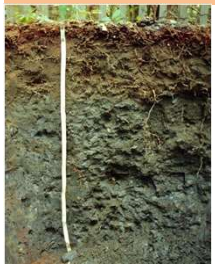
Soil Genesis



Content

- Factors of soil formation
- Soil profile
- Formation of soil horizons
  - *Master horizons & subordinate horizons*
  - *Diagnostic horizons*
- Processes of soil formation

What is soil?

- Soils are often defined as "dynamic natural bodies having properties derived from the combined effect of climate and biotic activities, as modified by topography, acting on parent materials over periods of time" (Brady and Weil, 2007).

Soil Genesis/ Formation of Soils

Five soil-forming factors

1. Climate*
2. Vegetation and living organisms/biosphere*
3. Parent material (PM)*
4. Topography*
5. Time or age of the landscape*

* Active factors

* Passive factors

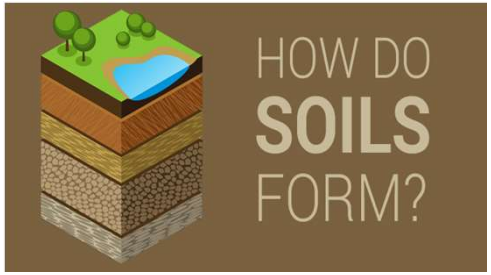
Aim

The aim of this section is for students

- To understand how the 5 major soil forming factors influence soil development.
- To understand how the soil horizons form
- To understand soil forming processes

Learning Objectives

- Identify the 5 factors of soil formation.
- Explain the effects of each of the factors on soil formation.
- Explain the soil horizons and formation.
- Identify 2 major soil forming processes.



1. Climate

- Depends on Temperature, Precipitation (MC-rain/snow etc…) & Wind (seasonal changes like in winter storms…etc.)
- SL – Tropical country with 3 climatic zones
- Wet Zone, Intermediate Zone, Dry Zone

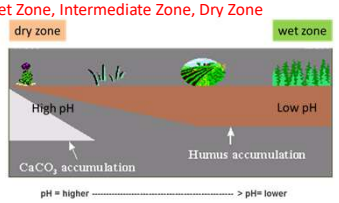
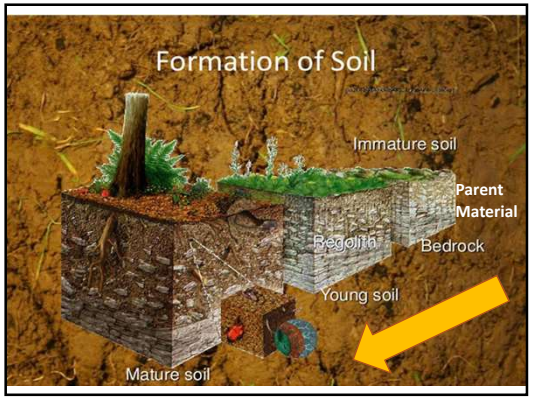


Figure 1. The general effect of climate on soil pH, $CaCO_3$ and humus accumulation, from the dry to wet zone

- Wet Zone: High precipitation /high MC enhances the soil genesis
- more precipitation, which promotes $CaCO_3$ dissolution and movement downward into the subsurface, where it re-precipitates
- soil surfaces will have a lower pH, while subsoil pH will be higher.
- Increase in moisture promotes more plant and microbial growth.
- Plant litter falls to the soil surface where it is decomposed by microorganisms and turned into humus (soil organic matter).
- This accumulation of humus generally decreases soil pH.

2. Vegetation and living organisms

- **Micro-organisms, plants, animals, and humans affect soil formation**
- **Animals and micro-organisms (MO) mix soils**
- **Soil MOs play a vital role in the degradation of organic matter and humus formation.**
- **These Humus acts as a gluing agent, essentially holding primary soil particles (sand, silt, clay) together to form secondary aggregates or 'peds'.**
- **Further, MOs affect chemical exchanges between roots and soil**
- **Plant roots open channels in the soils**
- **Different types of roots have different effects on soils**
  E.g. Grass roots are "fibrous" near the soil surface and easily decompose, adding organic matter. Taproots open pathways through dense layers.
- **Influence of human activities (fires, deforestation, tillage..etc.)**



Dry Zone: Low precipitation slow down the soil genesis

-less removal of soluble products; therefore rich in many soluble nutrients (higher fertility, high % of bases)

-Low biomass production (low content of soil organic matter)

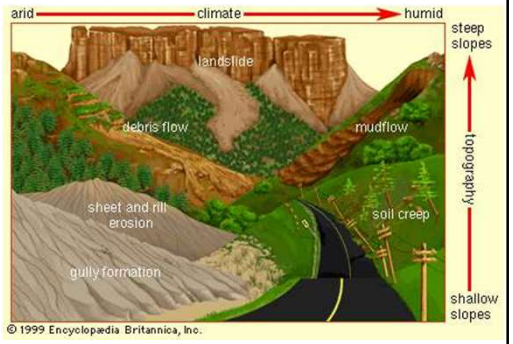
-lack of moisture and high temperatures promote evaporation and thus for example, $CaCO_3$ (lime) materials accumulate near the surface making soil pH higher (Alkaline soil or low acidic soil).

3. Parent material

- The material in which soils form is called "parent material (PM)"
- parent material is not static (dynamic).
- classified based on its mode of transportation: ice, water, gravity, wind, lakes and oceans.
- PM rich in limestone ($CaCO_3$)- delay in soil development due to alkaline condition

4. Topography

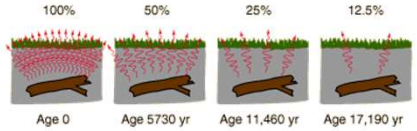
- Differences in elevation & slope or landform
- Influence on drainage, organic matter accumulation, and profile development
- Topography has a strong influence on soil development.
- Soils on the side of hills tend to be shallow, due to erosional losses.
- Soils on the tops of hills tend to be deep, but lighter in color, due to downward leaching losses.
- Evident in the gently undulating landscape of DZ – reddish brown in colour & lower adjacent is grayish brown in colour



For your knowledge

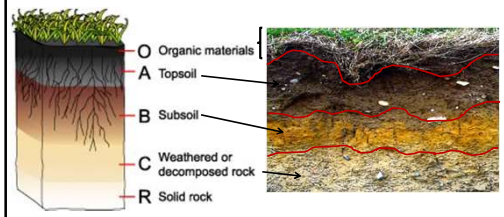
Q:What is Carbon dating?

- Find what is carbon dating and bring the answer to the next class…



Soil Profile contd.

- Definition: A vertical exposure of a soil consisting of various soil horizons which are differ from each other in their physical, chemical and biological properties is called a **soil profile**



5. Time

- Soil formation processes are continuous
- Over time, soils exhibit features that reflect the other forming factors
- Soil develop very slowly (several thousand years to million years)
- According to the time changes soil can be recognized as young soil, mature soils and old soils
- Indirect methods such as Carbon dating can be used to assess the approximate time

Soil Profile

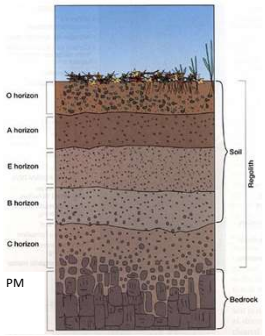
- During soil formation, new formed secondary minerals and primary minerals (from PM) may accumulate where they are formed or move downward and accumulate in lower soil zones
- As materials are removed from one layer and accumulate in another, soil horizons are formed
- Soil layers (horizons) are approximately parallel to the land surface and several horizons may develop simultaneously over a period of time
- The soil horizons are differ from each other in their physical, chemical and biological properties

Formation of soil horizons

- **Soil Horizon**: A layer of soil approximately parallel to the land and differing from adjacent related layers in physical, chemical and biological properties
- Horizonation (Formation of soil horizons) results from **gains, losses, transformations and translocations** that occur overtime within various parts of a vertical section of the PM

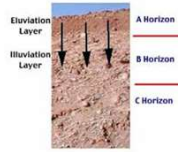
Examples of the major kinds of changes that occur to produce horizons are;

1. **Gains-**Addition of OM from plant growth (top soil)
2. **Transformations-** Weathering of rocks and minerals & decomposition of OM
3. **Losses-**Loss of soluble components by water moving downward
4. **Translocations-** Movement of suspended mineral & organic particles from the top soil to the sub soil



Formation of B Horizon

- The C horizon under favorable conditions develops a different layer and some other properties that distinguish of from the A horizon and forms an altered sub soil called B horizon



- This weakly developed B horizon can be distinguished primarily by color, arrangement of soil particles, and OM

Formation of E horizon

- The downward translocation of colloids from the A horizon may result in the concentration of sand & silt particles of quartz in the upper part of many soils
- As a result, a light colored E horizon may develop at the boundary of A & B horizons
- This is normally grayish in colour
- E horizon consists of low OM content
- It contains silt & sand sized particles of quartz & other resistant materials

Formation of A & C Horizons

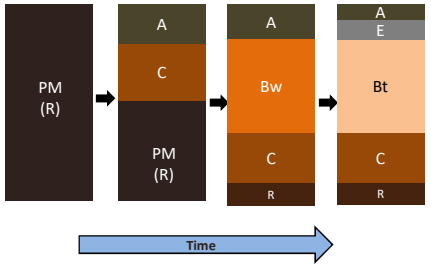
- The resistant OM which is called 'humus' has black or dark brown colour
- This accumulated OM form the A horizon
- The A horizon is the upper most horizon of many soils
- At this stage the upper part of PM has been slightly altered
- This part is known as the C horizon
- The soil at this stage of evolution has 2 horizons (A & C horizons)
- Such soils are called 'AC soils'

- A weakly developed B horizon is symbolized as Bw (weakly developed character-distinctive colour or structure)
- The clay produced by weathering tends to be slowly translocated downward from A horizon to the B horizon by percolating water
- When significant increase in clay content of a Bw horizon it becomes a Bt horizon

Formation of O horizon

- In some cases extreme wetness and acidity at the surface of the soil are unfavorable for decomposition of OM
- The result is formation of O horizon on the top f the soil
- 'O' refers to soil layers dominated by organic material

Development of soil horizons in a parent material



Special characters of subordinate distinctions

Letter	Distinction
a	Organic matter; highly decomposed
b	Buried soil horizon
c	Nodules/concretions
e	Organic matter; intermediate decomposed
f	Frozen soil
h	Illuvial accumulation of OM
i	OM; slightly decomposed
k	Accumulation of carbonates
m	Cementation or hardening
n	Accumulation of sodium
o	Accumulation of Fe & Al oxides
t	Accumulation of silicate clays
w	Distinctive color or weak structure

Podsolization

- Podzolization is the process leading to the formation of Podzols
- It takes place under condition where climate is sufficiently cool (humid)
- It was first reported in the temperate countries or closer to polar regions, East Asia & North America (not in SL)
- **Podzolization** is the comprehensive name for the process of mobilization and precipitation of dissolved organic matter, together with aluminum and iron as they leach down from the A and E horizons to the B horizon
- The complexes move to the brown, red or black horizon, which consist of cemented and/or organic compounds
- The process of podzolization usually occurs under low pH values

Master horizons

- Six master horizons are recognized
- Use capital letters O, A, E, B, C, and R (top to bottom within the soil profile)
- Not all of these layers are present in every location

Transitional horizons

- These are transitional between the master horizons
- Eg. AE, EB, BE, and BC
- The dominant one is listed first (eg. AE- A horizon is dominant)

Subordinate distinctions

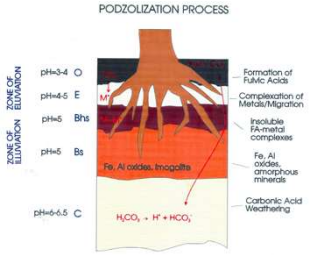
- Master horizons are further characterized by specific properties such as distinctive color or the accumulation of materials such as clays and salts
- These SD are identified by using lower case letters that designate specific characteristics

Processes of soil formation

- Identifying various soil forming processes does not mean that such processes are mutually exclusive can be rigidly separated
- They are linked into one another or are super imposed on each other

1. **Podsolization**
2. **Latosolization**
3. **Salinization, Solonization & solodization**
4. **Calcification**
5. **Gleization**

- The corresponding soil type is called **Podzol**
- Podzols are not good as soil for farming due to the sandy portion, resulting in a low level of moisture and nutrients
- The best agricultural use of Podzols is for grazing



•Under the cool climate OM decomposition is incomplete and large quantities of organic acid such as Fulvic acids are formed
• The formation of these acids result in a low pH in the soil

Latosolization

- Found in SL
- Old term "laterization"
- Describe the formation of soil rich in Fe &/or Al oxide and lower in Silica than most other soils
- According to Fanning & Fanning (1989) the term Laterization is applied to the genesis of Plinthite ('කබොක්')kabok
- In Latosolization, Silica & bases are considered to be preferentially lost by solution & leaching, form oxides, hydroxides & oxyhydroxides (Al, Fe, Ti) and minerals such as kaolinite

- It is economically most important for the formation of lateritic deposits (Plinthite)

Iron stone

- Found mostly in wet zone in SL (warm T)
- Iron oxides are accumulated in a soil material
- As the ion is not added evenly throughout the material the formation is commonly referred as vascular or nodular
- The hardened form of Laterite is known as 'ironstone'

Salinization, Solonization & solodization

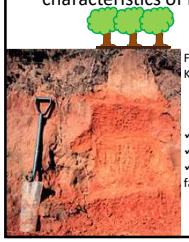
- Salinization, Solonization & solodization are 3 succeeding processes in the formation of saline-alkaline soils

Salinization

- Salt accumulates in the surface horizons of the soil (salt crust)-Salic horizon
- Irons, which precipitates as salts by dessication commonly are brought to the soil surface by capillary rise from deeper horizons
- These irons deposited as salts have various origin
  - Released by weathering of minerals
  - Present in seas that dries up
  - Brought by Rainfall (small amount)
  - Leached from Saline rocks

Latosolization contd.

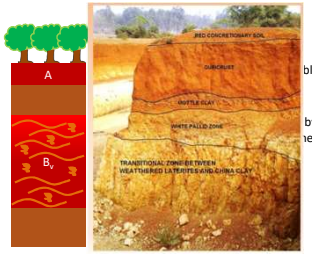
- Occurs in monsoonal climatic regions
- If continued for a long period of time (100/1000 years) oxic horizon may form
- Due to extreme weathering, the soil profile is deep & characteristics of PM are less dominant



Form Oxic horizons
Kaolinite, Gibbsite, Hematite, Geothite minerals are formed

✓Uniform red colours
✓Very low CEC
✓Rocks high in weatherable minerals (Basalt, Serpentine) favor the latasolization

- Laterites form in areas where the drainage is restricted; the groundwater table is close to the surface
- Form over igneous or sedimentary rocks including limestone or alluvium

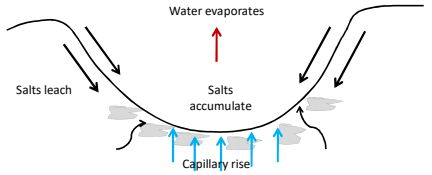


ble-pinthite or not

by re-distribution within
ena

Salinization contd.

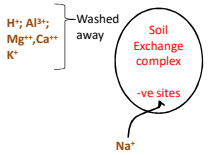
- Salts produced by salinization is known as '**Solonchaks**' or '**Salorthids**'
- The soils produced by salinization are sometimes known as white alkali soils



Diagrame of salinization in an arid region

Solonization

- Is the process to the formation of a '**solonetz**' (a black alkali soil)
- In this process, soluble salts are leached away (naturally or artificially) leaving an exchange complex saturated dominantly with Na

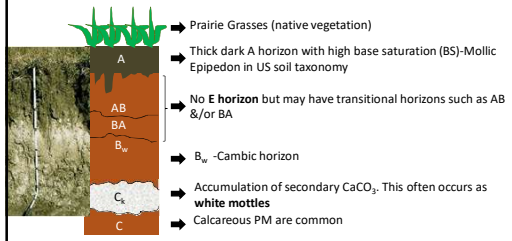


- Therefore a very high pH (sometimes as 10) may develop

Calcification

- The calcification is the major process in soils of good drainage in semi arid to arid regions with calcareous (carbonate bearing) PM
- Calcium is the major cation on the exchange complex of such soils
- Ca is provided by weathering of primary carbonate minerals (mainly calcite & dolomite) of the PM but some from ca-bearing silicates
- In low RF areas due to plant transpiration process the $CaCO_3$ will come to the surface by water movement (Deposited in B horizon)
- A horizon is dark colour

Calcification contd.



profile of a Mollisol

Solodization

- Solodization is the process leading to a '**solodized solonetz**' or '**soloth**'
- With continued leaching of the upper part of the solonetz, the soil becomes more acidic or Na^+ is lost
- In this process Na^+ in the exchange complex is replaced by H^+ ions resulting an increase in soil acidity
- The dispersed OM & clay (natric horizon) moves deeper into the soil
- Not suitable for agriculture

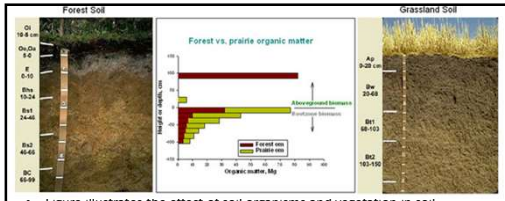
Calcification contd.

- Underground decomposition of organic material in the presence of bases produces calciuim humates
- Ca-humate is referred to ca-saturated humic acid type of humified organic matter
- The OM added in the soil by the root systems of grasses is apparently very important for the formation of these soils
- The dark colours of A, and sometimes upper B horizons may largely result from Ca humate
- The Ca apparently slows the rate of decomposition of this type of OM, so the OM content of calcification affected soils is typically quite high
- The soils formed as a result of calcification usually have thick dark A horizons
- This process leads to the formation of Chernozem/Mollisol

Gleization

- Gleization (from Russian 'Gley': clay; Polish 'Glej': muddy ground
- Formed in response to wetness-induced reduction of iron (from Fe^{3+} to Fe^{2+})
- The Fe as Fe^{2+} solubilized by this process & commonly leaches or diffuses within the soil profile, or may leach from soil
- The reduction id typically followed by oxidation of Fe2+ to Fe3+ and precipitation of iron oxides, which includes oxyhydroxides such as FeOOH (Ferric oxyhydroxides)
- The reduce process give gray colours and oxidation give rust colours
- Poorly drained (low humic gley) or very poorly drained (humic gley) soils; **Aquic sub groups**

Any Questions?



- Figure illustrates the effect of soil organisms and vegetation in soil formation.
- The percentage of humus content tends to be greater in grassland soils, as compared to forest soils.
- Thus dead grassland plants have neutral to basic pH and forest covers have acidic pH.
- The relatively basic pH of the grassland help microorganisms to degrade organic matter easily.
- Oppositely, in forests organic matter is more difficult for microorganisms to degrade.
- Thus, the humus content of forest soils tends to be less than grassland

Diagnostic horizons

- Soil horizons that have a set of quantitatively defined properties which are used for identifying soils are called diagnostic horizons
- These are called 'epi-pedons'
- They are considered to be "**diagnostic**" when they reach a minimum degree of expression, which is determined by appearance, measurability, importance, relevance and quantitative criteria
- To be considered diagnostic, soil horizons also require a minimum thickness
- The five naturally-occurring epi-pedons are called the mollic epipedon, umbric epipedon, ochric epipedon, melanic epipedon, and histic epipedon (will discuss later).

What is carbon dating?

the determination of the age or date of organic matter/soil from the relative proportions of the carbon isotopes carbon-12 and carbon-14 that it contains. The ratio between them changes as radioactive carbon-14 decays and is not replaced by exchange with the atmosphere.

- The acidic nature of the forest litter, however, causes acids to flow through the soil profile and help to develop horizons quicker than a grassland soil.
- The acids can dissolve soil materials and re-deposit them deeper in the soil, which helps to more quickly create horizons.
- It also illustrates that humus content decreases with soil depth.
- This makes sense, because humus is derived from decaying plant material which originates at or near the soil surface.