WEATHERING AND SOIL FORMATION

A. ROCKS AND PETROLOGY

Petrology

- Petros = rocks
- Logia = study of
- Study of rocks concerned with composition, structure, and origin

Rocks

- Aggregates of different kinds of minerals in varying proportions
- E.g. granite contains minerals such as biotite, quartz, and feldspar

B. TYPES OF ROCKS

1. Igneous rocks

- From Latin word 'Ignis' meaning Fire
- Forms from solidification of hot molten material such as magma and lava
- Most abundant rock in the Earth's crust – 95%

Intrusive Igneous (Plutonic)	Extrusive Igneous (Volcanic)
From trapped magma	From lava upon rapid cooling
Slow cooling	Fast cooling
Coarse-textured due to crystal growth	Fine-textured due to lack of crystal growth
Granite, gabbro, diorite, pegmatite	Basalt, rhyolite, andesite

Texture of Igneous Rocks	
Phaneritic	Coarse-textured → Intrusive Igneous
Aphanitic	Fine-textured → Extrusive Igneous
Porphyritic	Larger crystals (PHENOCRYST) surrounded by matrix of smaller crystals (groundmass)

2. Sedimentary rocks

- Forms from the compaction and cementation of sediments of pre-existing rocks such as igneous and metamorphic rock subjected to weathering
    1. e.g. Sandstone

- May also form from parts of living organisms
    1. e.g. Bituminous coal (from plant)

- Major processes of sedimentary rock formation
    1. Mechanical and chemical weathering of parent material
    2. Transport of weathering products through water, gravity, wind or ice
    3. Deposition of sediments
    4. Compaction and cementation

Difference between <u>SEDIMENTATION</u> and <u>LITHIFICATION</u>:

- **Sedimentation** – collective term for step 1 to step 3 → weathering, transport, and deposition
- **Lithification** – refers to step 4 → compaction and cementation → from unconsolidated material (sediments) to consolidated (rock)

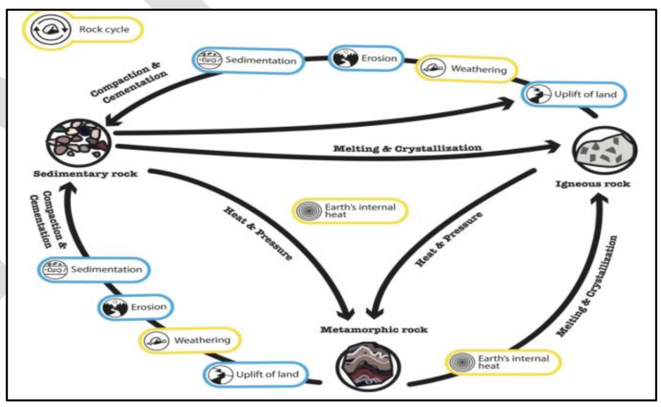
3. Metamorphic rocks

- Metamorphism – change in structure or composition due to heat and pressure
- Form from pre-existing rocks such as igneous and sedimentary rocks subjected to heat and pressure

Pre-existing rock	Metamorphic Rock Equivalents
Sandstone	Quartzite
Limestone	Marble
Conglomerate	Meta-conglomerate
Shale	Slate
Basalt	Schist
Granite	Gneiss

C. ROCK CYCLE

- Continuous transformation of different types of rocks through geologic time



D. ABUNDANT ELEMENTS IN THE EARTH'S CRUST

1. Oxygen – 46.6%
2. Silicon – 27.72%
3. Aluminum – 8.13%
4. Iron – 5.00%
5. Calcium – 3.63%
6. Sodium – 2.83%
7. Potassium – 2.59%
8. Magnesium – 2.09%
9. Others elements – 1.41%

E. MINERALS AND MINERALOGY

Minerals

- Naturally occurring inorganic substance that has definite internal arrangement and definite chemical composition and physical properties

Mineralogy

- Study of minerals concerned with structure and properties

F. CLASSIFICATION OF MINERALS

1. Primary minerals

- Form from crystallization of igneous rocks
- Source of sand and silt fractions
- e.g. Olivine, Pyroxene, Amphibole, Plagioclase, Mica
    - Black mica = Biotite
    - White mica = Muscovite

2. Secondary minerals

- Form from weathering of pre-existing minerals
- Source of clay fraction
- e.g. Pyrite (Fool's gold), Halite (salt or NaCl), Kaolinite (clay mineral), Hematite (oxidized iron)

G. BOWEN'S REACTION SERIES

1. Discontinuous series

- left branch where minerals such as Olivine, Pyroxene, Amphibole, and Biotite can be found
- High magma temperature
- High in Iron and Magnesium but low in Silica

2. Continuous series

- Right branch → from Calcium rich to Sodium rich
- form as temperature decreases in a more gradual and continuous manner

3. Residual phase

- discontinuous and continuous series join
- Low in Fe, Mg, and Ca but high in Silica

H. WEATHERING

1. Physical weathering

a) Exfoliation – observable cracks caused by pressure release during uplift and erosion
b) Freeze-thaw – water enters cracks and expands rock upon freezing
c) Thermal expansion – cracking of rocks due to repeated expansion (high temperature) and contraction (low temperature)
d) Abrasion – collision of rocks resulting to smooth surface

2. Chemical weathering

a) Oxidation
    - Combination of oxygen to minerals
    - Loss of electrons
    - Oxidation of magnetite to hematite

b) Reduction
    - Removal of oxygen to minerals
    - Gain of electrons

c) Hydrolysis – attack of water to minerals which causes:
    - Change in mineral composition
    - Change in mineral structure
    - Decomposition
    - e.g. Hydrolysis of Kaolinite → Silt clay

d) Hydration
    - Water is absorbed in the mineral structure
    - Does not destroy chemical structure

e) Carbonation
    - Rocks or mineral with carbonic acid

3. Biological weathering

a) Root wedging – entry of plant roots in small cracks which causes further cracks as it grows
b) Animal activity
    - Burrowing and excavation of animal
    - e.g. Piddocks

I. SOIL

Definition of Soil (Soil Survey Staff, 1999)

- natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the followings: horizons or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment

Well-known Soil Scientists

- Vasily Dokuchaev – Father of Soil Science
    - Born in Russia
    - Considered soil as a living system

- Hans Jenny – 5 Factors of Soil Formation
    - Born in Switzerland
    - Most acknowledged model (CLORPT)

J. 5 FACTORS OF SOIL FORMATION

1. Climate

a) Temperature
    - Rate of biochemical reaction is faster with high temperature, thus faster weathering

b) Precipitation / Rainfall
    - Higher rate of precipitation means higher rate of weathering and leaching
    - Leaching – soluble substances are translocated through water

NOTE: Tropical soils are usually older due to higher temperature and precipitation as compared temperate soils which are usually young soils

SBRC

2. Living Organism

a) Animals
   - Bioturbation causes soil mixing
     - e.g. Termite mounds

b) Microorganisms
   - Fungi and bacteria help in decomposition of organic matter

c) Plants
   - Source of organic matter in the soil

Grassland Soil	Forest Soil
Thick surface horizon (A horizon)	Thin surface horizon (A horizon)
Darker A horizon due to organic matter	Formation of thin O horizon

3. Relief / Topography

a) 5 Hillslope position

1. Summit 2. Shoulder	• Fast development of soil due to high leaching and relatively less erosion as compared to backslope
3. Backslope	• Slow development of soil due to less leaching and faster runoff causing soil erosion
4. Footslope 5. Toeslope	• Slow development of soil due to accumulation of sediments from upslope • Prone to flooding

4. Parent material

a) Residual – from the bedrock

b) Transported – water, wind, gravity, or ice
   - Water – alluvium
   - Wind – aeolian
   - Gravity – colluvium
   - Ice – glacial drift

5. Time

- Developed horizons
- Iron and clay accumulation
- Increase acidity
- Leaching
- Time zero – initial state of the soil system

NOTE: Age of soil is not considered in number of years but in the number of soil horizons that developed

Young	
	A
	C

Old	
	A
	E
	B
	C

K. NAMING SOIL HORIZONS

1. O horizon – part of Topsoil
- Layer of organic matter at various stages of decomposition
- Oi (Fibric) – undecomposed or slightly decomposed
- Oe (Hemic) – moderately decomposed
- Oa (Sapric) – highly decomposed

2. A horizon – part of Topsoil
- Mineral horizon
- Organic matter coats the minerals (sand, silt, and clay) which causes darkening of soil

3. E horizon
- Zone of **E**LUVIATION → EXIT
- Zone of leaching → Clay, OM, and sesquioxides (Fe/Al oxides) are leached
- Light colored

4. B horizon - Subsoil
- Zone of **I**LLUVIATION → INTO
- Zone of accumulation → accumulation of leached Clay, OM, and sesquioxides (Fe/Al oxides) from overlying horizons

NOTE: O, A, E, and B horizons are considered Solum or True soil → "Zone of pedogenic activity" (humification and weathering are dominant)

5. C horizon
- Outside the zone of pedogenesis
- Partially weathered parent material
- Weathered or soft bedrock
- Regolith

6. R horizon
- Unweathered parent material
- Hard bedrock (cemented/consolidated)

L. SOIL HORIZONATION

1. Horizonation
- Includes processes and conditions by which initial materials are differentiated into soil profiles with many horizons
- e.g. Illuviation, Eluviation, Podzolization, Littering

2. Haploidization
- Includes processes and conditions by which horizonation is inhibited or decelerated or by which horizons are mixed or disturbed
- e.g. Erosion and Pedoturbation

M. GENERAL PROCESSES OF SOIL FORMATION

Simonson's model → Soil = f (a, r, t1, t2)

a = addition
r = removal/losses
t1 = translocation
t2 = transformation

NOTE: These general processes are regulated by 5 factors of soil formation (CLORPT)

1. Addition

a) **Enrichment** – general term for any material added to soil body
b) **Melanization** – darkening of light-colored mineral by admixture of organic matter
c) **Cumulization** – aeolian, hydrologic, and man-made additions of mineral particles to the surface of a soil solum
d) **Littering** – accumulation on the mineral soil surface of organic litter and associate humus to a depth of less than 30cm

2. Removal

a) **Erosion** – removal of material from the surface layer of a soil
b) **Leaching** – general term for washing out or eluviating soluble materials from the solum

3. Transformation

a) **Decomposition** – breakdown of mineral and organic materials
b) **Synthesis** – formation of new particles of mineral and organic species
c) **Mineralization** – release of minerals components (inorganic) of organic matter through decomposition
d) **Humification** – transformation of raw organic materials into humus
e) **Ripening** – chemical, biological, and physical changes in organic soil after air penetrates previously waterlogged soil
f) **Loosening** – increase in volume of voids by activity of plants, animals, and humans and by freeze-thaw or other physical processes and by removal of material by leaching
g) **Hardening** – decrease in volume of voids by collapse and compaction and by filling of some voids with fine earth, carbonates, silica, and other materials

4. Translocation

a) **Salinization** – accumulation of soluble salts such as sulfates and chlorides of calcium, magnesium, sodium, and potassium in salty (salic) horizons
b) **Alkalization / Solonization** – accumulation of sodium ions on the exchange sites in a soil
c) **Dealkalization / Solodization** – leaching of sodium ions and salts from nitric horizons
d) **Podzolization / Silication** – chemical migration of aluminum and iron and/or organic matter, resulting in concentration of silica in the layer eluviated
e) **Laterization / Desilication** – chemical migration of silica out of the soil solum and thus the concentration of sesquioxides in the solum
f) **Braunification, Rubification, Ferrugination** – release of iron from primary minerals and the dispersion of particles of iron oxide in increasing amounts; their progressive oxidation or hydration, giving the soil mass brownish, reddish brown, and red colors, respectively
g) **Gleization** – reduction of iron under anaerobic "waterlogged" soil conditions, with the production of bluish to greenish gray matrix colors, with or without yellowish brown, brown, and black mottles, and ferric and manganiferous concretions
h) **Lessivage** – washing in suspension of fine clay down cracks and other voids in a soil body
i) **Illuviation** – movement of material into a portion of soil profile as in an argillic or spodic horizon
j) **Calcification** – processes including accumulation of calcium carbonate

L. PEDOTURBATION / BIOPEDTURBATION

1. Faunalturbation – soil mixing by animals
2. Floraltubation – soil mixing by plants
3. Argilliturbation – soil mixing by action of clay (shrinking and swelling)
4. Cryoturbation – soil mixing by freezing and thawing of ground ice

ADDITIONAL TERMS:

1. Concretions – redoximorphic feature, compact (cemented) mass of mineral matter
2. Hectare furrow slice – 2,000,000 kg
3. Pedon – smallest volume of soil that should be recognized as a soil individual
4. Polypedon – composed of several homogeneous pedons
5. Saprolite – chemically weathered rock that has remained on original site (in situ) and has preserved original rock structure
6. Soil horizon – layer parallel to soil surface whose physical, chemical, and biological characteristics differ from layers above and beneath.
7. Soil Profile – vertical exposure that includes all material that has been altered by chemical, physical, and biological reactions; composed of soil horizons
8. Transitional horizon – horizon contains characteristics of two horizons but one is dominant over the other (e.g. AB horizon) → characteristics of A horizon is more dominant than B horizon

Soil Texture

- relative proportion of sand, silt, and clay (soil separates)
- Inherent property of the soil
- Has influence on the soil properties

Particle Fraction	USDA (mm)	ISSS (mm)
Gravel	> 2	> 2
Sand	2 – 0.05	2 – 0.02
Silt	0.05 – 0.002	0.02 – 0.002
Clay	< 0.002	< 0.002

Sand

- Largest soil separate
- 0.05 mm to 2 mm
- Feels gritty when rubbed
- Non-plastic or non-sticky when moist

Silt

- Intermediate soil separate
- 0.002 mm to 0.05 mm
- Feels smooth and floury
- Slightly plastic or sticky when moist

Clay

- smallest soil separate
- < 0.002 mm
- Feels smooth and sticky
- Plastic when moist

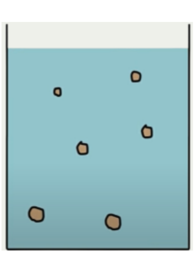
Textural Group	Textural Class
Sand	Sand
	Loamy Sand
Loams	Sandy loam
	Loam
	Silt loam
	Silt
	Sandy clay loam
	Silty clay loam
	Clay loam
Clays	Sandy clay
	Silty clay
	Clay

Hydrometer method

- Quantitative analysis
- Soil texture determination

Stoke's Law

- bigger particles will fall faster in a liquid medium than the smaller particles



Dispersing Agent

- Calgon (Sodium hexametaphosphate) is commonly used to disperse the soil particles in hydrometer method

Flocculating Agent

- Clay, Organic matter, lime, sesquioxides (Fe/Al oxides), and silica binds soil particles to form aggregates

Coarse-Textured	Fine-Textured
More macropores	More micropores
High bulk density	Low bulk density
Low porosity	High porosity
High permeability	Low permeability
Low water holding capacity	High water holding capacity
Good drainage	Poor drainage

Soil Structure

- Grouping of soil particles into aggregates
- arrangement of aggregates

Soil aggregate

- groups of soil particles that bind to each other strongly than adjacent particles

Aggregate Stability

- ability of soil to resist disruptive forces such as such as wind and water erosion
- Slake test – test the stability of soil aggregates in water
  - Stable macropores allows water movement in the soil without breaking the aggregates

Types of soil structure

1. **Granular** – common in A horizon; formation is influenced by humus; rapid water permeability
2. **Blocky** – angular or subangular; forms in B horizon
3. **Prismatic** – forms in B horizon; moderate water permeability
4. **Columnar** – common in arid and semiarid conditions; presence of salt caps
5. **Platy** – forms as a result of compaction; very slow water permeability
6. **Single grained** – grains are not connected; lacks structure
7. **Massive** – mass of soil particles with no pattern.

Puddling

- Deliberately destroying soil structure by plowing and harrowing the soil in a flooded or saturated state.
- Formation of impervious of layer

Densities and Porosity

Bulk Density

- ratio of mass of soil solids to the volume of soil
- Expressed in g/cm
- Indicator of compaction and porosity

$$\text{B.D.} = \frac{mass\ of\ soil\ solid}{total\ volume\ of\ soil}$$

Effects of High Bulk Density

- High soil compaction
- less porous
- lacks good soil structure
- waterlogging

Factors Affecting Bulk Density

1. Soil texture - coarse-textured soils have higher bulk density as compared to fine-textured soils. This is because coarse-textured is less porous than fine-textured soil.
2. Soil Structure - soil with good soil structure has less compaction due to good aggregation and porosity, thus, bulk density is lower
3. Organic matter - addition of organic matter lowers bulk density by improving soil aggregation
4. Depth of Profile - bulk density increases as soil goes deeper due to increasing compaction and decreasing amount of organic matter
5. Excessive Tillage - tillage can reduce bulk density in the soil by breaking compacted soil, however, excessive tillage can later on increase bulk density as it disrupts soil structure

Particle Density

- ratio of mass of soil solids to the volume of soil solid
- Expressed in g/cm
- PD (mineral soils) = 2.65 g/cm

Porosity

- signifies the extent of pore space expressed as percentage of bulk volume of the soil

$$\%\ Pore\ space = 1 - \left(\frac{bulk\ density}{particle\ density}\right) x\ 100$$

Water Movement

Infiltration - downward entry of water via the soil surface

Percolation - water moves downward through the soil layers due to gravity

Factors affecting infiltration

- Soil Texture – clayey (fine-textured) = slow
- Moisture Content – dry soil = faster
- Soil Structure – soil crusting = slow

Permeability

- ability of soil or rock to transmit water or other fluids through its pore spaces

Moisture Content

1. Gravimetric Moisture Content

$$\%\theta_m = \frac{FW\ - ODW}{ODW}\ x\ 100$$

2. Volumetric Moisture Content

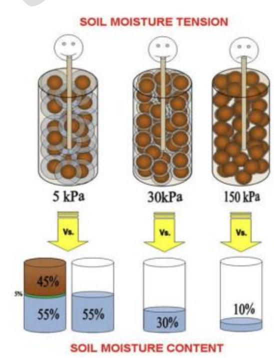
$$\%\theta_v = \%\theta_m\ x\ \frac{\rho_b}{\rho_w}$$

3. Height of Water

$$H_{sw} = \theta_v\ x\ Ht$$

Soil Moisture Tension

- measurement of how tightly a water is held in the soil
- force that must be overcome to move water in the soil
- also called as “soil matric potential” or “soil suction”



- SMT increases when moisture content decreases

Water at Various Moisture Condition

Saturation (0 Bar) - all soil pores are filled with water

Field Capacity (1/3 bar) - gravitational water is drained from the soil; upper limit of available moisture range

Permanent Wilting Point (15 Bar) – water can no longer be extracted by plants; lower of available moisture range

Hygroscopic coefficient (31 Bar) – film of water tightly held by soil particles; water unavailable for plants

SBTC

Gravitational Water

- the difference between saturation and field capacity

Available Water

- the difference between field capacity and permanent wilting point

Soil Water Potential

- sum of gravitational, matric and osmotic potentials
- water moves from higher water potential to lower water potential

Summary

- HIGH soil moisture tension → DIFFICULT water extraction
- low soil moisture tension → easy water extraction
- HIGH water potential in <u>PLANT</u> than soil → water <u>goes out</u> of roots
- HIGH water potential in <u>SOIL</u> than plant → water <u>goes in</u> the roots (transpiration occurs)

Soil Consistency

- physical condition of soil at various moisture contents under applied stress
- resistance of soil to deformation and rupture
- refers to the way a soil feels

Soil Moisture Content	**Soil Behavior**
Dry	Friable
Wet	Sticky and Plastic
Super saturated	Viscous

Atterberg Limits

1. Liquid Consistency
2. Plastic Consistency
3. Friable Consistency
4. Hard Consistency

Soil Color

Munsell color chart

- developed by Albert Henry Munsell
- standard color chart
- describes soil color based on Hue, Value and Chroma

Hue

- dominant spectral color
- red, orange, yellow, etc.
- 10R, 7.5YR, 2.5Y

Value

- lightness or darkness of color
- scale runs vertically from top (lightest) to bottom (darkest)
- ranges from 0 (pure black) to 10 (pure white)

Chroma

- intensity, purity, or strength of a color
- scale runs horizontally from left (weak) to right (strong)
- ranges from 0 to 20

Concretions - compact mass of mineral matter, usually spherical or disk-shaped, embedded in sedimentary rocks

Clay skins - morphological feature that coat the surfaces of voids, grains or aggregates; waxy appearance

Mottles - spots or blotches of different color shades interspersed with the dominant soil color

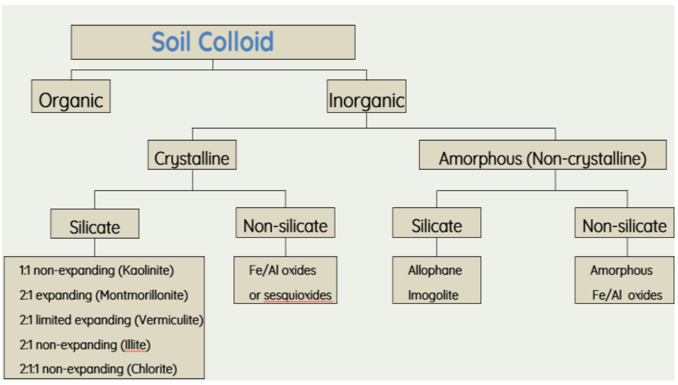
SOIL CHEMISTRY

Soil Colloid

- most active constituent of the soil and determines the physical and chemical properties of the soil
- seat of various chemical reaction

Characteristics of Soil Colloid:

- Very fine particles (<1 micron)
- High Surface area
- Chemically reactive



Basic Units of Silicate Clays

1. Silica Tetrahedron
2. Aluminum Octahedron

Crystalline Silicate Clays

A. **1:1 Non-expanding Type (Kaolinite)**

- Tetrahedral and octahedral sheets are tightly held by oxygen atoms, which are mutually shared by silicon and aluminum cations
- Unit layers held by hydrogen bonding
- Little isomorphous substitution
- Low surface area
- Low CEC

B. **2:1 Highly Expanding (Montmorillonite)**

- Octahedral sheet sandwiched between two tetrahedral sheets
- Unit layers are held by weak attraction between oxygen atoms
- Aluminum is replaced by Magnesium (isomorphous substitution) → causes (-) charge
- High CEC, high swelling and shrinkage

C. **2:1 Limited Expanding (Vermiculite)**

- Octahedral sheet is either aluminum dominated (di-octahedral) or magnesium dominated (tri-octahedral)
- Very high net negative charge in tetrahedral sheet
- Ions act as bridges of unit layers as they are strongly adsorbed in the interlayer space
- Highest CEC

D. **2:1 Non-expanding (Illite)**

- called fine-grained micas
- Potassium ions (K+) act as binding agents of tetrahedral sheets as they are attracted in the interlayer space
- Potassium ions (K+) act as binding agents of tetrahedral sheets as they are attracted in the interlayer space

E. **2:1:1 Non-expanding (Chlorite)**

- Magnesium dominates the tri-octahedral sheet
- Magnesium dominates the tri-octahedral sheet

Surface Charges

- soil colloids carry negative or positive charges on their external and internal surfaces
- some soil colloids in very acid soils have net positive charge
- for most soil colloids, net negative charge predominates

Sources of Negative Charge

1. Isomorphous substitution

- Substitution of one ion for another of similar size within a crystal lattice
- Major source of negative charges in 2:1 layer silicates
- Permanent charge
- Important for 2:1 clay mineral

2. Ionization of exposed hydroxyl group

- pH dependent charge
- Important for 1:1 clay mineral

3. Organic colloids (Functional groups)

Source of Positive Charge

1. Protonation of exposed hydroxyl group

Chelates – produced by active decomposition of organic matter that tend to hold micronutrients such as Fe, Mn, and Zn

Chelation – Chemical process of binding metal ions or other substances to a molecule, such as chelating agent, to form a stable, ring-like complex called a chelate

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Ion exchange - movement of cations and anions in the soil

Cation exchange - process by which cations are reversibly adsorbed on charged surfaces of sediments from soil solution

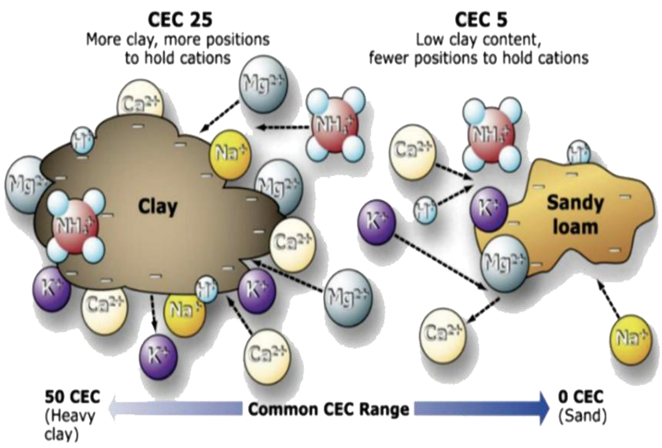
Characteristics of Cation Exchange

- Reversible
- Stoichiometric

- Instantaneous

Cation Exchange Capacity

- measure of total negative charges within the soil
- measure of the soil's ability to hold and exchange positively charged ions or exchangeable cations



Soil Properties Affecting CEC

1. **Soil Texture** – Clayey soils have higher CEC than sandy soils
2. **Type of Clay** - Montmorillonitic soils have higher CEC than Kaolinitic soils
3. **Amount of Organic Matter** - Soils with high amount of organic matter have higher CEC than those with low amount of organic matter content.
4. **Soil pH** - The number of negative charges on soil colloids increases as soil pH increases, thereby increasing CEC

Computation for CEC

Formula: CEC = sum of all exchangeable cations

CEC = 1.0 + 3.0 + 1.5 + 2.5 + 6.0 + 9.0

CEC = 23me/100g soil

Exchangeable cations	me/100g soil
H^+	1.0
Al^{3+}	3.0
Na^+	1.5
K^+	2.5
Mg^{2+}	6.0
Ca^{2+}	9.0

Note: Do not include anions (e.g. NO3-, HPO42-)

Percent Base Saturation

- Percentage of cation exchange capacity occupied by basic cations such as Calcium (Ca2+), Magnesium (Mg2+), Potassium (K+), and Sodium (Na+)
- Generally, soils with high percent base saturation have higher pH → more buffered against acid cations that acidify the soil
- Expressed in percentage

Computation for Base Saturation

$$\%\,BS = \frac{sum\ of\ exchangeable\ bases}{CEC} x100$$

Using the table provided in CEC, base saturation can be computed:

%BS = (1.5 + 2.5 + 6.0 + 9.0) / 23

%BS = 82.61%

Note:

- Basic cations → Ca^{2+}, Mg^{2+}, K^+, Na^+
- Acidic cations → H^+, Al^{3+}

Exchangeable Sodium Percentage

- percentage of cation exchange capacity occupied by sodium.
- Used in classification of saline and alkali soils or to determine if a sodium hazard exists

$$ESP = \frac{exchangeable\ sodium}{CEC}\ x\ 100$$

Soil pH

- Soil Reaction
- Master Variable
- Measure of acidity or alkalinity
- Acidic – below pH 7 → **dominated by H^+**
- Neutral – pH 7
- Alkaline – above pH 7 → **dominated by OH^-**
- pH = -log[H+]

Pools of Acidity

1. Active acidity - Hydrogen ions [H+] dissolved in soil solution
2. Reserve Acidity - Hydrogen ions [H+] dissolved in soil solution

Sources of acidity

- Hydrogen and Aluminum ions
- Organic acids
- Weathering
- Crop removal
- Excess nitrogen fertilizers
- Acid rain

Lime - Calcium or calcium-magnesium containing compounds capable of reducing harmful effects of an acid soil by neutralizing soil acidity and raising the soil pH

- Lime is not soluble in water thus must be finely ground to neutralize soil acidity

Relative Neutralizing Value (Calcium Carbonate Equivalent)

- Neutralizing ability of the liming material when chemically compared to a standard (pure $CaCO_3$)
- The lower the CCE, the more lime is needed to neutralize the soil's acidity

Lime	RNV or CCE
CaO (Burned or Quick lime)	179
$Ca(OH)_2$ (Slaked or Hyrdated lime)	136
$CaMg(CO_3)_2$ (Dolomitic limestone)	109
$CaCO_3$ (Calcium carbonate)	100

Buffering Capacity

- Indicates the capacity of the soil to resist pH change
- Soil with high amount of clay and organic matter has high buffering capacity due to large surface area
- Soil with high buffering capacity will require more lime

PROBLEM SOILS

1. Acidic Soil

- soil with pH less than 7
- Strongly acidic soils (<5.0) contain excessive amounts of dissolved Al, Fe, Mn, and Cu, which causes toxicity
- Decreases availability of Ca, Mg, K, P, and Mo
- Aluminum toxicity - Toxic levels of aluminum in the soil affect root cell division and the ability of the root to elongate

Management Practices for Acidic Soil

- Liming
- Split application of nitrogen fertilizer
- Planting acid tolerant crops

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2. Acid-Sulfate Soil

- common in coastal and inland settings where waterlogged conditions with iron sulfides are present
- rich in pyrite (iron sulfide)
- pH is less than 3.5
- may also cause Al toxicity

Management Practices for Acid-Sulfate Soil

- With proper management of water, selected crops can be planted such as rice, oil palm, and cocoa
- Maintain the area flooded to prevent oxidation-reduction reactions
- Liming can be done but would be required in high amounts
- Generally, acid-sulfate soil is left under natural vegetation or used for mangrove forestry

3. Saline Soil

- soil with high amount of soluble salts
- pH is less than 8.5
- common in arid and semi-arid regions where evaporation exceeds rate of water leaching
- Exhibits white crust of salt on the surface → "White Alkali"

Management Practice for Saline Soil

- Leaching is mostly used as a cultural practice to remove salts in the soil
- Crops that are tolerant to saline soil can be planted such as wheat, oat, barley and sorghum

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4. Sodic Soil

- soil with high amount of exchangeable sodium
- Sodium (Na+) → dispersing agent → destroys soil structure
- Black surface of the soil due to dispersion organic matter and humus → "Black Alkali"

Management Practices for Sodic Soil

- Application of Gypsum (calcium sulfate dihydrate) | Gypsum → is not considered a lime

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5. Saline-Sodic Soil

- soil that contain large amounts of total soluble salts greater than 15 percent exchangeable sodium
- When the soluble salts are leached out, the soil becomes sodic due to remaining Na+ in the exchange sites

Management Practices for Saline-Sodic Soil

- Gypsum should be applied and incorporated in the soil to replace the exchangeable sodium with calcium. This is followed by leaching of displaced sodium along with soluble salts using good quality water.

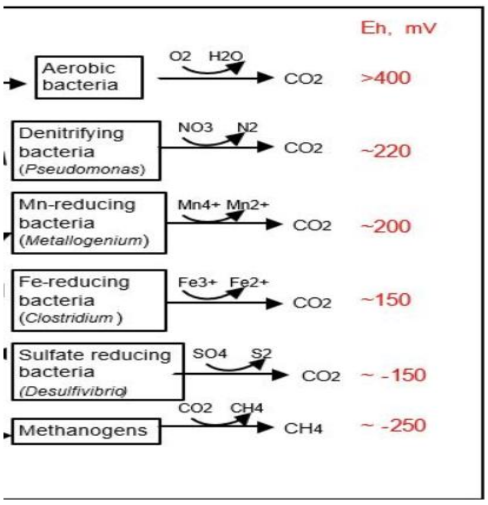
Soil Electrical Conductivity

- Measures the ability of the soil to carry electrical current due to dissolved ions in soil water that carry electrical charges
- Used principally as a measure of soil salinity

Effect of Flooding in Soil pH

- Flooding increases pH in acidic soil
- Flooding decreases pH in alkaline soil
- Flooding increases redox potential which leads to reduction (e.g. Fe^{3+} → Fe^{2+})

Succession of Electron Acceptors



1. Oxygen
2. Nitrate
3. Manganese
4. Iron
5. Sulfate
6. Carbon dioxide

Reduction process

Explain why irrigated rice could not be planted in areas near beaches

1. Soil Texture

- sandy composition that provides good drainage. However, beach soils have low organic matter content due to less vegetation and organic matter decomposition

2. Soil Structure

- Loose and unconsolidated
- Limited aggregate formation
- Single grain structure

3. Water Retention

- Due to the sandy composition, beach soils drain quickly
- Proximity to the ocean can mean a fluctuating water table, affecting soil moisture
- rice is typically grown in flooded conditions, and if the soil is too sandy or well-draining, maintaining a flooded field can be challenging

4. Soil pH and Nutrient availability

- coastal soils can also exhibit higher pH levels due to salt accumulation, which may further limit nutrient availability.
- rice generally prefers slightly acidic to neutral pH levels (around 5.5 to 7.0)
- often low in organic matter and essential nutrients, which are crucial for healthy rice growth

5. Cation Exchange Capacity

- Coastal soils, especially those near beaches, are often sandy with low CEC.
- reduced ability to hold and exchange essential cations (positively charged ions) like calcium, magnesium, potassium, and sodium
- for rice, which requires a steady supply of these nutrients, low CEC can lead to nutrient deficiencies and poor growth.
- Due low CEC, sandy coastal soils are prone to leaching that limit nutrients

6. Salinity

- soils near beaches often have high salt concentrations due to the proximity to seawater
- coastal soils often have elevated salinity due to sea spray, tidal action, and the presence of saltwater
- High salinity can inhibit seed germination and plant growth, as rice is sensitive to salt levels

SBRTC

BIOLOGICAL PROPERTIES OF THE SOIL

Soil Organisms

- Diverse array of living organism that inhabit the soil and have the following functions:
    - Decomposition
    - Nutrient Cycling
    - Soil Structure Formation
    - Disease Suppression
    - Organic Matter Breakdown
    - Bioturbation
    - Symbiotic relationship

Classification of Soil Organisms based on Metabolism:

Type	Energy Source	Carbon Source
Photoautotrophs	Light	Carbon dioxide
Chemoautotrophs	Inorganic compounds	Carbon dioxide
Photoheterotrophs	Light	Organic compounds
Chemoheterotrophs	Organic compounds	Organic compounds

Classification based on Domain:

Domain	Cell type	Nucleus	Cell Wall composition	Habitat	Examples
Eukarya	Eukaryotic	Yes	Cellulose – plants Chitin – fungi	Diverse (terrestrial, aquatic, etc.)	Humans, plants, fungi, protists
Bacteria	Prokaryotic	No	Peptidoglycan	Everywhere	N-fixing cyanobacteria
Archaea	Prokaryotic	No	No peptidoglycan	Extreme environment	Methanogens Thermophiles Halophiles

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Major groups

1. Bacteria

- Prokaryotic, single-celled microorganism that lack true nucleus and membrane-bound organelles
- Morphological grouping
    - Cocci (spherical)
    - Rods (short, long, curved)
    - Spiral (vibrio)
- Based on oxygen requirement:

Type of Bacteria	Oxygen Requirement
Obligate Aerobes	Require oxygen for growth
Obligate Anaerobes	Cannot survive in the presence of oxygen
Facultative Anaerobes	Use oxygen when available but can switch to anaerobic or fermentation
Microaerophiles	Require lox oxygen levels (2-10%)
Aerotolerant	Do not use oxygen but can tolerate its presence

- Based on Temperature requirement:

Type of Bacteria	Temperature Requirement
Psychrophiles	-5°C to 15°C
Psychrotrophs	20°C to 30°C
Mesophiles	20°C to 45°C
Thermophiles	45°C to 70°C
Hyperthermophiles	70°C to 110°C

- Grouping based on gram reaction:

Type of Bacteria	Gram stain result	Cell wall structure
Gram-positive bacteria	Purple (Retains crystal violet dye)	Thick peptidoglycan layer, no outer membrane
Gram-negative bacteria	Pink/Red (Does not retain crystal violet dye, takes up safranin)	Thin peptidoglycan layer, outer membrane present

2. Fungi

- eukaryotic microorganisms which include yeasts, molds, and mushrooms; heterotrophic
- Most abundant in terms of biomass
- highly adaptable organisms that can thrive in a wide range of environmental conditions, including both acidic and alkaline environments

3. Actinomycetes

- Intermediate between bacteria and fungi
- Branched mycelial structures
- Known for decomposing more resistant organic materials such as chitin, a complex sugar found in the outer skeleton of insects and elsewhere

4. Algae

- photosynthetic organisms that can be found in various aquatic environments, including freshwater, marine, and damp terrestrial habitats
- Blue-green algae, green algae, diatoms
- Presence of heterocyst (specialized cell)
- Aerobic, photoautotrophs

5. Protozoa

- diverse group of single-celled eukaryotic microorganisms that can ingest food through oral openings
- Aerobic
- Reproduce either binary fission or budding
- Types: Flagellates, Ciliates, Amoeba

Earthworms

- Feed primarily on organic material in soils, eating fresh and decaying material from plant roots
- move the soil around and create tunnels that alter soil in a beneficial way
- Consumer carbon is processed and then excreted by earthworms is a key building block in a well-structured soil

Types of Earthworms

1. Epigeic

- *Eisenia foetida*
- Smallest
- Most pigmented
- Live mainly on leaf litter or surface soil and eat litter and soil microbes

2. Endogeic

- *Allolobophora caliginosa*
- Moderately sized
- Unpigmented
- Inhabit mineral level of the soil (Top 10-30 cm)

3. Anecic

- *Lumbricus terrestris*
- Live in permanent burrows in the soil
- Dorsally pigmented
- Feed on surface leaf litter that they drag down into their burrows

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Soil Organic Matter

- organic component of soil, which includes all decomposed or decomposing plant and animal material, microorganisms, and substances synthesized by soil organisms.
- Four components:
    - Living organism (soil biota) - <5%
    - Fresh residue – 10%
    - Stable OM (humus) – 33-50%
    - Decomposing OM – 33-50%

Components of Humus

1. **Fulvic acid** – lowest in molecular weight and lightest in color. Soluble both in acid and alkali.
2. **Humic acid** - medium in molecular weight and color. Soluble in alkali but insoluble in acid
3. **Humin** - highest in molecular weight and darkest in color. Insoluble both in acid and alkali

Roles of Soil Organic Matter

- Nutrient supply
- Improve soil structure
- Enhance water retention and infiltration
- Support microbial life
- Carbon sequestration
- Detoxifying pollutants and filtering water
- Reduce erosion and stabilize soil
- Increases CEC
- Buffer soil pH

C/N Ratio - crucial indicator of the balance between carbon and nitrogen in organic matter, such as plant residues, compost, and soil organic matter.

- Lower C/N ratio = faster rate of decomposition
- 20:1 – optimum C/N ratio

Compost - nutrient-rich organic matter produced through the decomposition of plant and animal materials. It is commonly used as a natural fertilizer and soil amendment to improve soil structure, fertility, and microbial activity.

- By products = water, heat, carbon dioxide

Composting - involves the breakdown of organic materials by microorganisms, such as bacteria and fungi, along with larger decomposers like earthworms and insects

Stages in Composting:

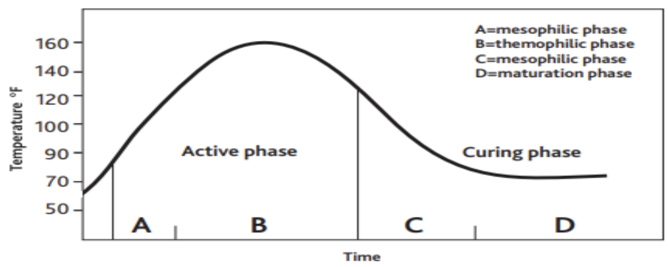

Figure 2. Temperature changes in an average compost pile. (Source: Cooperband, L. 2002. The Art and Science of Composting. Center for Integrated Systems, University of Wisconsin. http://www.cias.wisc.edu/wpcontent/uploads/2008/07/artofcompost.pdf [accessed November 6, 2010])

General phases: Active phase and Curing phase

1. Mesophilic stage (10-42°C)

- temperature rapidly rises and initiates organic matter decomposition

2. Thermophilic stage (65-50°C)

- Mesophilic microorganisms are replaced by thermophiles; these thermophiles breakdown complex carbon sources
- Turning over the compost is crucial for aeration, temperature, and moisture

3. Cooling stage (40-45°C)

- temperature is lowered down to 40-45 ºC. The mesophilic appears again and decomposes the remaining material of cellulose and lignin
- 2nd mesophilic

4. Maturation stage

- secondary reactions are produced that triggers condensation and polymerization of the humus

Vermicomposting - type of composting in which certain species of earthworms are used to enhance the process of organic waste conversion and produce a better end-product

- Vermi-cast - earthworm secretions which can improve biological, chemical, and physical properties of the soil

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Microbial Transformation of Nitrogen

1. Nitrogen fixation - process by which atmospheric nitrogen (N_2) is converted into a form that is usable by living organisms, primarily in the form of ammonia (NH_3) or related compounds

- Processes:
    - Lightning
    - Biological Nitrogen Fixation
    - Haber-Bosch

Biological Nitrogen Fixation

Symbiotic

- Rhizobium
- Bradyrhizobium
- Frankia

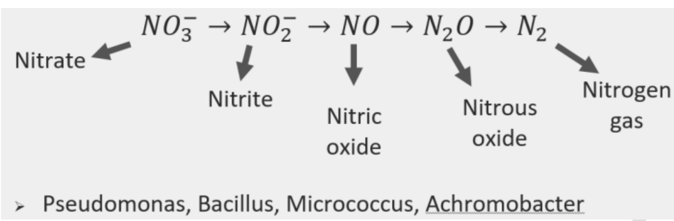
Non-symbiotic

- Azotobacter
- Clostridium
- Beijerinckia

2. Nitrification – 2-step process by which ammonia or ammonium is converted to nitrate

1. NH_4^+ to NO_2^- caused by *Nitrosomonas*
2. NO_2^- to NO_3^- caused by *Nitrobacter*

3. Denitrification - process nitrate (NO_3^-) and nitrite (NO_2^-) are reduced to nitrogen gas (N_2) or, to a lesser extent, nitrous oxide (N_2O)



4. Ammonification - conversion of organic nitrogen from decomposing organic matter into inorganic ammonia (NH_3) or ammonium ions (NH_4^+)

Mineralization - process by which ORGANIC NITROGEN (and other nutrients) in decomposing organic matter is converted into INORGANIC FORMS, such as ammonium (NH_4^+)

- Nutrients are released

Immobilization - conversion of inorganic nitrogen (such as ammonium and nitrate) into organic forms by microorganisms and plants

- nutrients are assimilated by living organisms

SOIL FERTILITY AND MANAGEMENT

Soil Fertility – capability of soil to provide essential nutrient in right amount

Soil Productivity – ability of soil to support or produce a desired quantity of plant yield

Plant Nutrition - study of the chemical elements and compounds that are necessary for plant growth, metabolism, and overall health. It focuses on how plants absorb, transport, and utilize nutrients from the soil and environment to support their physiological processes, such as photosynthesis, respiration, and reproduction.

Essential elements - elements or compounds that are required by plants to complete their life cycle, including growth, reproduction, and metabolic functions. These nutrients are vital for various physiological and biochemical processes, and plants cannot substitute them with other elements.

Criteria for Essentiality:

1. A plant cannot complete its life cycle without the nutrient.
2. The function of nutrient is specific and irreplaceable by another element.
3. The nutrient must be directly involved in the plant's metabolism or structure.

Element	Symbol	Function
Carbon	C	Fundamental component of all organic molecules, including carbohydrates, proteins, and fats
Hydrogen	H	Involved in energy transfer and is a component of water (H_2O) and organic compounds.
Oxygen	O	Major component of organic molecules and water; critical for respiration and photosynthesis
Nitrogen	N	Key component of amino acids, proteins, nucleic acids, and chlorophyll. Promotes leaf growth.
Phosphorus	P	Vital for energy transfer (ATP), root development, flowering, and fruiting.
Potassium	K	Regulates water balance, enzyme activation, and improves disease resistance.
Calcium	Ca	Strengthens cell walls, involved in cell division and root growth
Magnesium	Mg	Central element in chlorophyll, activates many plant enzymes.
Sulfur	S	Integral to amino acids and proteins, important for chlorophyll formation.

Element	Symbol	Function
Iron	Fe	Essential for chlorophyll synthesis and respiration; acts as a cofactor in enzyme reactions.
Copper	Cu	Plays a role in photosynthesis, enzyme activation, and lignin synthesis.
Zinc	Zn	enzyme for chlorophyll synthesis, auxin production, and protein synthesis.
Manganese	Mn	Involved in photosynthesis, respiration, and nitrogen assimilation.
Molybdenum	Mo	Involved in nitrogen fixation and nitrate reduction in plants.
Boron	B	Necessary for cell wall formation, sugar transport, and reproductive development.
Chlorine	Cl	For osmosis and ionic balance, assists in photosynthesis (splitting of water).
Nickel	Ni	Component of the enzyme urease, which is important for nitrogen metabolism in plants.
Sodium	Na	Osmotic regulation, key enzyme in C4 and CAM pathways

Beneficial Elements - elements that are not considered essential for all plants but can promote growth, improve stress tolerance, or enhance other physiological functions in certain plant species.

Mechanisms of Nutrient Uptake

1. **Mass Flow** – movement of nutrients to the roots through water
2. **Diffusion** – nutrients or ions move from higher to lower concentration (**P and K**)
3. **Root interception / Contact Exchange** – root comes in contact with soil colloids containing nutrients

Mobile elements - nutrients that can move within the plant from older tissues to younger tissues. Therefore, deficiencies typically manifest in older leaves first

- N, P, K, Mg, Zn

Immobile elements - cannot move within the plant, so deficiencies usually appear in younger leaves first

- Cu, Mn, Bo, S, Ca, Fe

Liebig's Law of Minimum

- proposed by the German chemist Justus von Liebig in the 19th century
- states that the growth and development of an organism is limited by the scarcest resource or nutrient, rather than the total amount of resources available

Mitscherlich Law

- When a deficient nutrient is added to the soil, the plant's growth increases, but each additional unit of that nutrient provides progressively smaller increases in growth. Initially, the growth response is significant, but as the nutrient levels approach sufficiency, the benefit of adding more decreases

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Nutrient Levels

Level	Definition	Effects
Deficient	Below required amounts	Stunted growth, poor yield, visible deficiency symptoms (e.g., yellowing leaves).
Sufficient	Adequate for optimal growth	Healthy foliage, robust growth, and productive yields.
Excess	Exceeds necessary amounts	Potential toxicity, symptoms like leaf burn, nutrient imbalances.
Toxic	Extremely high levels	Severe damage to plants, including leaf drop and root damage, leading to plant death in extreme cases.

Deficiencies

1. Nitrogen

- Chlorosis of older leaves
- Stunted growth
- Poor fruit and seed development
- Overall reduced vigor

2. Phosphorus

- Dark green or purplish leaves (older leaves)
- Stunted growth
- Poor root development
- Delayed maturity

3. Potassium

- Marginal chlorosis or necrosis on older leaves
- Weak stems
- Poor fruit quality
- Susceptibility to pest and diseases

Element	Deficiency
Nitrogen	Chlorosis (yellowing) of older leaves; stunted growth; poor fruit and seed development; overall reduced vigor.
Phosphorus	Dark green or purplish leaves, especially on older leaves; stunted growth; poor root development; delayed maturity.
Potassium	Marginal chlorosis or necrosis on older leaves; weak stems; increased susceptibility to diseases and pests; poor fruit quality.
Calcium	New growth is stunted or distorted; blossom end rot in fruits; tip burn in lettuce; poor root development.
Magnesium	Interveinal chlorosis on older leaves; leaf curl; general yellowing; poor fruit quality; premature leaf drop.
Sulfur	Uniform yellowing of younger leaves; stunted growth; delayed maturity; light green foliage.

Element	Deficiency
Iron	Interveinal chlorosis of young leaves; leaves may turn completely yellow; small, stunted leaves; poor fruit development.
Copper	Dark green leaves; dieback of young shoots; stunted growth; wilting; poor seed production
Zinc	Interveinal chlorosis; leaf curling or deformation; reduced internode length; poor fruit set; "rosetting" of leaves.
Manganese	Interveinal chlorosis on young leaves; small, pale leaves; necrotic spots; poor fruit quality.
Boron	Death of growing points; flower and fruit drop; corking of fruit; stunted growth; wilting of leaves.

Symptoms Beginning in Older Leaves (Mobile)

1. Nitrogen

- Symptoms appear on leaves as a v-shaped yellowing, starting at the tip and progressing down the midrib toward the leaf base

2. Phosphorus

- Dark green with reddish purplish leaf tips and margins on older leaves
- Phosphorus deficient plants are smaller and grow more slowly than do plants with adequate phosphorus

3. Potassium

- Yellowing and necrosis of the corn leaf margins, beginning on the lower leaves
- When potassium deficiency is severe, older leaves turn yellow with tissue necrosis along the margins, but the upper new leaves may remain green
- deficient corn tends to lodge late in the growing season due to poor stalk strength

4. **Magnesium**

- first seen as yellow to white interveinal striping of the lower corn leaves
- Dead, round spots sometimes follow, which give the impression of beaded streaking
- Older leaves become reddish-purple, and the tips and edges may become necrotic if the deficiency is severe
- favored by very acid, sandy soils in regions of moderate to high rainfall where magnesium has been extensively leached from the soil profile

Symptoms Beginning in New Leaves (Immobile)

1. Calcium

- appears on younger leaves with light green or whitish spots on tips of corn and leaf tips stick to the next lower leaf and may be severely stunted.

2. Iron

- appears as chlorosis on younger leaves to become pale green to yellow
- interveinal area along the length of the upper leaves pale green to nearly white

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3. Manganese

- Newly emerged leaves become olive green and may become slightly streaked
- If the condition is severe, deficient leaves become elongated with white streaks that turn brown in the center, deteriorate and fall out

4. Sulfur

- shows on small corn plants as a general yellowing of the foliage, similar to nitrogen deficiency
- Yellowing of the younger upper leaves is more pronounced with sulfur deficiency than with nitrogen deficiency
- Stunting of plants and delayed maturity also are symptoms
- Interveinal chlorosis of the youngest leaves may occur
- favored by acid sandy soils; low soil organic matter

5. Zinc

- interveinal, light striping or a whitish band beginning at the base of the leaf and extending towards the tip
- margins of the leaf, the midrib area, and the leaf tip usually remain green

6. Copper

- youngest leaves are yellow as the emerge from the whorl and leaf tips die back and are twisted
- Copper deficiency is favored by organic soils (very high soil organic matter) and by high soil pH (above 7.5)

7. Boron

- Leaves have small dead spots and are brittle
- favored by drought; sandy soils that are low in organic matter; and high soil pH
- stunted growth and either yellow or white spots

Fertilizer Computation

How many kg/ha Urea (46-0-0) is needed to satisfy the fertilizer recommendation of 90-0-0

$$kg\ urea/ha = \frac{90}{0.46} = 195.65$$

How many bags of urea?

$$bags\ urea/ha = \frac{195.65kg}{50kg} = 3.913 \approx 4$$

How many kg/ha complete fertilizer (15-15-15) is needed to satisfy the fertilizer recommendation of 90-90-90

$$kg\ CF/ha = \frac{90}{0.15} = 600$$

How many bags of CF?

$$bags\ CF/ha = \frac{600\ kg}{50kg} = 12$$

How many bags of the following fertilizers are needed to satisfy the fertilizer recommendation of 75-60-35?

CF = 15-15-15 ✓ **5 bags**
AP = 16-20-0 ✓ **3 bags**
AS = 21-0-0 ✓ **2 bags**

$$CF = \frac{35kg}{0.15} = 233.33kg \approx 4.6\ bags \approx 5\ bags$$

$$AP = \frac{60kg - (233.33kg\ x\ 0.15)}{0.20} = 125.025\ kg \approx 2.5\ bags \approx 3\ bags$$

$$AS = \frac{75kg - [(233.33kg\ x\ 0.15) + (125.025\ kg\ x\ 0.16)]}{0.21} = 95.24\ kg \approx 1.9 \approx 2\ bags$$

How many tons of chicken manure (3-2-2) is needed to satisfy the fertilizer recommendation of 90-90-90?

$$Amount\ of\ manure\ required\ for\ K = \frac{90kg}{0.02} = 4500kg$$

$$Amount\ of\ manure\ required\ for\ P = \frac{90kg}{0.02} = 4500kg$$

$$Amount\ of\ manure\ required\ for\ N = \frac{90kg}{0.03} = 3000kg$$

How many tons of chicken manure (3-2-2) is needed to satisfy the fertilizer recommendation of 90-90-90?

Phosphorus and potassium are the most limiting nutrients. Therefore, 4500kg of chicken manure is needed.

$$Chicken\ manure = 4500kg\ x\ \frac{1\ ton}{1000kg}$$

$$\boxed{Chicken\ manure = 4.5\ tons}$$

Soil Survey - systematic examination, description, classification, mapping, and characterization of soils in an area and evaluation of its agronomic potential (BSWM)

Soil Classification

- concerns the grouping of soils with a similar range of properties (chemical, physical and biological) into units that can be geo-referenced and mapped
- the systematic categorization of soils based on distinguishing characteristics as well as criteria that dictate choices in use

USDA Soil Taxonomy - a classification system developed by the United States Department of

Agriculture (USDA) to systematically categorize soils based on their characteristics and properties.

Levels of Classification:

1. Order
2. Suborder
3. Great Group
4. Subgroup
5. Family
6. Series

Order	For. el.	Description
Alfisol	alf	Argillic B horizons with high base saturation; fertile forest soil
Andisol	and	Formed from volcanic ash and volcanic materials; high P fixing capacity
Aridisol	id	Soils of arid regions; limited change in parent material due to dryness
Entisol	ent	Recently formed soil, no profile development
Gelisol	el	Presence of permafrost
Histosol	ist	Organic soil

Order	For. el.	Description
Inceptisol	ept	Embryonic soil with few diagnostic features
Mollisol	oll	Grassland soils of steppes and prairies; very high base saturation
Oxisol	ox	Highly weathered soil with B horizon containing 1:1 (Kaolinite)
Spodosol	od	Acidic sandy soil with thick E horizons; subsoil with accumulation of Fe and Al oxides
Ultisol	ult	B horizon with significant amount of clay but low degree of base saturation; more weathered than alfisol
Vertisol	ert	Show large cracks due to dominance of montomorillonites

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Soil Order in the Philippines

- of the 12 soil orders in Soil Taxonomy, **9** can be found in the Philippines
- Three soil orders in Soil Taxonomy are not found in the country—Gelisols (permafrost soils), Aridisols (soils of the dry region), and Spodosols (soils with subsoil accumulations of humus and sesquioxides)
- It should be noted that considering advances of pedology in the Philippines, the presence of Spodosols in the country is now a subject of study.
- There are Spodosols in the Cordillera-Sierra Madre mountains with soil formation and development conditions similar to the Spodosols of Vietnam. The soil series we are yet to establish.

1. Entisols (-ent)

- Recently formed soils, no profile development
- little or no evidence of the development of pedogenic horizons

2. Inceptisols (-ept)

- Embryonic soils with few diagnostic features
- have profile features more weakly expressed than those of many other soils and retain a close resemblance to their parent material

3. **Vertisols (-ert)**

- Shrinking and swelling dark clay soils
- Pedoturbation, slickensides
- major process seems to be shearing of wet, plastic soil materials, which may result in argillipedoturbation
- generally utilized for rice production; and in fact, its best land use
- dominated by montmorillonite

4. **Andisols (-and)**

- Soils with andic properties
- Formed from volcanic ejecta/tephra (ash, cinder, pumice, basalt)
- soils with properties dominated by short-range-order compounds such as aluminosilicates, ferrihydrite, and organometallic complexes
- Presence of allophane and imogolite
- Very light, low bulk density
- High P-fixing capacity

5. Mollisols (-oll)

- Grassland soils of steppes and prairies
- characterized by having a deep, dark, friable and relatively fertile surface horizon (or horizons) known as a mollic epipedon
- high organic carbon content

6. Alfisols (-alf)

- High-base status soils with finer-textured subsoils
- forest soils that occupy relatively stable landscape positions and thus have a subsurface zone of clay accumulation

7. Ultisols (-ult)

- Low-base status soils with finer-textured subsoils (low base saturation <35%) □ called "LOW ACTIVITY CLAY"
- form in acidic parent materials in locations where precipitation exceeds potential evapotranspiration during a portion of most years
- Dominated by kaolinite (red soil and acidic)

8. **Oxisols (-ox)**

- Low-activity clay
- Very weathered soils; low base sat. and CEC
- Older than ultisols

9. **Histosols (-ist)**

- soils developed from the decay of vegetation under wetland conditions
- Organic soils saturated with water for at least 30 days or are artificially drained and contain ≥12 to 18% organic carbon by weight, excluding live roots, depending on clay content