

Soil compaction or drainage system? How to improve?

Jukka Rajala
Senior planner

University of Helsinki Ruralia Institute

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What's the problem in this field?



Why this field doesn't grow well?
5x



Organic oatfield at the end of June

Kuva: Jukka Rajala

Right questions?

Does water flow from outlet?

Organic oatfield at the end of June



Kuvat: Jukka Rajala

Right questions?

Does ENOUGH water flow from outlet?

Organic oatfield at the end of June

=>Goundwater level was very high 30-40 cm
=>Reason: Rootblockage in the main pipe

Photos: Jukka Rajala



Problems in soil physical fertility %

- OSMO-research fields in autumn 2015



Problems in under-
ground drainage

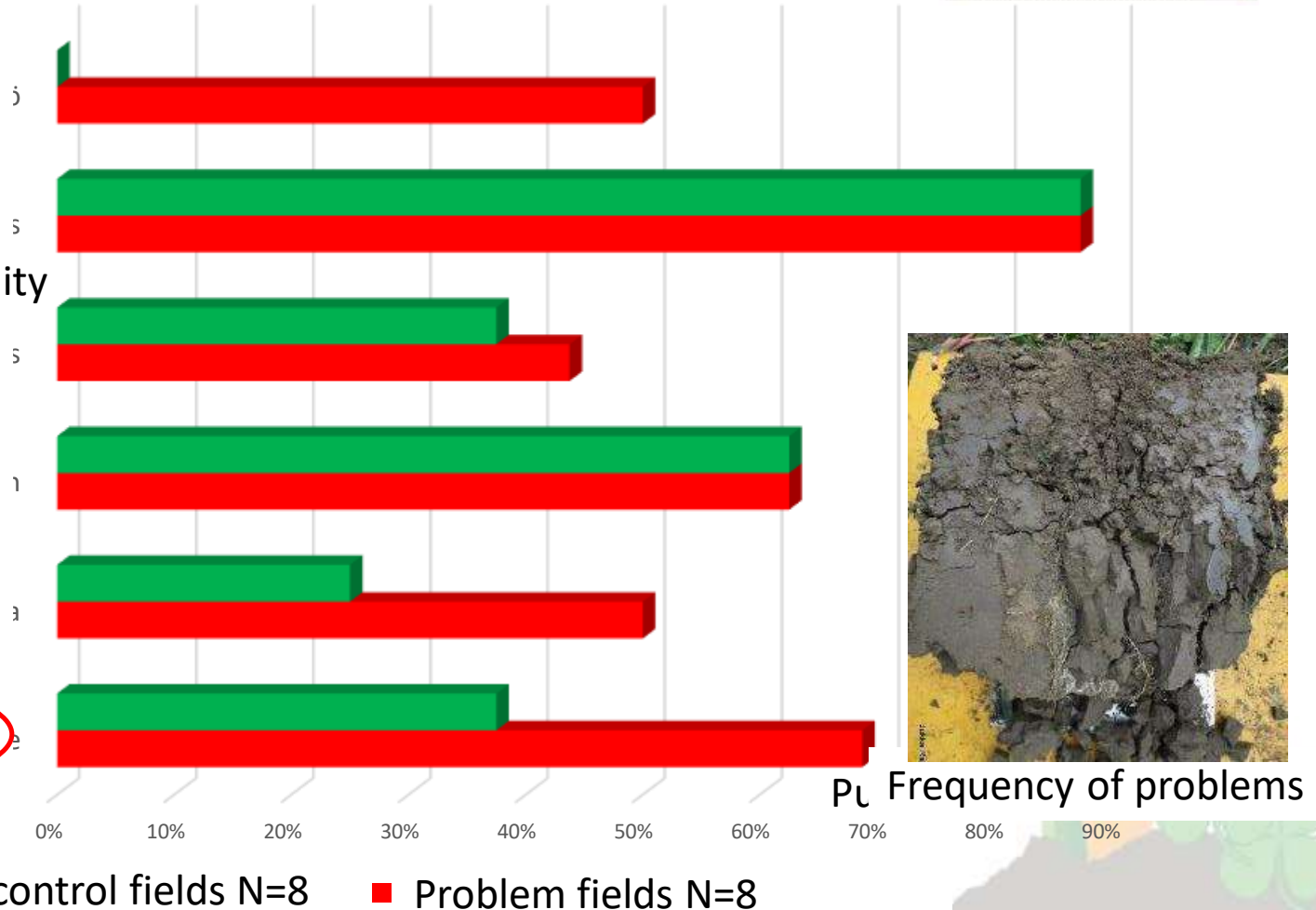
Low water infiltration

Slow water permeability

Compacted layers
in subsoil

Compacted layers
in topsoil

Visual soil structure
assessment



Frequency of problems

[Mattila ja Rajala 2017. Report 171](#)

Physical fertility: Need to improve



- **Drainage**
 - Outlets blocked
 - Waterponds on the fields
 - Side ditches too low
 - Permeability insufficient
 - **Structure**
 - Compacted layers in topsoil and in subsoil from 1cm to over 100 cm
 - **Water**
 - Low infiltration and permeability
 - **Roots**
 - Poor growth, poor soil and nutrient use
 - **Crumble harness**
 - Low; sensitive to sludging and erosion
- => **Compacted soils, where poor drainage**



Problems in drainage

OSMO-research fields



Farm	Outlet	Side ditches	Block age	Cesspit	Topo- grafya	Poor water infiltration and permeability			
						0-5 cm	5-35 cm	35-60 cm	60-150 cm
He	x		?			x	x	x	
Hy	(x)	x			x	x	x	x	
Ju	x		?		x	x	x	x	
Kä						x			
Lu	x					x		x	
Ha						(x)	x		
Pa		x		x	x			x	
Sa					x		x		

Clay
Sand
Org.
Loam

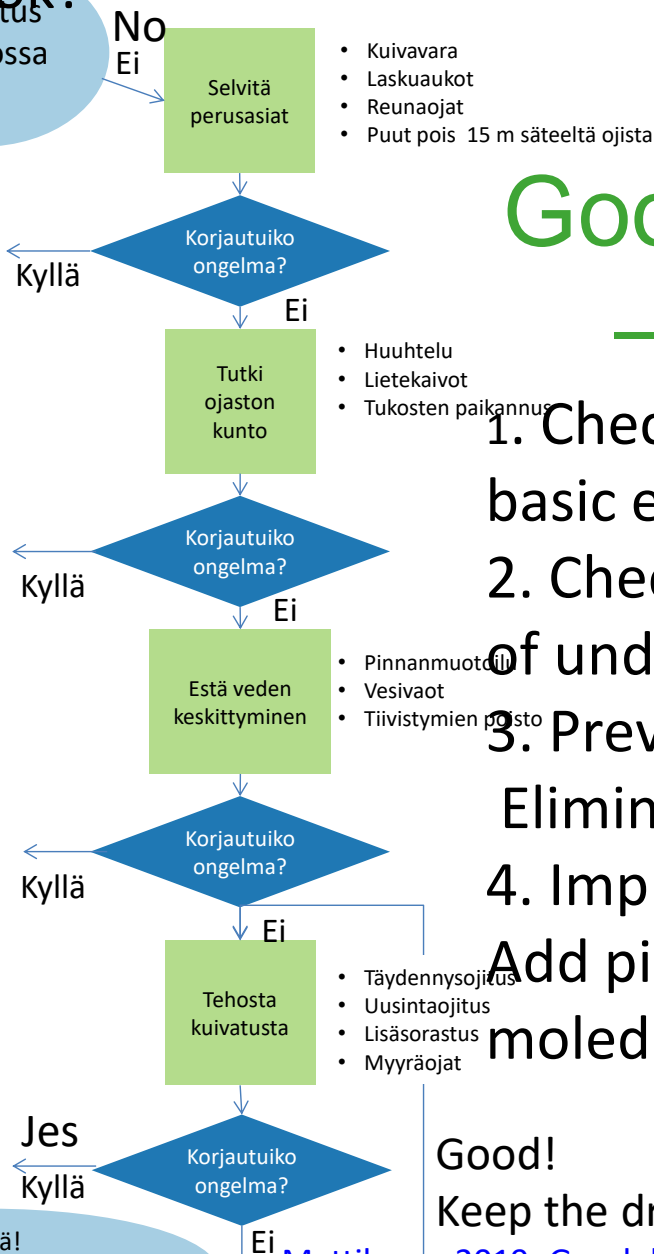
Texture



[Mattila ym. 2019. Good drainage – field by field. Report 195.](#)

Drainage ok?

Kuivatus kunnossa?



- Kuivavara
- Laskuaukot
- Reunaojat
- Puut pois 15 m säteeltä ojista

- Huuhtelu
- Lietekaivot
- Tukosten paikannus

- Pinnanmuotoilu
- Vesivaot
- Tiivistymien poisto

- Täydennysojitus
- Uusintaojitus
- Lisäorastus
- Myyräojat

Good drainage scheme – How to reach it?

1. Check the basic elements
2. Check the status of underdrainage
3. Prevent water ponds
Eliminate compacted layers
4. Improve underdrainage
Add pipes, more gravel, moledrainage



<35 cm

1 l/s/ha

<60 cm

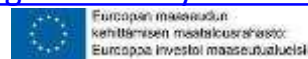
vä!
us kunnossa
llä huollolla.

Good!

Keep the drainage in good shape with regular service.

[Mattila ym 2019. Good drainage – Field by field 2019. HU Ruralia Institute Report 195](#)

Rajala J. Soil compaction or drainage



Farm example 1 - Sandy soil



150 ha

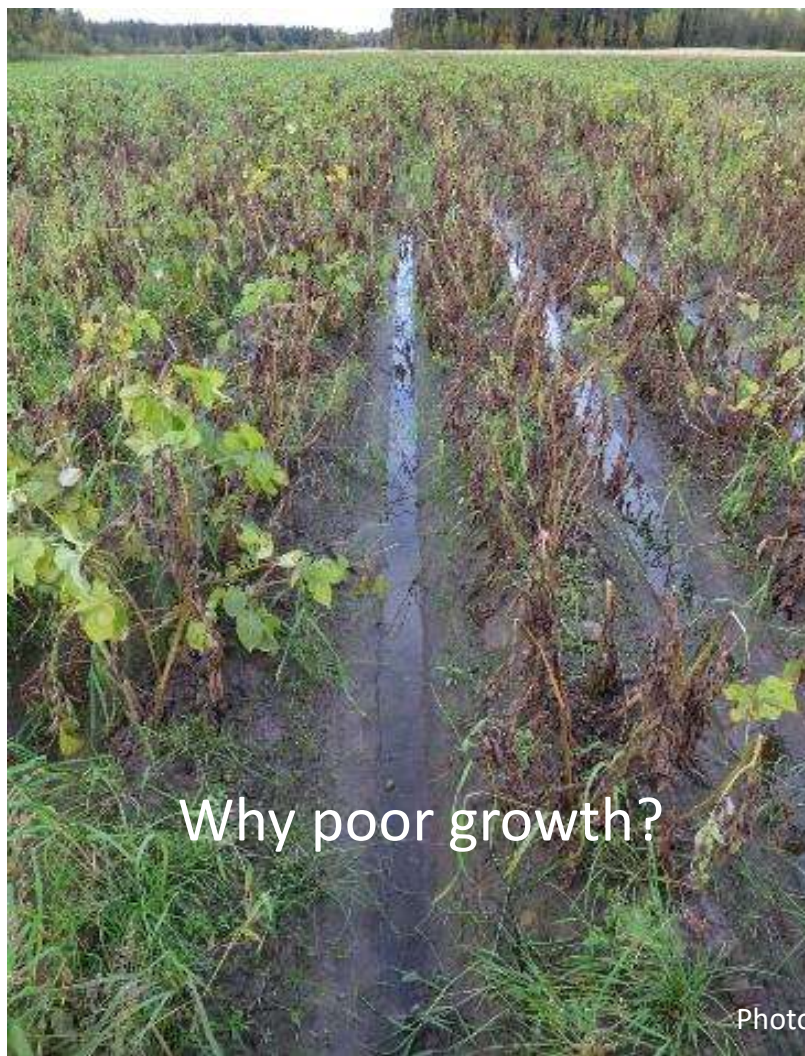
Sandy soils

Organic potato farming 25 ha/y

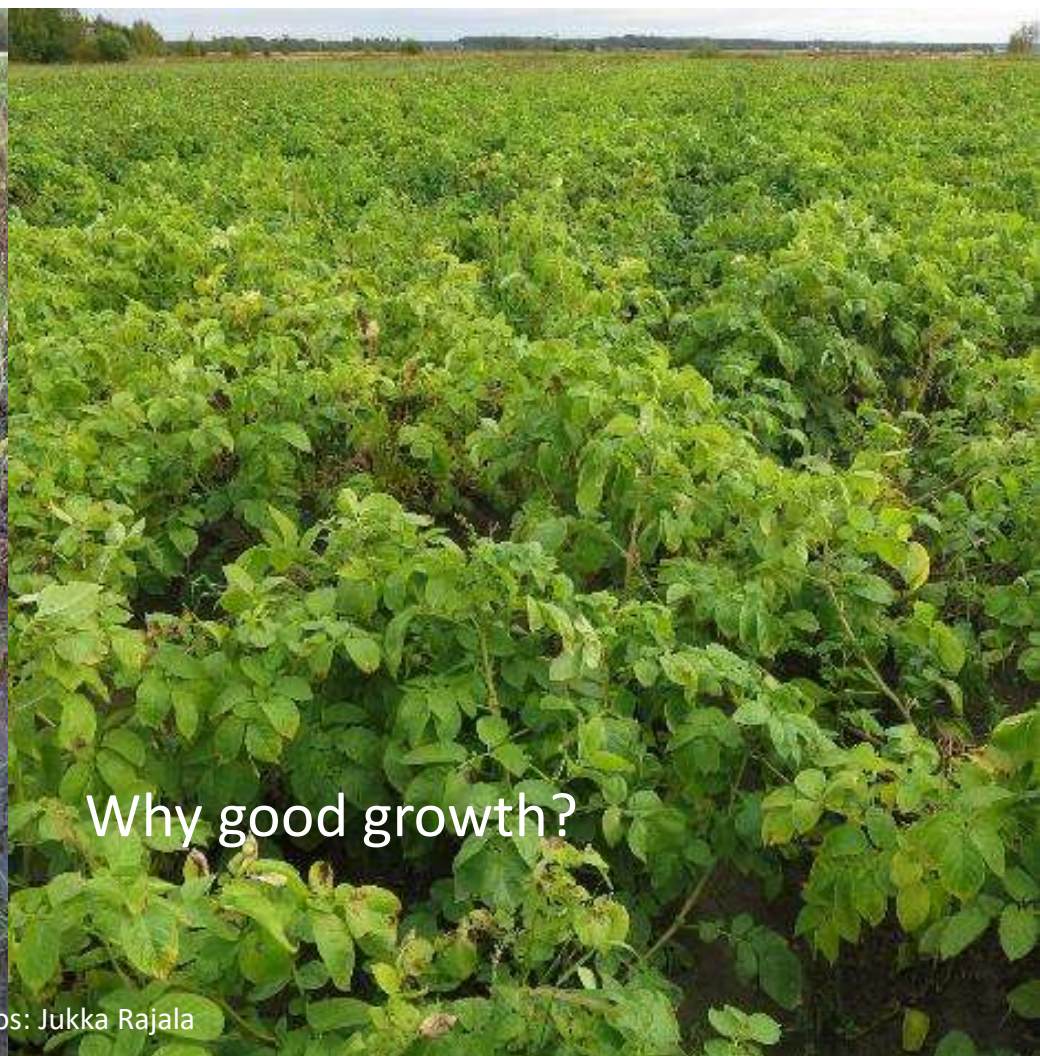
Very flat

Plowing

Potato field – Which are the problems?



Why poor growth?



Why good growth?

Photos: Jukka Rajala

Soil structure - Sandy soil



Poor field

Good field



Poorer structure

Kuvat Jukka Rajala 19.11.2015



Deficiency of potassium

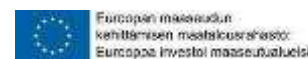


Kuvat Jukka Rajala 7.2016

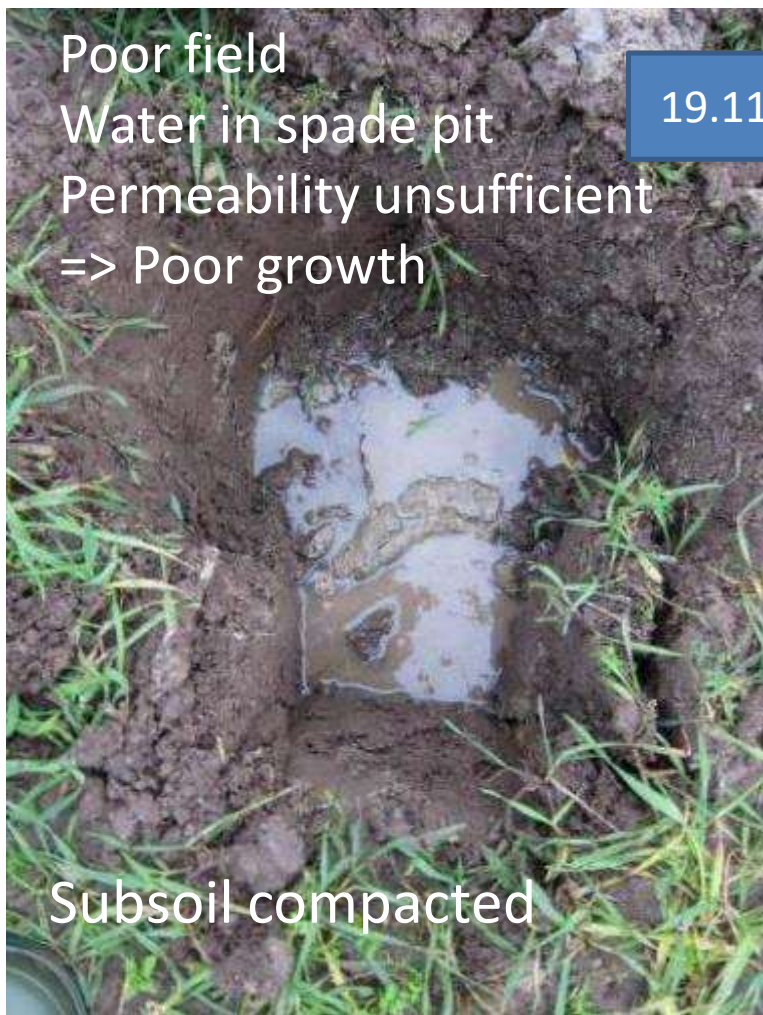
Compact to 60 cm deep

Jukka Rajala J. Soil compaction or drainage

PA
19.11.2015



Water level and Permeability



19.11. 2015



Kuvat Jukka Rajala

> Kuopan märkyys paljastaa kasvukunnon

Challenge is poor soil structure and poor permeability



Big difference
in yields

=>Structure!

=>Drainage!

Good growing field

Shale structure is soft with holes

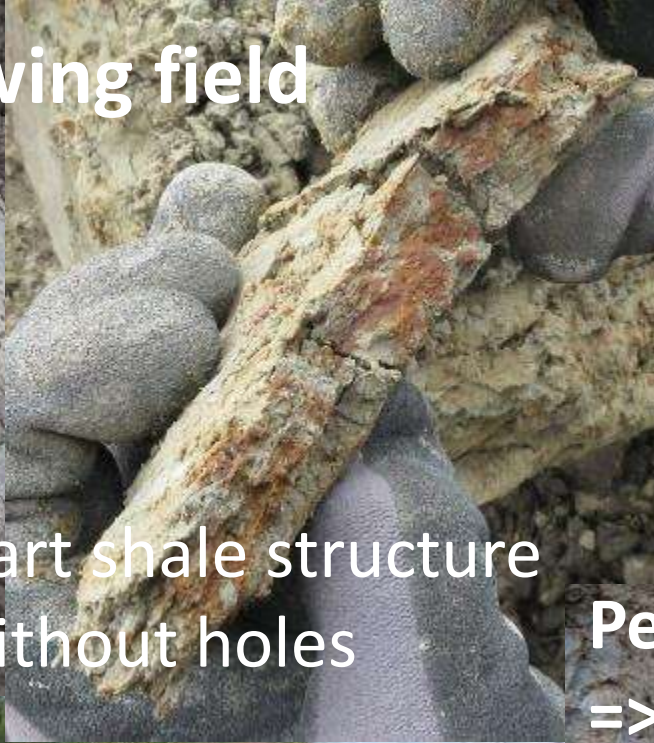
Pa K 9.5.2018

Permeability ok
to drainage pipes,
1 m deep



Kuvat: Jukka Rajala

Poor growing field



Hart shale structure without holes



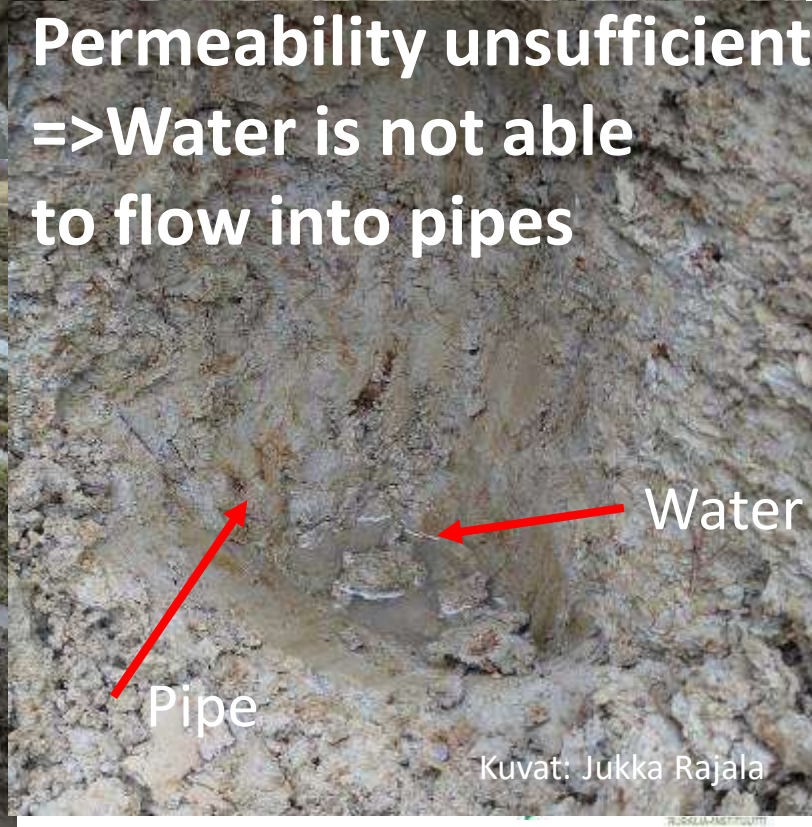
Pipes ok

Permeability insufficient => Water is not able to flow into pipes



Pa 1 9.5.2018

Water on the field



Water

Pipe

Kuvat: Jukka Rajala

Measures to fix the problems



- Crop rotation; Cloverley-cloverley-rye-potato-barley
- Organic fertilisation farmer already used
- Subsoiling
- Clearing side ditches
- Clearing cesspit
- Leveling soil surface – surface water is challenge
=> These measures were not enough
- Soil is sentive to sludging => permeability
Poor drainage is the basic problem
- => Adding pipes as usual is not enough
- => The field need special effective drainage system and after that aggregate stability will increase



Farm example 2 - Clay soil



140 ha cereal farming –summer cereals
Heavy clay soil
Light disc tillage + direct sowing



Wet

Water on the field

Water ponds



Compacted



Water don't move

Photos: Jukka Rajala



Problems in soil structure



- Drying slowly and unhomogenous
- Compacted/block type structure
- Good structure in surface 5-6 cm
- Topsoil 6-25 cm too dense
- Subsoil too dense
- No worm channels
=>permeability very poor
- Poor root growth - only in cracks
- Crumbles only in 0-5 cm layer
- Very high Mg –content, very low Ca:Mg -ratio



Kuva: Jukka Rajala

Measures 2016



- Clearing side ditches
- Leveling the field
- Diversifying crop rotation
=>Green manure crops, winter cereals, cover crops
- Organic fertilisation
 - Soil healing crops, more green weeks
 - Chicken manure
- Tillage
 - Disc => cultivator 15 cm deep
 - Subsoiling in july after second cut
- Gypsum for better Ca:Mg in July



Drainage checked and improved

21.4.2017



- Lost outlet found
40 cm deep under water
surface
- blocked with clay
- Sideditches cleared



Improvements of drainage



Kuvat: Jukka Rajala

- Underground drainage made in the year 1965
- Main pipe and some sidepipes spooled – they were ok
- Outlet found out from 40 cm deep in clay and cleared
- Main ditch, ditch between fields and side ditches cleared
- Field surface leveling to avoid water ponds

Results 2017- Winter wheat



HY 1 4.7.2017

2016: Hairy vetch+Deep tillage
+Gypsum



HY 0 4.7.2017

2016: Hairy vetch



Kuvat: Jukka Rajala

Winter wheat
grew well
Structure
improved

Weather in spring and
summer 2017
was good

Winter wheat
grew poorly
Structure
not improved
Hairy vetch alone
wasn't enough

Deficiencies in drainage



Wet
19.4.2018

- Permeability of subsoil is too low
- Field is sensitive for rainy periods
=> Groundwater up to topsoil and stays weeks



Groundwater level high
23.11.2015 and 19.4.2018



Algae
19.4.2018

Kuvat Jukka Rajala



Results and conclusions



- Better soil structure 0-35 cm
 - With better crop rotation, deep tillage and gypsum
- But: the field is very sensitive for wet periods
- => **Poor subsoil drainage is the basic problem**
- => Permeability and drainage is necessary to improve in deeper layers

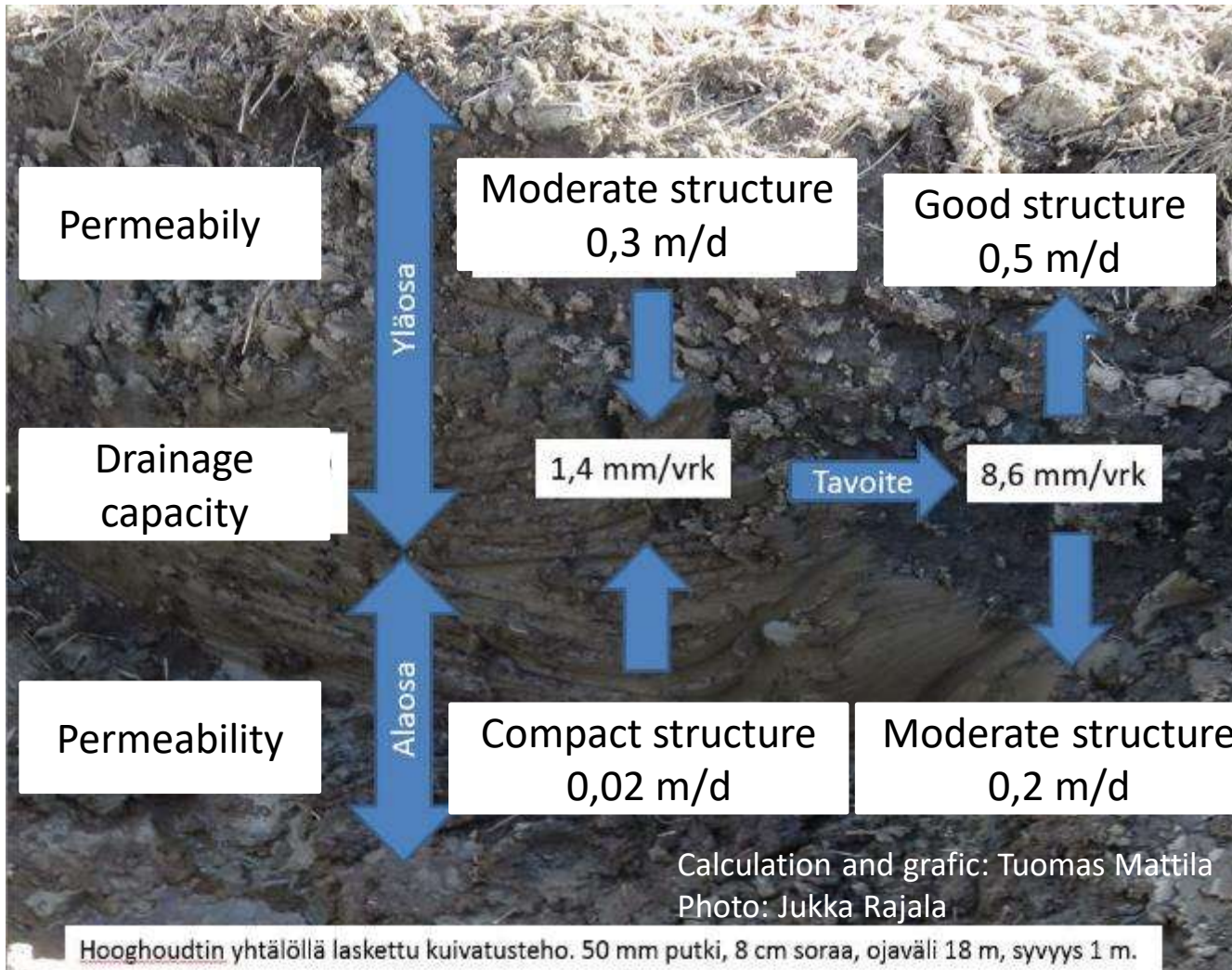


Good yields in years with optimal rainfall

Winterrye 2019



Structure and drainage capacity



Adding new pipes between old ones
 => drainage capacity 3,5x
 =>to 4,9 mm/d

Goal is 8,6 mm/d or more

**=>Normal new drainage system is not enough
 Other measures needed**

1,4 mm/d is probably too optimistic value for drainage capacity of this subsoil

Calculation and grafic: Tuomas Mattila
 Photo: Jukka Rajala

Hooghoudtin yhtälöllä laskettu kuivatusteho. 50 mm putki, 8 cm soraa, ojaväli 18 m, syvyys 1 m.

50 mm pipe, 8 cm gravel, pipe distance 18 m, 1 m deep

Fertility classes of drainage



	Poor	Tolerable	Satisfied	Good
Groundwater level	Topsoil waterlogged more 2 times	Waterlevel 1-2 times in topsoil	Always below 35 cm	Always below 60 cm
Permeability	After heavy rain many days water visible	Waterponds disappear less than in 24 hours	Waterponds disappear in few hours	Never water on the soil surface
Infiltration	On soil surface poured water runs horizontal >50 cm	<50 cm	<20 cm	Poured water disappears in small area into the whole topsoil
Drainage flow	2 mm/d	4 mm/d	8,6 mm/d	15 mm/d

[Mattila ym 2019. Good drainage – Field by field 2019. HU Ruralia Institute Report 195](#)

Compaction and drainage



- Poor drainage – basic reason for compaction
- => Soil is drying slowly, later than other parts of the field for tillage, sowing and harvesting
- => Wet soil is sensitive for compaction
- Heavy machinery didn't were the main reason for compaction
- Wet soil needs very light machinery and tire pressures
- Wetness is compacting the soil itself also



Farm example 3 - Dairy farm



400 ha
Heavy clay soils

Video: Field monitoring from drone

<https://www.helsinki.fi/fi/unitube/video/09232a4e-5157-4e0f-bd4e-8dd60ba75ef3>

- Fodder harvesting machinery are heavy and compacting
- Big distances between fields, lots of driving on the roads
- Legumes don't survive, yield- and quality losses

Kuva: Jukka Rajala

Monitoring risks for compaction –permeability



Drainage:

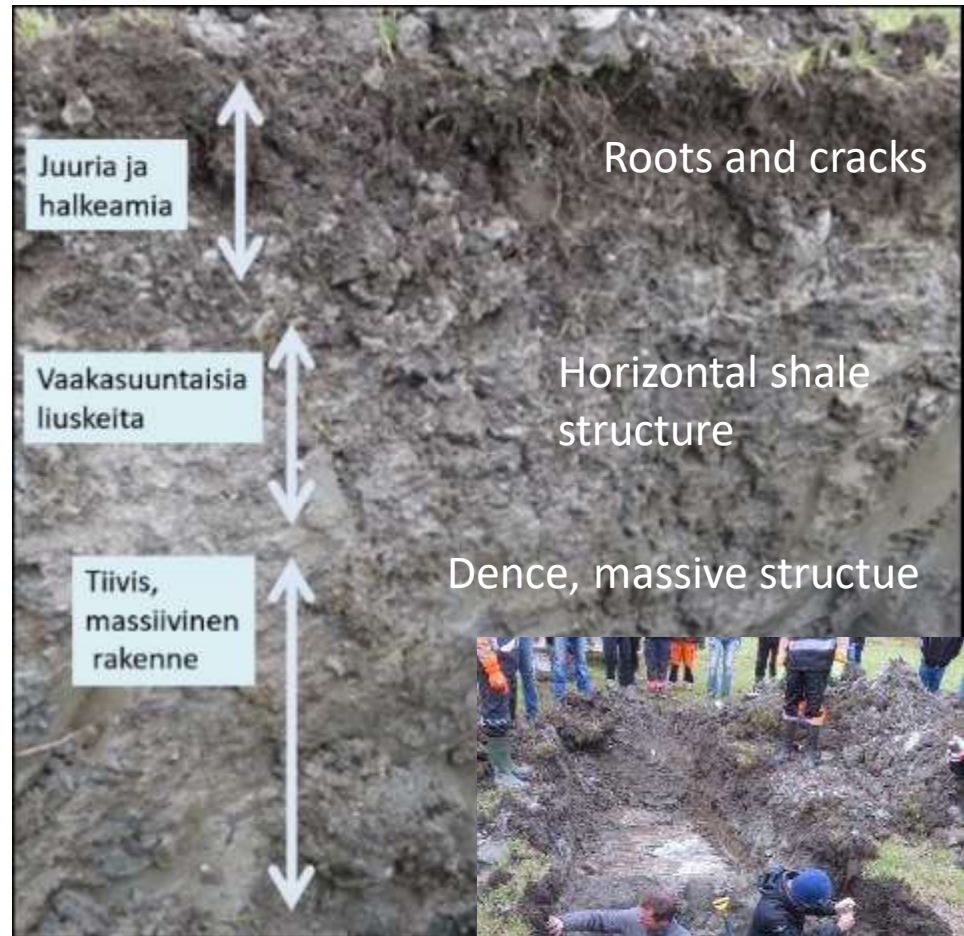
Check functionality of drainage system

-Water flow, outlets, chesspits, side ditches, water level

Permeability

- Very poor

=>How to to get good drainage?



Video: Assessment soil structure and permeability

<https://www.helsinki.fi/fi/unitube/video/09232a4e-5157-4e0f-bd4e-8dd60ba75ef3>

High risk for compaction



Water ponds in the field,
very compacted, layered structure, low permeability
+ heavy traffic, driving many times, three grass harvests
= poor conditions for root growth and for good soil structure
without proper measures/management



Measures

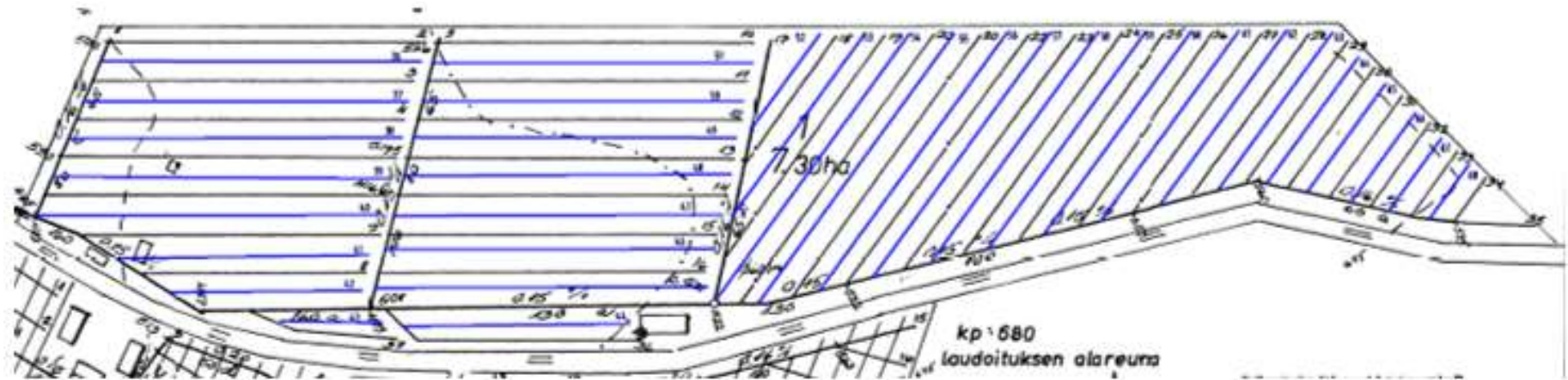


- Crop rotation with lusern/redclover grass leys
– winter cereals- summer cereals
- Organic fertilisation
- Field leveling
- Subsoiling
- More underground pipes + gravel fill
- Moul ditches
- Better tires with low tire pressures
- Slurry spreading with pulhose -system



Adding more drainage pipes + gravel fill up to 30 cm

- More effective drainage plan
- + drainage efficiency is sufficient, subsoiling helps
- Gravel costs are high



Drainage distance 17 m
new pipes between old ones

Gravel need vs. wide and deepness of ditch



Gravel up to 30 cm, m³/ha, 543 m

Width of ditch, m

Ojaleveys m

0,12

0,17

0,22

0,27

Ojasyvyys m

Gravel soraa, m³/ha

Deepness of ditch 0,75

16

23

30

37

0,80

20

28

36

44

0,85

23

32

42

51

0,90

26

37

48

59

0,95

49

42

54

66

1,00

33

46

60

73

aurasalaoja

'ketjumara'

'ketjumara'

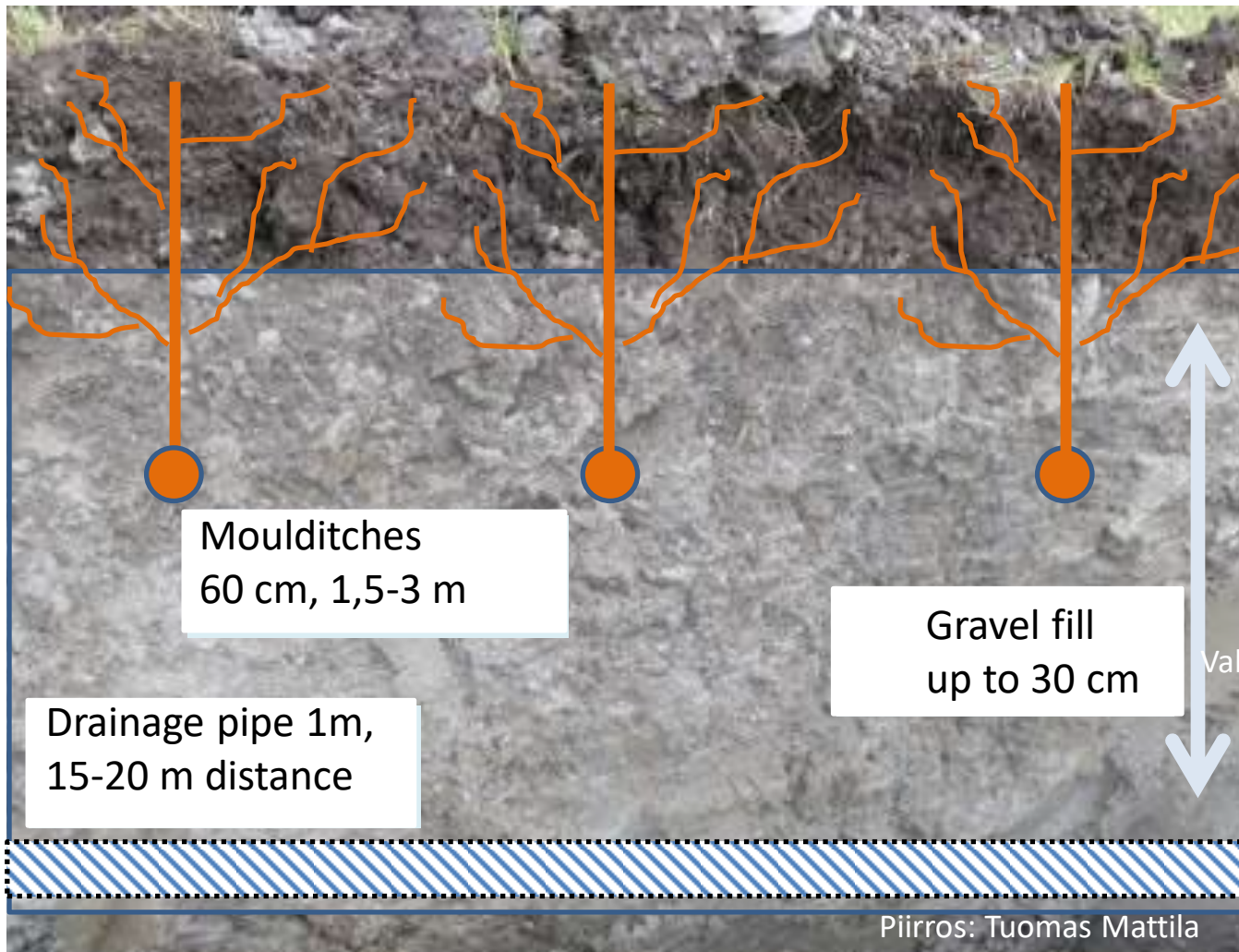
'ukkomara'

Drainage machinery types in use

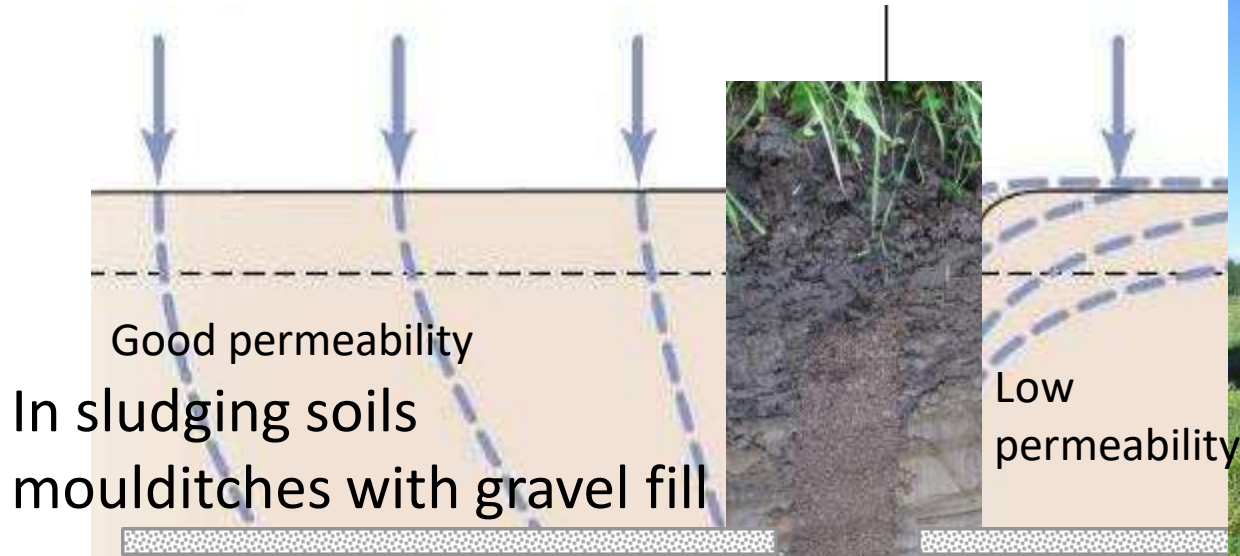


Kuva: Jukka Rajala

Gravel filled ditches + moulditches give better drainage

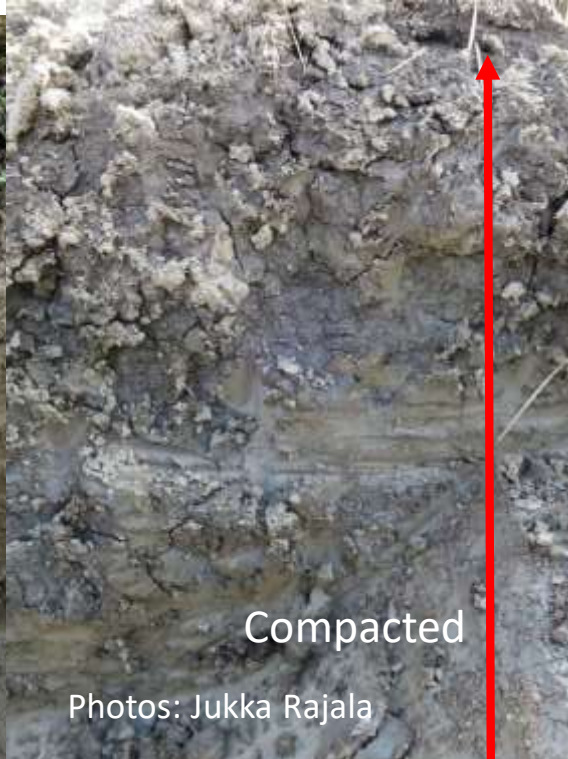


Water flow and permeability



oil compaction or drainage

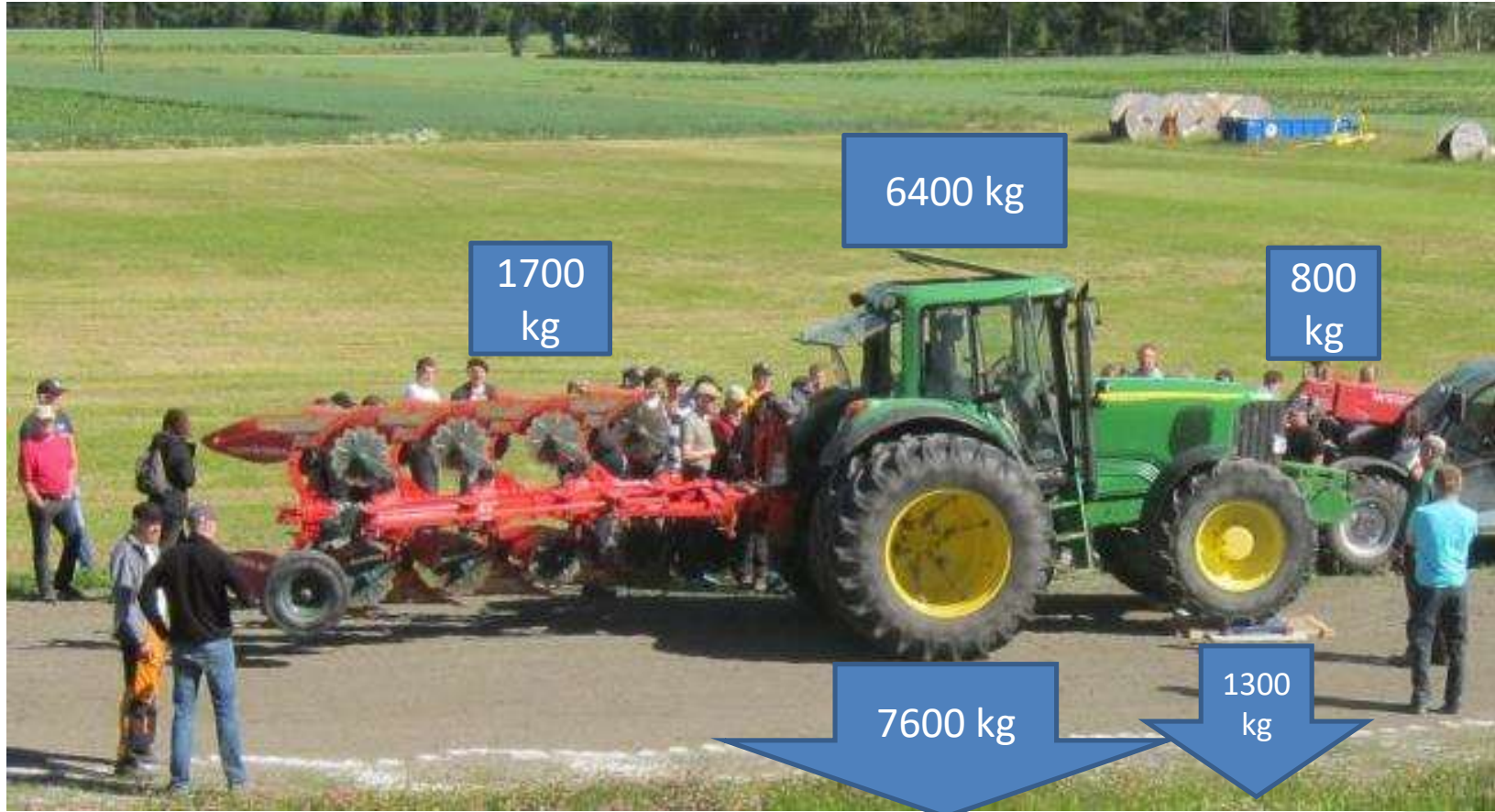
Different Soil profiles



Photos: Jukka Rajala

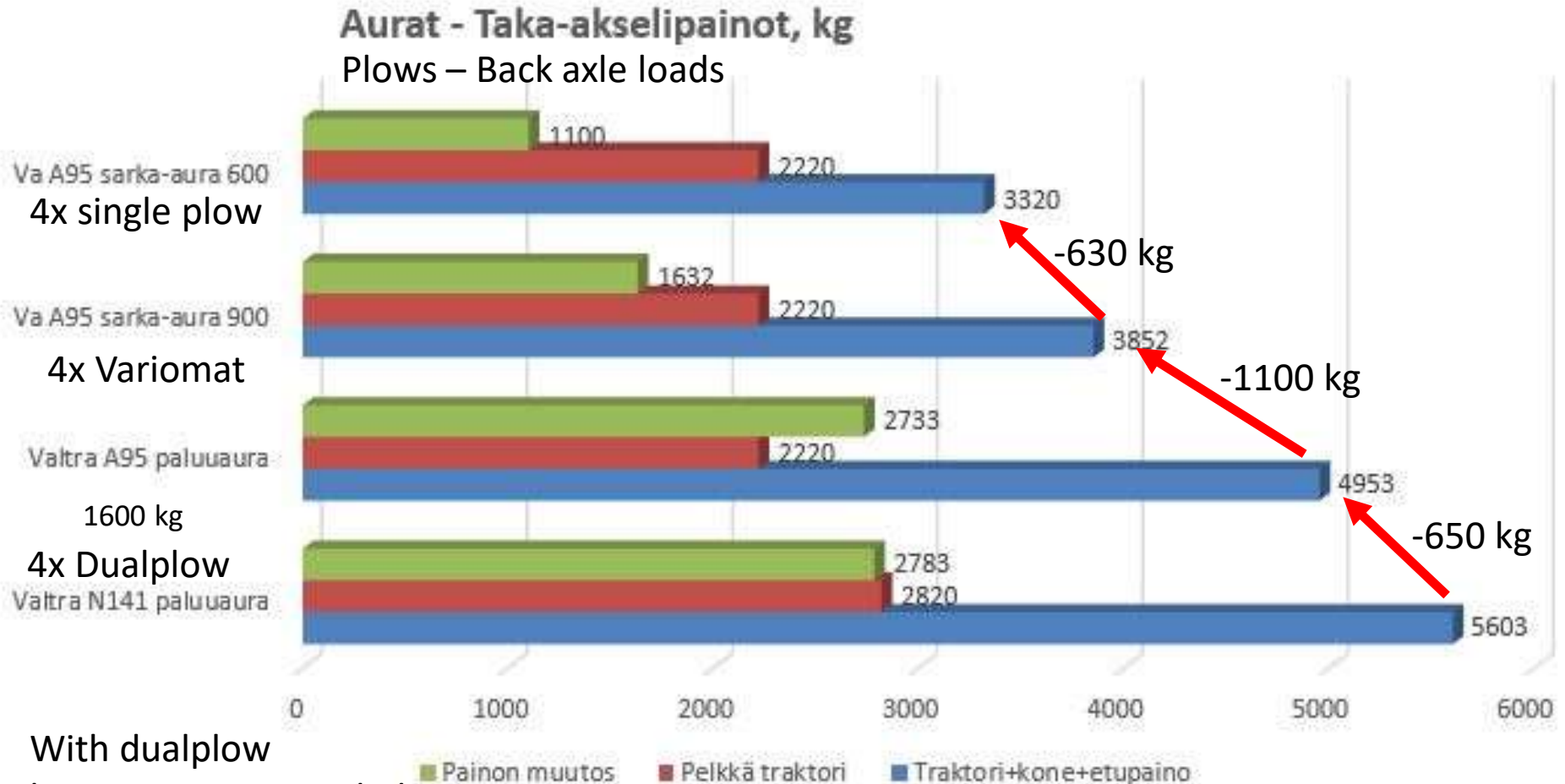
Risks for compacting

- How big are wheel loads?



Siva Jaana Ravander

Count wheel loads with OSMO-tool: Axle loads with different plows

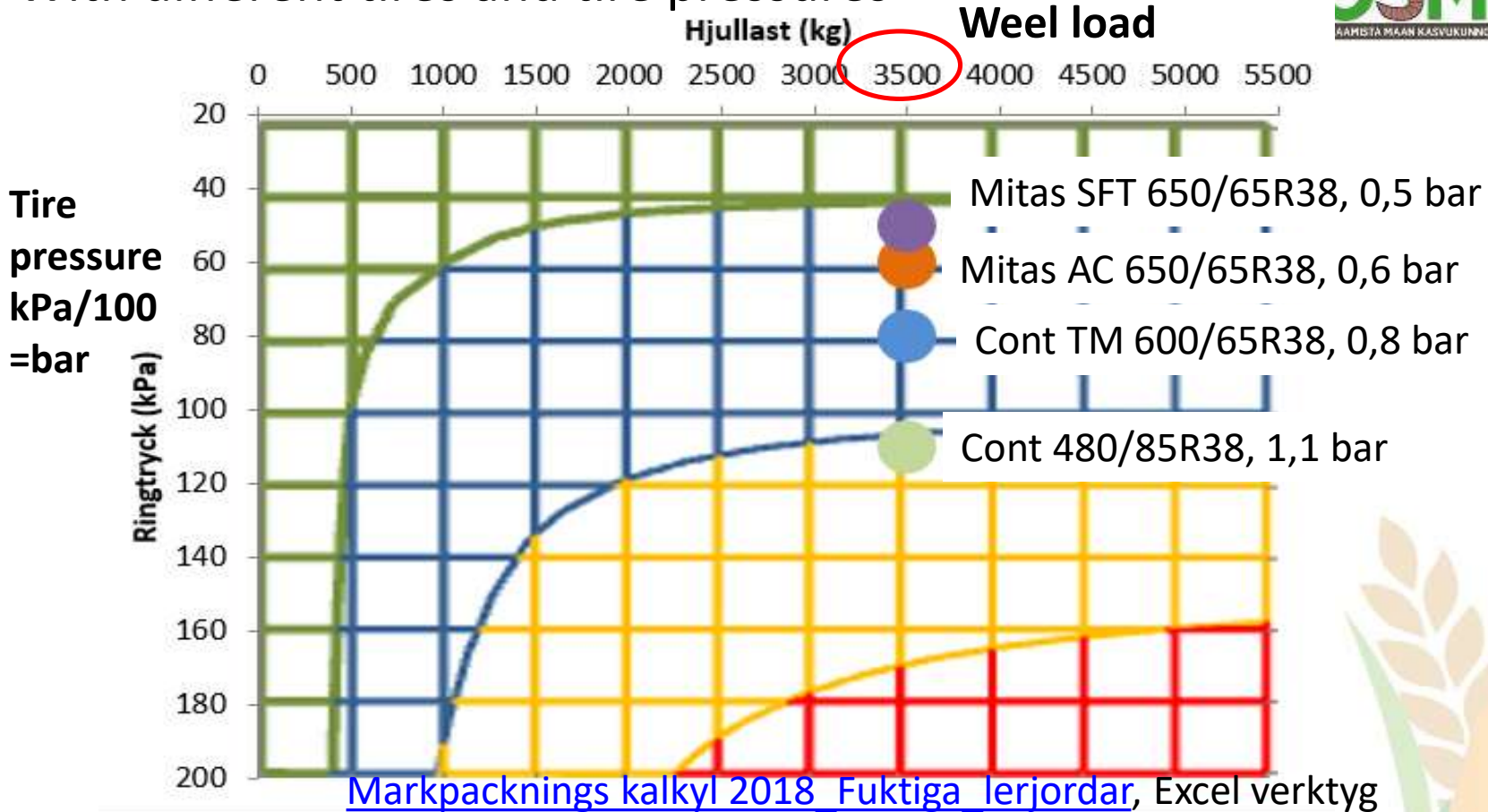


With dualplow
heavier tractor needed

[Maskinernas jämvikts-Verktyg](#)

Monitor Risk för markpackning 22 cm

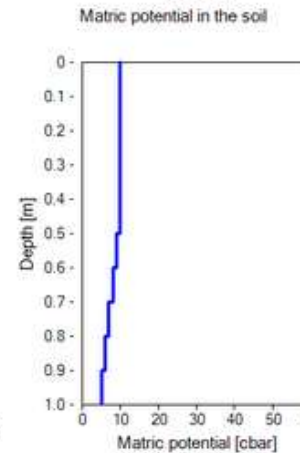
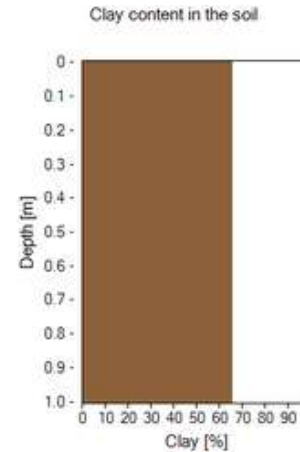
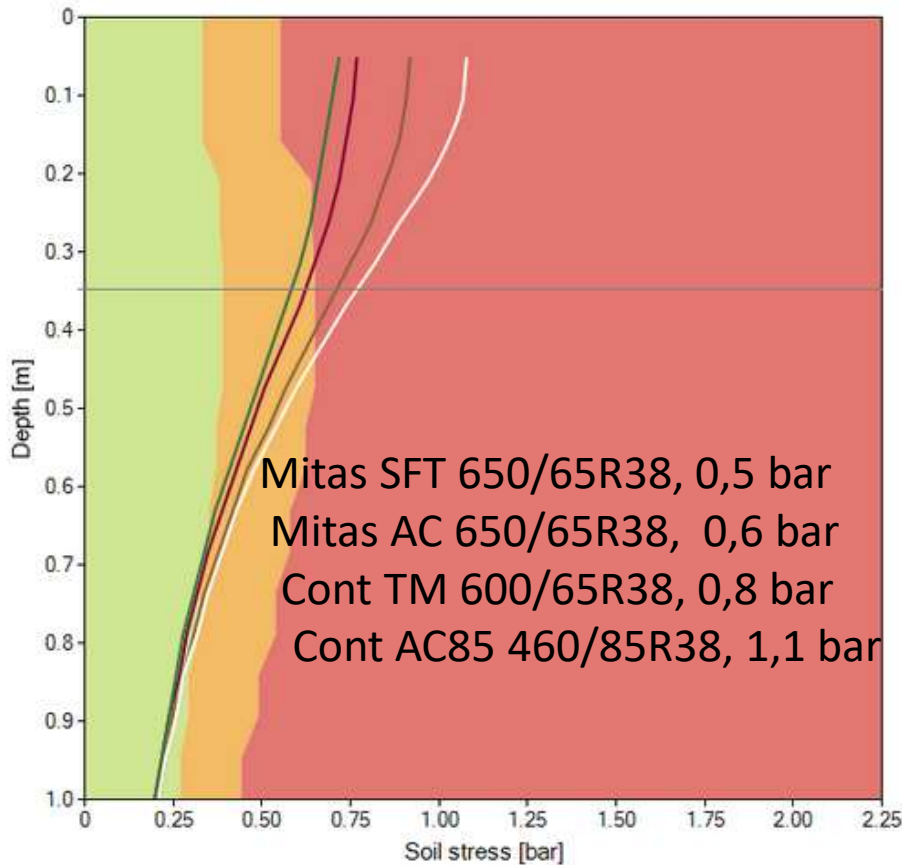
With different tires and tire pressures



Moist clay soil

< 50 kPa	God: låg risk för markpackning till ex. vid vårbruk
50-100 kPa	Dålig: Risk för markpackning i fuktiga förhållanden
100-200 kPa	Användning enbart i kruttorra förhållanden!!!!
> 200 kPa	Flytta till fasta körspår eller bort från åkern!!!!

Soil stress vs soil strength



Tires with
3500 kg
wheelload

Heavy clay soil,
moist

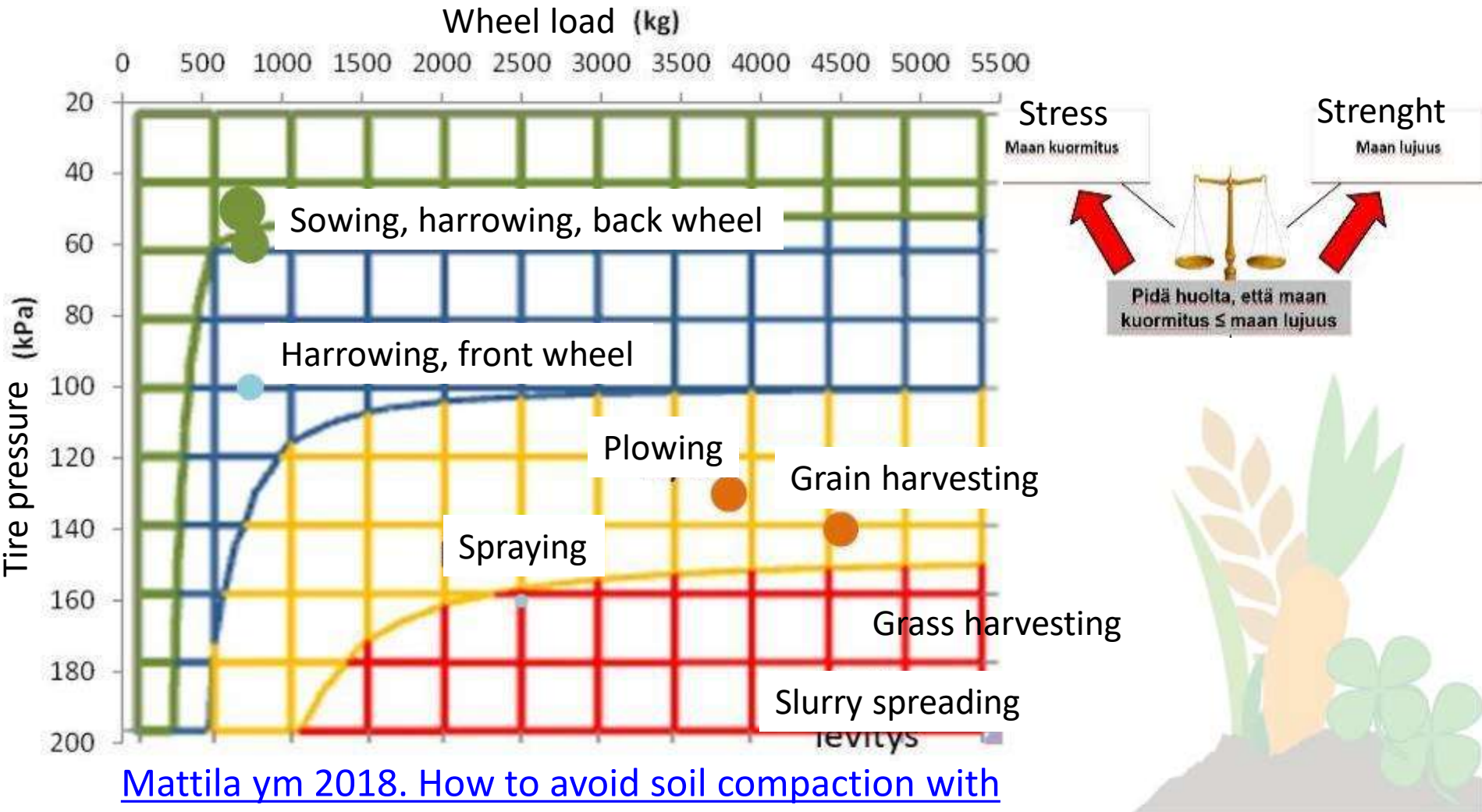
www.Terranimo.world

180-280 HP tractor	Color in diagram	Manufacturer	Tyre name	Tyre dimension	Wheel load	Pressure
Left front wheel		Continental	AC 85	460/85R38	3'500 kg	1.10 bar
Right front wheel		Continental	TractorMaster	600/65R38	3'500 kg	0.80 bar
Left rear wheel		Mitas	SFT (ex. SYT)	650/65R38	3'500 kg	0.50 bar
Right rear wheel		Mitas	AC 65	650/65R38	3'500 kg	0.60 bar

Rajala J. Soil compaction or drainage



Scan the risks for soil compaction



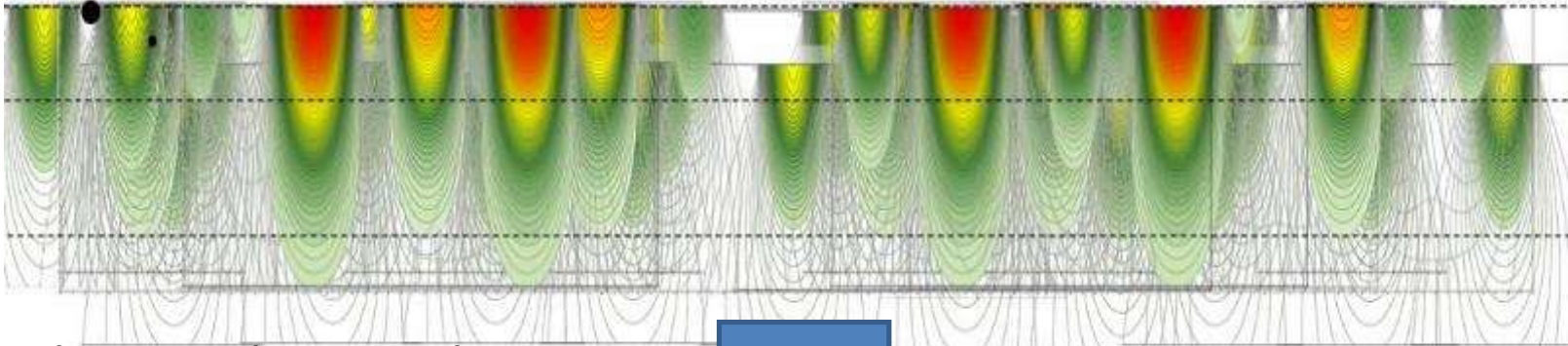
[Mattila ym 2018. How to avoid soil compaction with better tires. HU Ruralia Institute, Raport 175.](#)

Decrease risk for soil compaction



Present situation

1,6 m plow, 6 m slurry spreading, 3,8 m combine, 4 m sowing machine, 6 m harrow, 15 m spray



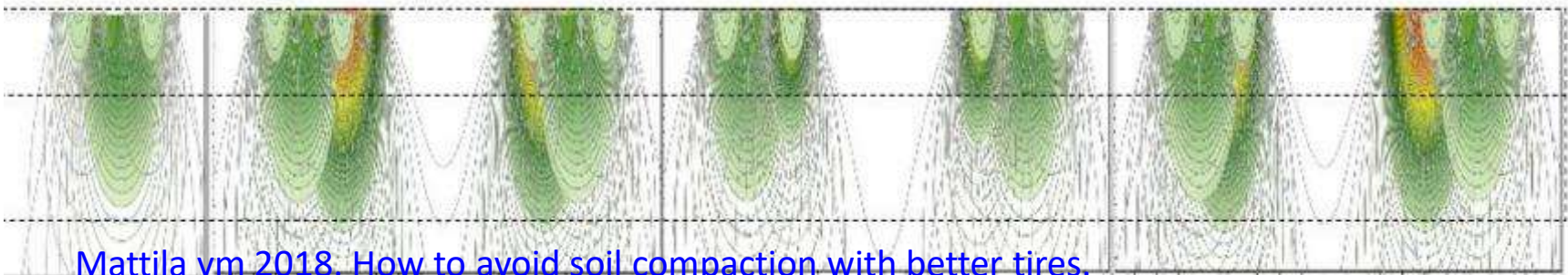
Plan machinery chains



Degrease tire pressures

Proposal -

4 m cultivator, 8 m slurry spreading, 4 m combine, 4 m sowing machine, 6 m harrow, 16 m spray



[Mattila ym 2018. How to avoid soil compaction with better tires.](#)

[HU Ruralia Institute, Raport 175.](#)

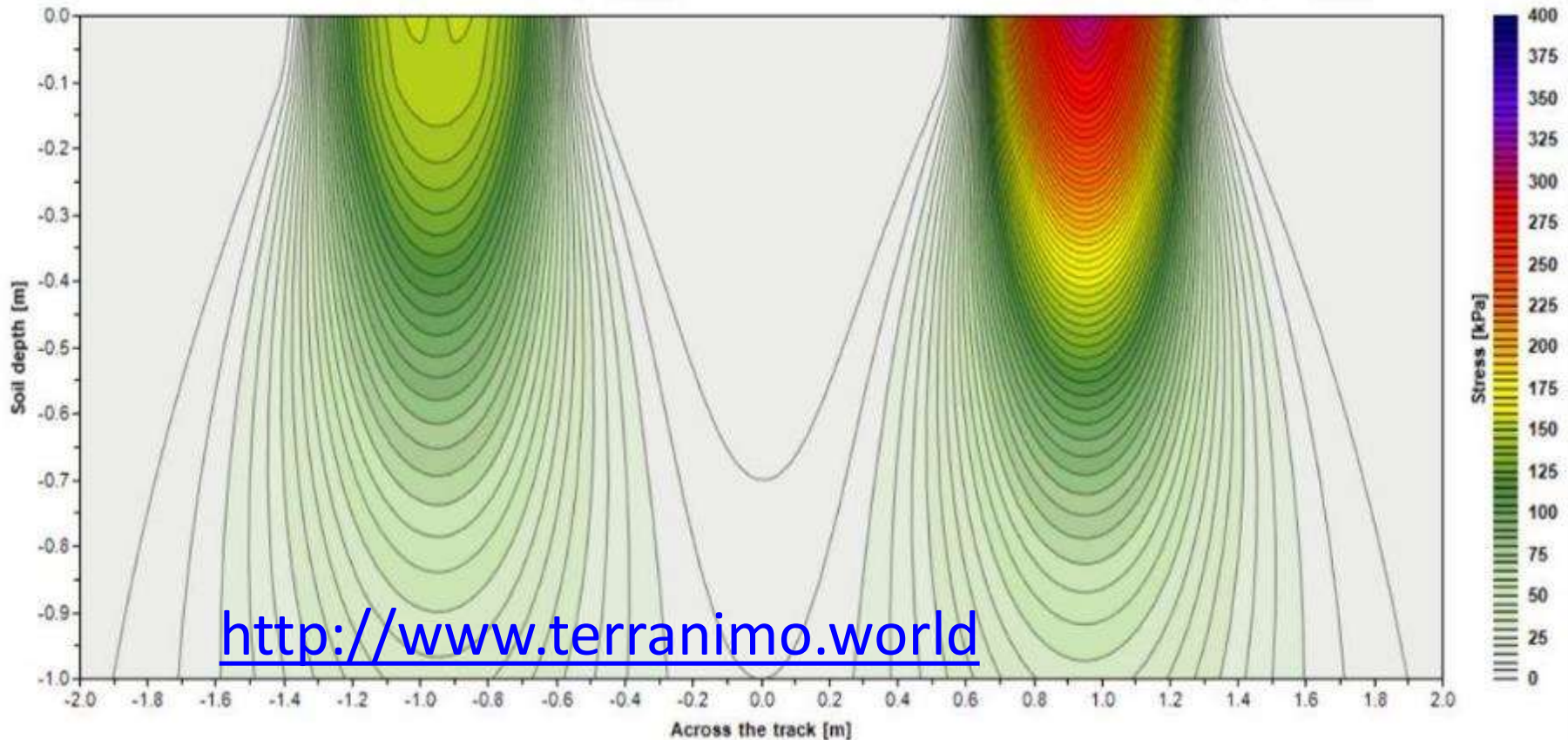
Decrease risk for compaction



Which tire for slurry trailer? 6000 kg wheelload

Nokia ESL SB 800/60R34, 0,7 bar

Nokia ESL SB 700/50R26,5, 2,1 bar



Tire pressures for tractor in different works



Maskin		Deutz-Fahr DX6.30							
Däck	Framaxeldäck 420/70R28 (133 AB) Belastad radie: 605 mm				Bakaxeldäck 520/70R38 (150 AB) Belastad radie: 789 mm				
	På vägen 25km/h		På åkern 10 km/h		På vägen 25km/h		På åkern 10 km/h		
Arbete	Däck- belastning (t)	Luft- tryck (bar)	Däck- belastning (t)	Luft- tryck (bar)	Däck- belastning (t)	Luft- tryck (bar)	Däck- belastning (t)	Luft- tryck (bar)	
1. Kultivering	0,5	0,5	0,5	0,5	0,9	0,5	0,9	0,5	
2. Djupluckring	0,3	0,5	0,6	0,5	1,4	0,6	1,4	0,6	
3. Harvning	0,5	0,5	0,5	0,5	0,9	0,5	0,9	0,5	
4. Släpvagn, dragning	0,7	0,7	0,7	0,7	2,7	1,2	2,7	0,8	

[Maskinernas ringtryck Tabell med Exempel](#)

How to fix?



- Monitoring. Symptoms vs basic reasons?
 - Soil structure; 0-5 cm, 5-15 cm, 15-25 cm, Upper subsoil, deeper subsoil, infiltration, permeability, crumble stability
- Avoid water ponds: Field leveling
- Drainage: Ground water level, side ditches, main ditches, outlet, underground drainage:
 - Clean and fix, Add new pipes with lots of gravel
 - Make sure that water can flow into pipes fast enough
- Use proper biol. and mech. tillage to loosen the compacted soil
- Avoid new compaction: Better crop rotation, field works on dry soil, Scan compaction risks, low wheel loads and tire pressures

Careful! - Easy to distroy



Harvested cereal field

- Rails every 7 m

Working wide of combine 3,6 m



No rails from combine 3,6 m

Raking and baling rails 7 m



Soil structure

Harvesting rails



Baling rails

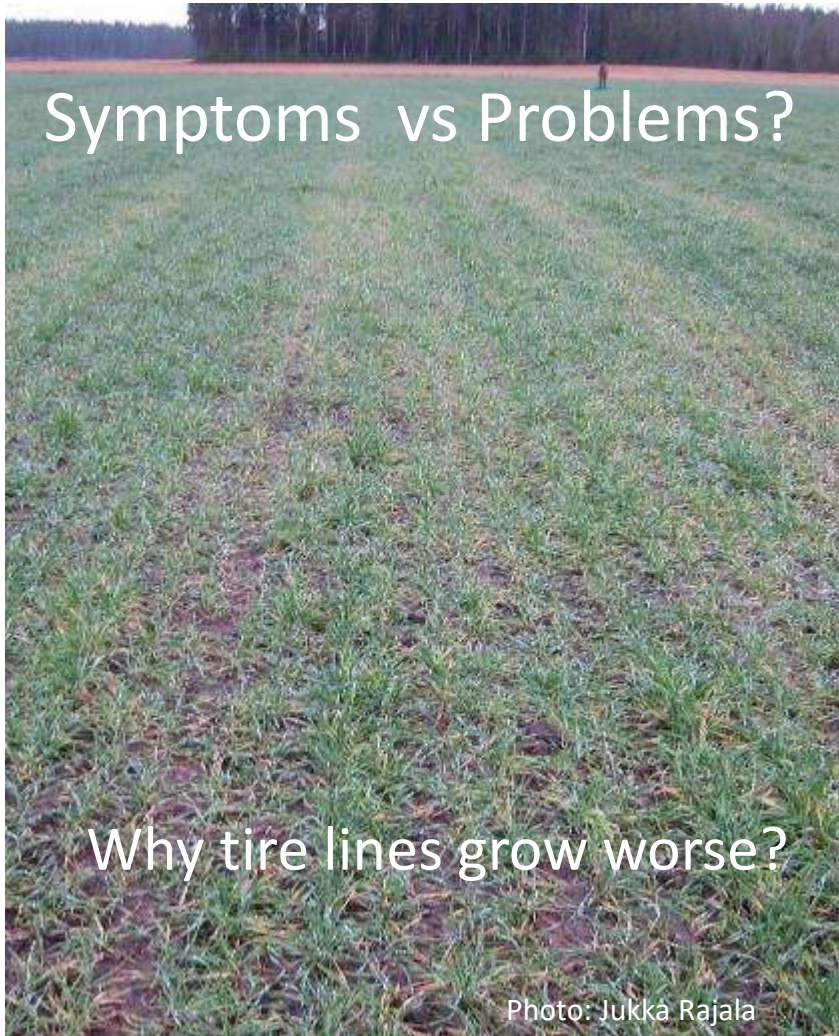


Water level in spade pits

10.10.2019



- Which are the problems?



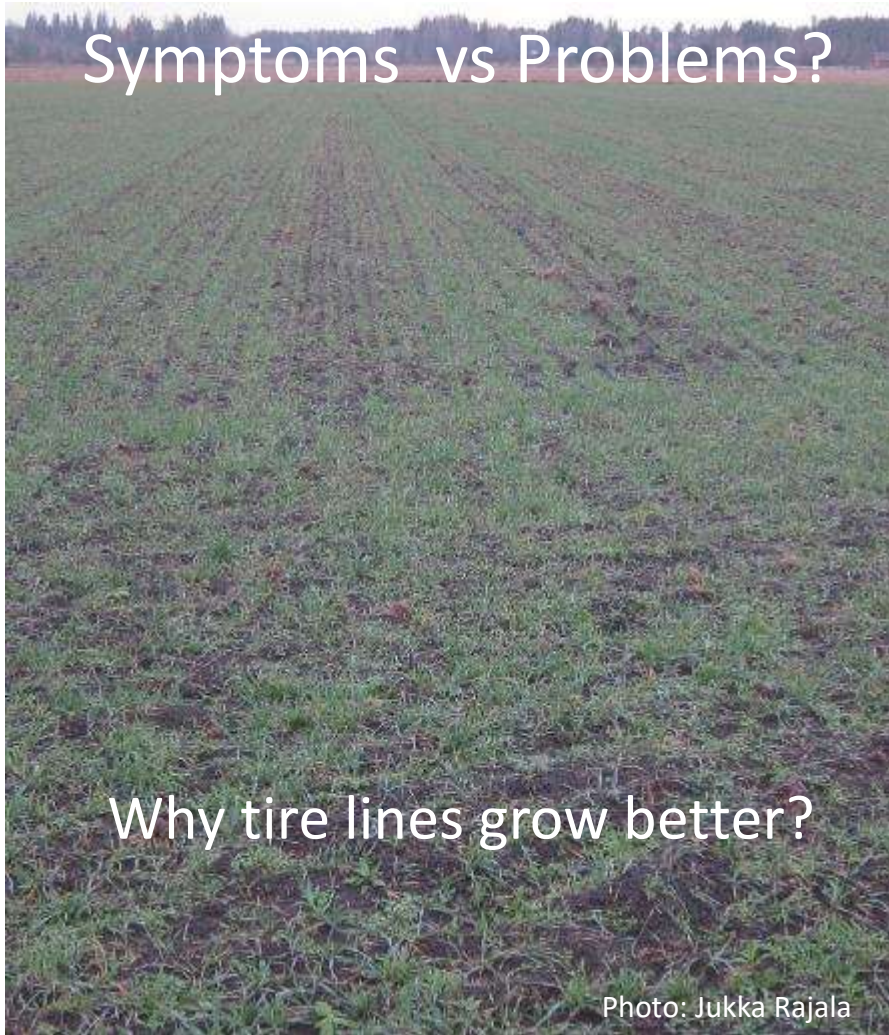
- Tire lines are compacted too much by sowing.
- The soil was too wet.
- =>Permeability is too low in tire lines
- =>Oxygen deficiency
- =>Poor root activity
- =>Potassium deficiency

Photo: Jukka Rajala

- Which are the problems?



Symptoms vs Problems?



Why tire lines grow better?

Photo: Jukka Rajala

Tire lines are compacted enough by sowing.

Between tire lines the soil is too loose.

In dry and warm period cereal fly (*Oscinella frit*) injured the crop where it was too loose.

=> Soil structure vs pest resistance of crops?



(*Oscinella frit*)

Conclusions

- Drainage and soil structure belongs together as "siamese twillings"
- Poor drainage makes soil sensitive for compaction
- Poor structure decreases infiltration and permeability. Permeability is more important than soil texture.
- It's important to monitor the situation in the field priefly
Symptoms vs basic reasons?
- Drainage and structure have to improve at the same time
- Avoid compaction!

Soil brought for leveling

New pipes added to a part of the field





More pipes installing
be running 6.2020



More info



[Mattila et al 2019. Good drainage – field by field.](#) (in Finnish)
Report 195, University of Helsinki Ruralia Institute

[Leaflets of soil structure and drainage](#)

[Markpacknings kalkyl 2018 Fuktiga lerjordar](#), Excel verktyg

[Maskinernas jämvikts-Verktyg 2017](#)

[Maskinernas ringtryck Tabell med Exempel](#)

www.terranimo.world

Video: Field monitoring from drone

<https://www.helsinki.fi/fi/unitube/video/09232a4e-5157-4e0f-bd4e-8dd60ba75ef3>

Video: Assesment soil structure and permeability

<https://www.helsinki.fi/fi/unitube/video/09232a4e-5157-4e0f-bd4e-8dd60ba75ef3>

Land drainage manual, Teagasc

<https://www.teagasc.ie/environment/soil/soil-drainage/>

Teagasc Manual on Drainage and soil management 2013

<https://www.teagasc.ie/publications/2016/teagasc-manual-on-drainage-and-soil-management.php>



Thankyou!



OSMO-team

Projectmanager

Jukka Rajala

University of Helsinki

Ruralia Institute Mikkeli

jukka.rajala@helsinki.fi

<https://helsinki.fi/ruralia/mikkeli>

www.maan-kasvukunto.fi



Jukka Rajala

www.maan-kasvukunto.fi