Introduction to Soils

Image: American Organic Energy

SOIL IS AN ECOSYSTEM

Soil is a mix of minerals, organic matter, *living organisms*, and space filled with air & water

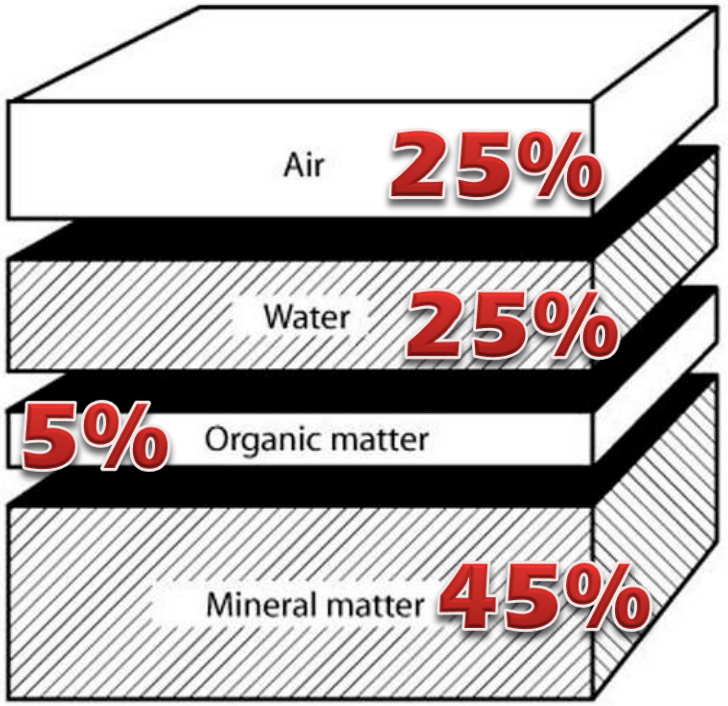
<u>Evaluating the conditions of the soil is critical to</u>

- **PLANT HEALTH**
- **IRRIGATON PRACTICES**
- **LANDSCAPE MANAGEMENT OVERALL**

Dead soil is dirt.

The dirt (non-living) parts of soil …

- **Mineral particles**
  - from rock
- **Organic matter**
  - from living things
  - Typically 3-8%
- **Water**
- **Air**



Ideal ratio for plant growth

Why is healthy soil important?

- Soil is the foundation of plant health
- Properties of soil:
  - Physical (texture and structure)
  - Chemical (fertility)
  - Biological (beneficial soil life)

Physical Properties of Soil:
Texture and Structure

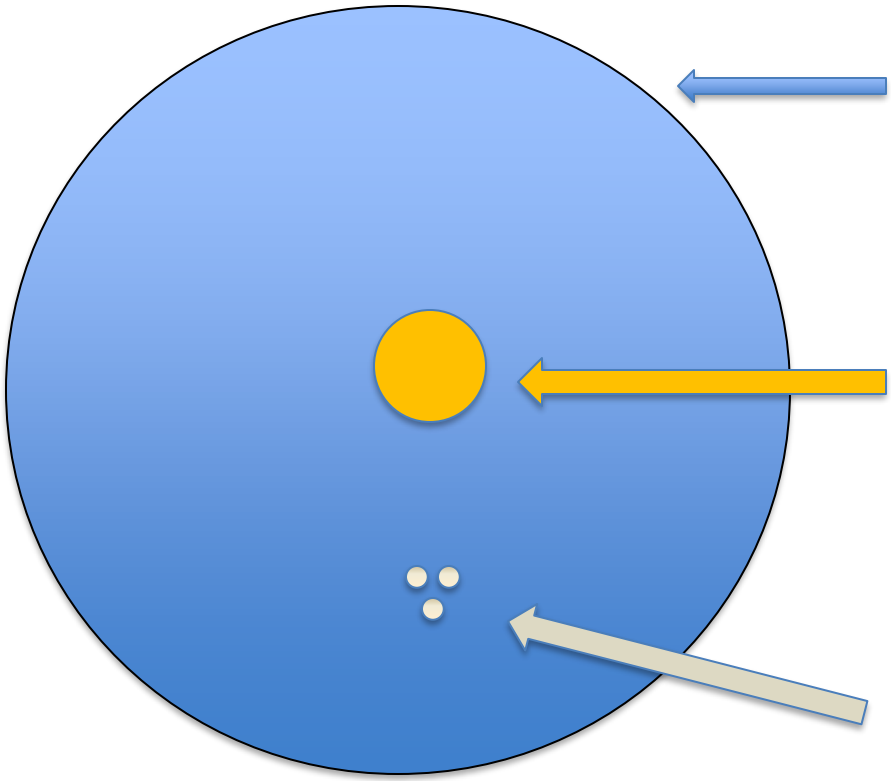
- **Unique properties of the soil**
- **Both have great effect on soil behavior:**
  - **Water holding capacity**
  - **Nutrient holding and supply (releasing)**
    - **Nutrient leaching (loss)**
  - **Drainage**

TEXTURE: mineral particle size

What is the % of individual particle sizes?

- **SAND, SILT and CLAY**
  - **Describe the size of the mineral particle**
  - **May be described as combinations of 'sandy,' 'silty', 'clayey', or 'loamy'**
  - **Most soils are a combo of these three**
  - **Infinite combinations of soil particle size & shapes**
  - **Loam: *a generalized ideal combination of particle sizes*: roughly 40% sand; 40% silt; 20% clay**

Relative Size Comparison of Soil Particles



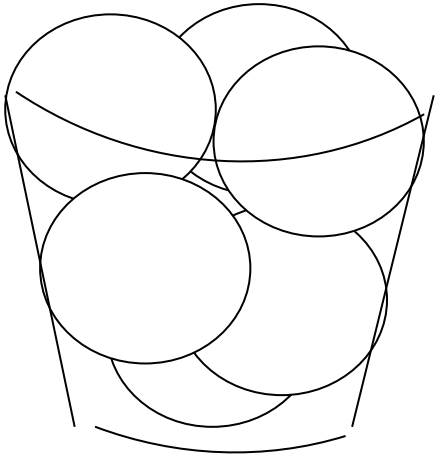
Fine sand
feels gritty - 0.5 – 2 mm

Silt
feels floury - 0.002 – 0.5 mm

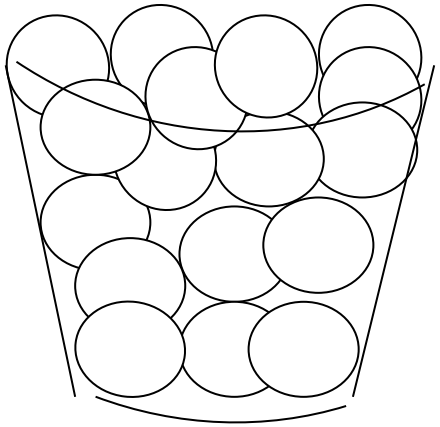
Clay
feels sticky and
smooth - <.002 mm

Soil Particle Size

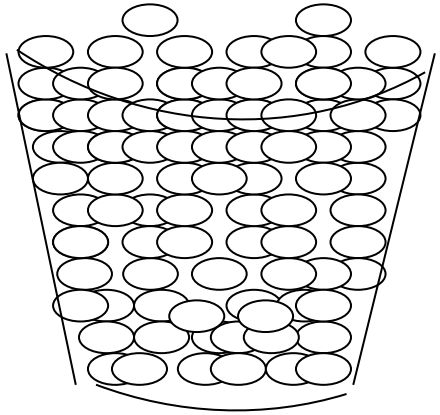
Sand: Basketballs/ Watermelon



Silt: Softballs/ Grapefruit

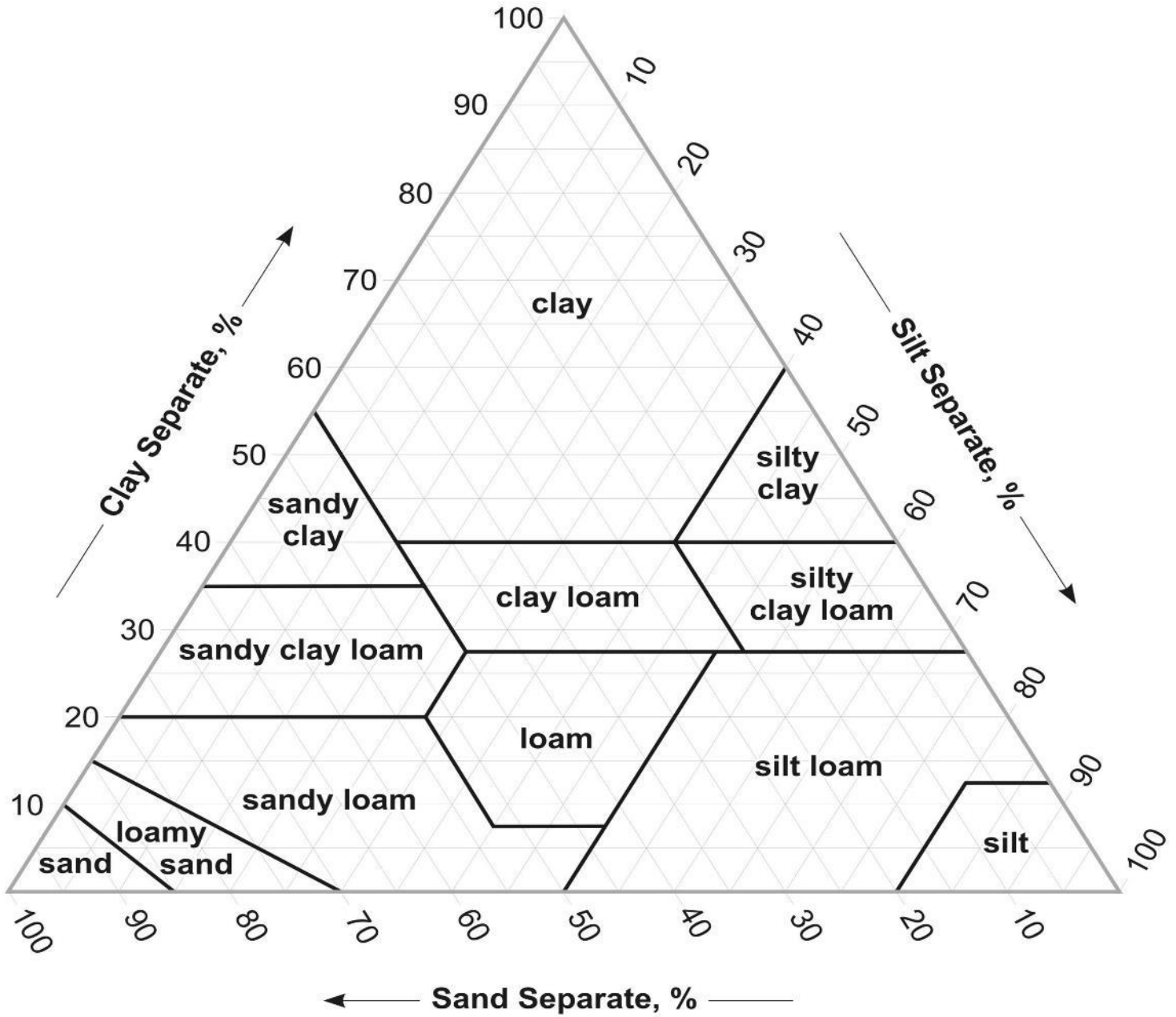


Clay: Golf balls/ Eggs



- **Which soil holds more water?**
  - **Clay: pore size is so small it holds tight to water**
- **Which soil has larger air spaces?**
  - **Sand: large spaces allow water to drain freely**

Soil Textural Triangle



Jar Method

- 1 c. soil in jar
- Add water to near top
- Shake and let sit for at least 24 hours
- Measure widths of solid layers

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Soil texture percent calculation

% Clay= (depth of top layer ÷ depth of all soil) x 100

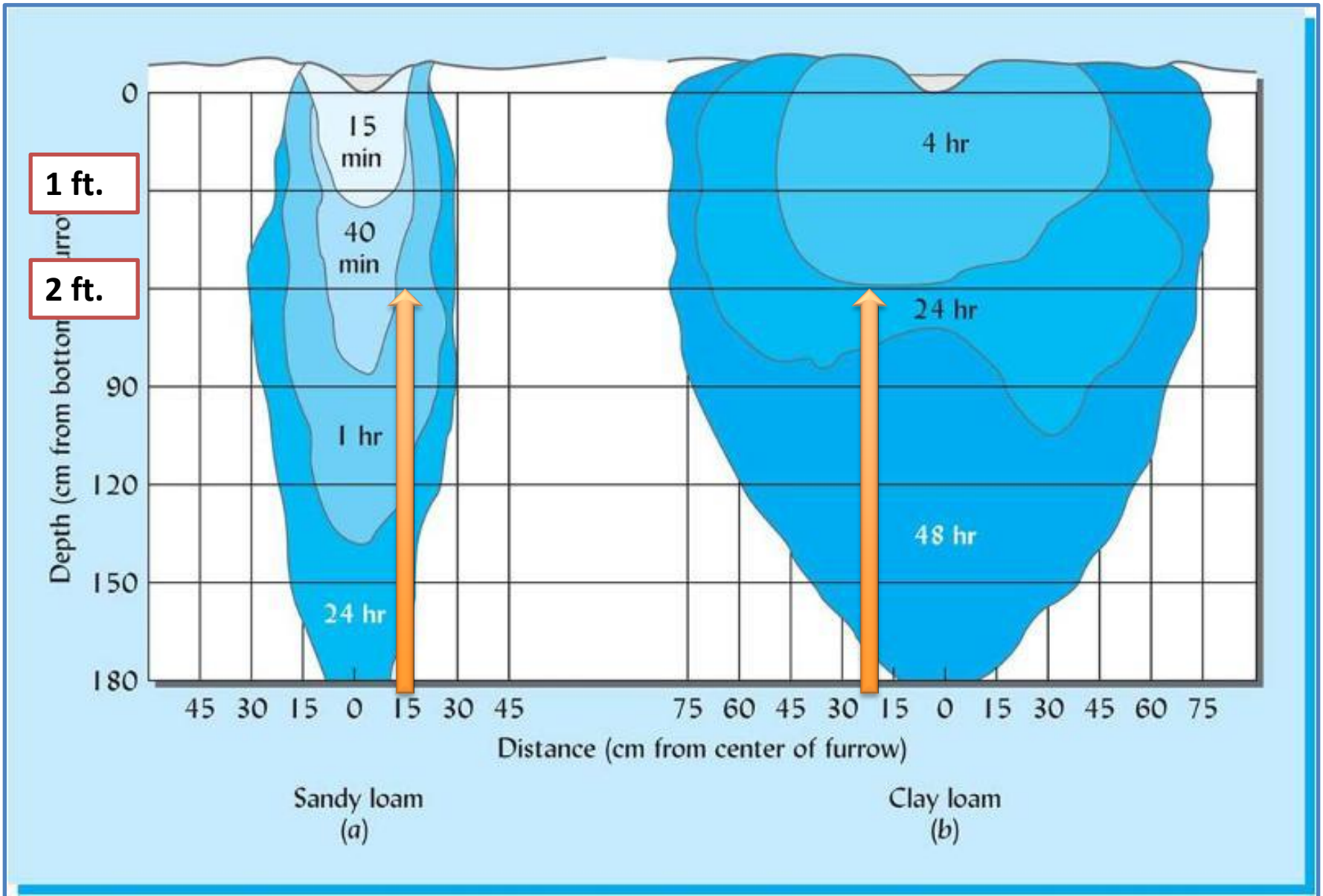
% Silt= (depth of middle layer ÷ depth of all) x 100

% Sand= (depth of bottom layer ÷ depth of all) x 100

Soil Texture & Irrigation

- Affects how you irrigate, and whether plants are stressed and pest susceptible

Time for water to infiltrate



Soil Texture & Irrigation

Can you irrigate properly without knowing soil texture?

NO: texture is fundamental to determines duration (how long) and frequency (how often) of irrigation scheduling

Soil Texture & Irrigation

- **How do you irrigate a plant in sandy soil?**
  - **Shorter, frequent watering will provide water to the roots but limits the amount lost to leaching (drainage) past the root zone.**
- **How do you irrigate a plant in clay soil?**
  - **Long, slow, infrequent watering or cycle-and-soak allows infiltration to root zone; allows dry-down to prevent flooding roots.**

Soil Texture & Irrigation

- What if you don't irrigate properly?
  - Plants are more likely to suffer from stress.
  - Over- and under-watering are both harmful. (Symptoms can look alike!)

Soil Texture & Irrigation

Examples:

- **What if you plant a water-loving plant in sandy soil that is often dry?**
  - **It will suffer from drought stress**

IT'S MUCH EASIER TO CHANGE YOUR PLANT SELECTION THAN TO CHANGE SOIL!

Soil Texture & Irrigation

What if you plant a low-water plant in a clay soil that is always wet?

- **The root crown will rot**
- **What will the foliage look like?**

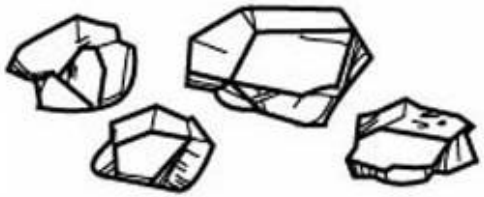
Physical Properties of Soil: STRUCTURE

- **How the soil binds together and breaks apart**
  - **the arrangement of particles into clumps called aggregates, which form distinctive shapes**
  - **The shapes in turn channel water and air, and can have a major impact on drainage, water retention, aeration, and other factors**
- **You can not easily change the soil *texture*, but you *can* change the *structure*.**

Structure classes

Single grain

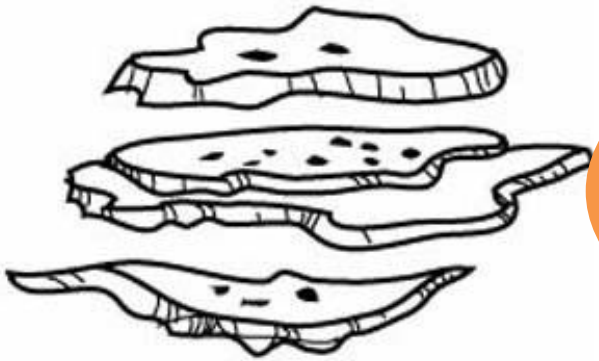
Blocky



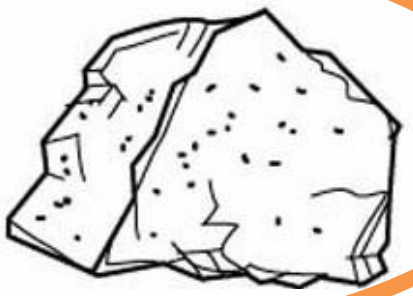
Granular

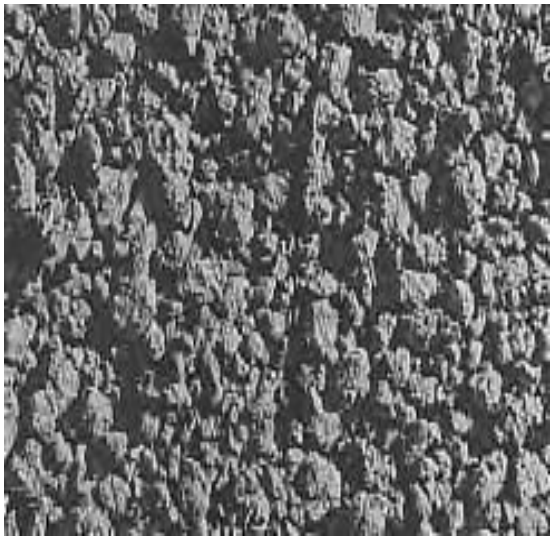
Prismatic

Platy



Massive

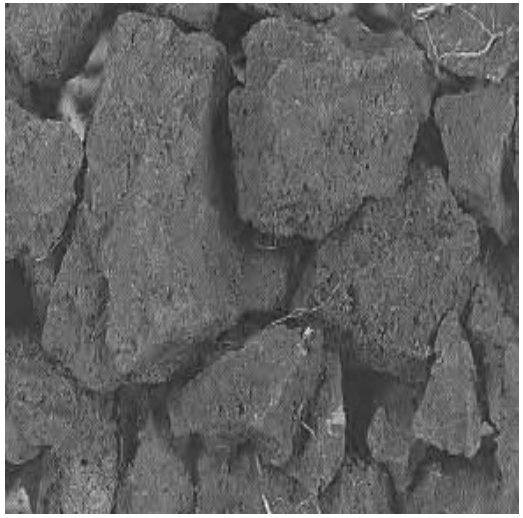




Granular

Columnar

Prismatic



Blocky

Platy

“Single Grain” and “Massive” are both groups that almost have no structure. Almost anything else is good. Fine structures, such as granular and platy, are often touted as the most desirable.

Soil Structure

- **Good structure allows for:**
  - **Best root growth**
  - **Gas exchange (helps the soil breathe, esp. with rain or irrigation**
  - **Water holding capacity**
  - **Adequate drainage**
- ***Soil microorganisms, worms, and fungi* help build and maintain good structure**

Building good soil structure

- **Build soil microbe populations**
  - feed them organic matter (CARBON)
  - compost, mulch
  - No over-watering
- **Prevent compaction**

How to Ruin Soil Structure

- Eliminate organic matter
  - Apply quick-release synthetic fertilizers
  - Over-till
- Apply too many pesticides
- Allow compaction

Compaction: crushing pores

CAUSES

- Cultivating moist soil
- Running equipment (or feet) over moist soil
- Running mowers repeatedly in the same pattern
- Parking cars under trees when soil is soft
- Developers scraping lots prior to building

PROBLEMS

- Oxygen eliminated from root zone
- Water can’t soak in
- Beneficial micro-organisms die
- Roots have trouble moving down

Effects of Compaction on Plants

- **Shallow roots**
  - Lack of drought resilience
  - Poor structural stability
  - Mower damage to roots
- **Stunted growth**
- **Poor leaf color**

Natural Soil ‘horizons’

‘O’ Horizon: Organic matter

‘A’ Horizon:
topsoil, root activity

‘B’ Horizon: subsoil
transition zone

‘C’ Horizon:
Rock / fragments, clay bed, or other parent material

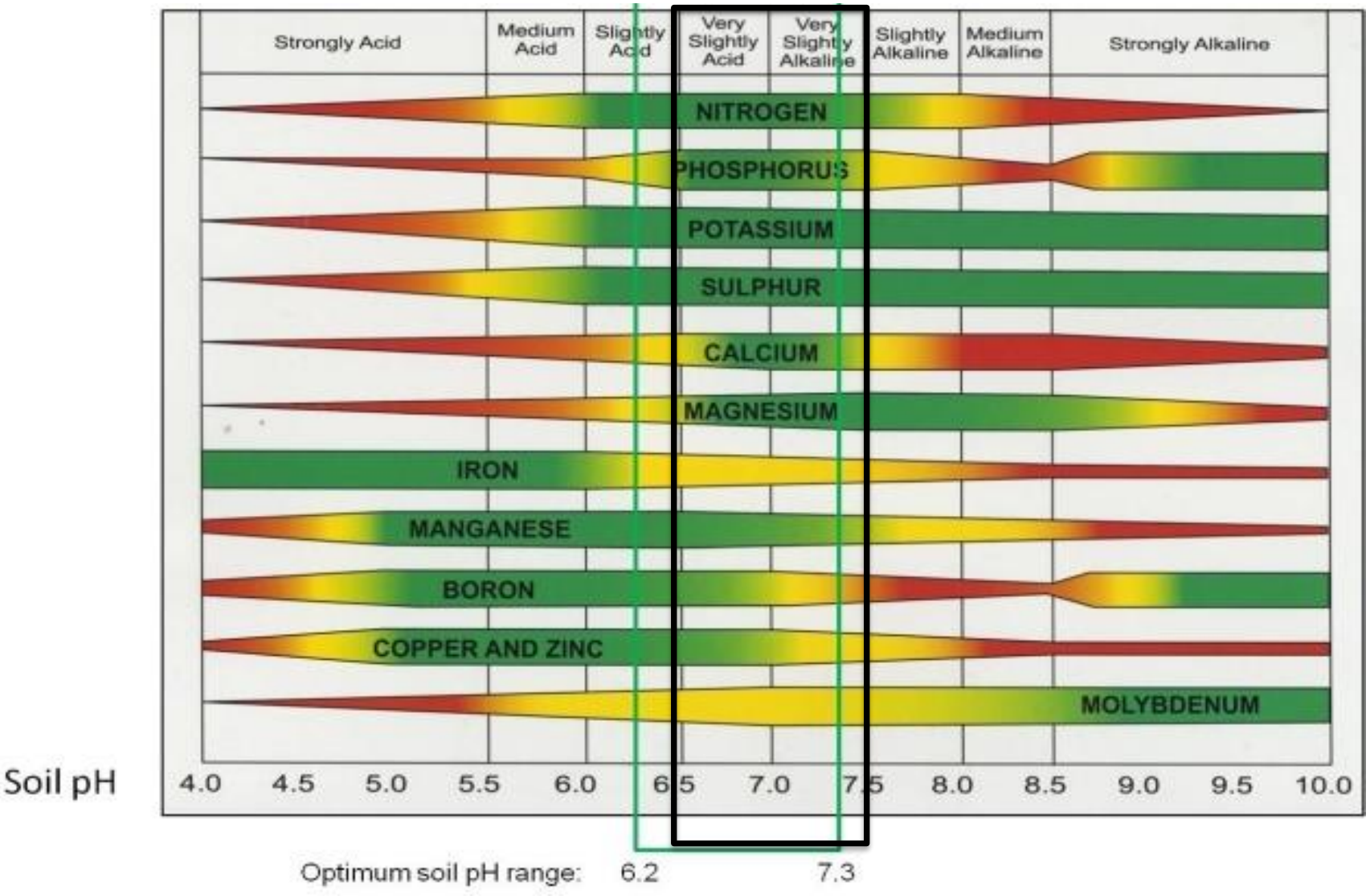
Root Zone

- Why is the top darker?
  - Organic matter
- Where does organic matter come from?
  - Plants die and decompose into the soil
- Why is it dark only down so far?
  - Active root depth

Soil Chemical Properties – pH

- Measure of how ***acidic*** or ***alkaline***
  - on a practical scale of 4-10
  - Low pH is acidic (4-6)
  - High pH is alkaline (8-10)
  - Neutral is 7
- Most plants prefer pH ~ 6.2-7.3

Why pH matters: nutrient uptake



Some plants prefer low pH

Examples:

- **Camellias**
- **Azaleas**
- **Gardenias**
- **Blueberries**

Symptom of high pH

- **Pale leaves**
- **Pale between veins**

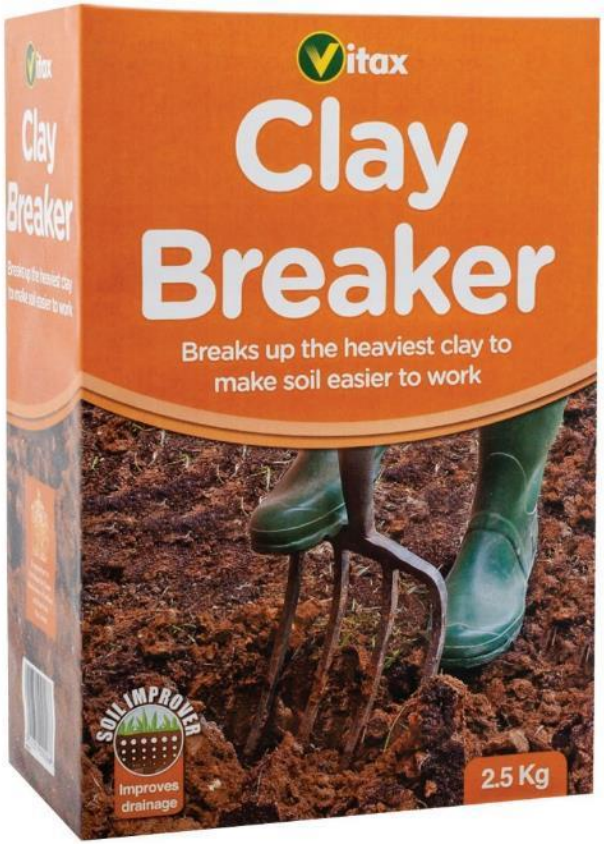
To LOWER pH - Add soil Sulfur

Pounds of Sulfur/100 ft^2 for loam. Reduce by 1/3 for sandy; Increase by ½ for clay
NOTE: This isn't permanent. Sulfur will have to be added every few years.

Present pH	DESIRED pH				
	6.5	**6.0**	**5.5**	**5.0**	**4.5**
8.0	3	4	5	6	7
7.5	2	3	4	5	6
7.0	1	2	3	4	5
6.5		1	2	3	4
6.0			1	2	3

When do you need gypsum?

- **Only necessary for high SODIUM soils**
- ***NOT* for all clay soils**



Soil-Water-Plant terms

- **Field Capacity**
- **Permanent Wilting Point**
- **Available Water**
- **Infiltration Rate**
- **Managed Allowable Depletion**

Field capacity

- The amount of water a soil holds after being saturated, and then allowed to drain for 1- 3 days.

Available Water (AW)

- **The amount of water present in the soil *that plant roots can take up.***
- **Some water is held tightly to the soil particles**
- **Some drains below the root zone.**
- **The remainder is *AVAILABLE*.**

Available water by soil type

Soil Texture	Total water (in/ft)	Available water(in/ft)	Unavailable water (in/ft)
Sand	0.6-1.8	0.4-1.0 (55-67%)	0.2-0.8
Sandy loam	1.8-2.7	0.9-1.3 (48-50%)	0.9-1.4
Loam	2.7-4.0	1.3-2.0 (48-50%)	1.4-2.0
Silt loam	4.0-4.5	2.0-2.1 (47-50%)	2.0-2.4
Clay loam	4.2-4.8	1.8-2.1 (43-44%)	2.4-2.7
Clay	4.5-4.8	1.8-1.9 (33-40%)	2.7-2.9

Available water at field capacity

Soil Texture Textura	Total water (in/ft) Agua Total	Available water (in/ft) Agua Disponible
Sand	0.6-1.8	0.4-1.0 (55-67%)
Sandy loam	1.8-2.7	0.9-1.3 (48-50%)
Loam	2.7-4.0	1.3-2.0 (48-50%)
Silt loam	4.0-4.5	2.0-2.1 (47-50%)
Clay loam	4.2-4.8	1.8-2.1 (43-44%)
Clay	4.5-4.8	1.8-1.9 (33-40%)

- Sandy loam has *less* total available water than loam
- Loam has *less* total available water than clay loam
- Clay loam or silt loam have the most available water

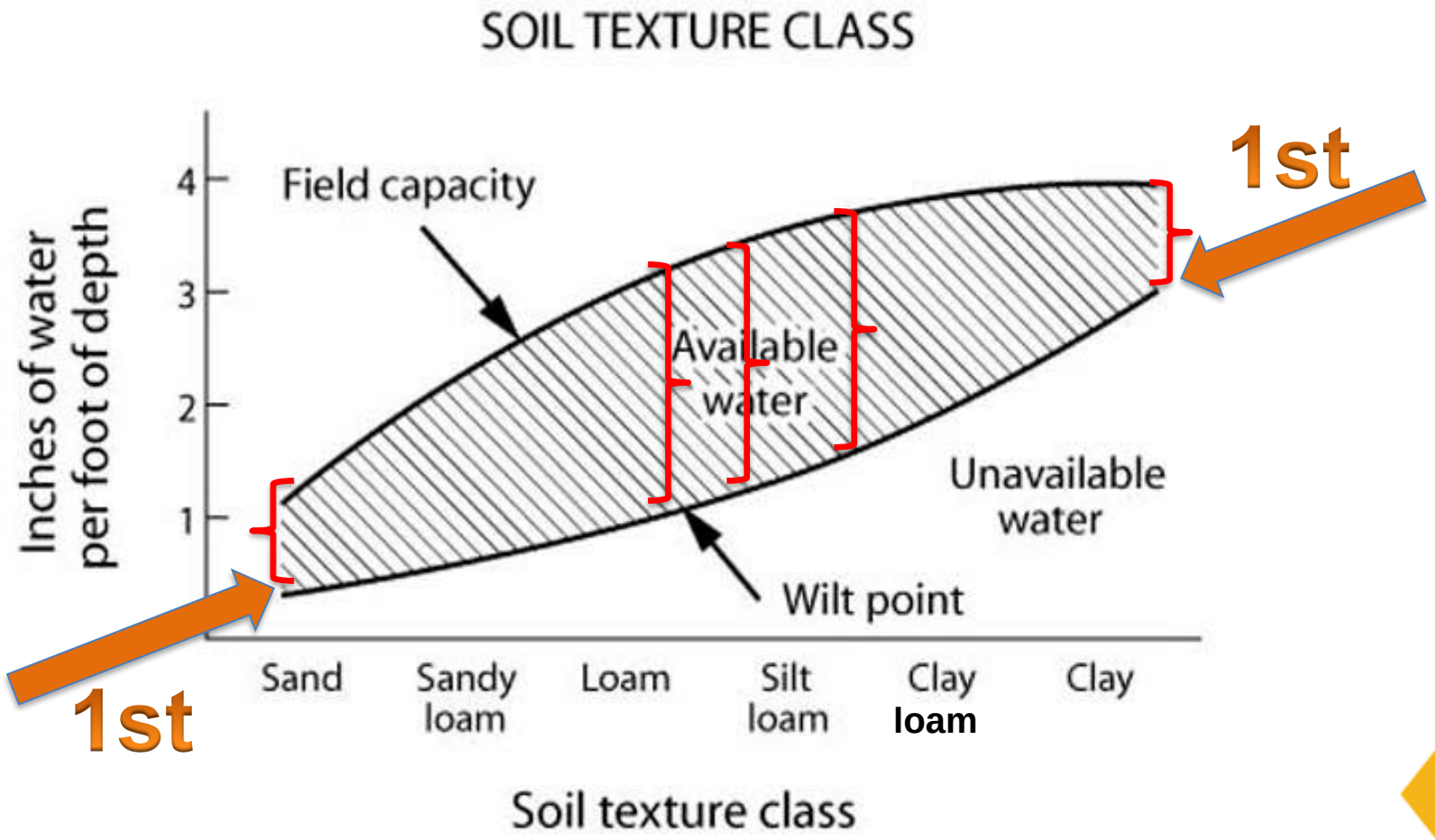
Permanent Wilting Point (PWP)

- The point at which a plant has become so dehydrated that it cannot recover.

Ideally, you should irrigate just before reaching PWP!

Texture/Field Capacity/PWP
Textura/Capacidad de Campo/PWP

How fast will each soil reach permanent wilting point?



Available water by soil type

Soil Texture Textura	Unavailable water (in/ft) Agua no Disponible
Sand	0.2-0.8
Sandy loam	0.9-1.4
Loam	1.4-2.0
Silt loam	2.0-2.4
Clay loam	2.4-2.7
Clay	2.7-2.9

- Clay will feel moister when it needs to be irrigated

WHY?

- More water in the soil that is *unavailable*

Questions?

Infiltration rate

- The rate at which water soaks into the soil
- Usually measured in inches/hour
- If the application rate is higher than the infiltration rate, you will have RUNOFF.

Infiltration rate

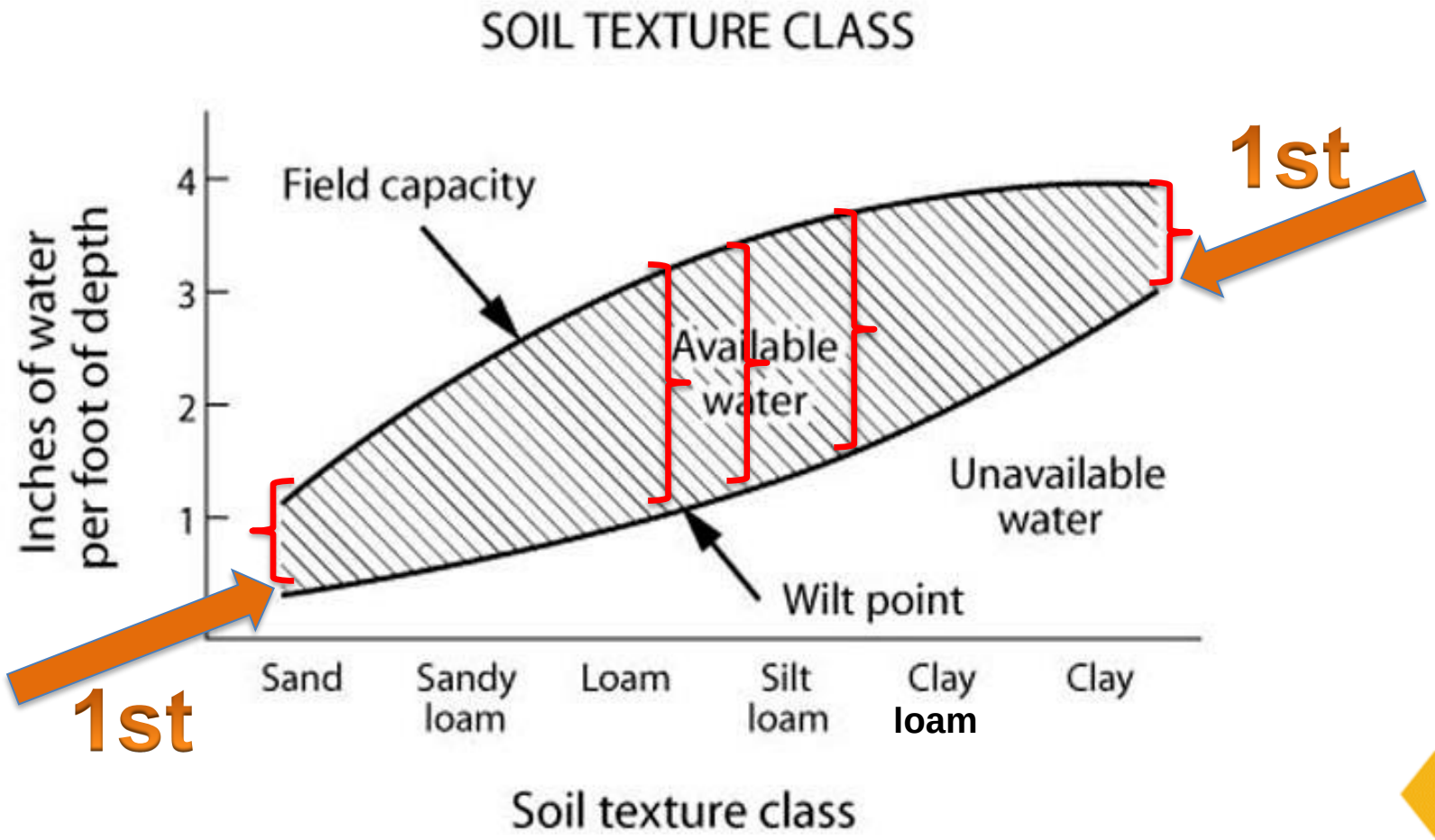
- Affected by soil texture
- Additionally affected by *compaction*
- Can be affected by a thatch layer
  - Sometimes slick leaf litter can affect it too
- Slopes can limit the application rate
  - Limit how much water can be applied before runoff occurs

Managed Allowable Depletion (MAD)

- The percentage of the total available water you allow to be used up.
- We typically irrigate landscapes at 50% MAD.
- Irrigate at lower MAD% (sooner) if
  - Plants are sensitive or newly planted
  - Soils are heavy clay or high sand

Texture/Field Capacity/PWP
Textura/Capacidad de Campo/PWP

How fast will each soil reach permanent wilting point?



Soil fertility and plant health

Plants get Carbon, Hydrogen, and Oxygen from the air and water. The soil provides:

- **Major Plant Nutrients (macronutrients)**
  - **Needed in largest amounts**
  - **Required for healthy growth**
  - **Nitrogen (N)**
  - **Phosphorus (P)**
  - **Potassium (K)**
  - **Calcium (Ca)**
  - **Magnesium (Mg)**
  - **Sulfur (S)**

- **Minor Plant Nutrients (micronutrients)**
  - **Needed in much smaller amounts**
  - **Usually available in soil already**
  - **STILL IMPORTANT TO HEALTH and GROWTH**
  - **Iron (Fe)**
  - **Zinc (Zn)**
  - **Chlorine (Cl)**
  - **Boron (B)**
  - **Manganese (Mn)**
  - **Copper (Cu)**
  - **Molybdenum and Nickel**

Some common symptoms- N

Nitrogen deficiency

- Old leaves turn yellow all over (chlorosis), and may die
- New leaves are pale, and sometimes small
- Growth slows

Some common symptoms- P
Síntomas communes -P

Phosphorus deficiency

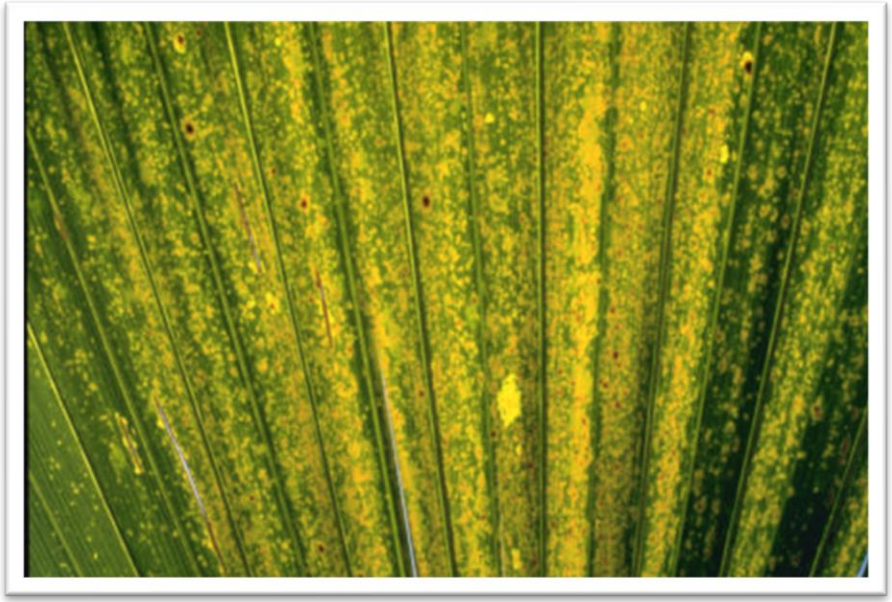
- Stunted or deformed leaves
- Purplish cast
- Leaf tips may appear burned

P binds strongly to soil-
Not always available

Some common symptoms- K

Potassium deficiency

- Not common in the North Bay
- Speckled yellowing on palms
- Older leaf tips and whole leaves die on severely deficient soils



Some common symptoms- Fe

Iron deficiency

- Yellowing between veins (*inter-veinal chlorosis*)
- Can happen in alkaline soils- iron is there, it's just not available

Soil Analysis

THINGS YOU CAN ASK FOR:

- Nutrients (Specific- all or a few)
- pH
- Salinity (CEC)
- Exchangeable Sodium (SAR)
- Organic matter (Carbon content)

THEY MAY RECOMMEND RATES/1000 ft^2 to correct deficiencies

Soil Analysis
Análisis de Suelo

A & L WESTERN AGRICULTURAL LABORATORIES

1311 WOODLAND AVE #1 • MODESTO, CALIFORNIA 95351 • (209) 529-4080 • FAX (209) 529-4736

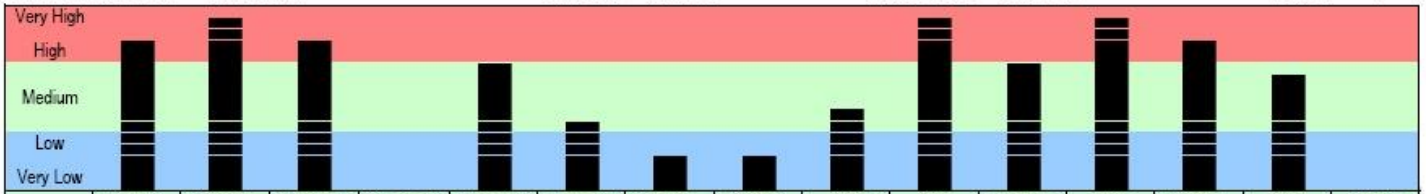
REPORT NUMBER: 08-126-025 CLIENT NO: 99999

SEND TO: [redacted] SUBMITTED BY: [redacted]

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 05/07/08 LAB NO: 51600 SAMPLE ID: 799DU PAGE: 1



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	5.9	107	85	105	445	246	1482	67	17	15.1	20	55	4.1	1.2	

Percent Cation Saturation (computed)

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
7.2	12.9	47.0	1.9

ACIDIC BASIC

LOW AVERAGE HIGH

2.2 ECe dS/m — INCREASING SALINITY

15.7 CEC meq/100g

L Ex. Lime

5.3 pH — INCREASING NEED FOR LIME

Buffer pH: 6.5

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: LANDSCAPE RATE: lb/1000 sq ft NOTES:

Dolomite (70 score)	Lime (70 score)	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
140					1.0			0.5						

COMMENTS:

SAMPLE SIZE: Please limit your sample size to about a pint in future. A small plastic bagful is sufficient for most tests. Please call if you require any of our A&L soil bags. Thanks.

EXCESSIVE NITROGEN may promote excessive vegetative growth, reduce pH and encourage disease. Restrict further nitrogen applications where soil levels are high. Protect ground water!

MICRONUTRIENTS: Where levels appear to be high, avoid any further applications for the time being. Very high (VH) levels may not necessarily be toxic, but avoid. Maintain correct soil pH.

What makes up soil life?

- Worms
- Insects
- Microorganisms
  - Bacteria
  - Fungi
  - Protozoans
  - Nematodes

This fungus kills root nematodes

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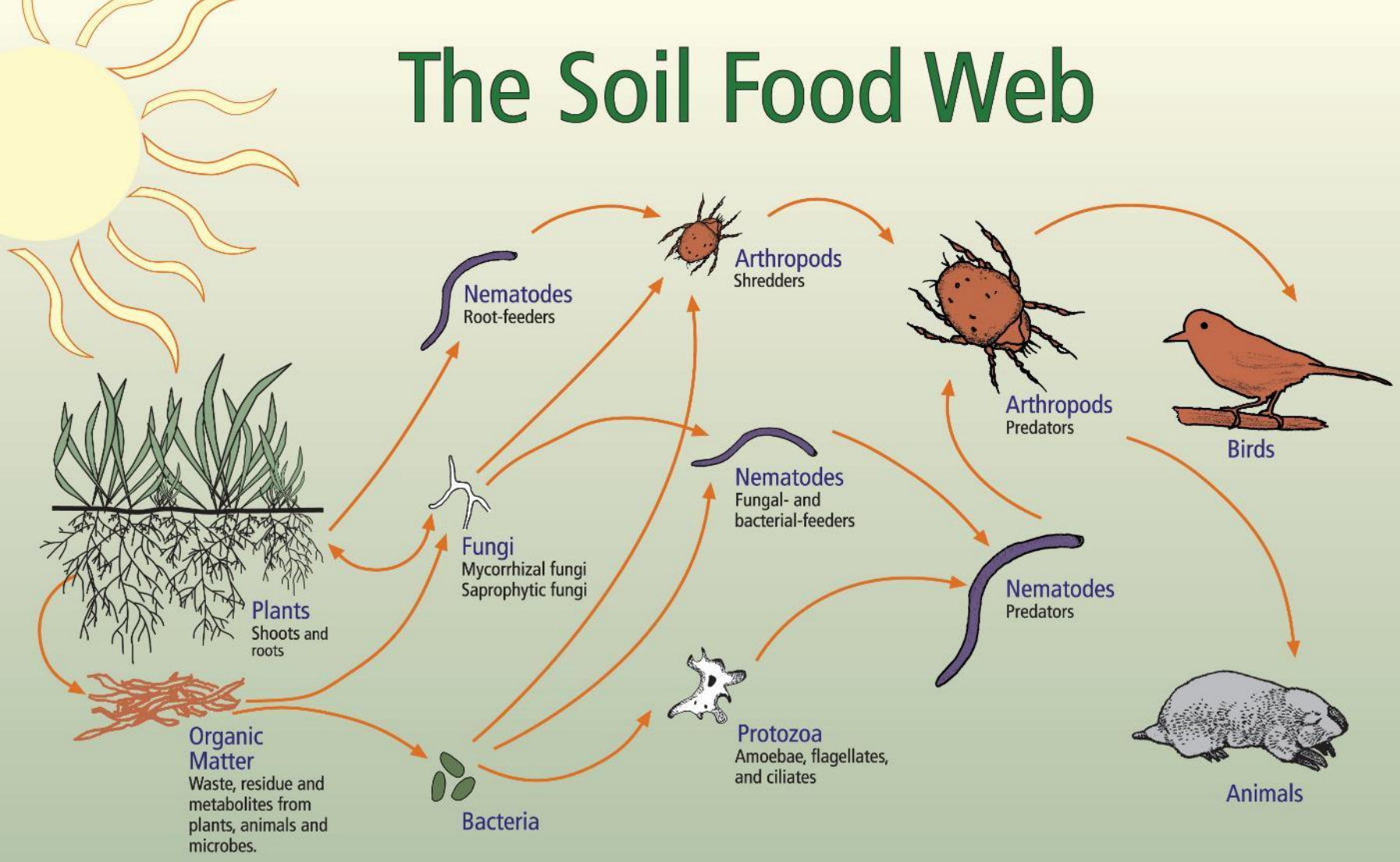
The Soil Food Web



First trophic level: Photosynthesizers

Second trophic level: Decomposers, Mutualists, Pathogens, Parasites, Root-feeders

Third trophic level: Shredders, Predators, Grazers

Fourth trophic level: Higher level predators

Fifth and higher trophic levels: Higher level predators

Image: USDA

Managing Soil Life

- **1 teaspoon of HEALTHY SOIL**

  (2 billion)

  2,000,000,000 microorganisms

- **1 teaspoon of DEPELETED soil**

  500 microorganisms

Soil Life

- **What do soil organisms do to improve the soil for plants?**
  - **Decompose organic matter (dead plants, fungi, animals, etc.)**
  - **Improve the soil by producing 'humus', which is stable soil organic matter**
  - **Break down mineral soil and release nutrients**

Plants growing in healthy soil are stronger and have fewer problems.

Root Zone

How are plant nutrients recycled?

- Mycorrhizal fungi digest organic matter
  - Dead plants & animals
  - Some mineral soil
- Plants trade sugar water to mycorrhizal fungi for nutrients
- Many other microorganisms also decompose organic matter in the soil- they use some of it and leave the rest.
- Humus isn't readily broken down, but

Managing Soil Life

How do you exhaust a good soil?

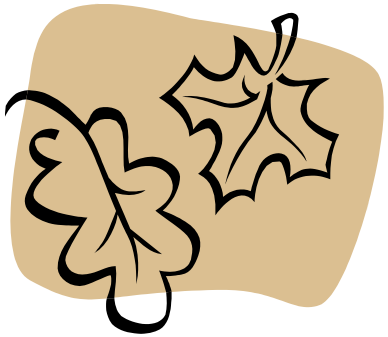
- Too many quick-fix fertilizers
- Too many pesticides (insecticides/ fungicides)
- Too little soil carbon
  - Not enough organic amendments or mulch
- Over-tilling
  - Ruins fungal colonies and disturbs other life

Managing Soil Life

- How do you rebuild healthy soils?
  - Reverse 1, 2, and 3 above
    1. Add organic matter to soil on a regular basis
    2. Reduce or eliminate pesticide use
    3. Minimize tilling soil

Managing Soil Life

- **What is the primary fuel for beneficial microorganisms?**
  - **Carbon (organic matter- living things)**
- **What landscape practices feed the soil life?**
  - **Adding compost and compost tea**
  - **Using *organic* mulch**
  - **Letting leaves lie**
  - **Leaving lawn clippings**



Evaluating Soil Characteristics

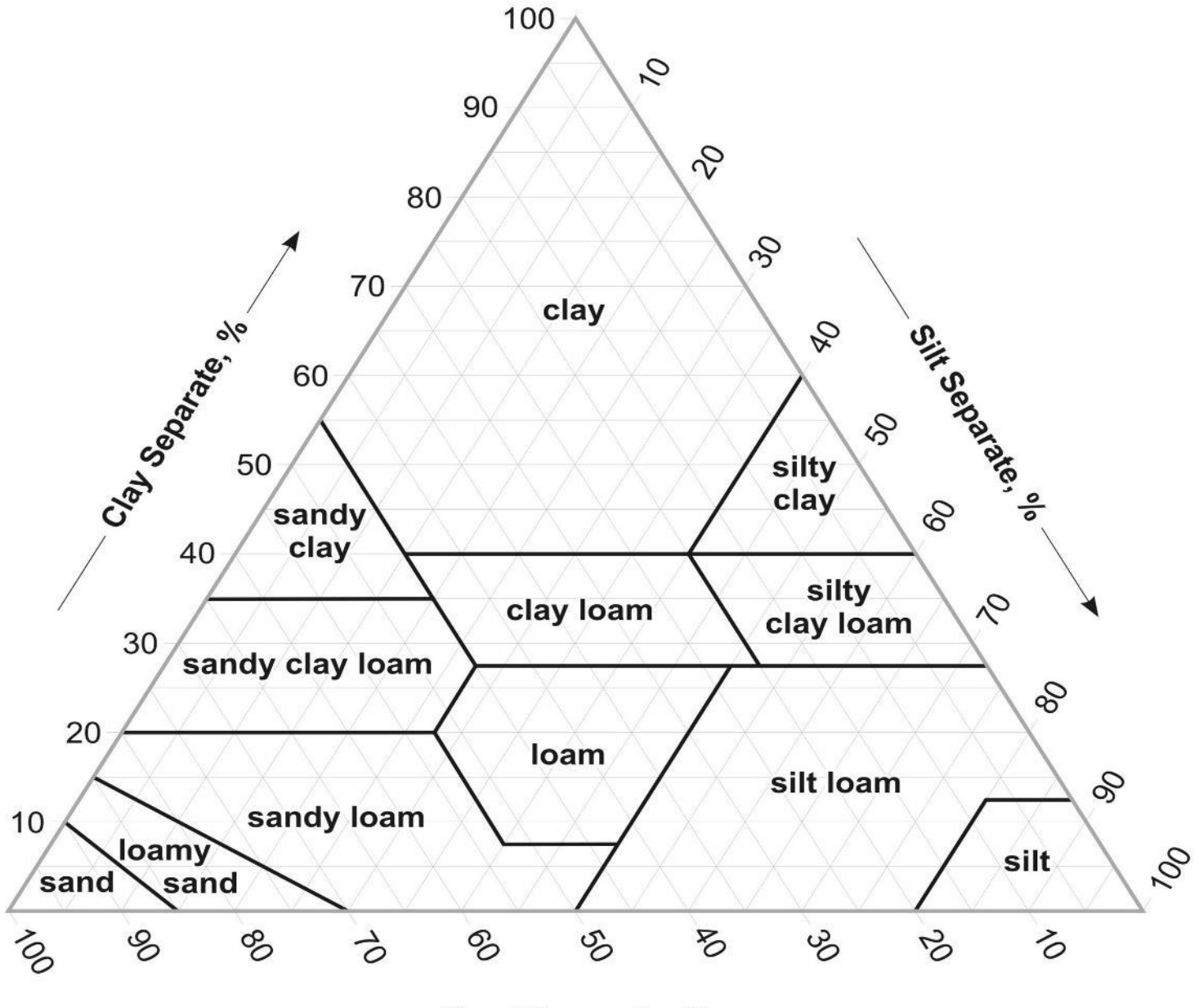
What are 3 things you can do when you pick up a handful of soil?

EVALUATING SOIL CHARACTERISTICS
Evaluación de Características del Suelo

1. Feel it
   - Sand / Silt / Clay (Texture)
   - Affects how you irrigate
   - Affects what you can plant
2. Smell it
   - An earthy/ foresty smell means high biological activity.
   - A lack of smell, or only the smell of minerals (like rust) indicates very limited biological activity- AMEND WITH COMPOST!
3. Look at it: what color?
   - Dark brown soil = high organic matter
   - Light gray or tan = low organic matter- ADD COMPOST and MULCH

https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Soil Textural Triangle



Jar Method

- 1 c. soil in jar
- Add water to near top
- Shake and let sit for at least 24 hours
- Measure widths of solid layers

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Soil texture percent calculation

% Clay= (depth of top layer ÷ depth of all soil) x 100

% Silt= (depth of middle layer ÷ depth of all) x 100

% Sand= (depth of bottom layer ÷ depth of all) x 100