Assessment of the traffic induced soil compaction risk

J.N. LOUVET, J. VERSWIJVEL, K. ABROUGUI, C. ROSIERE, C. ROISIN, M.F. DESTAIN

Introduction

Compaction affects many physical, chemical and biological properties and processes in the soil and may result in:

- **environmental problems** (e.g. erosion, flooding, nutrient and pesticide leaching to groundwater)
- **agronomic problems** (decreased root growth and plant development, with an associated reduction in crop yield)

Sugar beet harvesting

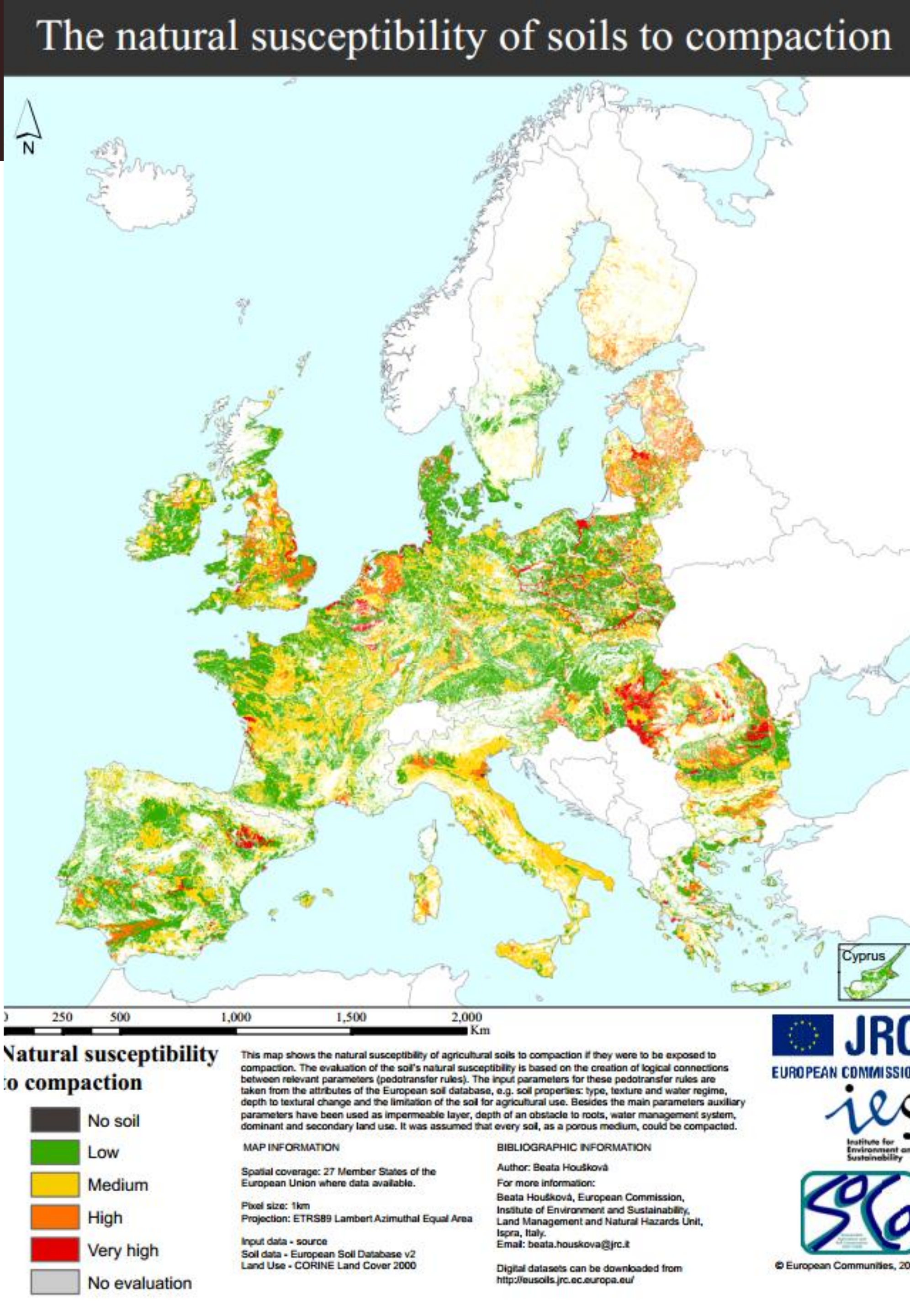
Root distortion due to soil compaction

Introduction

Pedotransfert function showed that Belgium is one of the European countries most affected by the soil compaction.

However, C. Rosière et al. (2010) showed that pedotransfert fonction can not accurately estimate compaction susceptibility.

→ Need to make more measurements and use physical models.



Objective of the study

The aim of the research project is to measure the compaction at the field scale and to extrapolate the results thanks to physical models and simulations.

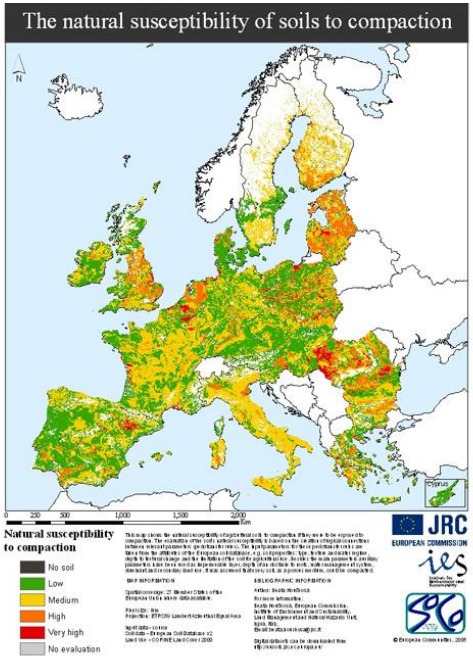
Two treatments are compared : reduced tillage and conventional tillage with ploughing.

Local measurement

Pedotransfert functions

Models and simulations

Map of soils susceptibility to compaction



Materials and Methods

<u>Measurements at the scale of the field</u>

- Oedometer tests
- Resistance to cone penetration
- Pore size distribution (with mercury porosimeter)
- Permeability
- Bulk density
- Proctor compaction test

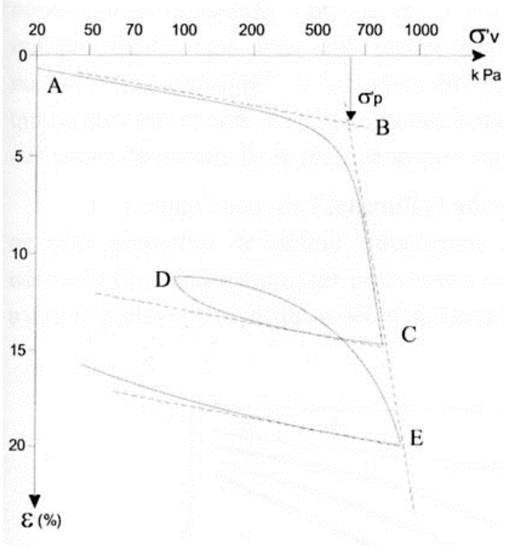
…

<u>Models</u>

- Soilflex
- The FEM with pseudo elastic model
- Sisol, (effect of tillage on soil structure)

Stress (kPa)

Strain (%)

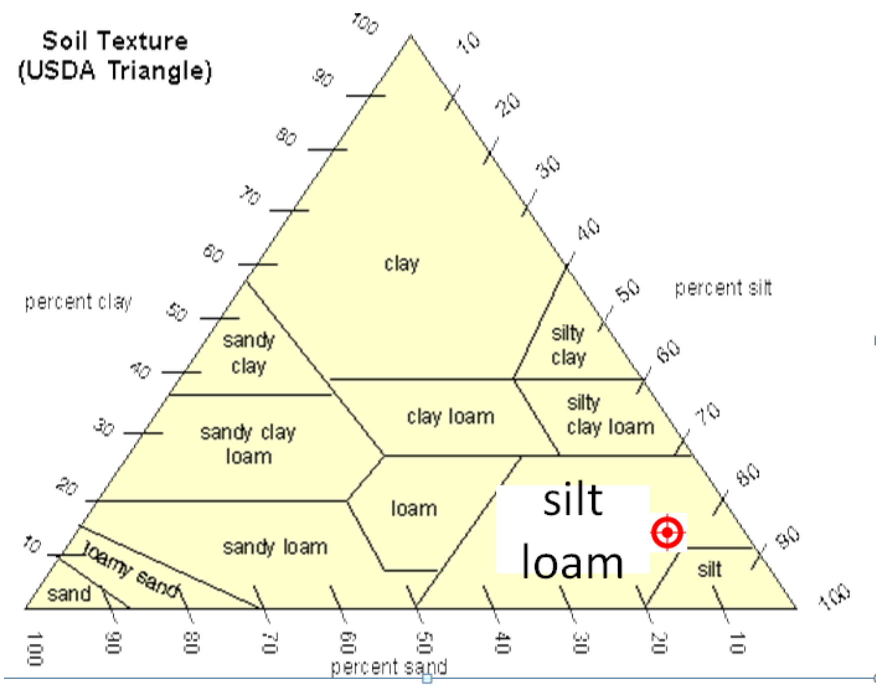


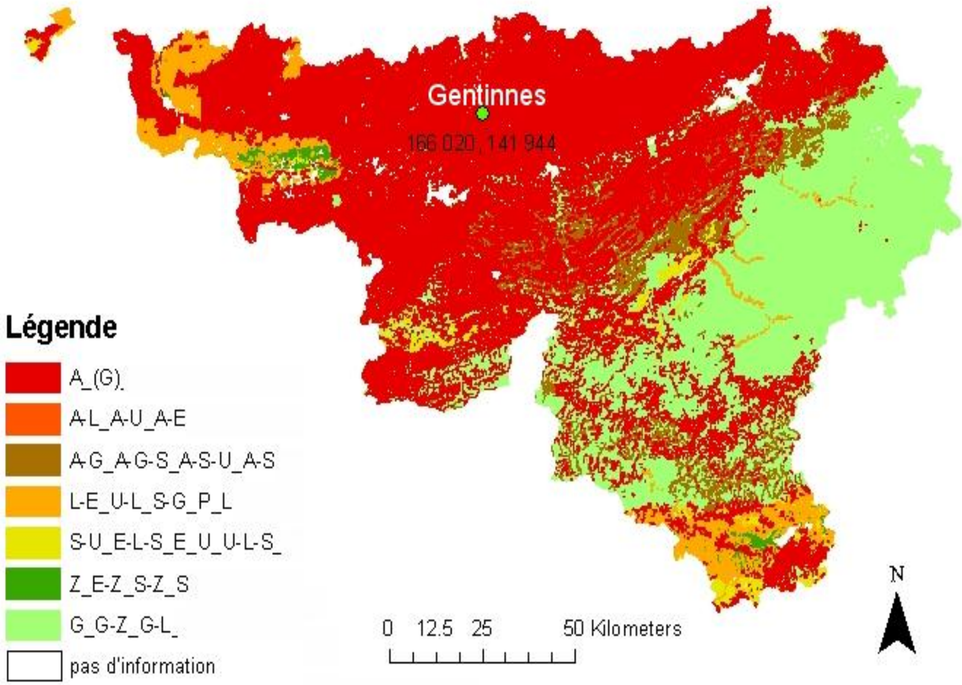
Exemple of an oedometer test

Resistance to penetration

Materials and Methods

The experiment field is located in Gentinnes in a silt loam soil.
This textural class is representative of the silt and of the Condroz region.





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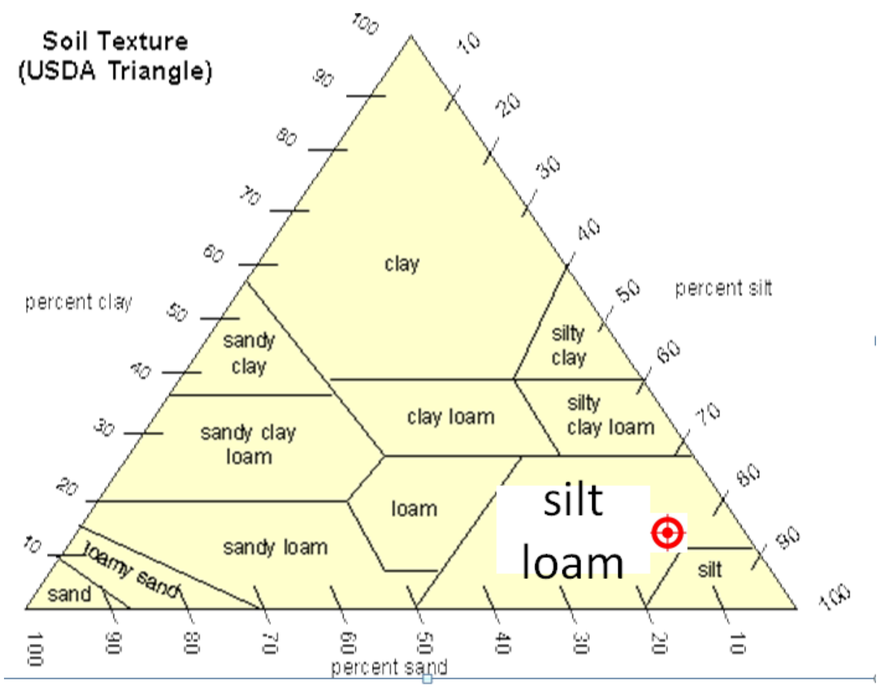
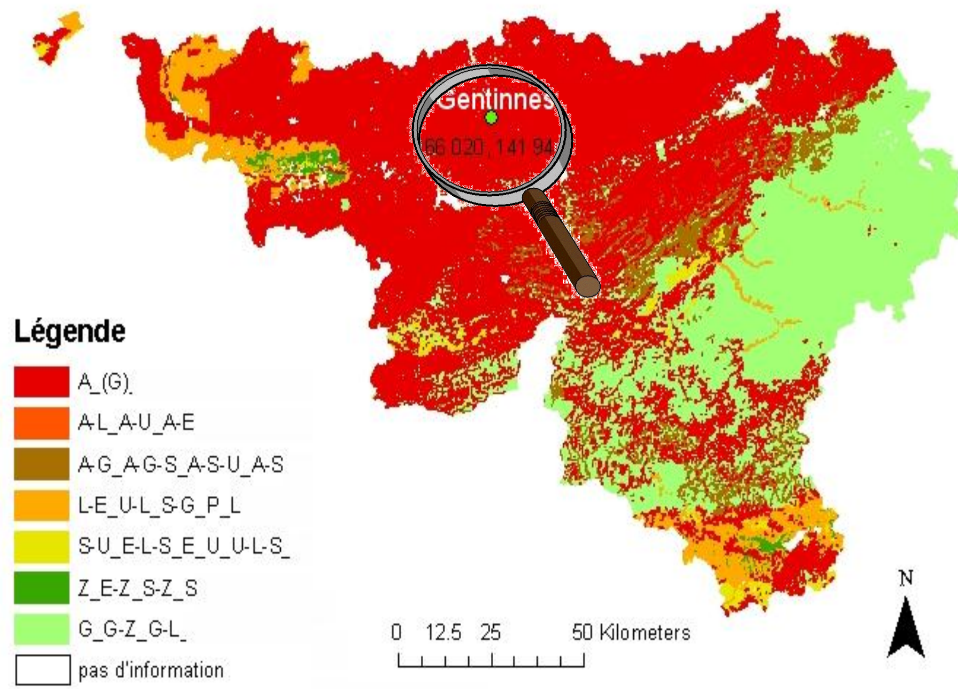
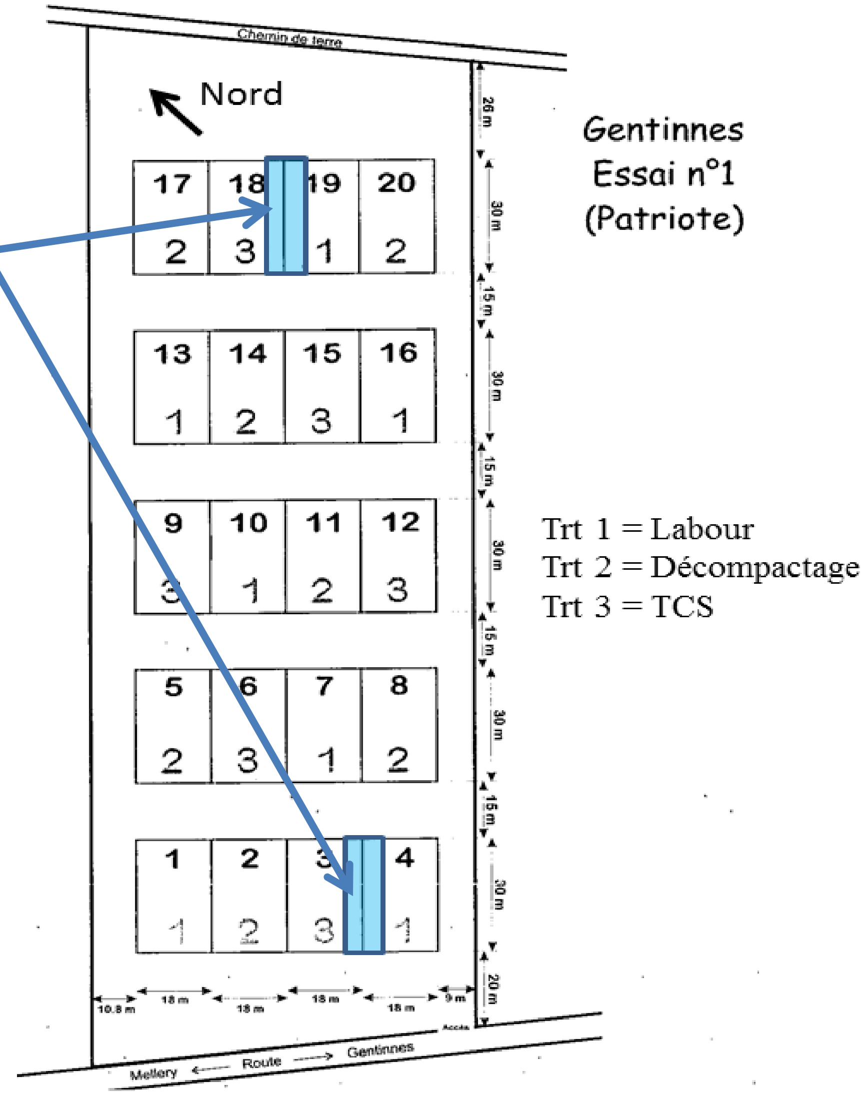




Materials and Methods

The location of the 2 repetitions were selected according to soil textural property in order to test the compaction with two different textures.

Plot of reduced tillage, and plot of conventional tillage with ploughing were selected close together in order to compare the results in the same conditions.



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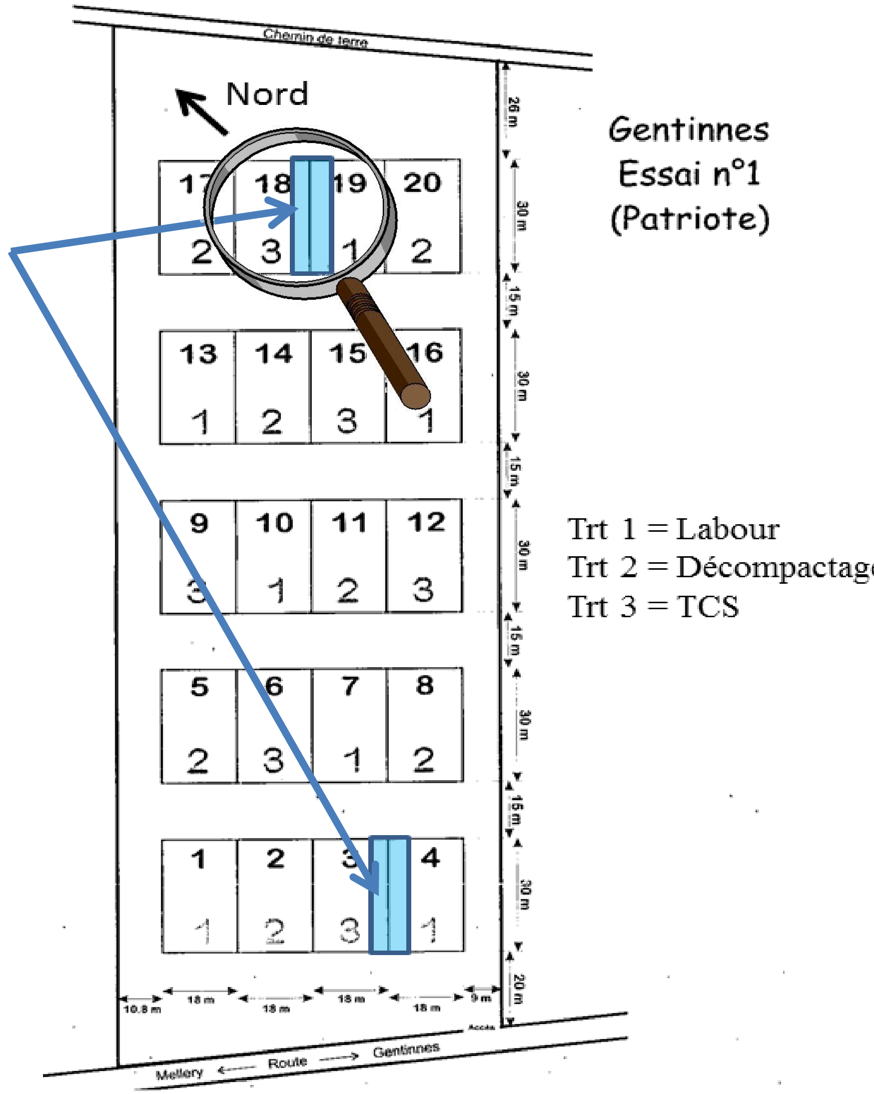
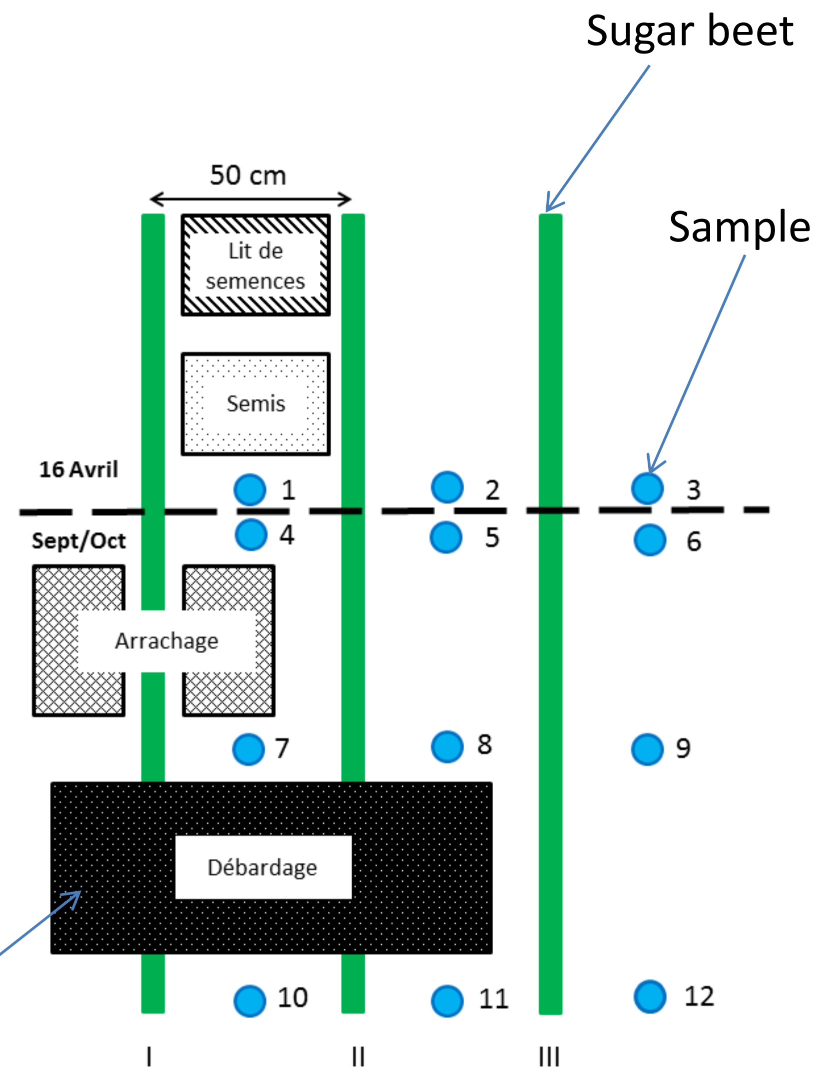


Materials and Methods

Soil sample locations were selected according to the path of the wheels

Samples were taken at 20 and 40 cm depth



Preliminary results

Soil pit showed that plot with reduced tillage has a massive structure compared to plot with conventional tillage

conventional tillage

reduced tillage

Preliminary results

The drop test confirmed that the soil with reduced tillage contains larger aggregates

Conventionnal tillage Reduced tillage

the drop test

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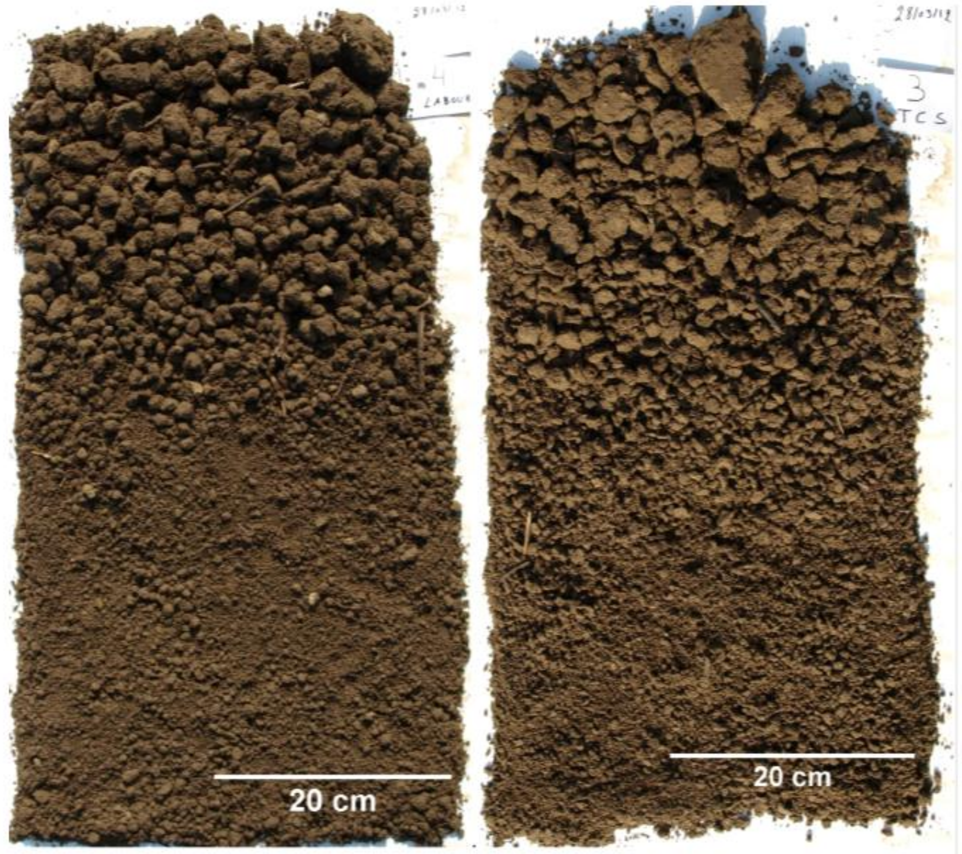


Conventionnal tillage   Reduced tillage

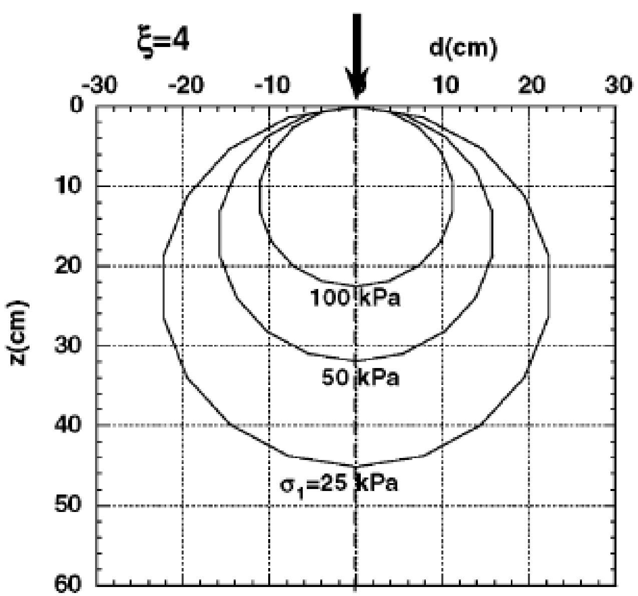
Do these differences influence the behavior of soils in response to traffic ?

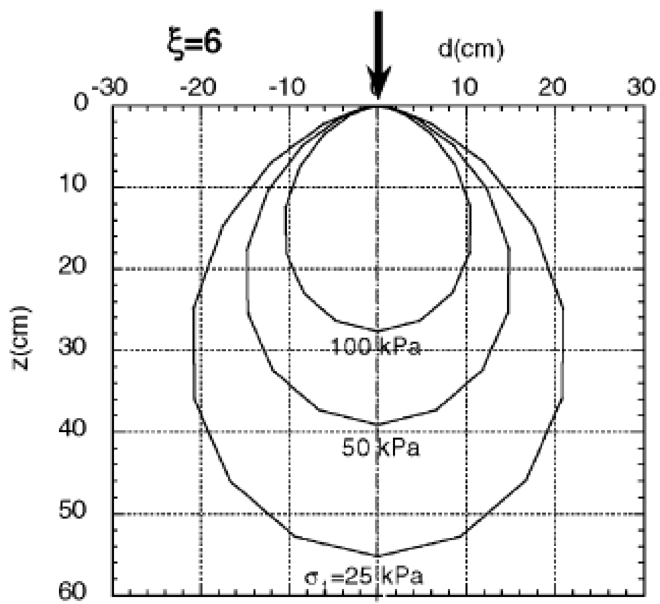
Modelling : The SoilFlex model

1) Stress on the surface of soil
2) Stress propagation through soil
3) Soil deformation

Analytical approach as used in SoiFlex was shown not to be inferior to finite element models with regard to the accuracy.

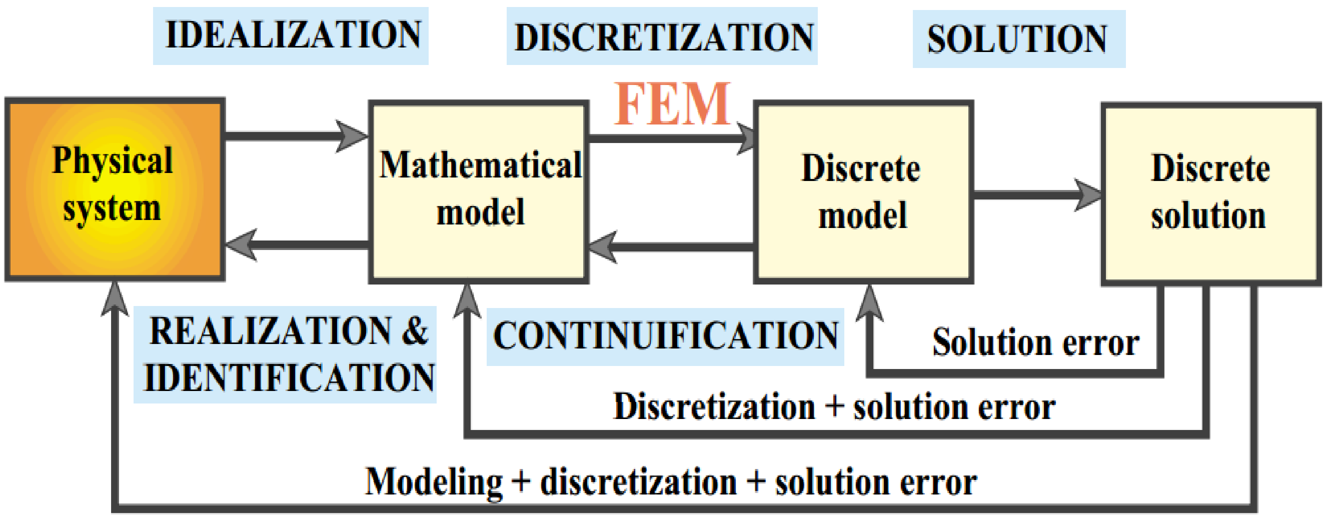
The weak point is the concentration factor ξ as it is not a directly measurable soil parameter.





Modelling : the Finite Element Method

Finite Element Method is a numerical technique for finding approximate solutions of partial differential equations as well as integral equations.



Modelling : the Finite Element Method

FEM were developed for isotropic linear elastic media characterised by E and μ.

Agricultural soil requires specific numerical methods because of the non-linear relationship between strain and displacement.

Mathematical model

$$\varepsilon_x = \frac{1}{E}[\sigma_x - \mu(\sigma_y + \sigma_z)]$$

$$\varepsilon_y = \frac{1}{E}[\sigma_y - \mu(\sigma_x + \sigma_z)]$$

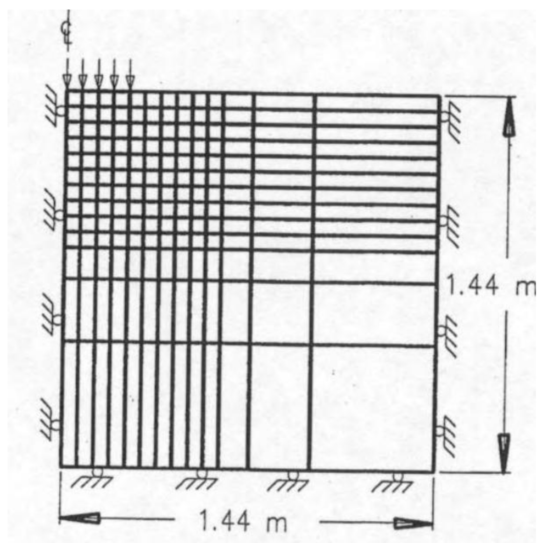
$$\varepsilon_z = \frac{1}{E}[\sigma_z - \mu(\sigma_x + \sigma_y)]$$

Strain

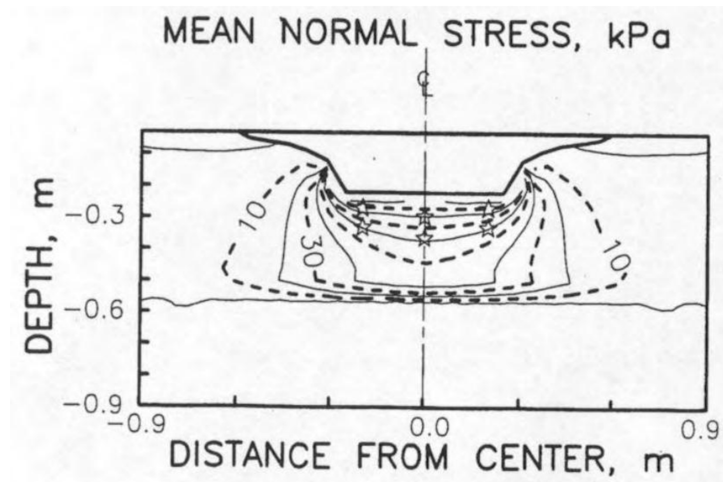
Young's modulus

Poisson's ratio

Discretisation: mesh used to model the soil medium



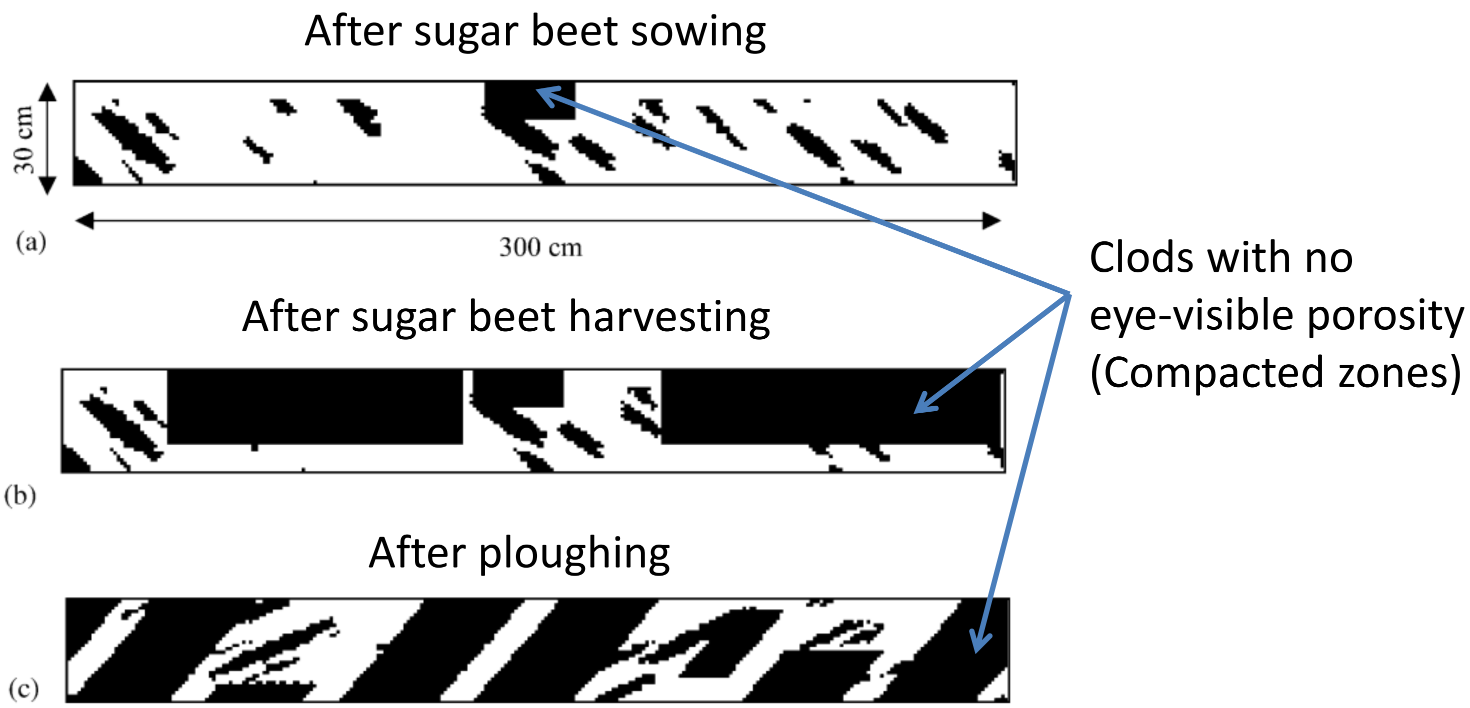
Exemple of simulation



Modelling: the Sisol model

Optimisation of tillage practices requires the evaluation of the long-term effects of cropping on changes in the soil structure.

→ The SISOL model estimate the quantity and location of Δ clods



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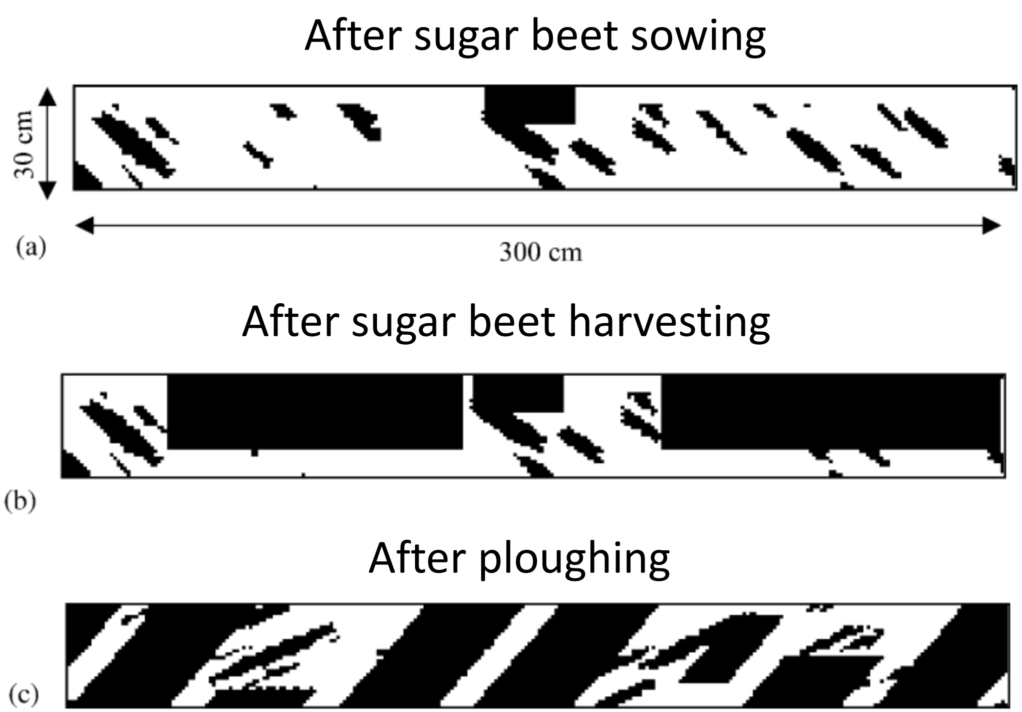

We will modify SISOL and try to estimate the bulk density

Conclusion

The numerous measurements focused on the same plot should allow a proper assessment of the compaction mechanism and risk.

The use of models should allow extrapolation of results and evaluation of different cultural practices.

Thank you for your attention !

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Mercury Intrusion porosimetry

Mercury does not wet substances and will no penetrate pores by capillary action. Entry into pore spaces requires applying pressure in inverse proportion to opening size.

Therefore, at any pressure, the pores into which mercury has intruded have diameters greater than

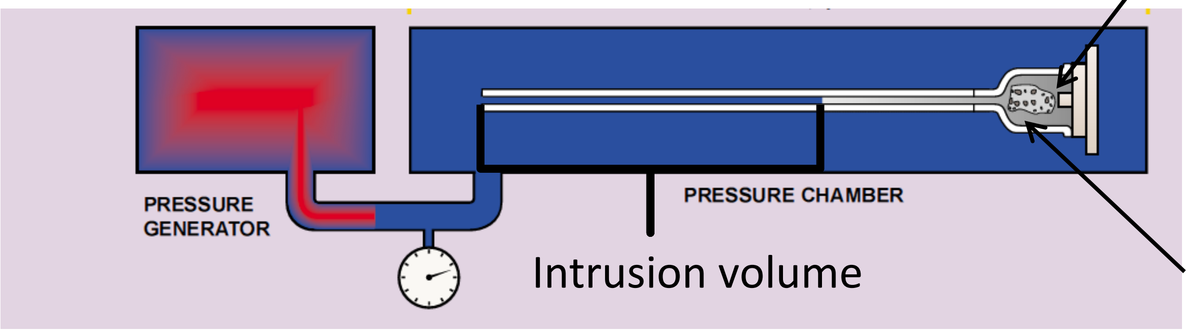
$$\mathbf{D = -4\Upsilon\cos\theta/P}$$

D: pore diameters

ϒ: mercury surface tension

θ: mercury contact angle

P: applied pressure



Mercury Intrusion porosimetry