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Soil and Plant Nutrients

What is soil ?

According to FAO, Soil has been defined as a natural body consisting of layers (soil horizons) that are composed of weathered mineral materials, organic material, air and water.

- The word soil originated from a **Latin** word ***solum*** Meaning **floor.**

Edaphology:

It is the study of influence of soil in relation to growth, nutrition and yield of crops.

Derived from two Greek words:

- ***Edaphos:*** soil
- ***Logos:*** Discourse

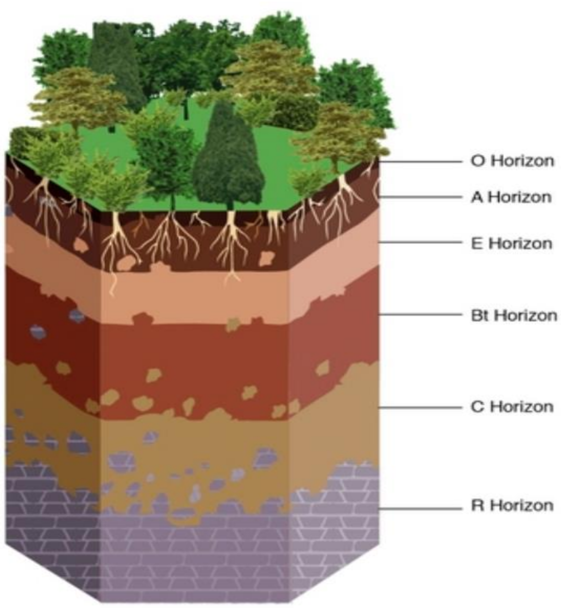
According to Edaphology soil is Natural habitat for plants.

Pedology:

- The study of soil origin, its classification and description of soil in its natural setting.
- Father of soil science and Pedology is V.V Dokuchaev.
- According to pedology, soil is a **natural body.**

Soil Horizon

- A vertical section through different layers of the soil is called the soil profile.
- A soil horizon is a layer generally parallel to the soil surface, whose physical characteristics differ from the layers above and beneath.



- **O- Horizon** containing a **high percentage of soil organic matter**.
- **A - Horizon** : darkened by the **accumulation of organic matter**. It is the part of top soil.
  - In this layer, organic matter is mixed with mineral matter.
  - It is the layer of mineral soil with the most organic matter accumulation and soil life.
  - This layer is depleted of (eluviated of) iron, clay, aluminum, organic compounds, and other soluble constituents.

- **E - Horizon** formed through the removal (**eluviation**) of clays, organic matter, iron, or aluminium. Usually lightened in color due to these removals.
- **B - Broad** class used for **subsurface horizons** that have been transformed substantially by a soil formation process such as
  - color and structure development;
  - **the deposition (illuviation) of materials** such as clays, organic matter, iron, aluminum, carbonates, or gypsum;
  - It is subsurface layer reflecting chemical or physical alteration of parent material

- **C - horizon** minimally affected or unaffected by the soil formation processes.
  - It is a layer of large unbroken rocks (**parent rock)**
- **R** – Bedrock; Unlike the above layers, R horizons largely comprise continuous masses of hard rock

TYPES OF ROCKS

Igneous Rocks or Primary Rocks

- Rocks formed out of solidification of magma (molten rock below the surface) and lava (molten rock above the surface) are known as igneous or primary rocks.
- Having their origin under conditions of high temperatures the igneous rocks are **unfossiliferous.**

  Eg. Granite, gabbro, basalt,
- **Intrusive Rocks Or Plutonic Rocks** : If magma cools slowly at great depths, mineral grains formed in the rocks may be very large. e.g. Granite
- **Extrusive Rocks Or Volcanic Rocks :** Sudden cooling of magma just below the surface or lava above the surface results in small and smooth grains in rocks as rapid cooling prevents crystallisation, as a result, such rocks are fine-grained. e.g. Basalt
  - The Deccan traps in the Indian peninsular region is of basaltic origin

Sedimentary rocks

- Sedimentary rocks rocks are formed by lithification — consolidation and compaction of sediments.
- Hence, they are layered or stratified of varying thickness. Example: sandstone, shale etc.
- Sediments are a result of denudation (weathering and erosion) of all types of rocks
- Depending upon the mode of formation, sedimentary rocks are classified into:
  - mechanically formed — sandstone, conglomerate, limestone, shale, loess.
  - organically formed — geyserite, chalk, limestone, coal.
  - chemically formed — limestone, halite, potash

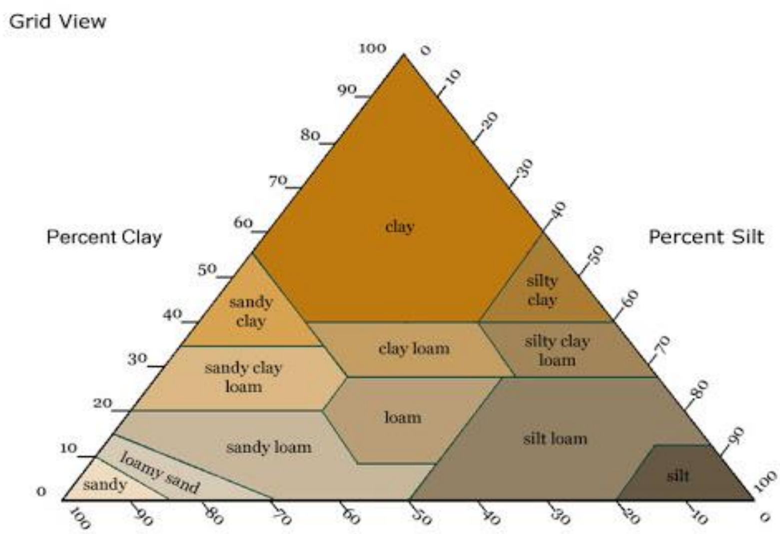
Metamorphic Rocks

- Metamorphism is a process by which recrystallisation and reorganisation of minerals occur within a rock. This occurs due to pressure, volume and temperature changes.
- When rocks are forced down to lower levels by tectonic processes or when molten magma rising through the crust comes in contact with the crustal rocks, metamorphosis occurs.
- In the process of metamorphism in some rocks grains or minerals get arranged in layers or lines. Such an arrangement is called foliation or lineation.
- Sometimes minerals or materials of different groups are arranged into alternating thin to thick layers. Such a structure in is called banding.
- Gneissoid, slate, schist, marble, quartzite etc. are some examples of metamorphic rocks.

Soil texture/grain size

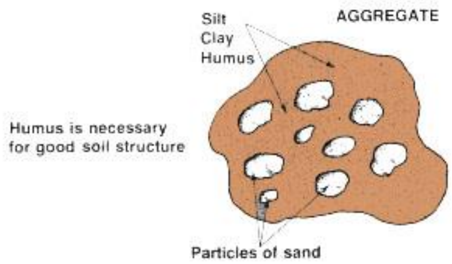
- The range of particle sizes encountered in soils is very large: from boulders with dimension of over 300 mm down to clay particles that are less than 0.002 mm. Some clays contain particles less than 0.001 mm in size which behave **as colloids, i.e. do not settle in water**.
- In the **Indian Standard Soil Classification System (ISSCS),** soils are classified into groups according to size, and the groups are further divided into coarse, medium and fine sub-groups.
- The grain-size range is used as the basis for grouping soil particles into boulder, cobble, gravel, sand, silt or clay.

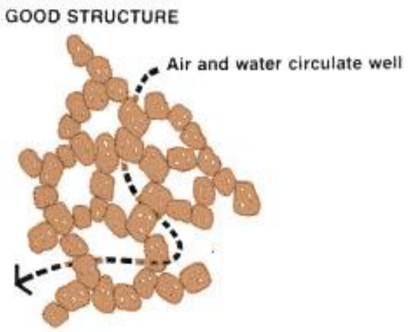
Very coarse soils	**Boulder size**		**> 300 mm**
	Cobble size		**80 - 300 mm**
Coarse soils	**Gravel size (G)**	***Coarse***	**20 - 80 mm**
		Fine	**4.75 - 20 mm**
	Sand size (S)	***Coarse***	**2 - 4.75 mm**
		Medium	**0.425 - 2 mm**
		Fine	**0.075 - 0.425 mm**
Fine soils	**Silt size (M)**		**0.002 - 0.075 mm**
	Clay size (C)		**< 0.002 mm**

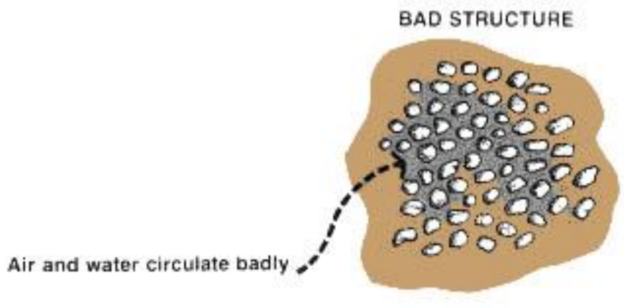


Soil Structure:

Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles when assembled appear as larger particles. These are called aggregates







Description of soil structure

Soil structure is most usefully described in terms of **grade** (degree of aggregation), **class** (average size) and **type of aggregates** (form).

Grades of soil structure

The grade of structure is the degree of aggregation, expressing the differential between cohesion within aggregates and adhesion between aggregates. As these properties vary with the moisture content of the soil, grade of structure should be determined when the soil is neither unusually moist nor unusually dry.

There are four major grades of structure rated from 0 to 3 as follows:

0 Structureless has no observable aggregation or no definite orderly arrangement

- Massive structure (coherent) where the entire soil horizon appears cemented in one great mass;
- Single-grain structure (non-coherent) where the individual soil particles show no tendency to cling together, such as pure sand;

1 Weak structure is poorly formed from indistinct aggregates that can barely be observed in place. When removed from the profile, the soil material breaks down into a mixture of very few entire aggregates, many broken aggregates and much unaggregated material;

2 Moderate structure is well formed from distinct aggregates that are moderately durable and evident but not distinct in undisturbed soil. When removed from the profile, the soil material breaks down into a mixture of many distinct entire aggregates, some broken aggregates and little unaggregated material;

3 Strong structure is well formed from distinct aggregates that are durable and quite evident in undisturbed soil. When removed from the profile, the soil material consists very largely of entire aggregates and includes few broken ones and little or no non-aggregated material.

Classes of soil structure

class of structure describes the average size of individual aggregates. Usually, five distinct classes may be recognized in relation to the type of soil structure from which they come. They are:

- Very fine or very thin;
- Fine or thin;
- Medium;
- Coarse or thick;
- Very coarse or very thick.

Type of structure

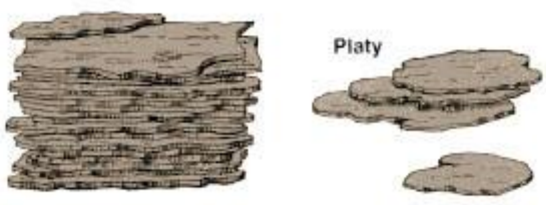
- Describes the form or shape of individual aggregates.
- Natural aggregates that can be clearly seen in the field are called peds.
- Clods, on the other hand, are aggregates that are broken into shape by artificial actions such as tillage.

Granular and crumb structures are individual particles of sand, silt and clay grouped together in small, nearly spherical grains.

- Water circulates very easily through such soils.
- When the granules are very porous, it is termed as crumb.
- This is specific to surface soil particularly high in organic matter/ grass land soils.
- They are commonly found in the A-horizon of the soil profile.

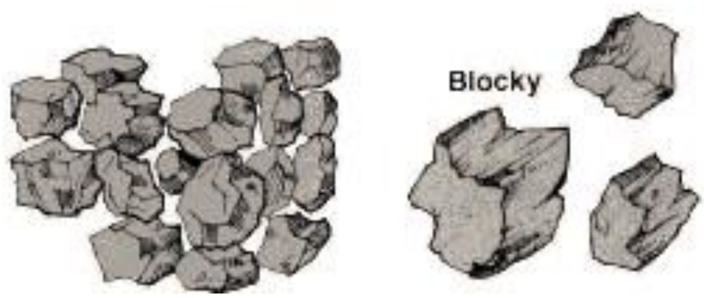
Plate-like (Platy) Structure :

- In this type, the aggregates are arranged in relatively thin horizontal plates or leaflets. The horizontal axis or dimensions are larger than the vertical axis.
- When the units/ layers are thick they are called platy. When they are thin then it is laminar.
- Platy structure is most noticeable in **the surface layers** of soils but may be present in the subsoil.
- It is commonly found in forest soils, in part of the A- horizon.



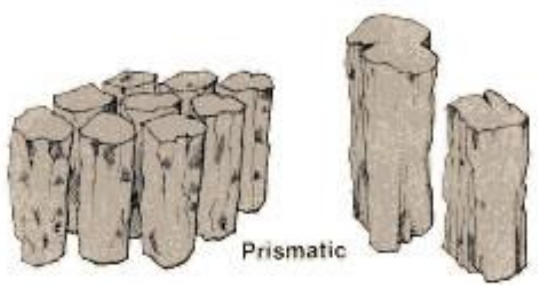
Blocky and subangular blocky structures

- These are soil particles that cling together in nearly square or angular blocks having more or less sharp edges. Relatively large blocks indicate that the soil resists penetration and movement of water.
- They are commonly found in the B-horizon where clay has accumulated.
- The strongest blocky structure is formed as a result of swelling and shrinking of the clay minerals which produce cracks.



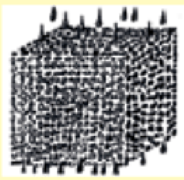
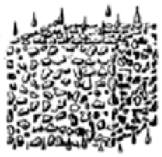
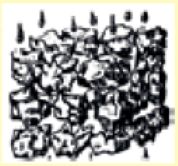
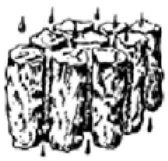
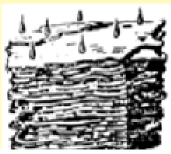
Prismatic and columnar structures

- The vertical axis is more developed than horizontal, giving a pillar like shape. Vary in length from 1-10 cm.
- Commonly occur in sub soil horizons of Arid and Semi arid regions.
- When the **tops are rounded,** the structure is termed as columnar when the tops are flat / plane, level and clear cut – **prismatic**
- Columnar structure is very dense and it is very difficult for plant roots to penetrate these layers.
- Techniques such as deep plowing have help to restore some degree of fertility to these soils.



The role of soil structure in relation to plant growth

- Soil structure influences the amount and nature of porosity.
- Structure controls the amount of water and air present in the soil.
- Not only the amount of water and air dependent on soil structure, but their movement and circulation are also controlled by soil structure.
- It affects tillage practices.
- Structure controls runoff and erosion.
- **Platy structure** normally **hinders free drainage** whereas sphere like structure (granular and crumby) helps in drainage.
- **Crumby and granular** structure provides optimum infiltration, water holding capacity, aeration and drainage. It also provides good habitat for microorganisms and supply of nutrients

Structure type	Structure shape	Description	Plant available water	Root penetration	Internal drainage	Erodibility
Single grains (none)		No observable aggregation, no natural lines of weakness, but non-coherent.	Very low	Usually very deep	Very rapid	High
Apedal (weak)		Moderately aggregated forms a micro-crumb structure. Common to sesquioxic Ferralsols and Oxisols.	Low to medium	Deep	Very rapid	Medium to high
Crumb (moderate)		More or less small rounded peds and relatively porous.	Medium	Deep	Rapid	Medium to high
Blocky (strong)		Flat or less rounded peds and relatively non-porous. Common in Chromic Luvisols.	High	Moderately deep	Moderate	Medium
Prismatic and columnar (strong)		Vertical dimension exceeds horizontal dimension. Common to dry climate soils, e.g. Vertisols.	Medium	Shallow, poor roots	Slow	Medium to low
Platy (strong)		Horizontal dimension exceeds vertical dimension. Can be caused by heavy infield compaction under wet conditions.	Low	Very shallow, poor roots	Very slow	Low

Classification of soil :

Soils found in India as per the USDA Soil taxonomy.

Order	Percentage
Inceptisols	39.74
Entisols	28.08
Alfisols	13.55
Vertisols	8.52
Aridisol	4.28
Ultisols	2.51
Mollisols	0.40
others	2.92

Inceptisols :

- These soils are in the beginning stages of soil profile development. The differences between horizons are just beginning to appear.
- The natural productivity of these soils varies widely, and is dependent upon clay and organic matter content, and other edaphic (plant-related) factors.
- prominent in mountainous regions.

Entisols

- There is little profile (horizon) development. Includes the soils of unstable environments, such as floodplains, sand dunes, or those found on steep slopes.
- Entisols are commonly found at the site of recently deposited materials (e.g., alluvium), or in parent materials resistant to weathering
- Entisol soils also occur in areas where a very dry or cold climate limits soil profile development

.

Note : ***Alluvial soil can be of both Inceptisols and entisol order.***

Alfisols

- Alfisols are found in cool to hot humid areas, and in the semiarid tropics; they are formed mostly under forest vegetation, but also under grass savanna.
- Alfisols generally show **extensive profile development**, with distinct argillic (clay) accumulations in the subsoil.
- Extensive leaching often produces a **light-colored E horizon below the topsoil.**
- Red soils are formed from this order.

Vertisols

- Soils with high content of **shrinking/swelling clay minerals**, **montmorillonite.**
- Self-mixing due to shrink-swell of clay minerals
- Dark colored with variable organic matter content (1 – 6%)
- Typically form in limestone or basalt, or in topographic depressions.
- Most commonly formed in warm, subhumid or semi-arid climates.
- Black soils are formed from this order.

Aridisols

- Dry soils with $CaCO_3$ (lime) accumulations, common in desert regions.
- Aridisols are commonly light in color, and low in organic matter content. Lime and salt accumulations are common in the subsurface horizons
- Crops cannot be grown in these soils without irrigation.
- Productivity of Aridisols is generally low, and there is potential for land degradation due to overgrazing by livestock. If irrigation water is available, Aridisols can be made productive through use of fertilizers and proper management.

Ultisols

- Intensely weathered soils of humid areas
- Form on older geologic locations in weathered parent materials

- Contain subsurface clay accumulations (claypans).
- Low in natural fertility (Ca^{2+}, Mg^{2+}, and K^{+}) and high in soil acidity (H^{+}, Al^{3+})
- Mostly acidic soils, Can be made agriculturally productive with inputs of lime and fertilizers .

Mollisols

- The Mollisol order takes its name from the Latin word mollis, meaning soft.
- These mineral soils have developed on grasslands, a vegetation that has extensive fibrous root systems.
- The topsoil of Mollisols is characteristically dark and rich with organic matter, giving it a lot of natural fertility.
- These soils are typically well saturated with basic cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) that are essential plant nutrients.
- These characteristics of Mollisols place them among the most fertile soils found on Earth.

Soil Minerals

- **Primary minerals** are usually derived from igneous and metamorphic rocks in soil .
- In most soils, feldspars, micas, and quartz are the main primary mineral constituents.
- The crust of the earth is made up of more than 2000 minerals, but out of these, only six are the most abundant and contribute the maximum.

Feldspar:

- **Silicon and oxygen** are major elements of all types of feldspar.
- **Sodium, potassium, calcium, aluminium**, etc are found in specific feldspar varieties.
- Half of the earth's crust is composed of feldspar (plagioclase (39%) and alkali feldspar (12%)).
- It has light cream to salmon pink colour.
- It is commonly used in ceramics and glass making.

Quartz:

- It is one of the most important components of sand and granite.
- It consists of silica and it is a hard mineral virtually insoluble in water.

- It is usually white or colourless.
- **About 12% of the earth's crust is made up** of quartz.
- They are used in the manufacturing of radio, radar, etc.

Pyroxene:

- The common elements in pyroxene are **Calcium, aluminium, magnesium, iron and silicon.**
- **About 10% of the** earth's crust is made up of pyroxene.
- It is commonly found in meteorites.
- Its colour is usually green or black.

Amphibole:

- Aluminium, calcium, silicon, iron and magnesium are the major elements of amphiboles.
- They **form 7% of the** earth's crust.
- It is green or black in colour and is used in asbestos industries commonly.
- Hornblende is another form of amphiboles.

Mica:

- It is made up of elements like **potassium, aluminium, magnesium, iron, silicon,** etc.
- It **forms 4% of the** earth's crust.
- It is commonly found in igneous and metamorphic rocks.
- Mica is widely used in electronic instruments.

Olivine:

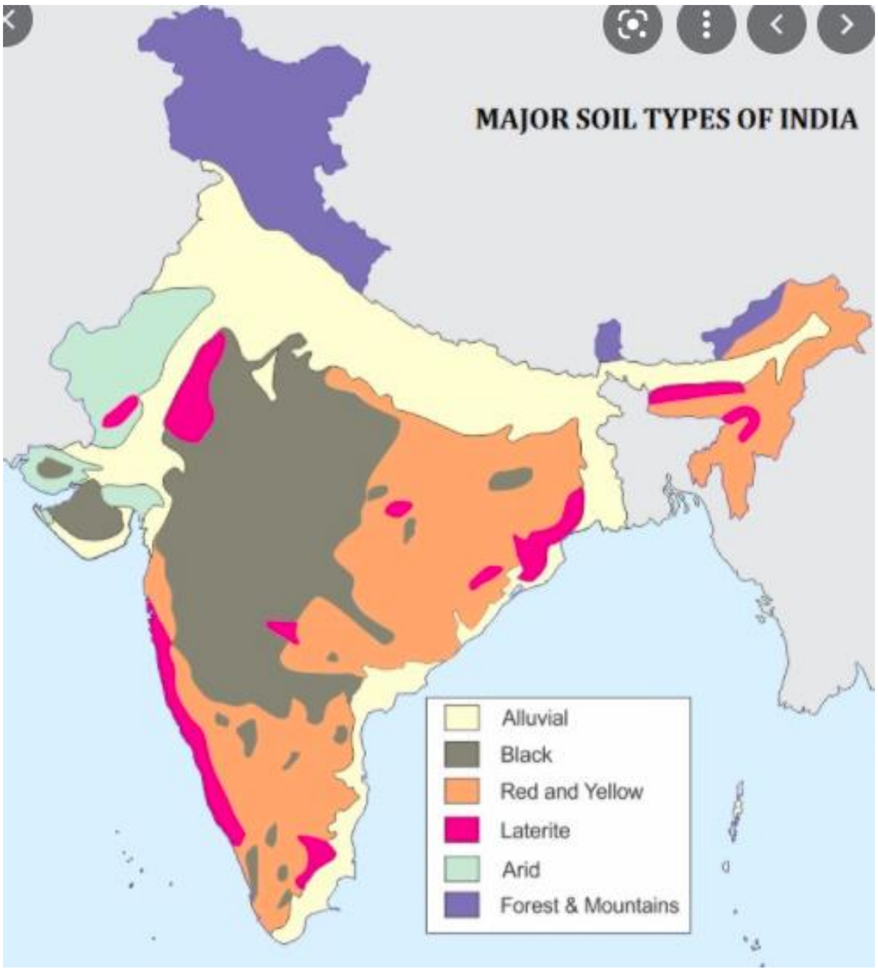
- Magnesium, iron and silica are the major elements of olivine.
- It is commonly found in basaltic rocks with a greenish colour.
- Olivine is used commonly in jewellery.

The **secondary minerals** do not occur during the formation of the parent rock, rather later introduced or substituted during the weathering process or changes in the primary or original mineral constituents of the rock.

The most common secondary minerals are as follows:

- The kaolinite created by the processes of change and chemical weathering of feldspar.
- The chlorite created by the processes of change and weathering of biotite, pyroxene, and amphibole.
- The sericite created by the processes of change and weathering of feldspar.
- The serpentine created by the processes of hydrothermal modification of olivine.

Soils in India



Alluvial soil:

- Mostly available soil in India (about 43%) which covers an area of 143 sq.km.
- Widespread in northern plains and river valleys and In peninsular-India, they are mostly found in deltas and estuaries.
    - Indus-Ganga-Brahmaputhra plain, Narmada-Tapi plain etc are examples.
- **Humus, lime and organic matters** are present.; Highly fertile.
- They are **depositional soil** – transported and deposited by rivers, streams etc.
- **Sand content decreases from west to east** of the country.
- New alluvium is termed as **Khadar** and old alluvium is termed as **Bhangar.**
- **Colour :** Light Grey to Ash Grey.
- **Texture** : Sandy to silty loam or clay.
- **Rich in:** potash
- **Poor in:** phosphorous
- **Major crops :** Wheat, rice, maize, sugarcane, pulses, oilseed etc are cultivated mainly.
- Formed mainly from **Inceptisols and Entisols**

Black soils:

- Also known as Regur soil/Black cotton soil ; best soil for cotton cultivation.
- Most of the Deccan is occupied by Black soil.
- Zonal/Mature soil.
- High water retaining capacity, dark fine grained soil
- Swells and will become sticky when wet and shrink when dried, has **high montmorillonite clay mineral**.
- Self-ploughing is a characteristic of the black soil as it develops wide cracks when dried.
- Black soils are formed from **Vertisols.**
- **Rich in:** Iron, lime, calcium, potassium, aluminum and magnesium.
- **Deficient:** Nitrogen, Phosphorous and organic matter.
- **Colour:** Deep black to light black.
- **Texture :** Clayey.

- Found in Maharashtra, Madhya Pradesh, parts of Karnataka, AP, Gujarat and TN
- **Major crop**: cotton, wheat, jowar, linseed, castor, sunflower, and millets

Red Soil:

- Red soils are generally derived from the weathering of ancient crystalline and metamorphic rocks.
- Also known as Omnibus group.
- Absence of lime, kankar (impure calcium carbonate).
- **Deficient in**: lime, phosphate, manganese, nitrogen, humus and potash.
- **Rich in iron** .
- **Colour:** Red because of Ferric oxide. It looks **yellow in its hydrated form**.
- **Texture:** Sandy to clay and loamy.
- Wheat, cotton, pulses, tobacco, oilseeds, potato etc are cultivated.
- Formed by **Alfisols**
- Spread in TN, Karnataka, South east of Maharashtra, Chhattisgarh, Odhissa, North-east India, West Bengal, South Bihar.
- Occupy about 10% of total geographic area of country.

Laterite soils:

- Derived its name from Latin word **'Later' which means Brick**.
- Become so soft when wet and so hard when dried.
- Develops in the areas **of high temperature and high rainfall**; formed as a result of **intense leaching** due to tropical rains
- Lime and silica will be leached away from the soil..
- **Rich in:** Iron and Aluminum
- **Deficient in**: Nitrogen, Potash, Potassium, Lime, Humus
- **Colour:** Red colour due to iron oxide.
- Rice, Ragi, Sugarcane and Cashew nuts are cultivated mainly.
- Formed **from ultisols and oxisols soil groups**
- Kaolinite is a **dominant silicate clay**

Arid soils:

- Seen under Arid and Semi-Arid conditions; Deposited mainly by wind activities.
- Low moisture ; High salt content.
- Kankar or Impure Calcium carbonate content is high in lower layers which restricts the infiltration of water.
- Poor in Nitrogen and humus ; Phosphate is normal.
- **Texture**: Sandy
- **Colour:** Red to Brown.
- **Mostly** found in western Rajasthan

Saline soils

- Also known as Reh/Usar/Kallar soil
- Occur in arid and semi arid regions and waterlogged and swampy areas
- High salt content ,largely because of dry climate and poor drainage.
- These are infertile soil; high content of Sodium, Potassium and Magnesium
- Texture : sandy to loamy
- Poor in Nitrogen and calcium
- Found in western Gujarat, deltas of eastern coast and sunderban areas of West Bengal.
- Excessive use of irrigation ,especially in areas of Green Revolution, turning fertile alluvial soils saline.
- Farmers are advised to add gypsum to solve the prob of salinity.

Peaty/marshy soils:

- Areas of heavy rainfall and high humidity.
- Growth of vegetation is very less.
- A large quantity of dead organic matter/humus is present which makes the soil acidic; organic matter may go upto 40-50%.
- Heavy soil with black colour; spongy
- They are deficient in potash and phosphate

- Found in Kottayam and Alappuzha districts of Kerala where it is called kari.
- Also occur in the coastal areas of Odisha and Tamil Nadu, Sunderbans of West Bengal, in Bihar and Almora district of Uttarakhand.
- Most of the peaty soils are under water during the rainy season but as soon the rains cease, they are put under paddy cultivation
-

Forest soils

- Regions of high rainfall.
- Texture ; Loamy and silty on valley sides and coarse grained in upper slopes.
- They are rich in humus, but are deficient in potash, phosphorus, and lime; thus, they require a large amount of fertilizers for plantations of tea, coffee, spices, and tropical fruits
- Soils in valleys are fertile while in the snow bound areas of Himalyas, soils are acidic with low humus content.

Problematic soil

Acid soils

- Soil acidity refers to presence of higher concentration of H+ in soil solution and at exchange sites.
- They are characterized by low soil pH and with low base saturation.
- In acid soil regions (ASR) precipitation exceeds the evapotranspiration and hence leaching is predominant causing loss of bases from the soil.

Reasons behind acidity

- Humus decomposition results in release of large amounts of acids. There by lowering the pH.
- Rainfall: In areas with more than 100 cm rainfall, Ca, Mg is dissolved in water and leached out due to this , base saturation of soil decreases.

- Continuous application of acid forming fertilizers like ammonium sulphates or ammonium chlorides results in depletion of Ca by CEC (cation exchange capacity) phenomenon.

Production constraints

- Increased solubility and toxicity of Al, Mn and Fe
- Deficiency of Ca and Mg,
- Reduced availability of P and Mo and
- Reduced microbial activity
- Plant root system does not grow normally due to toxic hydrogen ions.

Amelioration

- Lime is added to neutralize acidity and to increase the pH, so that the availability of nutrients will be increased.
    - Liming also **increases atmospheric N fixatio**n as well as N mineralization in acid soils through enhanced microbial activity.
    - **Lime sources :** Among, the naturally occurring lime sources calcitic, dolomitic and stromato litic limestones are important carbonates.
        - The other liming sources are marl, oyster shells and several industrial wastes like **steel mill slag, blast furnace slag, lime sludge from paper mills, pressmud,** cement wastes, precipitated calcium carbonate
        - **Basic slag and pressmud are superior to calcium oxide or carbonates** for amending the acid soils.
        - **Fly ash** also improves pH and nutrient availability

- **Ammonium sulphate and Ammonium chloride should not be applied** to acid soils but urea can be applied.
- Calcium Ammonium Nitrate (CAN) is suitable to acidic soils.

Note : Cation Exchange Capacity (CEC)

- Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilisers and other ameliorants
- The **clay mineral and organic matter components of soil have negatively charged sites** on their surfaces which adsorb and hold positively charged ions (cations) by electrostatic force. This electrical charge is critical to the supply of nutrients to plants because many nutrients exist as cations (e.g. magnesium, potassium and calcium). In general terms, soils with large quantities of negative charge are more fertile because they retain more cations
- However, as soils become more acidic these cations are replaced by H+, Al3+ and Mn2+,

ESP (exchangeable sodium percentage) : ESP is the percentage of sodium cation as a percentage of total CEC.

Crops	**Optimum pH range**
Cereals	
Maize, sorghum, wheat, barley	6.0-7.5
Millets	5.0-6.5
Rice	4.0-6.0
Oats	5.0-7.7
Legumes	
Field beans, soybean, pea, lentil etc.	5.5-7.0
Groundnut	5.3-6.6
Others	
Sugarcane	6.0-7.5
Cotton	5.0-6.5

Alkaline soils/Sodic soils

- Alkali soils are formed due to concentration of exchangeable sodium and high pH.
- The sodium ions are attached to the negatively charged sites of clay and organic matter of the soil .
- They are **present in complex** form thus it **doesnot conduct electricity as effectively as saline soil** in which sodium ion is in soluble form

Characteristics:

- The pH is usually between **8.5 – 10.0.**
- conductivity of the saturation extract less than 4 dS m-1(deci Siemens per meter)
- ESP (exchangeable sodium per cent) is more than 15
  - The presence of excessive amounts of exchangeable sodium reverses the process of aggregation and causes soil aggregates to disperse into their constituent individual soil particles. This is known as **deflocculation and occurs in sodic soil.**
  - The soil has poor infiltration and drainage in wet condition ; and when it dries , become quite hard

Injury to Crops

- Restricted root system and delay in flowering in sensitive varieties.
- Typical leaf burn in annuals and woody plants due to excess of chloride and sodium.
- Bronzing of leaves in citrus.

Amelioration:

- **Physical Amelioration:**
  - **Deep ploughing** is adopted to break the hard pan developed at subsurface due to sodium and improving free-movement water. This also helps in **improvement of aeration**.
  - **Providing drainage** is also practiced to improve aeration and to remove further accumulation of salts at root zone.

    - **Sand filling** which reduces heaviness of the soil and increases capillary movements of water.
  - **Profile inversion** – Inverting the soil
- **Chemical Amendments**:
  - The materials that directly or indirectly furnish or mobilize divalent cations, usually Ca^{2+} for the replacement of sodium from the exchange complex of the soil, followed by leaching to remove soluble salts and other reaction products
  - **Direct Ca suppliers**: Gypsum, calcium carbonate, phospho-gypsum, etc.
  - **Indirect Ca suppliers:** Elemental Sulphur, sulphuric acid, pyrites, $FeSO_4$, etc
    - **Calcium carbonate** is insoluble in nature which of no use in calcareous sodic soils (have already precipitated $CaCO_3$) but **can be used in non-calcareous sodic soils** (do not have precipitated $CaCO_3$) since pH of this soils are low at surface and favouring solubilisation of $CaCO_3$.

Relative tolerance of crops to sodicity

ESP (range*)	Crop
2-10	Deciduous fruits, nuts, citrus, avocado
10-15	Safflower, black gram, peas, lentil, pigeon pea
16-20	Chickpea, soybean
20-25	Clover, groundnut, cowpea, pearl millet
25-30	Linseed, garlic, cluster bean
30-50	Oats, mustard, cotton, wheat, tomatoes
50-60	Beets, barley, sesbania
60-70	Rice

Relative tolerance of fruit trees to sodicity

Tolerance to sodicity	ESP	Trees
High	40-50	Ber, tamarind, sapota, wood apple, date palm
Medium	30-40	Pomegranate
Low	20-30	Guava, lemon, grape
Sensitive	20	Mango, jack fruit, banana

Saline Soils:

- The saline soils contain toxic concentration of soluble salts in the root zone.
- **Soluble salts** consist of **chlorides and sulphates of sodium, calcium, magnesium**. Because of the white encrustation formed due to salts, the saline soils are also called **white alkali soils**

Reasons for Salinity:

- In arid and semi arid areas, salts formed during weathering are not fully leached.
- During the periods of higher rainfall the soluble salts are leached from the more permeable high laying areas to low laying areas and
- where ever the drainage is restricted, salts accumulate on the soil surface, as water evaporates

Characteristics:

- Saline soil has soil pH of less than 8.5
- EC is more than 4.0 m.mhos/cm
- ESP (exchangeable sodium percent) is less than 15
- Dominated by sulphate and chloride ions and low in exchangeable sodium
- Flocculation due to excess soluble salts.
- High osmotic pressure of soil solution

Effect on Crops:

- High osmotic pressure decreases the water availability to plants .

- Consequently water intake by plants is restricted and thereby nutrients uptake by plants are also reduced.
- As a result, retarded growth rate, leaves and stems of affected plants are stunted.
- In this soil due to high salt levels ,microbial activity is also reduced.

Amelioration:

The reclamation of saline soils involves basically the removal of salts from the saline soil through the processes of leaching with water and drainage

- **Subsurface drainage** is the removal of water and salt from the rootzone. It is accomplished by deep open drains or buried pipe drains.
- **Flooding and drainage**
  - Plots are to be flooded with good quality water up to 15 – 20 cms and puddled. Thus, soluble salts will be dissolved in the water.
  - The excess water with dissolved salts is to be removed into the drainage channels.
  - Flooding and drainage are to be repeated 5 or 6 times, till the soluble salts are leached from the soil to a safer limit
- **organic manures** like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition.
- **Green manure crops** like Daincha can be grown up to flowering stage and incorporated into the soil. Paddy straw can also be used

Relative tolerance of crops to salinity

Plant species	Threshold salinity (dS m^{-1})	Plant species	Threshold salinity (dS m^{-1})
Field crops		**Vegetables**	
Cotton	7.7	Tomato	2.5
Sugarbeet	7.0	Cabbage	1.8
Sorghum	6.8	Potato	1.7
Wheat	6.0	Onion	1.2
Soybean	5.0	Carrot	1.0
Groundnut	3.2	**Fruits**	
Rice	3.0	Citrus	1.7
Maize	1.7	-	-
Sugarcane	1.7	-	-

Saline-alkali/ sodic soils

- Saline-alkali / sodic soil is defined as a soil having a conductivity of the saturation extract **greater than 4 dS m-**1 and an exchangeable sodium percentage **greater than 15.**
- The **pH** is variable and usually **above 8.5** depending on the relative amounts of exchangeable sodium and soluble salts.
- When soils dominated by exchangeable sodium, the pH will be more than 8.5 and when soils dominated by soluble salts, the pH will be less than 8.5.

Formation

- These soils form as a result of the combined processes of salinization and alkalization.

- If the excess soluble salts of these soils are leached downward, the properties of these soils may change markedly and become similar to those of sodic soil.

Amelioration:

- The reclamation / management practices recommended for the reclamation of sodic soil can be followed for the management of saline – sodic soil.

Physical Classification of soil water:

Gravitational Water

- Gravitational water is free water moving through soil by the force of gravity.
- It is largely found in the macropores of soil and very little gravitational water is available to plants as it drains rapidly down the water table in all except the most compact of soils

Capillary Water

- Capillary water is water held in the micropores of the soil, and is the water that composes the soil solution.
- Capillary water is held in the soil because the surface tension properties (cohesion and adhesion) of the soil micropores are stronger than the force of gravity.
- However, as the soil dries out, the pore size increases and gravity starts to turn capillary water into gravitational water and it moves down.
- **Capillary water is the main water that is available to plants as it is trapped in the soil solution right next to the roots if the plant.**

Hygroscopic Water

- Hygroscopic water forms as a very thin film surrounding soil particles and is generally not available to the plant.
- This type of soil water is bound so tightly to the soil by adhesion properties that very little of it can be taken up by plant roots.

- Since hygroscopic water is found on the soil particles and not in the pores, certain types of soils with few pores (clays for example) will contain a higher percentage of it.

Fertilizers and its classification

Fertilizer is any material of natural or synthetic origin added to the soil to supply one or more plant nutrients.

Classification of fertilizers:

- **Straight fertilizers**: Straight fertilizers are those which supply only one primary plant nutrient, namely nitrogen or phosphorus or potassium.
  eg. Urea, ammonium sulphate, potassium chloride and potassium sulphate.
- **Complex fertilizers**: Complex fertilizers contain two or three primary plant nutrients of which two primary nutrients are in chemical combination. These fertilisers are usually produced in granular form.
  eg. Diammonium phosphate, nitrophosphates and ammonium phosphate.
- **Mixed fertilizers**: are physical mixtures of straight fertilisers. They contain two or three primary plant nutrients. Mixed fertilisers are made by thoroughly mixing the ingredients either mechanically or manually

***Fertilisers can also be classified based on physical form**:*

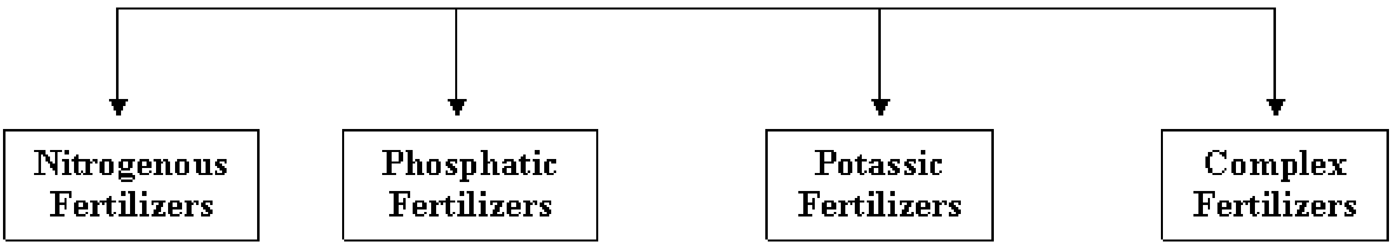
Solid fertilizers : **Solid fertilizers** are in several forms *viz.*

- Powder (single superphosphate),
- Crystals (ammonium sulphate),
- Prills (urea, diammonium phosphate, superphosphate),
- Granules (Holland granules),
- Supergranules (urea supergranules) and
- Briquettes (urea briquettes).

Liquid fertilizers :

- Liquid form fertilizers are applied with irrigation water or for direct application.
- Ease of handling, less labour requirement and possibility of mixing with herbicides have made the liquid fertilisers more acceptable to farmers.

***The fertilizers also classified on the basis of the nature of nutrient elements like Nitrogen, phosphorus, potassium (NPK) present chemically in the compounds**.*



Nitrogenous Fertilizers

can be further classified as given below:

Ammoniacal fertilizers

- They contain the nutrient nitrogen in the form of ammonium or ammonia.
- Ammoniacal fertilizers are readily soluble in water and therefore readily available to crops.

- Except rice, all crops absorb nitrogen in nitrate form. These fertilizers are resistant to leaching loss, as the ammonium ions get readily absorbed on the colloidal complex of the soil.

Ammonium sulphate [(NH4)2 S04]

- It is a white salt completely soluble in water containing 20.6 .per cent of nitrogen and 24.0 per cent of sulphur.
- It is used advantageously in **rice and jute cultivation**.
- It is easy to handle and it stores well under dry conditions. But during rainy season, it sometimes forms lumps.
- It can be applied before sowing, at the time of sowing or as a top-dressing to the growing crop.

Ammonium chloride (NH4Cl)

It is a white salt contains 26.0 per cent of nitrogen.

It is usually not recommended for tomato, tobacco and such other crops as may be injured by chlorine.

Anhydrous ammonia (NH4)

- It is a colourless and pungent gas containing 82.0 per cent nitrogen.
- It is the cheapest and can be applied directly to soil by injection using blade type applicator having tubes.
- It becomes liquid (anhydrous ammonia) under suitable conditions of temperature and pressure

Amide fertilizers

- Amide fertilizers are readily soluble in water and easily decomposable in the soil.
- The amide form of nitrogen is easily changed to ammoniacal and then to nitrate form in the soil.

Urea [CO (NH2)2]

- It is the most concentrated solid nitrogenous fertilizer, containing 46 per cent nitrogen.
- The nitrogen in urea is readily fixed in the soil in an ammoniacal form and is not lost in drainage.
- Urea sprays are readily absorbed by plants.

- It is suitable for most crops and can be applied to all soils.

Calcium cyanamide ($CaCN_2$)

- Calcium cyanamide or nitrolime contains 20.6 per cent of nitrogen.
- It is a greyish white powdery material that decomposed in moist soil giving rise to ammonia

Nitrate Fertilizers

- Nitrate fertilizers contain the nitrogen in the form of NO_3
- These ions are easily lost by leaching because of the greater mobility of nitrate ions in the soil.
- Continuous use of these fertilizers may reduce the soil acidity as these nitrogenous fertilizers are basic in their residual effect on soils.

Sodium nitrate ($NaNO_3$)

- Sodium nitrate is a white salt containing about 15.6 per cent of nitrogen.
- It is completely soluble in water and readily available for the use of plants as such, without any chemical change in the soil.
- Sodium nitrate is also known as chile salt peter or chilean nitrate.
- Sodium nitrate is particularly useful **for acidic soils**

Calcium nitrate [$Ca(NO_3)_2$]

- It is a white crystalline hygroscopic solid soluble in water containing 15.5 per cent nitrogen and 19.5 per cent calcium.
- The calcium is useful for maintaining a desirable soil pH.

Potassium nitrate (KN03)

- The purified salt contains 13.0 per cent nitrogen and 36.4 per cent potassium.
- The nitrogen of the potassium nitrate has the same properties and value as that of the sodium nitrate.

Ammoniacal and nitrate fertilizers

- These fertilizers contain nitrogen in both ammonium and nitrate forms. The nitrates are useful for rapid utilization by crops and the ammonical is gradually available.

Ammonium nitrate (NH4N03)

- It is white, water soluble and hygroscopic crystalline salt containing 35 per cent nitrogen half as nitrate nitrogen and half in the ammonium form.
- This fertilizer is quick-acting, but highly hygroscopic and not fit for storage.
- It has an acidulating effect on the soil.
- It is **dangerous in pure form** because of explosion hazard.

Calcium ammonium nitrate (CAN)

- Calcium ammonium nitrate is a fine free-flowing, light brown or grey granular fertilizer, containing 26 per cent of nitrogen.
- It is almost neutral and can be safely applied even to acid soils.
- Half of its total nitrogen is in the ammoniacal form and half is in nitrate form.
- It is made harmless by adding lime.

Ammonium sulphate nitrate [(NH4)2S04 NH4NO3]

- It contains 26 per cent nitrogen, three fourths of it in the ammoniacal form and the rest (6.5 per cent) as nitrate nitrogen.
- In addition to nitrogen it contains 12.1% sulphur.
- It is a mixture of ammonium nitrate and ammonium sulphate.
- It is available in a white crystalline form or as dirty-white granules.

Essential Plant Nutrients

Criteria of Essentiality was long back established by Arnon and Stout in 1939, who stated that an essential element:

- Must require for the completion of the life cycle of the plant.
- Must not be replaceable by another element.
- Must be directly involved in plant metabolism, that is, it must be required for a specific physiological function.

Classification of Essential Nutrients

There are different basis of classification of essential nutrients:

i) Quantity of nutrient required
ii) Mobility of nutrient in soil
iii) Mobility of nutrient with in plant
iv) Functions in plant

Classification on the basis of quantity of nutrient required

1. Basic nutrients: These constitute 96% of total dry matter of plant.
   - Name of Basic nutrients: Carbon, Hydrogen, Oxygen
   - Among these, carbon and oxygen constitute 45% each and hydrogen is 6%.
2. Macro nutrients : The nutrients which are required by plants in large quantities are called macro or major nutrients.
   Macro nutrients have again two categories:
   - **Primary nutrients** : Nitrogen, Phosphorus and Potassium
   - **Secondary nutrients :**Calcium, Magnesium and Sulphur which are known as secondary nutrients.
3. Micro nutrient : These nutrients required by plants in small quantities and also known as minor or trace elements. These are eight in number

- Manganese, Iron, Zinc, Copper, Boron, Molybdenum , Chlorine and Cobalt.

Classification on the basis of mobility of nutrient in the soil:

- Mobile nutrients : The nutrients are highly soluble and these are not adsorbed on clay complexes.
  Example: NO3-, SO42-,BO32-, Cl- and Mn+2
- Less mobile nutrients: They are soluble, but they are adsorbed on clay complex, so their mobility is reduced.
  Example: NH4+, K+, Ca+, Mg2+, Cu2+
- Immobile nutrients: Nutrient ions are highly reactive and get fixed in the soil.
  Example: H2PO4-,HPO42-, Zn2+

Classification on the basis of mobility with in plant:

- Highly mobile: N, P and K.
- Moderately mobile: Zn
- Less mobile: S, Fe, Mn, Cl, Mo and Cu
- Immobile: Ca and B

Classification on the basis of functions in the plant

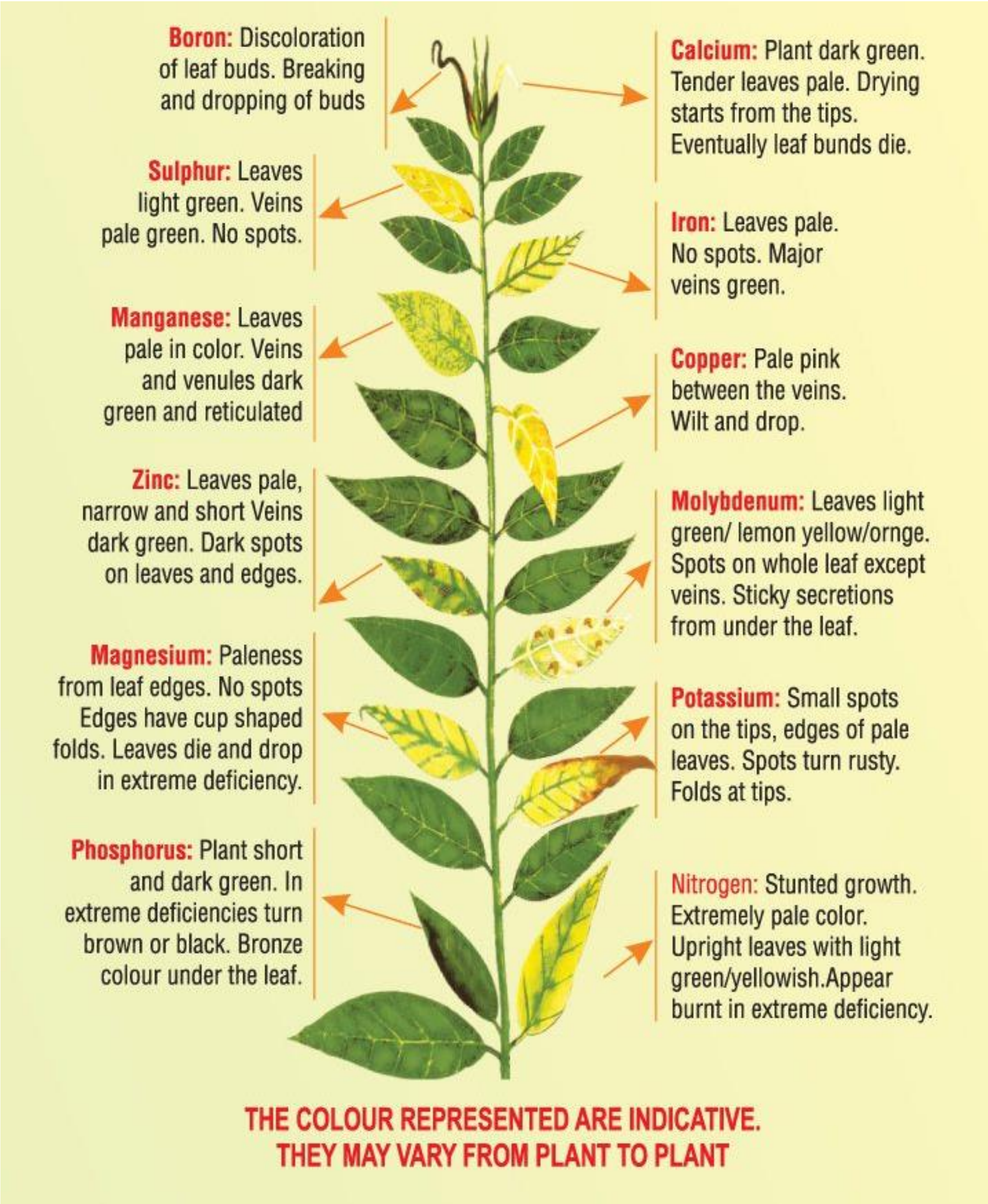
- **Elements that provide basic structure to plant :** Carbon, Hydrogen and Oxygen
- **Elements useful in energy storage, transfer and bonding:** These are accessory structural elements which are more active and vital for living tissues.
  Example: N, S and P
- **Elements necessary for charge balance :** K, Ca and Mg.
- **Elements involved in enzyme activation and electron transfer**: Fe, Mn, Zn, Cu, B, Mo and Cl.

Function of plant nutrients :

Nutrients	Functions
Nitrogen	• Component of many important organic compounds from protein to nucleic acids • Necessary for the formation of aminoacids, building block of proteins • Essential for plant cell division,vital for plant growth • Imparts green colour to the plants • Constituent of protoplasm of chlorophyll • Synthesis of auxins
Phosphorous	• Energy storage and Transfer of energy(component of ATP) and act as energy currency • Essential component of nucleic acids • Necessary for root development • Increases disease resistance • Required for **grain formation** and maturity of grains
Potassium	• Most important is stomata regulation. helps in **osmotic and ionic regulation** • Increases disease resistance • Activator for many enzymes of carbohydrate and protein. • Helps in chlorophyll formation • Reduce the transpiration rate and increase photosynthetic rate
Calcium	• Involved in cell division • Plants require Ca to develop strong cell walls and membranes. • Calcium is only xylem mobile, meaning it can only move up the plant, and once in place, it cannot be remobilized
Magnesium	• **Central component of chlorophyll** • Cofactor for many enzymatic reactions involving respiration, photosynthesis and nucleic acid synthesis. • Act as Phosphorous carrier in plants
Sulphur	• essential element in forming proteins, enzymes, vitamins, and chlorophyll in plants • crucial in nodule development and efficient nitrogen fixation in legumes. • Protein synthesis requires large amounts of sulphur • contributes to crop winter hardiness
Manganese	• Involved in oxygen evolving system of photosynthesis. • Cofactor of enzymes
Iron	• Essential for formation of chlorophyll • Acts as an oxygen carrier
Zinc	• Required for biosynthesis of hormones • Aids in seed formation

	• Necessary for starch formation
Copper	• Constituent of many enzymes • Important for reproductive growth • Aids in root metabolim • Necessary for photosynthesis. And respiration
Boron,	• Necessary for pollen germination • Regulates the intake of water into the cell • Necessary for sugar translocation
Molybdenum	• Required for norma assimilation of N in plants • Helps in nitrogen fixation in pulses • Converts inorganic phosphates to organic forms in the plants
Chlorine	• Necessary for photosynthesis • Activator for enzymes involved in splitting water • Also functions in osmoregulation of plants growing in saline soils
Cobalt	• necessary for the processes of stem growth, elongating the coleoptiles, and expanding leaf discs. • critical to reach maturity and for healthy bud development • required for nitrogen fixation by bacteria in root nodules

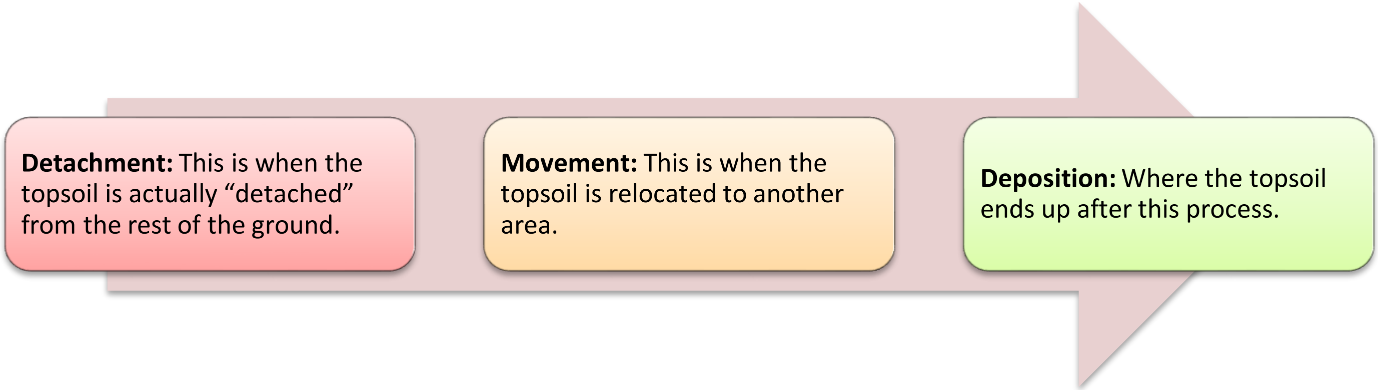
Plant Nutrients Deficiency



SOIL EROSION

Soil erosion is the loosening and displacement of topsoil particles from the land.

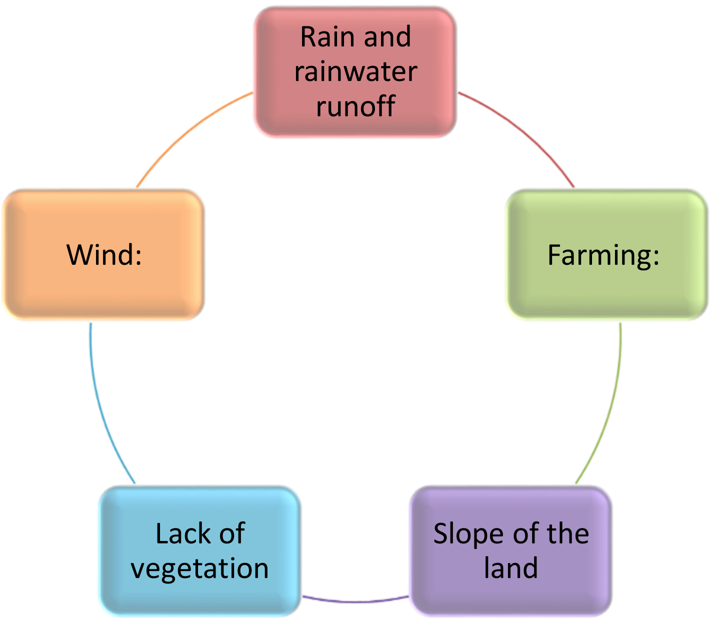
- Erosion, whether it is by water, wind or tillage, involves three distinct actions – **soil detachment, movement and deposition.**



Soil erosion in nature may be

- a slow process (or geological erosion) or
- a fast process promoted by deforestation, floods, tornadoes or other human activities.

Causes of erosion


Rain and rainwater runoff
Farming:
Slope of the land
Lack of vegetation
Wind:

- **Rain and rainwater runoff:** This occurs when the soil is saturated by water to its full capacity, and the rain arrives more quickly than the soil can absorb it.
- **Farming:** it reduces the overall structure of the soil and the levels of organic matter, making it more susceptible to the effects of rain and water. Tilling in particular, breaks up and softens the structure of soil, making it susceptible to erosion.
- **Slope of the land:** The physical characteristics of the land can also contribute to soil erosion. For example, land with a high hill slope will perpetuate the process of rainwater or runoff saturation in the area, particularly due to the faster movement of the water down a slope.

- **Lack of vegetation:** Plants and crops help maintain the structure of soils, reducing the amount of soil erosion. Areas with less naturally-occurring flora may be a hint that the soil is prone to erosion.

- **Wind:** Wind can be a major factor in reducing soil quality and promotion erosion, particularly if the soil's structure has already been loosened up. However, lighter winds will typically not cause too much damage, if any. The most susceptible soil to this type of erosion is sandy or lighter soil that can easily be transported through the air.

Water Erosion

Running water is one of the main agents, which carries away soil particles.

Soil erosion by water is termed differently according to the intensity and nature of erosion.

i) Raindrop erosion (ii) Sheet erosion (iii) Rill erosion (iv) Steam banks erosion (v) Erosion due to landslides (vi) Coastal erosion.

Raindrop erosion/Splash erosion

- Raindrops behave like tiny bombs when falling on exposed soil, displace soil particles and destroy soil structure.
- Average size of a raindrop is approximately 5 mm in diameter falling through the air hits the soil at a velocity of 32 km/hr.
- Presence of vegetation on land prevents raindrops from falling directly on the soil thus erosion of soil in areas covered by vegetation is prevented.

Sheet erosion

- Sheet erosion is the uniform removal of soil in thin layers, and it occurs when soil particles are carried evenly over the soil surface by rainwater that does not infiltrate into the ground.
- This is a very slow process and often remain unnoticed.

Rill erosion

- In rill erosion ,**finger like rills appear** on the cultivated land after it has undergone sheet erosion.
- These rills are usually smoothened out every year while forming.
- Each year the rills slowly increase in number become wider and deeper.
- **When rills increase in size, they are called gullies. Ravines are deep gullies**.

Streambank erosion

- The erosion of soil from the banks (shores) of the streams or rivers due to the flowing water is called bank erosion.

Landslide

- A sudden mass movement of soil is called a landslide.
- Landslides occur due to instability or loss of balance of land mass with respect to gravity.

Coastal erosion

- Coastal erosion of soil occurs along seashores.
- It is caused by the **wave action** of the sea and the inward movement of the sea into the land.

Consequences of water erosion

- Erosion **removes the most fertile** part of the soil. The less fertile subsoil is left.
- The fine particles of the topsoil which contain the bulk of **nutrients and organic matter** needed by the plants are lost from soil erosion.
- Erosion may result in **removal of seeds or seedlings** so that the soil becomes bare. Bare soil is more vulnerable to erosion both by wind and water.
- Removal of seeds and seedlings reduces the ability of soil to store water.
- Sheet, rill, gully and stream bank erosion also cause siltation of rivers, streams and fields.

Wind erosion

- Soil erosion by wind is more common in areas where the natural vegetation has been destroyed.
- Such conditions **occur mainly in arid and dry areas along the sandy shores of oceans, lakes and rivers.**
- The **loose soil particles are blown and transported from wind by following three ways**:
    - Siltation: blown by the wind in a series of short bounces.
    - Suspension: transported over long distances in the form of suspended particles.
    - Surface creep: transported at ground level by high-velocity winds.

Consequences of wind erosion

- Wind erosion removes the finer soil material including organic matter, clay and slit, in a suspension (colloidal) form and leaving behind coarser, less fertile material.
- The productive capacity of the soil is lost as most of the plant nutrients which remain attached to smaller colloidal soil fraction, are lost.
- Wind erosion also damages roads and fertile agricultural fields by depositing large quantities of air blown sand particles.

Soil Conservation

Soil conservation is the **prevention of soil from erosion or reduced fertility** caused by overuse, acidification, salinisation or other chemical soil contamination

Crop Rotation

- In many parts of India, **a particular crop is sown in the same field year after year**. This practice leads to **exhaustion of certain nutrients in the** soil making it infertile.
- Crop rotation is a practice in which a different crop is cultivated on a piece of land each year.
- This helps to **conserve soil fertility as different crops require different nutrients from the soil**. Crop rotation will provide enough time to restore lost nutrients.
    - For example, **potatoes require much potash, but wheat requires nitrate**. Thus, it is best to alternate crops in the field.
    - Legumes such as peas, beans, and many other plants, add nitrates to the soil by converting free nitrogen in the air into nitrogenous nodules on their roots.

Contour Ploughing

- If ploughing is done at right angles to the hill slope, the ridges and furrows break the flow of water down the hill.
- This prevents excessive soil loss as gullies are less likely to develop and also reduce run-off so that plants receive more water.

Checking Shifting Cultivation

- Checking and reducing shifting cultivation by persuading the tribal people to switch over to settled agriculture is a very effective method of soil conservation.
- This can be done by planning for their resettlement which involves the provision of residential accommodation, agricultural implements, seeds, manures, cattle and reclaimed land.

Ploughing the Land in Right Direction

- Ploughing the land in a direction perpendicular to wind direction also reduces wind velocity and protects the topsoil from erosion.

Mulching

- The bare ground (topsoil) between plants is covered with a protective layer of organic matter like grass clippings, straw, etc.

Benefits

- Protects the soil from erosion.
- It helps to retain soil moisture.
- Reduces compaction from the impact of heavy rains.
- Conserves moisture, reducing the need for frequent watering.
- Maintains a more even soil temperature.
- Prevents weed growth.
- Organic mulches also improve the condition of the soil. As these mulches slowly decompose, they provide organic matter which helps keep the soil loose.

Contour barriers

- Stones, grass, soil are used to build barriers along contours. **Trenches are made** in front of the barriers to collect water.
- They **intercept downslope flowing water and soil particles**. These barriers slow down the water movement and reduce its erosive force.
- A long term advantage of barriers is that soil tends to build up behind them, creating a terrace effect.
- Barriers can be classified as **live (strips of living plants), dead (rocks, crop residues), or mixed (a combination of the previous two).**

Rock Dam

Rocks are piled up across a channel to slow down the flow of water. This prevents gullies and further soil loss.

Terrace farming

- In terracing, a number of terraces are cut along the hill slope.
- These are made on the steep slopes so that flat surfaces are available to grow crops. They can reduce surface run-off and soil erosion.

Contour Bunding

- Contour bunding involves the construction of banks along the contours.
- Terracing and contour bunding which divide the hill slope into numerous small slopes, check the flow of water, promote absorption of water by soil and save soil from erosion.

Shelterbelts or Windbreaks

- In the **coastal and dry regions**, rows of trees are planted to check the wind movement to protect soil cover.

Sand fences

- Sand fences are barriers made of small, evenly spaced wooden slats or fabric.
- They are erected to reduce wind velocity and to trap blowing sand.
- Sand fences can be used as perimeter controls around open construction sites to keep sediments from being blown offsite by the wind
- 

Afforestation

- It includes the prevention of forest destruction along with growing new forests or increase in area under forests.
- A minimum area of 20 to 25 per cent of forest land was considered healthy for soil and water conservation for the whole country.
- It was raised to 33 per cent in the second five-year plan – 20 per cent for the plains and 60 per cent for hilly and mountainous regions.

Checking Overgrazing

- Overgrazing accentuates erosion.
- During the dry period, there is a shortage of fodder, and the grass is grazed to the ground and torn out to the roots by animals. The **soil is pulverised (reduce to fine particles) by the hoofs of animals**. All this leads to the weak top layer.
- So overgrazing needs to be checked to prevent soil erosion.
- This can be done by creating separate grazing grounds and producing larger quantities of fodder.

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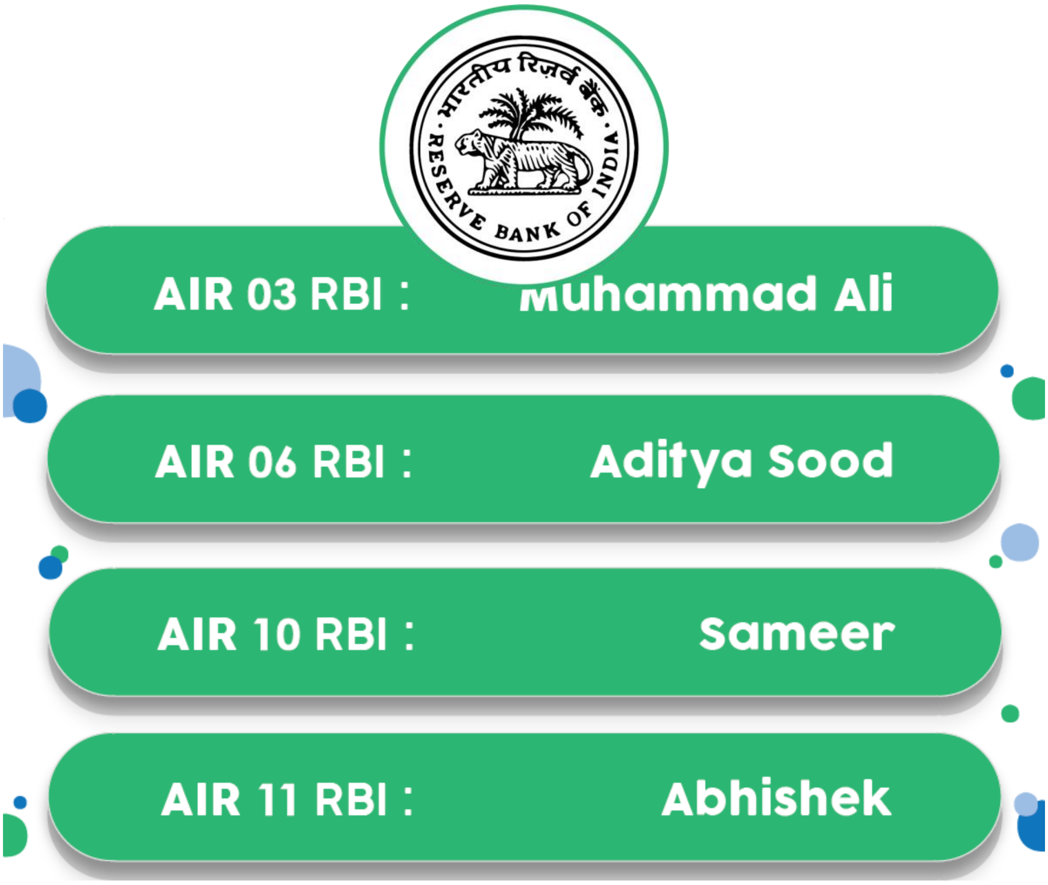

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NABARD

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