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College of Soil Physics

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Soil compaction 1

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Soil Compaction

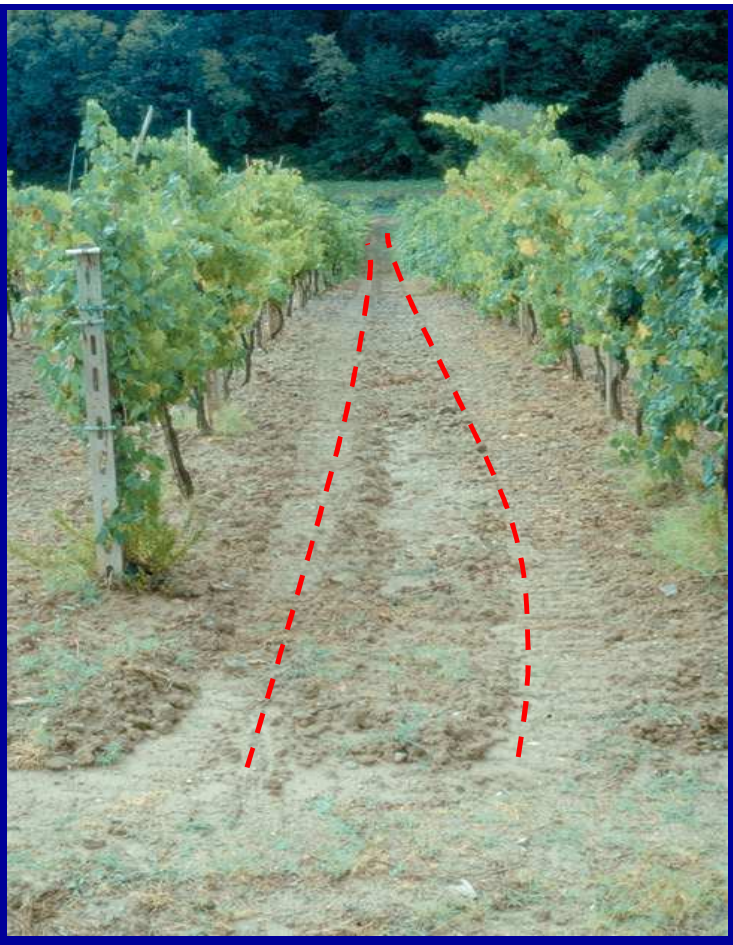
Effect on soil porosity

- Soil compaction is one of the most important factors responsible for environmental degradation. It causes strong modifications to soil structure and reduces soil porosity.
- Soil compaction is caused by a combination of natural forces, which generally act internally, and by man-made forces related to the consequences of soil management practices. The latter forces are mainly those related to vehicle wheel traffic and tillage implements and have a much greater compactive effect than natural forces such as raindrop impact, soil swelling and shrinking, and root enlargement.

- Soil compaction is estimated to be responsible for the degradation of an area of 33 million ha in Europe.
- About 32% of soils in Europe are highly vulnerable to soil compaction and another 18% is moderately vulnerable to soil compaction.
- Due to the ever-increasing wheel loads in agriculture, compaction is increasingly in the subsoil.

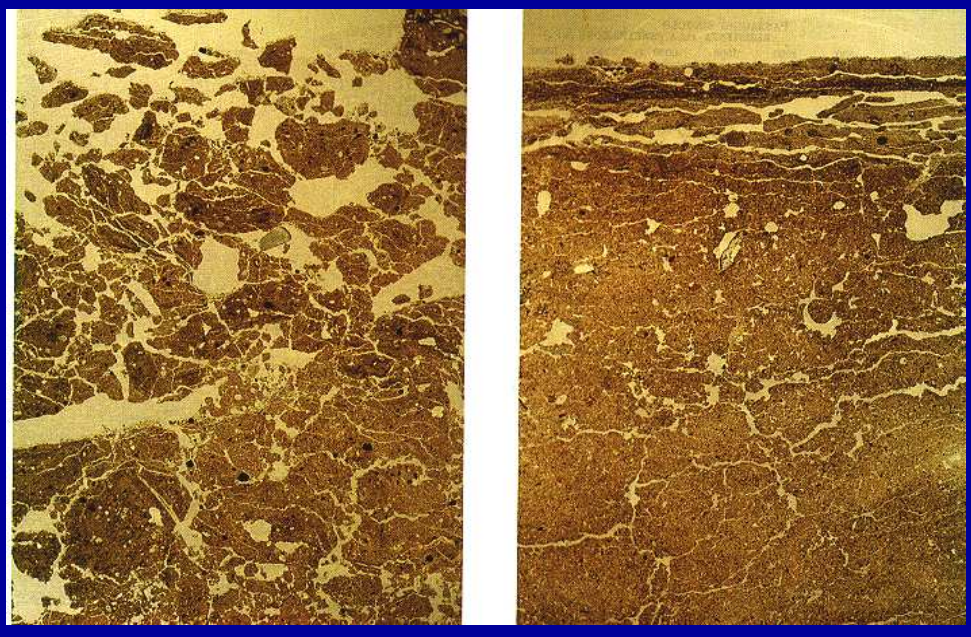
The costs of soil degradation in Europe are not precisely known

- Results of Concerted Action on subsoil compaction in the ambit of EC Research Projects have pointed out that it has been estimated the effect of 38 ton sugar-beet harvesters on yield losses to be 0.5% per year.
- Assuming that such harvesters are used on at least 500.000 ha in the EC this results in an annual loss of sugar-beet yield of 100.000 kEURO.
- It is expected that these heavy harvesters will be increasingly used.



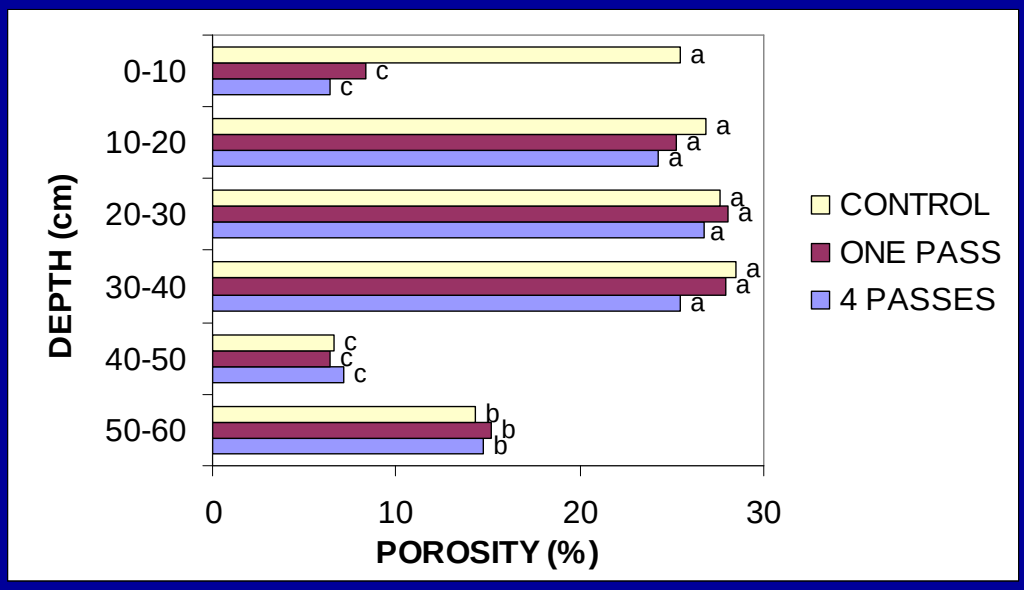
From Paolo Bazzoffi, ISSDS-2002

Soil structure

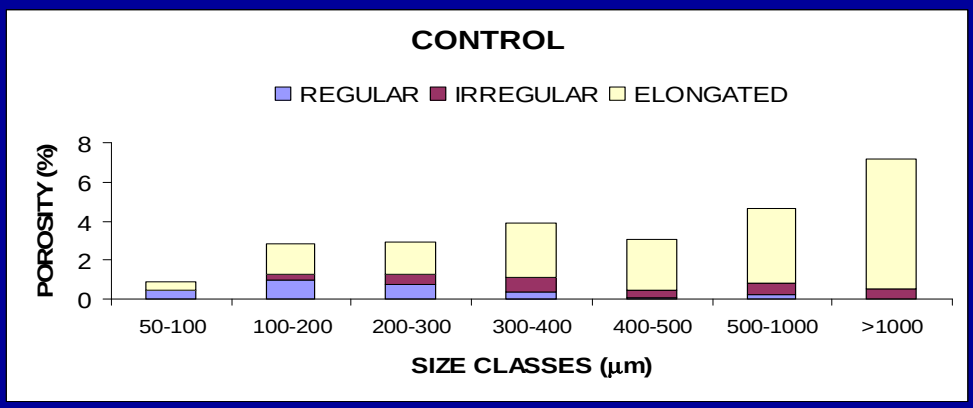


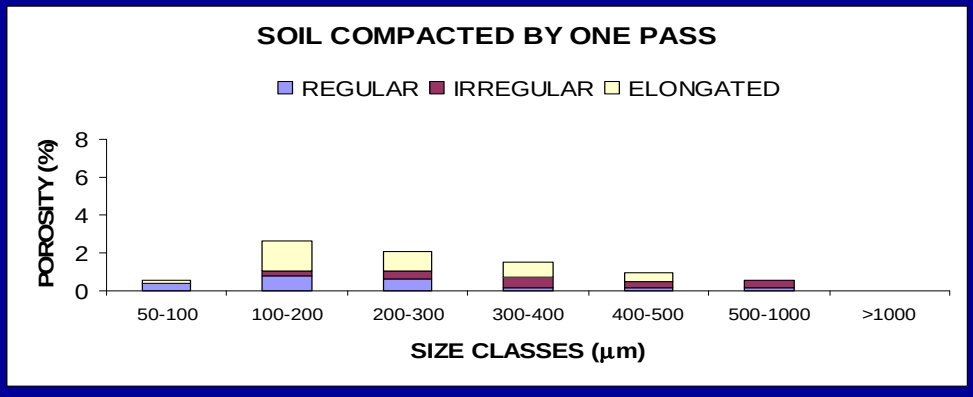
Surface layer (0-5 cm) of the uncompacted (left) and compacted areas (right) of a loam soil. Frame length 3 cm.

Soil Porosity



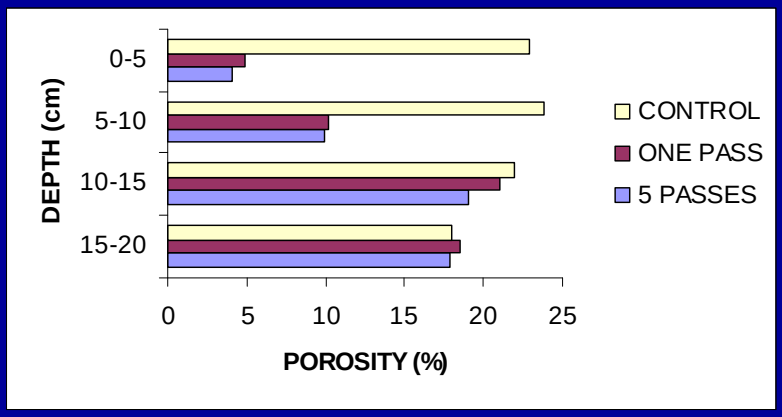
Effects of soil compaction, caused by one and four passes of tractors, on soil porosity expressed as a percentage of area occupied by pores larger than 50 μm per thin section.

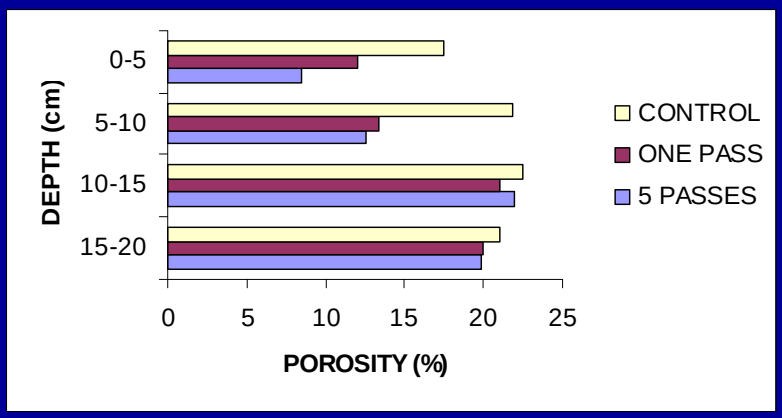




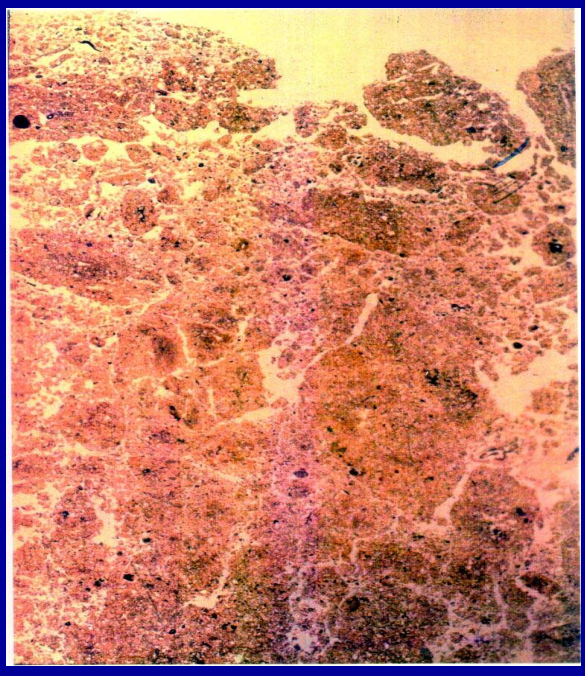
Pore size distribution

Soil regeneration



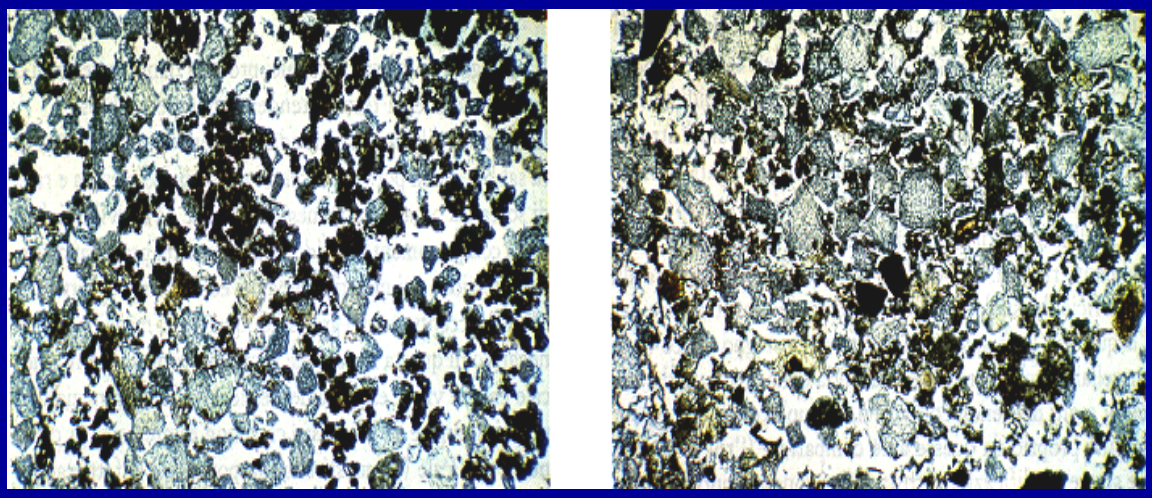


Soil structure

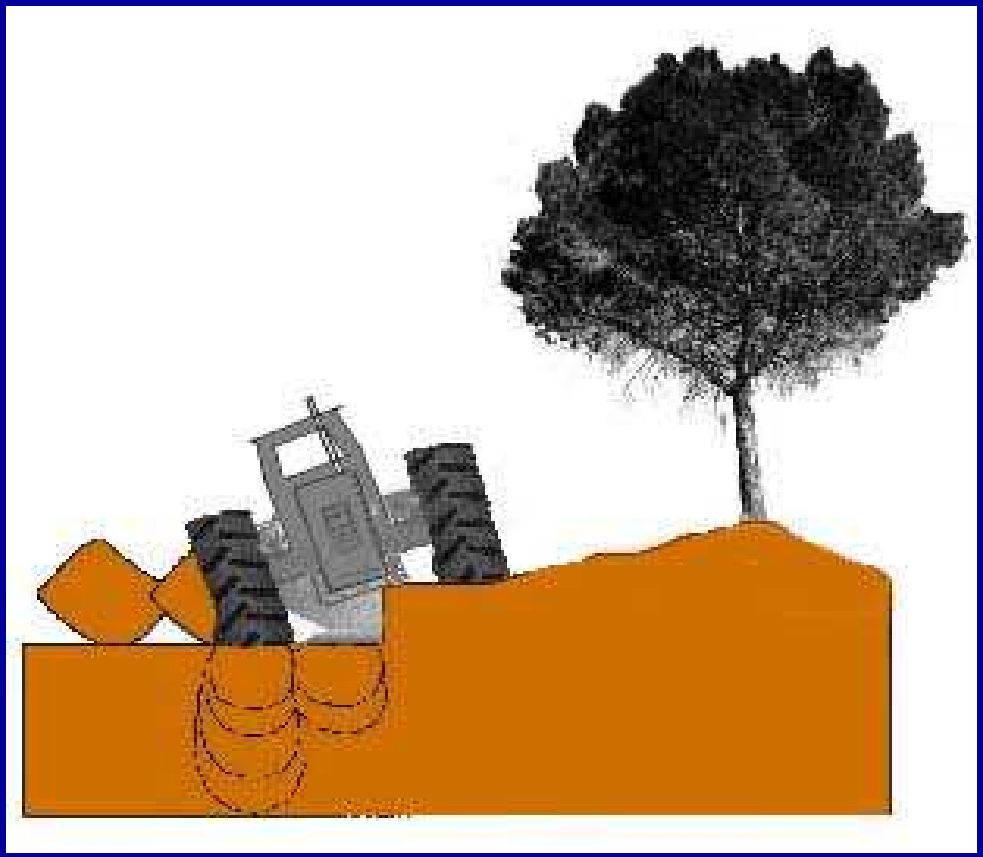


Surface layer of the uncompacted (left) and compacted areas (right) of a sandy loam soil. Frame length 3 cm.

Sandy forestry soil



Vertically oriented thin sections from the surface layer (0-5 cm) of the uncompacted (left) and compacted areas (right) of a loam soil. Frame length 3 mm

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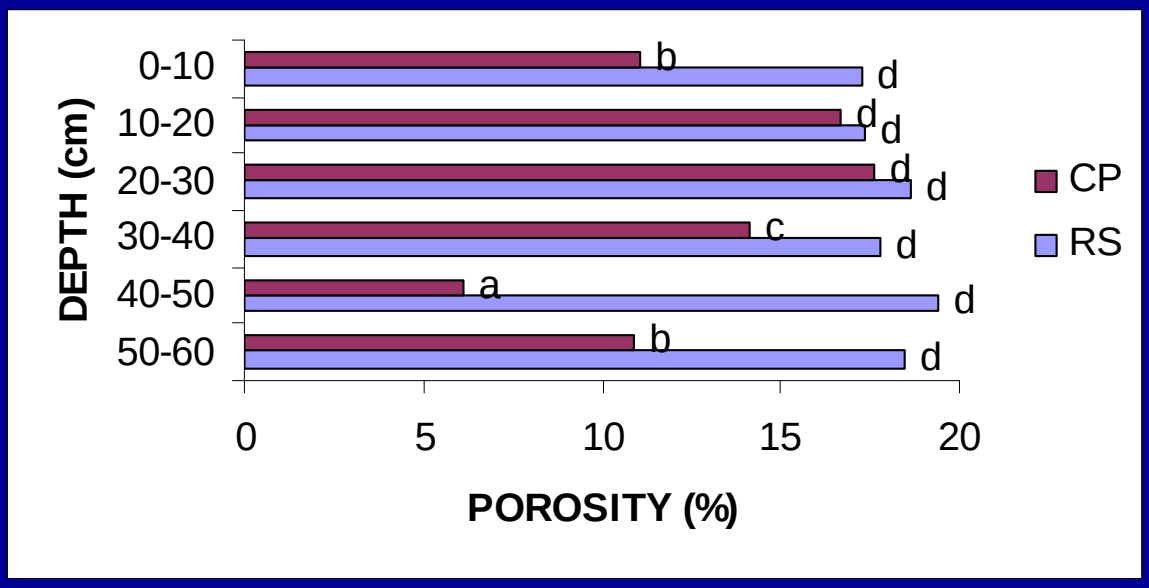
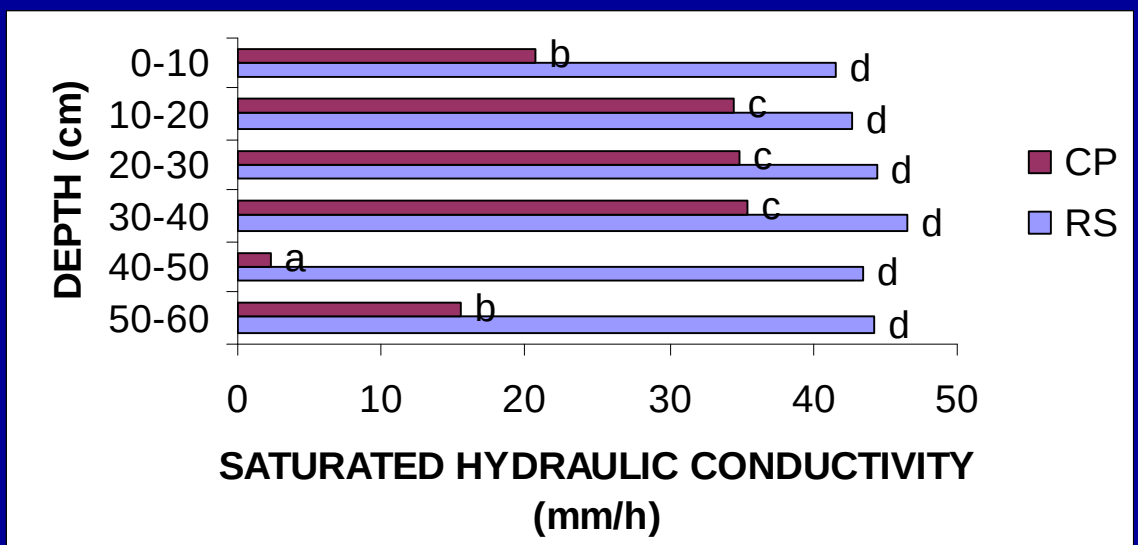
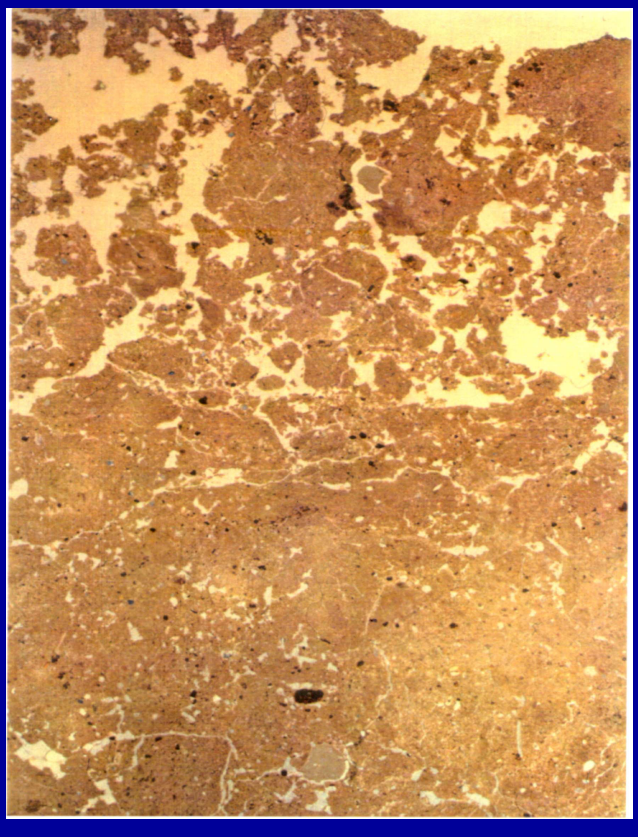
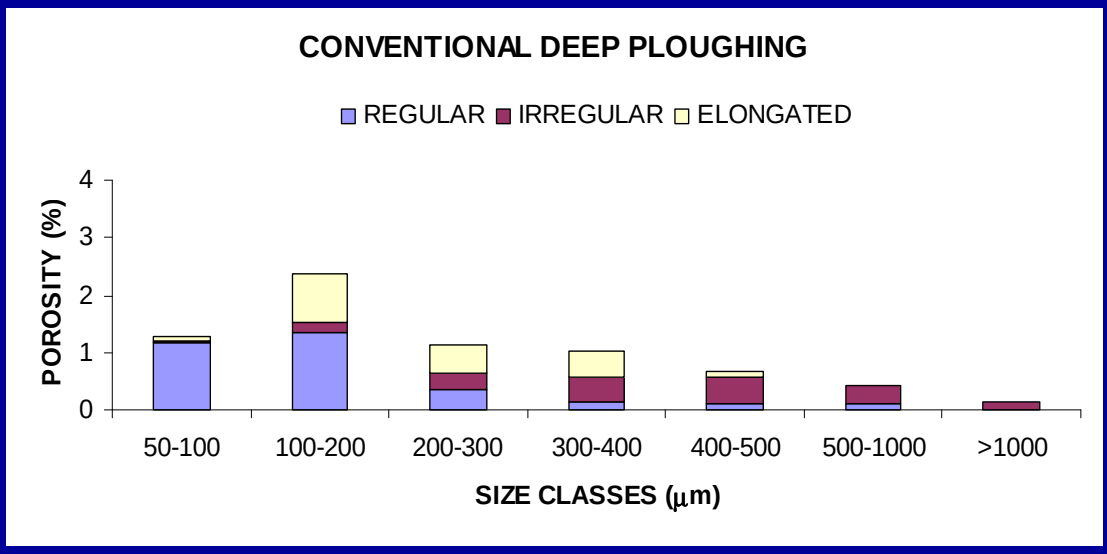

DEPTH (cm)
0-10
10-20
20-30
30-40
40-50
50-60
b
d
d
d
d
d
c
d
a
d
b
d
0
5
10
15
20
POROSITY (%)
CP
RS

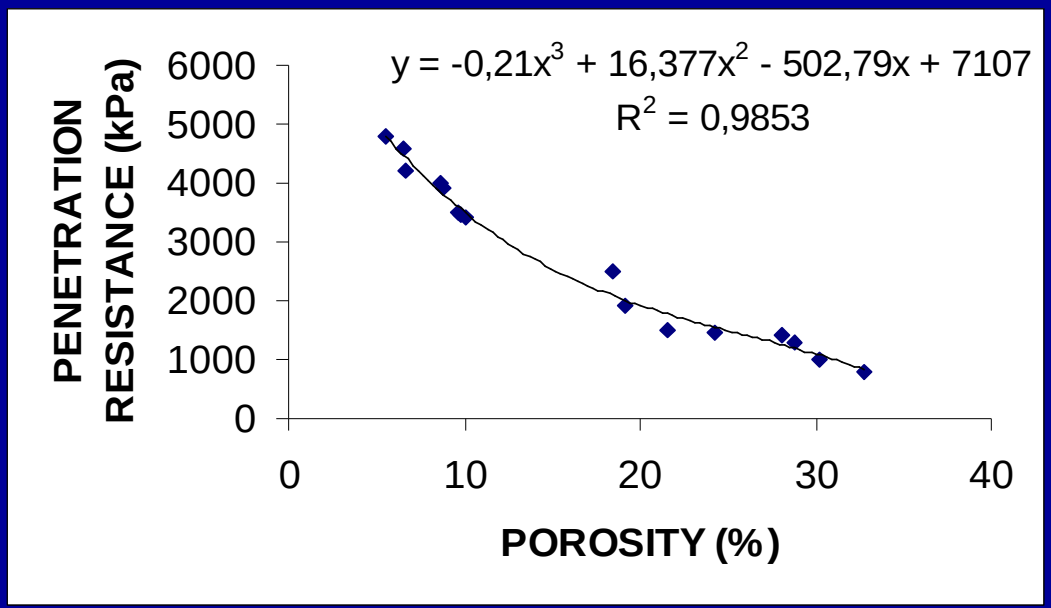

DEPTH (cm)
0-10
10-20
20-30
30-40
40-50
50-60
b
d
c
d
c
d
c
d
a
d
b
d
0
10
20
30
40
50
SATURATED HYDRAULIC CONDUCTIVITY (mm/h)
CP
RS



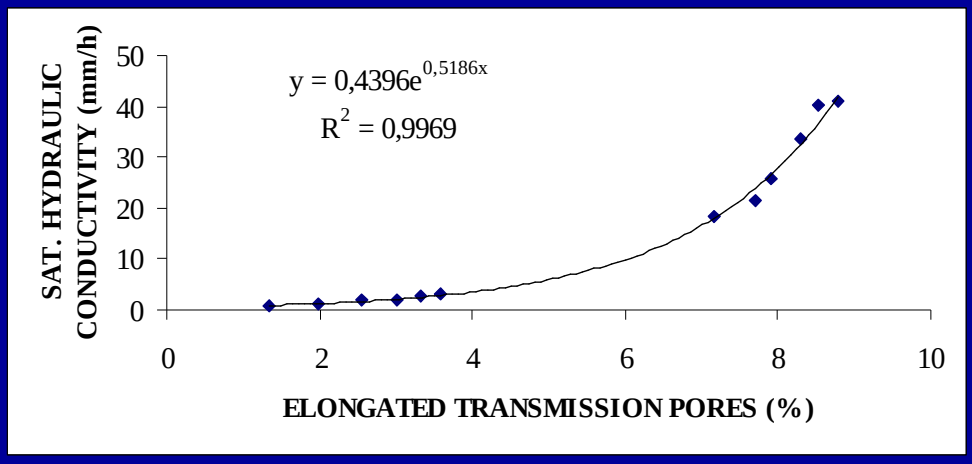


Pore size distribution in the 40-50 cm layer.

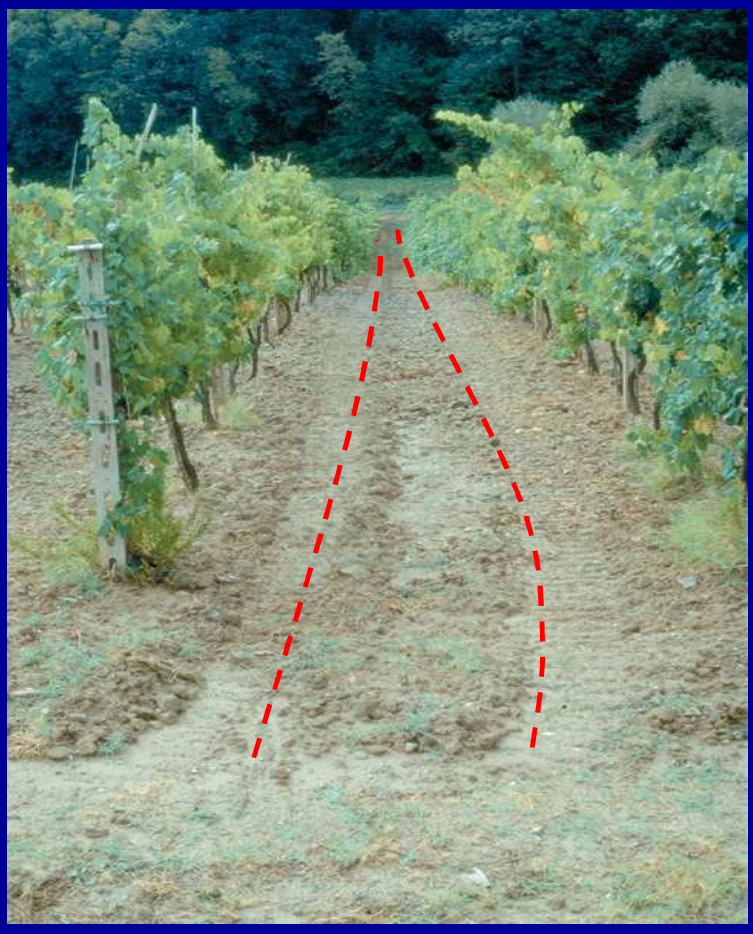
Soil porosity and penetration resistance



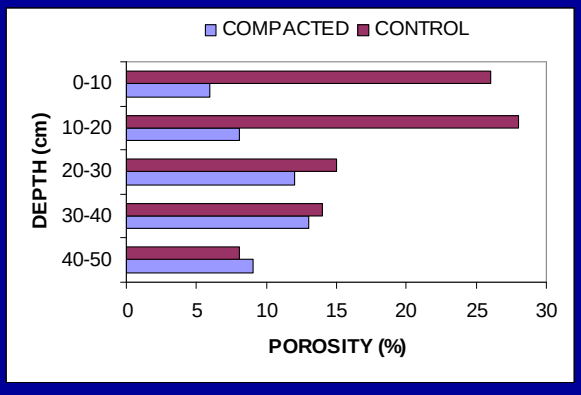
Soil porosity and hydraulic conductivity

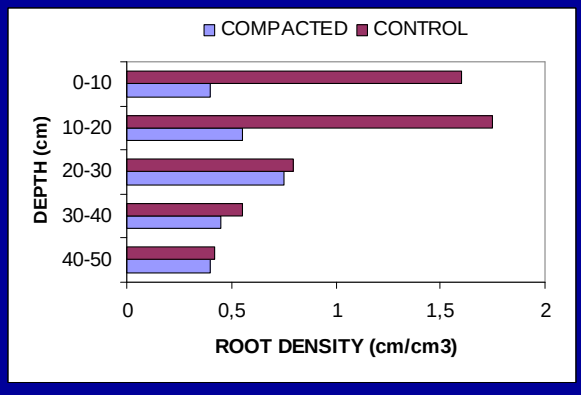


Exponential correlation between soil porosity formed by elongated pores and saturated hydraulic conductivity in the surface layer (0-10 cm) of the compacted (elongated pores less than 4%) and uncompacted areas (elongated pores greater than 7%).



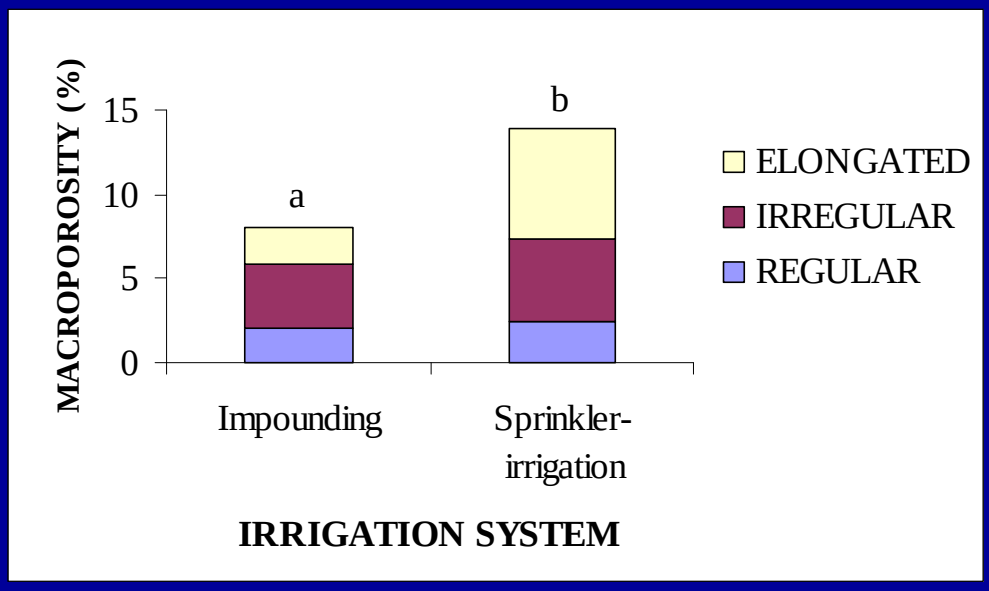
Soil porosity and root growth

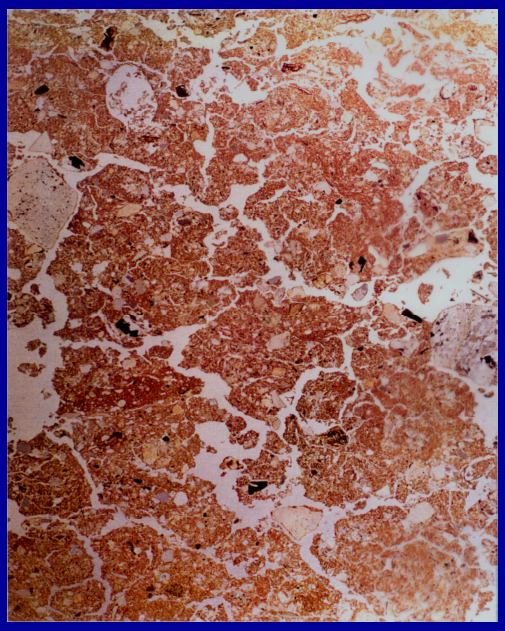


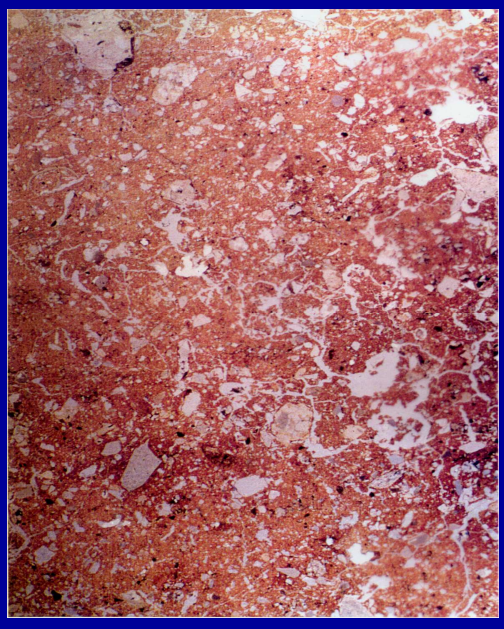


Effects of soil compaction, caused by wheel traffic of machines in a peach orchard, on soil porosity expressed as a percentage of area occupied by pores larger than 50 μm per thin section (on the left) and on root density expressed as root length/cm^3 (right).

Irrigation







Macrophotographs of vertically oriented thin sections prepared from undisturbed samples from the surface layer (0-10 cm) of a peach orchard sandy loam soil under sprinkler irrigation (left) and irrigated by impounding (right). Frame length 3 cm.

Laboratory approach

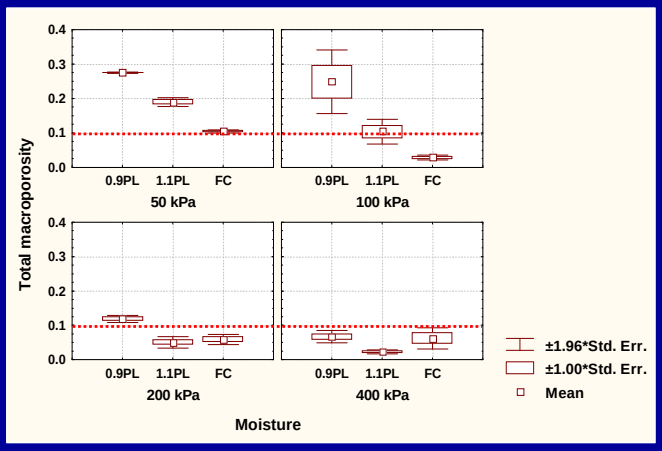
- **Uni-axial compaction tests were carried out on air-dried and sieved (2 mm) samples of a silty clayey Vertic Haploxerept from central Italy under arable (AR) and natural vegetation (NV).**
- **Soil samples were moistened and equilibrated at 3 different water contents: field capacity (-33 kPa), 110% and 90% (w/w) of plastic limit (FC, 1.1PL and 0.9PL, respectively).**

Soil use	Clay (%)	Silt (%)	Sand (%)	Plastic limit (% w/w)	Field cap. (% w/w)	Org. matter (%)
Arable	39.7	50.9	9.4	20	27.6	2.2
Natural veg.	31.7	57.7	10.6	39	42.3	6.2

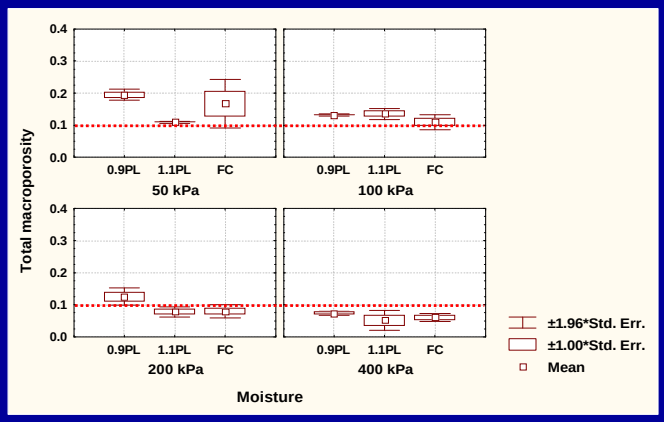
Four different pressures (50, 100, 200 and 400 kPa) were then applied by a hydraulic press.

- **Saturated hydraulic conductivity measurements were performed by falling-head method on the soil samples previously compacted at different moisture content.**
- **The same samples were used to obtain soil thin sections on which total macroporosity (>50μm), and pore shape and size distribution of the surface soil layer (0-1 cm) were measured by image analysis.**

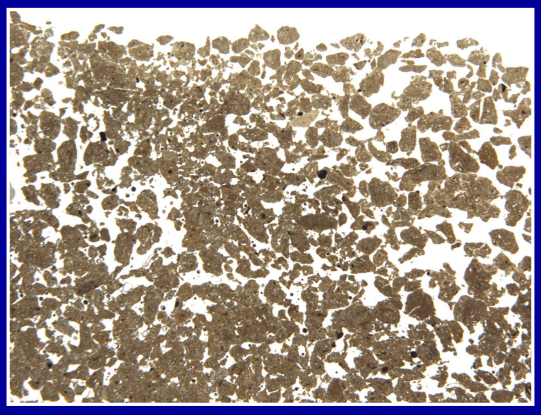
Macroporosity



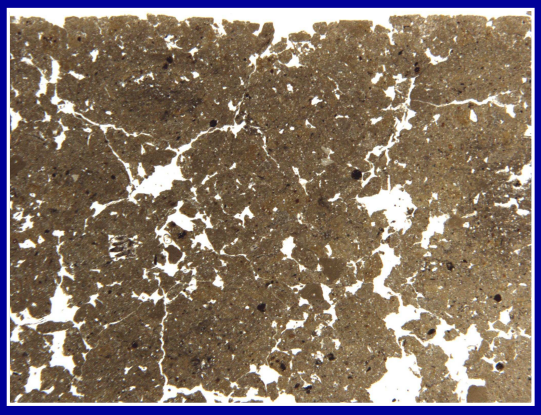
Arable



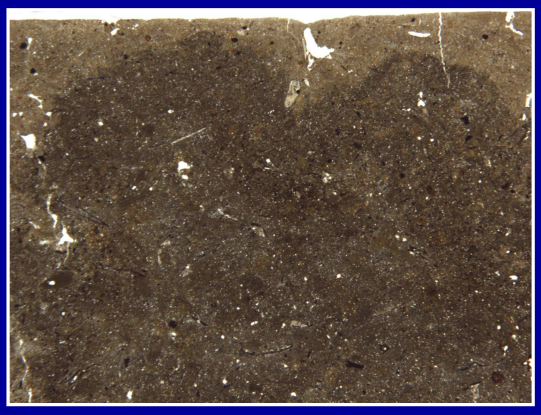
Natural vegetation



Arable 0.9PL – 100kPa

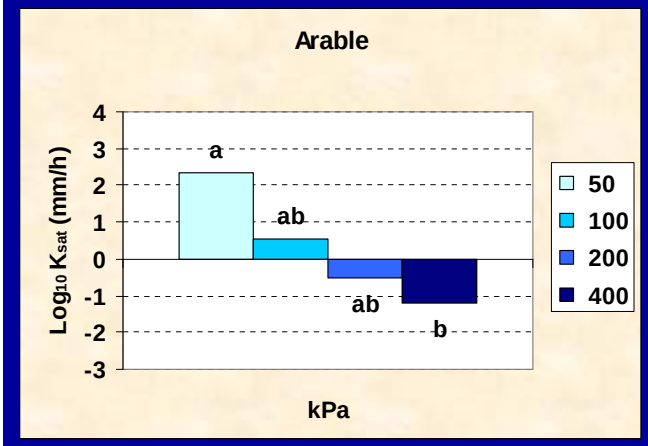


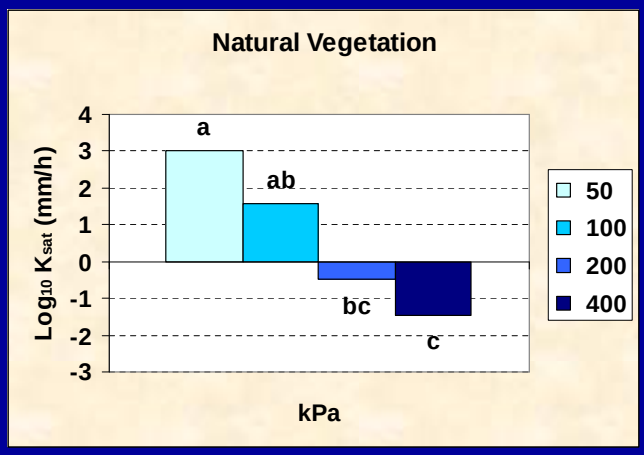
Arable 1.1PL – 100kPa



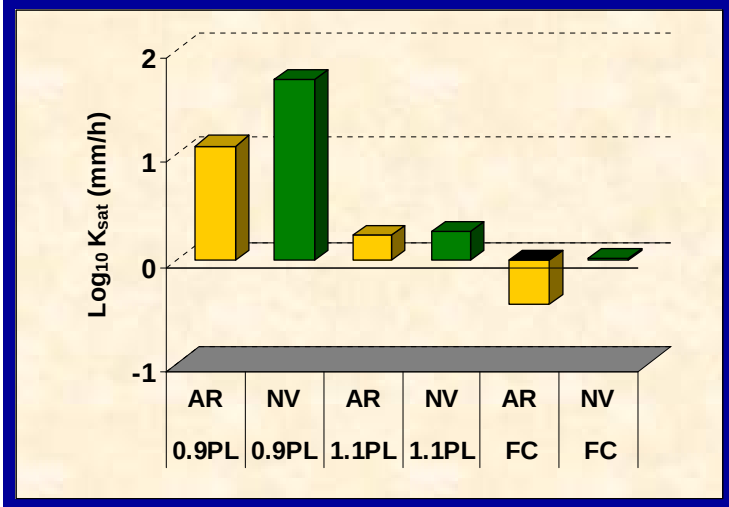
Arable FC – 100kPa

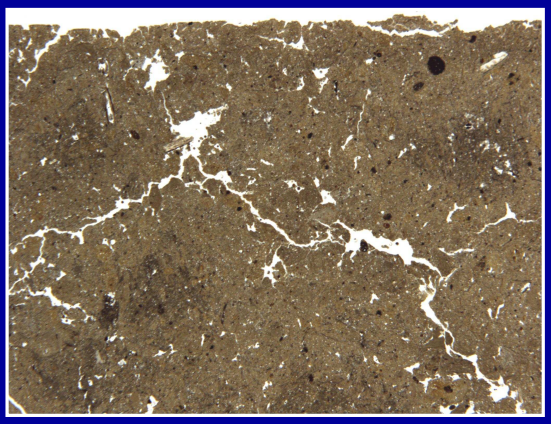
Hydraulic conductivity



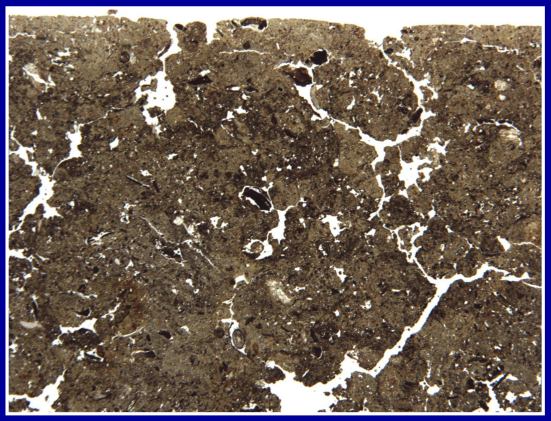


Soil Use



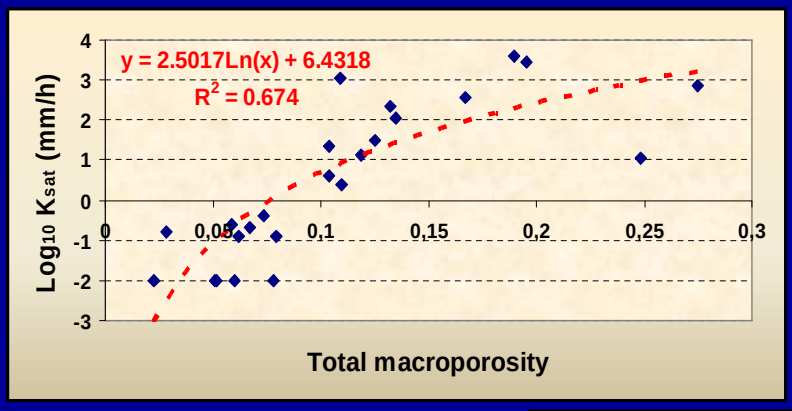


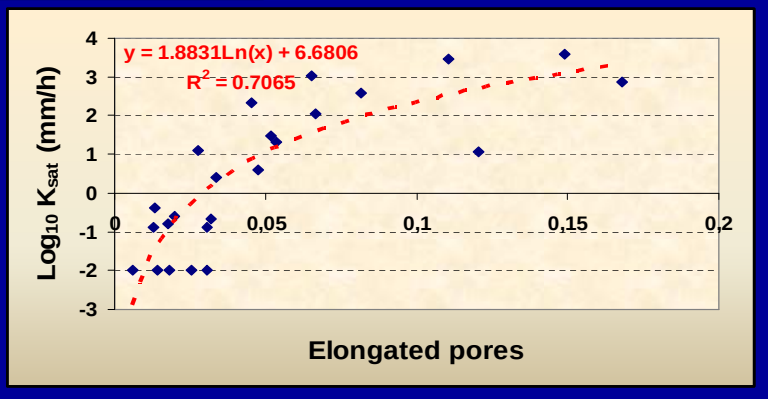
Arable 1.1PL - 200kPa



Natural vegetation 1.1PL - 200kPa

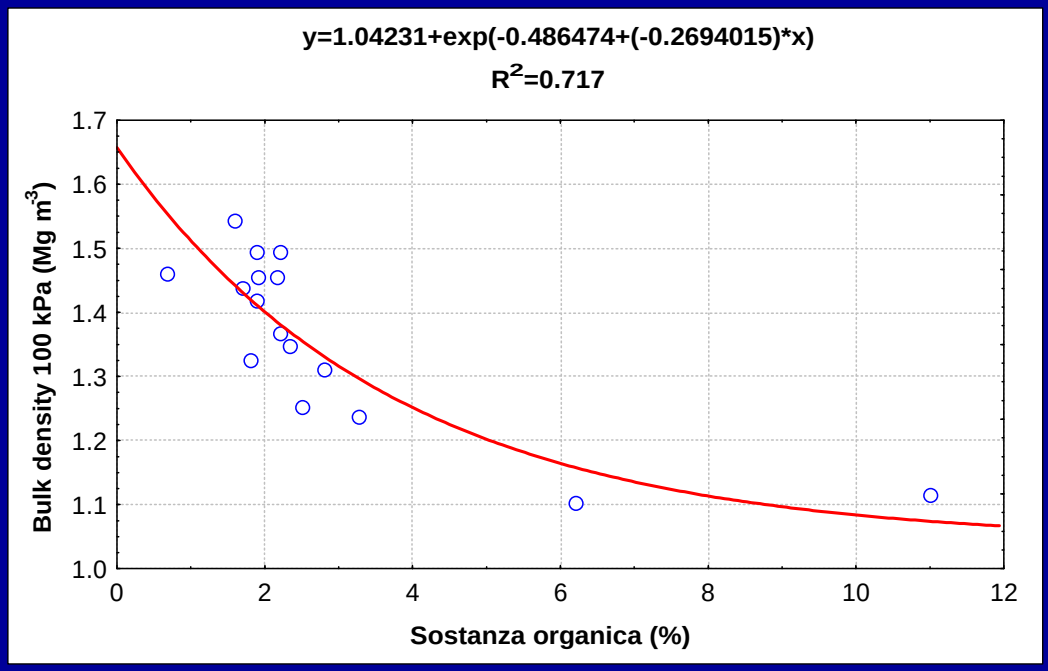
Hydraulic conductivity-macroporosity correlations





Assessing the compaction susceptibility

- Smith equation *(Soil and Tillage Research, 43, 335-354, 1997)*
- C = -0.09266 + 0.01576*(% of silt+clay) – 0.00012*(% of silt+clay)^2
- C = compressibility index



C_c = -0.09266 + 0.01576*(% of silt+clay) – 0.00012*(% of silt+clay)^2 + (1.04231 + exp(-0.486474 + (-0.2694015)*(% of organic matter)

Compressibilty index C_c	Risk
< 1.5	Very low
1.5 – 1.6	Low
1.6 – 1.7	Moderate
1.7 – 1.8	High
> 1.8	Very high

Conclusions

- Soil compaction is one of the most important factors responsible for environmental degradation. It causes strong modifications to soil structure and reduces soil porosity.
- 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.

- To preserve environment and natural resources it is absolutely necessary to protect soils.
- For this, it is strongly important to educate people on knowledge and correct use of soil and to persuade farmers to adopt soil management practices able to prevent soil degradation.
- The goal of the soil scientists is to give a contribution in this way through the discussion and dissemination of experiences in all part of the world.
- Such experiences can be a useful contribution for the new rural development Regulation of Agricultural Policy.