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A Soil Quality Story from The Netherlands

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Canada

Soil Quality vs. Soil Health

- “soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans”

  - Natural Resources Conservation Service, USA (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/)

- “soil quality is the preferred term of researchers, soil health is often preferred by farmers.”

Bunemann, et al., 2018

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Soil Quality vs. Soil Health

- "Distinction between soil quality and soil health developed from a matter of principle to a matter of preference and we therefore consider the terms equivalent."

Bunemann, et al., 2018

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Threats, Functions, & Services

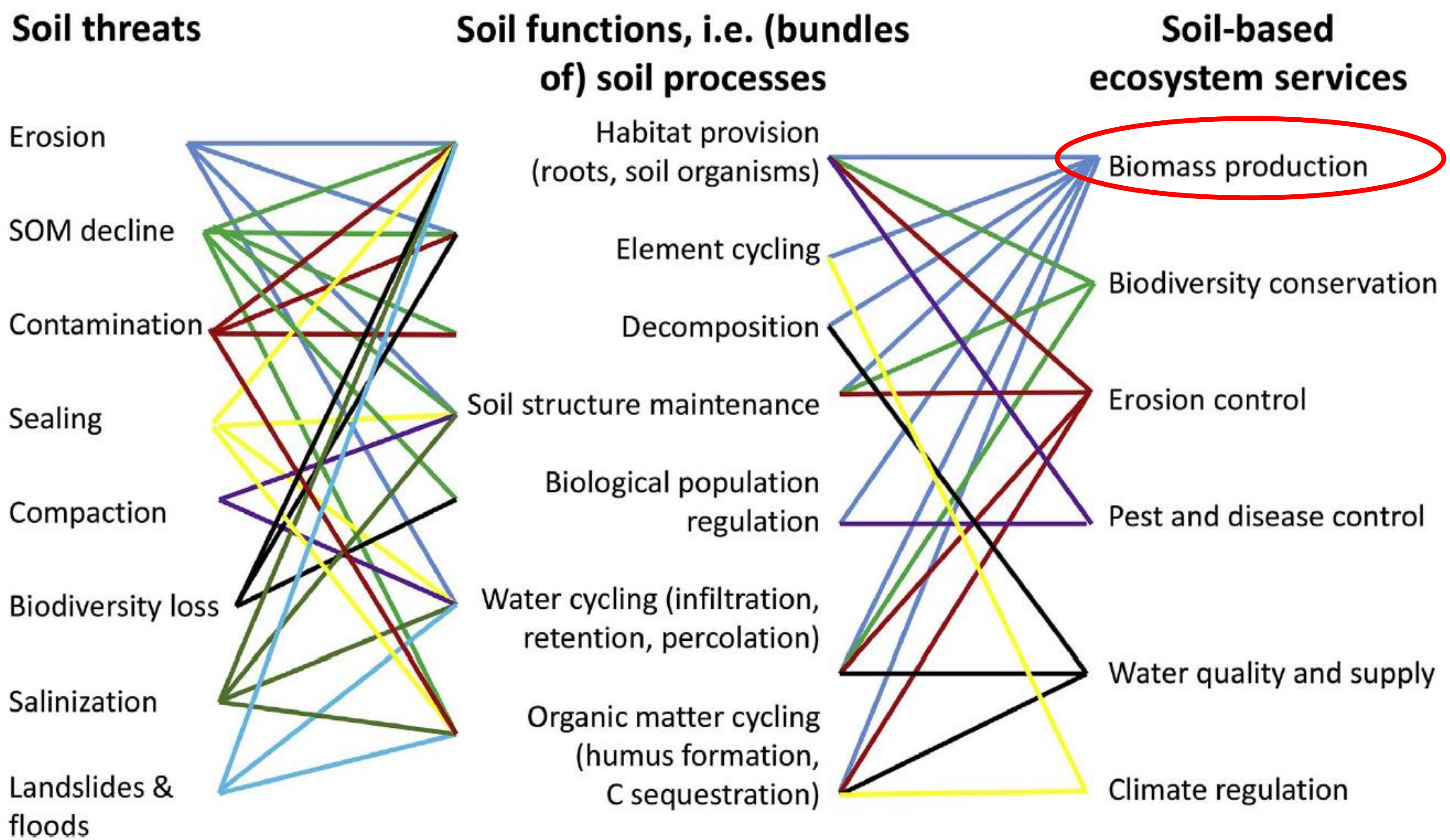

Fig. 2. Linkages between soil threats, soil functions and soil-based ecosystem services. Further developed from the scheme presented by Kibblewhite et al. (2008a) and modified by Brussaard (2012). Bunemann, et al., 2018

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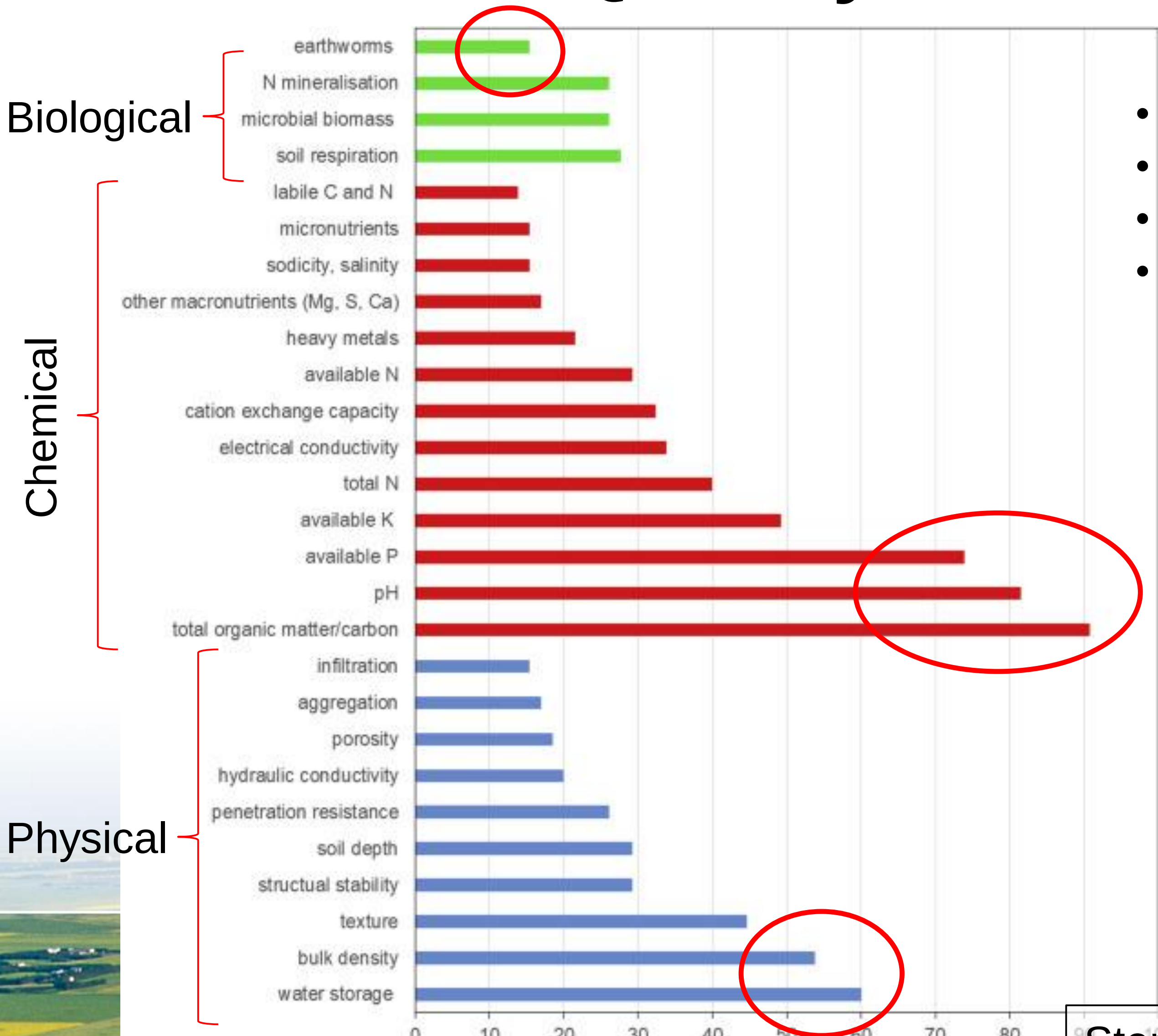
Soil Quality Indicators



Bunemann, et al., 2018

- 65 soil quality assessments
- 5 are Canadian
- Avg. 11 indicators per
- Most frequent indicators:
  - Carbon
  - pH
  - Available P
  - Water storage
  - Density

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BIOPHYSICAL SOIL QUALITY OF TILLAGE SYSTEMS IN CONVENTIONAL AND ORGANIC FARMING

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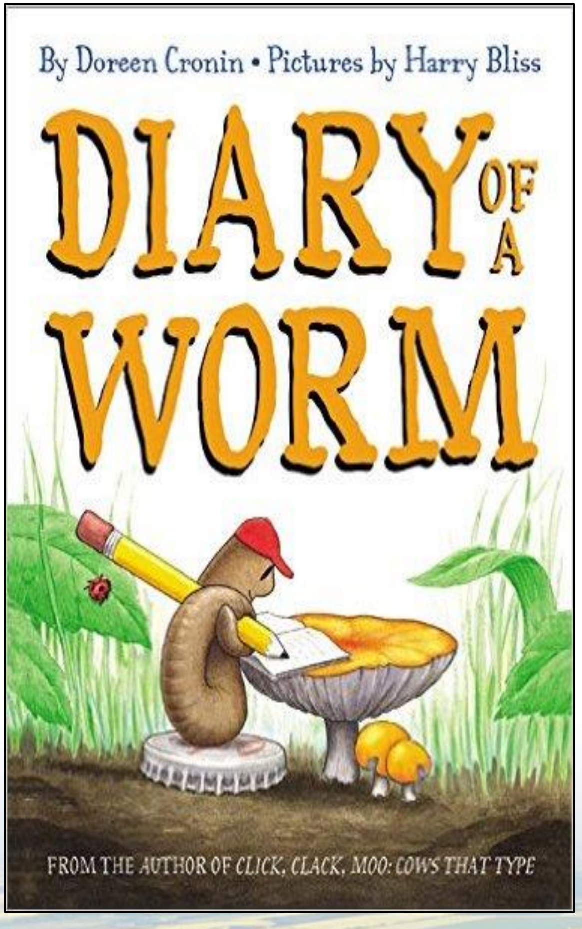
Earthworms are Everywhere



"When we dig tunnels, we help take care of the earth“

"must make tunnel - help Earth breathe!"

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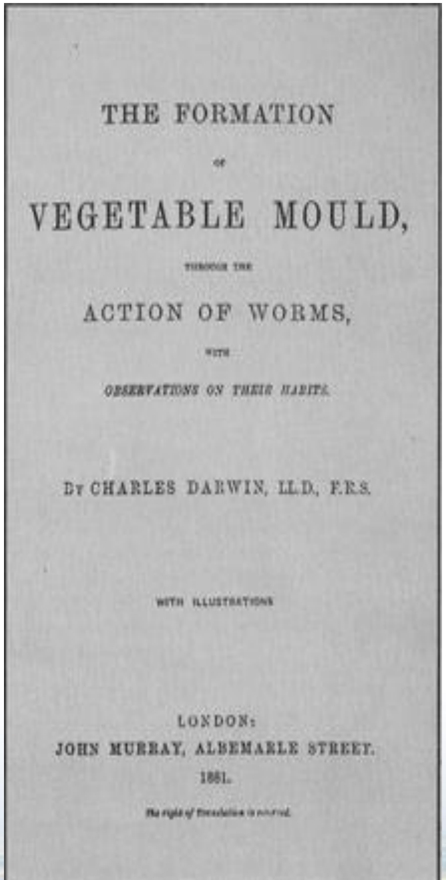
Darwin’s Book After Evolution


THE FORMATION
OF
VEGETABLE MOULD,
THROUGH THE
ACTION OF WORMS,
WITH
OBSERVATIONS ON THEIR HABITS.

BY CHARLES DARWIN, LL.D., F.R.S.

WITH ILLUSTRATIONS

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1881.

“The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be thus ploughed by earth-worms.”

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Soil Degradation

Photo: Mirjam Pulleman

Dutch crop rotations including potatoes and sugar beets cause soil compaction

- Decreased physical functioning
- Impede crop growth
- GHG
- Soil biota, including earthworms

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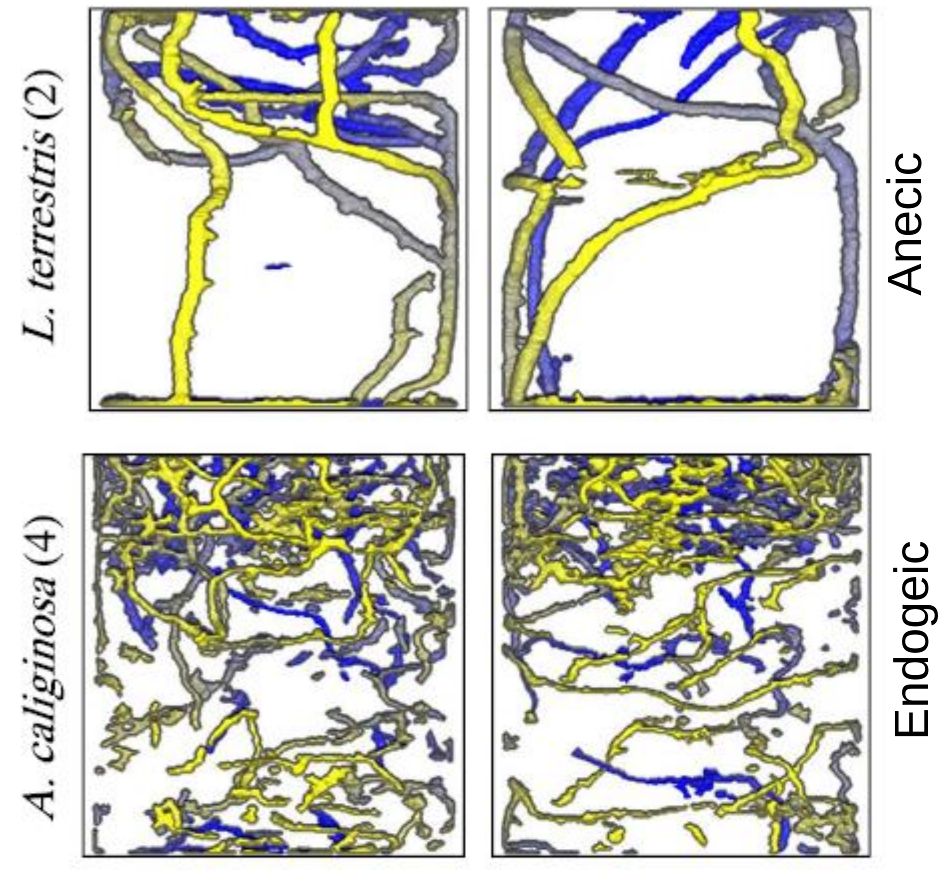
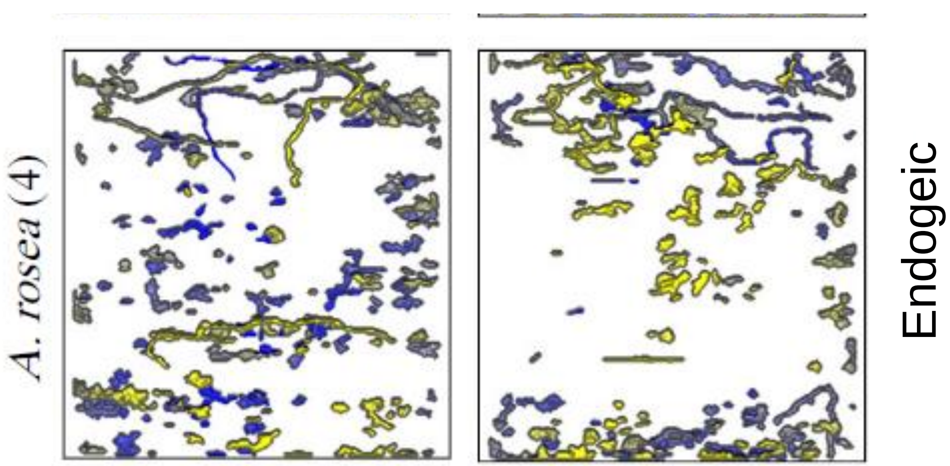
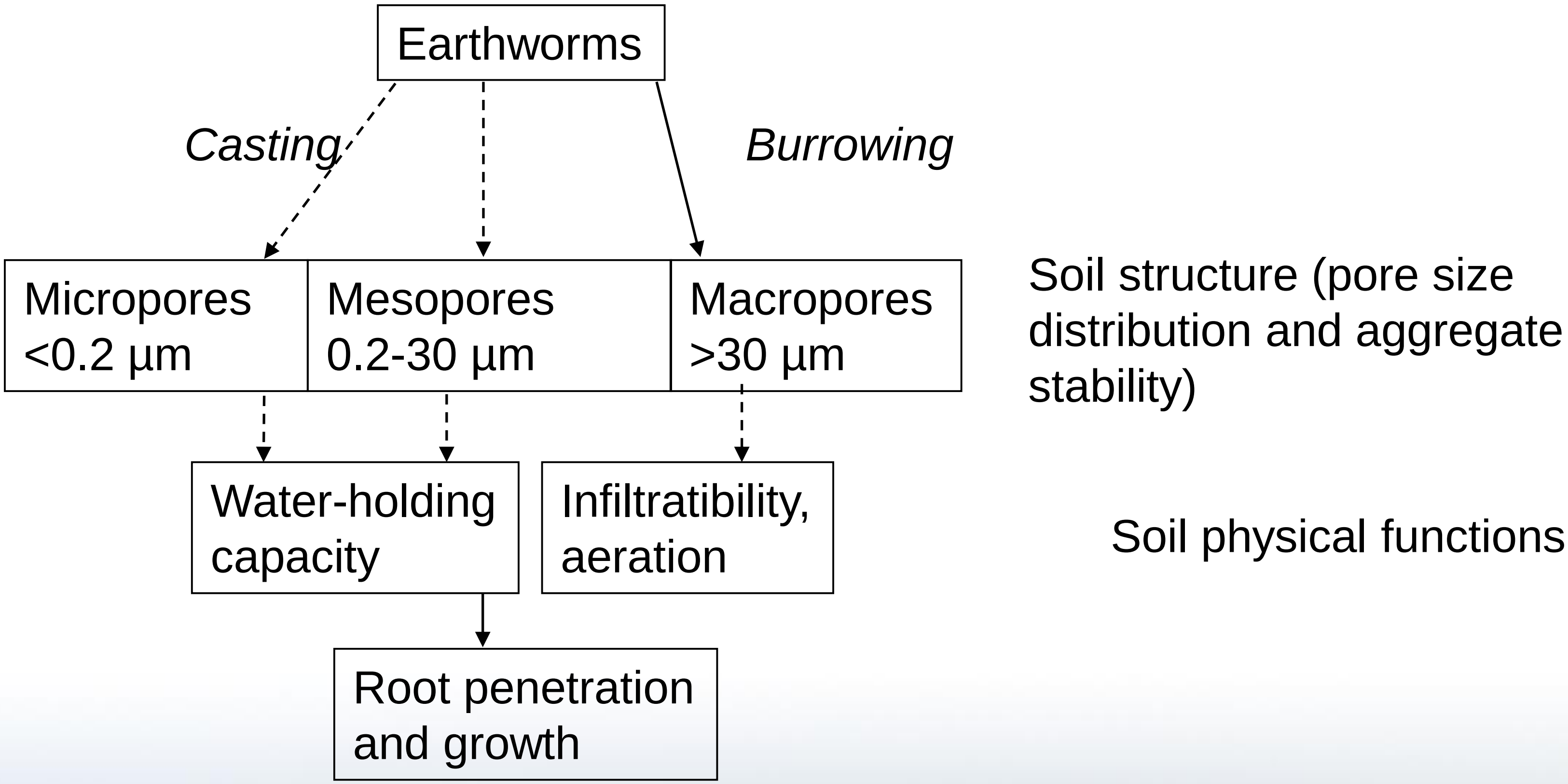
- Earthworm species behaviour differ
- Called ecological groups
- Influence different soil functions





Botinelli, et al., 2015

Earthworms Influence Structure and Function



Brown, G., Edwards, C., Brussaard, L. 2004. How Earthworms Affect Plant Growth: Burrowing into the Mechanisms. In: Edwards, C. (Ed.), Earthworm Ecology. CRC Press, USA, pp 28

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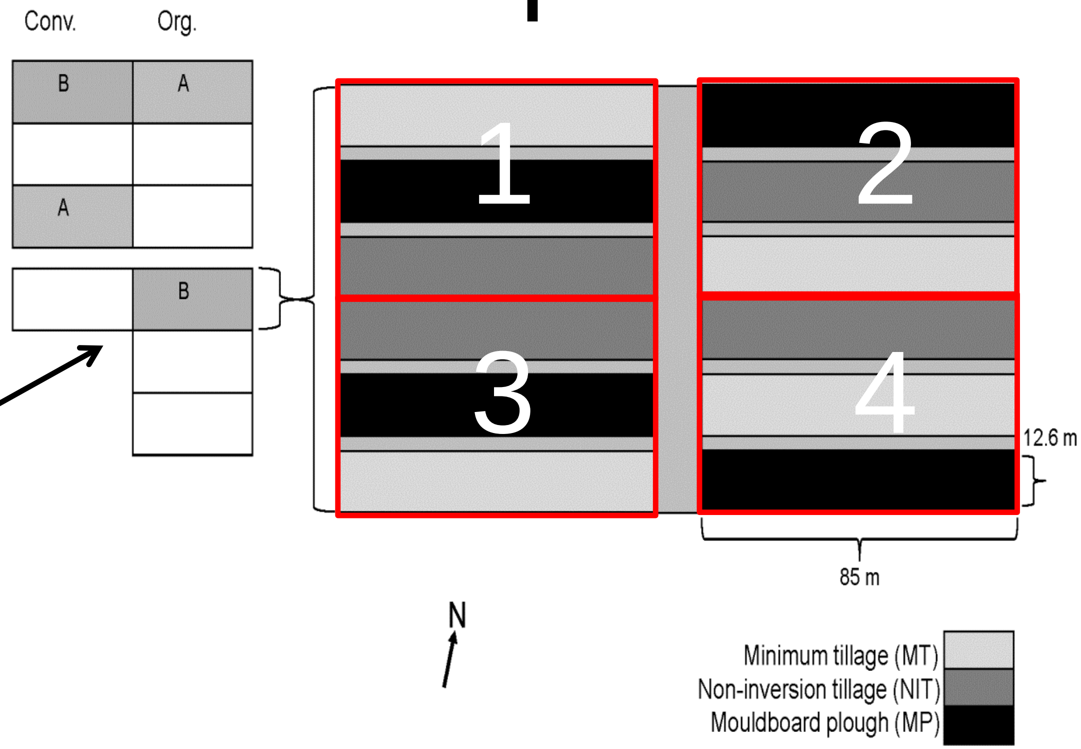
Site Description



Flevopolder, the Netherlands - reclaimed land (1950’s)
Soil: Calcareous marine clay loam, 23% clay, 12% silt, 66 % clay, pH 7.9, SOM 3.2% avg.
Mean temp. 36 F winter, 63 F in summer, 31.5 inches per yr

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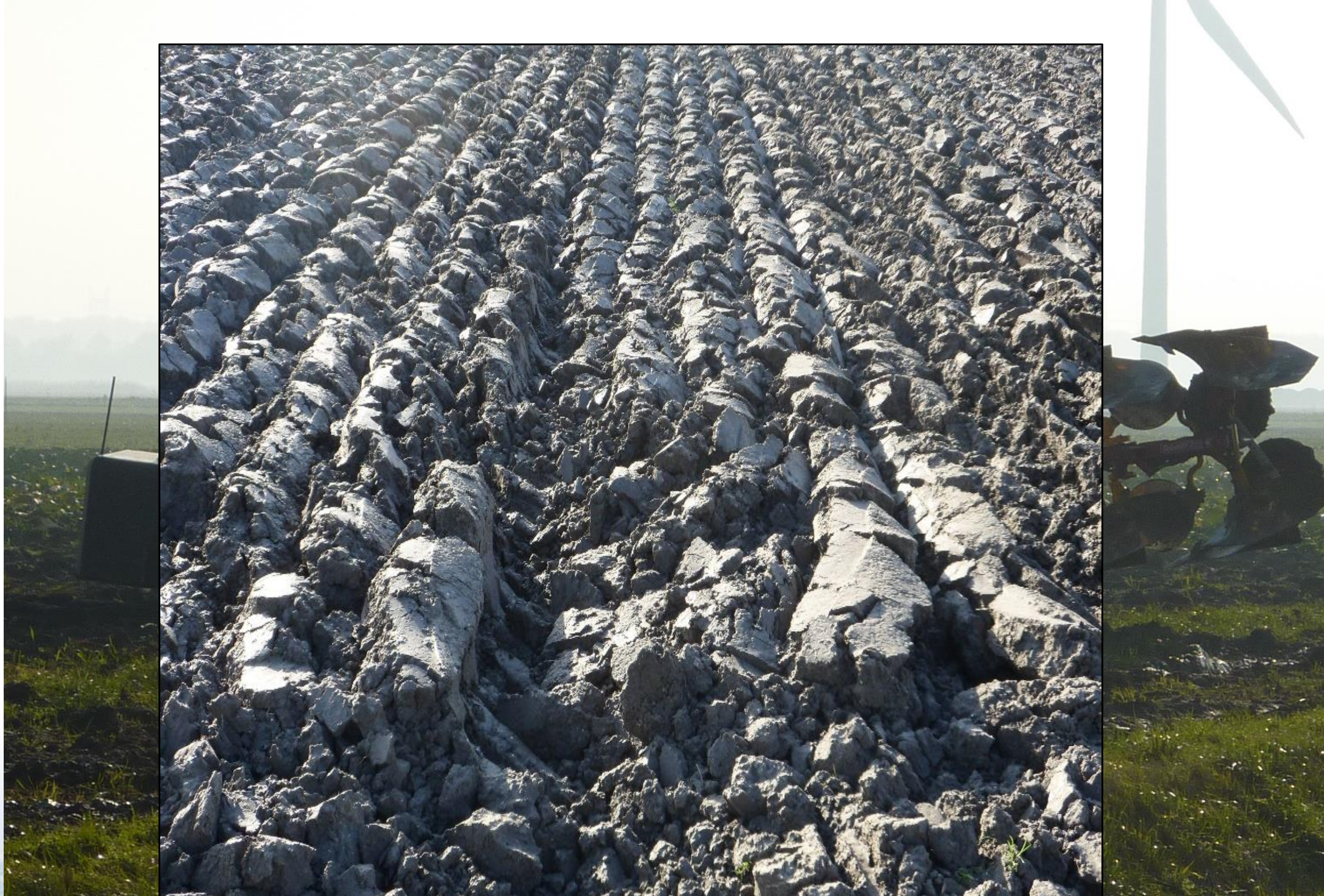
Mouldboard Ploughing



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Non-inversion Tillage

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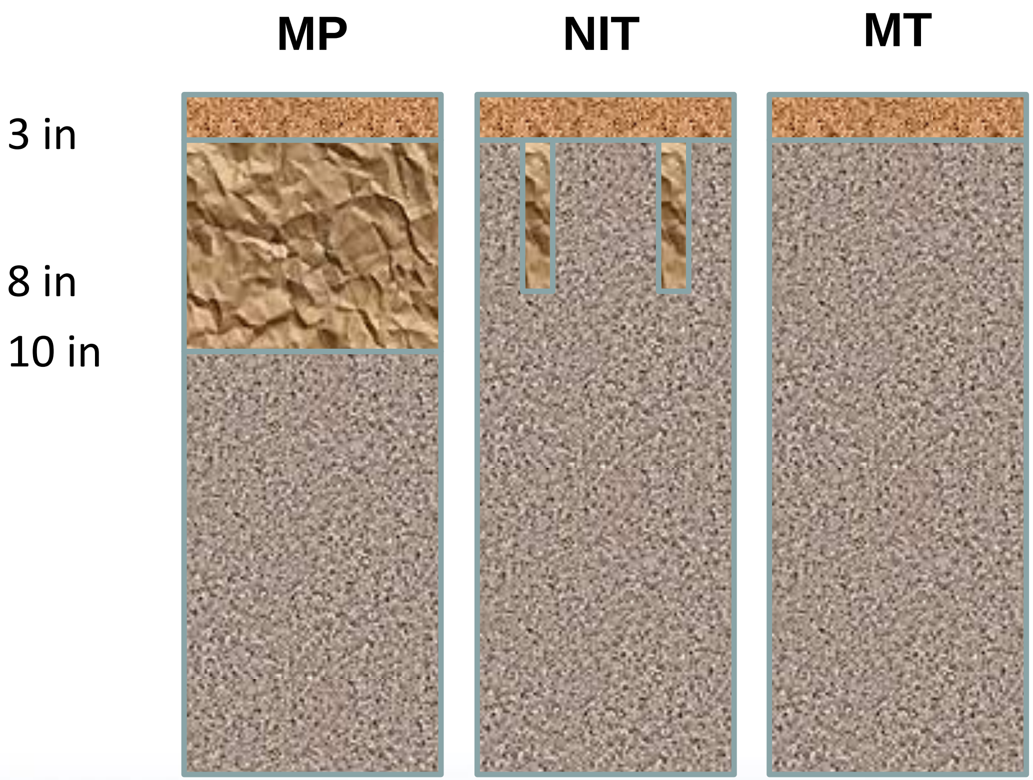
Tillage Treatments



All with controlled traffic lanes

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Crop Rotations

Conventional crop rotation (synthetic fertilizers)

Organic crop rotation (animal manure)

+ use of green manure where possible

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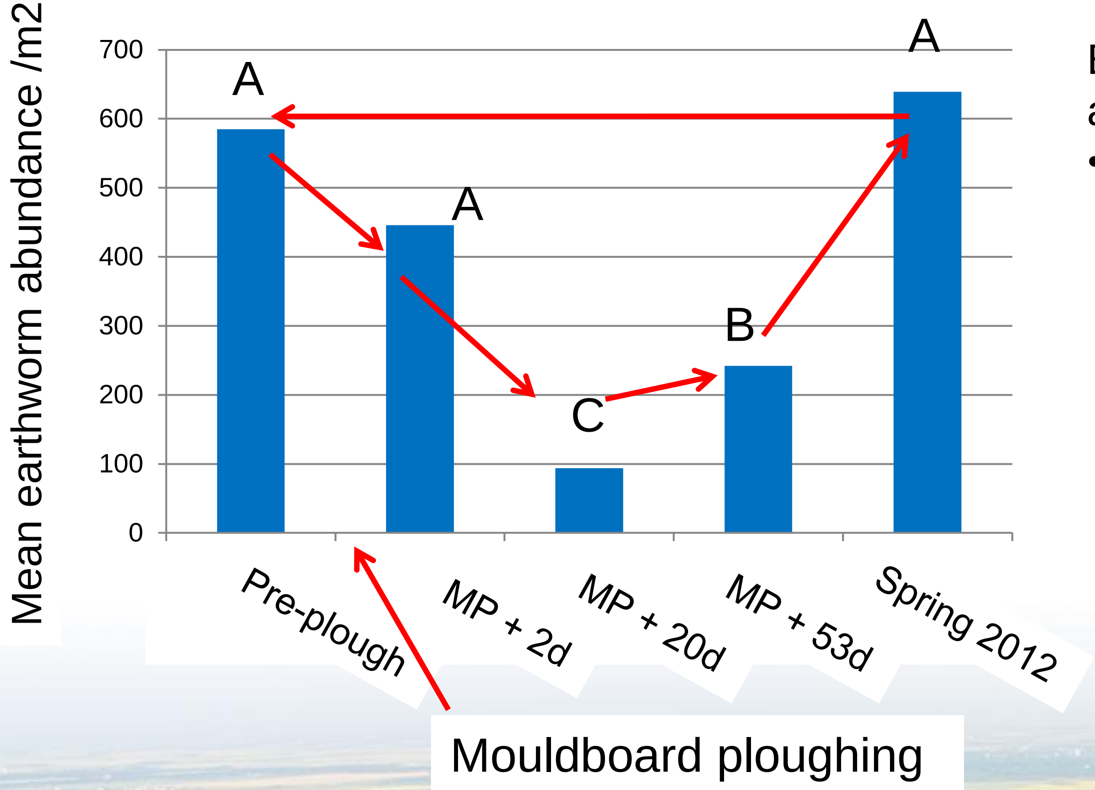
Short-term Earthworm Changes



Earthworm total abundances after ploughing in Org B

- Abundances recover by following spring

Crittenden et al., 2014

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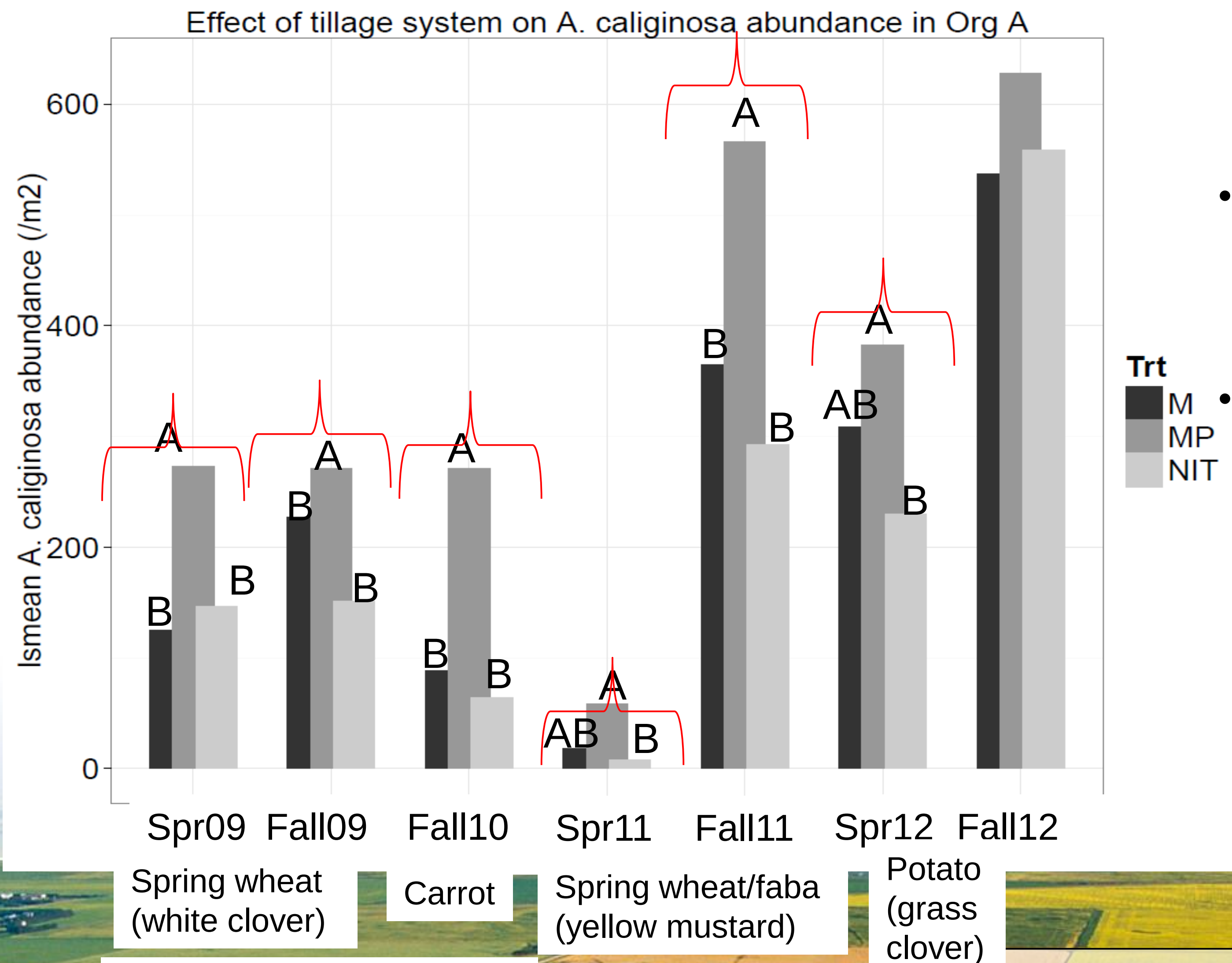
Effect of Tillage on Earthworms



Crittenden et al., 2014

- Sig. lower in reduced tillage at 6 of 7 samplings
- *A. caliginosa > L. rubellus > E. tetraedra > A. rosea*
- Difference in total abundance reaction to tillage

- *A. calignosa* dominant (76% of all earthworms)
- Incorporated manure benefits endogeics

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Effect of Tillage on Earthworms

- Sig. lower in reduced tillage at of 7 samplings
  caliginosa > *rubellus* > *tetraedra* > *rosea*
  fference in total undance reaction tillage
- *. calignosa* ominant (76% of ll earthworms) ncorporated nanure benefits ndogeics

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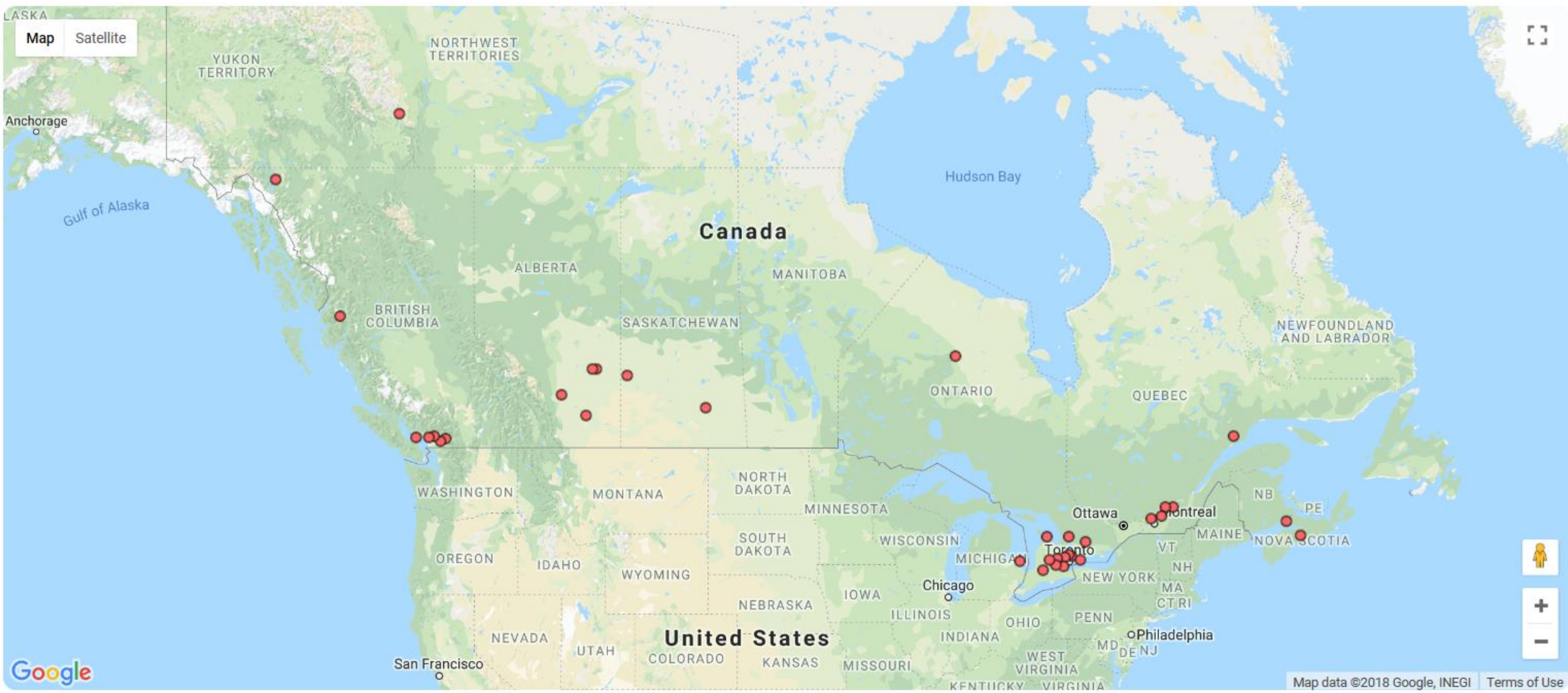
Manitoba Earthworms

- *Allolobophora chlorotica*
- *Aporrectodea rosea*
- *Ap. turgida*
- *Dendrobaena octaedra*
- *Eisenia foetida*
- *Eiseniella tetraedra*
- *Lumbricus rubellus*
- *L. terrestris*
- *Aporrectordea tuberculata*
- *Ap. Trapezoides*
- *Dendrodilus rubidus*
- *Octolasion tyrtaeum*
- Reynolds, 2000 + Gates, 1972,73,79

- 12 recognized species
- All non-native species
- No *A. caliginosa*

WormWatch

- www.naturewatch.ca/wormwatch/



Soil Physical Properties

Table 3
Soil physical properties by depth in soil profile.[a]

	Depth (cm)	Agg. stab. (mm)		SOM (%)		Depth (cm)	BD (g cm^{-3})	
		MP	NIT	MP	NIT		MP	NIT
Org A	0–10	0.64 (0.05)	0.65 (0.05)	3.7	4.1	0–5	1.42 (0.04)	1.40 (0.04)
	10–20	0.50 (0.05)	0.85 (0.05)*	3.4	3.3	10–15	1.42 (0.04)	1.47 (0.04)
	20–30			3.1	3.2	20–30	1.59 (0.04)	1.61 (0.04)
	30–40			2.7	2.5	30–40	1.38 (0.04)	1.33 (0.04)
	40–50			2.4	2.3	40–50	1.17 (0.04)	1.25 (0.04)
Org B	0–10	0.57 (0.05)	0.63 (0.05)	3.6	4.1	0–5	1.34 (0.03)	1.29 (0.04)
	10–20	0.56 (0.05)	0.75 (0.05)*	3.4	3.6	10–15	1.42 (0.03)	1.59 (0.04)*
Conv A	0–10	0.42 (0.05)	0.64 (0.05)*	2.8	3.2			
	10–20	0.45 (0.05)	0.71 (0.05)*	3.0	3.1			

- Non-inversion tillage had higher aggregate stability at 4-8” depth and higher soil organic matter in both conventional and organic farming.
- No bulk density differences
- Cultivation activities in top 10 cm may have disrupted aggregates.

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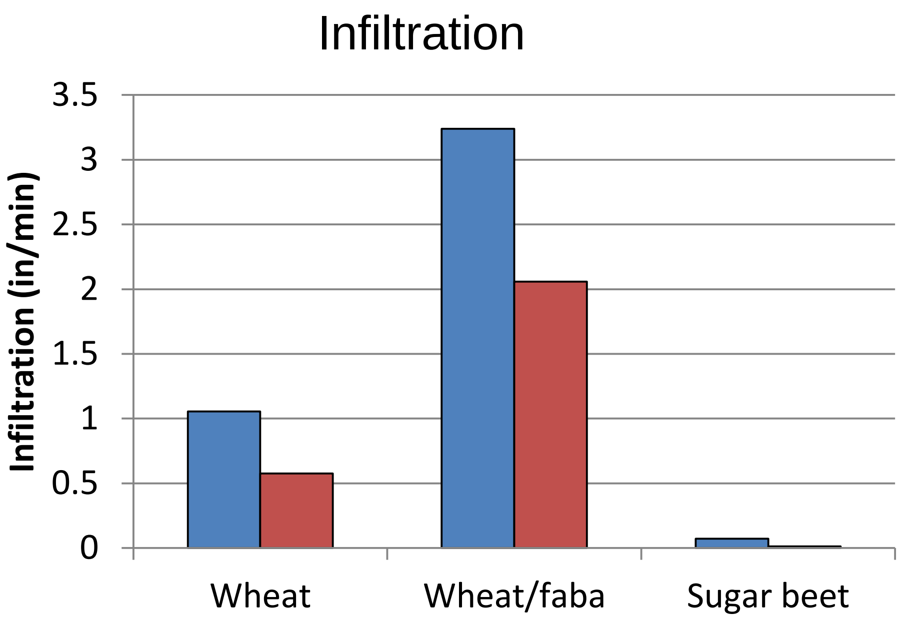
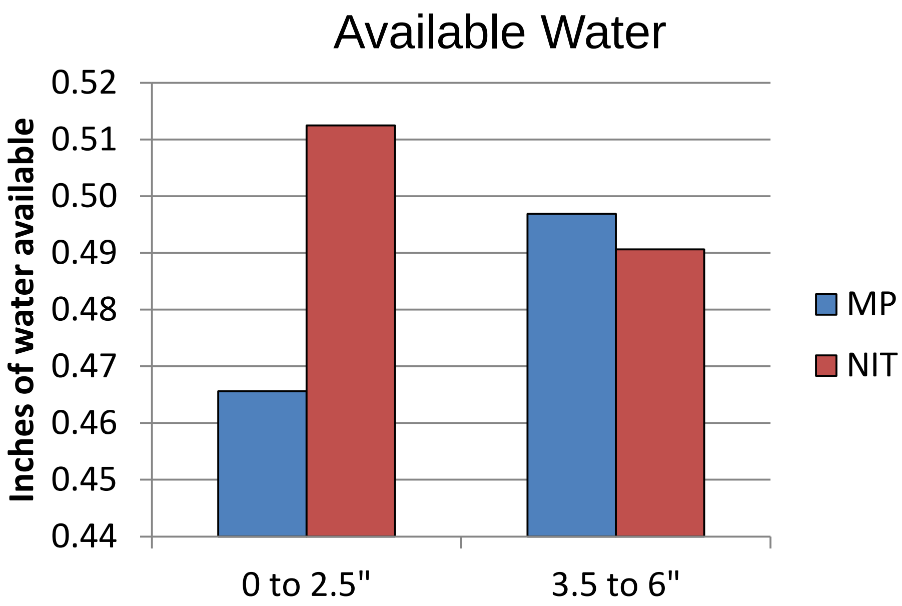
Infiltration and Retention?





Mouldboard ploughing (MP) versus non-inversion tillage (NIT; subsoiler/ripper)

NIT had higher carbon, aggregation, and water holding capacity, but was denser and had slower infiltration

Crittenden et al, 2015

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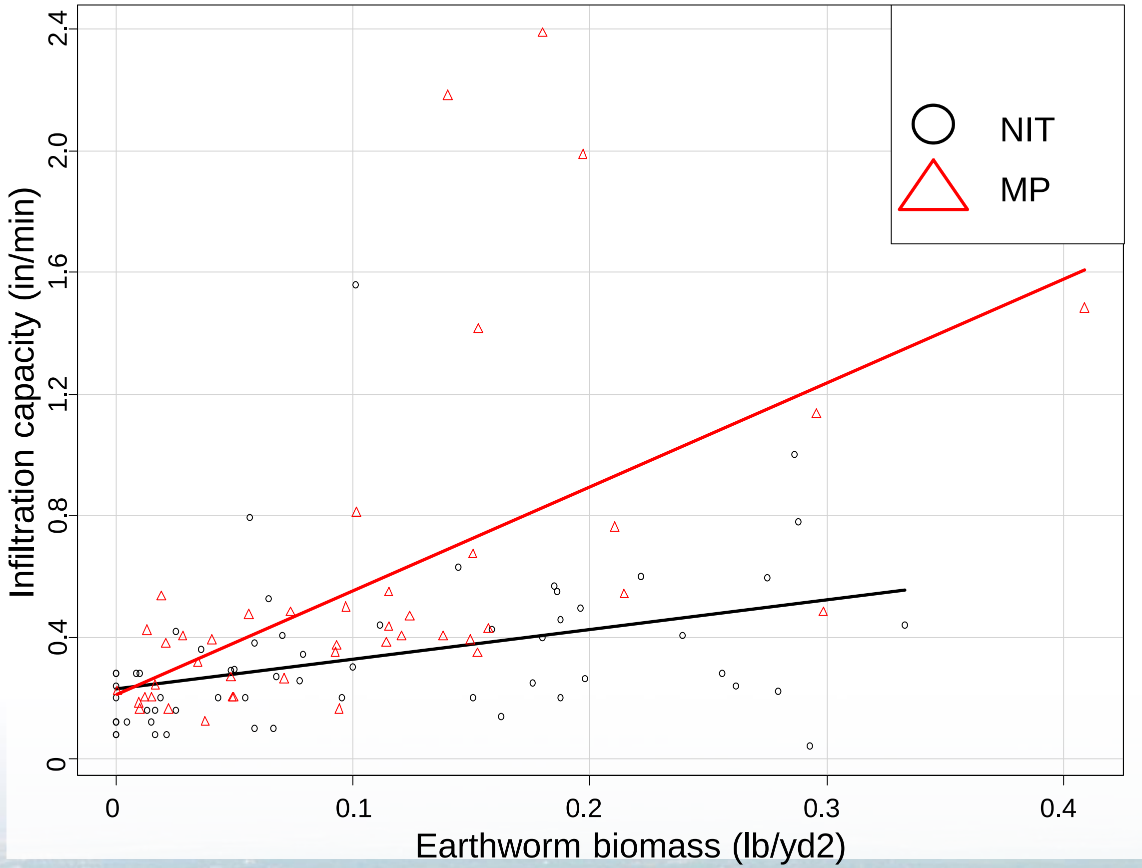
Earthworms Increased Infiltration

Infiltration increased with more earthworms. More earthworms were present in the ploughed system because of nutrient availability and species present.



Crittenden and de Goede, 2016

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Prairie Examples

- Two contrasting examples of infiltration and soil physical properties in tillage systems in Canadian prairies

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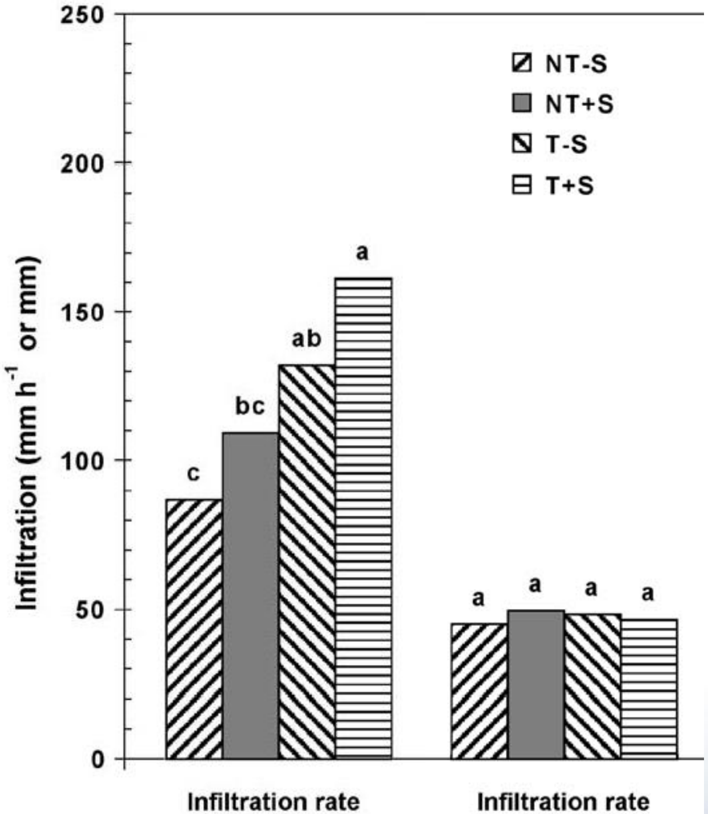
Prairie Examples



Black Chernozem   Grey Luvisol

- Innisfail (S of Red Deer), Black chernozem, loam, 6.5% OM
- Rimbey (N of Red Deer), gray luvisol, loam, 31 g/kg OM
- Double ring infiltrometer, 1hr, steady state
- Tillage – rototilled to 4 inch in autumn, spring, and before seeding
- No-till – seeded directly into stubble with drill, disc openers
- Spring barley

Fig. 8. Steady-state infiltration rate and cumulative intake of water during first hour of ponding in two soils as affected by tillage and residue management. Within a measurement, treatment means with a common lower case letter do not differ significantly ($P \leq 0.05$). NT − S, no tillage, straw removed; NT + S, no tillage, straw retained; T − S, tillage, straw removed; T + S, tillage, straw retained.

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Prairie Examples

- In the Black Chernozem,
- Infiltration was lowest (3.4” or 87.0 mm h^{-1}) under NT with residue removed and highest (6.5” or 161.3 mm h^{-1}) under T + S.
- Omission of tillage reduced infiltration by 33% and residue retention increased it by 24%.
- Aggregate stability highest in both soils for NT with residue, BD & PR higher in NT

- Infiltration in Gray Luvisol was not affected by tillage-residue treatments.
- May be due to compact subsoil below 6 inch depth that slowed IR.
- Partly due to the same reason, IR of the Gray Luvisol was an average of 2.6 times smaller than of the Black Chernozem.

Singh and Malhi, 2006

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Prairie Examples

Table 1. Steady ponded infiltration rate (*i*), its CV and initial soil water content (θ_i) for NT and CT in silt loam and sandy loam soils

Trt	1992 *i* (cm h^{-1})	
	17 June	
CT	1.02*b*	0.4
NT	2.76*a*	1.1”
	31 July	
CT	0.65*b*	
NT	1.51*a*	
	29 September	
CT	0.47*b*	
NT	0.89*a*	
	9 June	
CT	3.50*b*	
NT	5.03*a*	
	21 July	
CT	4.60*b*	1.8
NT	6.30*a*	2.5”
	9 September	
CT	2.90*b*	
NT	3.37*a*	

a–b Means for the given time followed by the same letter in the same column do not differ significantly at $P \leq 0.05$.

Azooz and Arshad, 1996

Dawson Creek, gray luvisol
Fine loamy, 26% clay, 2.5% OrgC

Rolla, gray luvisol, sandy loam, 18% clay, 1% Org C

Double ring infiltrometer

CT – fall deep cultivator with chisel 6 inches, 2 passes in spring at 4 inches
NT – direct seed with zero till press dril with residue left

Barley 1992, canola 1993

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Prairie Examples

- Long-term NT generally increased ponded infiltration rates under initial dry, near field capacity, and field capacity, but not under near saturated soil conditions.
- Differences in infiltration rate between NT and CT were related to differences in soil structure (pore size distribution), hydraulic conductivity and possibly pore continuity.
- Soil under NT had a significantly greater total volume of microporosity than soil under CT.
- Differences in volume of macroporosity between NT and CT were no significant.

Azooz and Arshad, 1996

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SOM and Water

- Big assumptions about soil bulk density and organic matter: BD 1.33g/cm3 and SOM holds 10x weight in water
- "Each 1 percent increase in soil organic matter helps soil hold 20,000 gallons more water per acre.“

https://www.nrdc.org/experts/lara-bryant/organic-matter-can-improve-your-soils-water-holding-capacity

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SOM and Water

- One organic field, no increase in PAW
- 2nd organic field,
  - 0.5% increase in SOM in NIT after 4 yr
  - 0.1625 cm (0.06 in) increase in PAW
  - 3500 gal/acre per 1% in top 2 inches based on current study

SOM and Water

Table 1 The rate of gravimetric water content increase (g H_2O 100 g^{-1} soil) with an increase of 10 g C kg^{-1} mineral soil.

	SAT	FC	WP	AWC
Mean	4.61	3.71	1.36	2.13
Standard deviation	3.43	2.93	0.77	2.35
n	9	32	33	30

SAT, saturation; FC, field capacity; WP, wilting point; AWC, available water capacity; *n*, number of samples.

Increase of:
2138 gal/acre
For 1% SOM

- 60 studies, > 50 000 measurements
- "A 1% mass increase in soil OC (or 10 g C kg^{-1} soil mineral), on average, increases water content at saturation, field capacity, wilting point and available water capacity by: 2.95, 1.61, 0.17 and 1.16 mm H_2O 100 mm $soil^{-1}$, respectively."
- "Compared with reported annual rates of carbon sequestration after the adoption of conservation agricultural systems, the effect on soil available water is negligible".

Minasny and McBratney, 2018

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Crop Yield

			NIT	yield ploughing (t/a)
	seed potato	Org B	101%	20
	carrot		79%	36
2009	spring wheat	Org A	108%	2.5
	sugar beet	Conv B	100%	47
	spring barley	Conv A	99%	4.5
	grass clover	Org B	108%	6
	faba bean/ spring wheat		83%	2.3
	carrot	Org A	84%	41
2010	winter wheat	Conv B	105%	5.5
	cabbage	Org B	95%	44
	potato	Conv A	95%	17
	faba bean/ spring wheat	Org A	110%	2.3
	onion	Conv A	91%	44
2011	seed potato		95%	17
	spring wheat	Org B	106%	3
	grass clover		139%	5.5
	potato	Org A	100%	10
	seed potato	Conv B	94%	19
2012	sugar beet	Conv A	103%	45

NIT was generally competitive with MP

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Conclusions

- Soil Health vs. Soil Quality – let's keep thinking about how our management affects soil
- Earthworms are influenced by soil management which can drive changes in soil functions
- Soil physical quality was improved by non-inversion tillage in one field and was not affected in the other.
- Tillage, phase of crop rotation, and organic matter management probably explain differences
- SOM and Water – don't believe everything you hear!

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Thank you!

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