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College of Soil Physics

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Soil structure 1

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- **Soil structure**
- **Soil pore system**
- **Relationships between soil porosity and water movement, penetration resistance, chemical properties and root growth**
- **Some aspects of soil degradation: Crusting and Compaction**
- **Evaluation of the impact of agricultural management practices on soil structure**
- **The soil pore system as an indicator to quantify soil physical degradation**

SOIL STRUCTURE

Definition

Soil structure may be defined either as "the shape, size and spatial arrangement of individual soil particles and clusters of particles (aggregates)" or as "the combination of different types of pores with solid particles (aggregates)".

Soil structure has generally been defined in the former way and measured in terms of aggregate characteristics. These can be related to plant growth only empirically. In fact, it is the pore shape, the pore size distribution and the pore arrangement which affect many of the most important processes in soil that influence plant developments such as storage and movement of water and gases, solute movements and ease of root growth.

According to Dexter (1988) soil structure was defined as "the spatial heterogeneity of the different components or properties of the soil".

This definition is meant to be comprehensive and includes within it earlier definitions about arrangements of particles and also large-scale features as cracks, biopores and even heterogeneity on large scales.

Genesis of soil structure

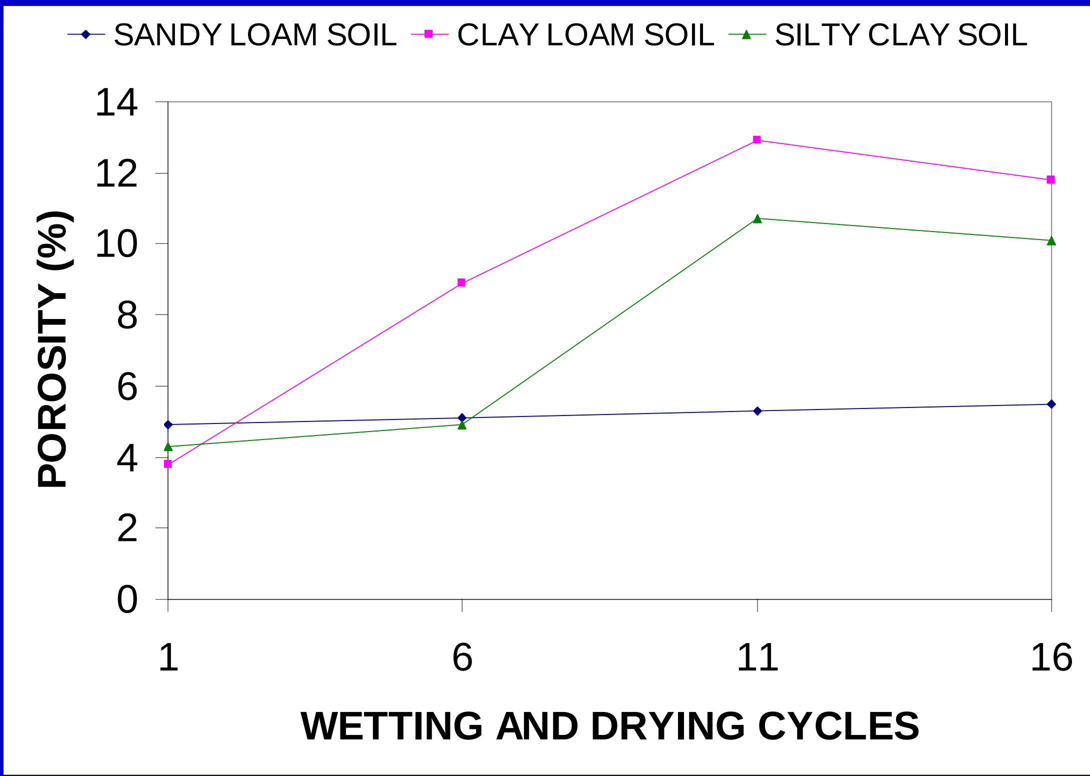
Soil structure is a dynamic property and it is subjected to genesis and degradation processes.

The main factors that affect the genesis of soil structure are represented:

- by the effect of cations,
- by the interaction between clay particles under the influence of soil water content (wetting and drying cycles) and temperature,
- by the effect of organic matter, which is the main agent of aggregate stabilization,
- by root growth and by the action of soil macro and micro-organisms.

Possible steps leading to the genesis of soil structure can be summarized as follows:

- flocculation of soil particles,
- microaggregation,
- aggregation and stabilization of aggregates.



The main factors that affect the degradation of soil structure are:

- the long-term intensive cultivations, which deplete the soil organic matter content,
- soil erosion,
- soil compaction and the formation of a compacted layer along the soil profile (e.g. Ploughpan),
- the formation of surface crusts.

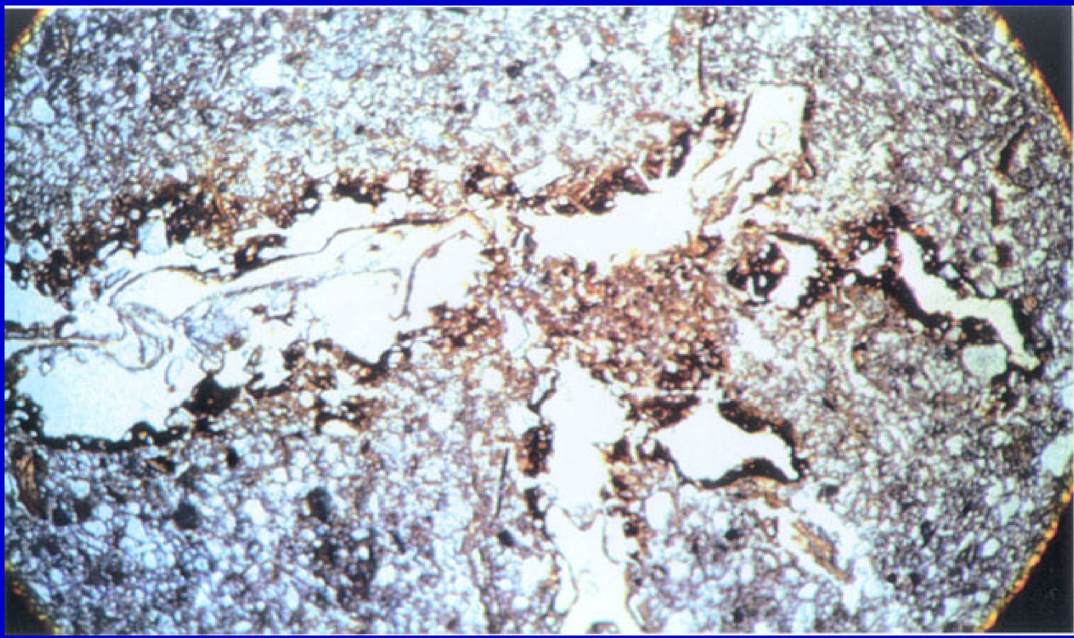
Possible steps leading to the degradation of soil structure can be summarized as follows:

- destabilization or mechanical destruction of soil aggregates,
- disaggregation,
- microdisaggregation and dispersion of soil particles.

The literature concerning the complex interrelationship of physical, biological and chemical reactions involved in the formation of soil aggregates is very wide.

It is possible to summarize the main mechanisms involved in soil aggregation as:

- the linkage between organic matter and mineral constituents,
- the adhesion of living organisms to mineral constituents,
- the physical actions of living organisms on inorganic constituents.



Macrophotograph of a vertically-oriented thin section. Organic materials can be seen clearly as coatings on pore walls. Plain light; pores appear white. Frame size 5 mm.

AGGREGATE STABILITY

- **Aggregate stability can be defined as the capacity of cohesive forces between soil particles to resist the externally applied destructive forces.**
- **The wet sieving is the most common method to determine the aggregate stability (water stability index).**

SOIL POROUS SYSTEM

Water desorption

Pore size in soil have generally been obtained by the application of the equation to the moisture characteristic curve:

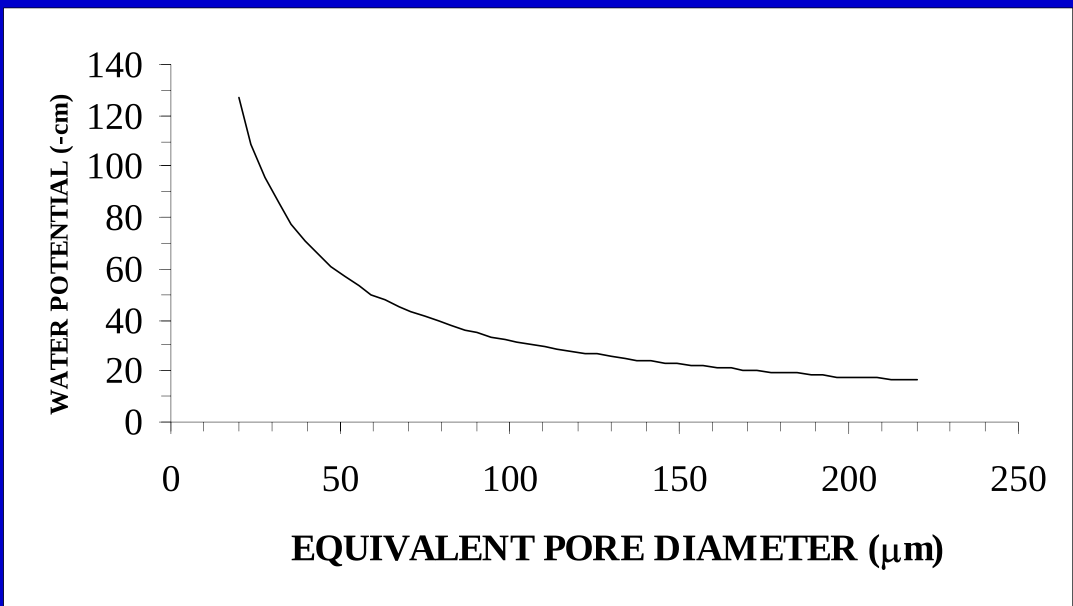
$$\rho gh = 2\gamma\cos\theta/r$$

where ρgh is the suction (ρ is the density of water = 0.9982 Mg m^{-3} at 20°C, g is the acceleration due to gravity = 9.80 m s^{-2} and h is the height of capillary rise expressed in m)

γ the surface tension of water (72.75 mMm^{-2} at 20°C)

θ the soil-liquid contact angle which is here assumed to be zero

r the equivalent cylindrical pore radius (m)



Mercury intrusion Porosimetry

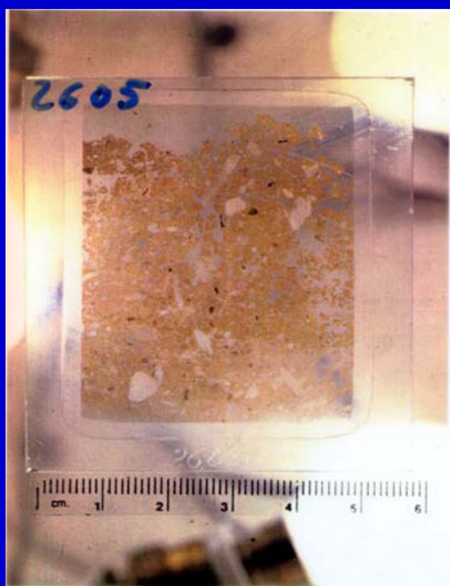
Pore size distribution can be determined over a wide range (100 μm to 10 nm) by measuring the pressure required to force mercury into the pores. For pores of cylindrical shape the relationships between pressure and the minimum pore diameter which my be intruded was given by Washburn as

$$P=-4\gamma\cos\theta/d$$

Where P is the required pressure; γ is the surface tension of the liquid; θ is the contact angle; d is the diameter of pores.

Micromorphometric Method

- **Soil thin section preparation – Image analysis.**
- **The method is based on the analysis of pores on thin section, prepared from undisturbed soil samples, by means of image analysis.**



SOIL POROSITY CHARACTERIZATION

- Pore shape
  - *Regular*
  - *Irregular*
  - *Elongated*
- Pore size
  - *Bonding spaces (<0.005 μm)*
  - *Residual pores (0.005-0.5 μm)*
  - *Storage pores (0.5-50 μm)*
  - *Transmission pores (50-500 μm)*
  - *Fissure (>500 μm)*
- Continuity
- Orientation

Morphologic pore size classification

Class	Subclass	Class limits (Equivalent diameter mm (10^{-6}m))
Macropores	Coarse	>5000
	Medium	2000-5000
	Fine	1000-2000
	Very Fine	75-1000
Mesopores		30-75
Micropores		5-30
Ultramicropores		0.1-5
Cryptopores		<0.1

Classification of soil pores

1. Submicroscopic pores which are so small that they preclude clusters of water molecules to form fluid particles or continuous water flow paths.
2. Micropores, or capillary pores where the shape of the interface between air and water is determined by the configuration of the pores and by the forces on the interface.

2.1. Matrix (intra-aggregate, intrapedal) pores within soil aggregates or within blocks of soil if aggregates are not present.

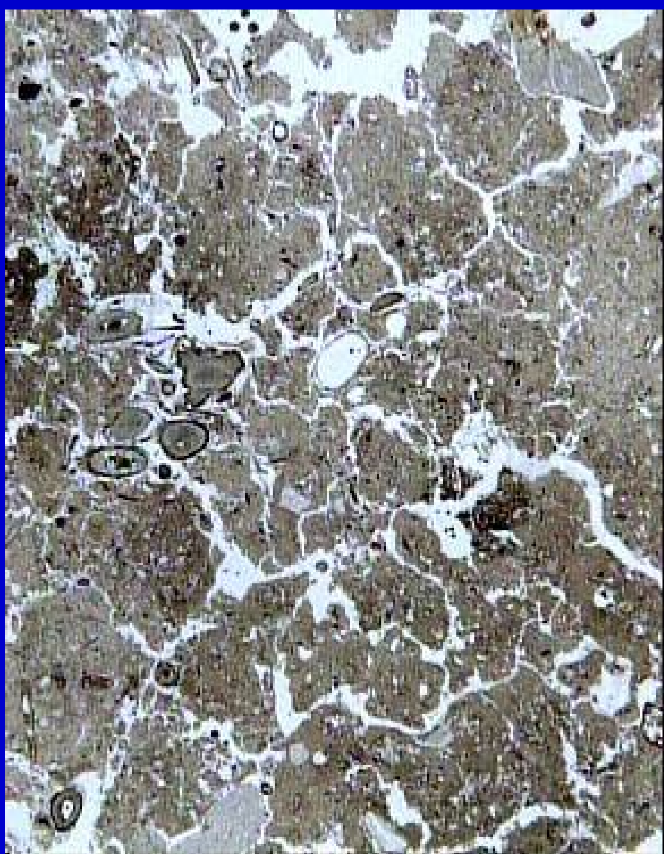
2.2. Structural (inter-aggregate, interpedal) pores between the aggregates.

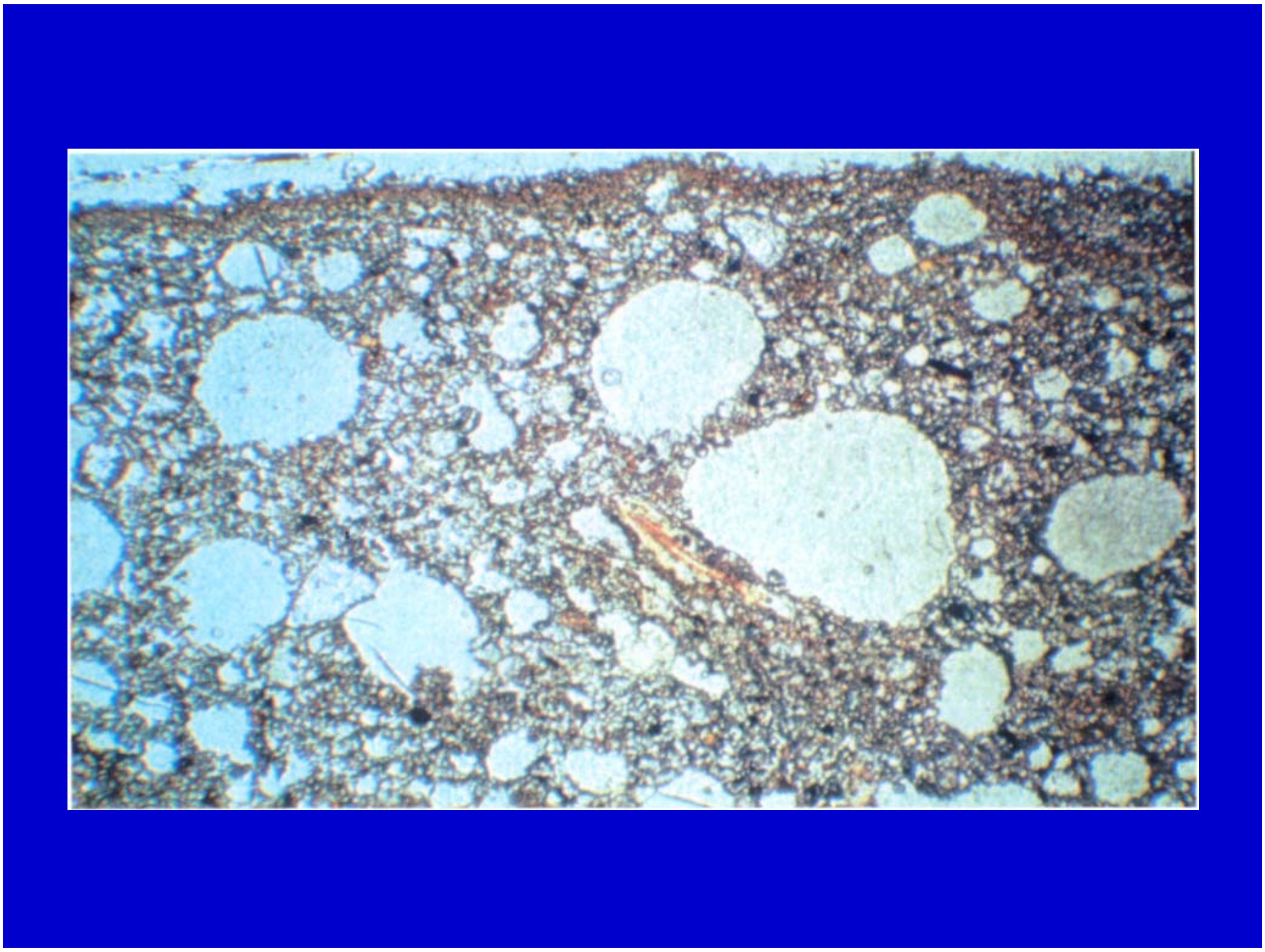
3. Macropores, or non-capillary pores of such a size that capillary menisci are not formed across the pore and the shape of air-water interface across the pore is planar.

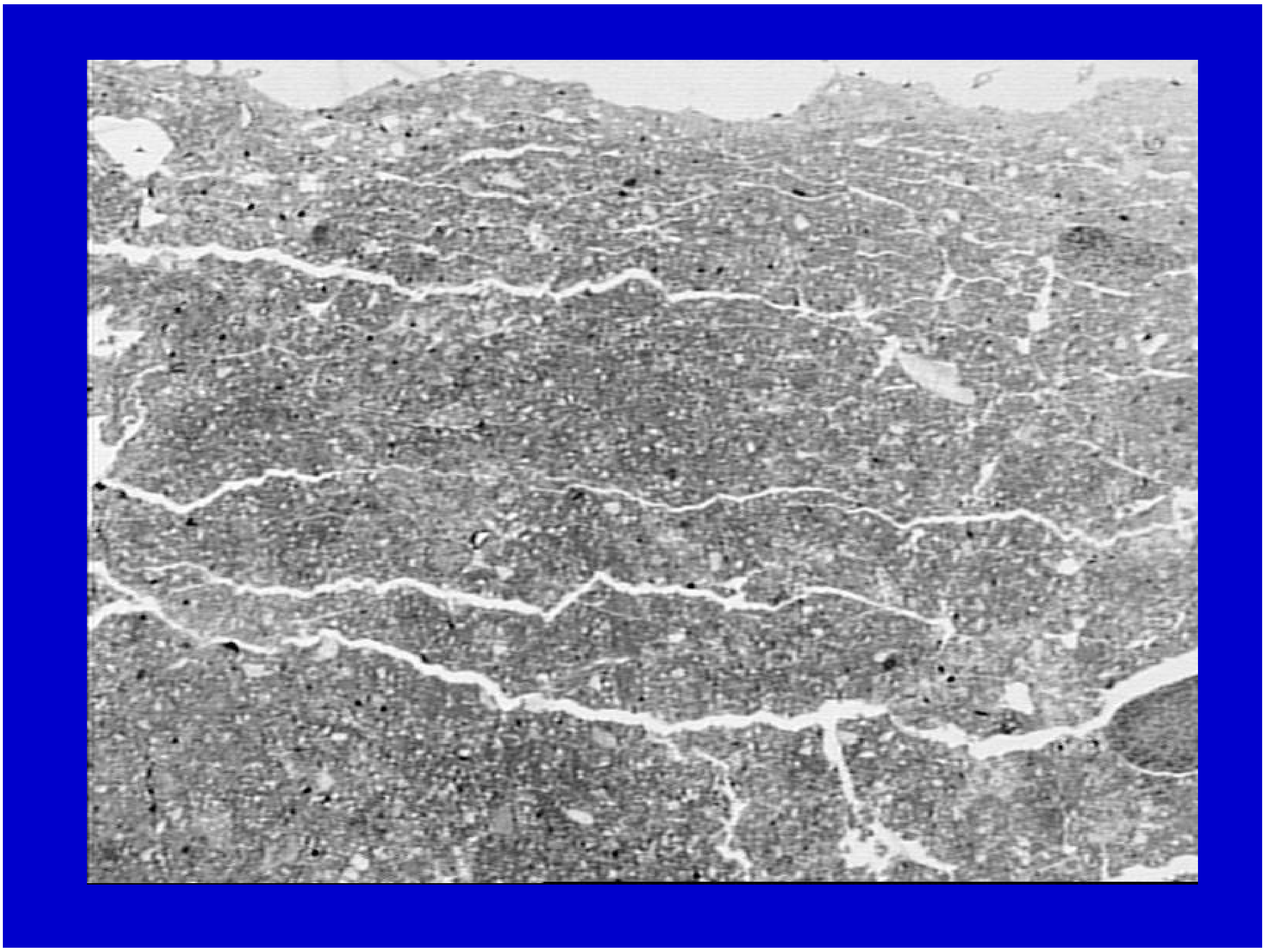
3.1. Macropores formed by the activity of pedo-edaphon such as decayed roots, earthworm channels etc.

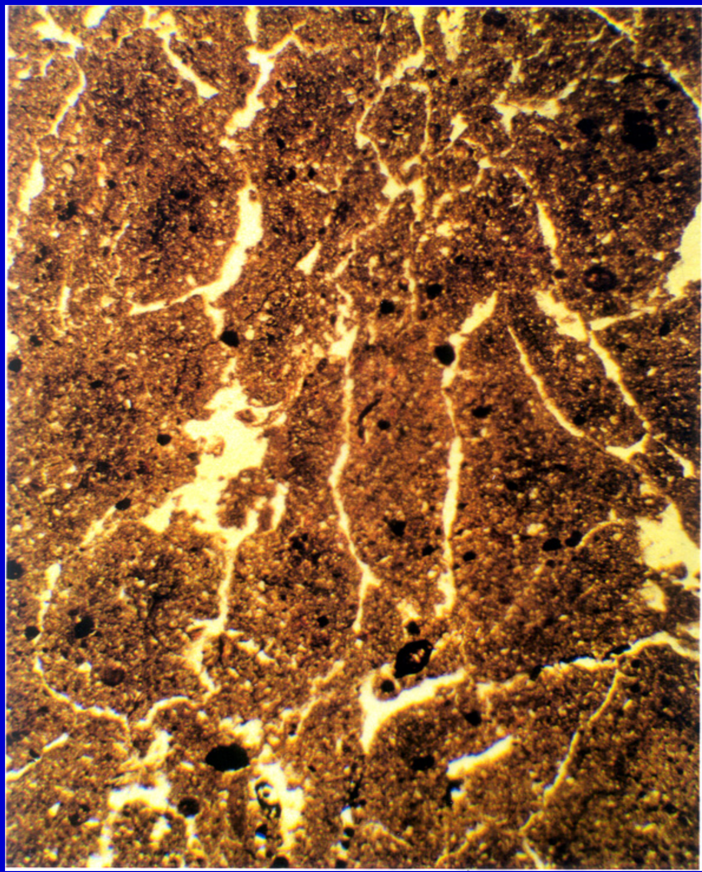
3.2. Fissures and cracks occurring as a consequence of volumetric changes of swelling-shrinking soils.

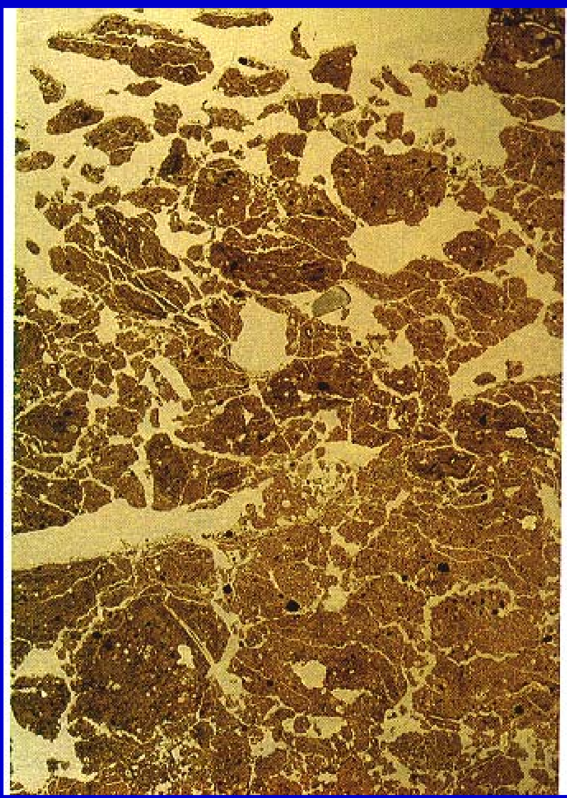
3.3. Macropores originating due to soil tillage.

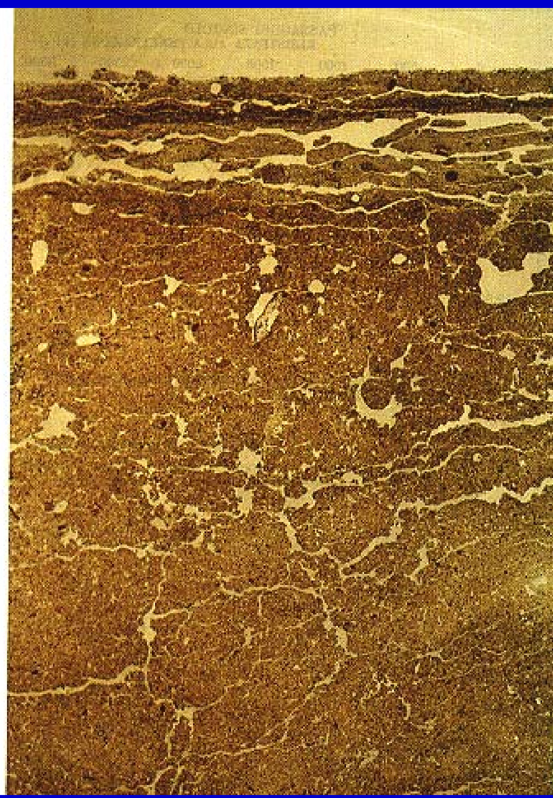












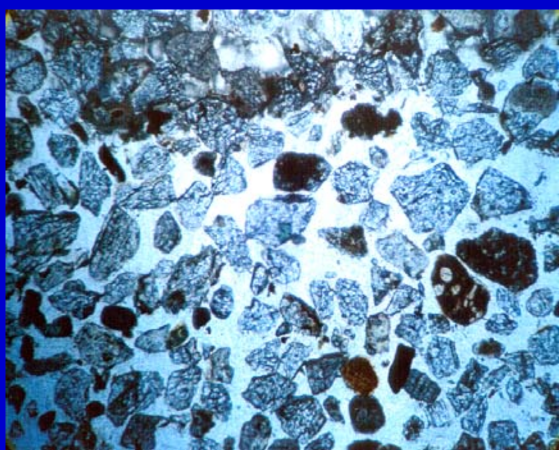
Types of soil structure

In general, three broad categories of soil structure can be recognized: single grained, aggregates and massive. The definition of the several types of soil structure is fundamental for a first qualitative evaluation of soil physical fertility. According to the definition of soil structure the different types of structure are originated by the combination and the spatial arrangement of different types of pores and aggregates.

The main types of soil structure can be summarized as follows:

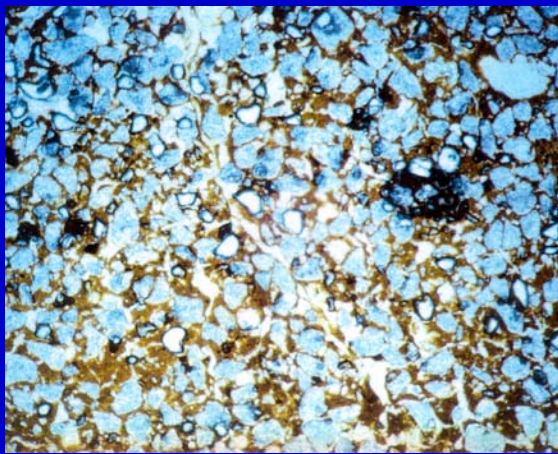
Single grain structure

- Typical of sandy soils; the quartz (sand-sized) grains are completely loose and the fine materials in the intergranular spaces are very rare.
- The porosity is represented by packing voids delimitated by quartz grains.
- When these grains are of a more or less uniform shape and size a rather compact grain structure can be originated.



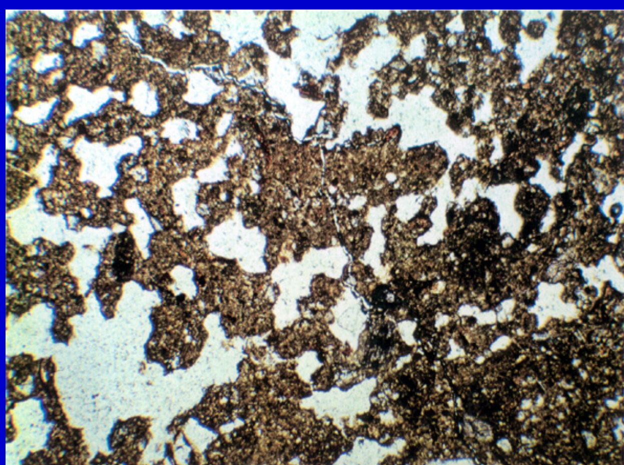
Bridged/pellicular grain structure

- The sand-sized grains are bridged or coated by fine materials, usually clay, which can cement some grains to each other, so originating microaggregates.



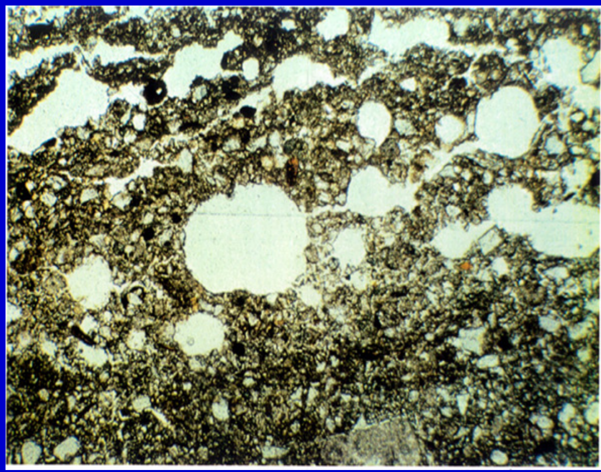
Vughy structure

- There are no separated aggregates and the mass is broken up by scattered but not interconnected irregular pores, "vughs", and occasional channels and chambers.
- Such a structure allows good soil aeration but the continuity of pores is limited.



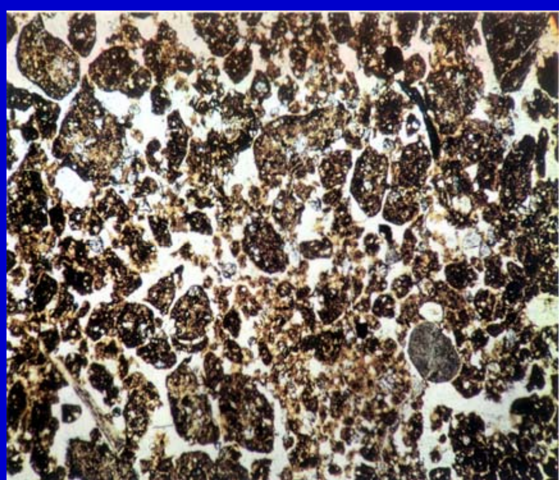
Vesicular structure

- There are no separated aggregates and the mass is broken up by rounded pores, "vesicles", originated by entrapped air during drying processes.
- This kind of structure is an indicator of degraded soils.



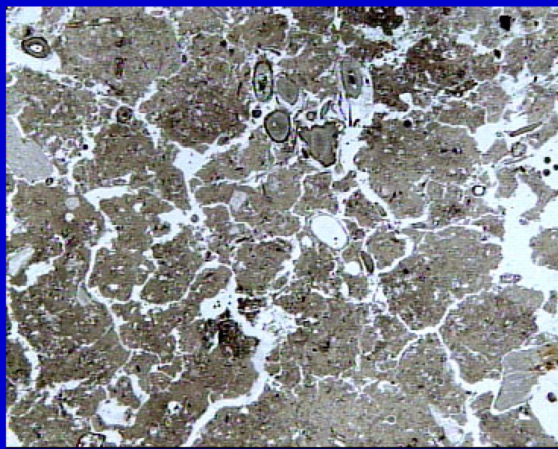
Crumb structure

- The soil aggregates are more or less rounded, often rugose, well separated from each other and rather compact inside.
- The porosity is represented by pore space (packing voids) which separates the aggregates.
- This type of structure is often originated by anthropogenic activities (soil tillage).



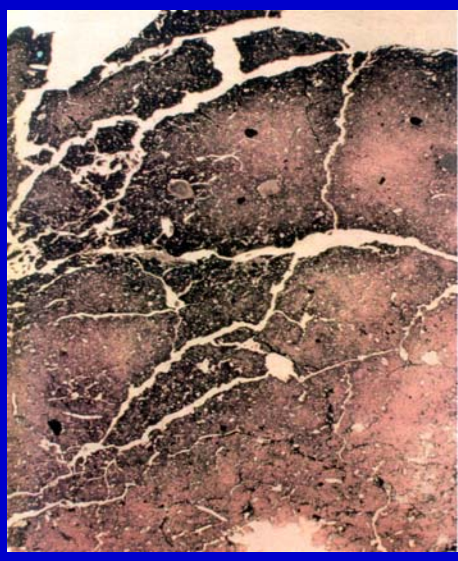
Subangular blocky structure

- **The soil aggregates are separated by elongated continuous pores (planes), are of different sizes and can be rather porous inside.**
- **Aggregate faces largely accommodate each other.**
- **From an agronomic point of view, this is the best type of soil structure because the continuity of elongated pores allows good water movement.**



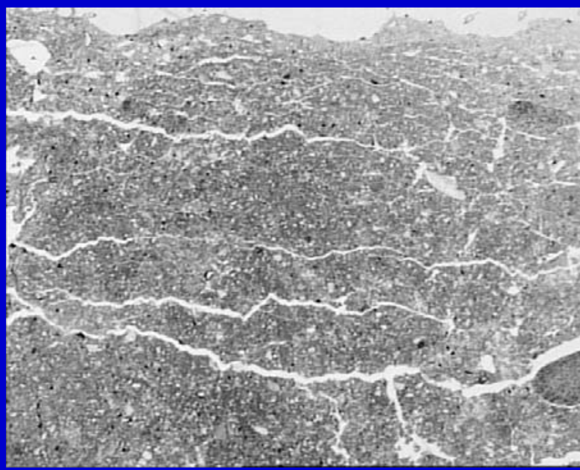
Angular blocky structure

- **The soil aggregates have angular edges and are separated by elongated pores of a regular shape.**
- **Aggregate faces normally accommodate each other.**
- **This is a typical structure of clay soils and it less stable than the subangular blocky structure.**



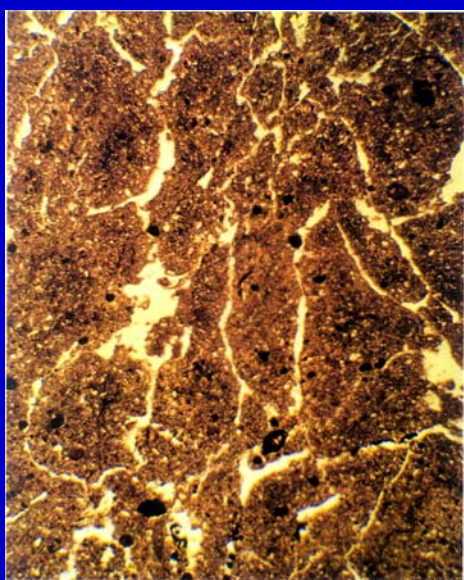
Platy structure

- The thin and flat soil aggregates are separated by elongated pores oriented parallel to the soil surface and, therefore, not continuous in a vertical sense.
- This leads, as a consequence, to a drastic reduction of water infiltration capacity.
- The platy structure is typical of compact soils.



Prismatic structure

- The soil macroaggregates are divided into prisms separated by vertically oriented elongated pores with accommodating walls.
- Also this type of structure is typical of clay soils, especially in the B horizon, and is not very stable because the swelling of the soil when wet causes the closing of pores.

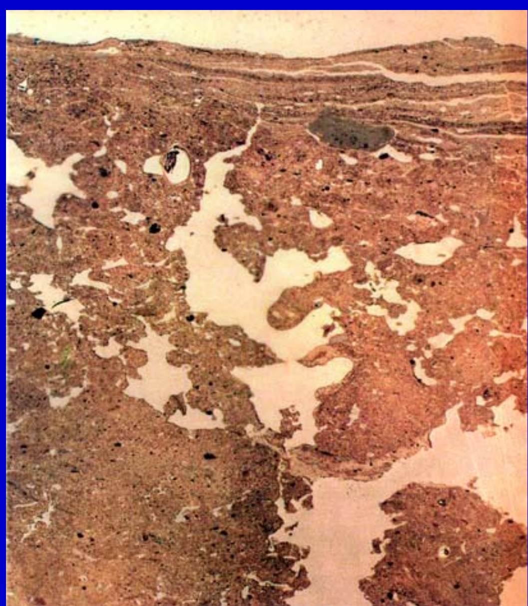


Massive structure

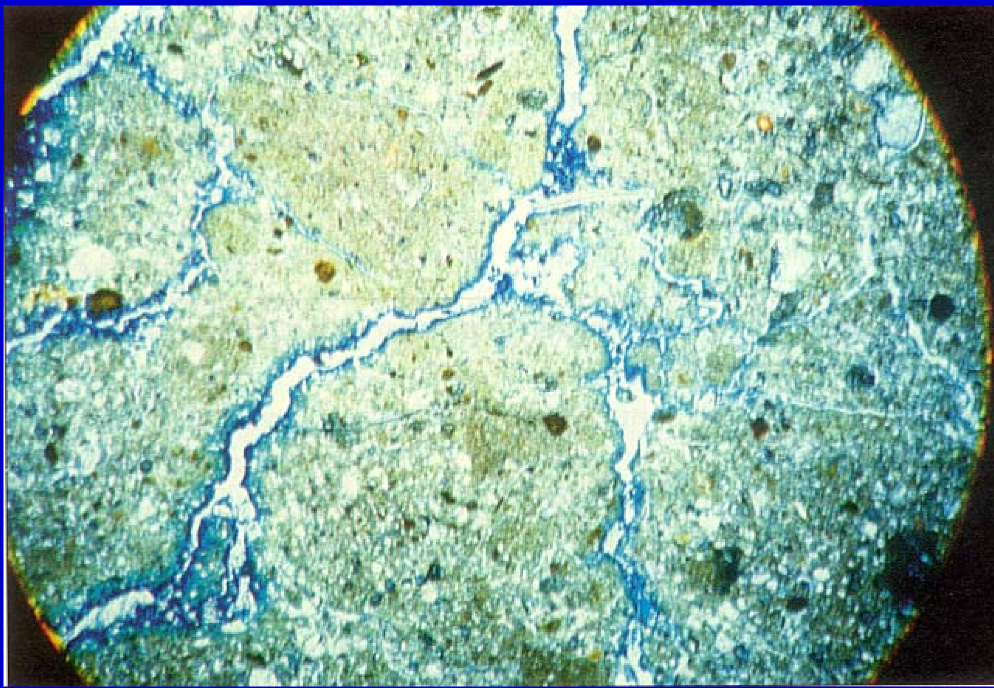
- The soil material is very compact, there are no visible separated aggregates.
- The porosity is very low and represented by small pores isolated in the soil matrix.
- This type of structure represents a bad "habitat" for plant development and is common in degraded soil with a low content of organic matter.

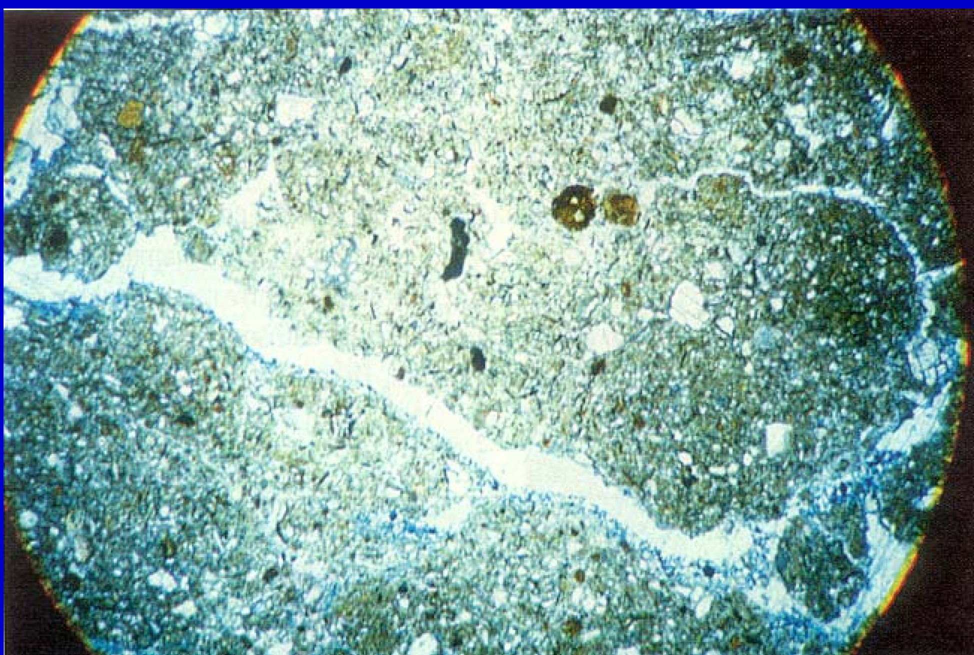
Complex structure

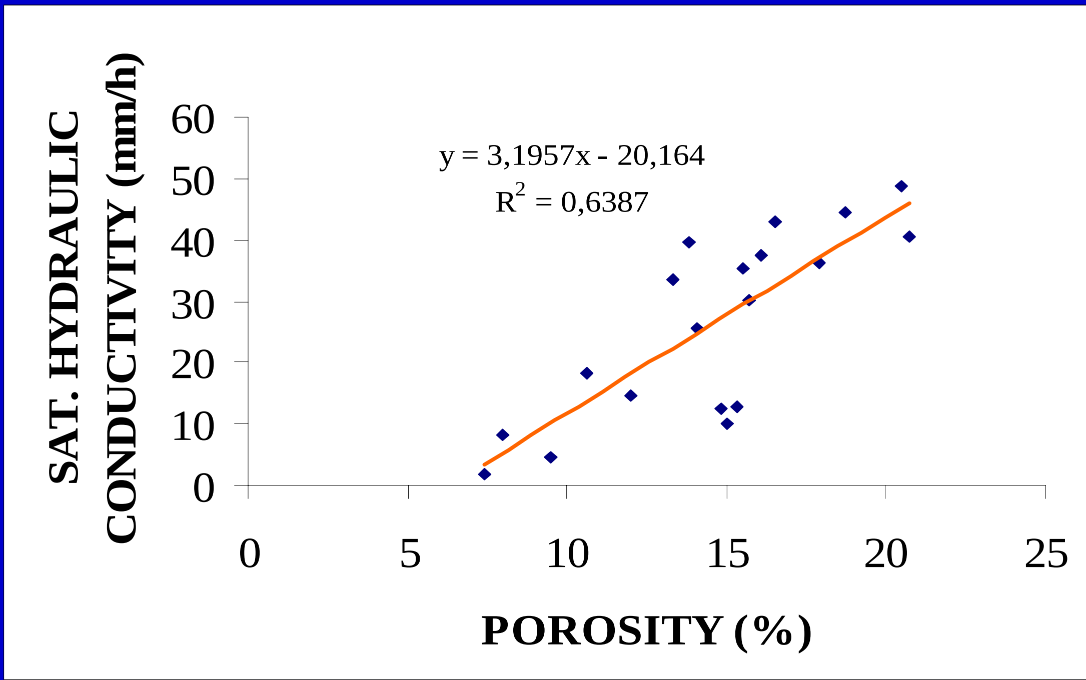
- The soil presents two or more types of soil structure.



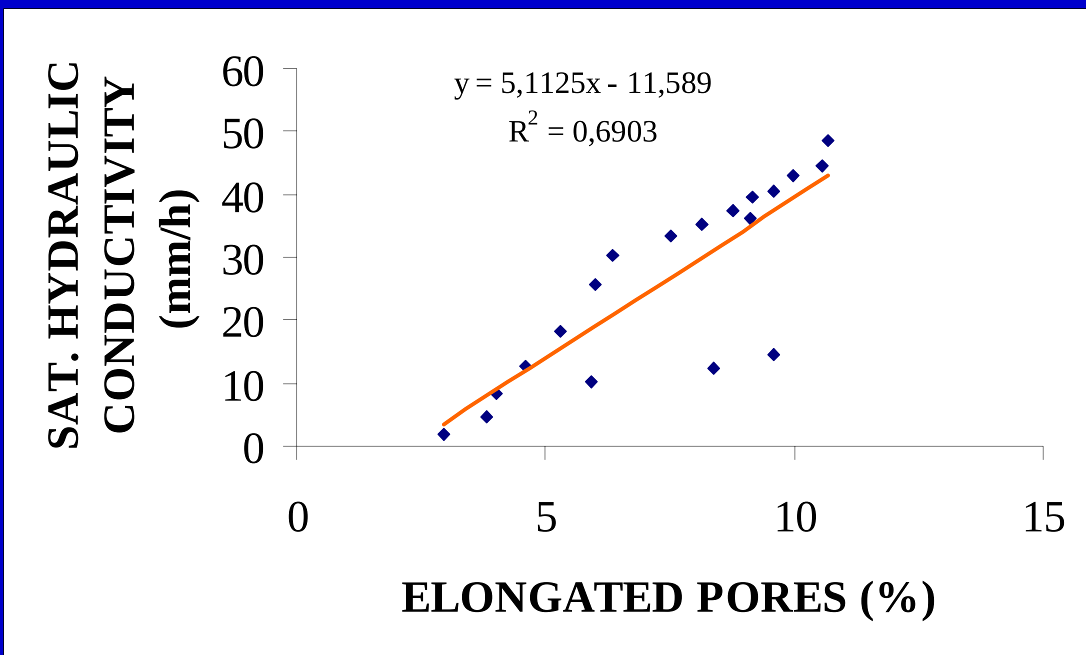
Relationships between Soil Porosity and Water Movement







Surface layer (0-10 cm) of a clay loam soil



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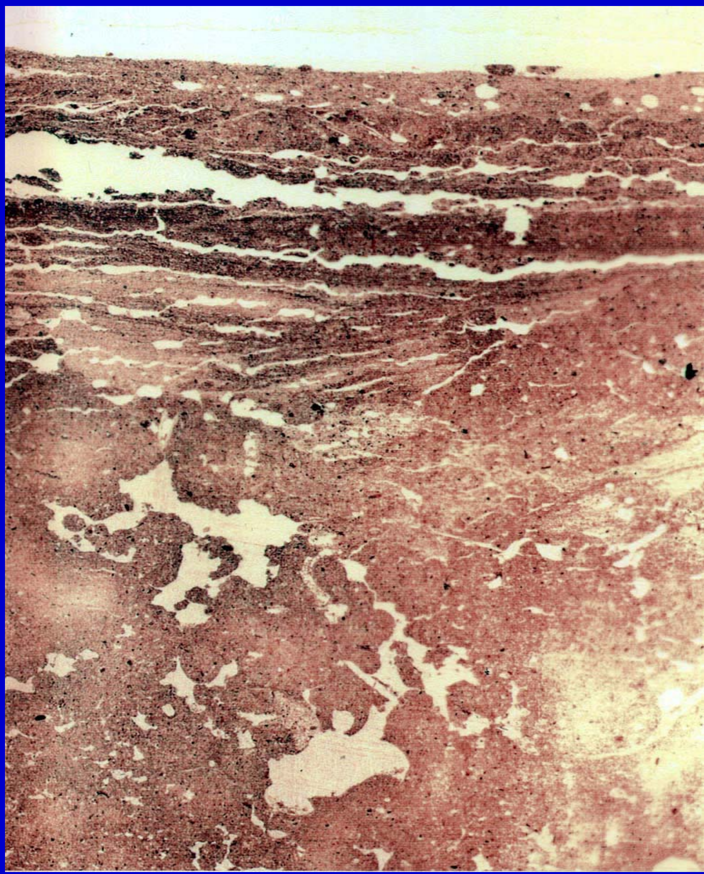
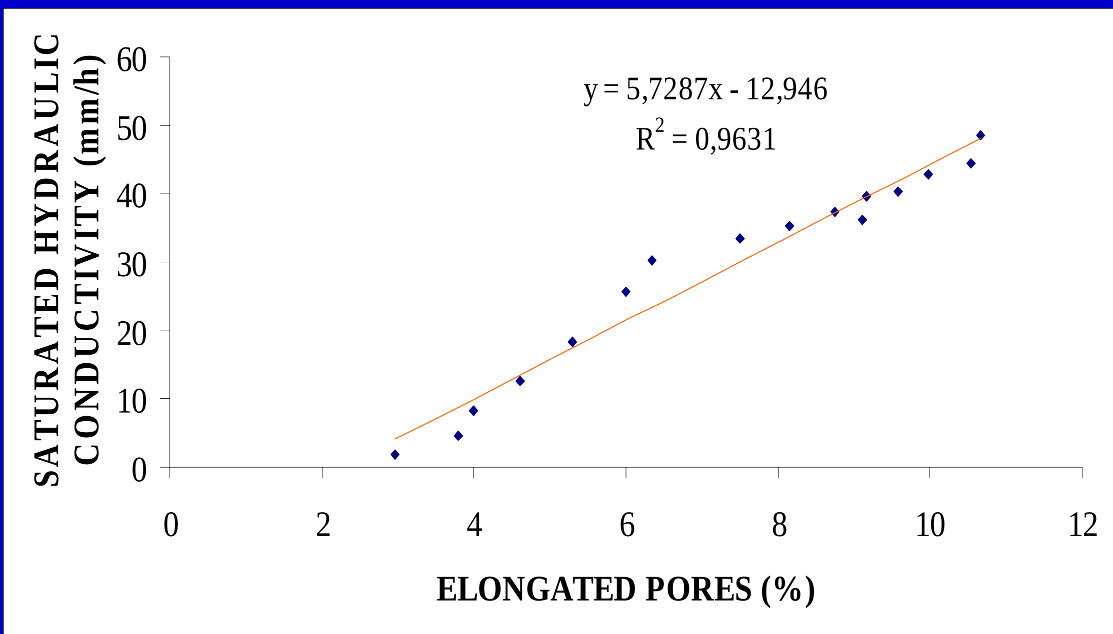
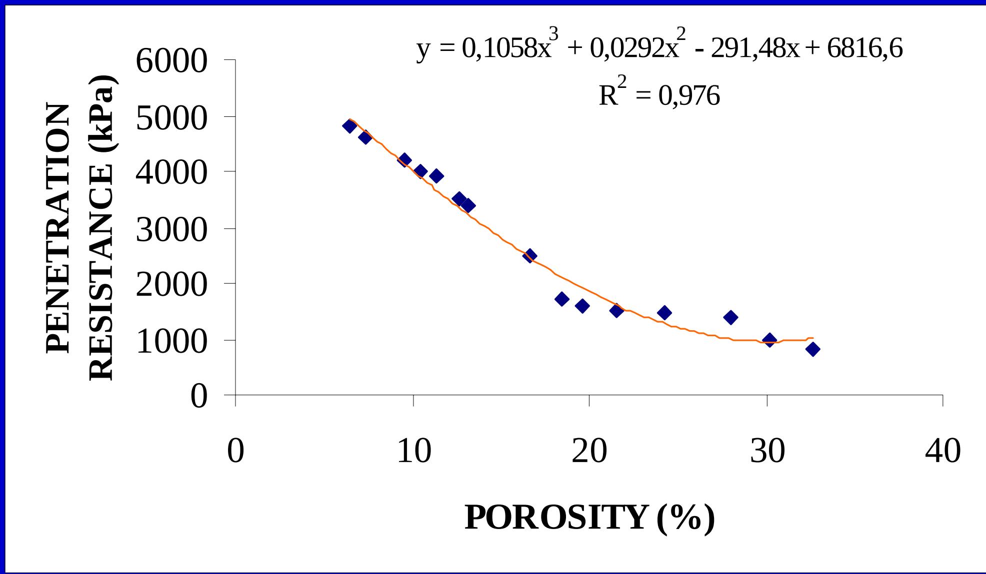




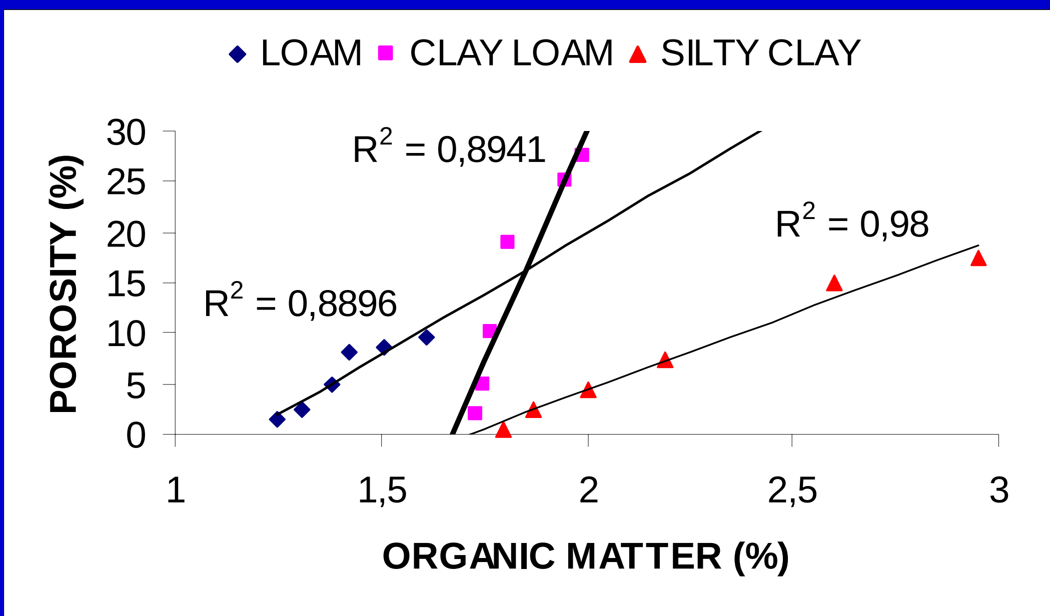
Surface layer (0-10 cm) of a clay loam soil

Relationships between soil porosity and penetration resistance

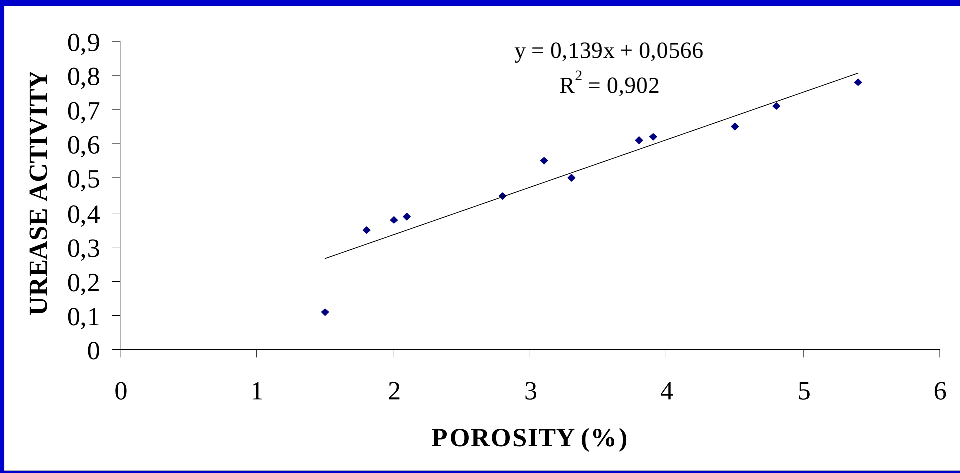


surface layer (0-10 cm) of a clay loam soil

Relationships between soil porosity and organic matter

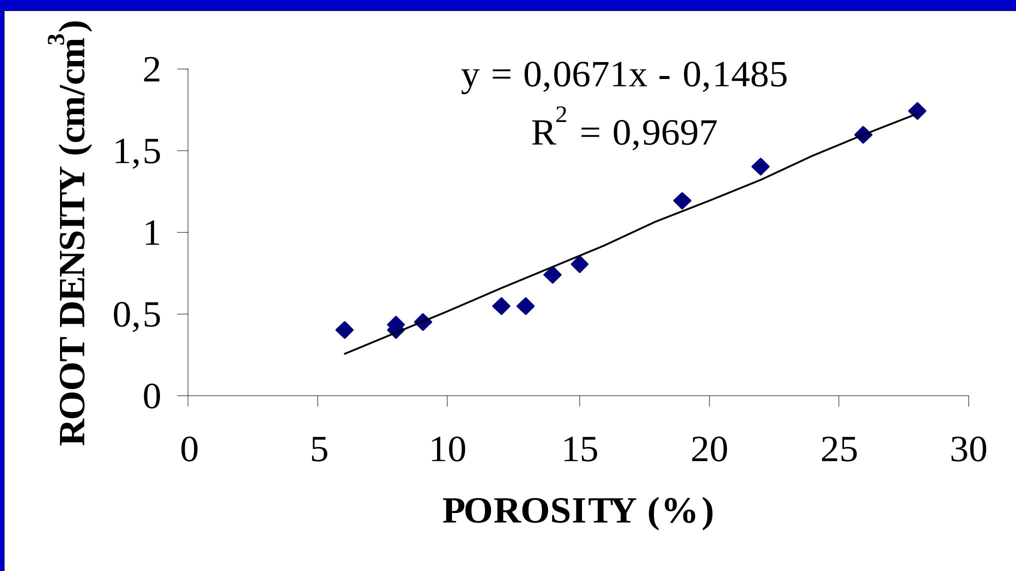


Relationships between Soil Porosity and some Chemical and Biochemical Properties



Correlation between soil porosity in the range 30-200 μm and urease activity (mmol ammonium release h^{-1} g^{-1} soil) in the surface layer (0-10 cm) of a clay loam soil.

Relationships between soil porosity and root growth



- The characterisation of soil pore system gives essential indications about the soil quality and vulnerability in relation to degradation events mainly connected with the human activity.
- Allows to study the relationships between soil physical, chemical and biochemical properties and to provide a realistic basis for understanding water retention and water movement in soil.
- The quantitative evaluation of water movement and solute transport along the macropores, open new horizons to realise the modelling of these phenomena.

- The major disadvantage of the development of the micromorphological technique can be represented by the difficulty and the time consuming for the preparation of soil thin sections.
- The quantification of the size, continuity, orientation, irregularity of elongated pores allows the modelling of water movement and solute transport, or, at least, allows to predict its changes following the soil structural modifications, or following soil degradation due to compaction, formation of surface crusts, etc.