Prévention des risques de tassement des sols

Mathieu Lamandé[1,2]

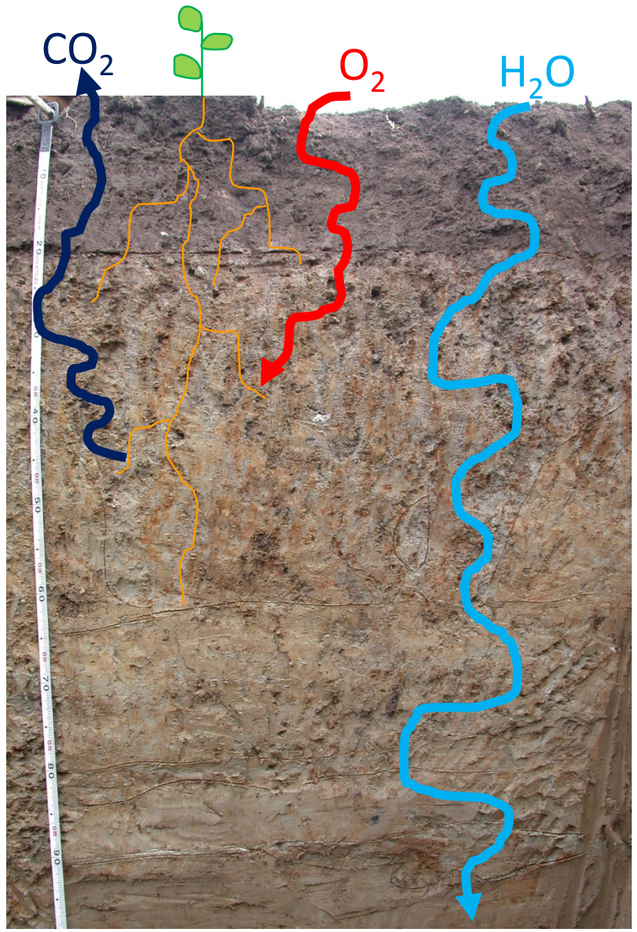
[1] Aarhus University, Dept of Agroecology

[2] Norwegian University of Life Sciences, Faculty of Environmental Sciences and Natural Ressource Management

AARHUS UNIVERSITY
DEPARTMENT OF AGROECOLOGY

Norwegian University of Life Sciences

Tassement en profondeur: une menace pour les services écosystémiques des sols



Habitat des organismes

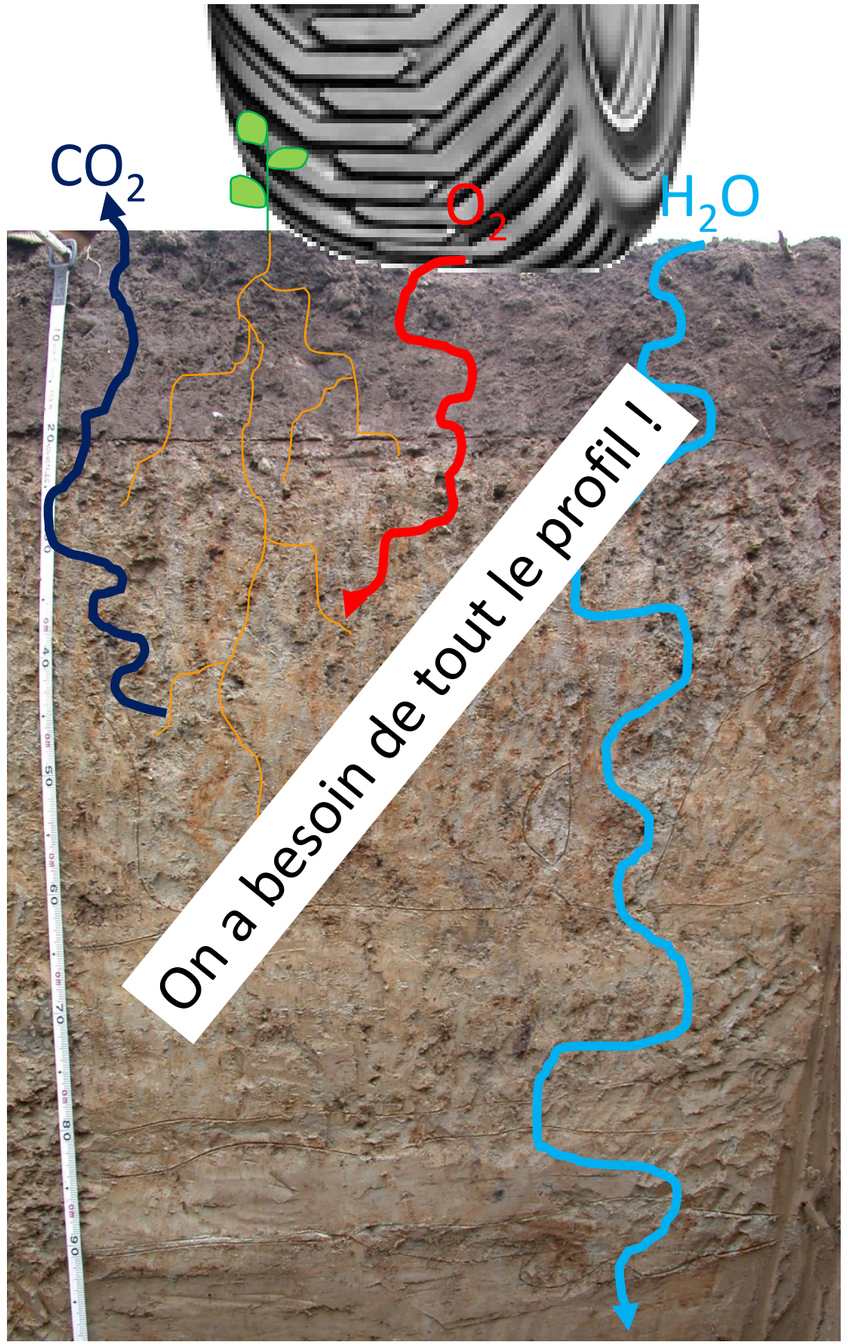
Croissance racinaire

Aération

Drainage

Purification de l’eau

Dégradation des contaminants

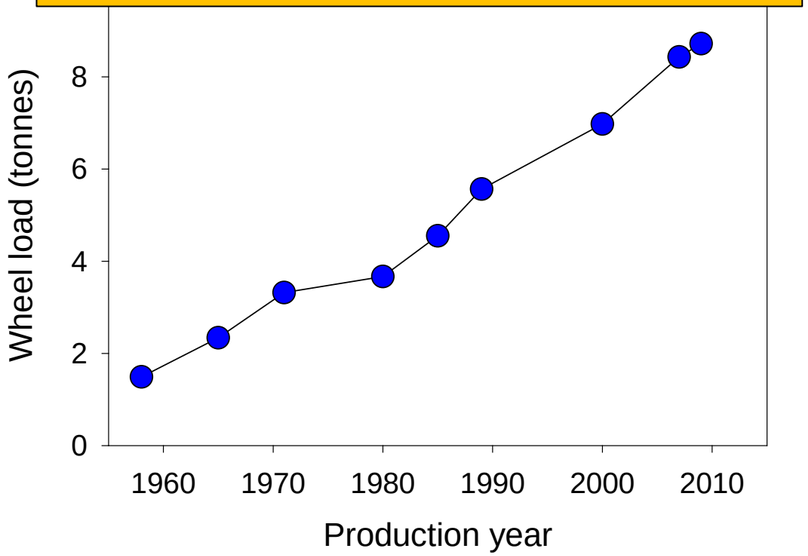


>50 cm, Horizon profond : principalement la **charge**

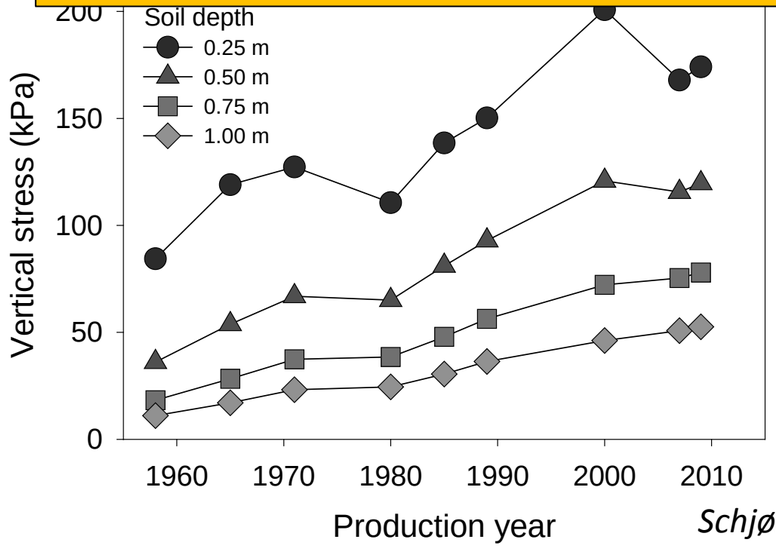
Dommage persistent

Le poids des machines augmente !

Augmentation de 600% de la charge par roue en 50 ans



Augmentation de 500% de la contrainte max. à 1 m



Schjønning et al., 2015, Adv. Agron.

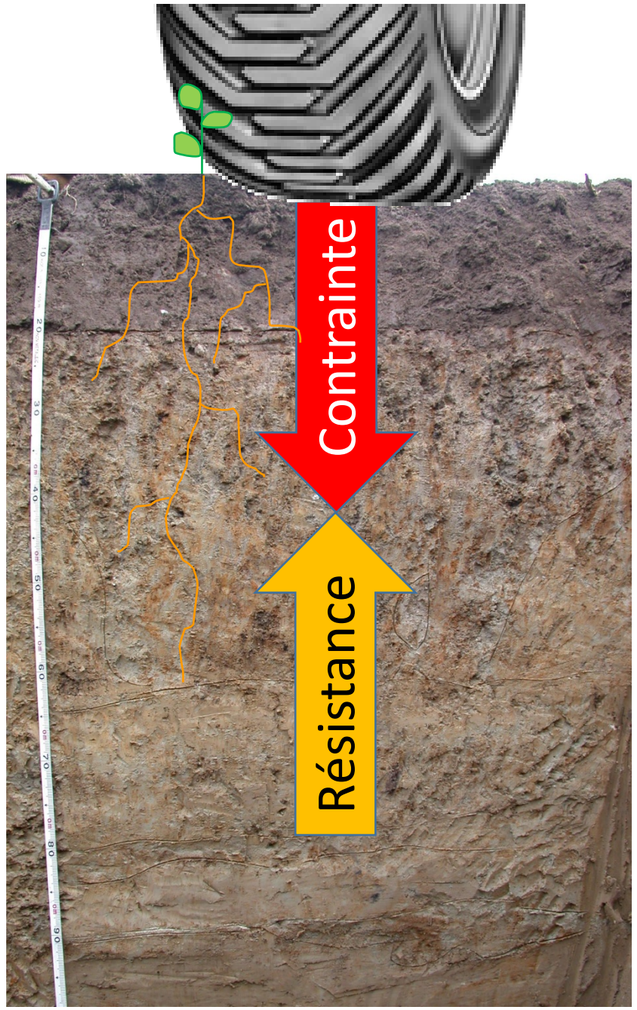
Tassement des horizons profonds

- Une menace pour les services écosystémiques des sols
- Les contraintes transmises augmentent avec le poids des engins
- L'amélioration des horizons profonds est très lente voire inexistante

→ Nous avons besoin de prévention!

→ Quelle méthode d'estimation du risque ?

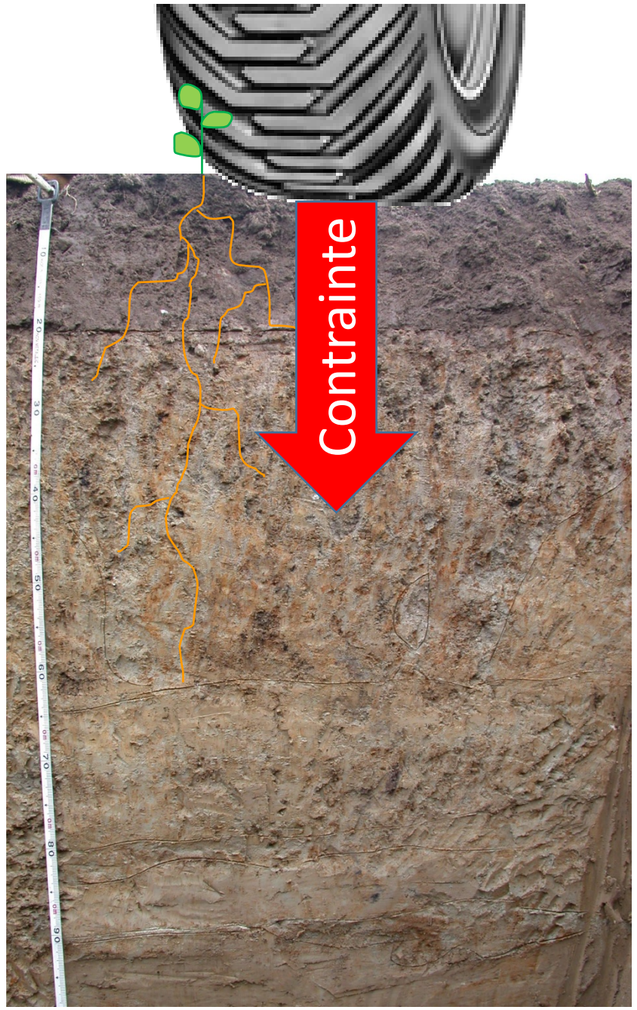
Méthode d’estimation du risque



- La détermination des contraintes ne suffit pas
- La détermination de la résistance du sol ne suffit pas

➢ Il faut une comparaison contrainte-résistance pour des conditions machine et sol données

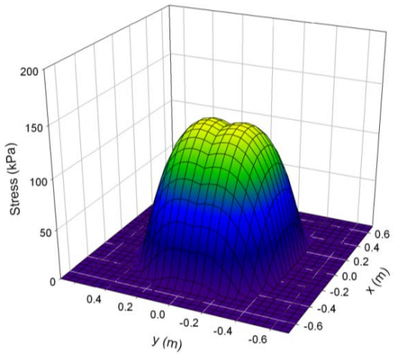
Estimation des contraintes dans le sol



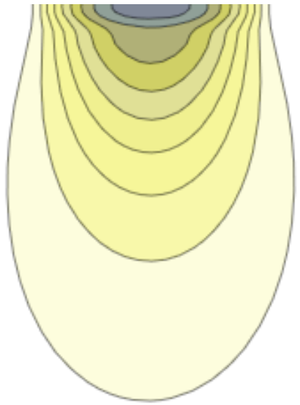
Dimensions du pneu
Charge
Pression de gonflage

Taux d'argile
Densité apparente
Potentiel matriciel

Modèle FRIDA
Schjønning et al., 2015, STILL



Distribution des contraintes au contact pneu-sol

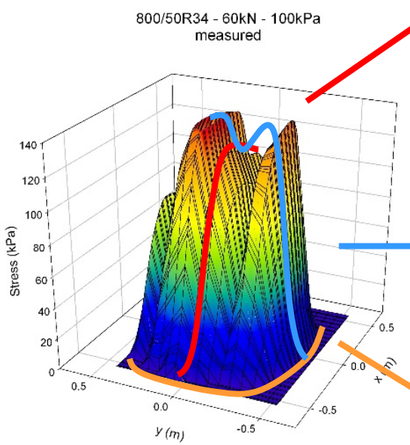


Solution de Boussinesq
Boussinesq, 1885

Distribution des contraintes dans le sol

Le modèle FRIDA

Mesures

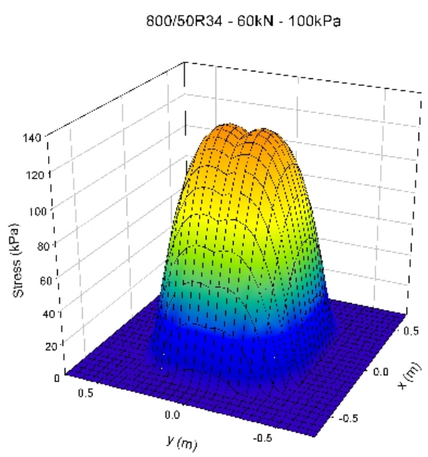


Une loi de puissance
(paramètre α)
Distribution des contraintes
dans la direction de roulage

Une function exponentielle
(parameter β)
Distribution des contraintes
en travers du pneu

Une super ellipse
(paramètres *a*, *b*, et *n*)
Aire de contact pneu-sol

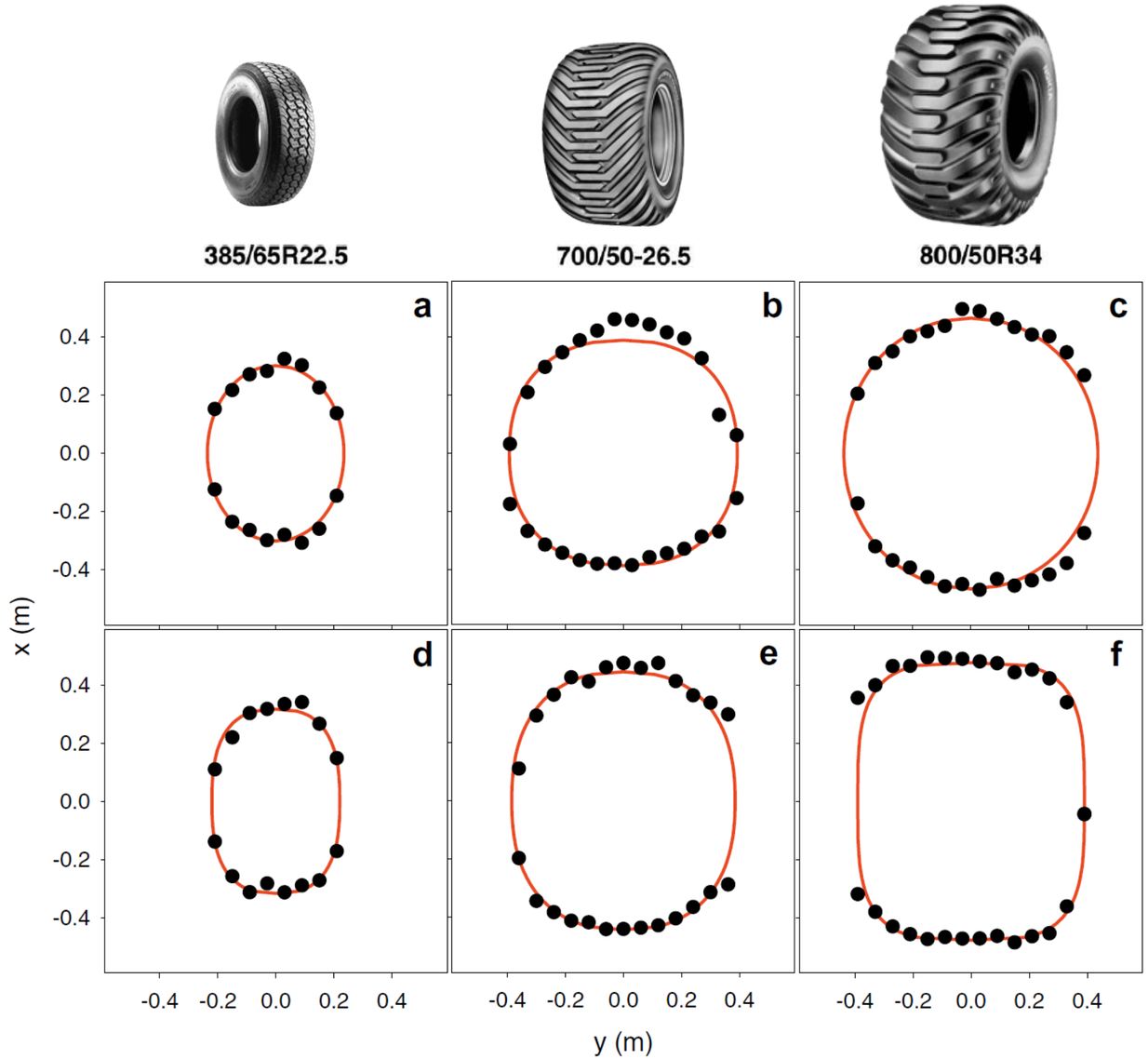
Modèle



Schjønning et al., 2008; Keller, 2005. Biosystems Engineering

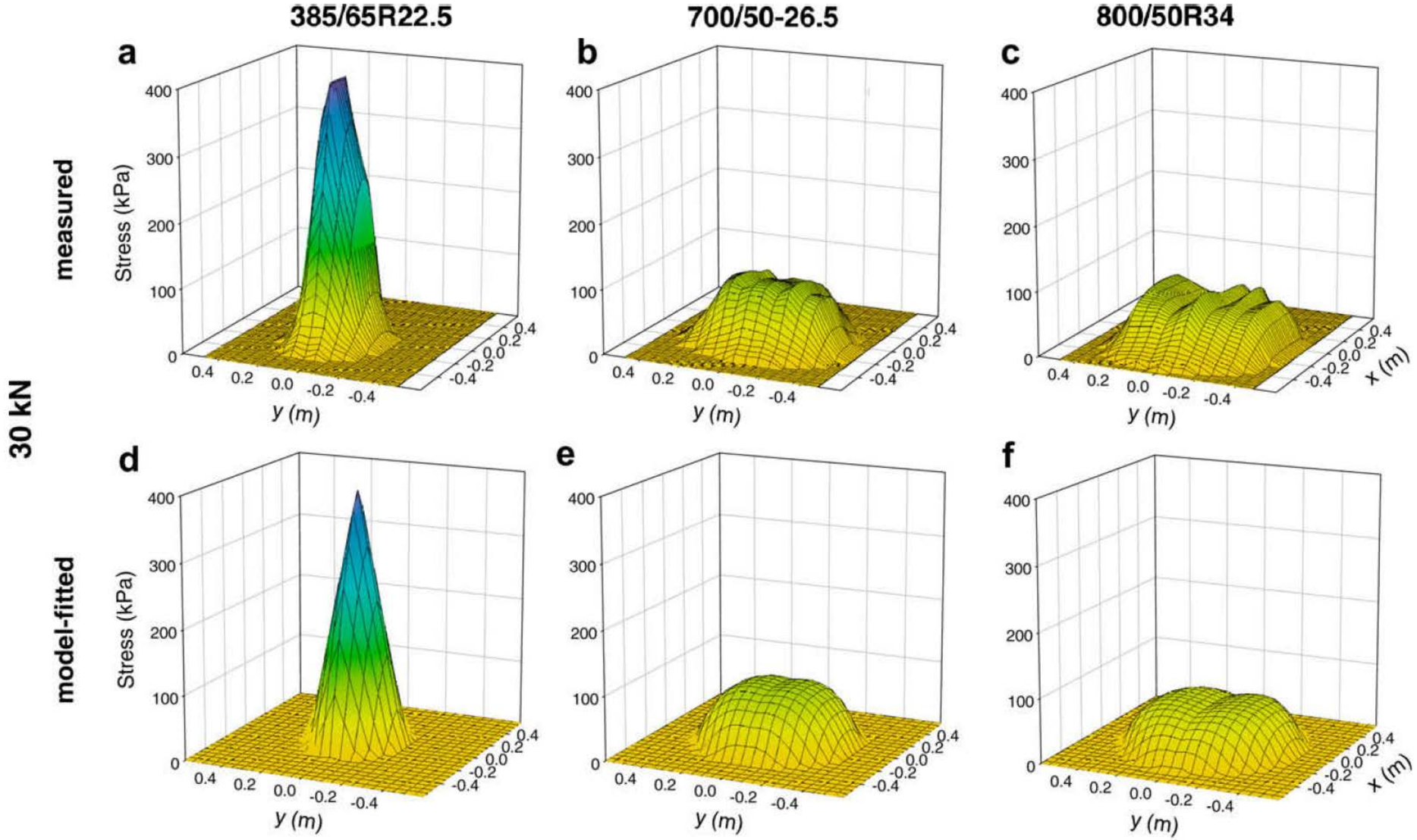
Mesures des contraintes au contact pneu-sol

Le modèle FRIDA : aire de contact



Lamandé and Schjønning, 2008, Journal of Terramechanics

Le modèle FRIDA : distribution des contraintes



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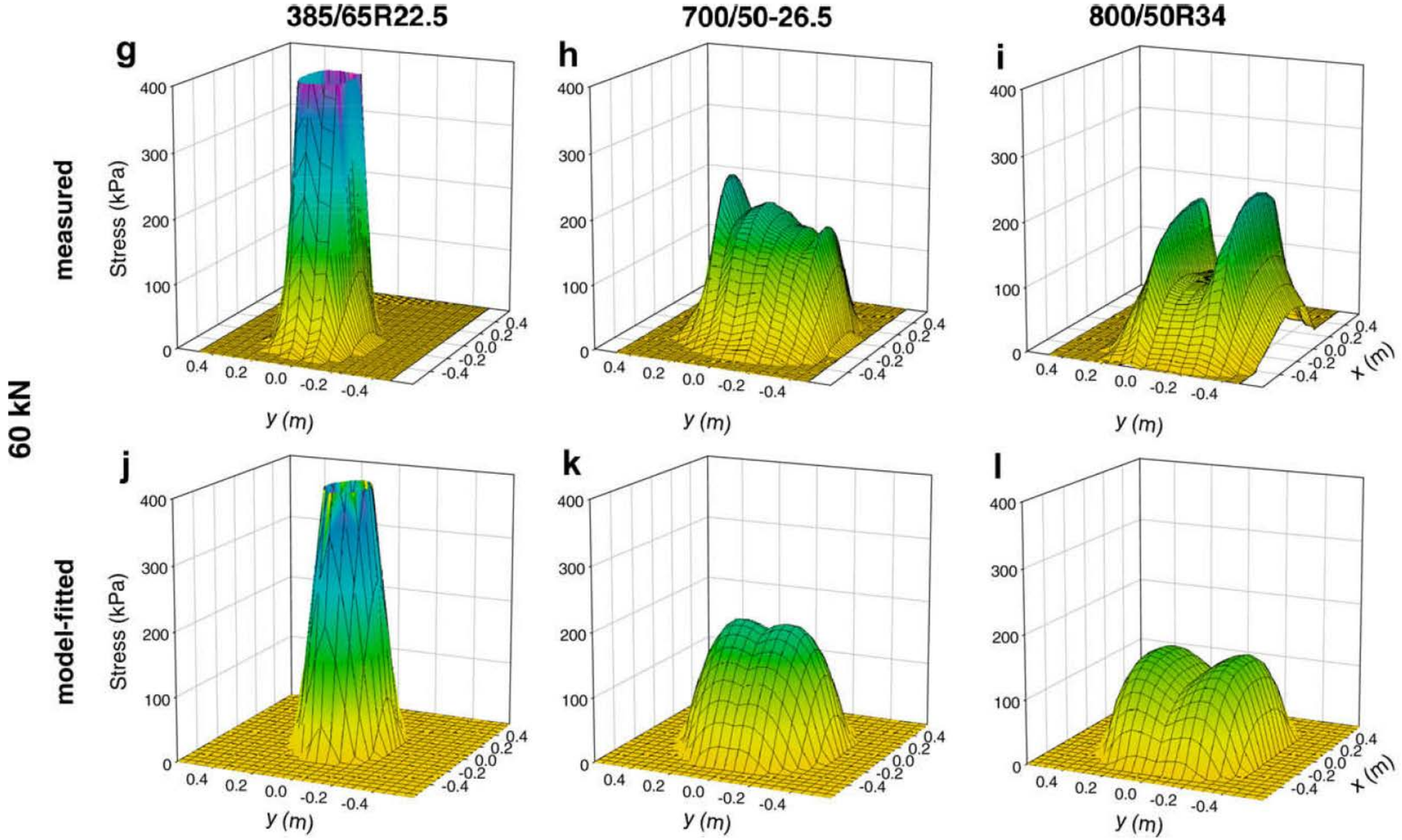
Le modèle FRIDA : distribution des contraintes

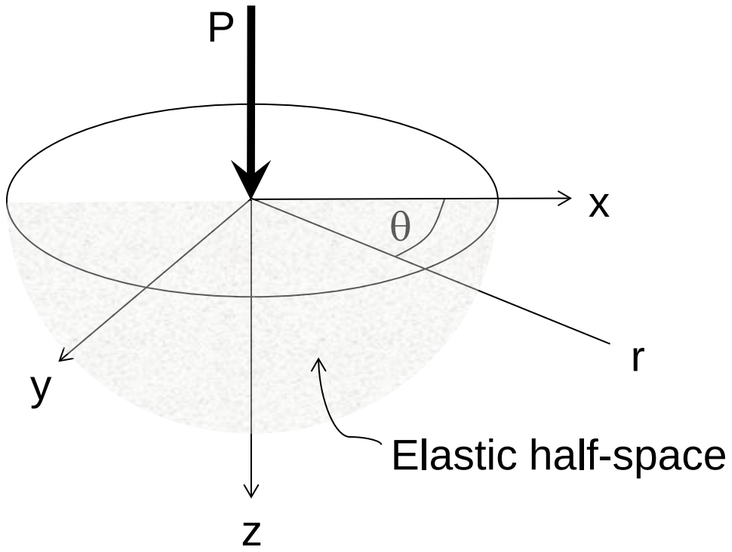


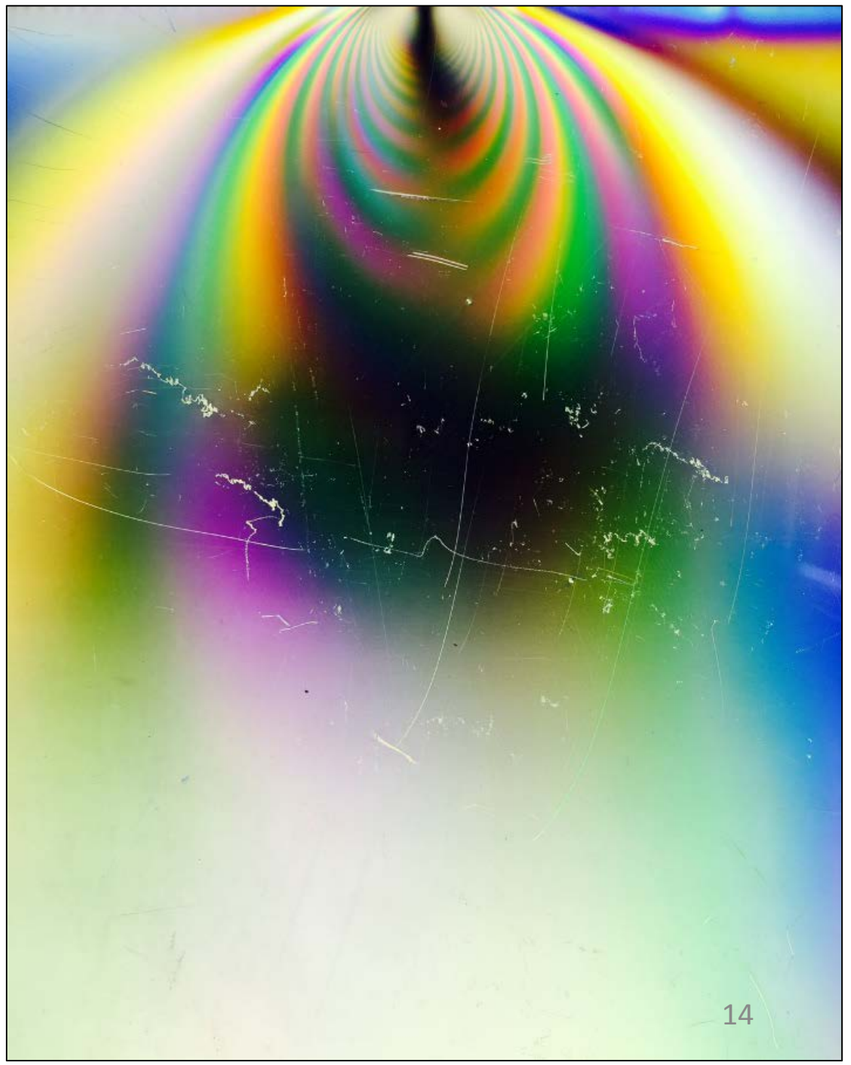
Lamandé and Schjønning, 2008, Journal of Terramechanics

Distribution des contraintes dans le sol

La solution de Boussinesq

(Boussinesq, 1885)

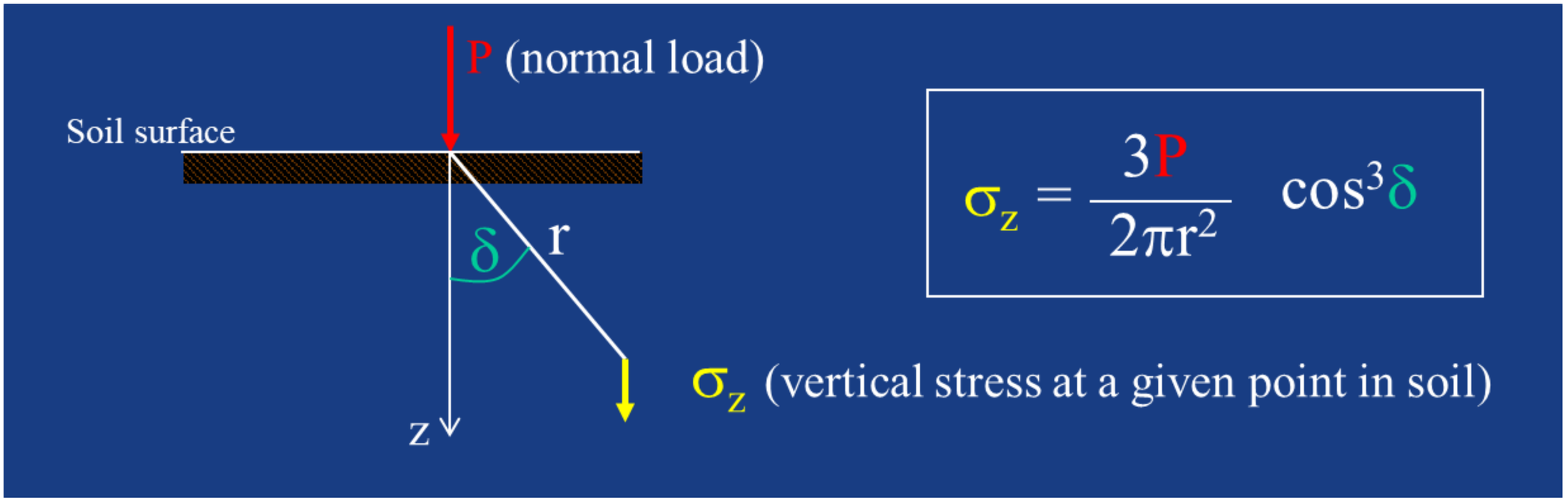




Distribution des contraintes dans le sol

La solution de Boussinesq

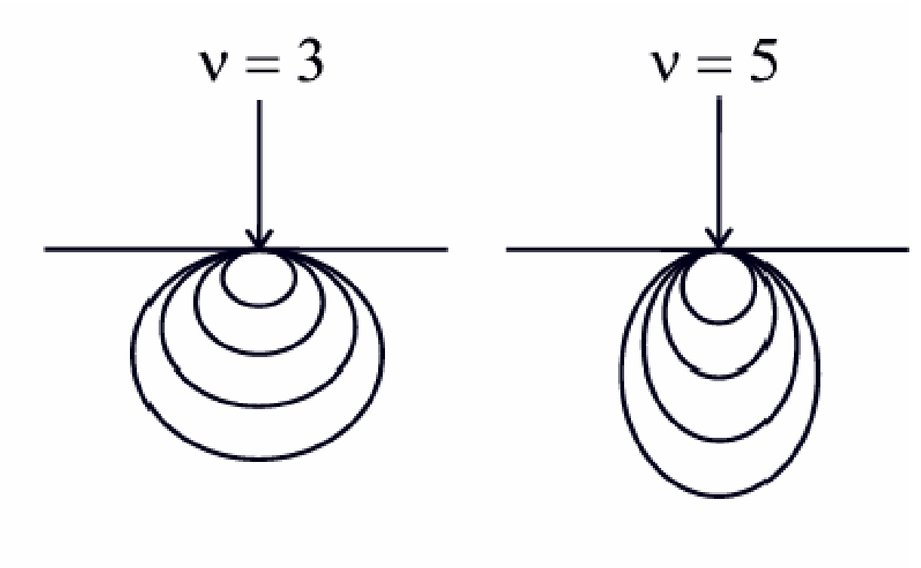
(Boussinesq, 1885)



Distribution des contraintes dans le sol

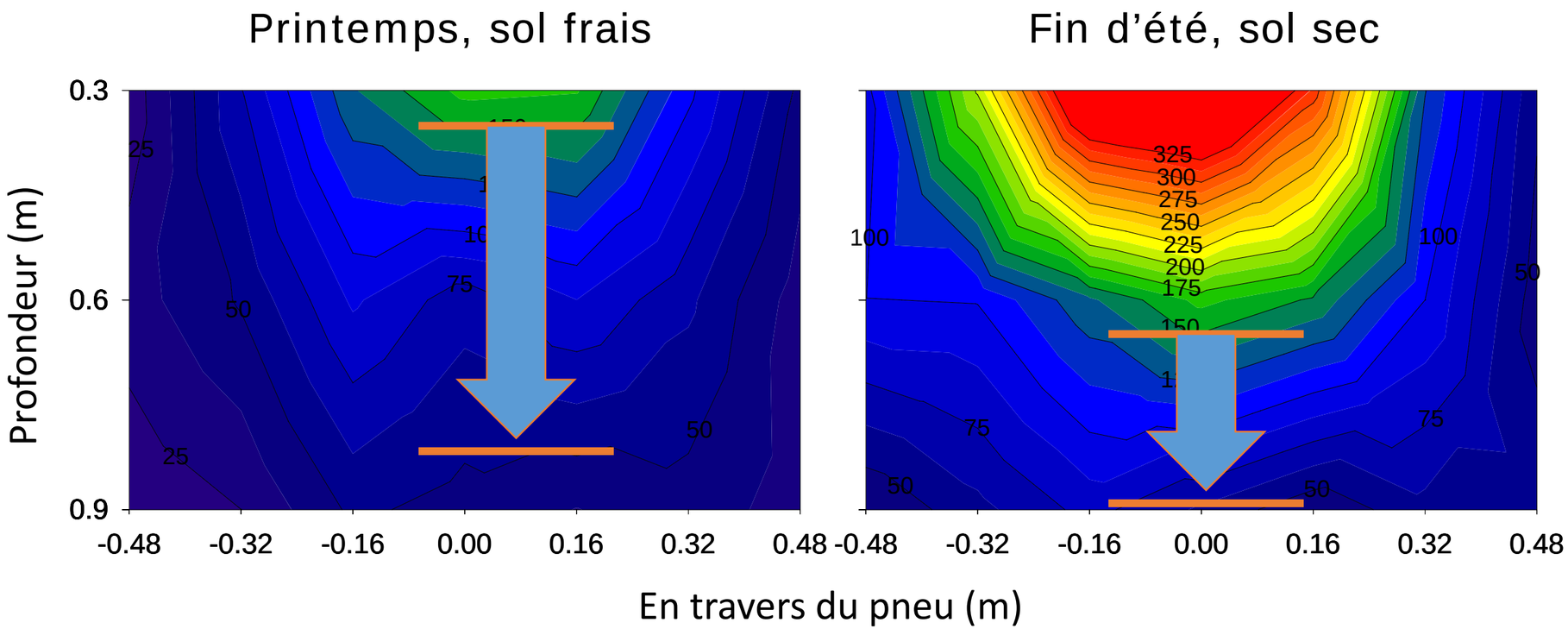
- Le facteur de Fröhlich, *v* (Fröhlich,1934)
  - La solution de Boussinesq : *v* = 3
  - Concentration des contraintes quand *v* > 3
  - *v* augmente quand le sol est plus souple

$$\sigma_z = \frac{\nu P}{2\pi r^2} \cos^{\nu+2}\delta$$



Distribution des contraintes dans le sol

Nokian 800/50R34
Charge = 6 t
Pression de gonflage = 100 kPa



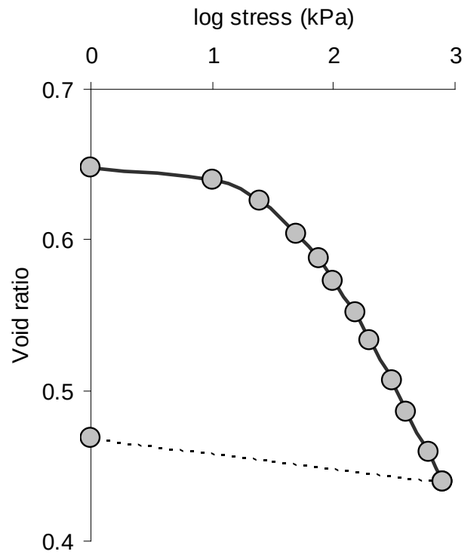
Estimation de la résistance du sol

- Expression de la résistance à comparer aux contraintes

→ Fonction pour l'estimation de la contrainte de compression, σ_{pc}

  - Essai de compression avec un oedomètre

- Détermination à partir de données accessibles et robustes



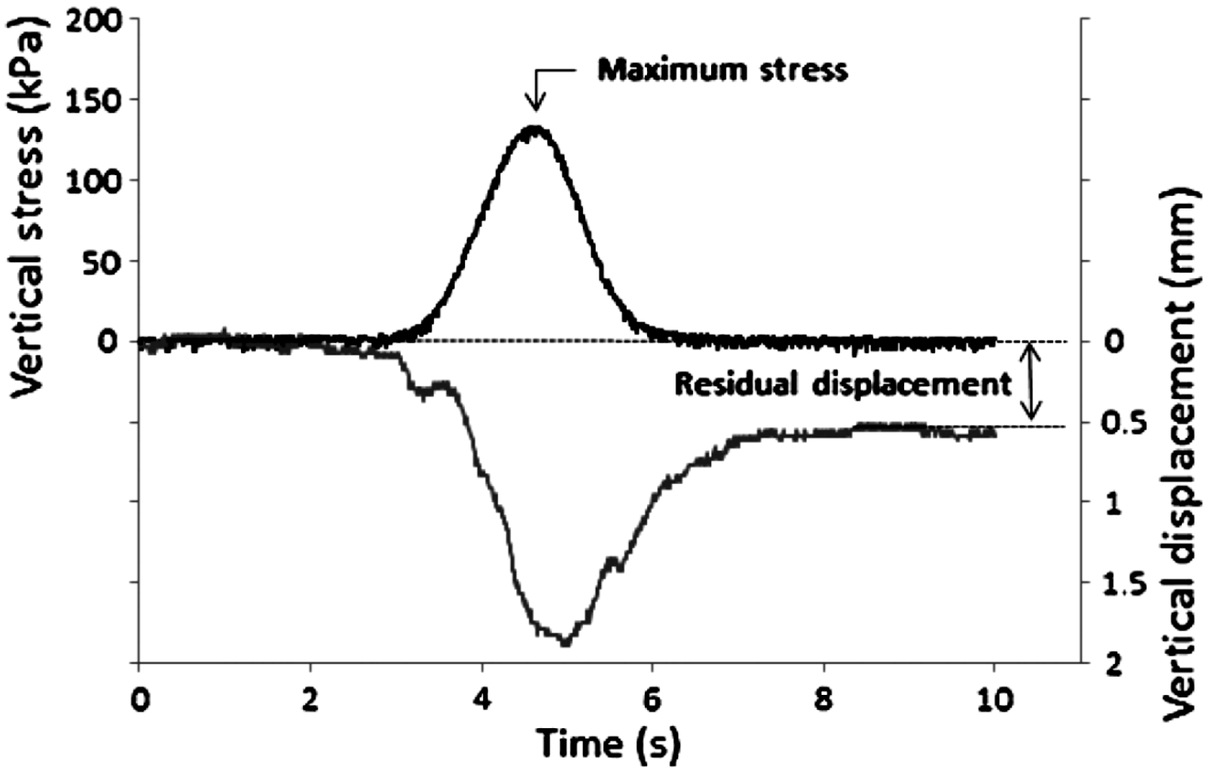
$$\sqrt{\sigma_{pc}} = -26.51 + 25.57 \times Densité\ apparente - 20.40 \times Argile + 10.26 \times Argile \times \log|Potentiel\ matriciel|$$

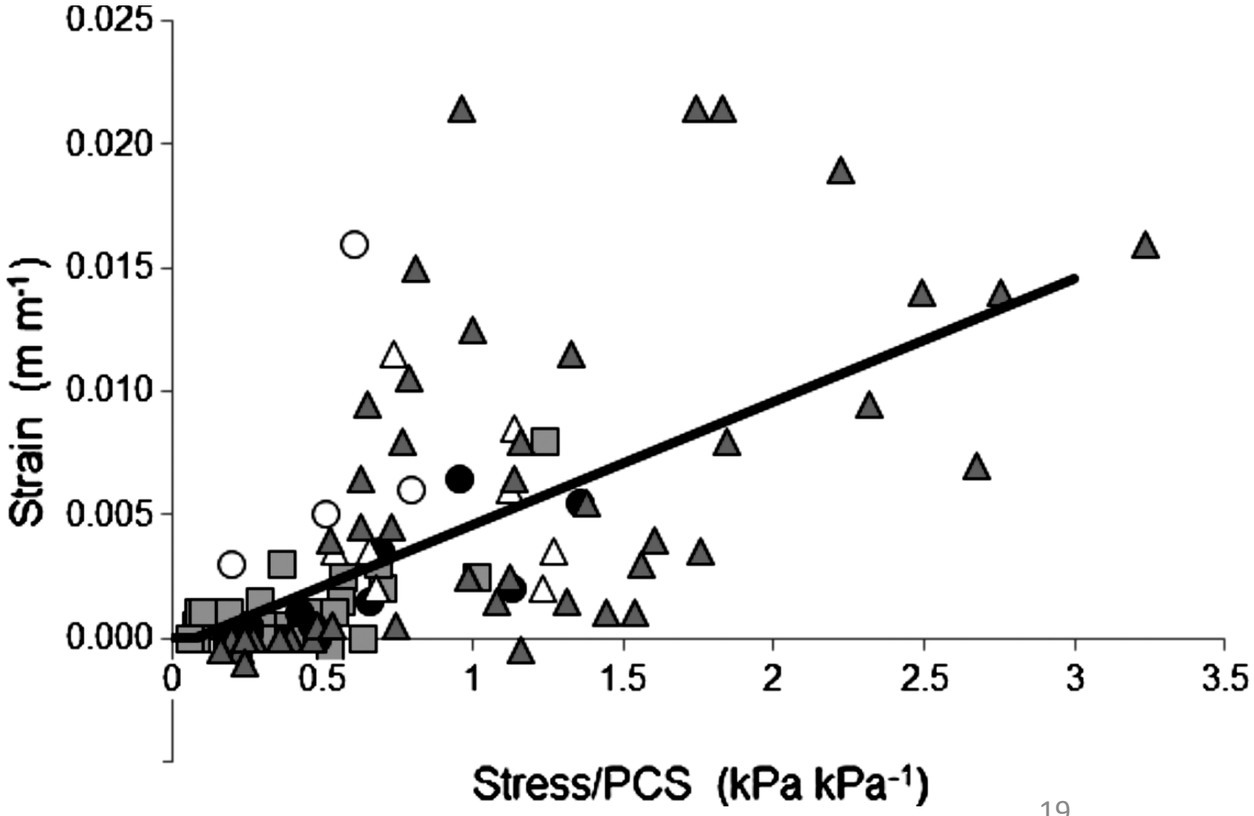
[1.33 – 1.73 g cm^{-3}] [0.12 – 0.46 g g^{-1}] [25 – 1995 hPa]

(Schjønning & Lamandé, 2018, Geoderma)

La résistance = contrainte de compression ?

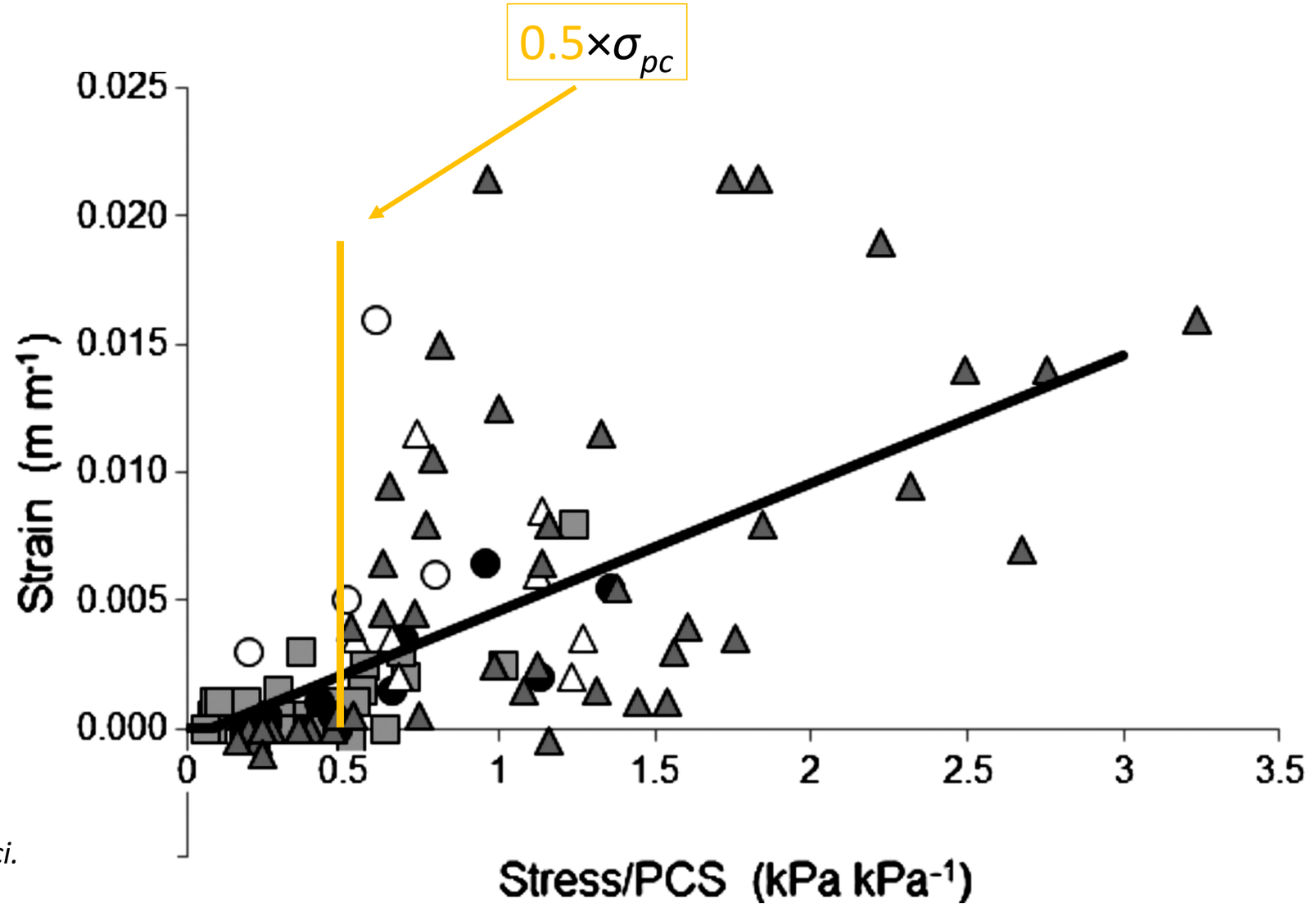
- Déformation résiduelle observée pour des contraintes inférieures !





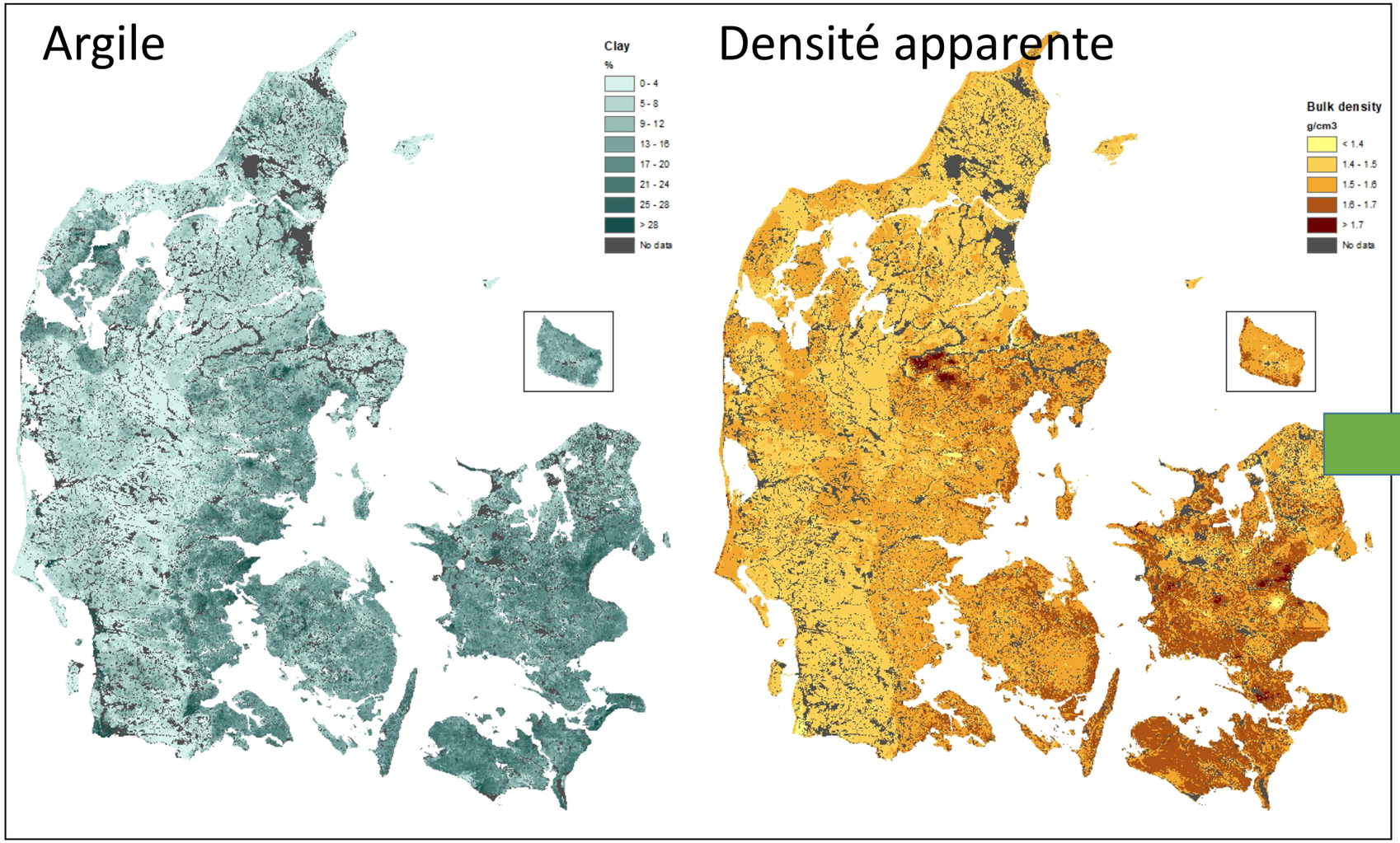
Keller et al., 2012, Soil Sci.

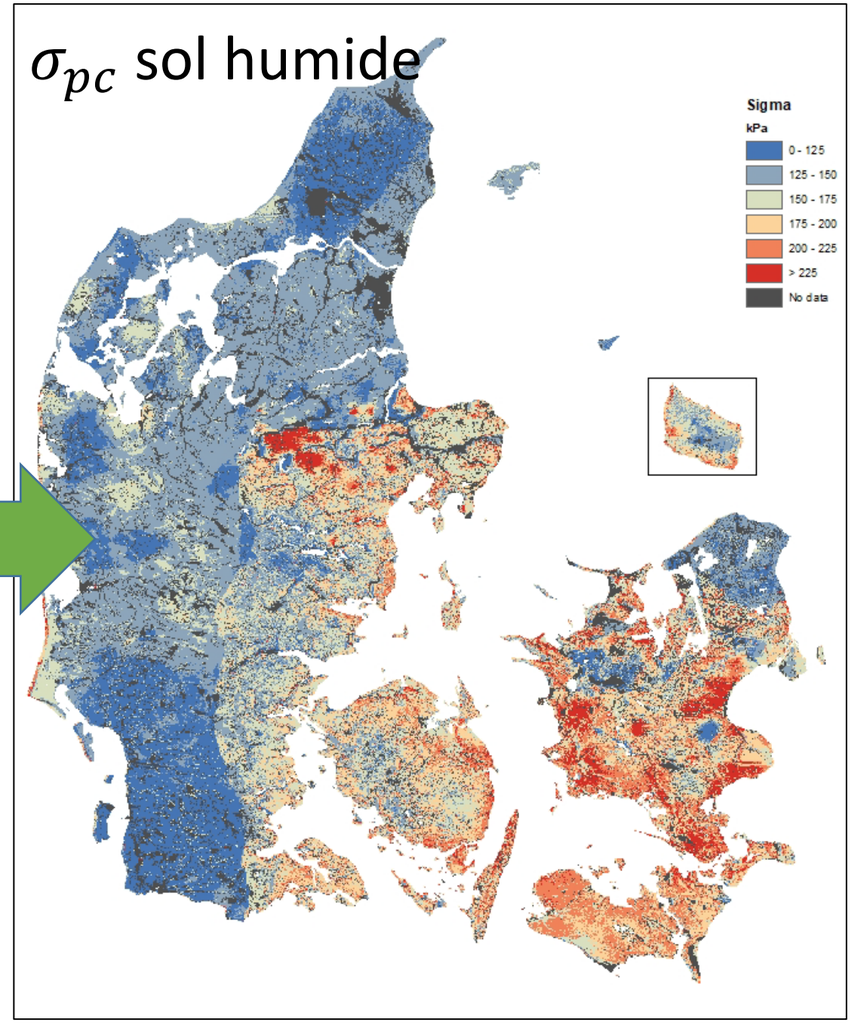
La résistance = contrainte de compression ?



Keller et al., 2012, Soil Sci.

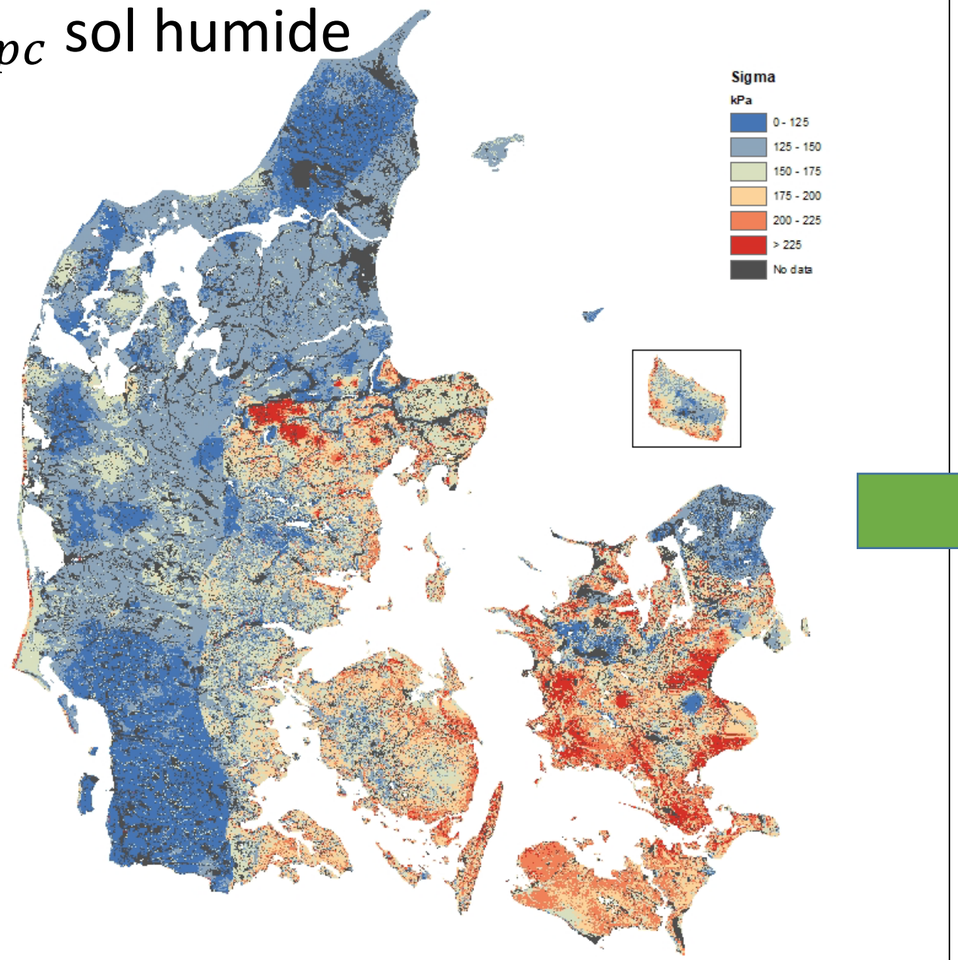
Estimation de la résistance du sol



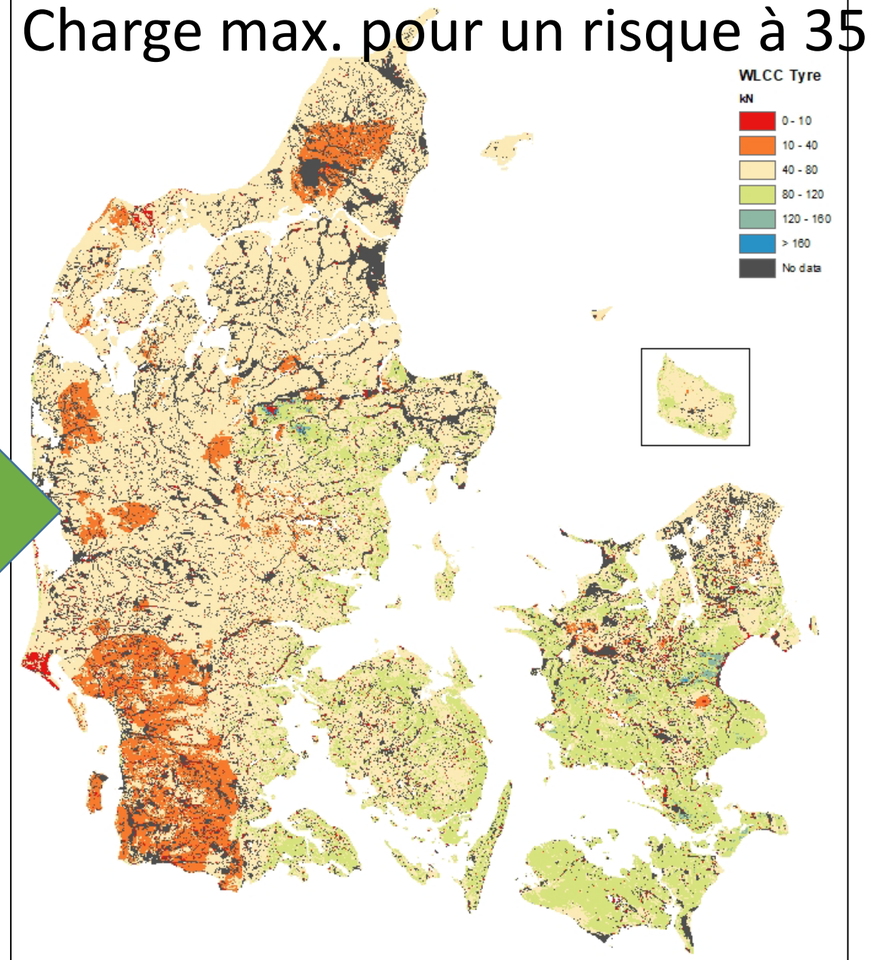


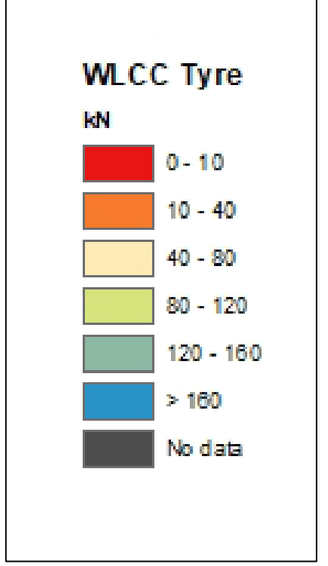
Charge max. selon les conditions sol-pneu

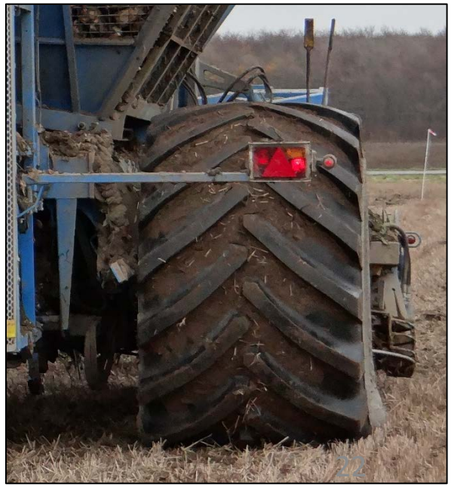
σ_{pc} sol humide



Charge max. pour un risque à 35 cm







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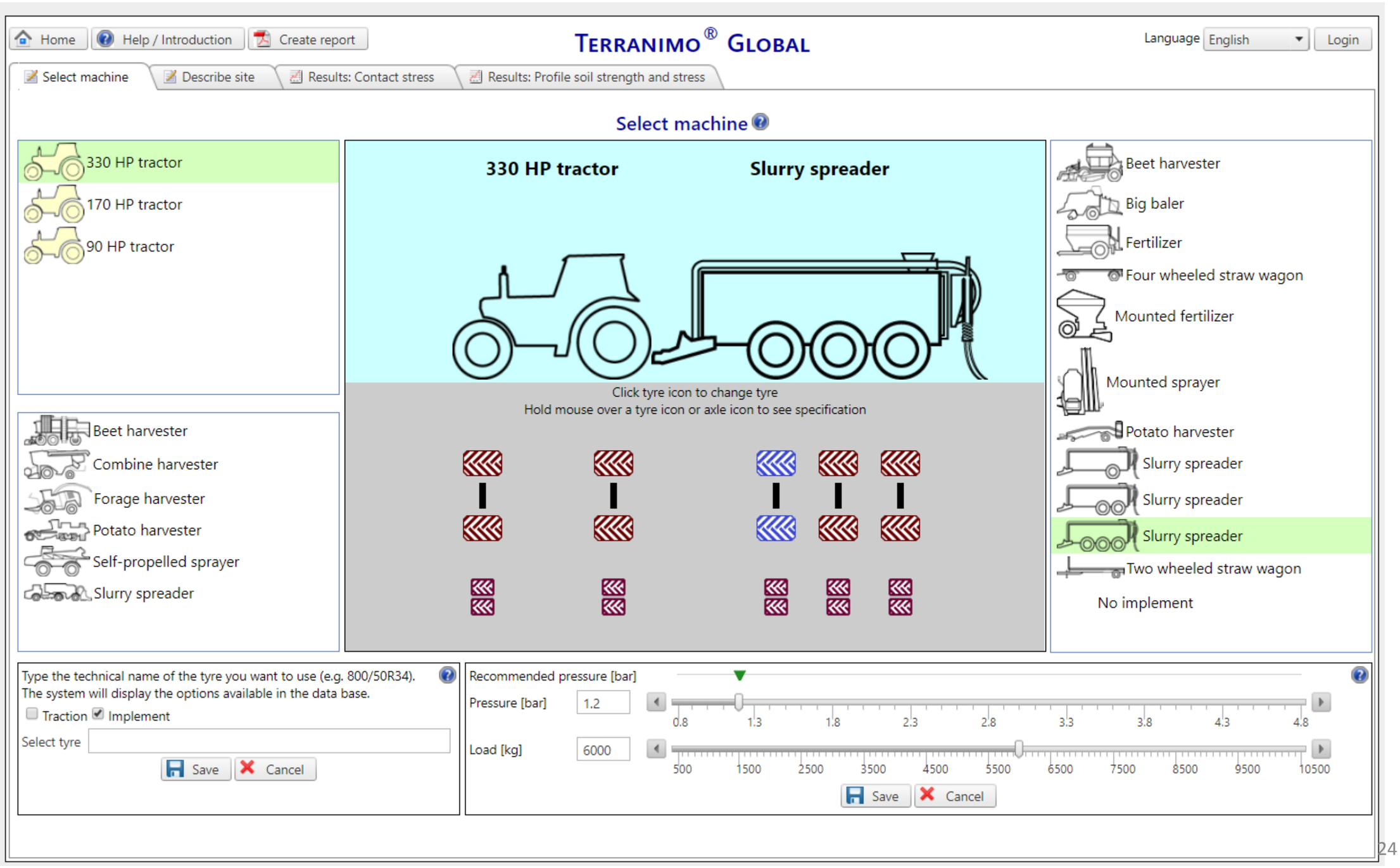
Home
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Create report
TERRANIMO® GLOBAL
Language English
Login
Select machine
Describe site
Results: Contact stress
Results: Profile soil strength and stress
Select machine
330 HP tractor
170 HP tractor
90 HP tractor
Beet harvester
Combine harvester
Forage harvester
Potato harvester
Self-propelled sprayer
Slurry spreader
330 HP tractor
Slurry spreader
Click tyre icon to change tyre
Hold mouse over a tyre icon or axle icon to see specification
Beet harvester
Big baler
Fertilizer
Four wheeled straw wagon
Mounted fertilizer
Mounted sprayer
Potato harvester
Slurry spreader
Slurry spreader
Slurry spreader
Two wheeled straw wagon
No implement
Type the technical name of the tyre you want to use (e.g. 800/50R34).
The system will display the options available in the data base.
Traction
Implement
Select tyre
Save
Cancel
Recommended pressure [bar]
Pressure [bar] 1.2
0.8 1.3 1.8 2.3 2.8 3.3 3.8 4.3 4.8
Load [kg] 6000
500 1500 2500 3500 4500 5500 6500 7500 8500 9500 10500
Save
Cancel

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TERRANIMO® DANMARK

Language English | Login

Select machine | Describe site | Results: Contact stress | Results: Profile soil strength and stress

Site information

Tillage ○ Yes (only if recently ploughed) ◉ No

Soil texture

◉ Automatic by soil type ○ Manual texture ○ Texture from soil database

Select soil type: JB6

No.	Bottom [cm]	Clay [%]	Silt [%]	Sand [%]	Organic matter [%]	Bulk density [g/cm³]
1	10	12.7	25.6	61.7	2.6	1.53
2	20	12.7	25.6	61.7	2.6	1.53
3	30	12.7	21.9	65.5	0.5	1.64
4	40	12.7	21.9	65.5	0.5	1.64
5	50	12.7	21.9	65.5	0.5	1.64
6	60	12.7	21.9	65.5	0.5	1.64
7	70	12.7	21.9	65.5	0.5	1.64
8	80	12.7	21.9	65.5	0.5	1.64
9	90	13.3	23.9	62.8	0.2	1.72
10	100	13.3	23.9	62.8	0.2	1.72
11	110	13.3	23.9	62.8	0.2	1.72
12	120	13.3	23.9	62.8	0.2	1.72
13	130	13.3	23.9	62.8	0.2	1.72
14	140	13.3	23.9	62.8	0.2	1.72
15	150	13.3	23.9	62.8	0.2	1.72

Soil water

◉ Automatic by wetness ○ Manual matric potential ○ DAISY matric potential

Select wetness: Moist

No.	Bottom [cm]	Matric potential [hPa]
1	10	100
2	20	100
3	30	100
4	40	100
5	50	100
6	60	100
7	70	100
8	80	100
9	90	100
10	100	100
11	110	90
12	120	80
13	130	70
14	140	60
15	150	50

Reset soil and water to default

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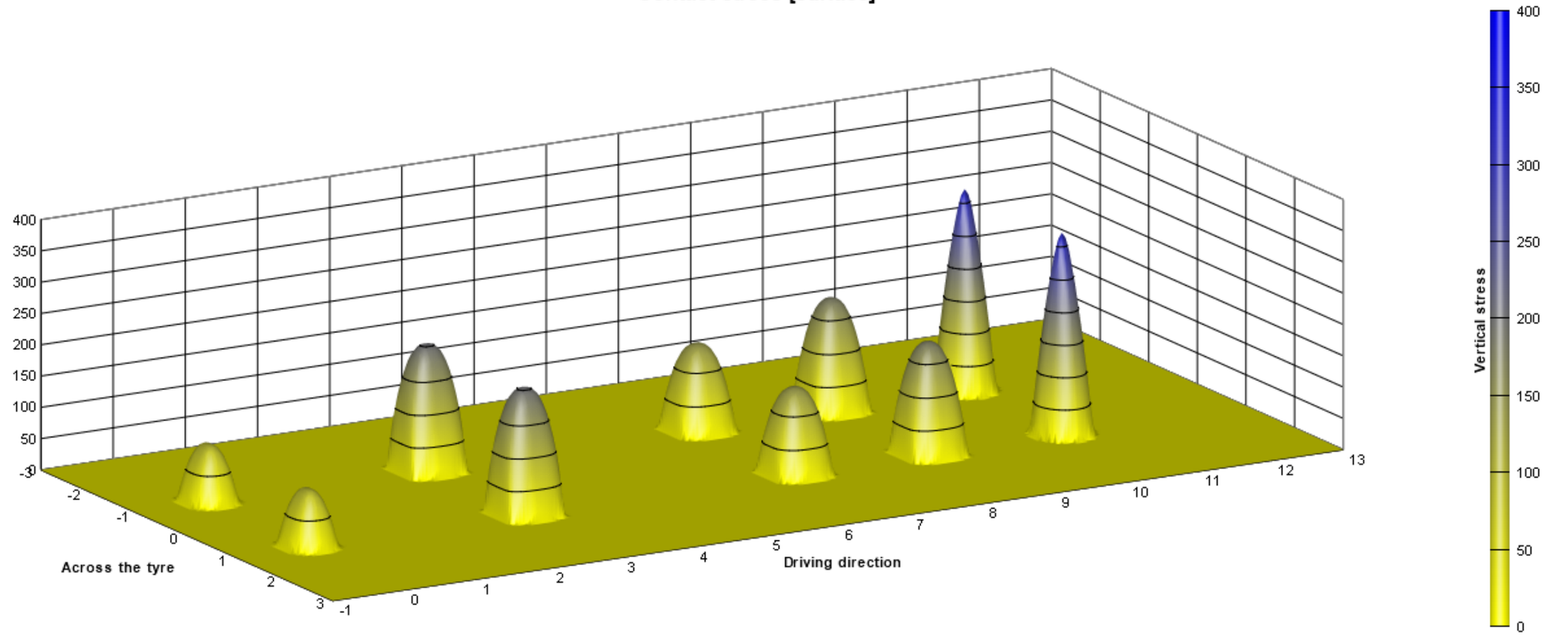
Select machine | Describe site | Results: Contact stress | Results: Profile soil strength and stress

Results: Contact stress

Surface Contour

Contact stress [surface]



Select machine	Axle	Wheel	Tyre	Wheel load [kg]	Pressure [bar]	Recommended pressure [bar]	Contact area [m²]	Mean ground pressure [kPa]	Maximum stress [kPa]
330 HP tractor	Front axle	Right	Michelin, Axiobib 600/70R30	1968	0.6	0.6	0.390	49	93
330 HP tractor	Rear axle	Right	Michelin, Machxbib 650/85R38	7052	1.4	1.4	0.628	110	203
Slurry spreader	Front axle	Right	Nokian, ELS Radial 710/55R34	4500	0.7	0.7	0.586	75	139
Slurry spreader	Mid axle	Right	Nokian, ELS Radial 710/55R34	6000	1.2	1.2	0.610	97	180
Slurry spreader	Rear axle	Right	Nokian, ELS Radial 710/55R34	6000	3.0	1.2	0.445	132	321

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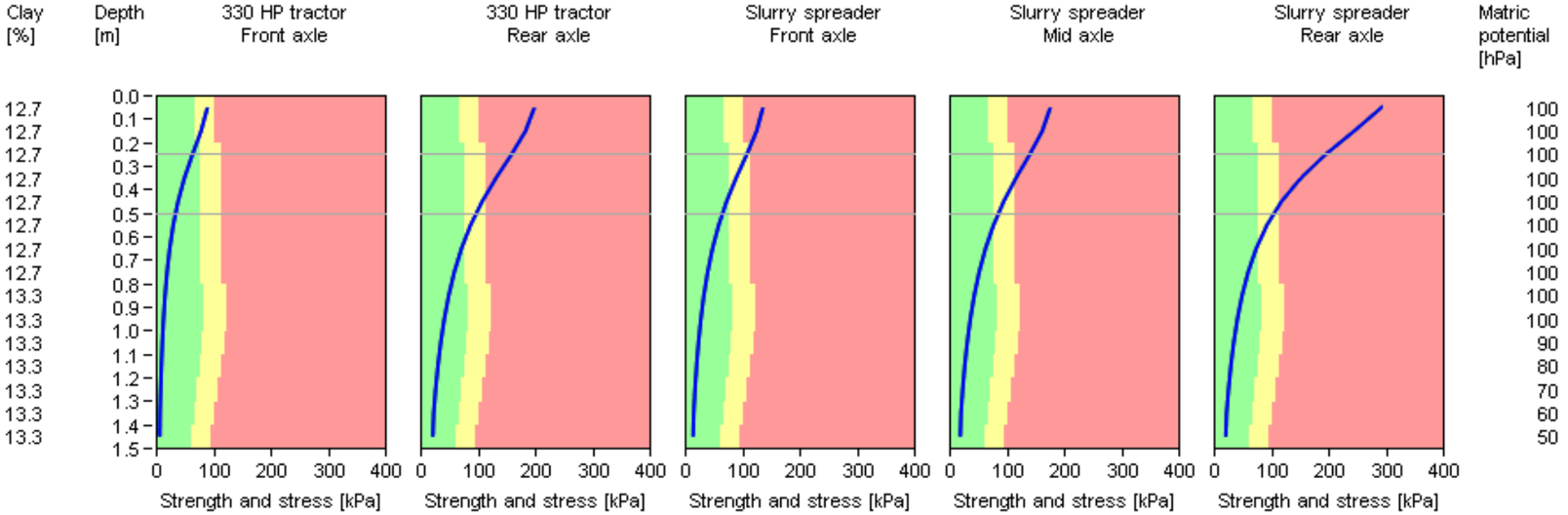
Select machine | Describe site | Results: Contact stress | Results: Profile soil strength and stress

Results: Profile soil strength and stress

Compare soil strength and stress

Compare soil strength and stress



The limit between green and yellow indicates soil strength estimate, and the limit between yellow and red gives strength 50% higher than estimated. The lines show vertical soil stress.

The intended traffic should not be undertaken if the lines runs within the red area (especially for layers deeper than 0.5 m). We suggest one or more of the following actions: 1) change tyre, reduce inflation pressure (primarily affecting stresses in upper soil layers), 2) reduce wheel load (primarily affecting stresses in the deeper soil layers), and/or 3) wait with the intended traffic to soil water content has reduced (which will increase soil strength).

Click tyre icon to select tyre for changing load and pressure
Hold mouse over a tyre icon to see specification

Recommended pressure [bar]

Pressure [bar]

0.6 1.1 1.6 2.1 2.6 3.1 3.6 4.1 4.6 5.1 5.6

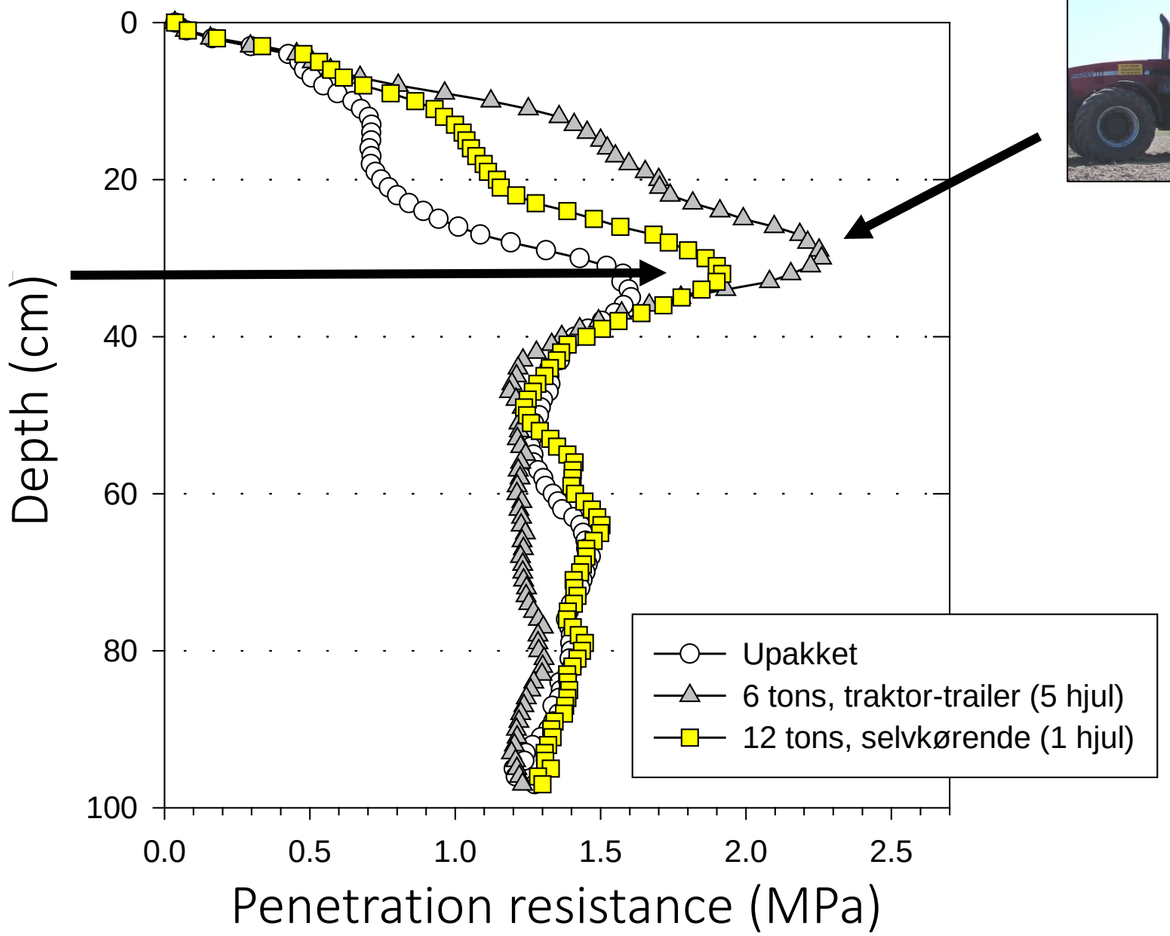
Load [kg]

500 1500 2500 3500 4500

Save | Cancel

Limites de cette méthode d'estimation du risque de tassement

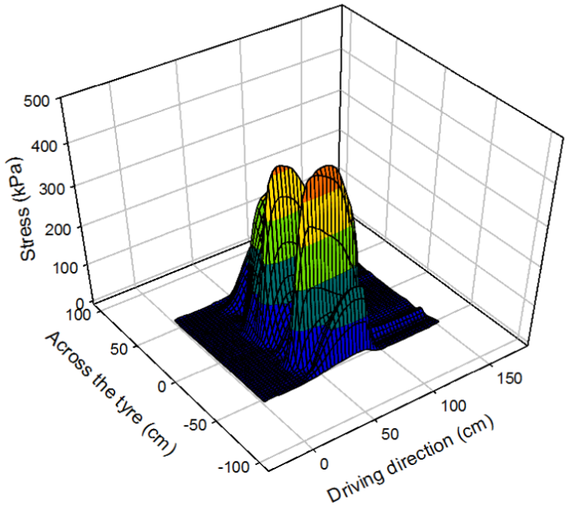
1 roue
12 t de charge
1.5 bar de pression



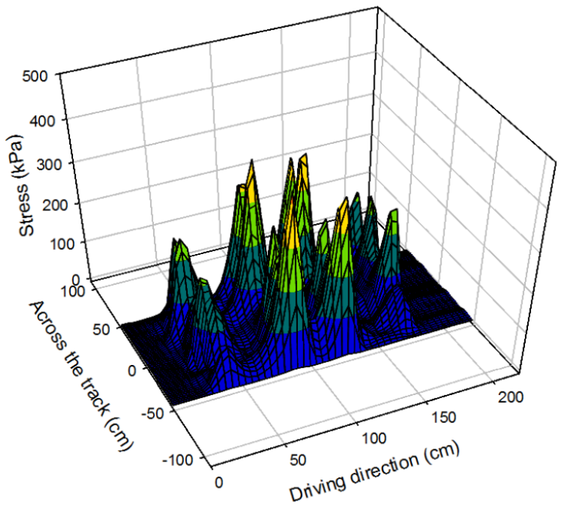
5 roues
7 t de charge
3 bar de pression

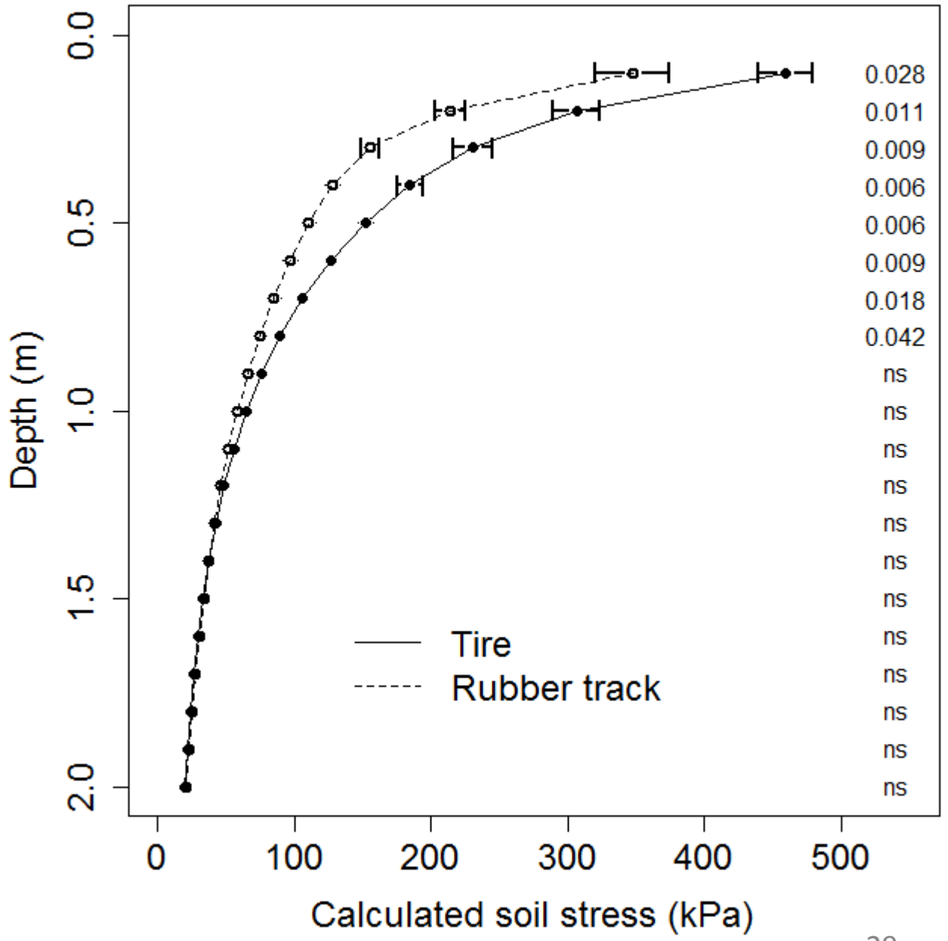
Limites de cette méthode d'estimation du risque de tassement

10 t de charge



Mesures des contraintes au contact





Validation de la méthode

10 t de charge

0.33-0.37 m	Densité apparente	Perméabilité à l'air
	g cm^{-3}	μm^2
Pneu	1.56	20.3
Chenille	1.55	7.92
	P=0.742	P=0.041

Conclusions et perspectives

- Il faut continuer les investigations !

→ Évaluation du risque pour une roue sans traction

→ Comment inclure les effets de la traction ?

→ Comment inclure les effets de plusieurs roues?

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