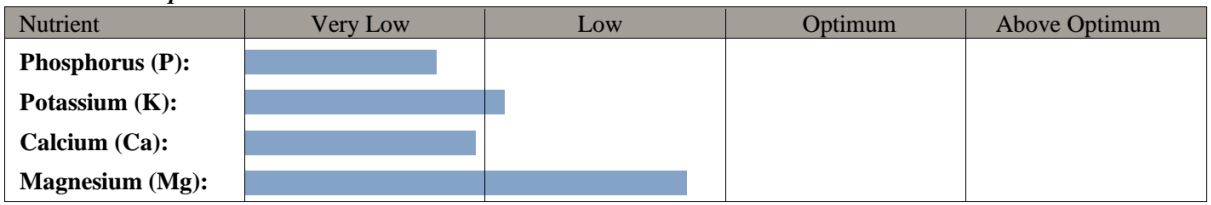
Results

Analysis	*Value Found*	*Optimum Range*
Soil pH (1:1, H2O)	6.4	
Modified Morgan extractable, ppm		
Macronutrients		
Phosphorus (P)	1.6	4-14
Potassium (K)	55	100-160
Calcium (Ca)	478	1000-1500
Magnesium (Mg)	46	50-120
Sulfur (S)	15.9	>10
*Micronutrients **		
Boron	0.1	0.1-0.5
Manganese (Mn)	1.7	1.1-6.3
Zinc (Zn)	1.3	1.0-7.6
Copper (Cu)	0.3	0.3-0.6
Iron (Fe)	16.9	2.7-9.4
Aluminum (Al)	107	<75
Lead (Pb)	0.0	<22

Analysis	*Value Found*	*Optimum Range*
Cation Exch. Capacity, meq/100g	5.3	
Exch. Acidity, meq/100g	2.4	
Base Saturation, %		
Calcium Base Saturation	45	50-80
Magnesium Base Saturation	7	10-30
Potassium Base Saturation	3	2.0-7.0
Scoop Density, g/cc	0.99	

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

Soil Test Interpretation



Other tests and procedures can assess compaction, soil aggregation, soil bacteria content, etc.

What kind of tree should I plant?

Apply this knowledge for successful tree planting

- Choosing the right tree for your soils
  - Know your **inherent** soil properties, especially related to drainage/soil moisture
    - Well drained or poorly drained?
    - How deep to the densic material?
    - Where is it on the landscape?
  - Look around or use ecological site description to see what forest community would be there naturally and mimic that

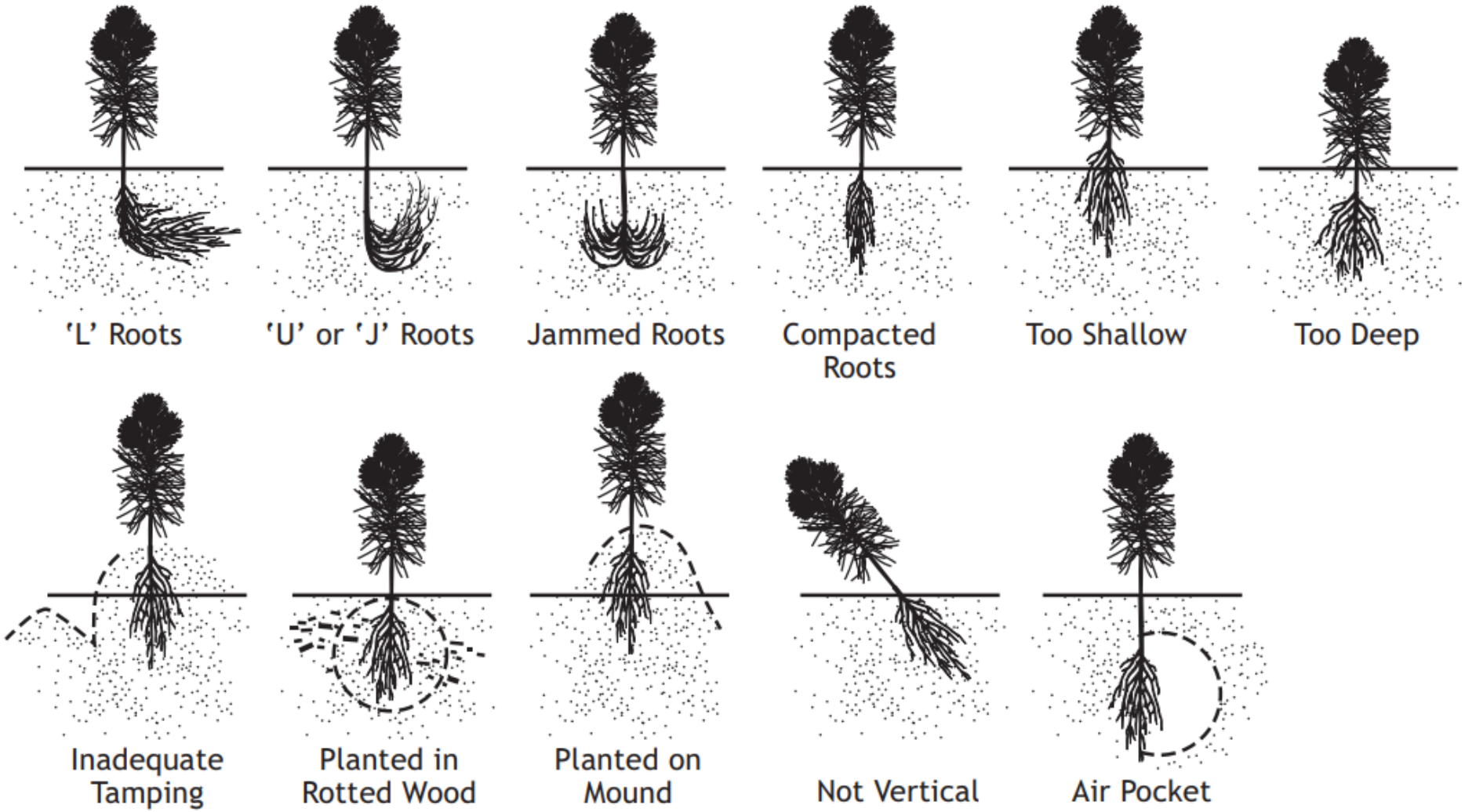
Apply this knowledge for successful tree planting

- Changing your soils for the right tree
  - Get a soil test and/or dig a soil pit to assess **dynamic** properties of soil
  - Know the needs of the species of interest and amend the soil:
    - Raise water and nutrient holding capacity, and improve soil life/bulk density by adding organic matter/peat
    - Raise pH with lime or wood ash, lower with elemental sulfur (not likely needed)
    - Get rid of compacted layer by tilling (not as applicable for tree planting)
    - Use organic amendments if nutrients are poor for the tree (usually no need to fertilize native tree species).

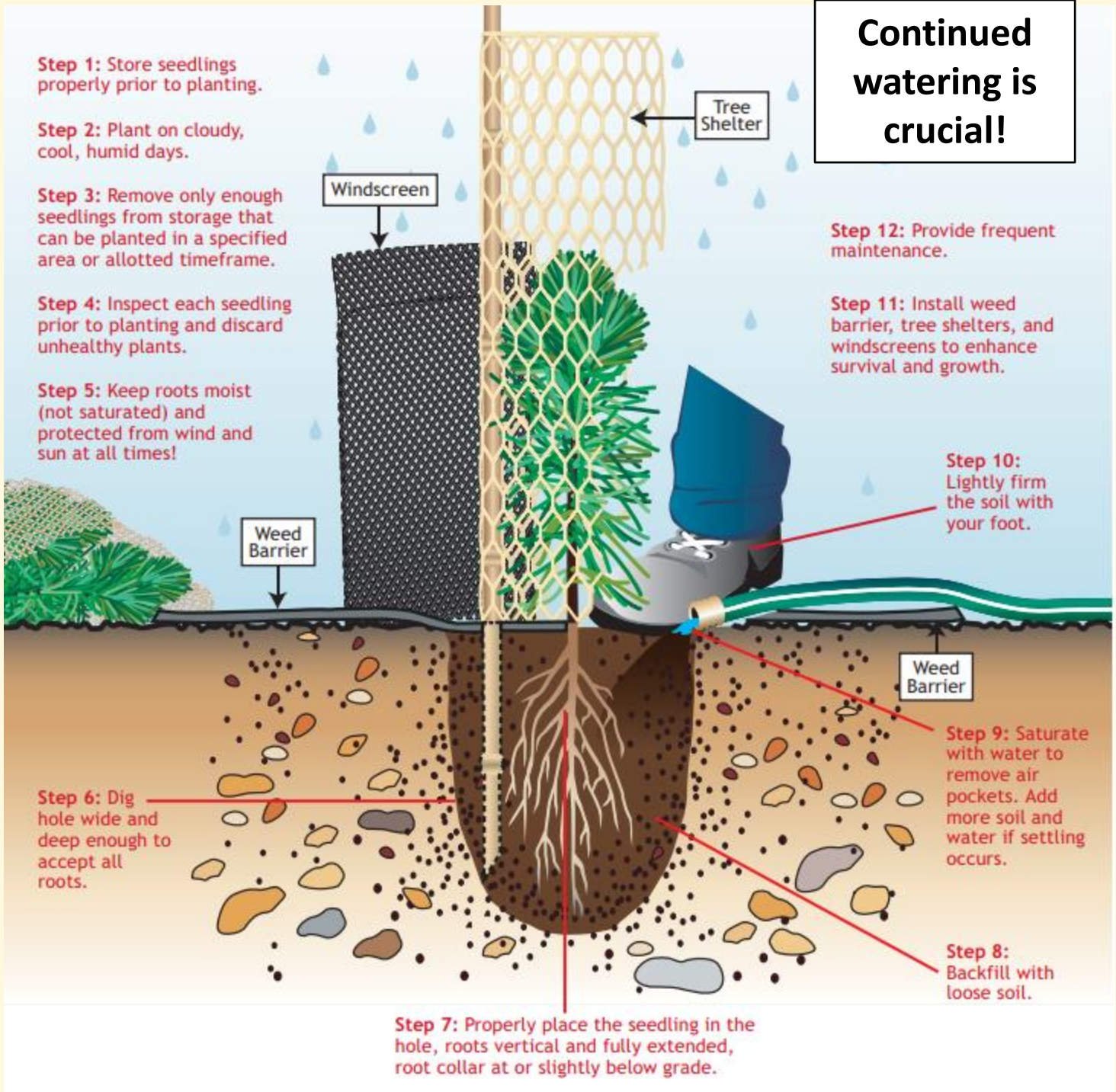
Taking care of your trees

A lot comes down to planting

Figure 1. How NOT to Plant A Bareroot Seedling



https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/mtpmcar5149.pdf


Continued watering is crucial!
Step 1: Store seedlings properly prior to planting.
Step 2: Plant on cloudy, cool, humid days.
Step 3: Remove only enough seedlings from storage that can be planted in a specified area or allotted timeframe.
Step 4: Inspect each seedling prior to planting and discard unhealthy plants.
Step 5: Keep roots moist (not saturated) and protected from wind and sun at all times!
Windscreen
Tree Shelter
Step 12: Provide frequent maintenance.
Step 11: Install weed barrier, tree shelters, and windscreens to enhance survival and growth.
Step 10: Lightly firm the soil with your foot.
Weed Barrier
Weed Barrier
Step 9: Saturate with water to remove air pockets. Add more soil and water if settling occurs.
Step 6: Dig hole wide and deep enough to accept all roots.
Step 8: Backfill with loose soil.
Step 7: Properly place the seedling in the hole, roots vertical and fully extended, root collar at or slightly below grade.

Thank you!

Email: Joel.Betts@usda.gov
Phone: 508-829-4477 ext. 7023

Land Trusts Connect Landowners to Resources to Help Achieve their Goals

If you have more questions, please reach out

Anna Wilkins, awilkins@northcountylandtrust.org

Jassy Bratko, jbratko@northcountlandtrust.org

Office: 978-466-3900

Website: NorthCountyLandTrust.org

Outside of our region? Find your local Land Trust at Massland.org

Resources for Forest Owners:

- Masswoods.org -a great starting point for summary information on the following programs:
  - MassWildlife Habitat Management Grant Program
  - Chapter 61 Current Use Tax Programs
  - Forest Stewardship Program & Green Certification
  - Foresters for the Birds
  - Environmental Quality Incentives Program (EQIP)
  - Landowner Incentive Program (LIP)
  - Tax Tips for Forest Landowners

New England Forestry Foundation

- Newenglandforestry.org Through the application of our core expertise in conserving forestland and advancing Exemplary Forestry, New England Forestry Foundation (NEFF) helps the people of New England to sustain their way of life, protect forest wildlife habitat and ecosystem services, and mitigate and adapt to climate change.
  - **Find a Land Trust in Your Community**
  - **Conservation FAQs**
  - **Forestry FAQs**
  - **My Land Plan**
  - **7 Steps to Successful Estate Planning**
  - **Common Elements of a Harvest Contract**
  - **How a Forester Can Help and How to Choose A Forester**
  - **Case Study – A Fair Price for your Timber**
  - **A Landowner's Guide to Critical Decisions about Land Management and Protection**
  - **What is High-Grading**
  - **NRCS Cost-Share Programs**
  - **American Tree Farm System**
  - **Northern Woodlands**
  - **Asian Long-Horned Beetle**

State Resources

- Massachusetts Division of Fisheries and Wildlife
  - Massachusetts premier website on wildlife, hunting, fishing. Go to this site to learn about the 100,000 acre wildlife management area system.
- MassGIS Online Mapping
  - This site contains an interactive mapping service that includes aerial photographs of the state. Also contains links to MassGIS, which has an extensive repository of GIS data layers for Massachusetts.
- Massachusetts Natural Heritage and Endangered Species Program
  - Explore the biodiversity of the Commonwealth. This site includes extensive information on the state's biodiversity including threatened and endangered species, unique natural communities, rare plants and animals, vernal pools and maps of locations of high biological conservation value. Information on Forestry and Rare Species , NHESP Review of Forest Cutting Plans , and Conservation Management Practices is available at this web site.

NRCS & Technical Service Providers

Natural Resources Conservation Service-

provides one on one technical advice to landowners, and funding programs for conservation including:

Your first Forest Management Plan,

Practices to improve Forest Health and Habitats

EQIP Environmental Quality Incentive Program, CSP Conservation Stewardship Program

Farmers, ranchers, and private forest landowners often use TSPs to address specific natural resource goals such as:

- developing nutrient management plans;
- *developing sustainable forestry plans;*
- developing grazing management plans;
- increasing irrigation efficiency; and
- transitioning from traditional agriculture to organic.

NRCS Field offices

- https://www.nrcs.usda.gov/wps/portal/nrcs/main/ma/contact/local/

NRCS Massachusetts field offices

Greenfield Field Office
Serving Franklin County
55 Federal Street, Suite 290, Greenfield, MA 01301
413-772-0384 ext. 3

Hadley Field Office
Serving Hampden and Hampshire counties
195 Russell Street, Suite B6, Hadley, MA 01035
413-585-1000 ext. 3

Holden Field Office
Serving Worcester County
52 Boyden Road, Suite 100, Holden, MA 01520
508-829-4477 ext. 3

Pittsfield Field Office
Serving Berkshire County
78 Center St., Suite 206, Pittsfield, MA 01201
413-443-1776 ext. 3

Westford Field Office
Serving Essex, Middlesex and Suffolk counties
319 Littleton Road, Suite 205, Westford, MA 01886
978-692-1904 ext. 3

Wareham Field Office
Serving Bristol, Norfolk and Plymouth counties
8 Thatcher Lane, Suite 2, Wareham, MA 02571
508-295-5151 ext. 3

West Yarmouth Field Office
Serving Barnstable, Dukes and Nantucket counties
303 Main St, Route 28, West Yarmouth, MA 02673-4661
508-771-6476 or 6518 ext. 3