RAMA UNIVERSITY

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FACULTY OF AGRICULTURAL SCIENCES & ALLIED INDUSTRIES

PEDOGENIC OR SOIL FORMING PROCESSES

The geological weathering produces weathered rock material i.e. the parent material and when the genetic factors set the stage for soil development . The pedogenic processes change the parent material in to soil with varying horizonations.

The pedogenic processes are extremely complex and dynamic involving many chemical and biological reactions, and usually operate simultaneously in a given area. One process may counteract another, or two other processes may work simultaneously to achieve the same result.

The relationship between pedogenic processes and genetic factors contributes in some manner or another, to the pedogenic development of each mature soil. All the genetic factors contribute to the development of each soil, but no single soil is influenced by all pedogenic processes.

The basic pedogenic processes involved in soil formation, according to Simonson (1959) include:

* *Gains or additions of water (mostly as rainfall) organic and mineral matter to the soil.*

* *Losses of above material from soil.*

* *Transformation of mineral and organic substances with in the soil.*

* *Translocation or movement of soil materials from one point to another with in the soil. It is usually divided in to i) movement in solution (leaching) and ii) movement in suspension (eluviation) of clay, organic matter and hydrous* oxides.

In contrast, the major cha nges that retard or offset horizon differentiation are due to :

- ✓ Mixing of materials by burrowing animals.

- ✓ Removal of surface soil by erosion (water or wind)
- ✓ Creep (by shifting old and its replacement by new materials); and
- ✓ Accretion of sediments in cultivated flood – plain areas, for instance silting of irrigated areas

BASIC / FUNDAMENTAL PEDOGENIC PROCESSES:

HUMIFICATION: Humification is the process of transformation (decomposition) of raw organic matter in to 'HUMUS'. It is an extremely complex process involving various organisms such as bacteria, fungi, actinomycetes, earth worms and termites.

The decomposition of organic matter takes place in two phases: mineralization and humification. Mineralization is a biochemical breakdown of dead plant tissues by soil microorganisms to produce simple structured soluble organic substances, mineral compounds, metal cations and gases (CO_2). During the second phase, that is humification, soluble organic substances regroup themselves in to large molecules by polymerization and become poorly soluble. They form major part of soil humus and provide site for retention of cations. The other part of humus is the polysaccharides – gummy products of microbial excretions, which help in soil aggregation.

The activities of microorganisms and soil formation are as under:

Mor : It refers to surface soil horizon developed under acid litter and humus from coniferous and heath vegetation, where fungi activity predominates.

Mull : Designated as forest soil horizon (A1) is of intimately mixed mineral matter and amorphous humus. It is slightly acid and is best developed under base rich litter, where bacterial activity predominates.

Sward: Is a dominantly rhizogenous A_1 horizon in grasslands as contrasted with zoogenous mull horizon of forest soils. This includes mollic epipedon or Ap horizon formed by cultivation of forest soils, in general.

Orterde: Is a humus rich B horizon in podzols.

ELUVIATION : Eluviation means "Washing out". It is the proc ess of removal of constituents in suspension or solution by the percolating water from the upper to lower layers. The eluviation encompasses mobilization and translocation of mobile constituents resulting in textural differences.

Mechanical movement of clay and iron oxides from 'A' horizon without undergoing chemical alteration – Lessivage (Dachaufour, 1977).

Leaching refers to the movement and removal of material in solution from the soil. It connotes the removal of the dissolved material from the entire solum.

Elemental mobility

$$Ca^{2+}\ Na^{+} > K^{+}, Mg^{2+} >>>> Fe^{2+} >> Si^{4+} >> Al^{3+}$$

(Most mobile) (Least mobile)

The leaching of an element depends not only on its relative mobility but also on the rate of water percolation through the soil. The effect of leaching is well illustrated with the depth of accumulation of $CaCO_3$ in soils (Jenny, 1941).

Hot arid zone	- < 50 cm
Less hot semi arid zone	- 100 – 150 cm
Sub humid zone	- >150 cm

Illuvation

The process of deposition of soil materials (remo ved from the eluvial horizon "E") in the lower layer (or horizon of gains having the property of stabilizing translocated clay materials) is termed as "illuviation". The horizons formed by this process are termed as illuvial horizons (B-horizon especially Bt).

All these basic pedogenic processes, combine to result in a number of wide ranging soils that are observed on surface of the earth.

Hot semi arid	- Calcisol
Cool humid	- Podsol
Hot humid	- Ferralsol

Specific pedogenic processes

The basic pedogenic processes provide a frame work for later operation of more specific processes.

Calcification

The process of precipitation and accumulation of calcium carbonate in some part of the profile is called calcification. This is a common process in arid and semi-arid regions, which are low in rainfall (Rainfall<PET).

The illuviated horizon of $CaCO_3$ is designated as 'calcic horizon' .

Whenever high carbon dioxide is produced in soils, it combines with water and forms into carbonic acid. This dissolves the calcium carbonate in soils into soluble

calcium bicarbonate, which moves along the percolating water. Again wherever a situation of high temperature and low carbon dioxide prevails, there calcium carbonate precipitates.

$$CO2 + H2O \ ? \ H2CO3$$

$$H_2CO_3 + Ca \longrightarrow Ca(HCO_3)_2$$

$$Ca(HCO_3)_2 \xrightarrow{? \text{ temp}} 2CaCO_3 + 2H_2O + 2CO_2 \downarrow CO_2$$

The calcium compounds are in solution as long as the CO_2 concentration or supply is maintained. The depth of "calcic horizon" depends on percolating rain water, ground water depth, amount of rainfall and the texture of the soil.

The depth of calcareous layer In hot arid zone-<50cm, in semi arid zone 100-150cm and in sub-humid zone the calcium carbonate accumulates at a depth of >150cm

DECALCIFICATION : It is the reverse of calcification that is the process of removal of $CaCO_3$ or calcium ions from the soil by leaching.

$$CaCO_3 + CO_2 + H_2O - Ca(HCO_3)_2 \text{ [Soluble]}$$

This occurs mostly in high rainfall or humid regions.

PODZOLIZATION : (Russian term) Pod = under and zola = ashlike

It is a process of soil formation resulting in the formation of podzols and podzolic soils. It is the process of accumulation of silica and eluviation of sesquioxides It is almost a reverse of calcification process due to leaching of all bases including calcium. The favourable conditions for podzolization are

- A cool and humid climate (Invariably found at high altitudes)
- Siliceous (san dy) or acidic parent material, having poor reserves of weatherable minerals, favor the operation of podsolization, as it helps i n easy

percolation of water.

- Acid loving vegetation, such as coniferous pines (*Pinus roxburghii*), hemlock (*Tsuga Canadensis*) and heath (*Calluna vulgaris*) are essential for this process.
- Under calcium free, acidic environment (pH <5.0), fungi plays active role in organic matter decomposition.
- Less microbial activity declines the polysaccharide production and keeps the soluble organic products in soluble form.
- The soluble organic acids react with sesquioxides and the remaining clay minerals, forming organic - sesquioxide and organic - clay complexes, which are soluble and move with the percolating water to the lower horizons .
- Alluminium ions in solution hydrolyse and make the soil solution very acidic.

$$2Al + 6H_2O \longrightarrow 2Al(OH)_3 + 6H^+$$

As the materials move out, it gives a bleached appearance (E-horizon) below the surface. The eluviated materials deposit in B horizon as dark coloured Bh (precipitated humus), reddish brown Bs (deposition of sesquioxides) and a yellowishish brown (silicate clay) layer which gradually merges with parent material. Hence a mature podzol has well developed horizonation. Podzols are highly acidic, low in fertility and used for forestry or pastures. Rarely crops like oats. Potato and clover can be cultivated.

LATERIZATION :

The term laterite is derived from the word "later" means "brick" or "tile".

In tropics, certain soils are massively impregnated with sesquioxides to the extent of 70 to 80% of the total mass, and forms a cemented horizon, which when dried becomes very hard like a brick. This soil forming process is called "laterization" or "Lotozation" Eg: Soils of Malabar hills of Kerala.

In laterization, unlike podzolisation, silica is removed leaving sesquioxides to remain in solum. The favorable conditions are

- ✓ Warm and humid (tropical) climate with 2000 to 2500 mm rainfall and continuous high temperature (±25°C) throughout the year. Rapid dec omposition of parent material and organic matter, and intensive leaching are very likely in this climate.
- ✓ The rain forests of tropical areas are the suitable vegetation for this process. Under this vegetation organic additions are low but organic matter de composition is at very high rate.
- ✓ Basic parent materials, having sufficient ferro -mangnesion minerals (Pyroxenes, amphiboles, biotite and chlorite) are congenial for the development of laterites.

The iron released during weathering is oxidized to form FeO, Fe_2O_3 and coats clay, silt or sand particles imparting characteristic red color to soils. The Al-oxides /hydroxides imparts grey coatings to the soil particles.

The high temperature, intense leaching and basic kind of parent material all favor the removal of silica (de-silication) and accumulation of sesquioxides. The soluble basic cations are quickly released during weathering, moves freely in the soil profile and shoots up the pH to neutrality. Under this basic environment silica liberated from parent material is solubilized and leached. The solubility of quartz and amorphous silica increases with increased temperature. The sesquioxides are left behind as these are more stable under these conditions. As the alkaline bases are removed from the seat o f their formation, the residual soil is acidic in reaction. Though considerable eluviation takes place, there is no marked horizonsiation as the eluviated materials are not re-deposited in the lower layers.

Laterite soils are non-plastic, non cohesive and have granular structure. They are low in cation exchange capacity and fertility. Phosphorus fixation is high in these soils. Plantation crops are usually grown on these soils.

GLEIZATION

"Glei" means blue, grey or green clay.

The gleization is a process of soil formation resulting in the development of a glei (or gley) horizon in the lower part of the profile above the parent material due to poor drainage conditions or water logged conditions. Such soils are called "hydromorphic soils". This proces s is not particularly dependant on climate (high rainfall as in humid regions) but often on drainage conditions.

Poor drainage may be due to lower topographic position, impervious soil parent material and lack of aeration.

Under anaerobic conditions, iron compounds are reduced to soluble ferrous forms. The reduction of iron is primarily biological and requires both organic matter and the micro organisms capable of respiring anaerobically. Iron exists as Fe^{2+} organo-compexes in solution or as a mixed precipitate of ferric and ferrous hydroxides, which is responsible for the production of typical bluish to grayish horizon. Due to seasonal fluctuations of ground waters, the gley shows distinct mottling of yellow and rusty brown colors caused by the alterna te oxidation and reduction phenomena.

SALINIZATION

It is the process of accumulation of salts such as sulphates, chlorides of calcium, magnesium, sodium and potassium in soils in the form of salty (salic) horizon. As a result of the accumulation of salts, solonchalks or saline soils develop with an electrical conductivity of > 4 dSm^{-1}. The soils are called saline soils, which have ESP less than 15 per cent and pH between 7 and 8.5.

The responsible factors :

- ✓ Arid or semi-arid climatic conditions, associated with shallow and brackish (high amounts of sulphates and chlorides) ground waters.
- ✓ Lower topographic positions / depression land forms.
- ✓ Imperfect or poor drainage conditions
- ✓ Old lake bottoms
- ✓ Alluvial deposits along the sea coasts
- ✓ Use of saline irriga tion waters.

The ground water containing high salts moves in an upward direction by capillary action. The water on evaporation leaves the salts behind, which accumulate at the surface or at some depth depending upon the capillary fringe. Surface accumulation of salts gives white appearance to soils .Hence the soils are called as white alkali soils.

These soils can be managed by leaching of salts followed by provision of sub-surface drainage.

SOLONIZATION OR ALKALIZATION

The process involves the accumulation of sodium ions on the exchange complex of the clay to an extent of >15%, resulting in the formation of sodic soils (solonetz) under arid and semi-arid conditions. This occurs when anions like carbonates and bicarbonates predominate in soil.

The calcium and magnesium in soil solution will precipitate as corresponding carbonates or bicarbonate when ever the ionic product of solution exceeds the solubility products of respective carbonates. This reduces the concentration of Ca and Mg in soil solution , there by releasing them from exchange complex. As this process continues, the sodium concentration on exchangeable complex increase. When the ESP in soils exceeds 15 %, the soil is designated as alkali soil with a high pH of >8.5, which results in less nutrient availability.

The high pH in soils results in dissolution of humus, which moves upward along the capillary water giving black colour to soils. Hence the soils are called black alkali soils. High sodium on clay minerals results in dispersion of soil aggregates leading to physical problems like poor aeration, low infiltration and percolation of water.

This process results in a very thin, friable horizon followed by a dark horizon of hard and impermeable heavy soils generally with illuviated clay and having a typical columnar structure, which is characteristic of "solonetz".

SOLODIZATION OR DEALKALIZATION

This process refers to the removal of Na^+ from exchange sites. The Na^+ can be eliminated by increasing the concentration of Ca^{2+} or Mg^{2+} in the water, followed by improved drainage facilities.

$$2NaX + CaSO_4 \longrightarrow Na_2SO_4 + CaX$$

PEDOTURBATION

It is the process of mixing of the soils. Mixing to some extent takes place in all soils.

- Faunal pedoturbation : Mixing by animals such as ants, earthworms, moles, rodents and man himself.
- Floral pedoturbation : Mixing by plants, as in tree tipping that forms pits and mounds.
- Argillopedoturbation : Mixing of materials in solum by churning process caused by swell - shrink clays as is observed in deep black cotton soil.
- ?Calcification, podzolization and laterization are zonal soil forming processes, where in the profile characteristics are influenced by prevailing conditions of climate and vegetation.
- ?Gleization, salinization, solonization and s olodization are the Intra -zonal soil forming processes, wherein, the profile characteristics are more influenced by certain local conditions, such as relief (topography) and / or parent material than the climate and vegetation.
- ?Salinization, alkalization and dealkalization processes operate in sequence and advance the soil to a certain point in transition until the zonal soils are formed.