Tools and methods to develop and validate soil-wheel interaction model and knowledge

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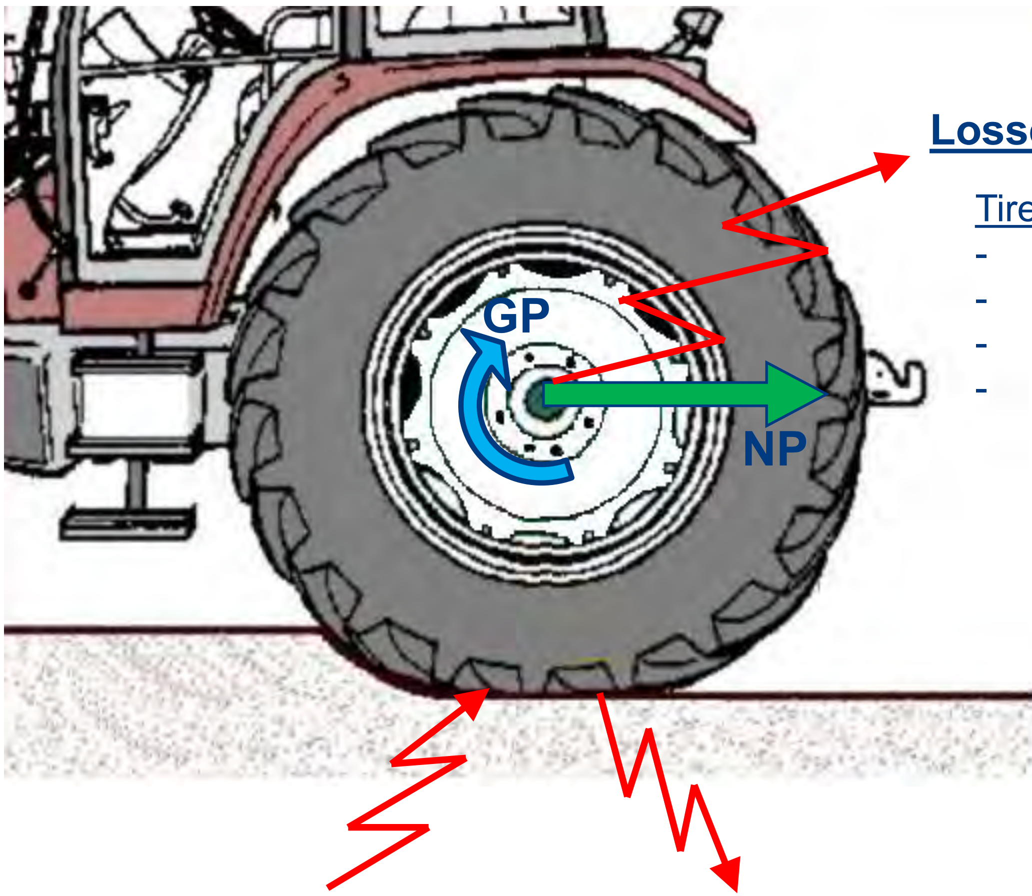
Introduction



Losses = f (tyre, soil):

Tire parameters
- structure,
- Vertical load,
- Inflation pressure,
- Tyre diameter, width.

Soil parameters
- texture,
- Temperature,
- Humidity,
- Cone Index.

Losses

On soft surface
(agricultural soil)
- *Rolling Resistance*
- *Slippage*
- *Tire efficiency*

On hard surface
(asphalt)
- *Rolling Resistance*
- *Tire efficiency*

Impact Soil → Tyre
- Tyre deformation.

Impact Tyre → Soil
- Rutting,
- Soil compaction.

Agenda

I°) Tyre efficiency measurement

II°) Tyre deformation measurement and tyre-sensor

III°) Tyre Soil compaction comparison using different tools and method

Conclusion

I°) Tyre efficiency measurement

The Single-wheel tester

Issues:

- $\frac{Input\ Power}{Output\ Power} = ?$ Efficiency issue
- Applied weight influence
- Tyre type, inflation, etc, influences
- Soil type, humidity, hardness, … influence

I°) Tyre efficiency measurement

The Single-wheel tester

Allows calculation:

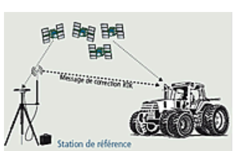
$NP_i = NTi.Vr_i$ - Net Power

$GPi = Ti.\omega_i$ - Gross Power

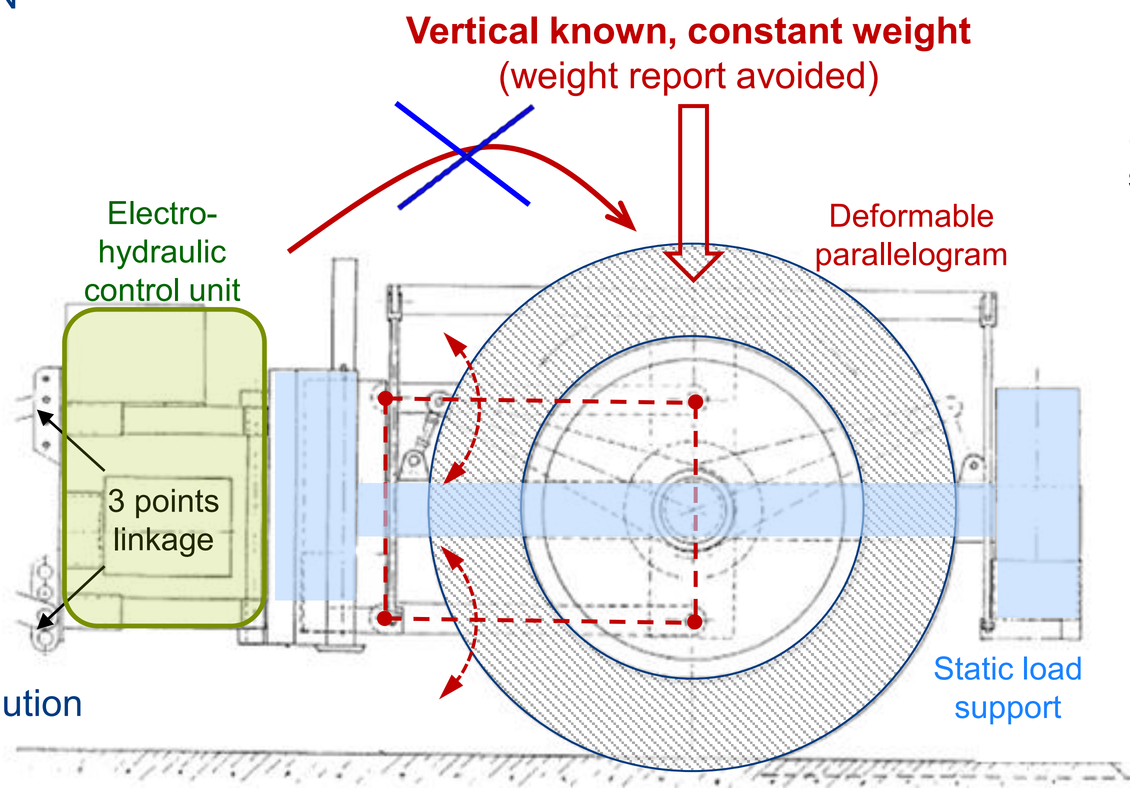
Net traction (NT) :
- Horizontal forces only
- Max. = 15000daN

Torque «(T) :
Max. = 2000daN.

Wheel angular velocity (ω)



Real speed (Vr):
- dGPS
- Centimeter resolution



Every tyre (depending sizes)

I°) Tyre efficiency measurement

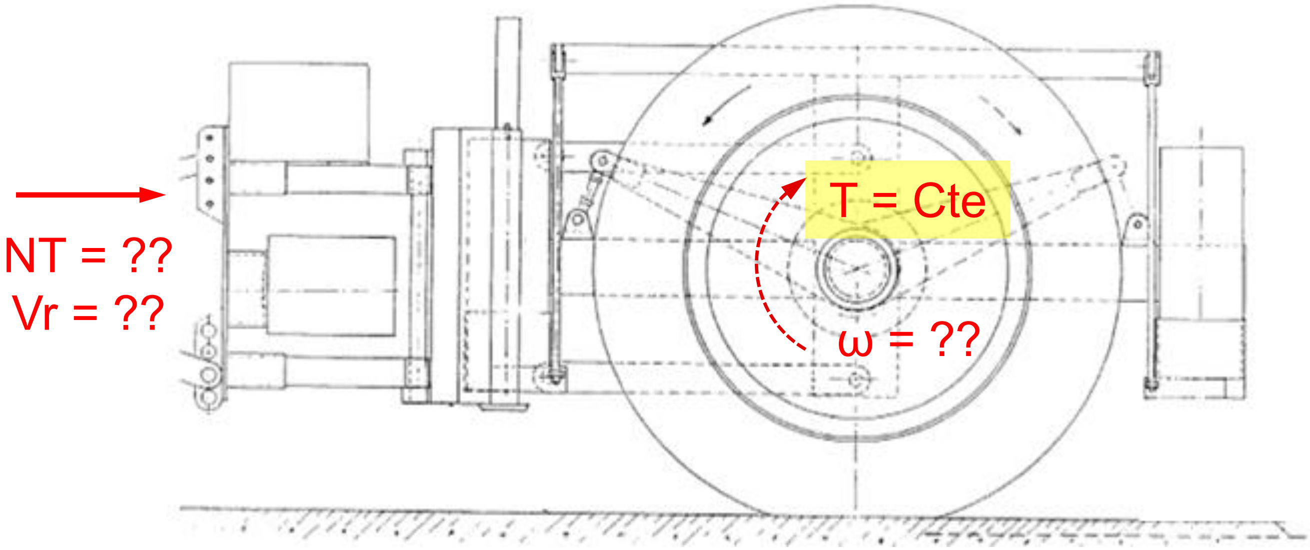
The Single-wheel tester

Electro-hydraulic control unit

<u>2 different control mode:</u>

- apply a Constant Torque / Measure NT, Vr and ω
- apply a Constant NT / Measure T, Vr and ω

(can be defined using $CT = \frac{NT}{W}$: Coef. Traction)

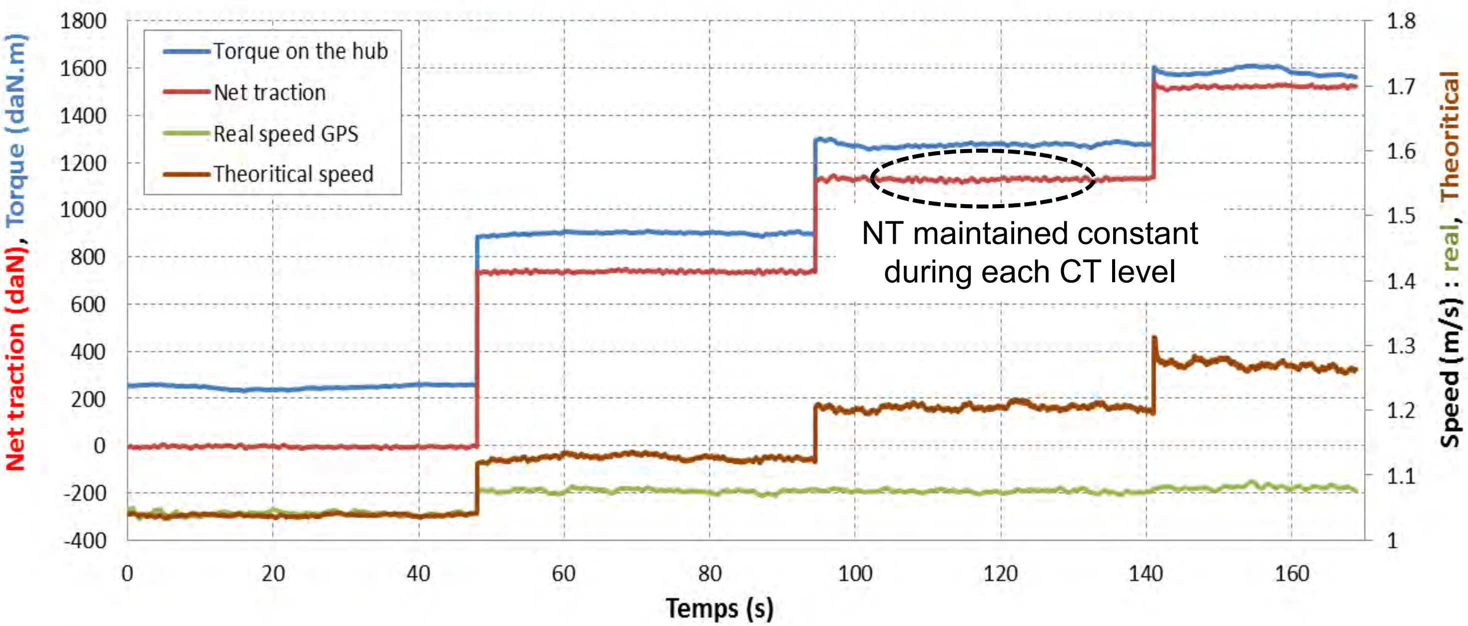


I°) Tyre efficiency measurement

The Single-wheel tester

Result examples for 4 increasing CT
(0 / 0,2 / ,3 / 0,4)

Signals registering on Irstea single-wheel regulated at constant force (4 steps)



CT ↗

- Vr →
- Torque ↗
- Vth ↗

NP and GP ↗

Which efficiency?

I°) Tyre efficiency measurement

The Single-wheel tester / Performance indices

ENTAM actual work:

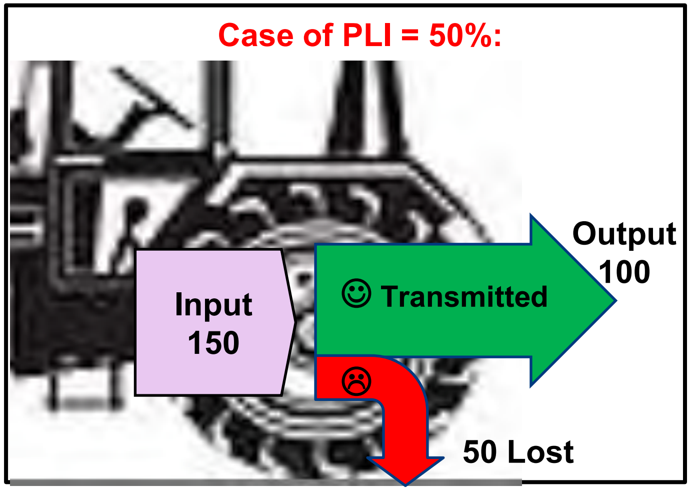
* Pull loss index (PLI):

Traction case

$$Pull\_Loss\_Index\ \ PLI = \frac{GP - NP}{NP}$$

« smaller is better »

The same than "efficiency", but with the relative value = used value "NP"



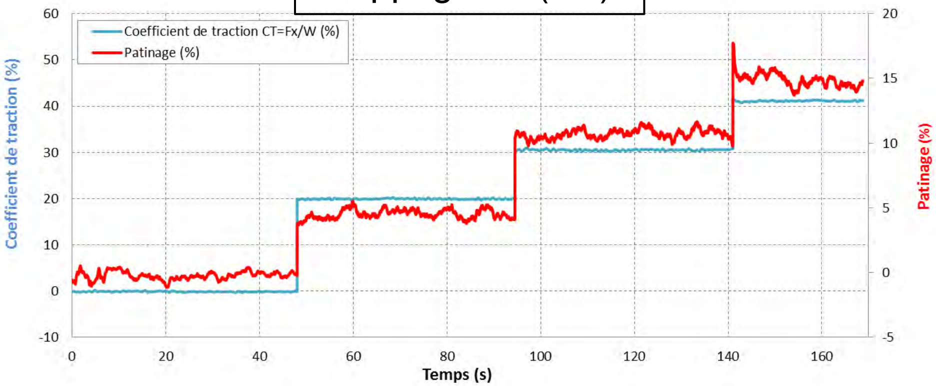
* Carry loss index (CLI):

Self-propelling case: NT = 0.

$$Carry\_Loss\_Index\ \ CLI = \frac{T \times \omega}{W \times V}$$

« smaller is better »

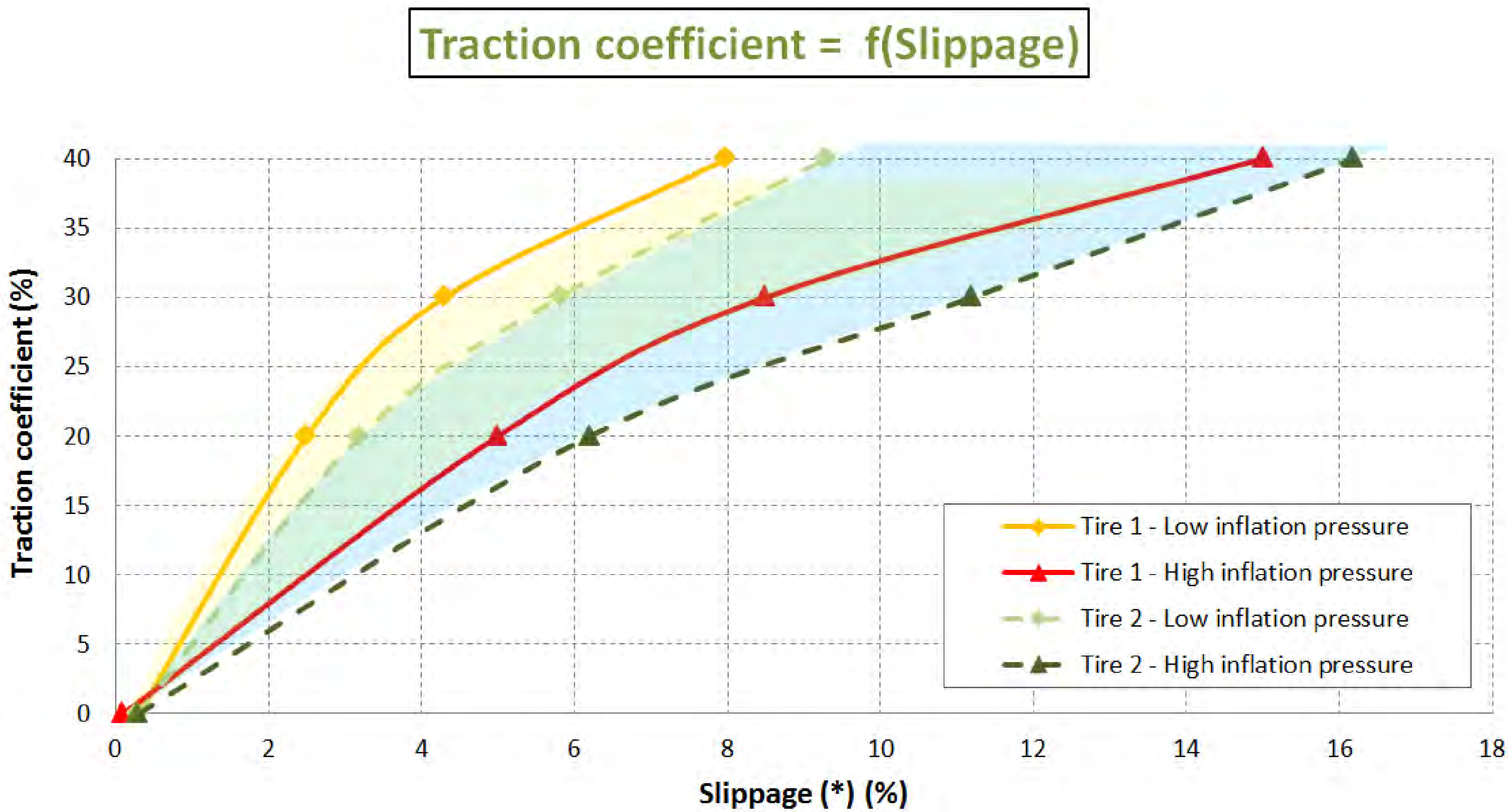
Slippage = f (CT)



Main losses:

- Rolling (soil and tyre deformation)
- Slippage

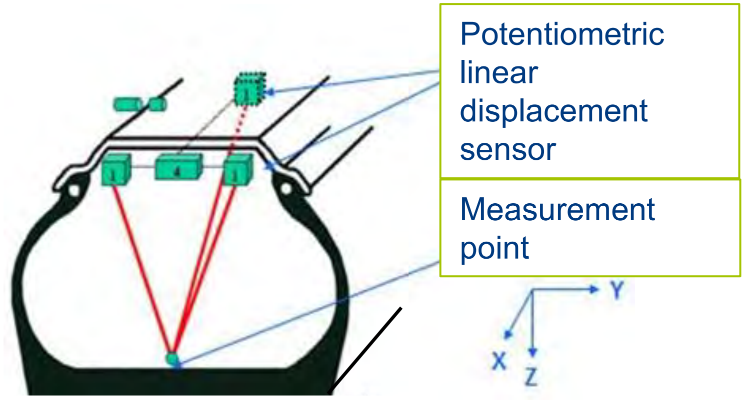
I°) Tyre efficiency measurement



II°) Tyre deformation / « Sensitive tyre »

Measurement devices embedded:

Trilateration method

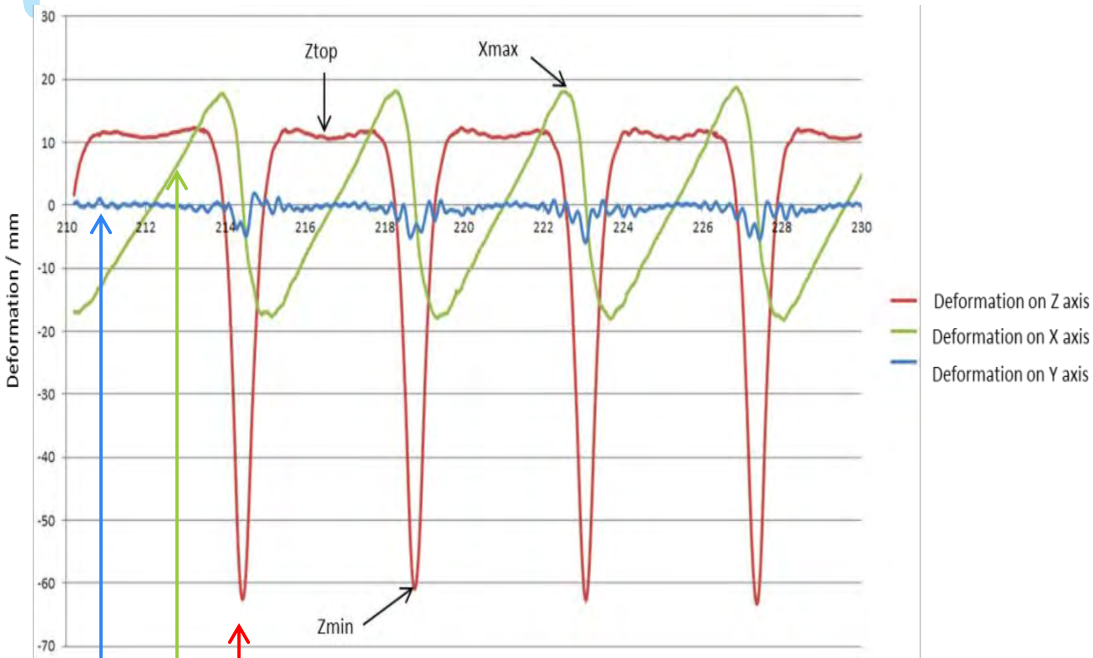


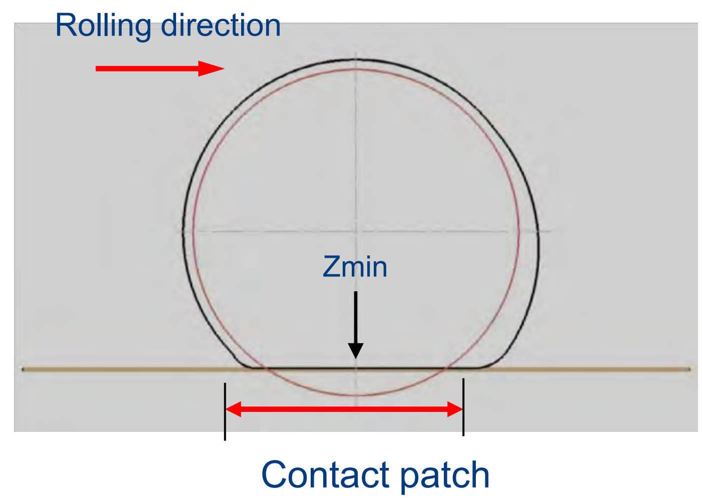
Strengths / Weaknesses:

- Technic with contact (tyre can slid on rim)
- Good accuracy (around 1 mm),
- High acquisition frequency (100Hz and more)
- Gives X, Y et Z deformations.

II°) Tyre deformation / « Sensitive tyre »

Deformation during rolling at constant speed on flat ground



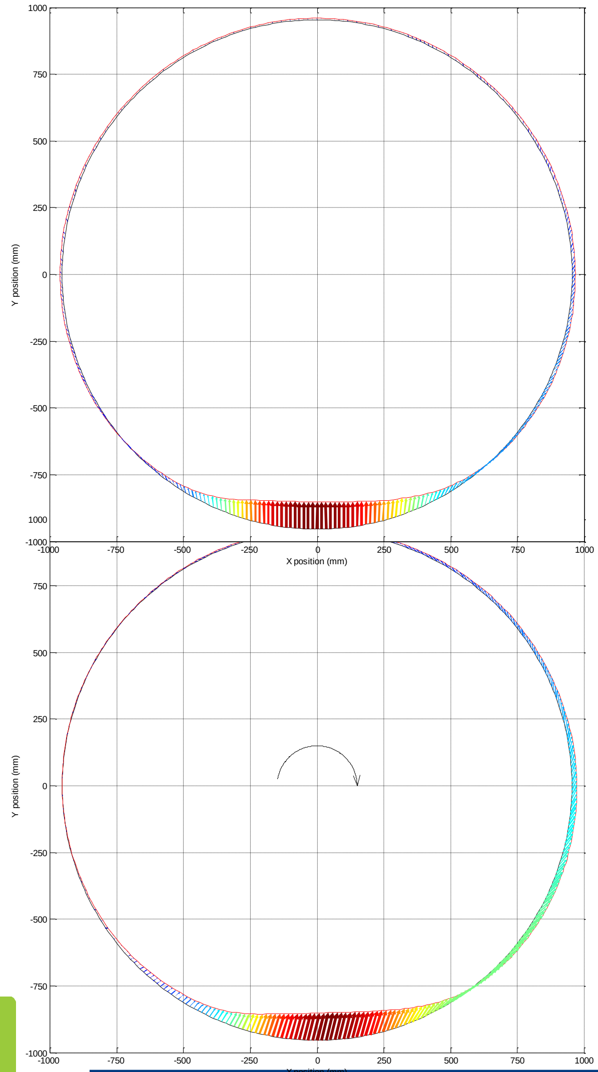


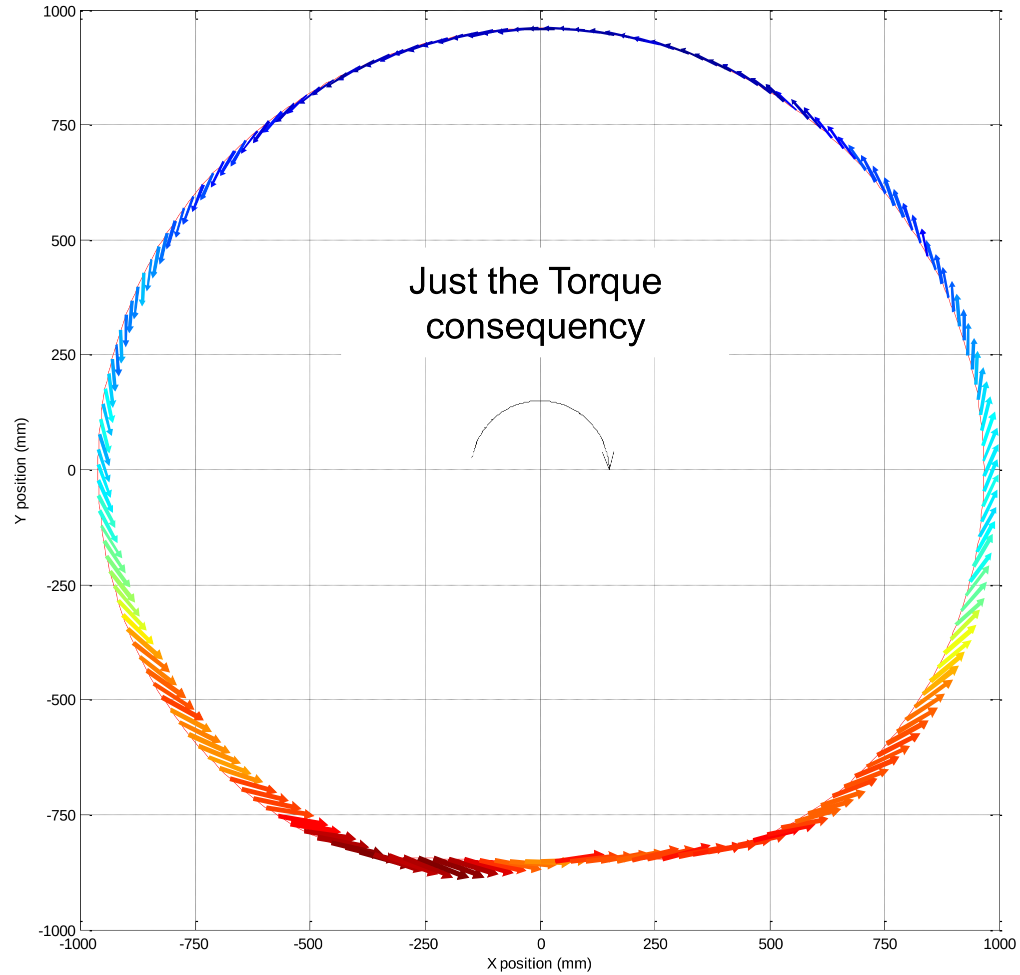
Some observations :

- No forces on lateral axe =▶ No deformation on **Y axis**
- **Z axis** : peak corresponding to the tire max. deflection =▶ increase of tyre radius outside the surface in contact with the ground
- **X axis** : "deradialization" deformation

II°) Tyre deformation / « Sensitive tyre »

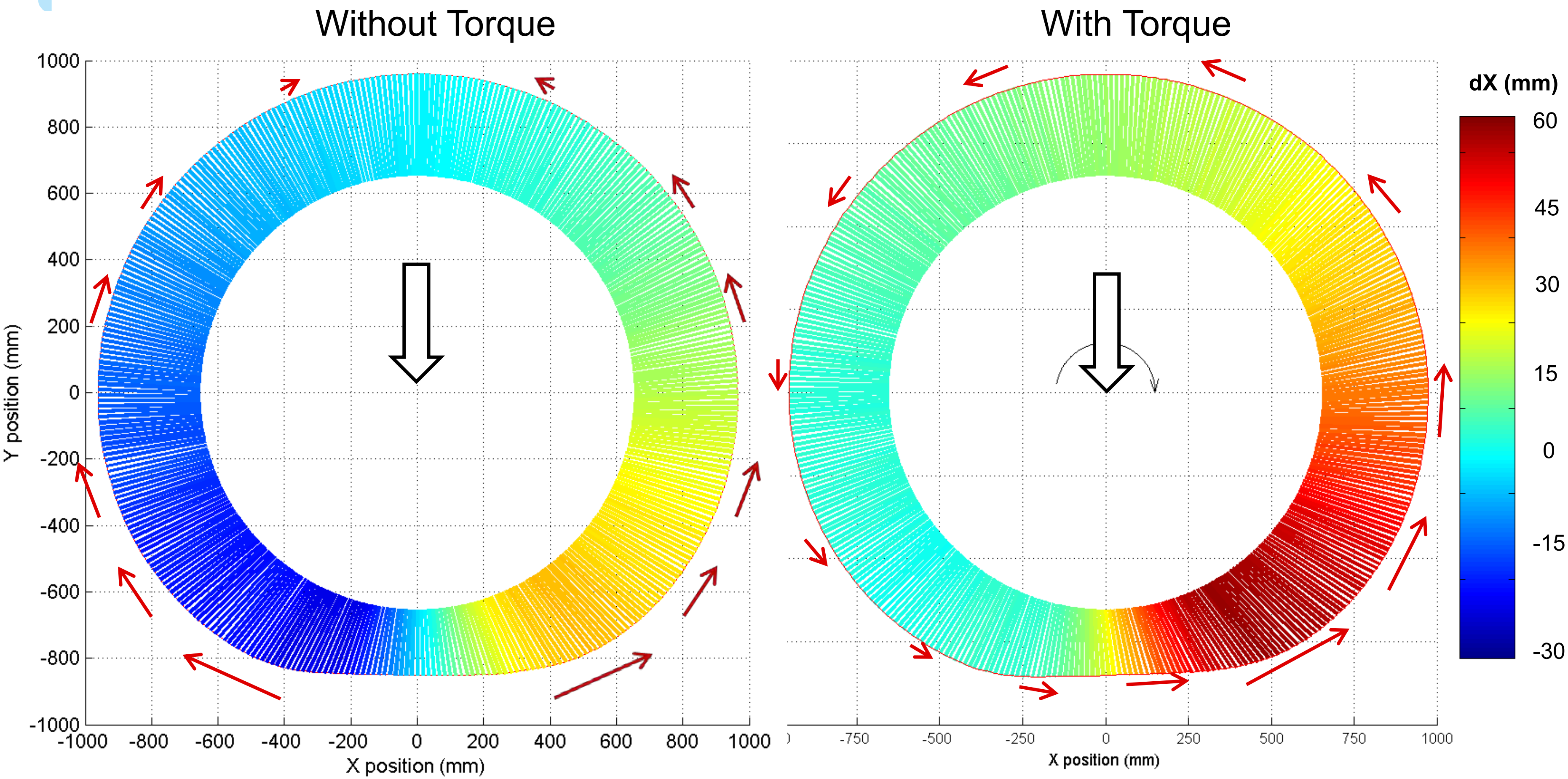
Deformation during rolling at constant speed on flat ground





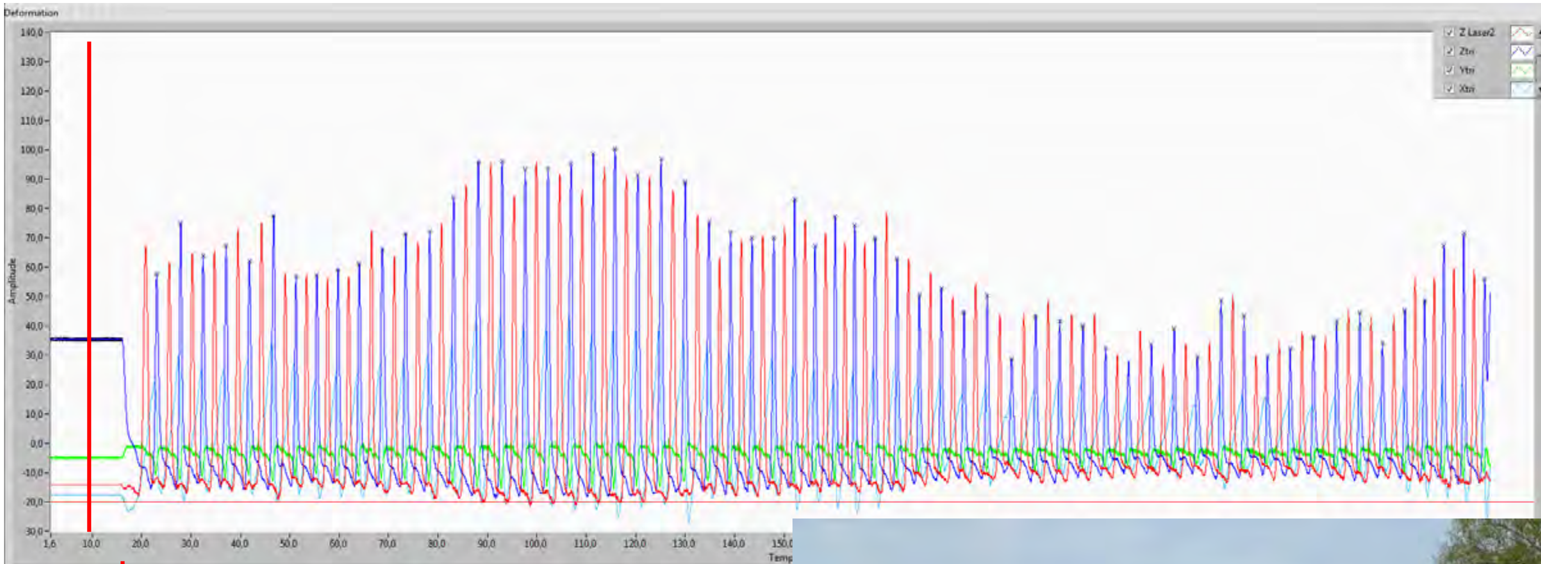
II°) Tyre deformation / « Sensitive tyre »

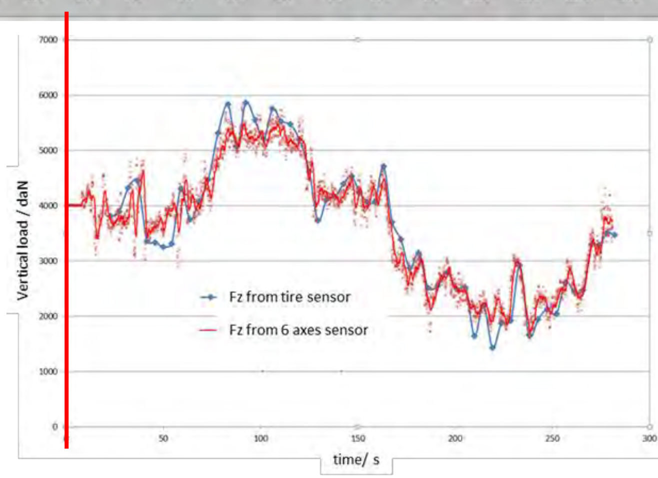
Radial deformation



II°) Tyre deformation / « Sensitive tyre »

Load estimation from radial deformations (ActisurTT project)

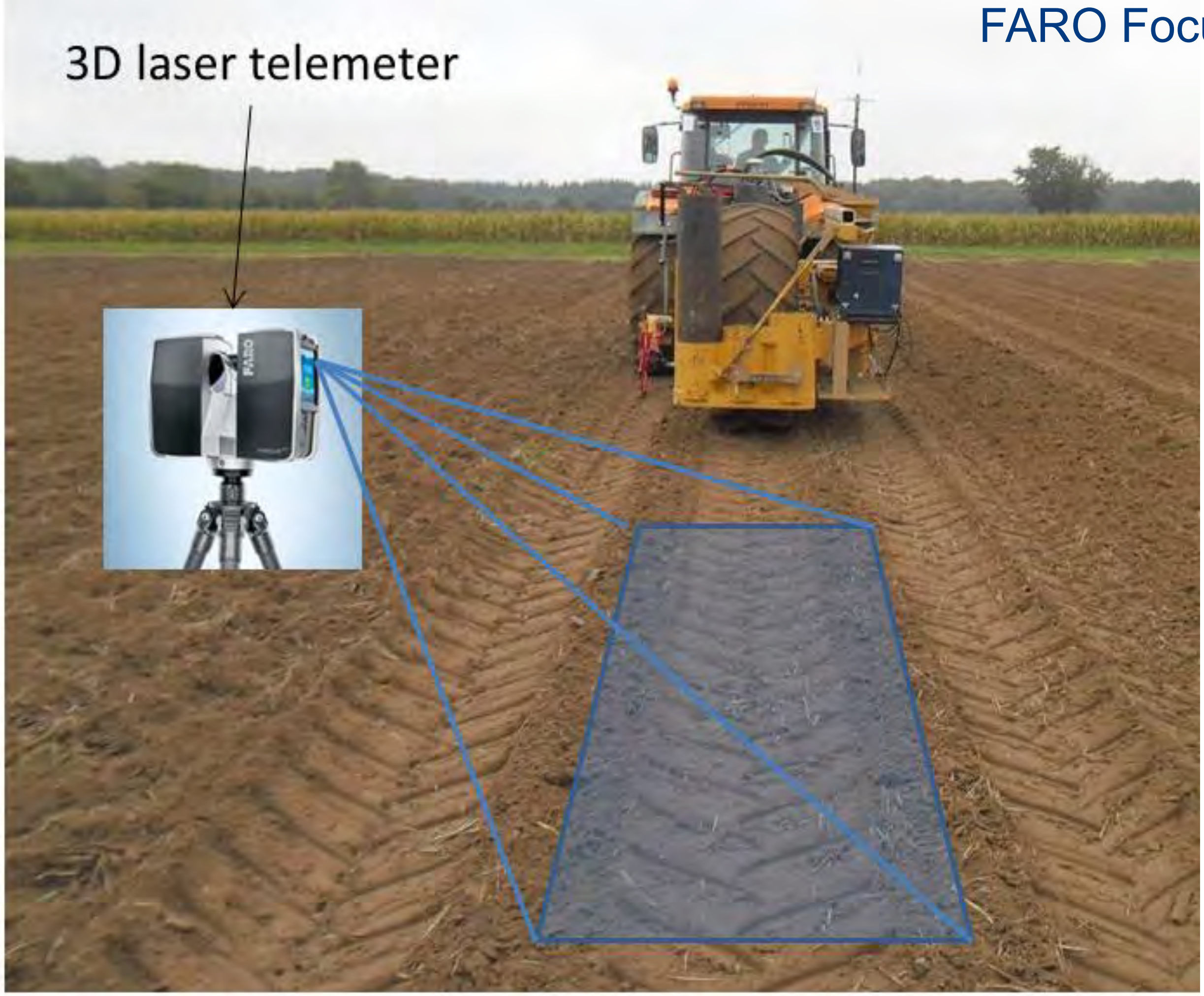




III°) Soil compaction measurement

3D laser Scanner

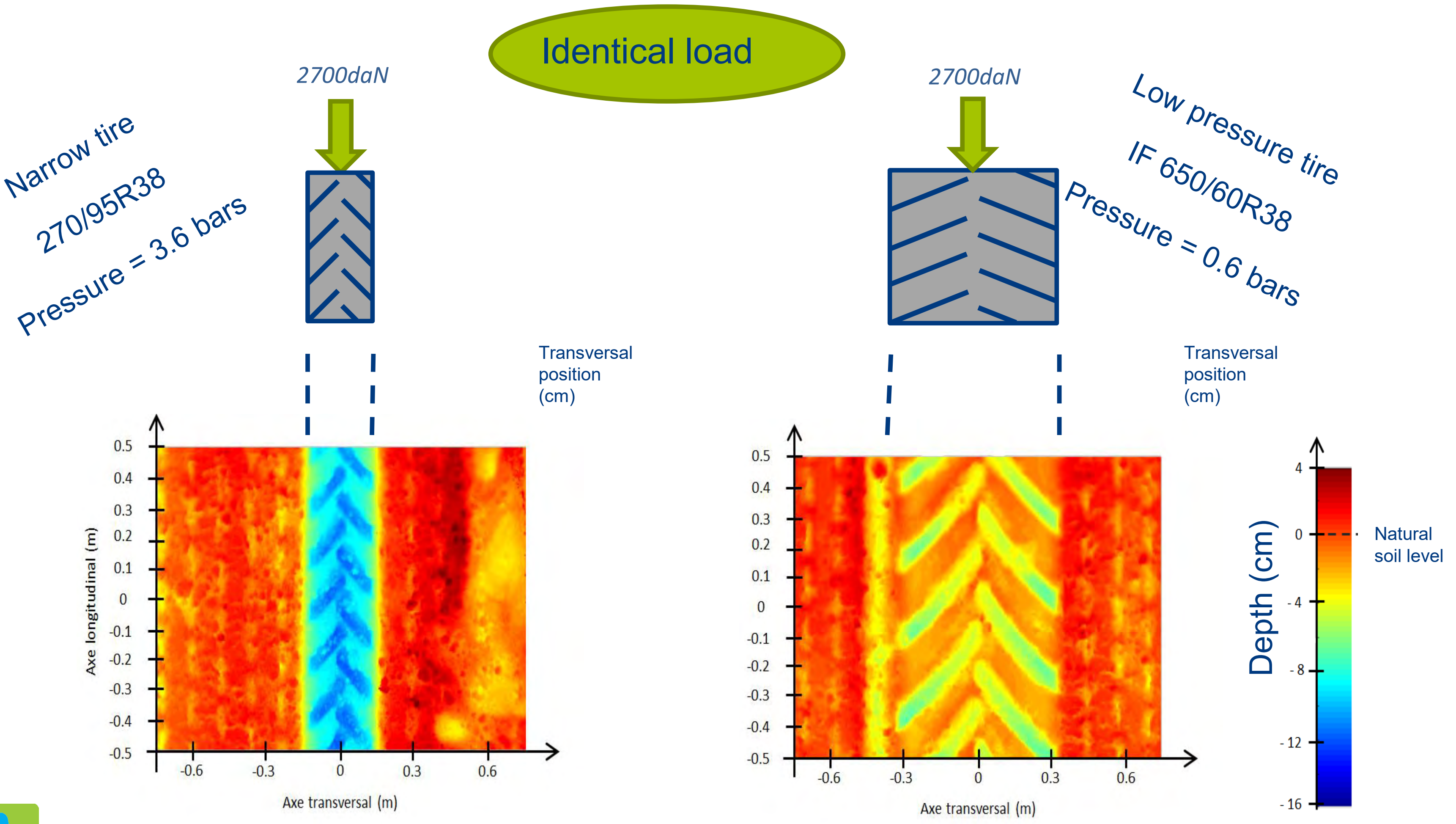
FARO Focus 3D X130



R=130m
Resol. = 1mm

III°) Soil compaction measurement

3D laser Scanner – Results examples

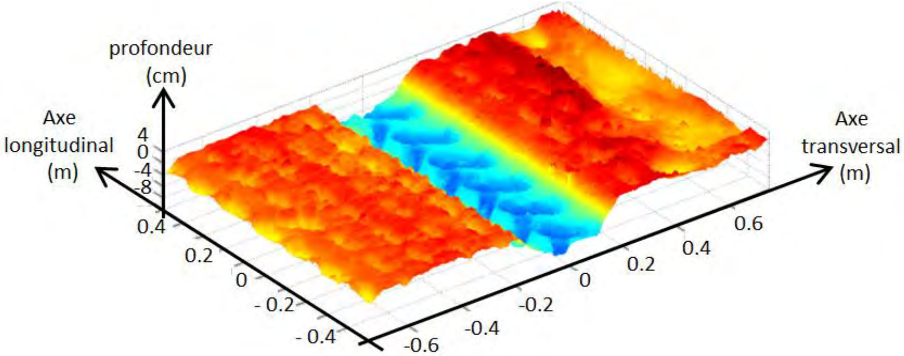


III°) Soil compaction measurement

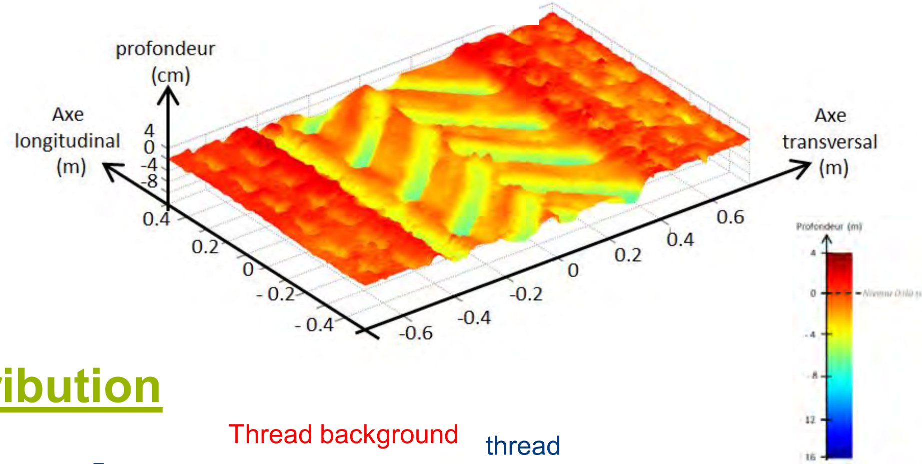
3D laser Scanner – Results examples

3D view

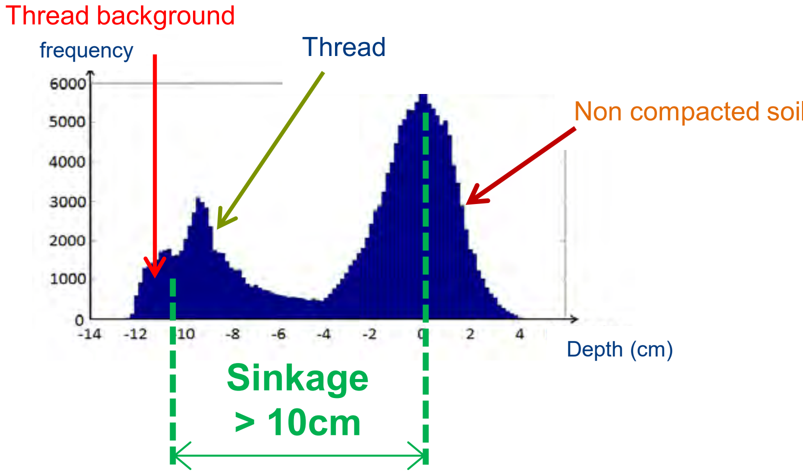
Narrow tire

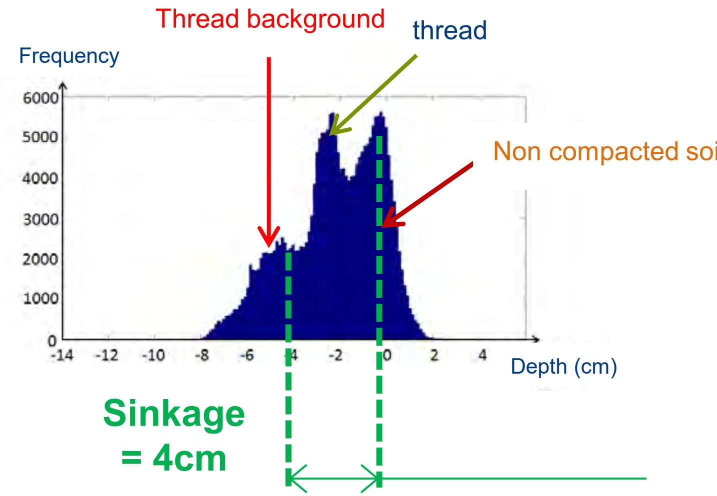


Low pressure tire



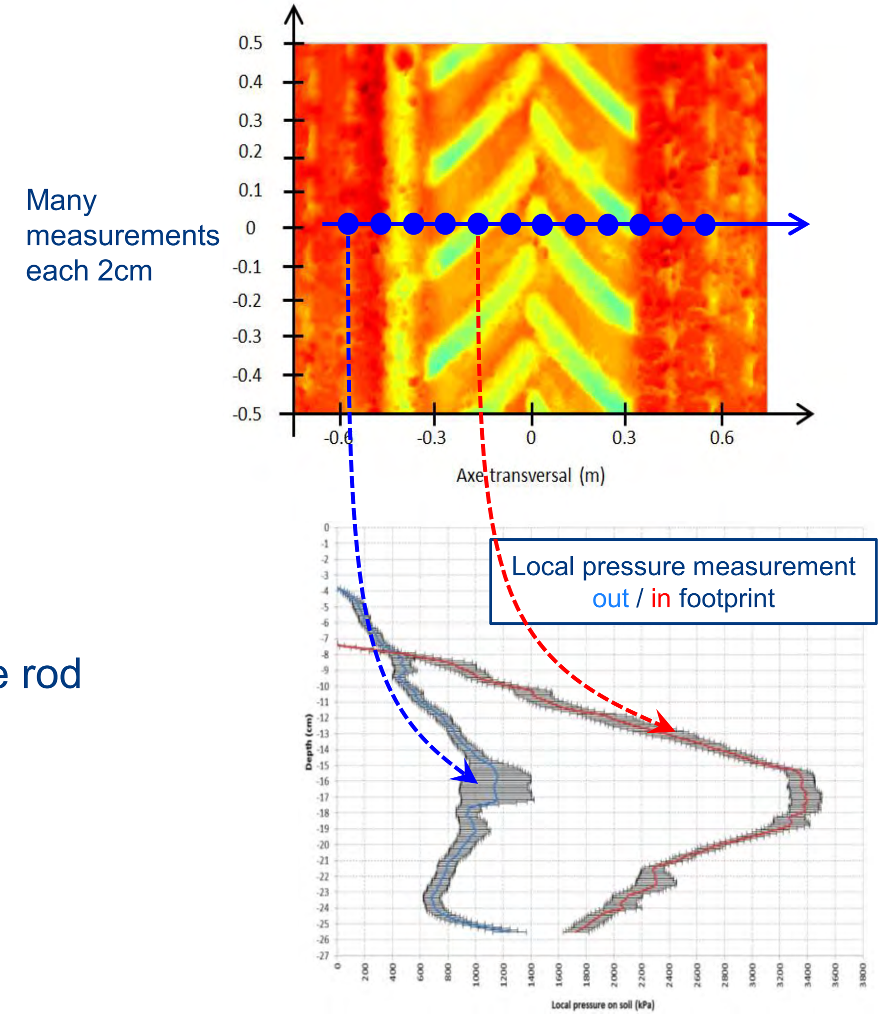
Depths distribution





III°) Soil compaction measurement

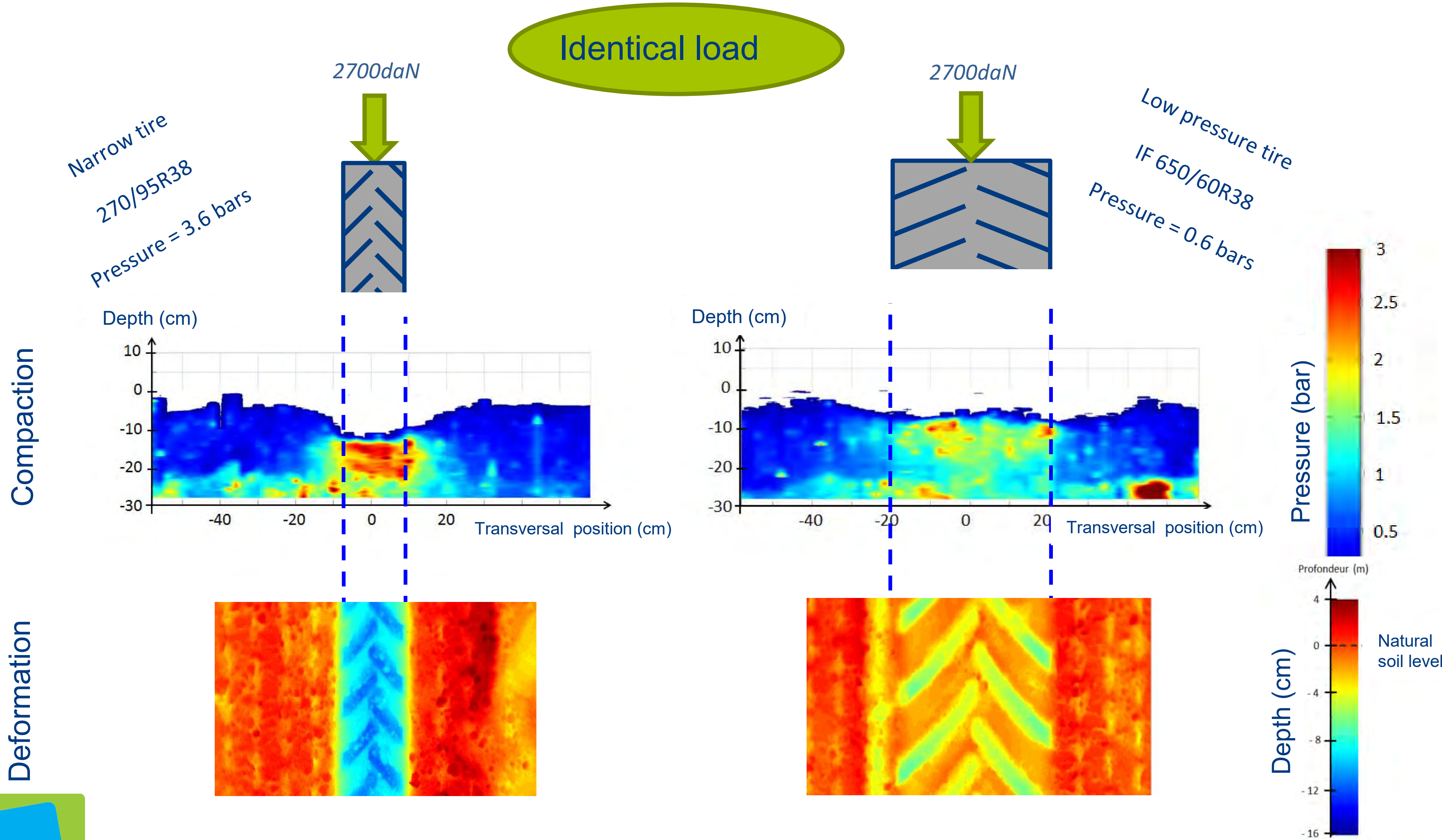
Automatic penetrometer



- local measurements, with high accuracy and high resolution
- recording force during the lowering of the rod
- section that can be achieved is 120 cm×115 cm (width × height)

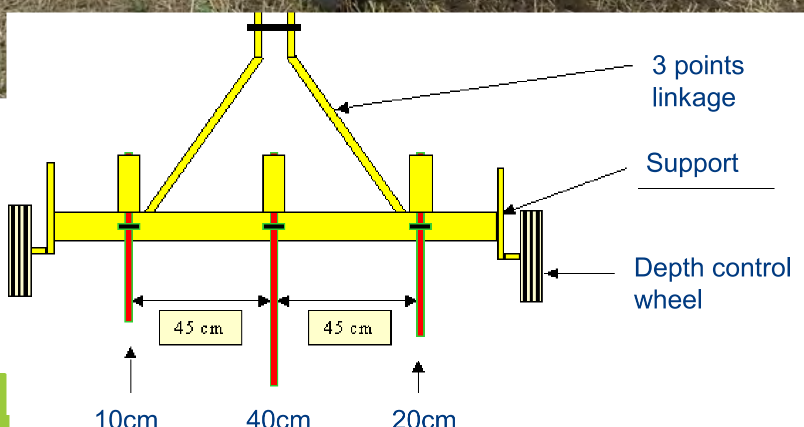
III°) Soil compaction measurement

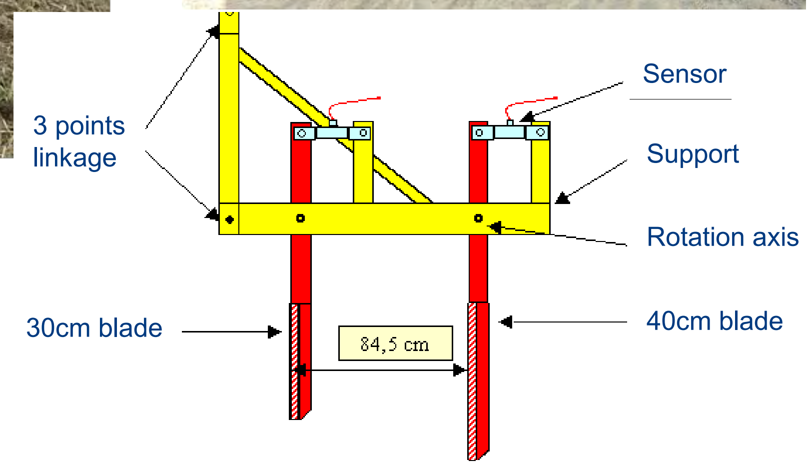
Automatic penetrometer: Example of results



III°) Soil compaction measurement

Scattering device measurement : OCPS





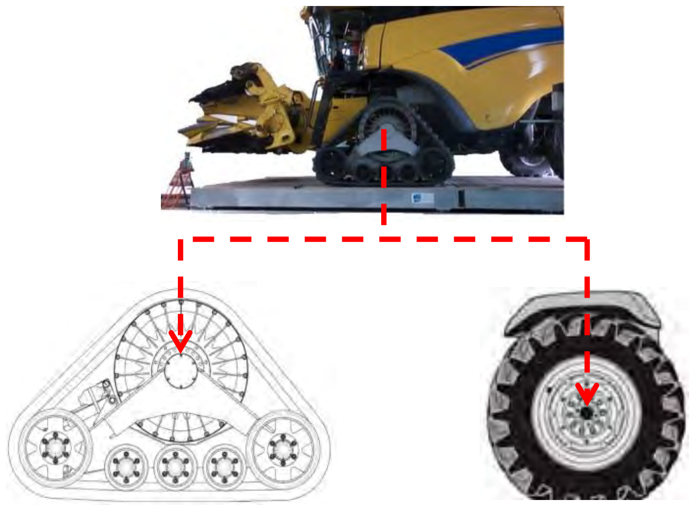
III°) Soil compaction

Example of use for **track vs tyre**:

Both technologies used to reduce impact on agricultural soils

Low pressure tyres

Rubber tracks



Highlighted commercial advantages:
- low pressure operation
- greatly increases the footprint

Highlighted commercial advantages:
- easy to install,
- greatly limits stress on the soil,

Front axle equipment:

Tyre/Track description		Inflating Pressure (bar)		Axle Load (Tons)		Total Load
		Front	Rear	Front	Rear	
Tyres	900/60R38	2.2	2.2	20.680	7.120	27.800
		1.4	1.4	20.680	7.120	27.800
Tracks	-	-	1.4	23.320	7.740	31.060

3 tested modalities:
- Tyres: inflation pressure influence,
- Tracks vs tire compaction with same loading.

III°) Soil compaction

Example of use for **track vs tyre**:

1st step: Use of different harvester equipment on an agricultural field

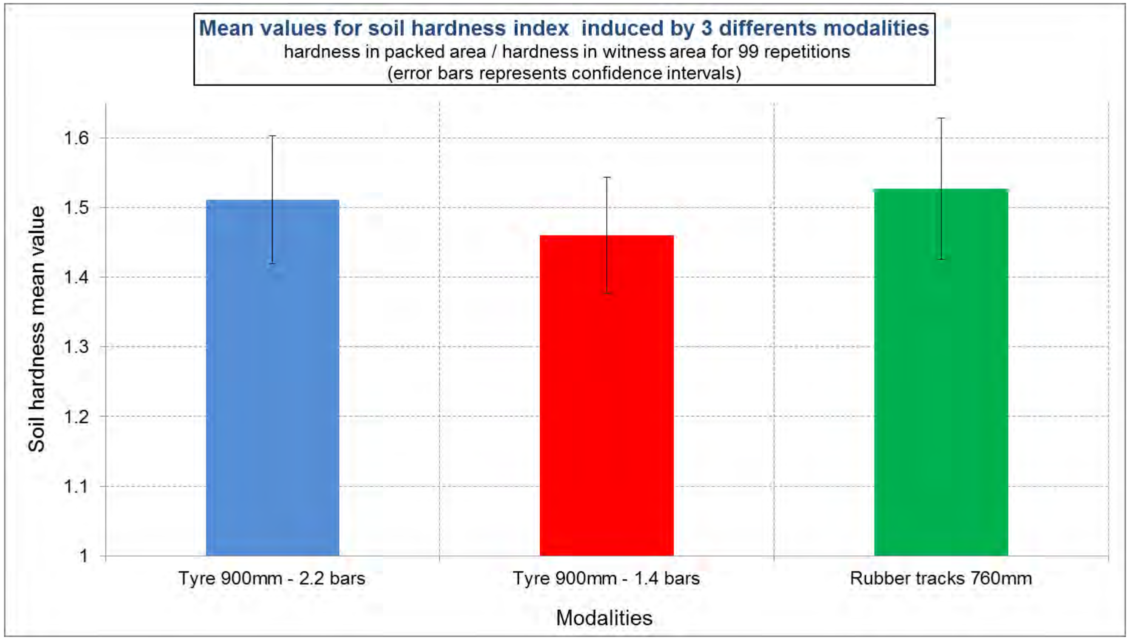
Harvester trajectories all record using centrimetric GPS

2nd step: Measure the hardness to « cut the soil »

Using OCPS device

3rd step: Data treatment

4th step: Results

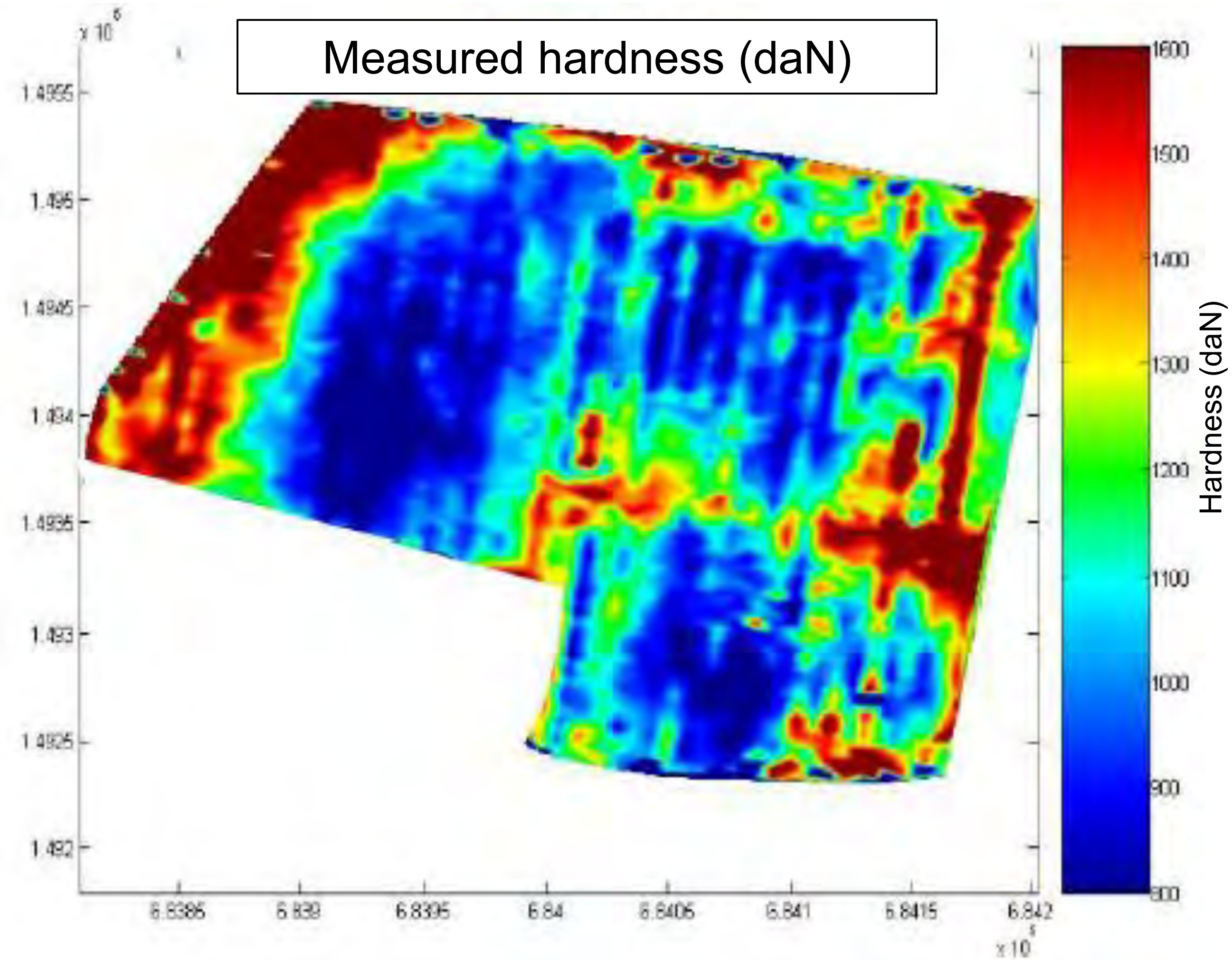


Hardness Mean Value for all repetitions

$$= \frac{\sum_{i=1}^{i=nb\_répet} \frac{DZTass(i)}{DZTemoin(i)}}{nb\_répet}$$

III°) Soil compaction measurement

Scattering device measurement: OCPS – Field hardness map



Conclusion

- Set of complementary tools around Tyre / Soil
- Usefull to:
  - Compare technologies (tyres)
  - Know more about phenomena
  - Validate models
- Available at Irstea AgroTechnoPôle Montoldre for research collaborations