The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

1867-7

College of Soil Physics

22 October - 9 November, 2007

Soil surface sealing and crusting 1

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The soil pore system as indicator of soil quality and as an indicator to quantify soil physical degradation

FACTORS AFFECTING ENVIRONMENTAL DEGRADATION

- Soil erosion
- Soil structural degradation
- Soil compaction
- Soil sealing and crusting
- Desertification
- Salinization
- Sodification
- Acidification
- *Leaching*
- *Volatilization*

Soil functions

Ecological functions

- Production of biomass
- Filtering, buffering and transforming
- Gene reserve and protection of flora and fauna

Socio-economic functions

- Support to human settlement (housing and infra-structure, recreation) and waste disposal
- Source of row materials, including water
- Protection and preservation of cultural heritage

SOIL QUALITY INDICATORS

DPSIR assessment framework applied to soil

- **Driving forces** – agriculture, industry, tourism, natural events, climate change, etc.
- **Pressure** – emissions to air, water and land; urban expansion (soil uptake); infrastructure construction; deforestation; forest fires
- **State** – soil degradation, soil loss
- **Impact** – direct: changes in soil functions, desertification; indirect: loss of biodiversity, changes in crop yields, climate changes, etc.
- **Responses** – development of a soil protection policy, CAP reform, Nitrate directive, sewage sludges directive, etc.

According to the micromorphometric method, a soil can be classified as follows where the total porosity represents the percentage of area occupied by pores larger than 50 μm per thin section:

Soil very compact	when total porosity is	<5%
Soil compact	when total porosity is	5-10%
Soil moderately porous	when total porosity is	10-25%
Soil porous	when total porosity is	25-40%
Soil highly porous	when total porosity is	>40%

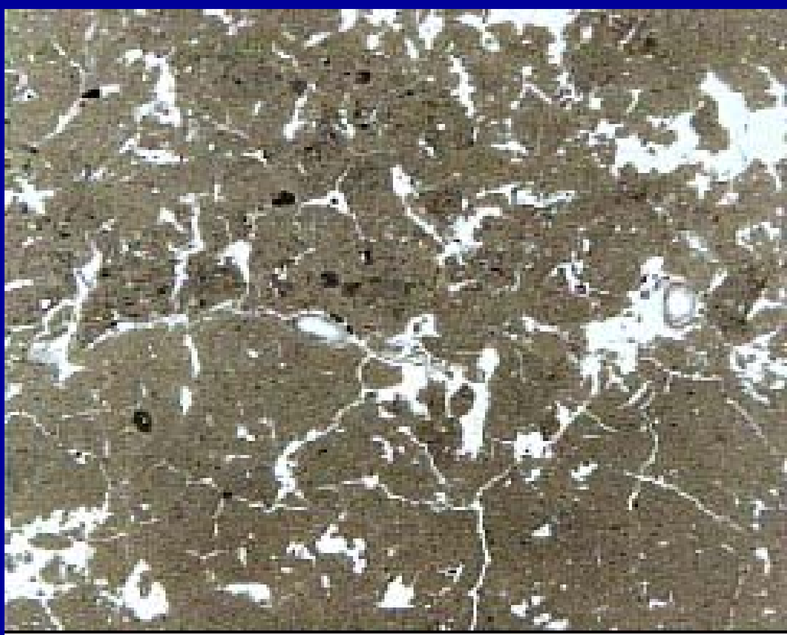
Soil very compact

POROSITY = 3.1%

Soil compact

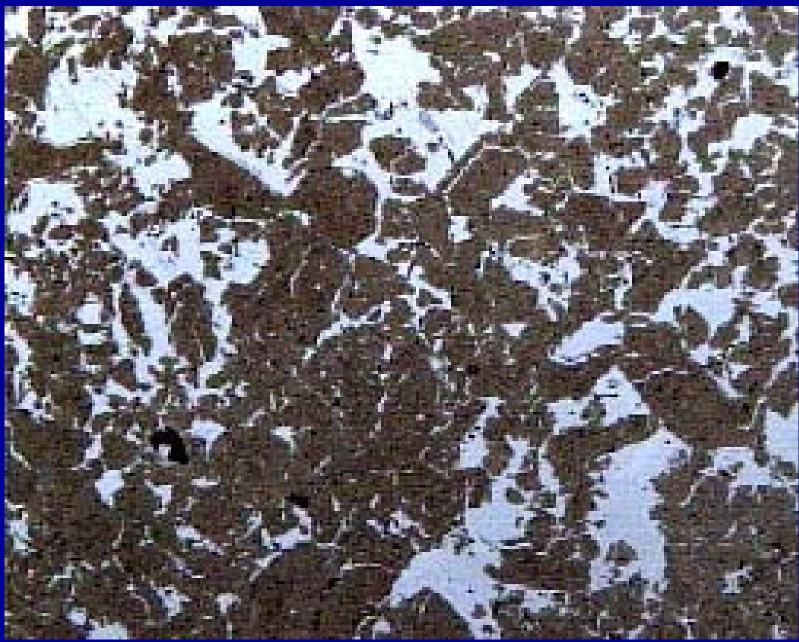
POROSITY = 7.5%

Soil moderately porous



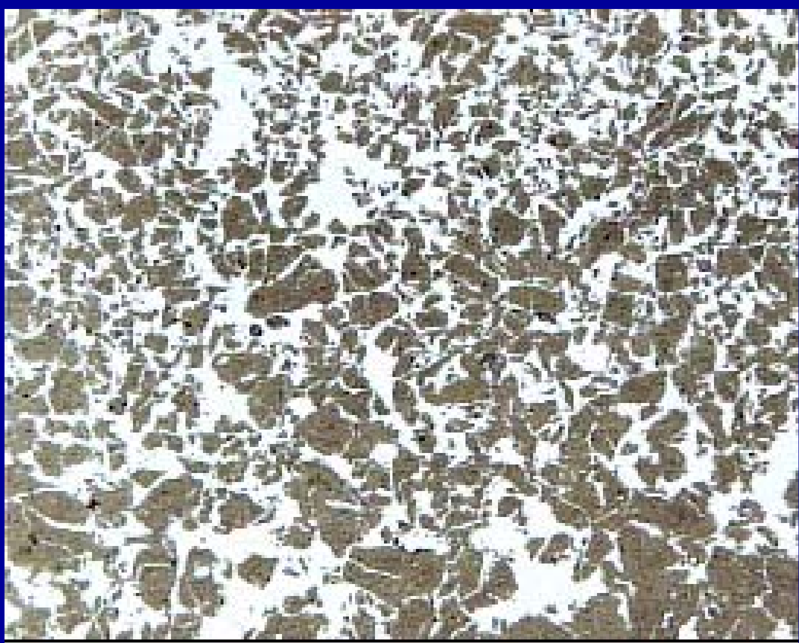
POROSITY = 16.9%

Soil porous



POROSITY = 28%

Soil highly porous



POROSITY = 42%

A total macroporosity of 10% is considered to be the lower limit for good soil structural condition, anyway, only the complete evaluation, both quantitative and qualitative, of the soil pore system can produce exhaustive information on actual soil quality.

Soil crusting

- Soil crusts are specific modifications in the top soil caused by natural events such as raindrop impact and the following drying process.
- They consist in the formation of hard thin layers at the soil surface and are widespread especially in the soils of arid and semiarid regions.
- Their thickness usually ranges from less than 1 mm to 5 cm.

MECHANISMS OF CRUST FORMATION

- mechanical destruction of soil surface aggregates by raindrop impact;
- leaching of fine particles and their subsequent deposition in the underlying pores ("washing in");
- compaction of the soil surface to form a thin film which restricts both the further entry of water and the movements of fine particles in the soil pores;
- cementation of the slaked soil at the soil surface due to the drying and reorientation. Upon drying, in fact, the orientation of the particles would contribute to the rigidity of the soil crusts.

SOIL PROPERTIES RELATED TO CRUST FORMATION

The susceptibility of soils to crusting not only depends on the external factors such as raindrop impact, but also on the following intrinsic soil factors:

- Soil texture
- Clay mineralogy
- Organic matter content
- Sesquioxide content
- Exchangeable cations
- Soil water content

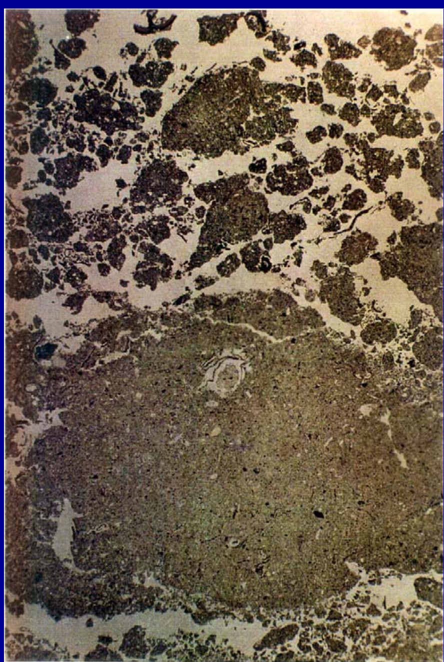
METHOD USED IN SOIL CRUSTING INVESTIGATION

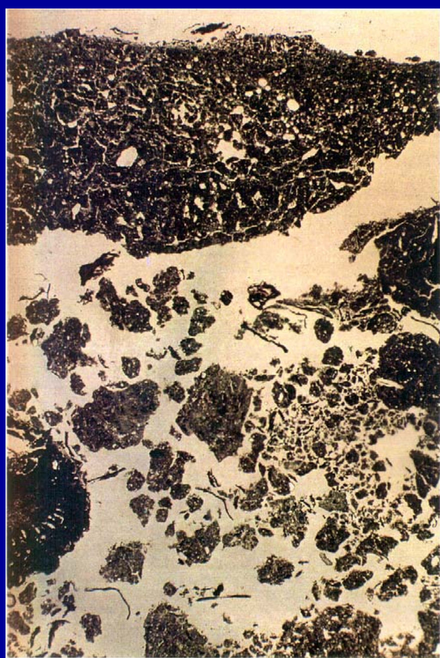
Scale of observation

- Optical and electron microscope
- Image analysis
- Penetration resistance
- Water infiltration rate
- Soil sodicity and electrolyte concentration
- Organic polymers

EFFECT OF SOIL MANAGEMENT ON THE FORMATION, PREVENTION AND CONTROL OF SURFACE CRUSTS

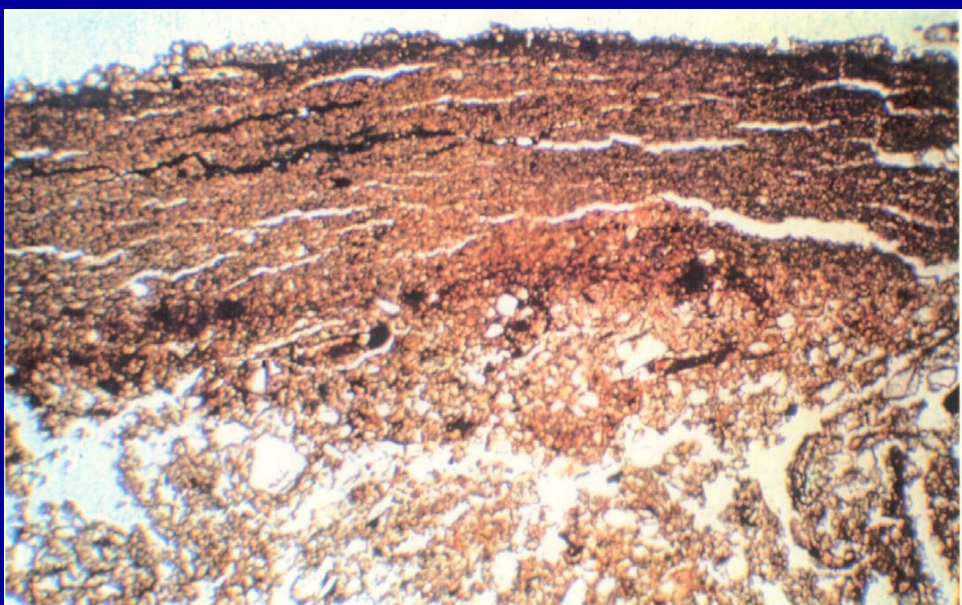
Soil tillage



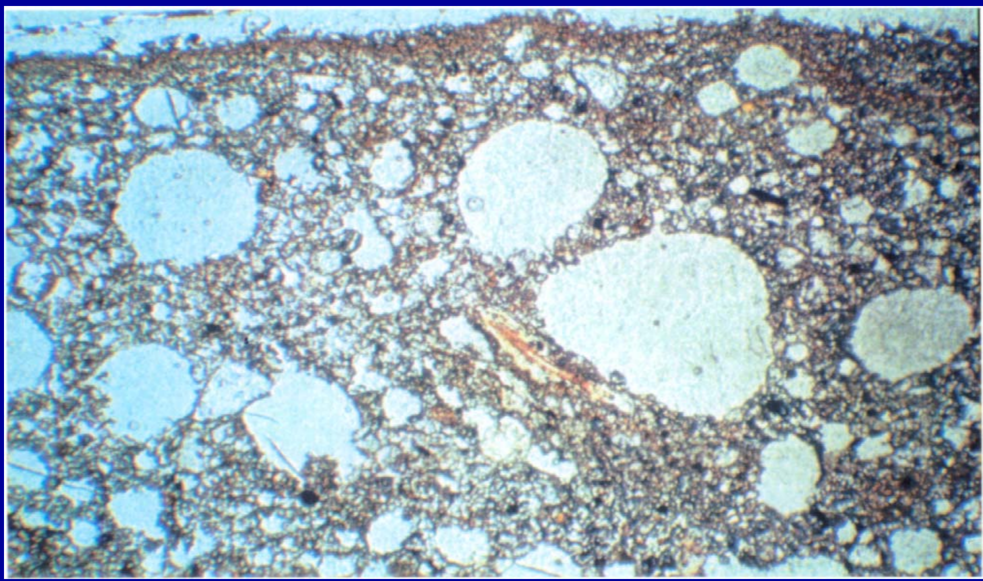


Soil structure before (left) and after (right) a rainfall event. Frame length 3 cm.

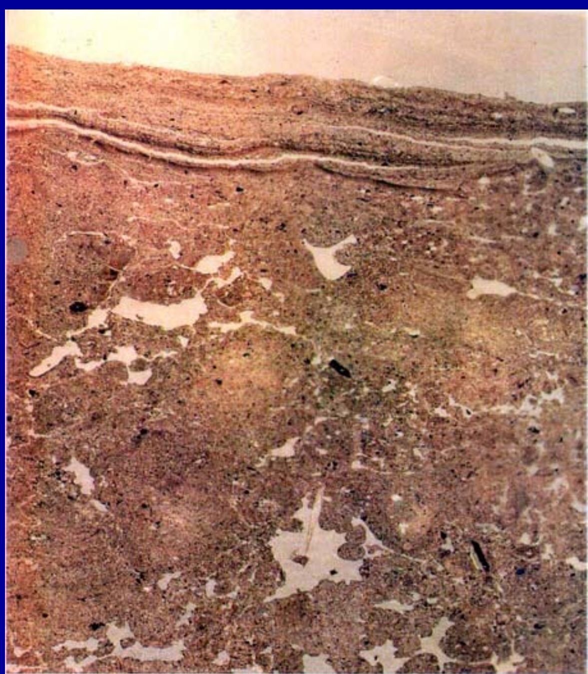
Field conditions after the formation of surface crusts



Surface crust in a cultivated sandy loam soil. Frame length 5 mm.

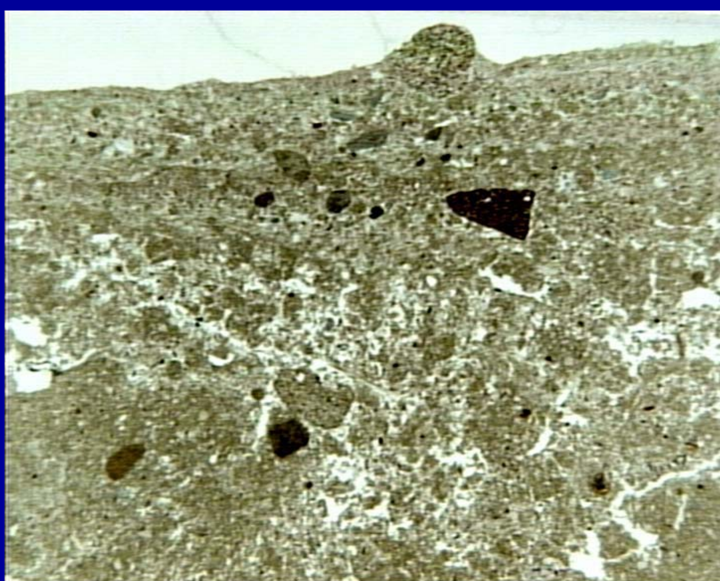


Sealing crust in a cultivated sandy loam soil. Frame length 5 mm.



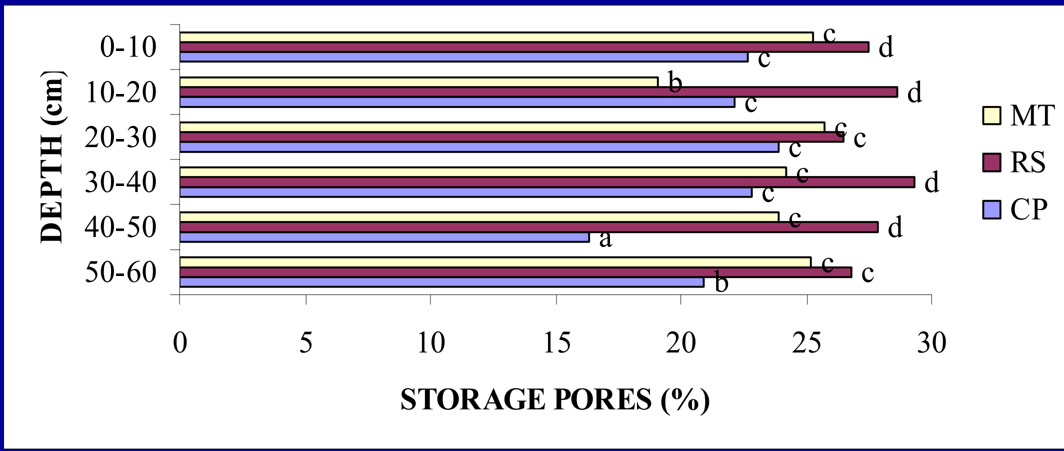
Cultivated loam soil. Frame length 3 cm.

Cultivated loam soil. Frame length 3 cm.

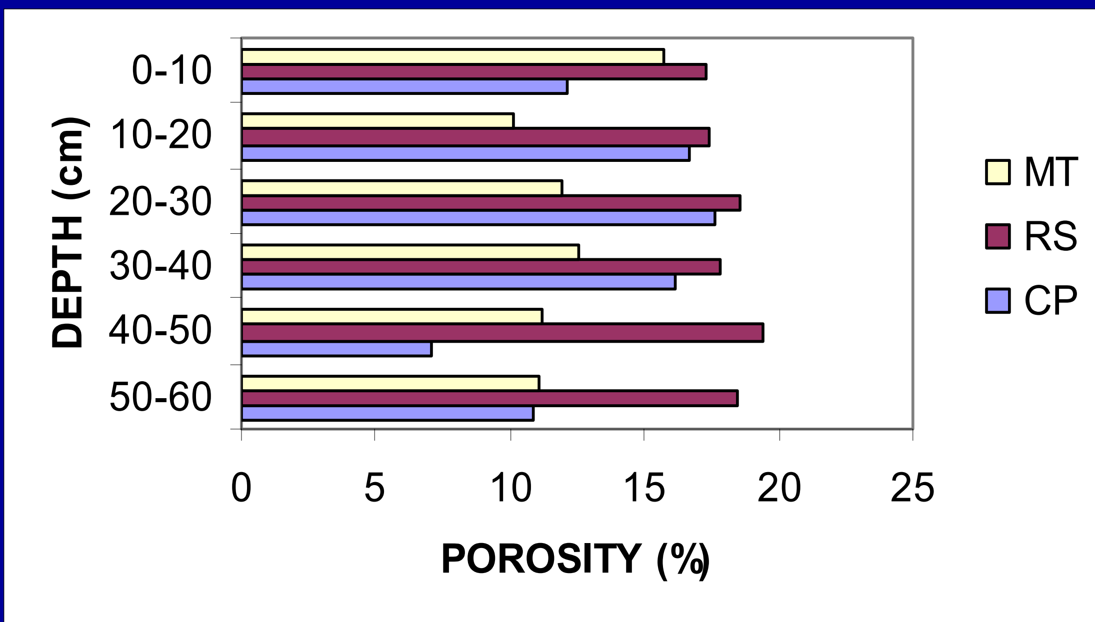


Cultivated clay loam soil. Frame length 5 cm.

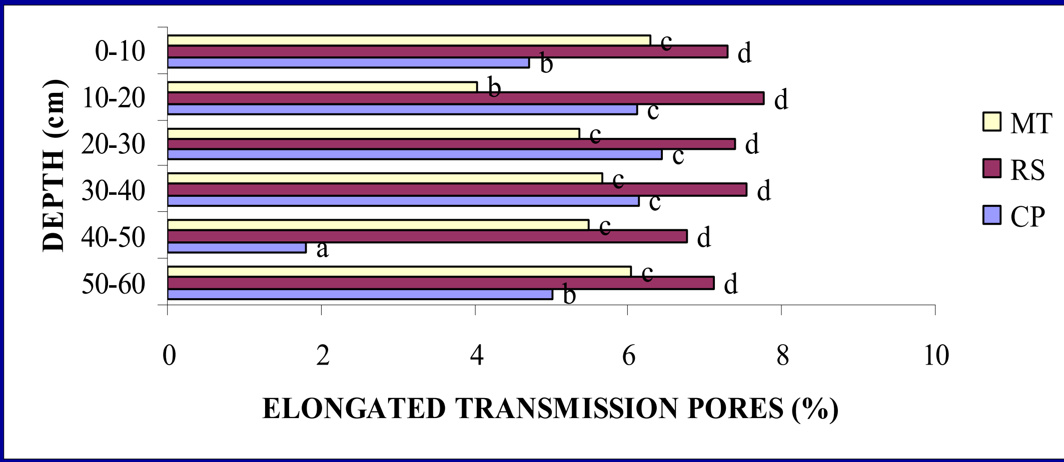
Soil tillage



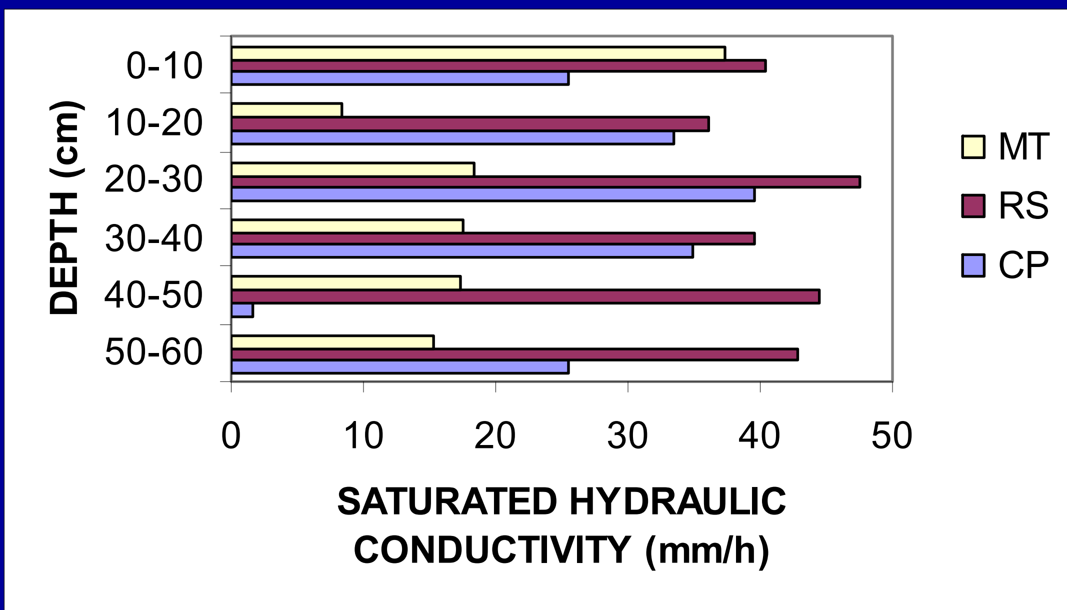
Effects of tillage systems on storage pores inside the aggregates measured by mercury intrusion porosimetry along soil profile (MT: minimum tillage; RS: ripper subsoiling; CP: conventional deep ploughing).

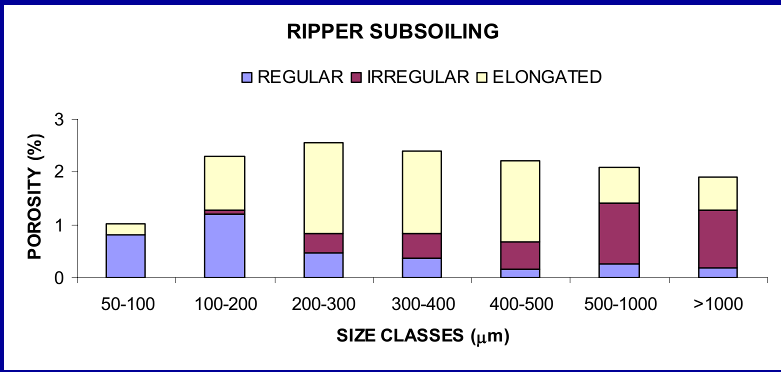


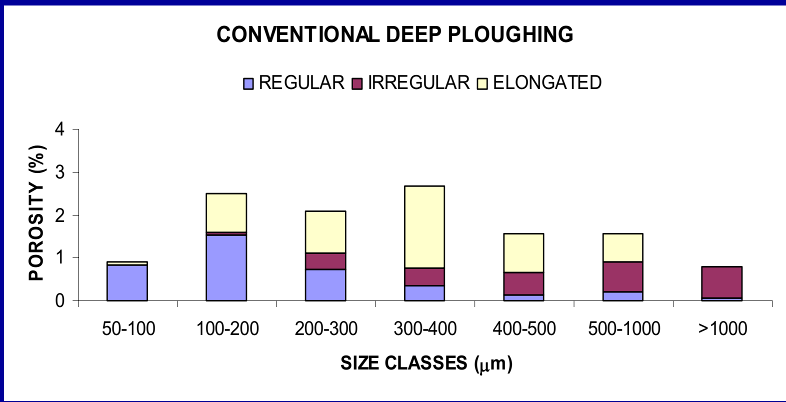
Effects of tillage systems on soil porosity along soil profile expressed as a percentage of total area occupied by pores larger than 50 μm per thin section (MT, minimum tillage; RS, ripper subsoiling; CP: conventional deep ploughing).



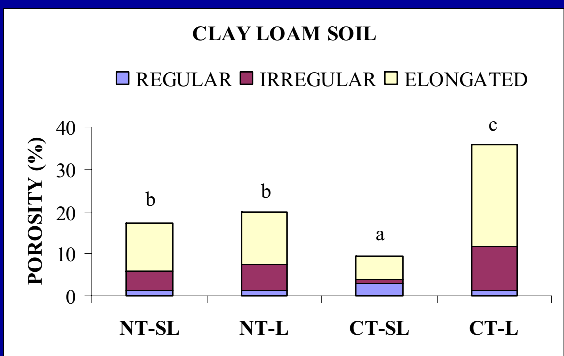
Effects of tillage systems on elongated transmission pores along soil profile expressed as a percentage of total area occupied by pores ranging from 50-500 μm per thin section (MT, minimum tillage; RS, ripper subsoiling; CP: conventional deep ploughing).

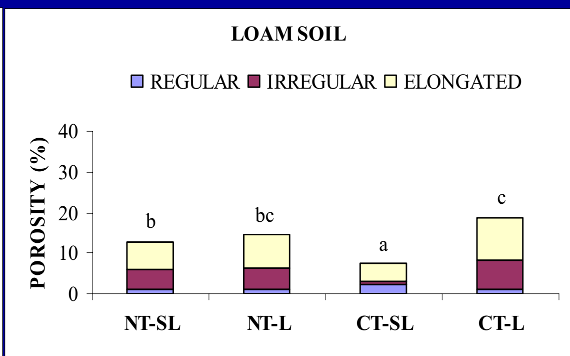




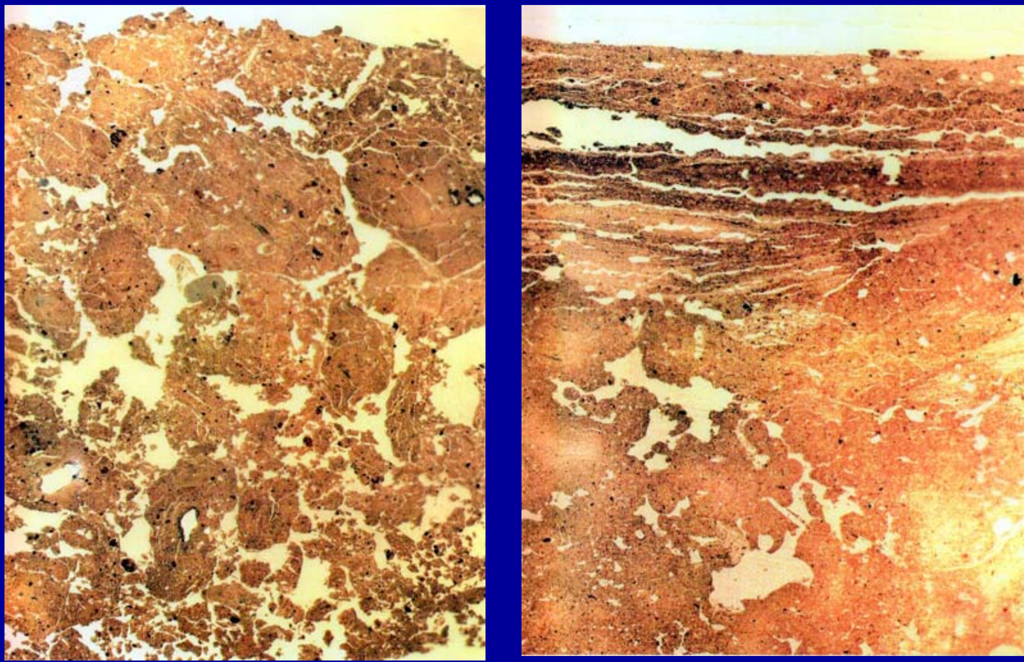


Pore size distribution of pores >50 μm in the surface layer (0-10 cm).

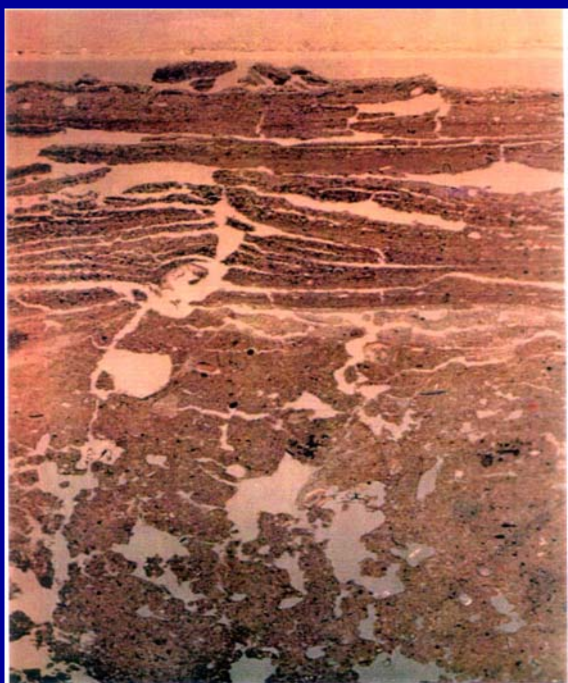




Effects of different management practices (NT: no-tillage; CT: conventional tillage) on soil porosity in the surface layer (0-2 cm) (SL) and in the layer below 5 cm (L).

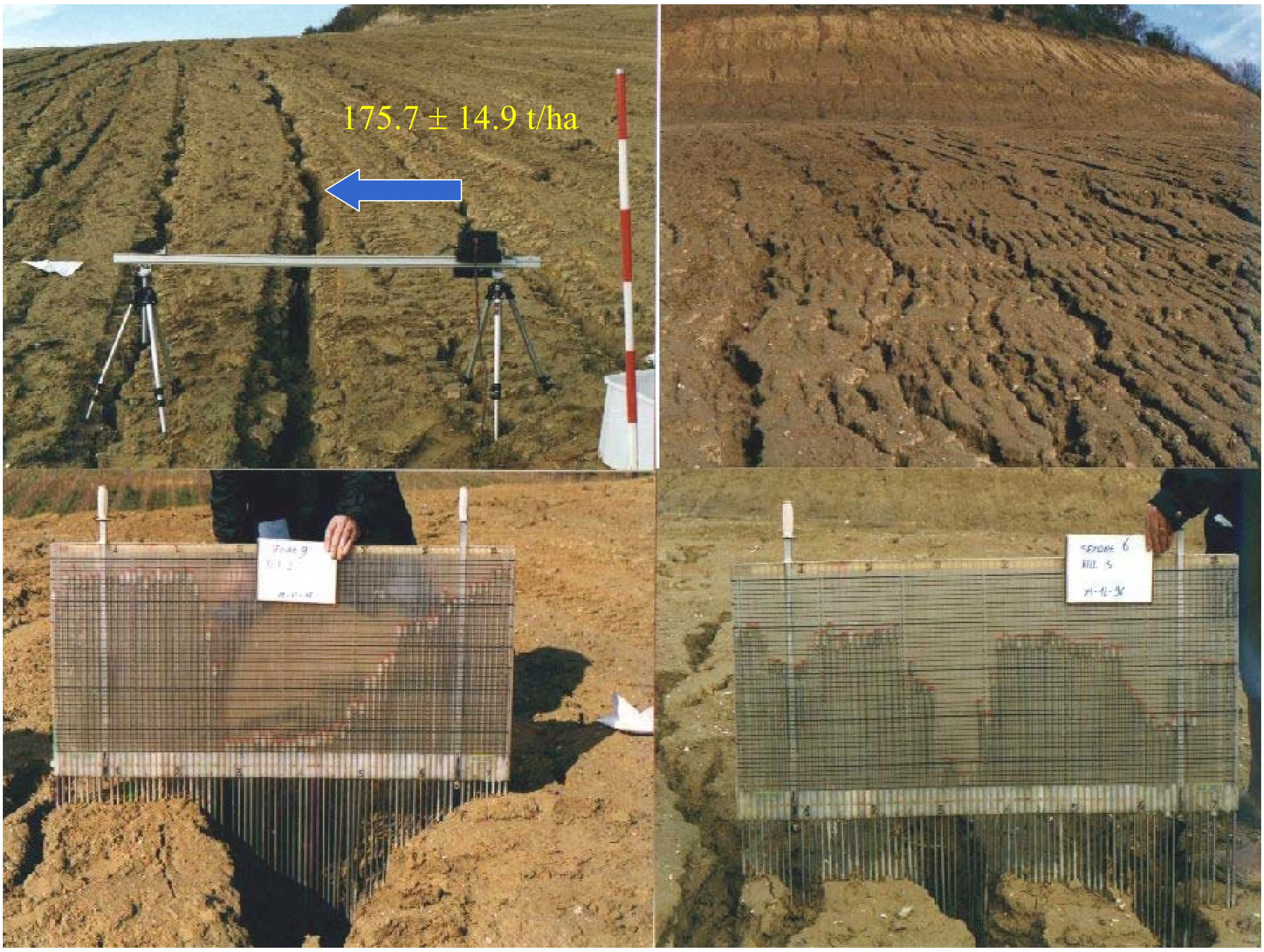


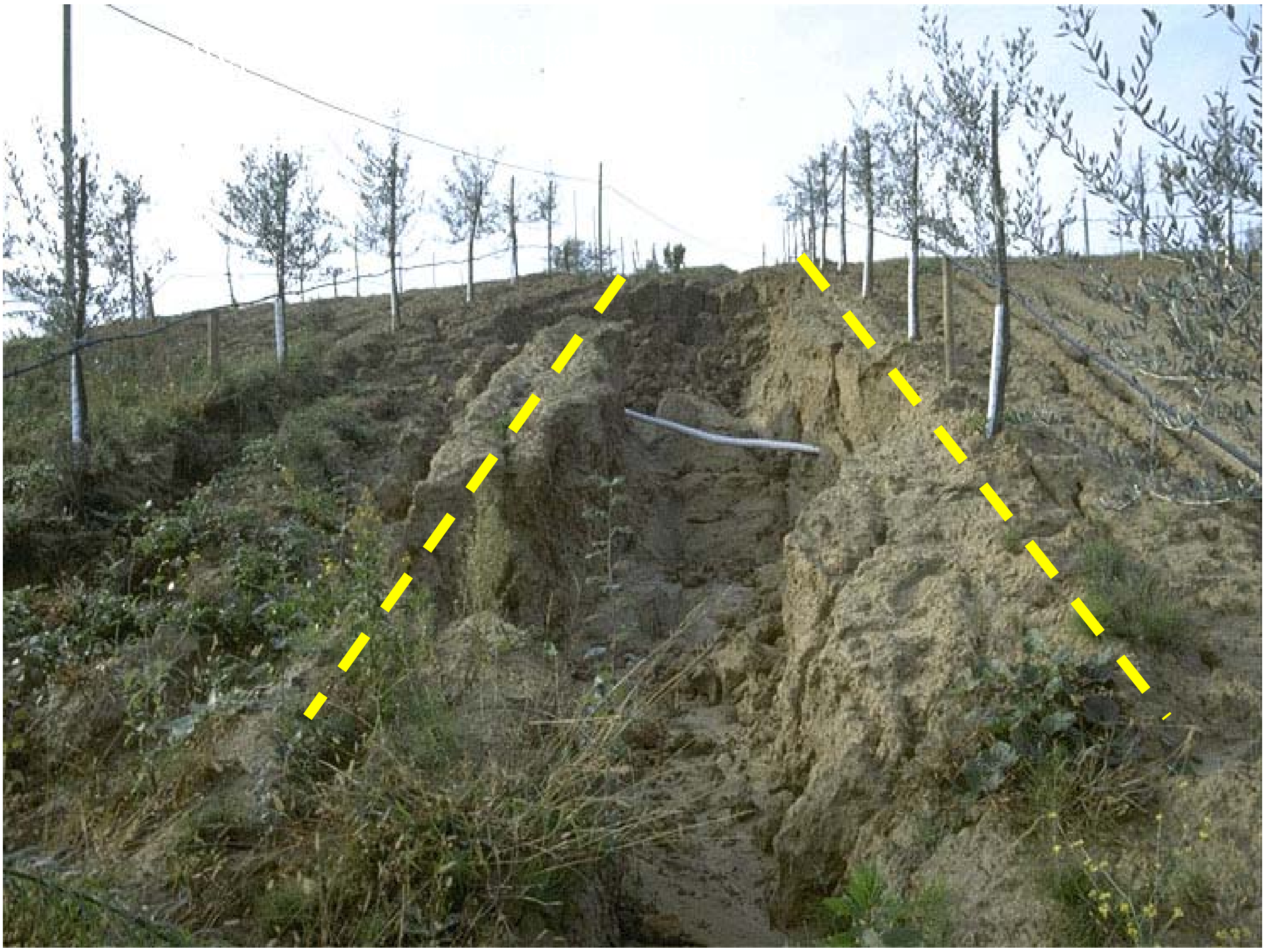
Loam soil under minimum tillage (left) and conventional tillage (right). Frame length 3 cm.



Cultivated loam soil. Frame length 3 cm.

Mechanical mass movement
Land levelling and scraping

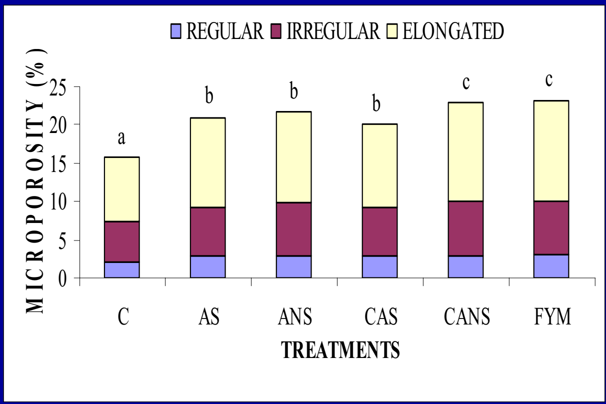


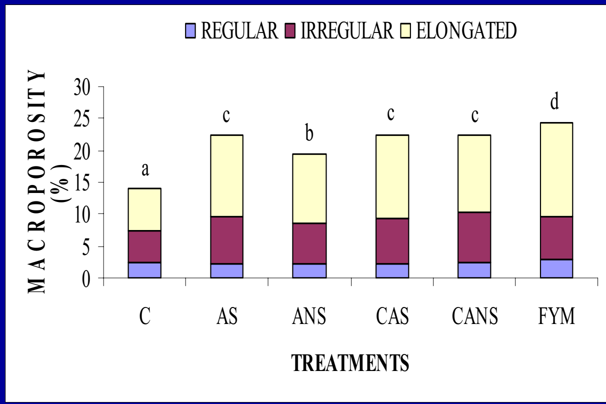


Irrigation management

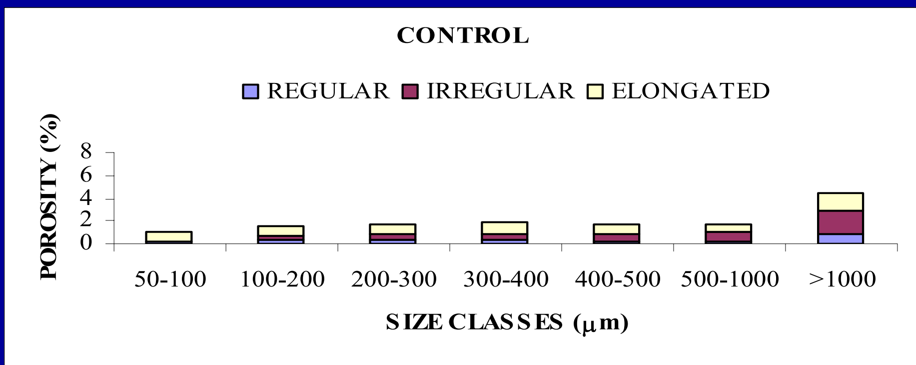
- Irrigation management can also strongly influence crust formation. The chemical composition of irrigation water and the kinetic energy of water applied by overhead irrigation are the most important factors to consider in the case of irrigation of soils susceptible to crusting.

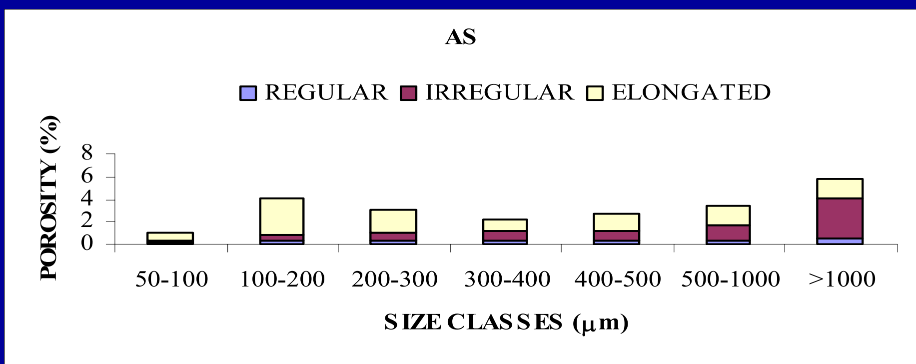
Applications of manures



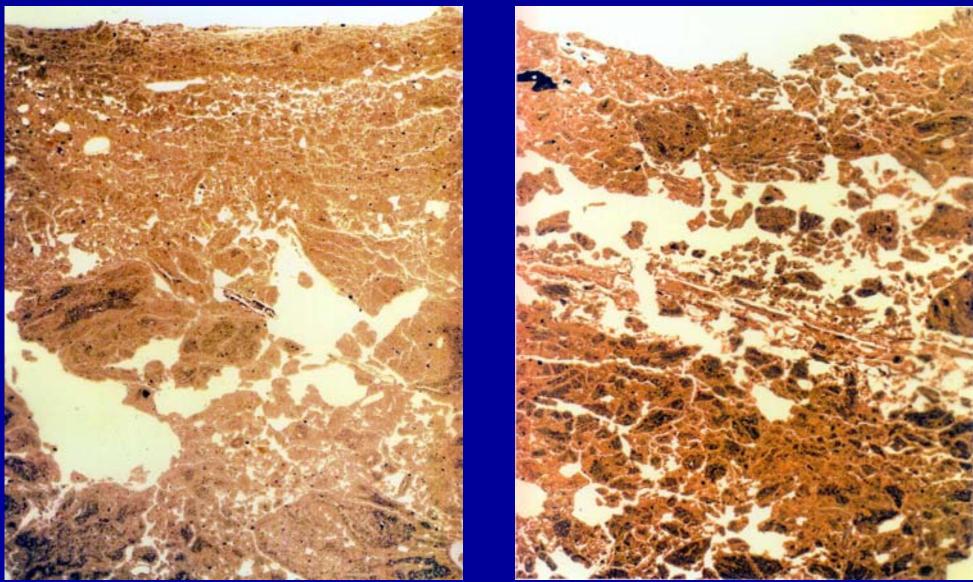


Effect of C: chemical fertilsation; AS: aerobic sludges; ANS: anaerobic sludges; CAS: compost of aerobic sludges and the organic fraction of urban refuse (40:60%); CANS: compost of anaerobic sludges and the organic fraction of urban refuse (20:80%); FYM: farmyard manure) on soil microporosity (0.5-50 μm) and macroporosity (>50 μm).

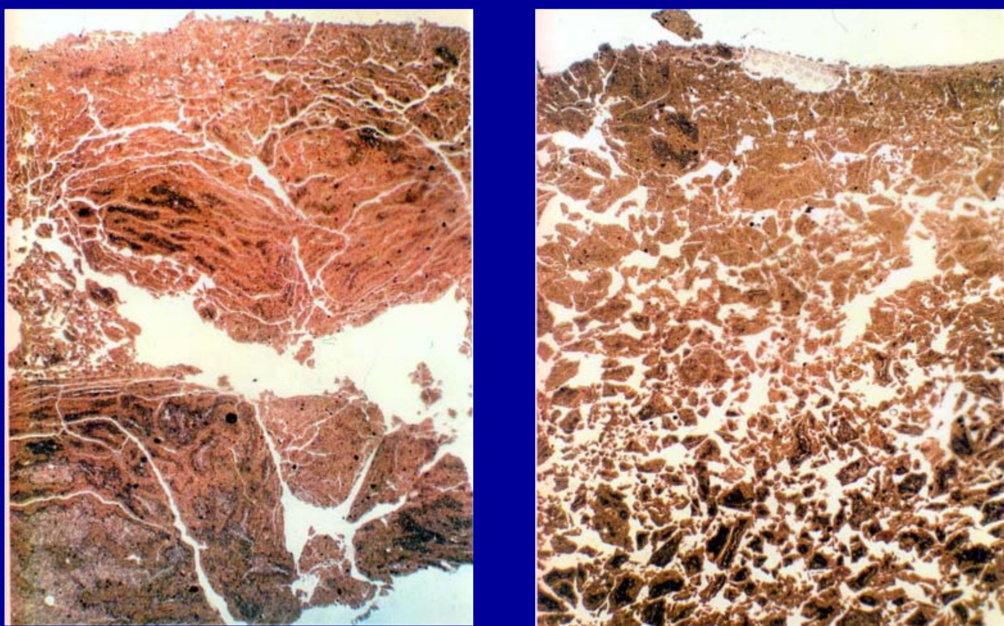




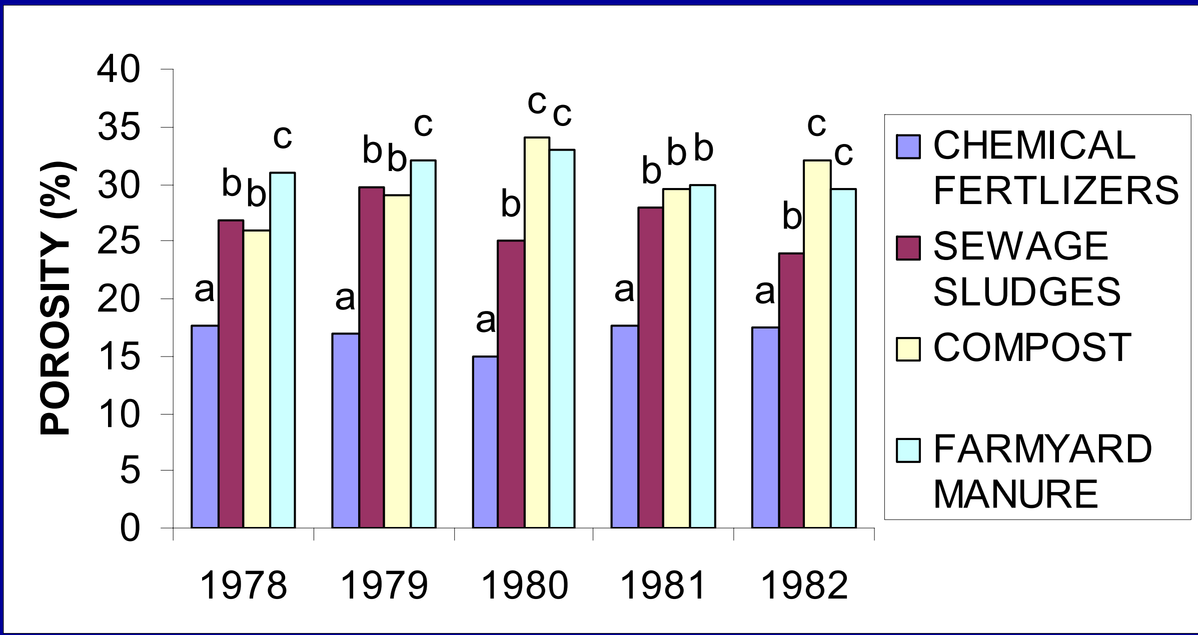
Pore size distribution of pores >50 μm



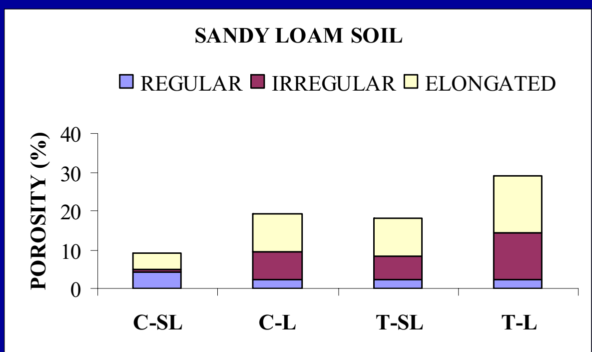
Macrophotographs of vertically oriented thin sections prepared from undisturbed samples from the surface layer (0-10 cm) of a loam soil untreated (left) and treated with compost (right). Frame length 3 cm.

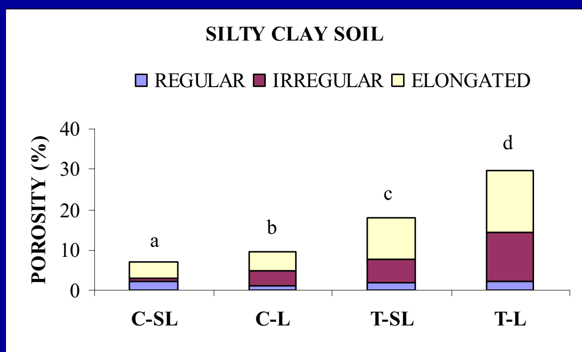


Macrophotographs of vertically oriented thin sections prepared from undisturbed samples from the surface layer (0-10 cm) of a clay loam soil untreated (left) and treated with pig slurry (right). Frame length 3 cm.



Application of organic materials





Effects of different management practices (C: control; T: treated with compost) on soil porosity in the surface layer (0-2 cm) (SL) and in the layer below 5 cm (L).

Other important practices to combat crust formation are:

- The addition to soil of gypsum/phospho-gypsum especially when sodicity is high or electrolyte concentration is very low.
- The use of synthetic soil conditioners.

Assessing the crusting susceptibility

$$CI = \frac{1.5\ (\%\text{fine silt}) + 0.75\ (\%\text{coarse silt})}{\text{clay} + 10(\%\ \text{organic matter})}$$

Crusting index CI	Risk
< 1.2	Low
1.2 – 1.6	Moderate
> 1.6	High

Readily dispersible clay

- $T_{ratio} = T_{1h}/T_{18h}$

T_{ratio}	Risk
< 0.40	Low
0.40 – 0.60	Moderate
> 0.60	High

Soil sealing

- Definition

  Soil sealing refers to changing the nature of the soil such that it behaves as an impermeable medium (for example, compaction by agricultural machines). Soil sealing is also used to describe the covering or sealing of the soil surface by impervious materials by, for example, concrete, metal, glass, tarmac and plastic.

- Soil sealing refers to the covering of soil as a result of urban development and infrastructure construction, with the result that the soil is no longer able to perform the range of functions associated with it.
- Over the past 20 years the extent of built-up area in many western and eastern European countries has increased by some 20% and far exceeds the rate of population growth in the EU over the same period (6%).

- Sealing: the area of the soil surface covered with an impermeable material, is around 9% of the total area in EU. During 1990-2000 the sealed area in EU increased by 6%