Bioecology
Module: Soil Science

Lecture 10.
Soil organic matter: Composition, Decomposability. Humus: Fractionation of organic matter

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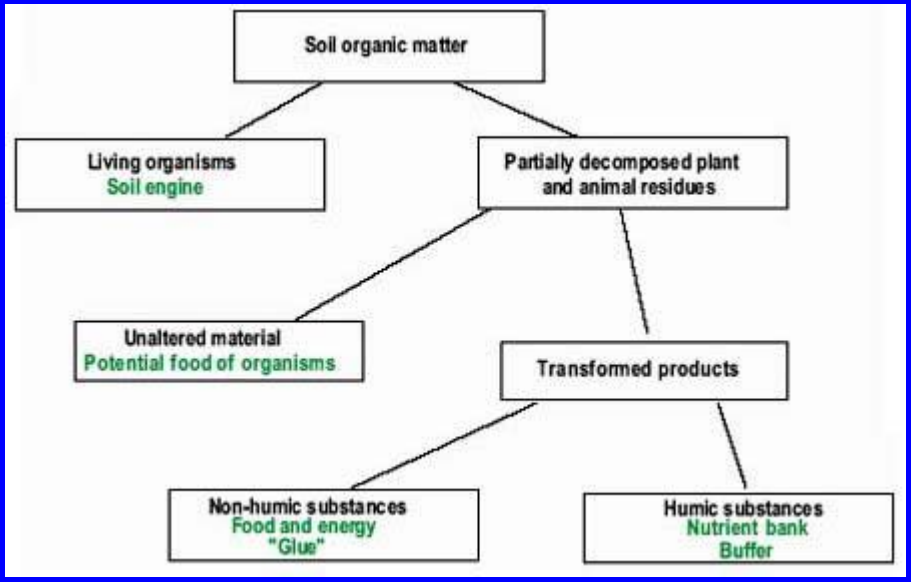
SOIL ORGANIC MATTER

Organic matter are substances containing carbon. Soil organic matter consists of decomposing plant and animal residues, also includes substances of organic origin either leaving or dead.

Soil organic matter plays an important role in deciding/maintaining soil physical conditions. It also influences soil chemical properties especially cation exchange capacity. Organic matters supply the energy sources for soil microorganisms. Soil development is another aspect which is influenced by the soil organic matter.

Plant tissue is the major source. Animals are considered as the secondary sources. They attack original plant tissues, contribute waste products and leave their own bodies after death.

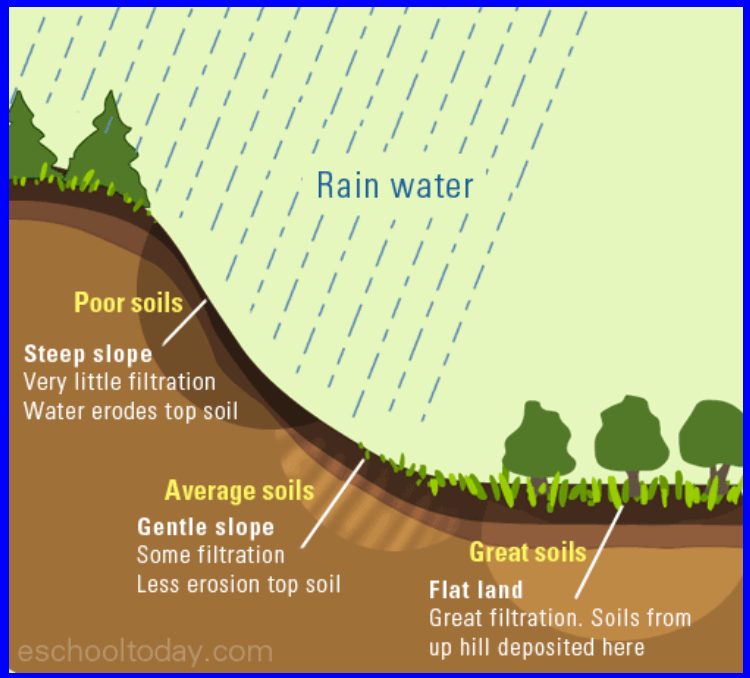


FACTORS AFFECTING SOIL ORGANIC MATTER

1. ***Climate***: Temperature and rainfall exert a dominant influence on the amounts of N and organic matter found in soils.

a) Temperature: The organic matter and N content of comparable soils tend to increase if one moves from warmer to cooler areas. The decomposition of organic matter is accelerated in warm climates as compared to cooler climates. For each 10^0C decline in mean annual temperature, the total organic matter and N increases by two to three times.

b) Rainfall: There is an increase in organic matter with an increase in rainfall. Under comparable conditions, the N and organic matter increase as the effective moisture becomes greater.



2. ***Natural Vegetation***: The total organic matter is higher in soils developed under grasslands than those under forests.

FACTORS AFFECTING SOIL ORGANIC MATTER

3. ***Texture***: Fine textured soils are generally higher in organic matter than coarse textured soils.

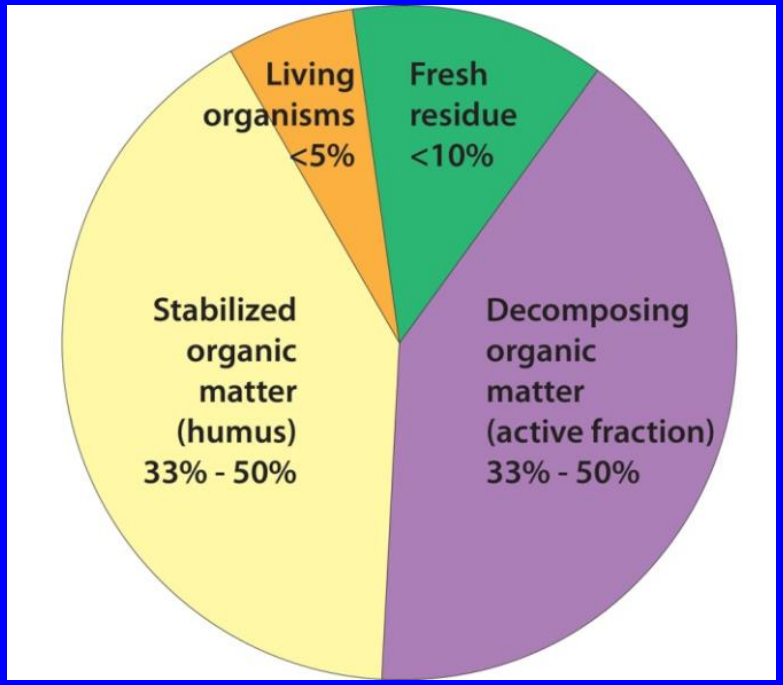
4. ***Drainage***: Poorly drained soils because of their high moisture content and relatively poor aeration are much higher in organic matter and N than well drained soils.

5. ***Cropping and Tillage***: The cropped lands have much low N and organic matter than comparable virgin soils. Modern conservation tillage practices helps to maintain high organic matter levels as compared to conventional tillage.

6. ***Rotations, residues and plant nutrients***: Crop rotations of cereals with legumes results in higher soil organic matter. Higher organic matter levels, preferably where a crop rotation is followed.

COMPOSITION OF ORGANIC MATTER

Soil organic matter is derived from plants and animals, with the primary source coming from plant residues. Soil organic matter includes all the organic substances in or on the soil.



Plant residues contain 75% moisture and 25% dry matter. This 25% is made up of Carbon (10-12%), Oxygen (9-10%), Hydrogen (1.5-2.5%), Nitrogen (1-2%) and mineral matter (1-3%).

The most important part of Soil organic matter is its carbon component. ***Soil organic carbon*** is equivalent to about 58% of the soil organic matter. Humus is usually the largest soil organic carbon pool

DECOMPOSITION OF SOIL ORGANIC MATTER

Different organic residues contain different organic compounds. There is great variation in the rate of decomposition of organic residues:

1. Rapidly decomposed : Sugars, starches, proteins etc.
2. Less rapidly decomposed : Hemicelluloses, celluloses etc.
3. Very slowly decomposed : Fats, waxes, resins, lignins etc

The general reactions taking place during decomposition are:

1. Enzymatic oxidation of the bulk with the release of CO_2, water, energy and heat
2. Essential elements are released (N, P, S etc) and immobilized by a series of reactions.
3. Formation of compounds which are resistant to microbial action.

Under aerobic conditions the products formed are CO_2, NH_4, NO_3 , H_2PO_4, SO_4, H_2O and essential plant nutrients like Ca, Mg, Fe, Cu, Zn etc.

Under anaerobic conditions the products formed are CH_4, organic acids like lactic, propionic, butyric, NH_4, various amine residues ($R\text{-}NH_2$)H_2S, ethylene (CH_2=CH_2) and humic substances.

DECOMPOSITION OF SOIL ORGANIC MATTER

Ammonification is the transformation of organic nitrogenous compounds (amino acids, amides, ammonium compounds, nitrates etc.) into ammonia. This process occurs as a result of hydrolytic and oxidative enzymatic reaction under aerobic conditions by heterotrophic microbes.

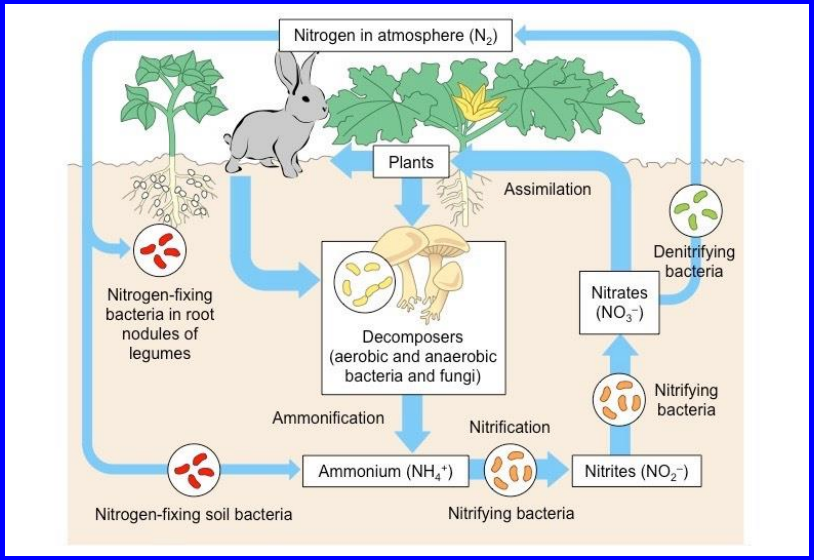
Nitrification is the process of conversion of ammonia to nitrites (NO_2) and then to nitrate (NO_3^-). It is an aerobic process by autotrophic bacteria.

Denitrification is the process, which involves conversion of soil nitrate into gaseous nitrogen or nitrous oxide. Water logging and high pH will increase N loss by Denitrification.

Aminization is the process of conversion of proteins to aminoacids.

Mineralisation is the biological conversion of organic forms of C, N, P and S to inorganic or mineral forms.

Immobilization is the conversion of inorganic forms of C, N, P and S by the soil organism into organic forms



FACTORS AFFECTING DECOMPOSITION

1. *Temperature*: Cold periods retard plant growth and organic matter decomposition. Warm summers may permit plant growth and humus accumulation.

2. *Soil moisture*: Extremes of both arid and anaerobic conditions reduce plant growth and microbial decomposition. Near or slightly wetter than field capacity moisture conditions are most favorable for both processes.

3. *Nutrients*: Lack of nutrients particularly N slows decomposition.

4. *Soil pH*: Most of the microbes grow best at pH 6 to 8, but are severely inhibited below pH 4.5 and above pH 8.5.

5. *Soil Texture*: Soils higher in clays tend to retain larger amounts of humus.

6. Other Factors: Toxic levels of elements (Al, Mn, B, Se, Cl), excessive soluble salts, shade and organic phytotoxins in plant materials.

ROLE OF ORGANIC MATTER

1. Organic matter creates a granular condition of soil which maintains favorable condition of aeration and permeability.
2. Water holding capacity of soil is increased and surface runoff, erosion etc., are reduced as there is good infiltration due to the addition of organic matter.
3. Surface mulching with coarse organic matter lowers wind erosion and lowers soil temperatures in the summer and keeps the soil warmer in winter.
4. Organic matter serves as a source of energy for the microbes and as a reservoir of nutrients that are essential for plant growth and also hormones, antibiotics.
5. Fresh Organic matter supplies food for earthworms, ants and rodents and makes soil P readily available in acid soils.
6. Organic acids released from decomposing organic matter help to reduce alkalinity in soils; organic acids along with released CO_2 dissolve minerals and make them more available.
7. Humus (a highly decomposed organic matter) provides a storehouse for the exchangeable and available cations.
8. It acts as a buffering agent which checks rapid chemical changes in pH and soil reaction.

HUMUS. HUMUS FORMATION

Humus is a complex and rather resistant mixture of brown or dark brown amorphous and colloidal organic substance that results from microbial decomposition and synthesis and has chemical and physical properties of great significance to soils and plants.

The humus compounds have resulted from two general types of biochemical reactions: Decomposition and Synthesis.

1. Decomposition: a) Chemicals in the plant residues are broken down by soil microbes including lignin. b) Other simpler organic compounds that result from the breakdown take part immediately in the second of the humus-forming processes, biochemical synthesis. c) These simpler chemicals are metabolized into new compounds in the body tissue of soil microbes. d) The new compounds are subject to further modification and synthesis as the microbial tissue is subsequently attacked by other soil microbes.

2. Synthesis: Involve such breakdown products of lignin as the phenols and quinones. a) These monomers undergo polymerization by which polyphenols and polyquinones are formed. b) These high molecular weight compounds interact with N-containing amino compounds and forms a significant component of resistant humus. c) Colloidal clays encourage formation of these polymers. d) Generally two groups of compounds that collectively make up humus, the humic group and the nonhumic group.

HUMUS. SOIL ORGANIC MATTER FRACTIONS

Soil organic matter fractions

Humic matter	**Non humic matter**
soluble portion forms extracted with alkali	insoluble portion forms
makes up about 60-80% of the soil organic matter.	makes up to 20-30% of the organic matter in soil.
most complex; most resistant to microbial attack.	less complex and less resistant to microbial attack as compared to humic substances.
have aromatic ring type structures: polyphenols and poly quinones.	polysaccharides, polymers having sugar like structures and polyuronides: proteins, carbohydrates, lignins, fats, waxes, resins, tannins and some compounds of low molecular weight.
formed by decomposition, synthesis and polymerization	
The humic substances are classified based on resistance to degradation and solubility in acids and alkalis into: Humic acid; Fulvic acid; Humin	

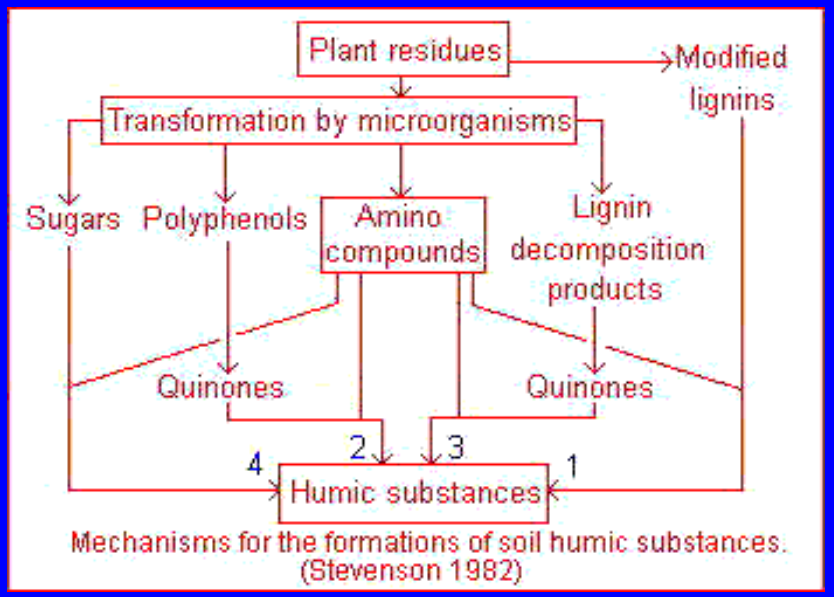
THEORIES ON HUMUS FORMATION

Lignin theory (Waksman, 1936). According to this theory humic substances are formed due to the incomplete degradation of lignin

Kononovas theory. According to this theory humic substances are formed by cellulose decomposing mycobacteria earlier to lignin decomposition

Polyphenol theory: (Flaig and Sochtig, 1964). As per this theory the humic substances are formed by the condensation of phenolic materials. The polyphenols of lignin are oxidized to quinones. These quinones are condensed with low molecular weight microbial products to form humic molecules. The microbial products are amino acids, nucleic acid and phospholipids.

The classical theory is that humic substances represent modified lignins (pathway 1) but the majority of present-day investigators favor a mechanism involving quinones (pathway 2 and 3). In practice all four pathways must be considered as likely mechanisms for the synthesis of humic and fulvic acids in nature, including sugar-amine condensation (pathway 4).



Mechanisms for the formations of soil humic substances. (Stevenson 1982)

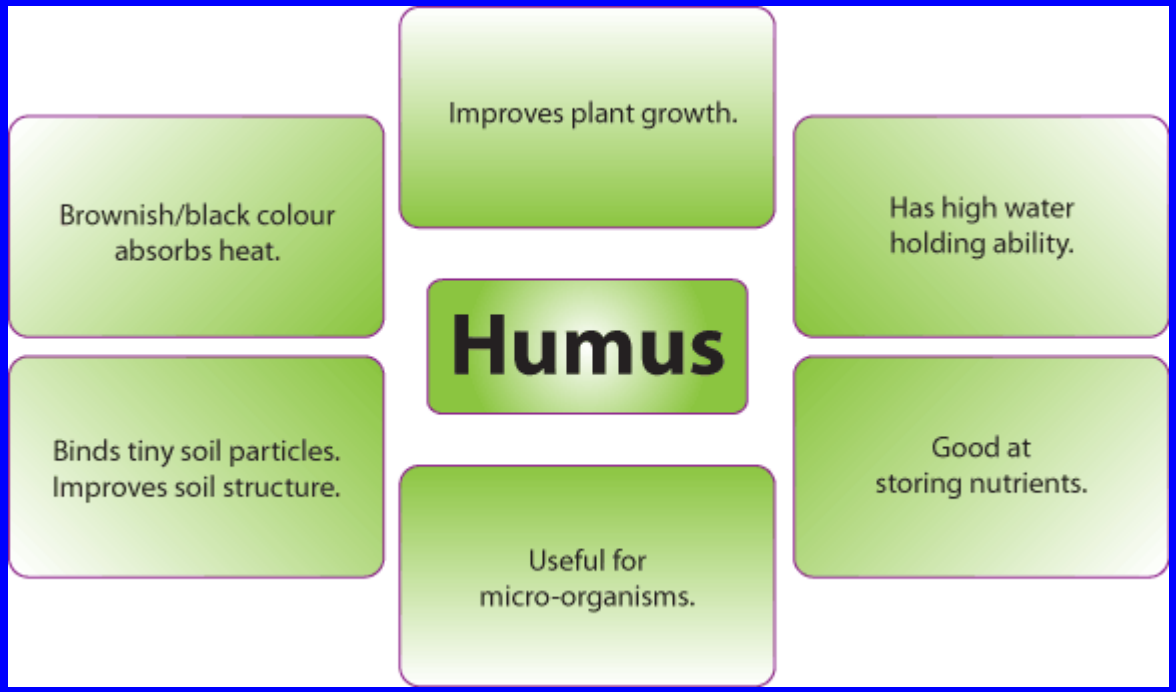
PROPERTIES OF HUMUS

1. The tiny colloidal particles are composed of C, H, and O_2

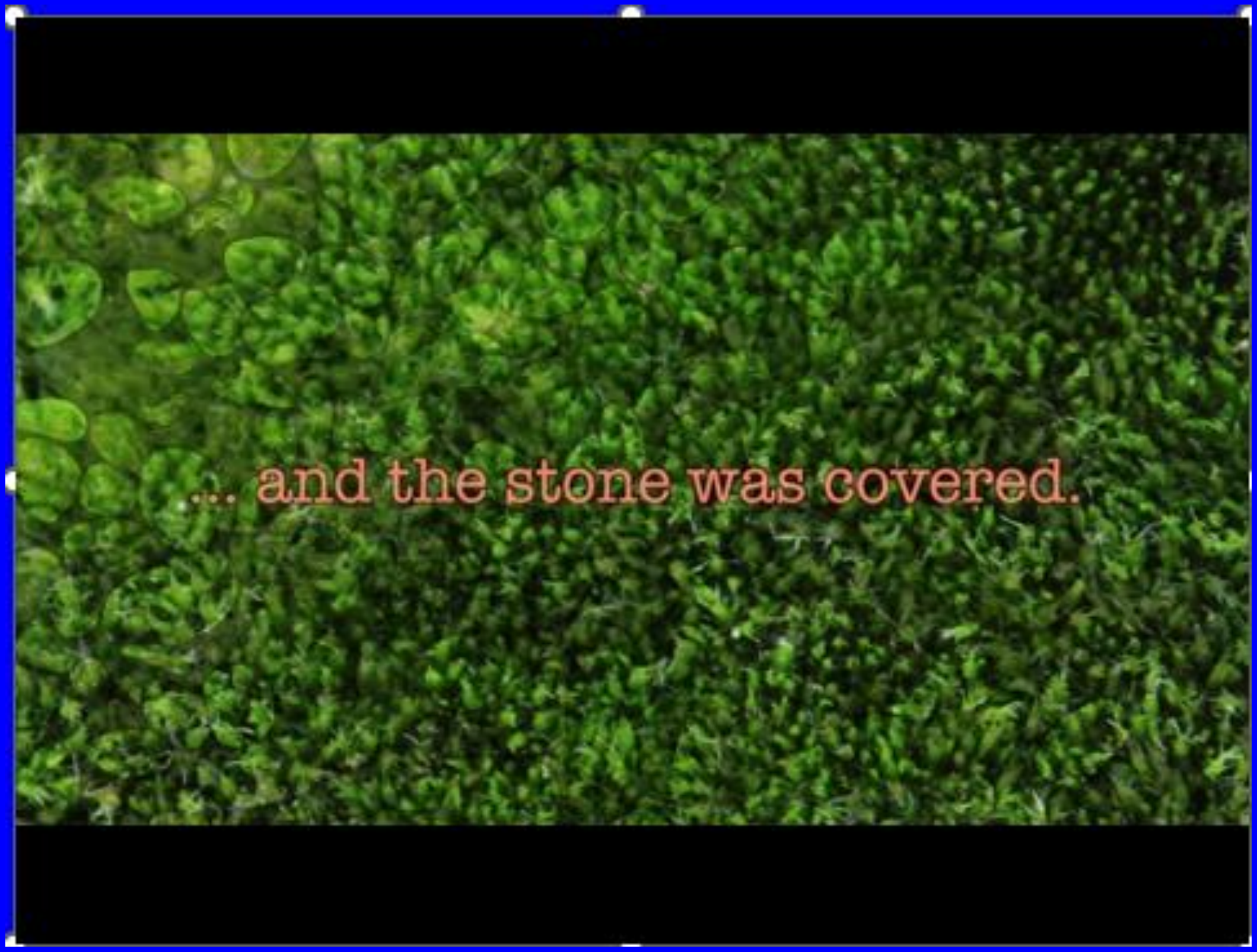
2. The colloidal particles are negatively charged (-OH, -COOH or phenolic groups), has very high surface area, higher CEC (150 – 300 cmol/kg), 4 - 5 times higher WHC than that of silicate clays.

3. Humus has a very favorable effect on aggregate formation and stability.

4. Impart black colour to soils.



HUMUS



Thank you for attention!