Dr. Jamal HALLAM

National Institute for Agricultural Research (INRA)
CRRA-Agadir, Morocco

المعهد الوطني للبحث الزراعي
Institut National de la Recherche Agronomique

UNIVERSITY of York

GLOBAL SYMPOSIUM ON SOIL BIODIVERSITY | 2-5 February 2021

Soil biodiversity and physico-hydraulic function:

How earthworm and plant root interaction contribute to ecosystem services?

...Our knowledge of ecosystems is fundamentally distorted by our above ground, visual perception of nature and our ignorance of life below-ground (BOUCHE(lee 1985 IX)).

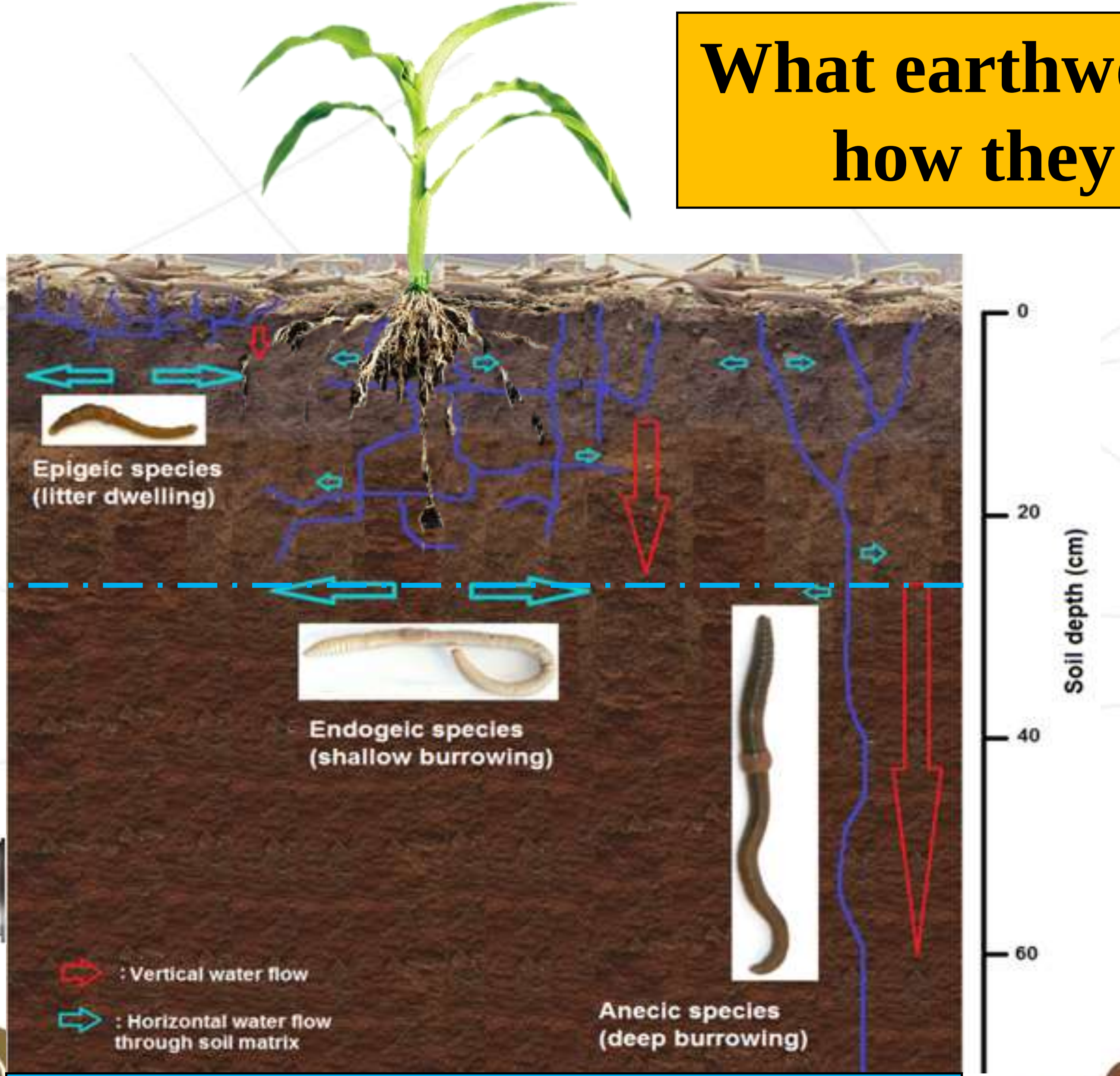
source: metrovancouver.org

Earthworms

What earthworms do to the soil ? and how they regulate soil water?

Water table

Drainage system

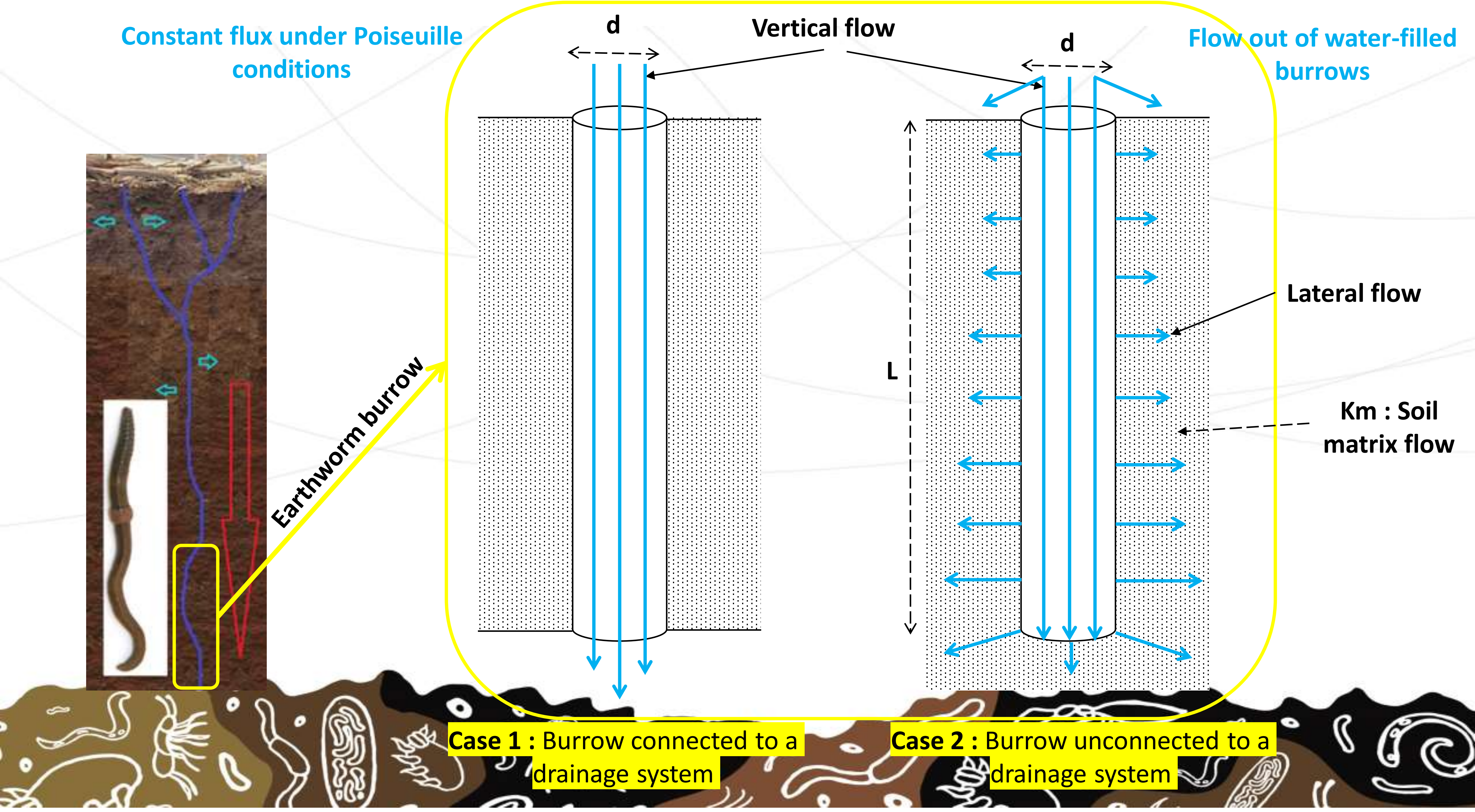


Ground water

Source: www.bbc.co.uk

Source: Library image ©FLPA/Imagebroker/Rex/Shutterstock

The arrows size is proportional to the earthworm species impact on a water flow type



Constant flux under Poiseuille conditions
Vertical flow
d
d
Flow out of water-filled burrows
Earthworm burrow
Lateral flow
L
Km : Soil matrix flow
Case 1 : Burrow connected to a drainage system
Case 2 : Burrow unconnected to a drainage system

How the association between plants and earthworms in soil affect soil water flow and soil physical proprieties?

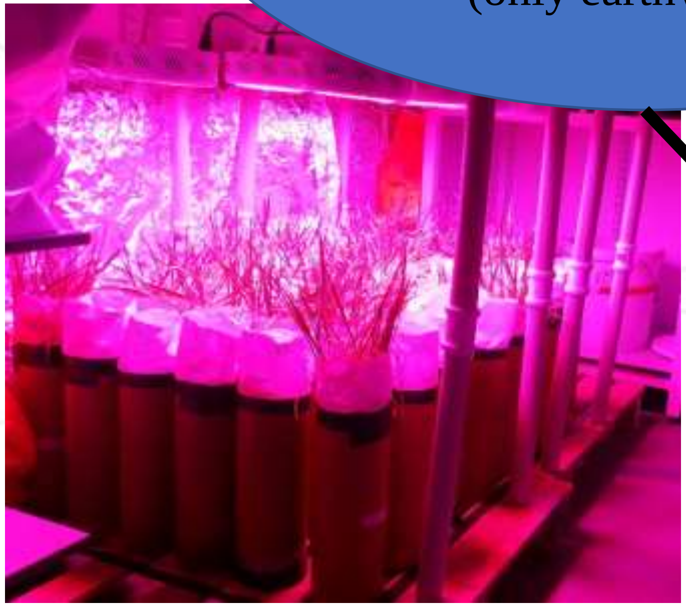
Bio-pores could provide pathways for water to move

Is it the earthworms action, or other direct aspects of these management methods that give rise to observed improvements in soil properties in pasture/ley fields ?

How ?

3 Lab experiments :

1 - *L. terrestris* + Winter wheat
2 -*A. chlorotica* + Winter wheat
3 - High density experiment (only earthworms)



Field experiment :

Soil monoliths + Different earthworms species + Plants (grass + clover)

Modelling

Experimental design

Experiment 1

+ Winter wheat + 3 soil types

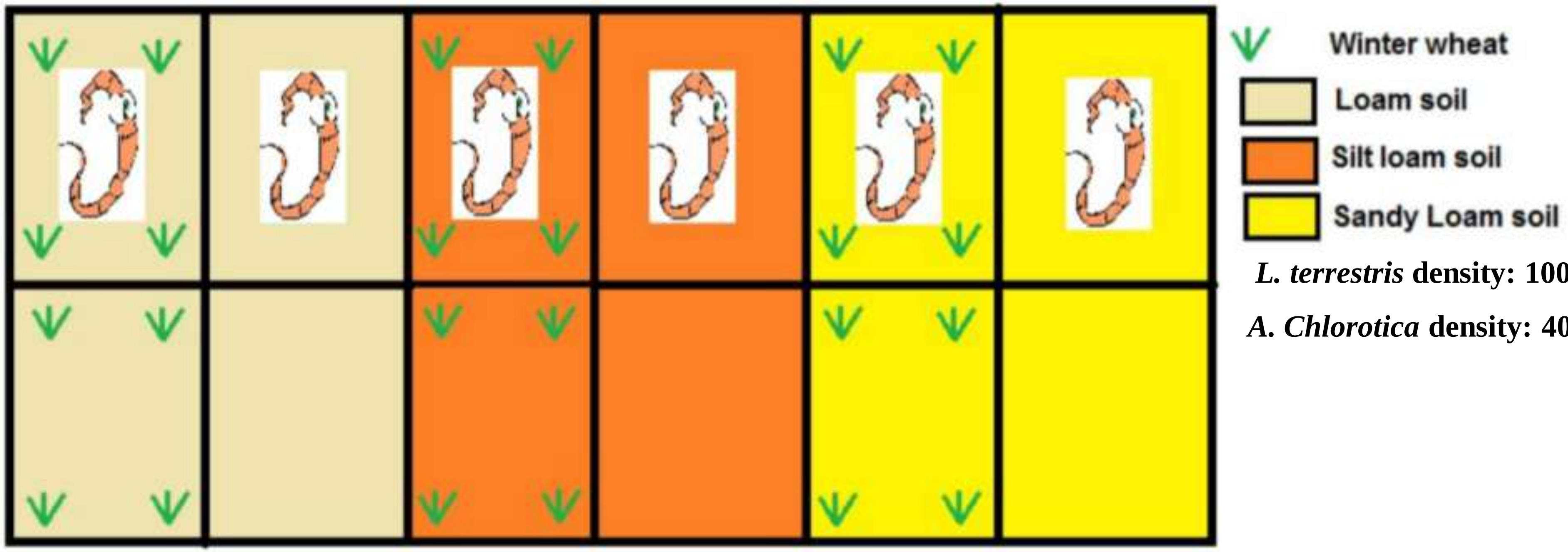
L. terrestris

Experiment 2

+ Winter wheat + 3 soil types

A. chlorotica

- 48 Columns : 3 soil textures X 4 treatments X 4 replicates

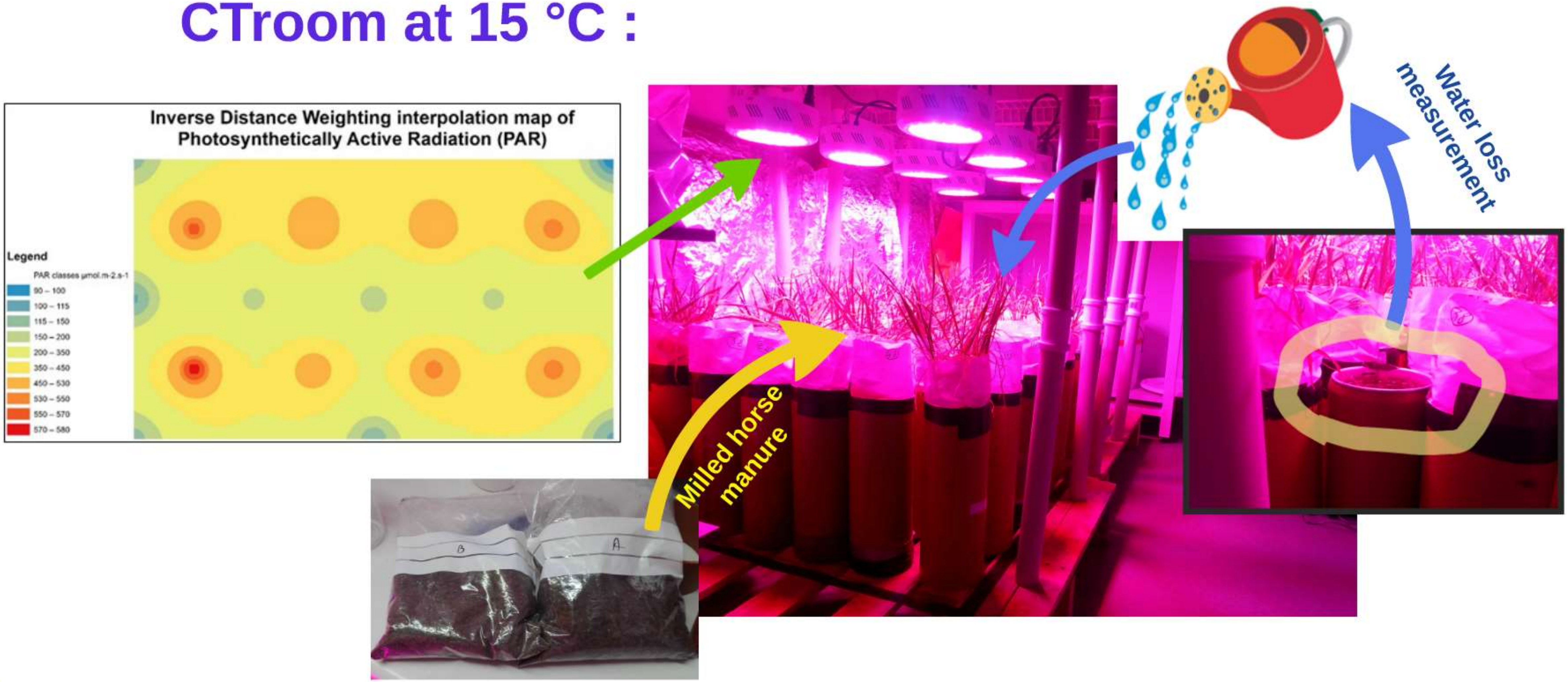


L. terrestris density: 100 ind m-2

A. Chlorotica density: 400 ind m-2

Experimental design

CTroom at 15 °C :



Experimental design

Out puts after 16 weeks :

Unsaturated hydraulic conductivity

At water tensions of of -6, -3, and -1 cm corresponding to pore diameters of < 0.5, 1 and 3 mm.

Field saturated hydraulic conductivity

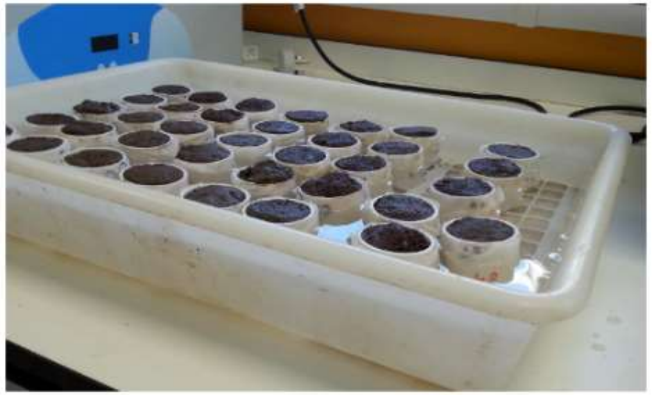
$$K_{fs} = \frac{G_d \alpha Q_1}{r\left(1 + (G_d \alpha \pi r)\left(\frac{Q_1}{Q_2}\right)^P\right.}$$

Reynolds and Elrick (1991) equation

Soil water release curves

Soil stable aggregates

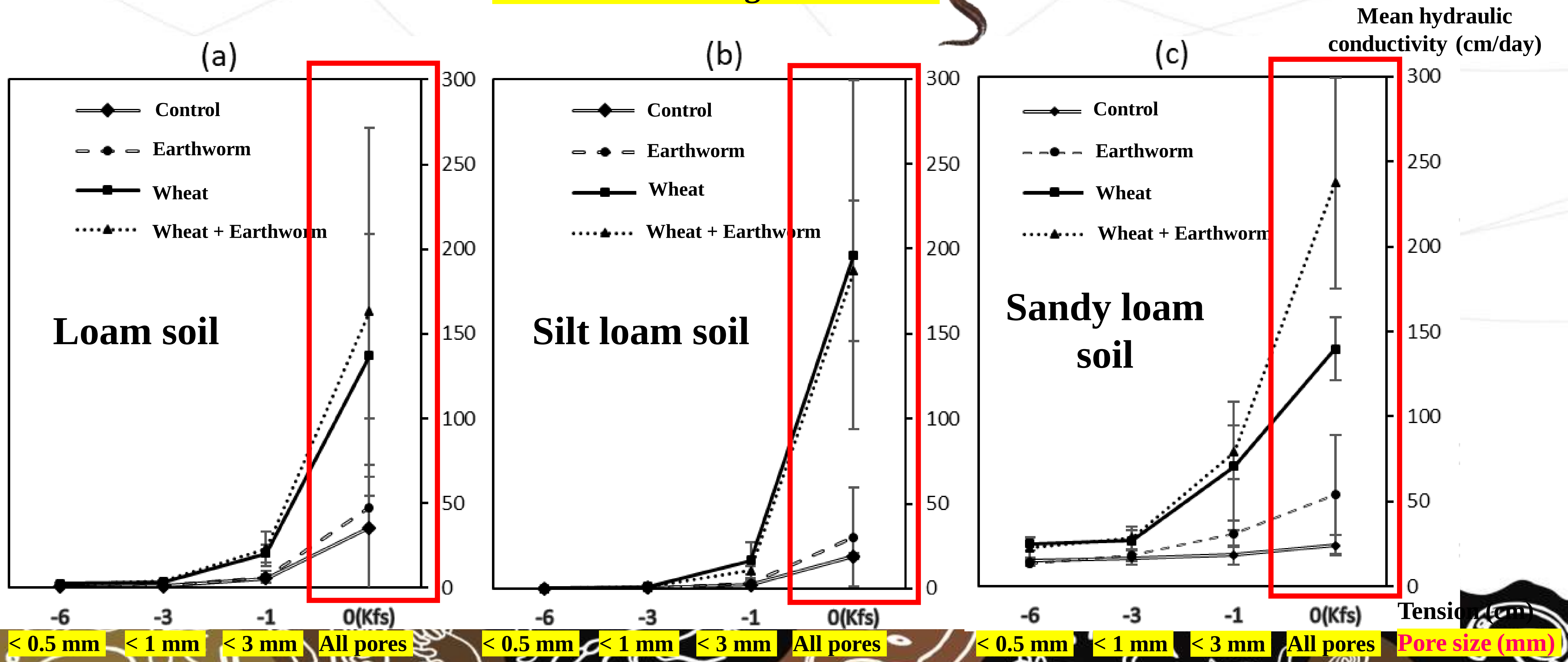
Water holding capacity



Plant shoot biomass

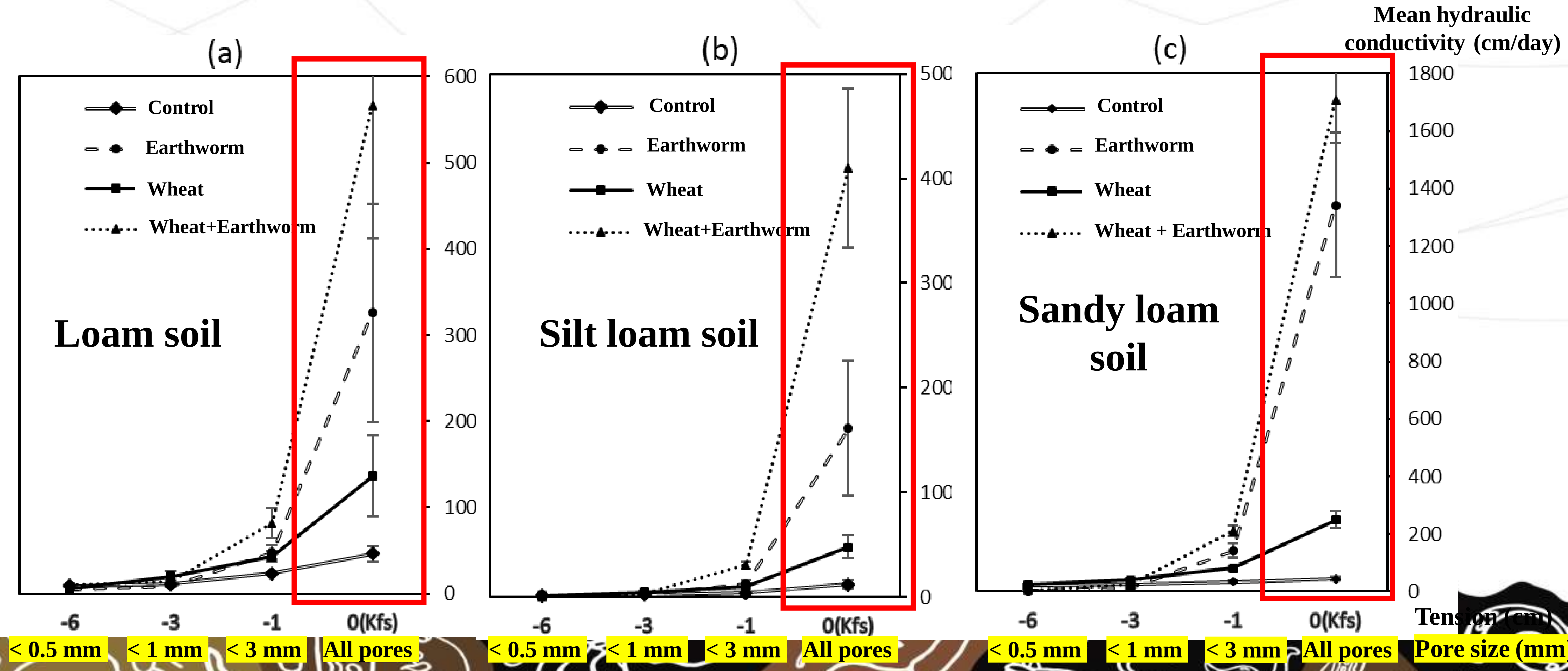
Unsaturated and field saturated hydraulic conductivity K(h)

Vertical burrowing *L. terrestris*



Unsaturated and field saturated hydraulic conductivity K(h)

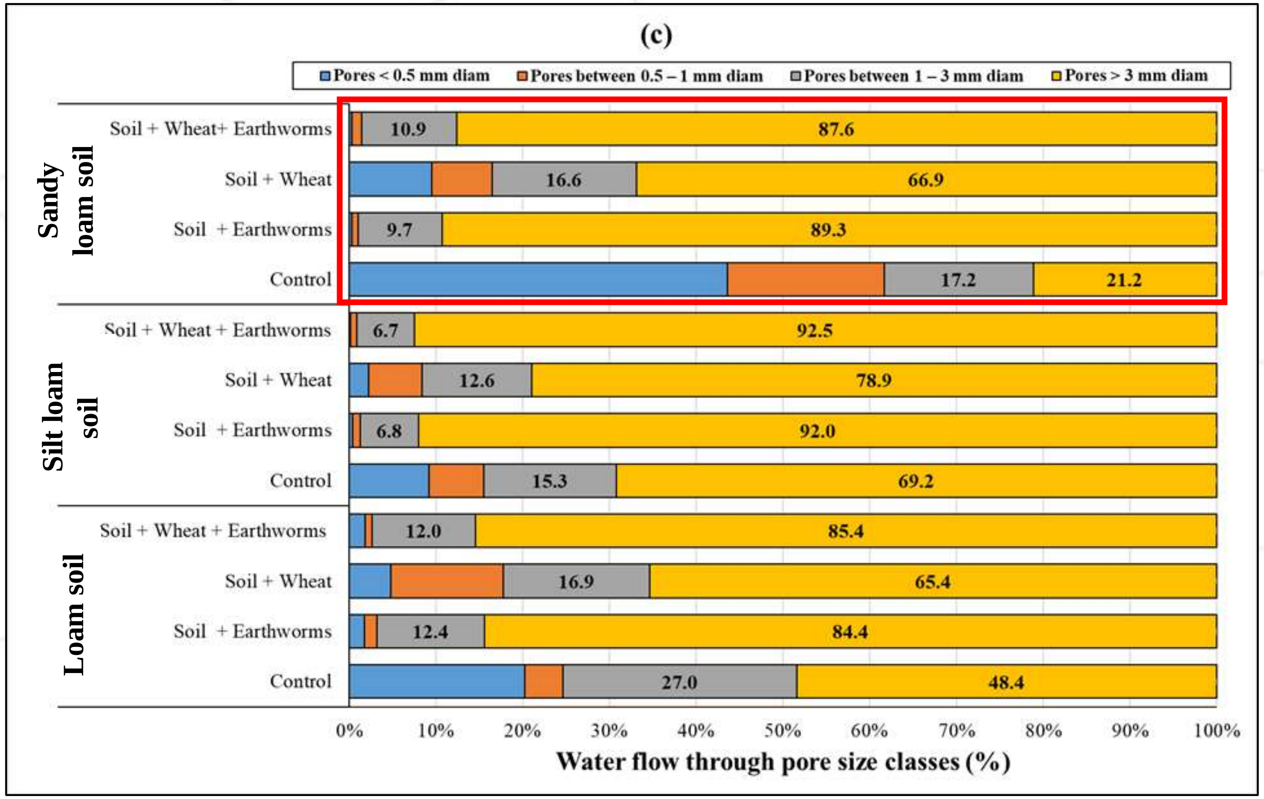
Lateral burrowing *A. chlorotica*

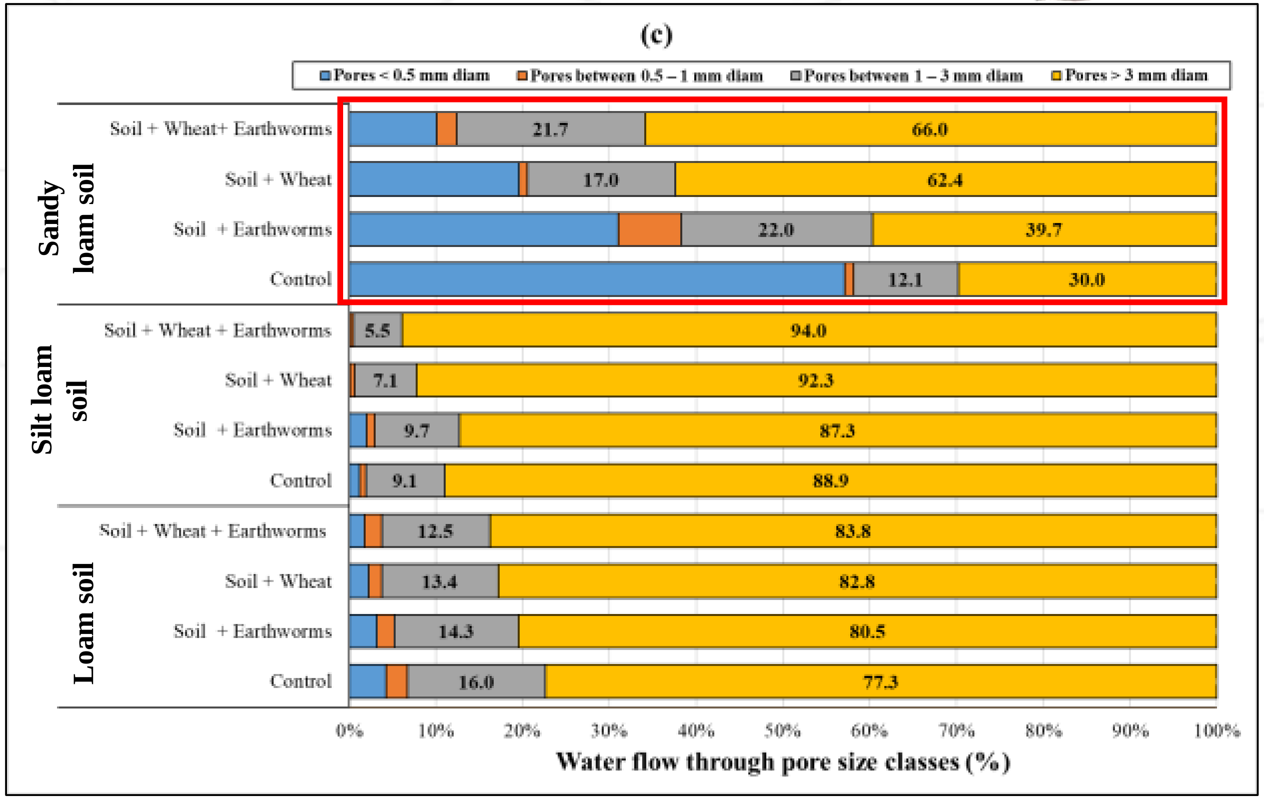


Pore size classes contribution to water flow

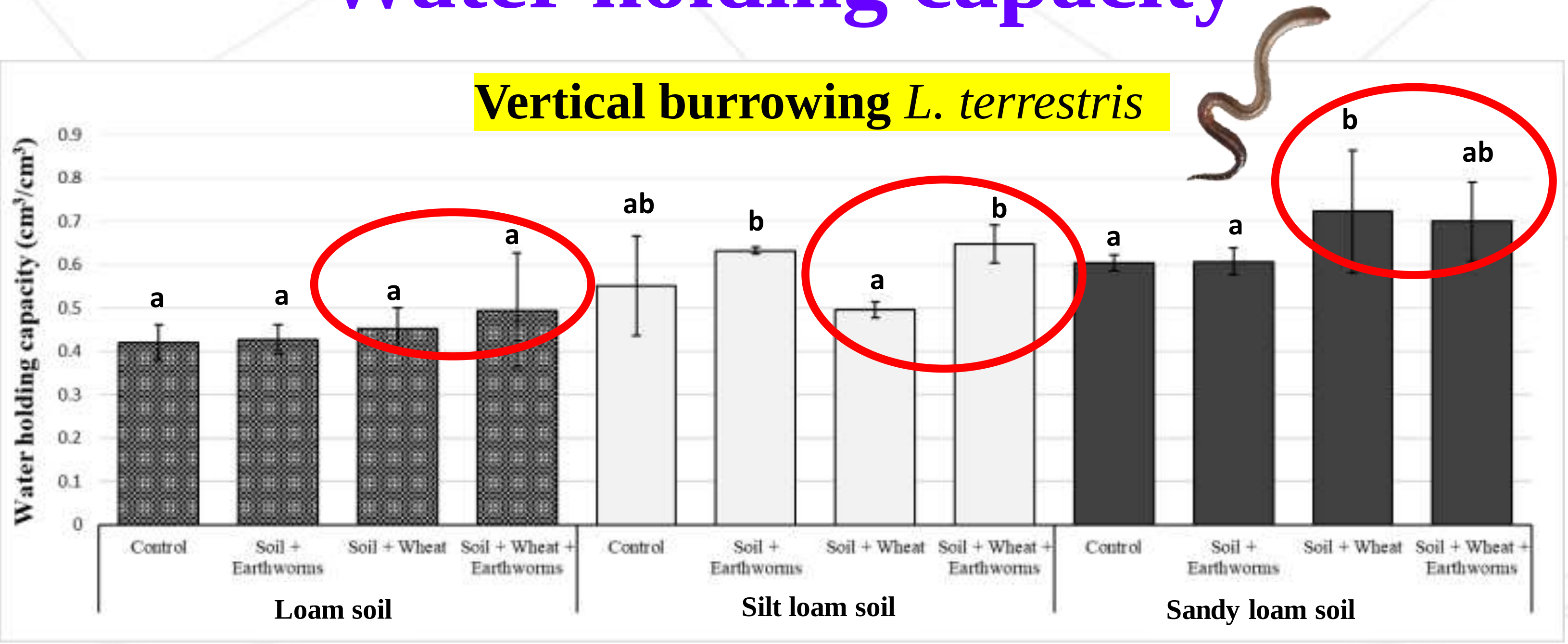
Lateral burrowing *A. chlorotica*

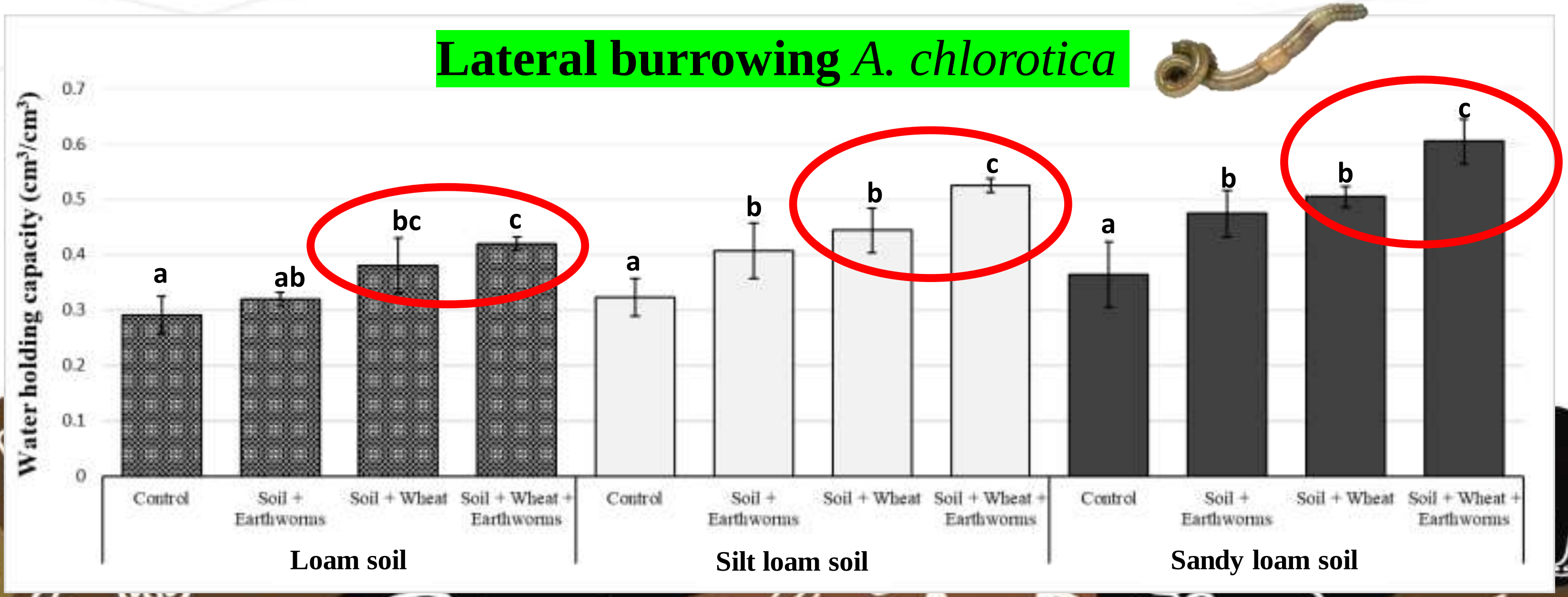
Vertical burrowing *L. terrestris*



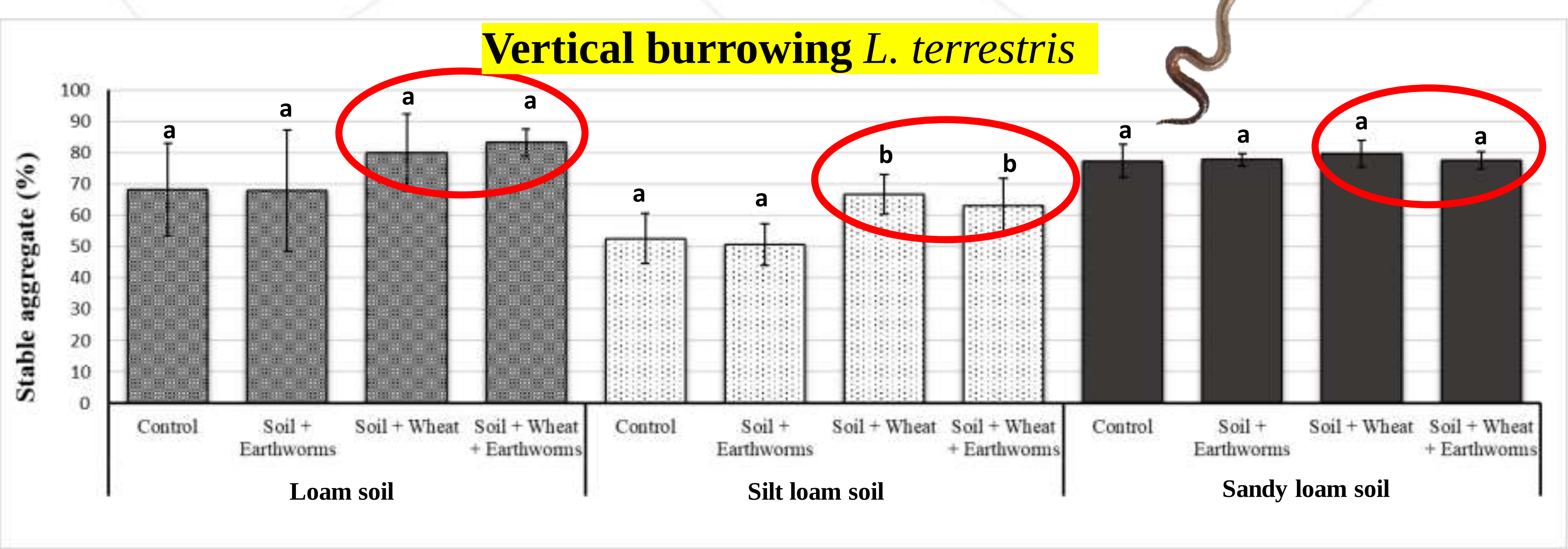


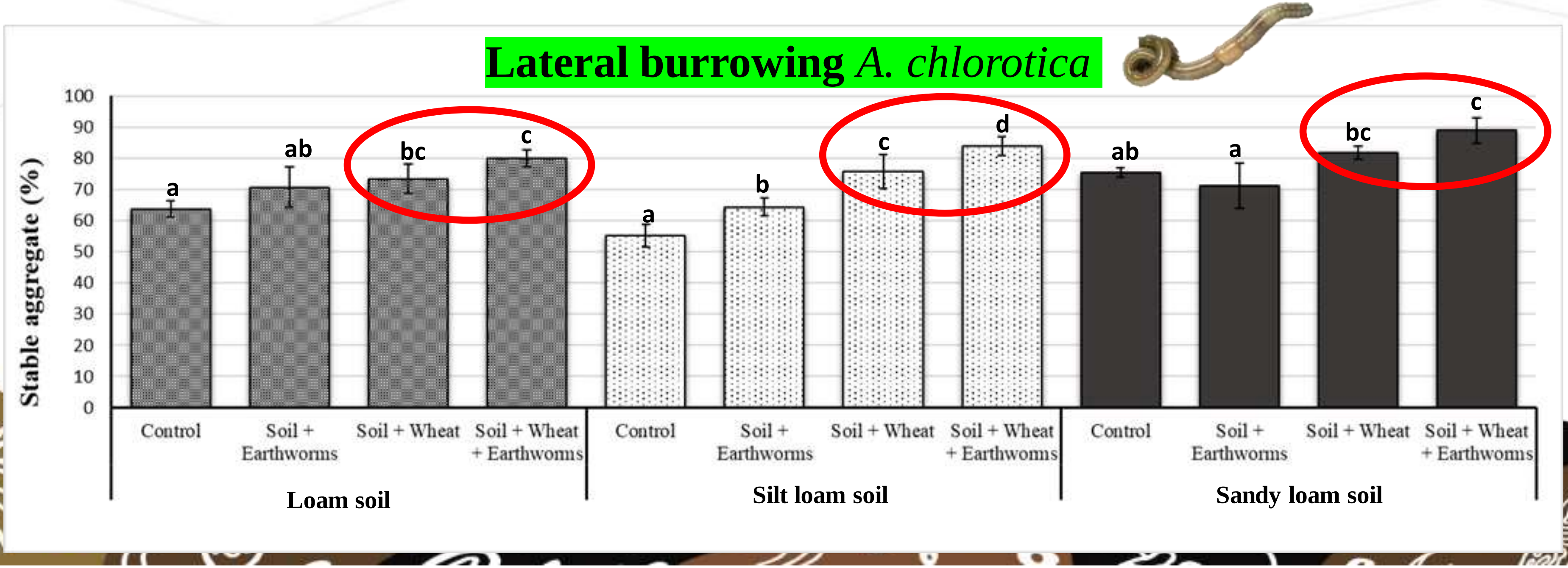
Water holding capacity





% Water stable aggregates





Field experiment

المعهد الوطني للبحث الزراعي

Institut National de la Recherche Agronomique

UNIVERSITY of York

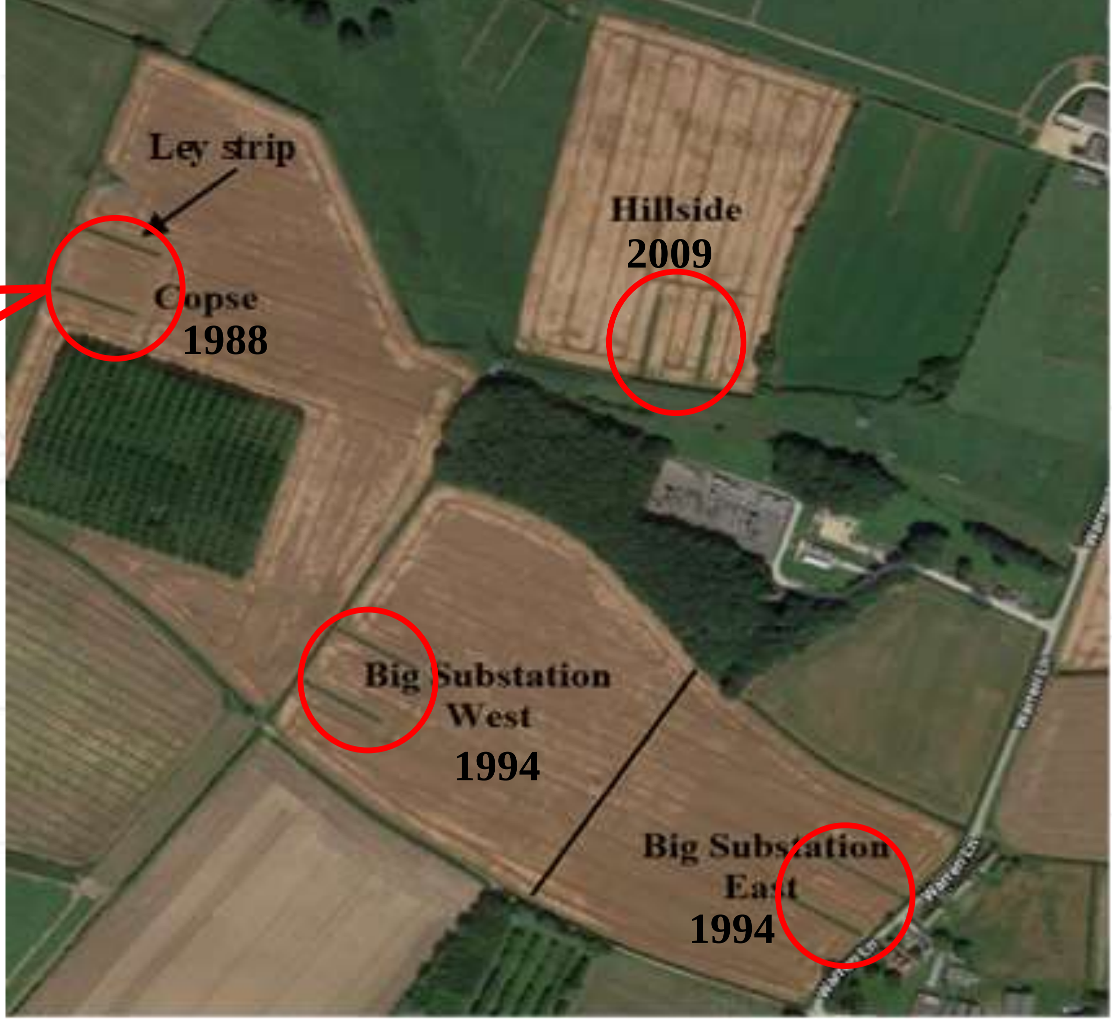
UNIVERSITY OF LEEDS

The University Of Sheffield.

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

White Rose Sustainable Agriculture Consortium

Soil monoliths + Different earthworms species + Plants (grass + clover)



Fields	Area (Ha)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Valley Field	5.7	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP
Sub Paddock	2.6	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP
Warren Paddock	3.4	MZ	WW	WW	POTS	WW	WW	OSR	WW	WW2	OSR	PP	PP	PP	PP	PP	PP	PP	PP
Copse	9.3	POTS	WW	WW	VPEAS	WW	OSR	WW	POTS	WW	OSR	WW	VPEAS	WW	WW2	SB	WB	OSR	WW
Big Sub Station (East/West)	11.0	POTS	WW	OSR	WW	BEET	WW	WW	POTS	WW	OSR	WW	VPEAS	WW	WW2	SB	WB	OSR	WW
Hill Side	5.4	PP	PP	PP	PP	PP	PP	PP	WW	OSR	WW	WW2	WB	OSR	WW	WW2	WB	OSR	WW

Pasture (green)
Arable (orange)

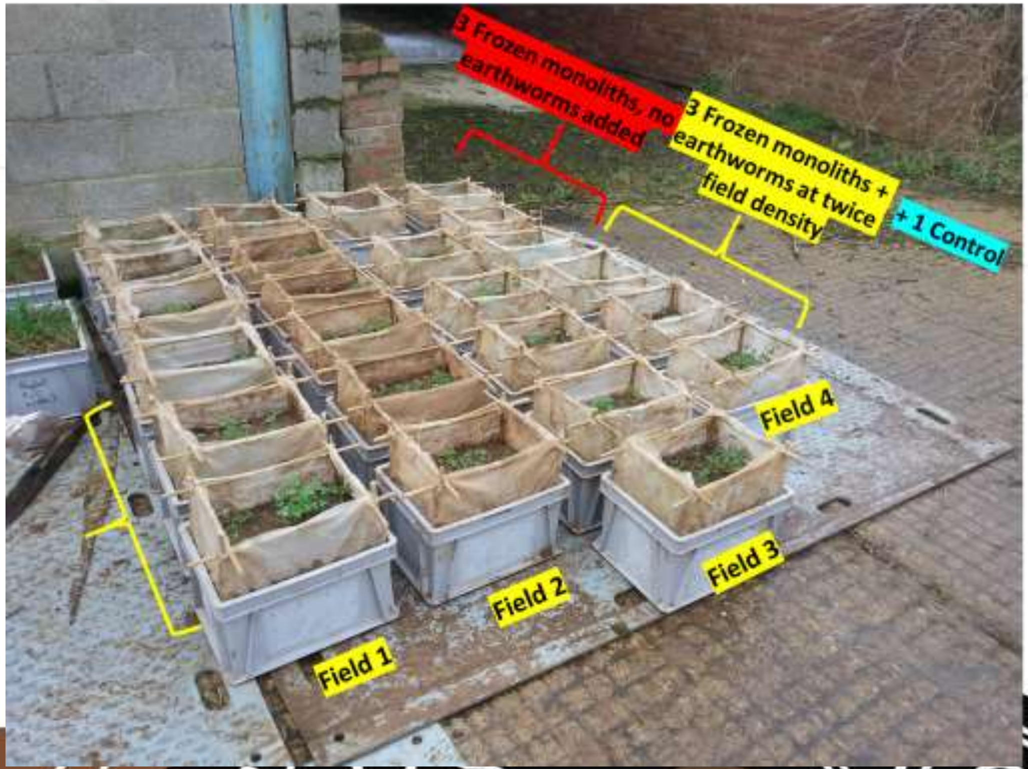
7 monoliths x 4 arable fields = 28 monoliths

Defaunation

Frozen at -20℃ for 3 weeks

Grass + Clover

Fences



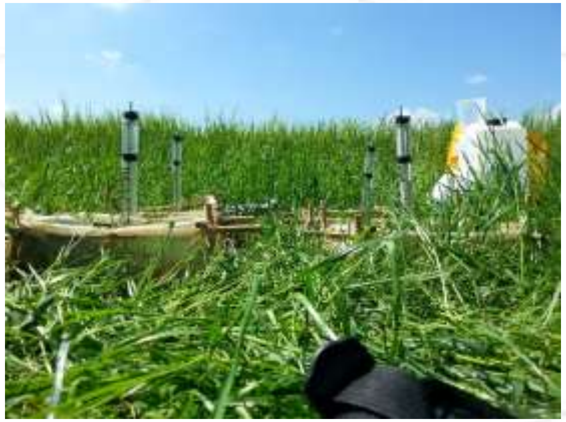
Earthworms population diversity based on that recorded in nearby pasture fields

	ENDOGEIC			EPIGEIC	ANECIC	
	Al-chl	Ap-ros	Ap-cal	L-cas	Ap-lon	L-ter
1st addition (March 2017)	12	3	3	3	0	2
2nd addition (November 2017)	12	2	3	0	1	2

Measurements

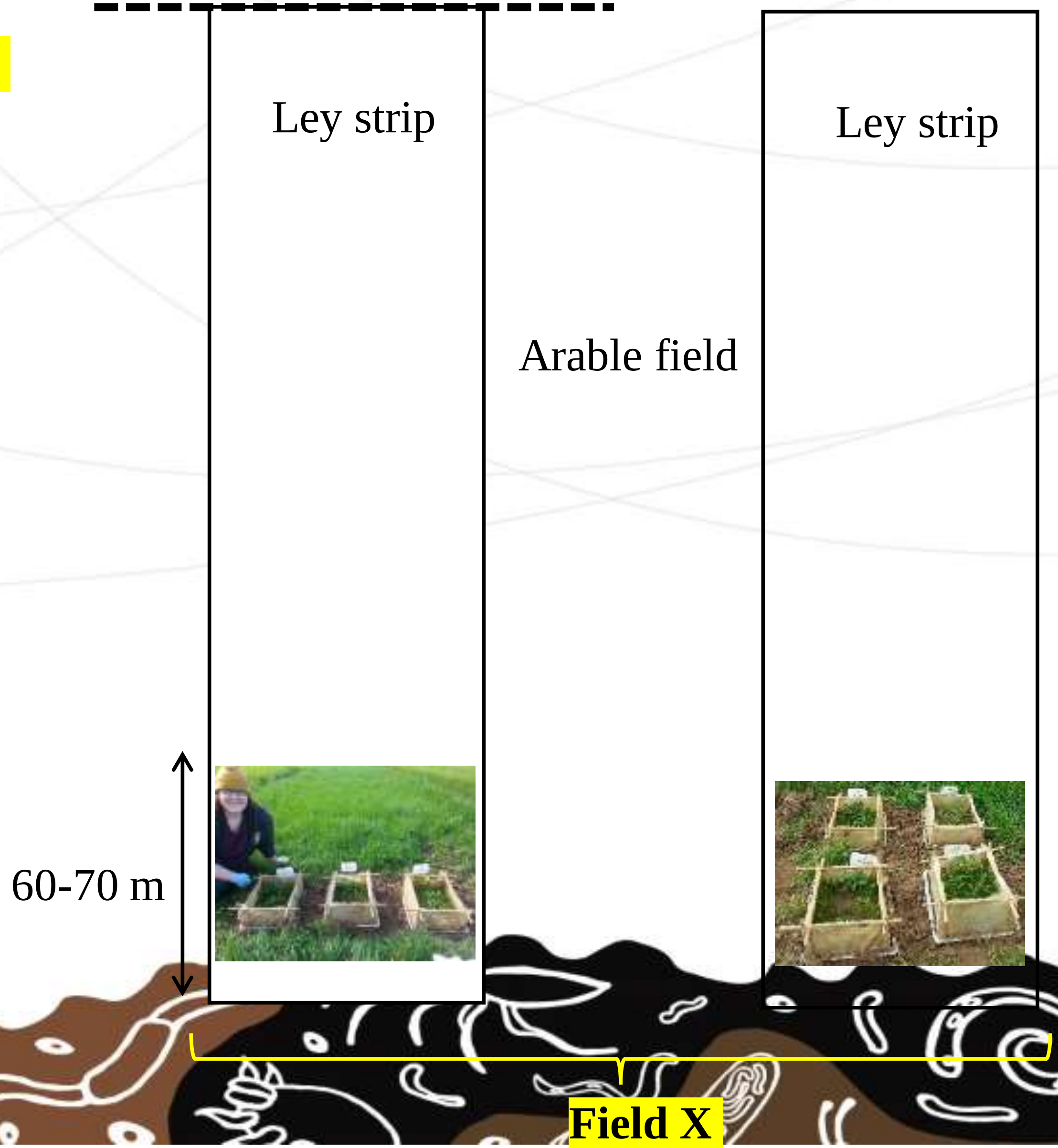
During the experiment (March 2017 - April 2018) :

- Seasonal measurements of hydraulic conductivity (five times a year)
- Plant shoot biomass measured twice

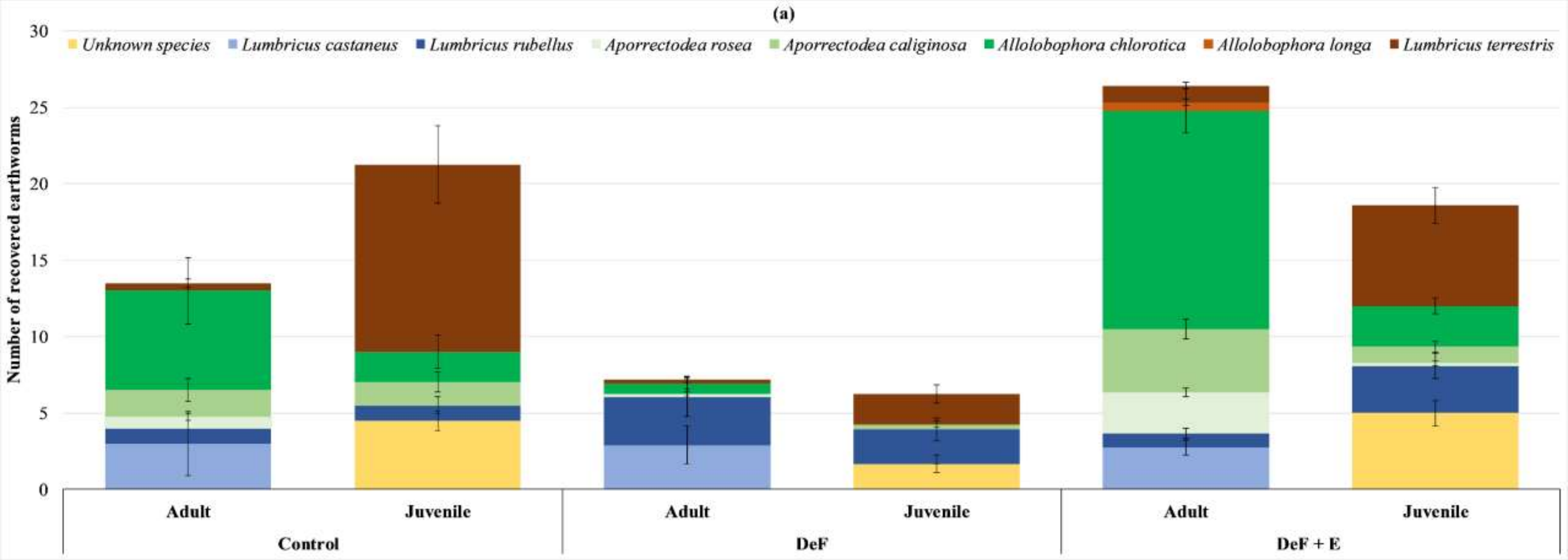


At the end of the experiment (April 2018) :

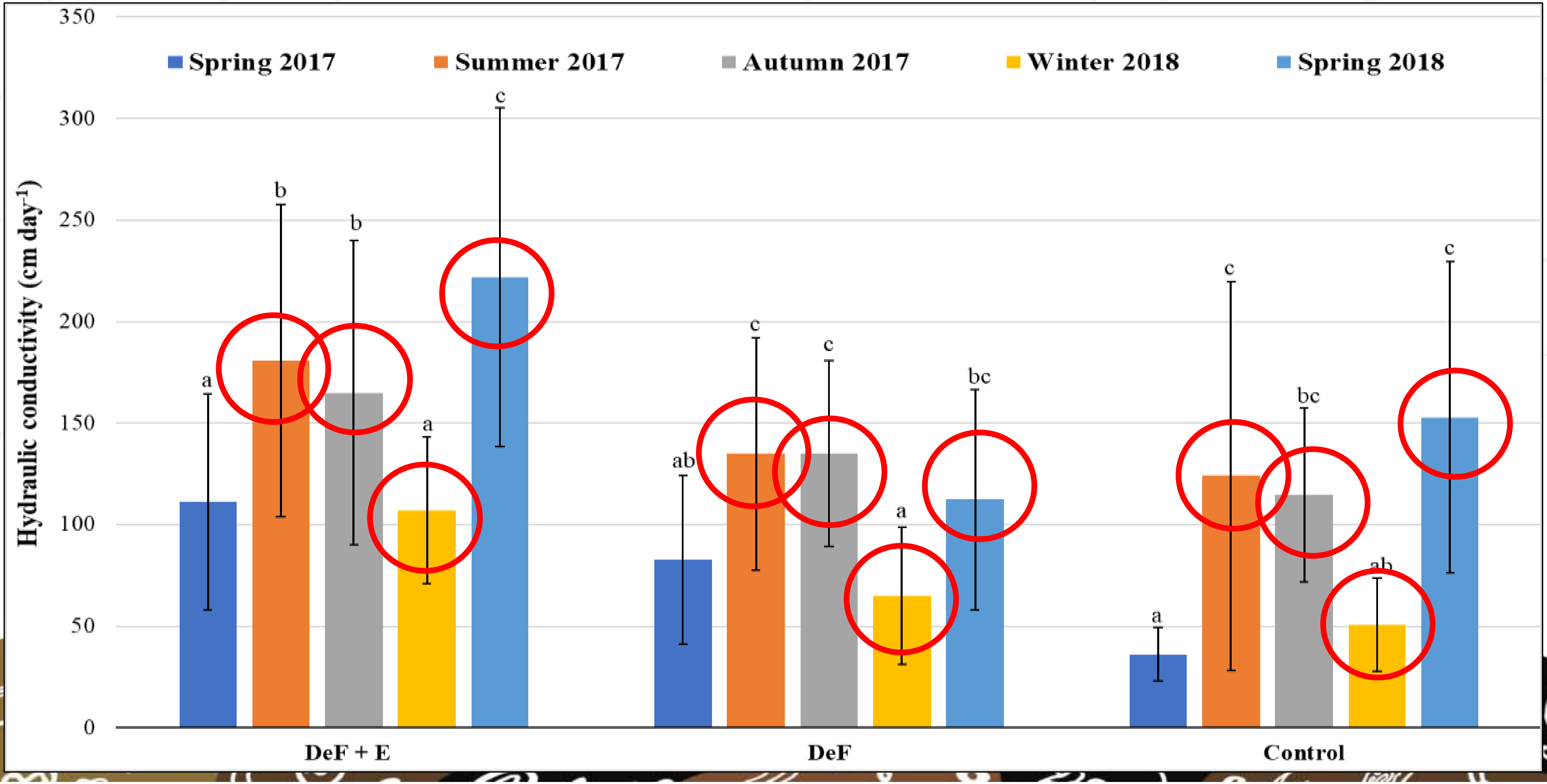
- Water release curves (SWRC),
- Water-holding capacity (WHC),
- Bulk density (BD),
- Percentage water-stable aggregates (WSA),
- Organic matter (%OM)
- Total nitrogen content (%N).
- Wheat bioassays were conducted on the soil from each monolith



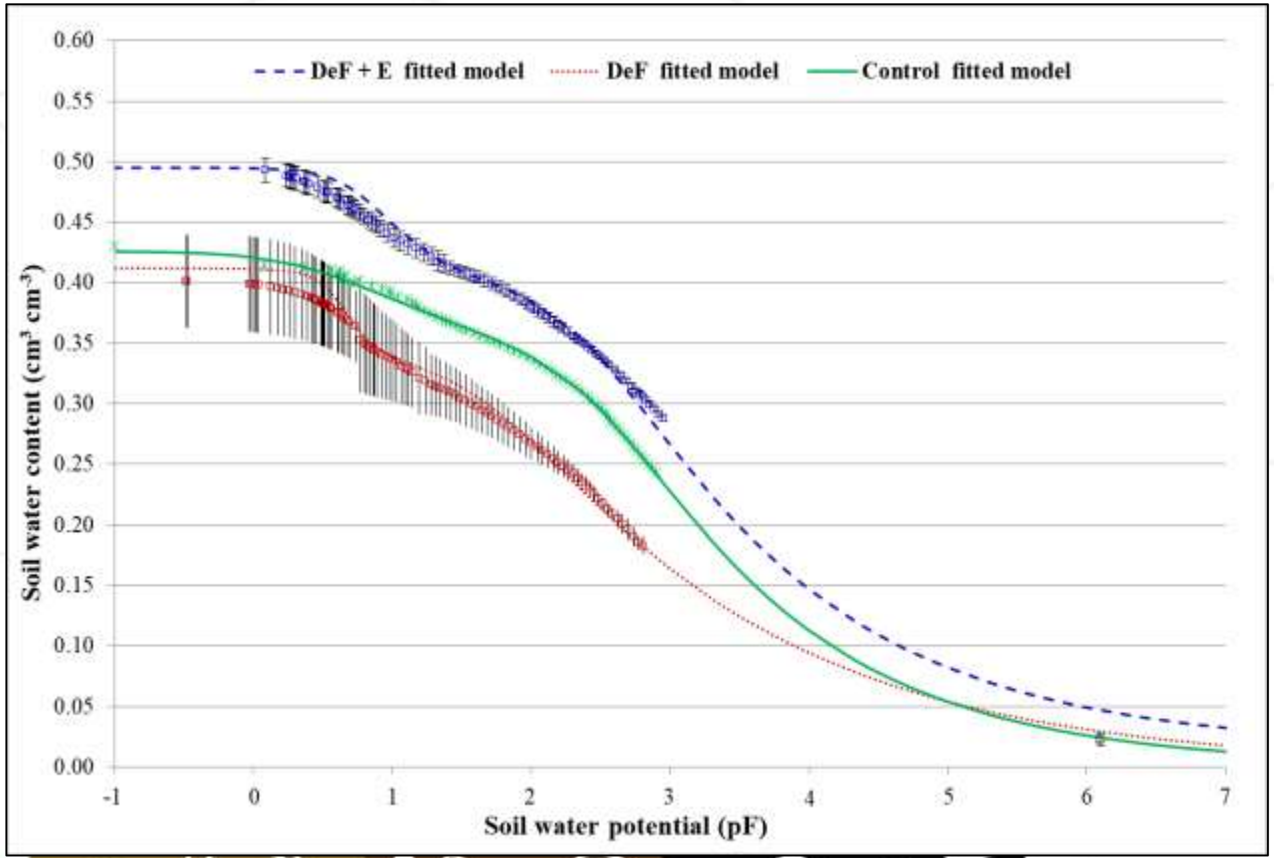
Mean of the recovered earthworm numbers per monolith for adults and juveniles across all fields (n = 4)



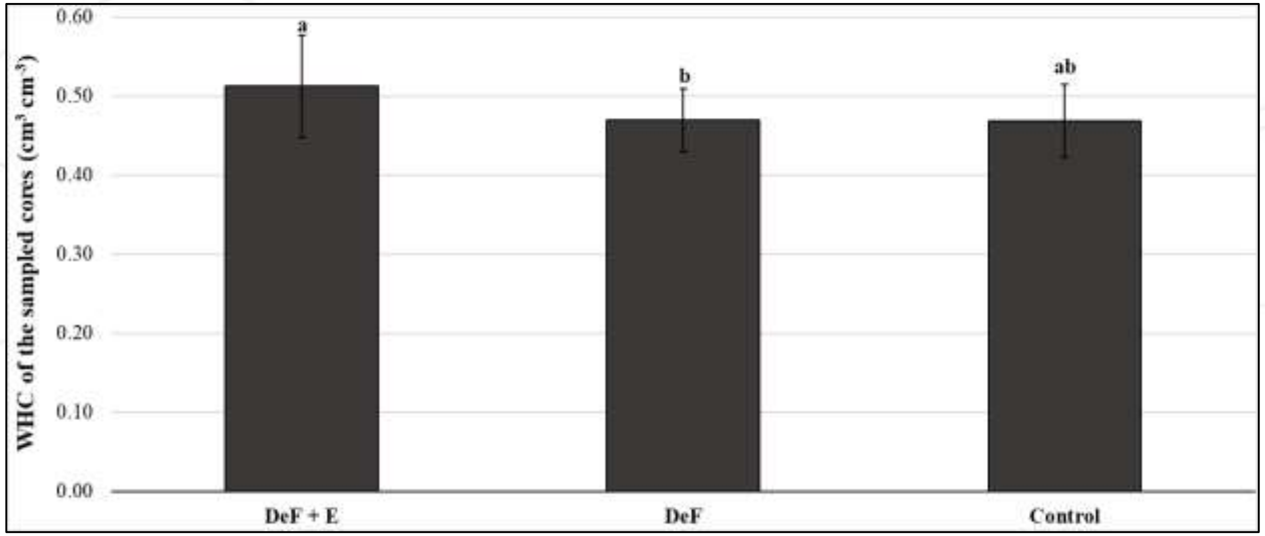
Mean hydraulic conductivity at -0.5 cm tension across seasons and all the fields (n = 4)



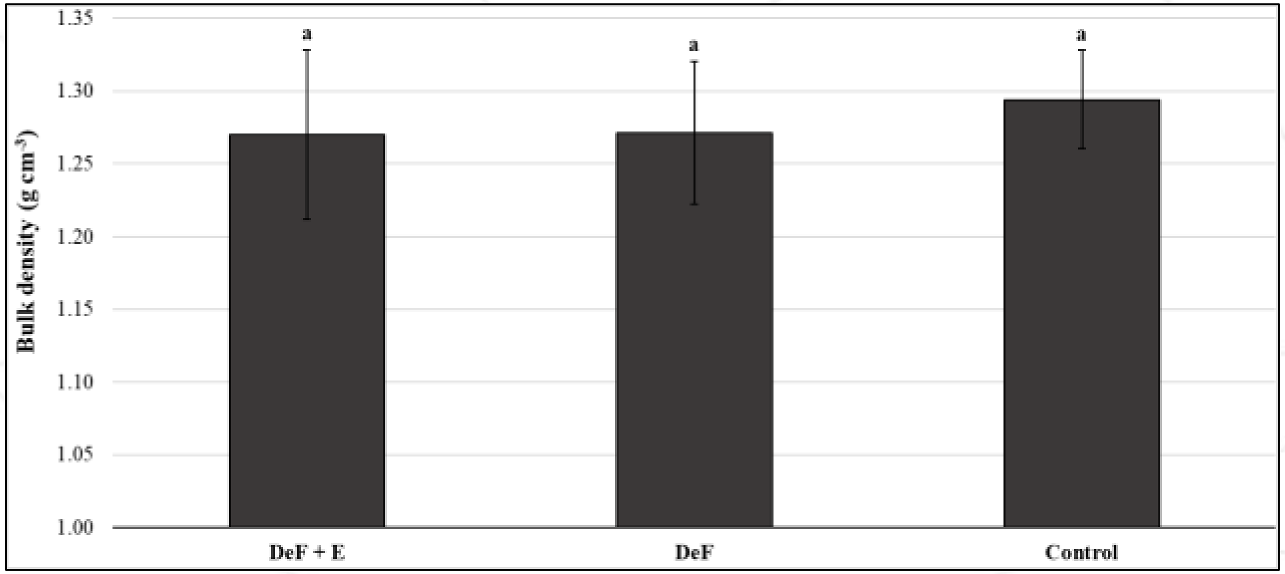
Soil water release curves (SWRC) of Copse field (Loam) fitted to the measured data using the bimodal constrained Van Genuchten (1980) model (Durner, 1994).



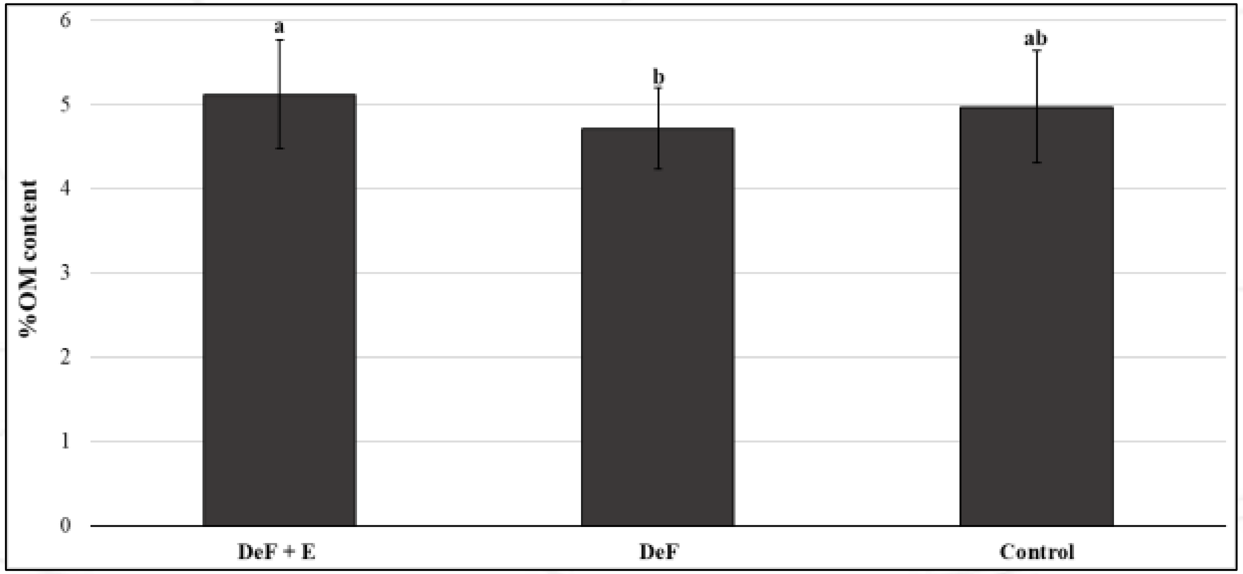
Water holding capacities



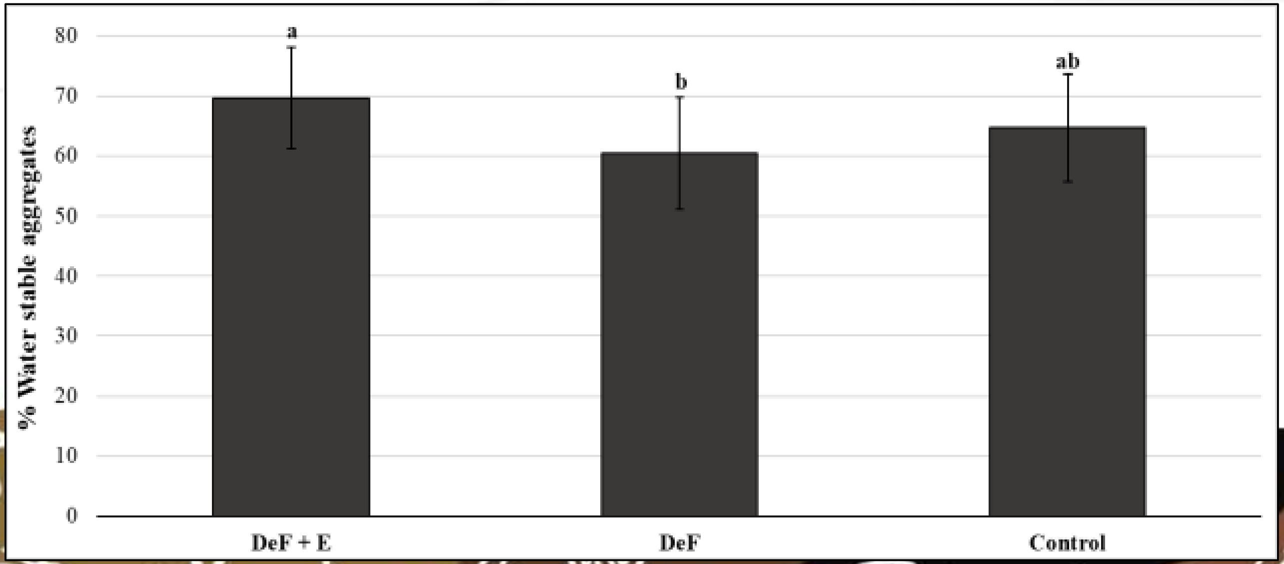
Soil bulk density



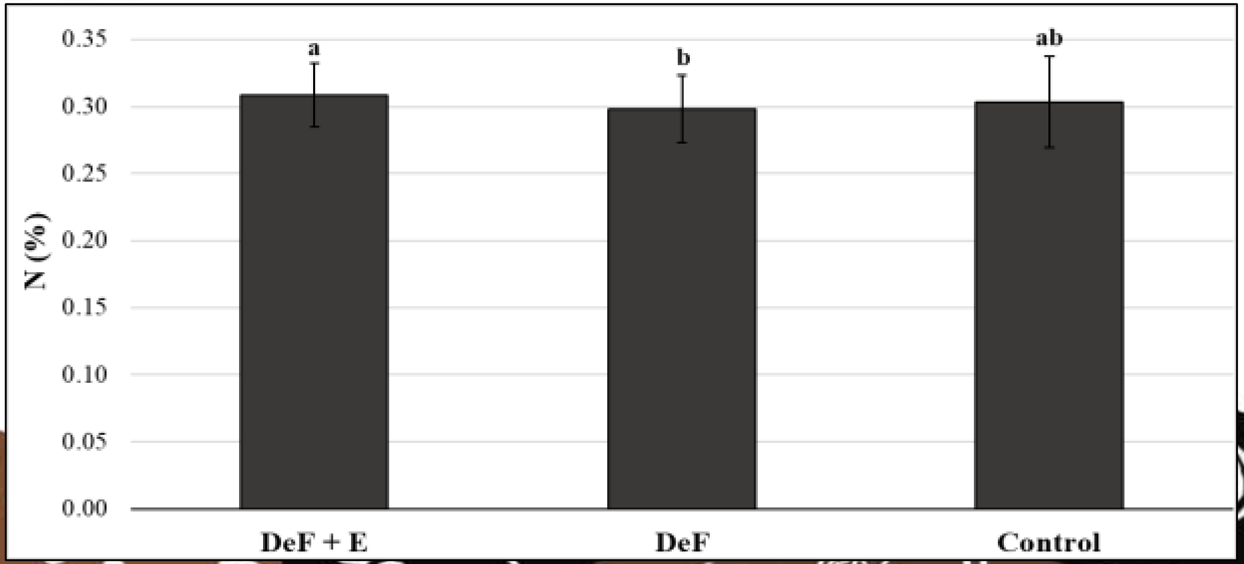
% Organic matter



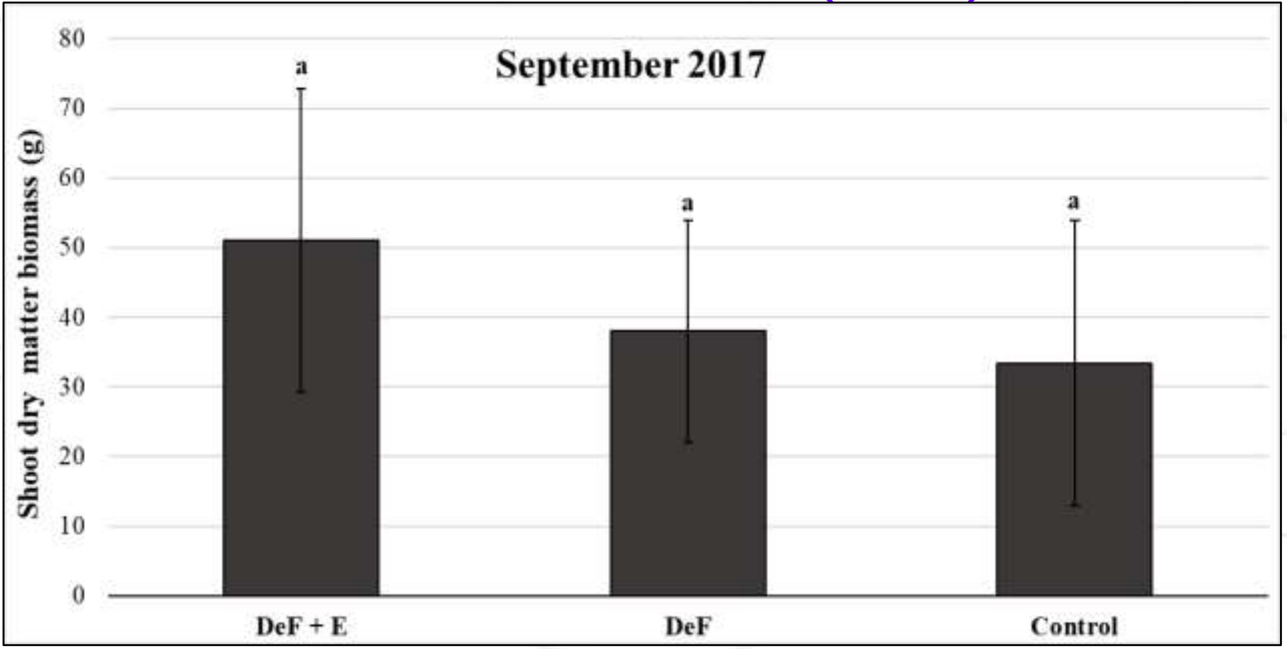
% Water stable aggregates

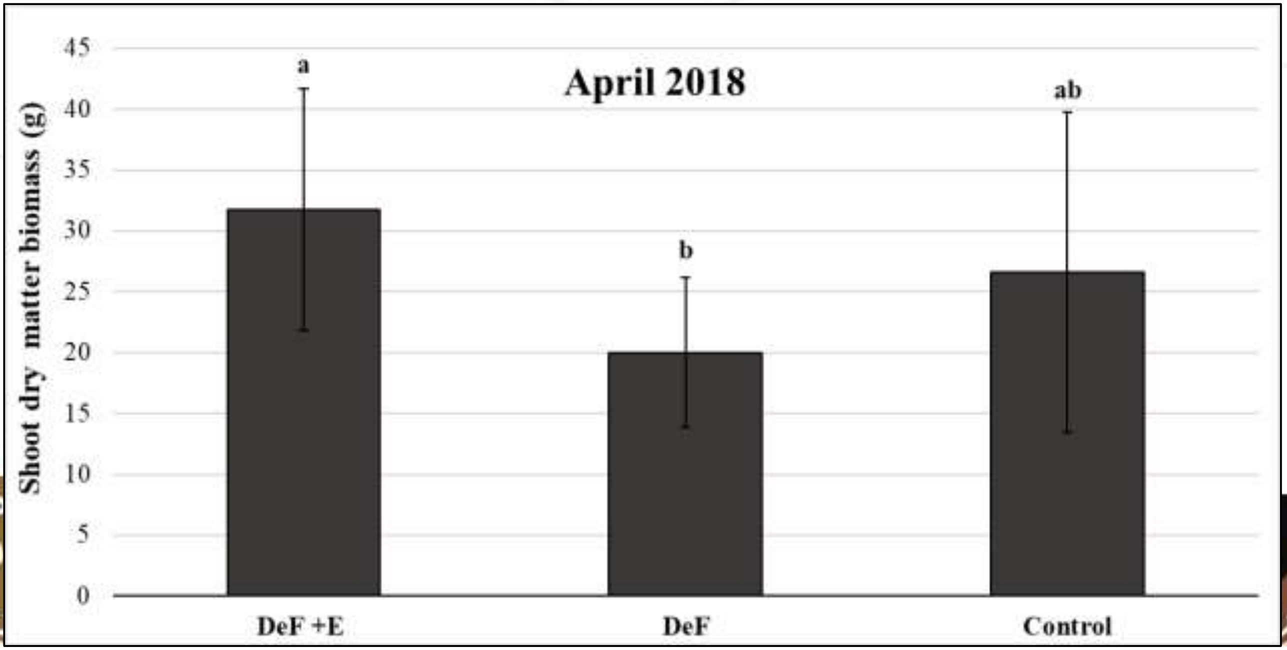


%Total nitrogen content

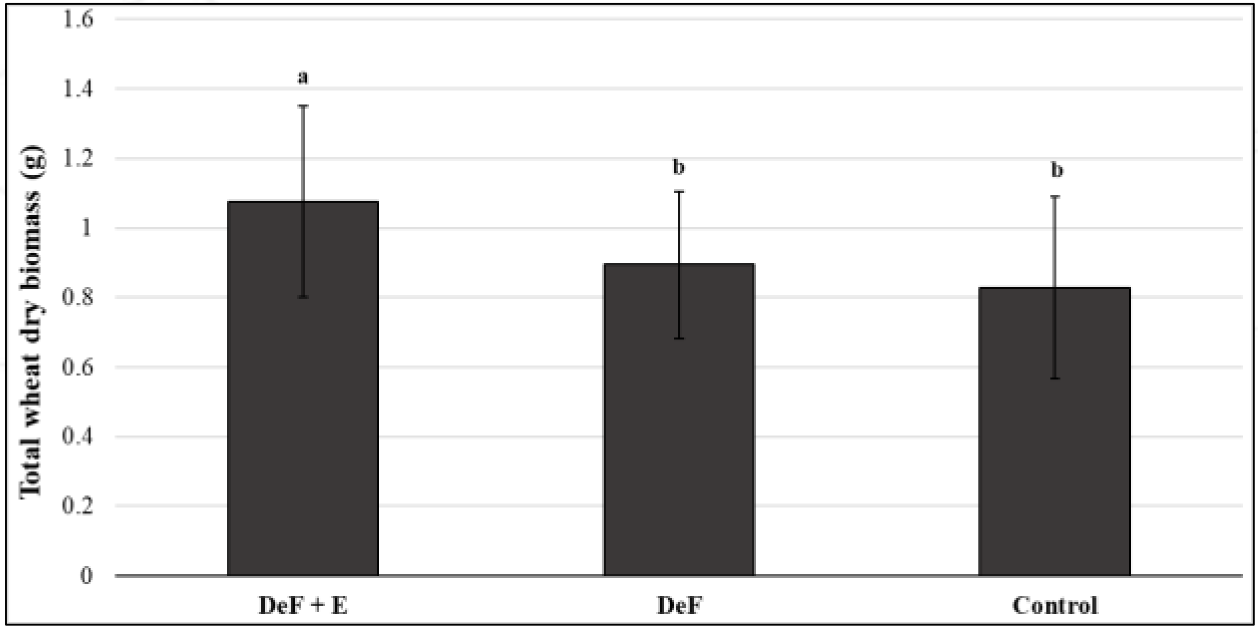


Mean clover and grass shoot dry matter biomass across all fields (n = 4)





Mean total dry biomass of wheat grown in the bioassay on soil taken from the fields (n = 4)



Take home message

Lab experiments

1) **The combined effect** of *earthworms* and winter wheat showed **the greatest effect on soil properties**.

2) **Lateral burrowing** earthworms, *A. chlorotica*, showed **more impact** than **vertical burrowing** *L. terrestris;*

Field experiment

1) Earthworms play a direct and significant role in the improvement of soil quality brought about by arable to ley conversion.

2) Their presence in the soil will largely reduce infiltration-excess overland flow and flooding which would help to alleviate negative effects of such events.

3) Boosting earthworm populations is a worthwhile practice to ensure successful and sustainable land reclamation and soil quality improvement.

Thank you for your attention

Contact

Jamal.hallam@gmail.com / Jamal.hallam@inra.ma

Published papers:

- Hallam J, Berdeni D, Grayson R, et al (2020) **Effect of earthworms on soil physico-hydraulic and chemical properties, herbage production, and wheat growth on arable land converted to ley**. Sci Total Environ 713:136491. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.136491

- Hallam J, Hodson ME (2020) **Impact of different earthworm ecotypes on water stable aggregates and soil water holding capacity**. Biol Fertil Soils. https://doi.org/10.1007/s00374-020-01432-5

- Hallam J (2018) **Soil hydraulic function: Earthworm-plant root interactions**. Unpublished PhD Thesis. University of York