Bioecology
Module: Soil Science

Lecture 4.
Soil physical properties. Soil texture.
Textural classes.

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Physical properties (mechanical behaviour) of a soil greatly influence its use and behaviour towards plant growth. The physical properties of a soil depend on the amount, size, shape, arrangement and mineral composition of its particles. These properties also depend on organic matter content and pore spaces.

Important physical properties of soils.

1. Soil texture,
2. Soil structure,
3. Surface area,
4. Soil density,
5. Soil porosity,
6. Soil colour,
7. Soil consistence

Soil texture

Soil texture is:

1) the relative proportion of particles;
2) the relative percentage by weight of the three soil separates viz., sand, silt and clay;
3) the size of soil particles.

The proportion of each size group in a given soil (the texture) cannot be easily altered and it is considered as a basic soil property.

The soil separates are defined in terms of diameter in millimeters of the particles.

Stones and gravels may influence the use and management of land because of tillage difficulties but these larger particles make little or no contribution to soil properties and capacity to store plant nutrients and their supply:

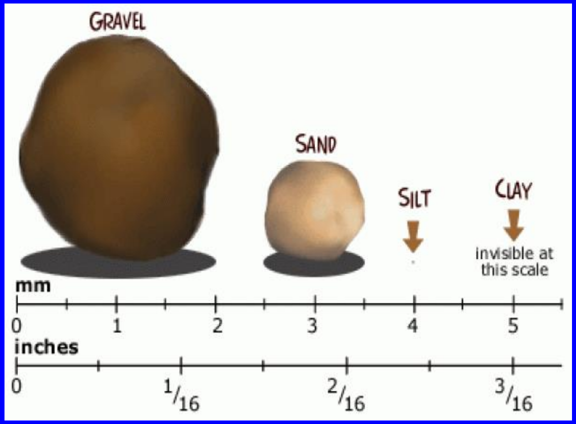
Gravels : 2 – 4 mm

Pebbles : 4 – 64 mm

Cobbles : 64 – 256 mm

Boulders : > 256 mm

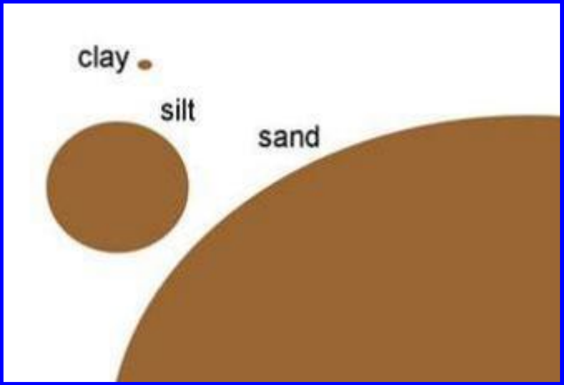
Particles less than 2 mm is called fine earth, normally considered in chemical and mechanical analysis.



Soil texture

The components of fine earth: Sand, Silt and Clay (Soil separates). The size limits of these fractions have been established by various organizations. There are a number of systems of naming soil separates.

(a) The American system developed by USDA
(b) The English system or British system (BSI)
(c) The International system (ISSS)
(d) European system



i) USDA

Soil separates	Diameter (mm)
Clay	< 0.002 mm
Silt	0.002 – 0.05
Very Fine Sand	0.05 – 0.10
Fine Sand	0.10 – 0.25
Medium Sand	0.25 - 0.50
Coarse Sand	0.50 - 1.00
Very Coarse Sand	1.00 – 2.00

iii) ISSS

Soil separates	Diameter (mm)
1. Clay	< 0.002 mm
2. Silt	0.002 – 0.02 mm
3. Fine sand	0.02 – 0.2 mm
4. Coarse sand	0.2 – 2.0 mm

iv) European System

S.No	Soil separates	Diameter (mm)
1	Fine clay	< 0.0002 mm
2	Medium clay	0.0002 – 0.0006
3	Coarse clay	0.0006 – 0.002
4	Fine silt	0.002 - 0.006
5	Medium silt	0.006 - 0.02
6	Coarse silt	0.02 - 0.06
7	Fine sand	0.06 - 0.20
8	Medium sand	0.20 - 0.60
9	Coarse sand	0. 60 - 2.00

Sand

- Usually consists of quartz but may also contain fragments of feldspar, mica and occasionally heavy minerals viz., zircon, Tourmaline and hornblende.
- Has uniform dimensions
- Can be represented as spherical
- Not necessarily smooth and has jagged surface

Silt

- Particle size intermediate between sand and clay
- Since the size is smaller, the surface area is more
- Coated with clay
- Has the physico- chemical properties as that of clay to a limited extent

Sand + Silt = SKELETON

Clay

- Particle size less than 0.002 mm
- Plate like or needle like in shape
- Belong to alumino silicate group of minerals
- Sometimes considerable concentration of fine particles which does not belong to alumino silicates (iron oxide and $CaCO_3$)
- These are secondary minerals derived from primary minerals in the rock
- Flesh of the soil

Soil Textural Classes

To convey an idea of the textural make up of soils and to give an indication of their physical properties, soil textural class names are used. These are grouped into three main fractions viz., Sand, Silt and Clay.

According to the proportion of these three fractions a soil is given a name to indicate its textural composition. Such a name gives an idea not only of the textural composition of a soil but also of its various properties in general.

Sands

>70% sand + <15% clay.

Two specific textural classes are recognized sandy and loamy sand although in practice two subclasses are also used Loamy fine sand and loamy very fine sand.

Silt

> 80% silt + <12% clay. Only one textural class - Silt sand.

Clays

>35-40% clay.

In such soils the characteristics of the clay separates are distinctly dominant, and the class names are clay, sandy clay and silty clay. Sandy clays may contain more sand than clay. Likewise, the silt content of silty clays usually exceeds clay fraction.

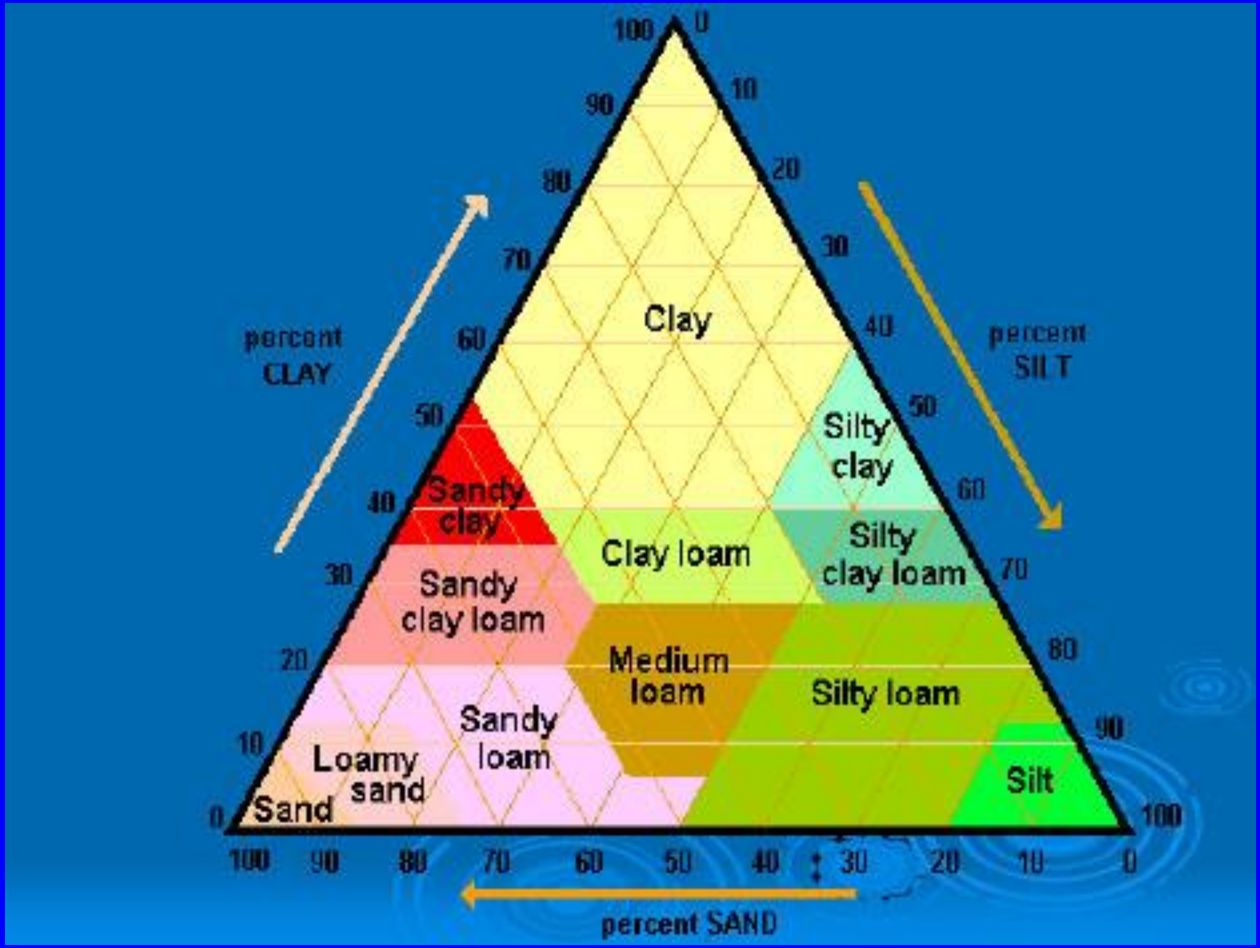
Loams

An ideal loam may be defined as a mixture of sand, silt and clay particles that exhibits the properties of those separates in about equal proportions. Loam soils exhibit approximately equal properties of sand, silt and clay.

The textural triangle

In the American system as developed by the United State Department of Agriculture 12 textural classes are proposed.

The textural triangle is used to determine the soil textural name after the percentages of sand, silt, and clay are determined from a laboratory analysis.



Importance of Soil Texture

Presence of each type of soil particles makes its contribution to the nature and properties of soil as a whole

- Texture has good effect on management and productivity of soil.
- Sandy soils are of open character usually loose and friable. Such type of the texture is easy to handle in tillage operations. Sand facilitates drainage and aeration. It allows rapid evaporation and percolation. Sandy soils have very little water holding capacity. Such soils can not stand drought and unsuitable for dry farming. Sandy soils are poor store house of plant nutrients, contain low organic matter. In sandy soil leaching of applied nutrients is very high. In sandy soil, few crops can be grown such as potato, groundnut and cucumbers.

- Clay particles play a very important role in soil fertility. Clay soils are difficult to till and require much skill in handling. When moist clayey soils are exceedingly sticky and when dry, become very hard and difficult to break. They have fine pores, and are poor in drainage and aeration. They have a high water holding capacity and poor percolation, which usually results in water logging. They are generally very fertile soils, in respect of plant nutrient content. Rice, jute, sugarcane can be grown very successfully in these soils.

- Loam and Silt loam soils are highly desirable for cultivation
- Generally, the best agriculture soils are those contain 10 – 20 % clay, 5 – 10 % organic matter and the rest equally shared by silt and sand.

Soil density

Particle Density is the weight per unit volume of the solid portion of soil. Generally particle density of normal soils is 2.65 grams per cubic centimeter. The particle density is higher if large amount of heavy minerals such as magnetite, limonite and hematite are present in the soil. With increase in organic matter of the soil the particle density decreases. Particle density is also termed as true density.

Textural class	Particle density (g/cm^3)
Coarse sand	2.655
Fine sand	2.659
Silt	2.798
Clay	2.837

Bulk Density is the oven dry weight of a unit volume of soil inclusive of pore spaces. The bulk density of a soil is always smaller than its particle density. The bulk density of sandy soil is about 1.6 g/cm^3, whereas that of organic matter is about 0.5. Bulk density normally decreases, as mineral soils become finer in texture. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. Generally soils with low bulk densities have favorable physical conditions.

Textural class	Bulk density (g/cm^3)	Pore space (%)
Sandy soil	1.6	40
Loam	1.4	47
Silt loam	1.3	50
Clay	1.1	58

Comparison of Bulk Density and Particle Density

In a soil profile, one cubic centimeter ($1.0cm^3$) appears like this:

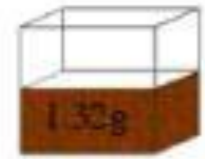
It contains solids and pore spaces, and the whole cm^3 has a mass of 1.32g.

If all the solids were compressed to the bottom, the cube would now look like this:

Half contains the pore spaces →

Half contains the solids →

(Notice the Volume change!)



To calculate **Bulk Density** of the soil:

Volume = $1.0cm^3$ (Solids and Pores)

Mass = 1.32g (Sieved Solids only)

Bulk Density = Mass of Dry Soil / Volume of soil (Solids and Pores)

Therefore:

$$\text{Bulk Density} = \frac{1.32}{1.0} = 1.32\ g/cm^3$$

To calculate **Particle Density** of the soil:

Volume = **$0.5cm^3$** **(Solids only)**

Mass = **1.32**g (Sieved Solids only)

Particle Density = Mass of solids / Volume of solids

Therefore:

$$\text{Particle Density} = \frac{1.32}{.5} = 2.64\ g/cm^3$$

Soil density. Factors affecting bulk density

1. Pore space

Since bulk density relates to the combined volume of the solids and pore spaces, soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influences soil pore space will affect bulk density.

2. Texture

Fine textured surface soils (silt loams, clays and clay loams) have lower bulk densities than sandy soils. This is because the fine textured soils tend to organize in porous grains especially because of adequate organic matter content. This results in high pore space and low bulk density. However, in sandy soils, organic matter content is generally low, the solid particles lie close together and the bulk density is commonly higher than in fine textured soils.

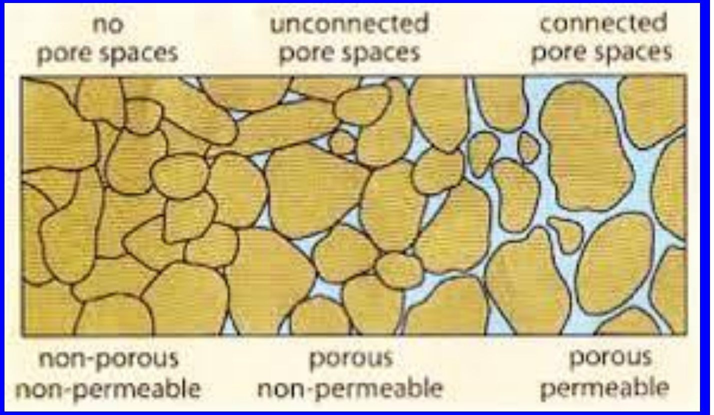
3. Organic matter content

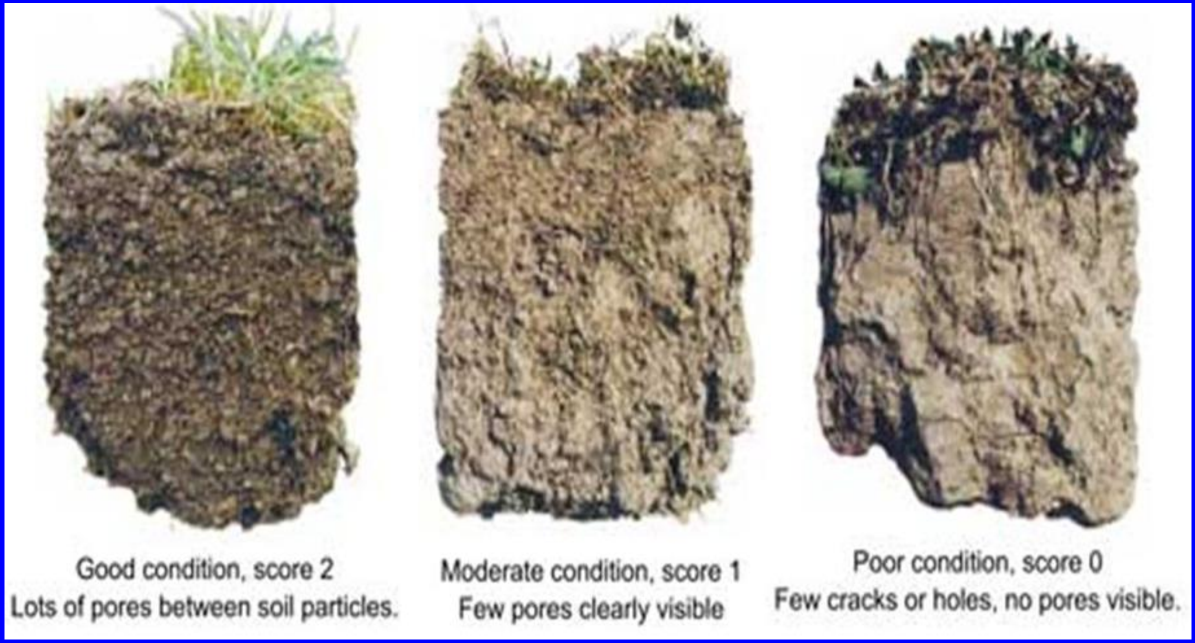
More the organic matter content in soil results in high pore space there by shows lower bulk density of soil and vice-versa.

Soil porosity

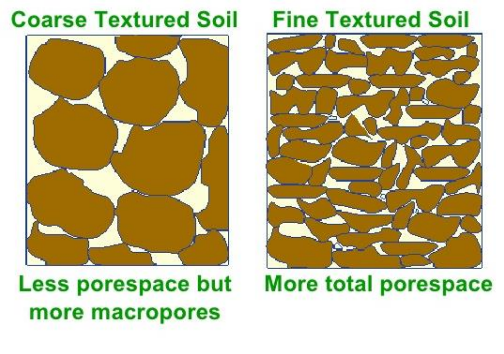
Soil porosity refers to that part of a soil volume that is not occupied by soil particles or organic matter.

The ***pore space*** of a soil is the space occupied by air and water. The amount or ratio of pore space in a soil is determined by the arrangement of soil particles like sand, silt and clay. In sandy soils, the particles are arranged closely and the pore space is low. In clay soils, the particles are arranged in porous aggregates and the pore space is high. Presence of organic matter increases the pore space.





Soil porosity. Factors influencing pore space



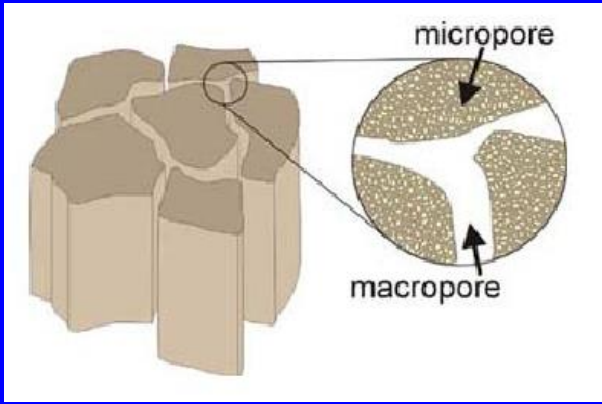
1 Soil texture

- Sandy surface soil : 35 to 50 %
- Medium to fine textured soils : 50 to 60 %
- Compact sub soils : 25 to 30%

2 Crops / vegetation

Some crops increases the porosity to 57.2% from the original 50%. Cropping reduces the porosity as cultivation reduces the organic matter content and hence decrease in granulation. Virgin soils have more pore space. Continuous cropping reduces pore space than intermittent cropping. More the number of crops per year, lesser will be the pore space particularly macro pores.

3 Size of pores



- Macro pores (non-capillary pores) : diameter >0.05 mm
- Micro pores (capillary pores) : diameter < 0.05 mm

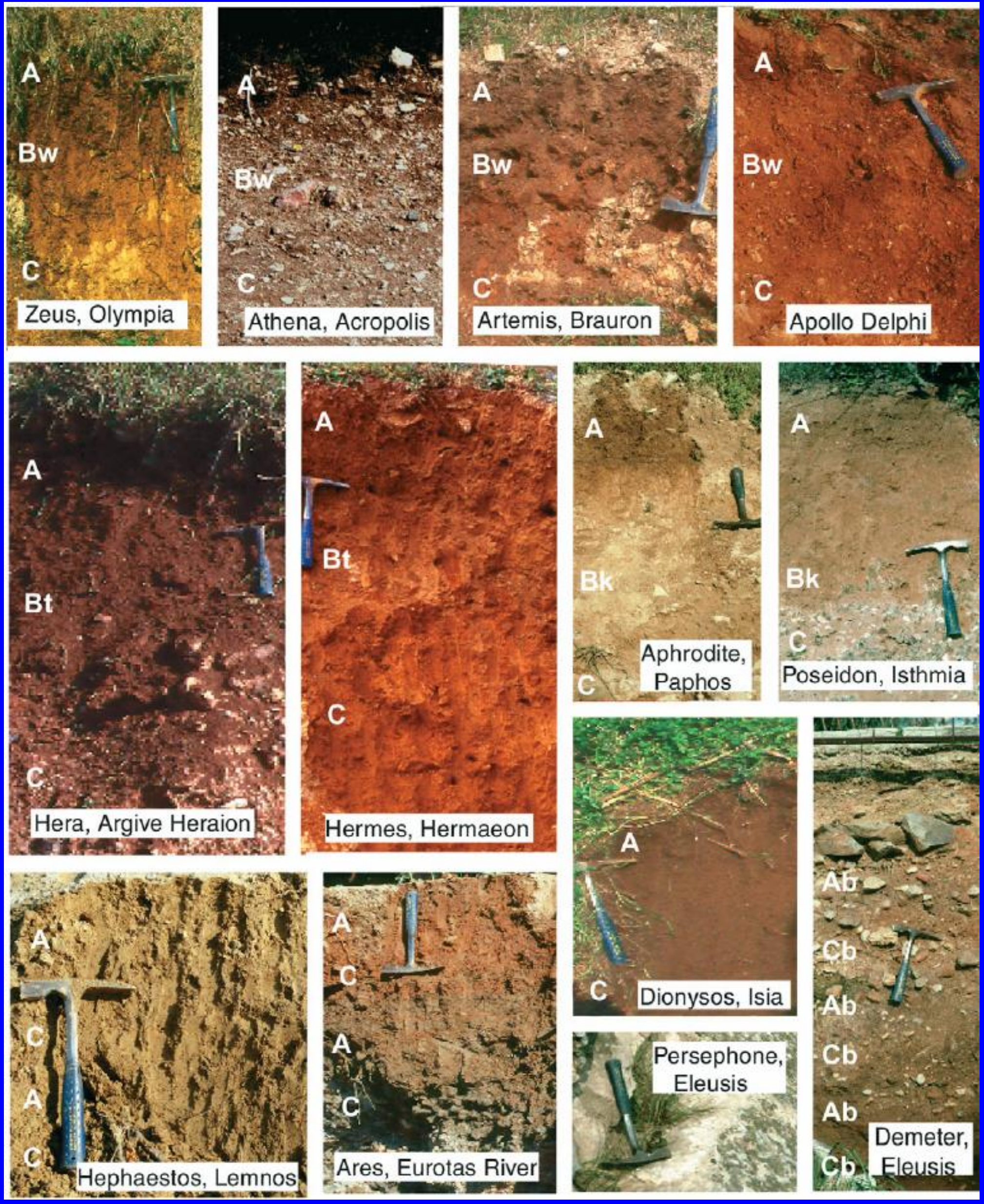
In macro pores, air and water moves freely due to gravitation and mass flow. In micro pores, the movement of air and water is very slow and restricted to capillary movement and diffusion. Sandy soil have more macro pores and clay soils have more micro pores. Loamy soils will have 50% porosity and have equal portion of macro and micro pores.

Soil colour

Soil colour indicates many soil features. A change in soil colour from the adjacent soils indicates a difference in the soil`s mineral origin (parent material) or in the soil development. Soil colour varies among different kinds as well as within the soil profile of the same kind of soil. It is an important soil properties through which its description and classification can be made.

Soil colour is inherited from its parent material and that is referred to as ***lithochromic***, e.g. red soils developed from red sandstone.

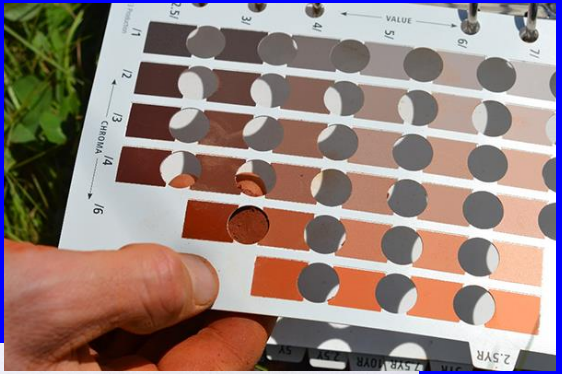
Soil colour develops during soil formation through different soil forming processes and that is referred to as ***acquired*** or ***pedochromic*** colour, e.g. red soils developed from granite or schist.



Soil colour. Factors affecting soil colour

There are various factors or soil constituents that influence the soil colour:

- Organic matter → the colour variation from black to dark brown;
- Iron compounds → red, brown and yellow tinge colour;
- Silica, lime and other salts → white or light coloured;
- Mixture of organic matter and iron oxides → brown colour;
- Alternate wetting and drying condition → the colour of soil in different horizons of the soil profile is variegated or mottled;
- Oxidation-reduction conditions → bluish and greenish colour.



The soil colours are best determined by the comparison with the **Munsell colour**.

Soil colour rotation is divided into three parts:

Hue - it denotes the dominant spectral colour (red,yellow ,blue and green).

Value - it denotes the lightness or darkness of a colour (the amount of reflected light).

Chroma - it represents the purity of the colour (strength of the colour).

Thank you for attention!