Effects of *Lumbricus terrestris* L. population size on incorporation of cereal harvest residues in no-till agroecosystems

[1]Bentley, P.R., [1]Butt, K.R., [2]Nuutinen, V.

1 Natural Sciences, University of Central Lancashire, Preston, PR1 2HE, UK

2 Soil Ecosystems, Natural Resources Institute (LUKE), 31600, Jokioinen, Finland

PBentley1@uclan.ac.uk

Introduction

A field experiment was designed to explore the effects of *L. terrestris* density on the incorporation rate of cereal residues between autumn harvest and spring sowing in boreal no-till farming. This period was focussed at to learn to what extent *L. terrestris* foraging can diminish the amount of surface residue prior to sowing where ample residue cover – as such useful for erosion control – can physically hamper sowing and also constitute a source of Fusarium infection for the following crop. The particular aims of the study were: (i) to investigate incorporation rate of harvest residues in no-till fields in relation to *L. terrestris* abundance, the main hypothesis being an increasing impact of the species presence (ii) to study the importance of surface casting by *L. terrestris* and other earthworms on residue burial and at the same time (iii) to investigate how *L. terrestris* presence is associated with the population densities of other ecological groups of earthworms.

Methodology

This study was conducted over the winter of 2015-2016 on three direct drilled cereal field sites in south-western Finland with differing soil properties (Figure 1). These were two of Luke's (Natural Resources Institute Finland) experimental fields in Jokioinen (Ojainen and Kotkanoja sites), and a no-till field under practical cultivation at Kiikoinen.

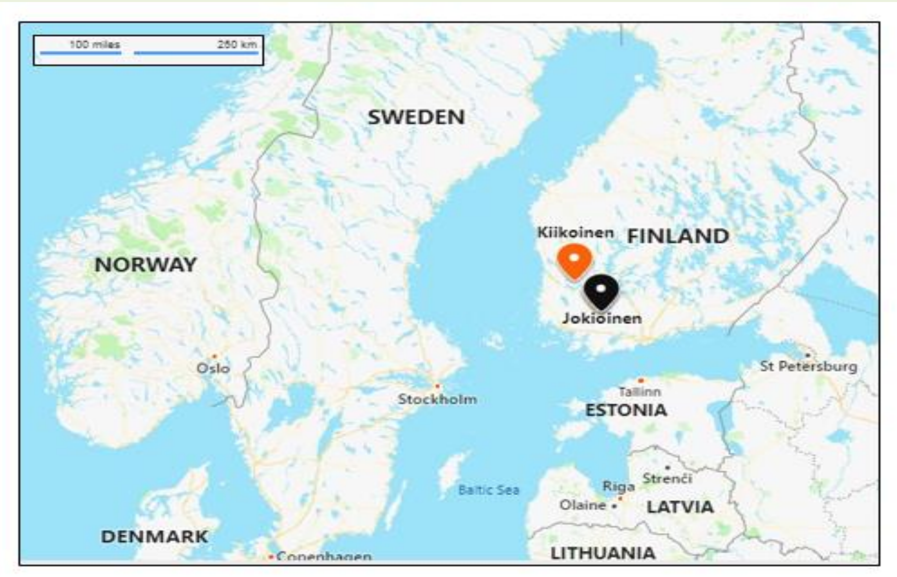
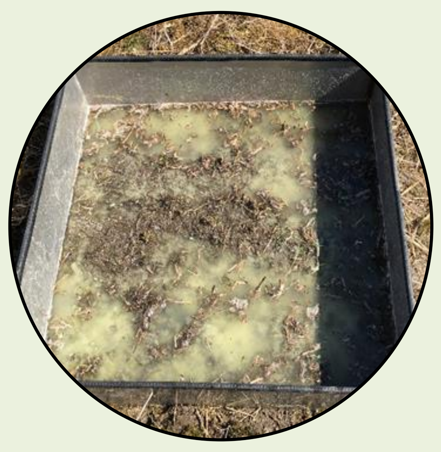


Figure 1. *Map indicating the two experimental locations, Jokioinen and Kiikoinen, in south-west Finland.*

1. In October 2015, weighed straw residues were placed on the soil surface in areas of high and low *L. terrestris* populations. Straw was contained in a 50 cm x 50 cm metal mesh cage throughout the winter.

2. In May 2016, prior to the Finnish sowing season, surface straw from each cage was removed, dried in the laboratory and weighed.

3. Photographs were taken at each sample before and after straw removal. Soil samples from each site were collected and soil moisture recorded.



4. Following straw collection, *L. terrestris* densities and biomasses at each site were determined by mustard extraction. Collected earthworms were categorised by ecological grouping.

Results and Discussion

This experiment supported the hypothesis that surface applied cereal residue can be incorporated into soil more rapidly when *L. terrestris* are present, where total mean reduction in straw residue mass was 4.6 ± 0.62% higher under LT+ treatments (Figure 2). Between sites, the rate of residue removal varied widely and was lowest on the Kiikoinen site. It was not possible to explain conclusively the differences between the sites, as the type of residue, *L. terrestris* abundance and many other environmental conditions varied across sites.

Table 1. *Mean abundance (± S.E.) of L. terrestris at high (LT+) and low (LT-) plots for each field site. Values denotes with a different letter within a site are statistically different at p < 0.001 level (one-way ANOVA; df = 1; p < 0.001).*

L. terrestris	Ojainen		Kotkanoja		Kiikoinen	
	LT+	LT-	LT+	LT-	LT+	LT-
Total (ind. 0.25 m^{-2})	5.0 ± 1.4^a	0.0^b	6.5 ± 1.7^a	0.4 ± 0.3^b	22.8 ± 2.0^a	6.0 ± 1.3^b
Adults (ind. 0.25 m^{-2})	0.8 ± 0.5^a	0.0^b	2.0 ± 0.8^a	0.0^b	1.8 ± 0.5^a	0.6 ± 0.4^b
Juveniles (ind. 0.25 m^{-2})	4.2 ± 1.0^a	0.0^b	4.5 ± 1.4^a	0.4 ± 0.3^b	21.0 ± 0.5^a	5.4 ± 1.1^b
Biomass (g 0.25 m^{-2})	5.1 ± 2.4^a	0.0^b	9.0 ± 2.9^a	0.2 ± 0.1^b	11.1 ± 2.1^a	3.3 ± 1.3^b

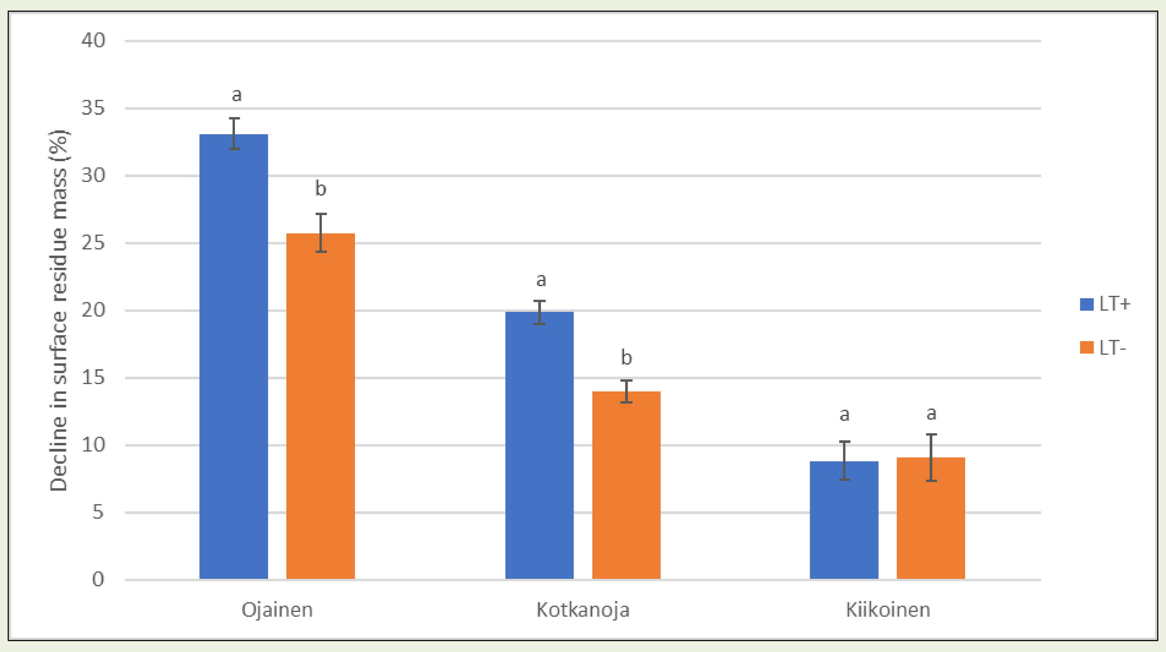


Figure 2. *Mean (± S.E.) reduction in mass of surface residue (% AFDW) at each site in LT+ and LT- areas. For Ojainen and Kiikoinen, N=5; for Kotkanoja, N=8. Statistically significant differences at sites (p < 0.001) are represented by different letters.*

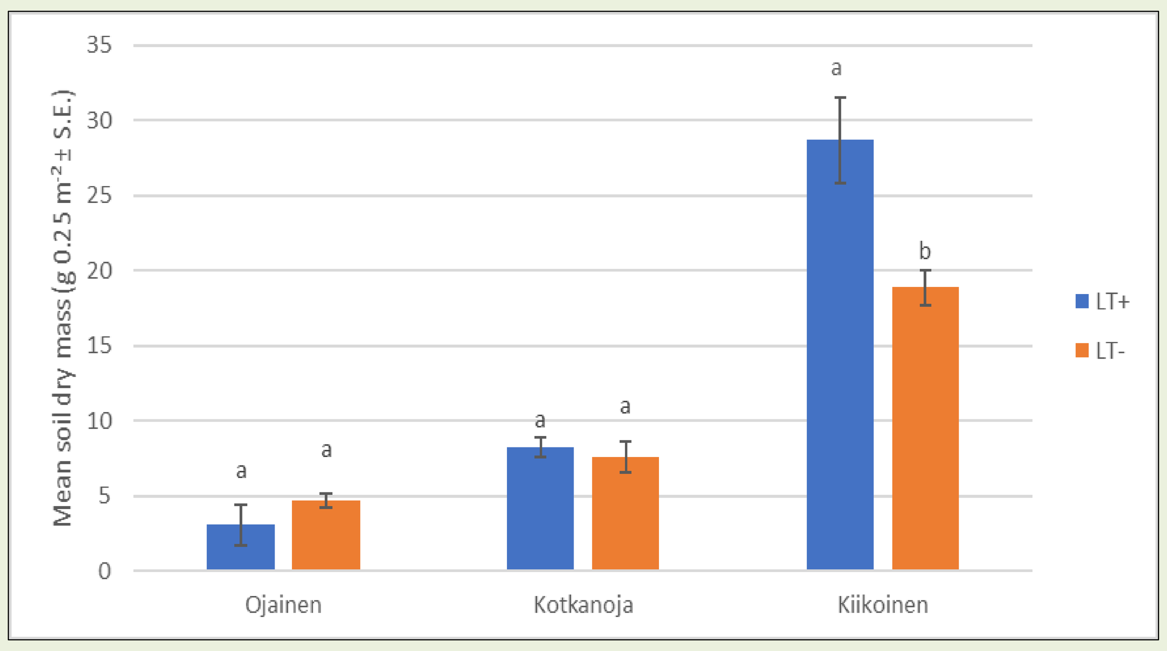


Figure 3. *Mean (± S.E.) dry mass (g) of soil detached from surface residues at experimental end at high and low L. terrestris densities for each field. A statistical difference between LT+ and LT- at each location is indicated by different letters (one-way ANOVA; p < 0.05). N=5 (Ojainen and Kiikoinen); N=8 (Kotkanoja).*

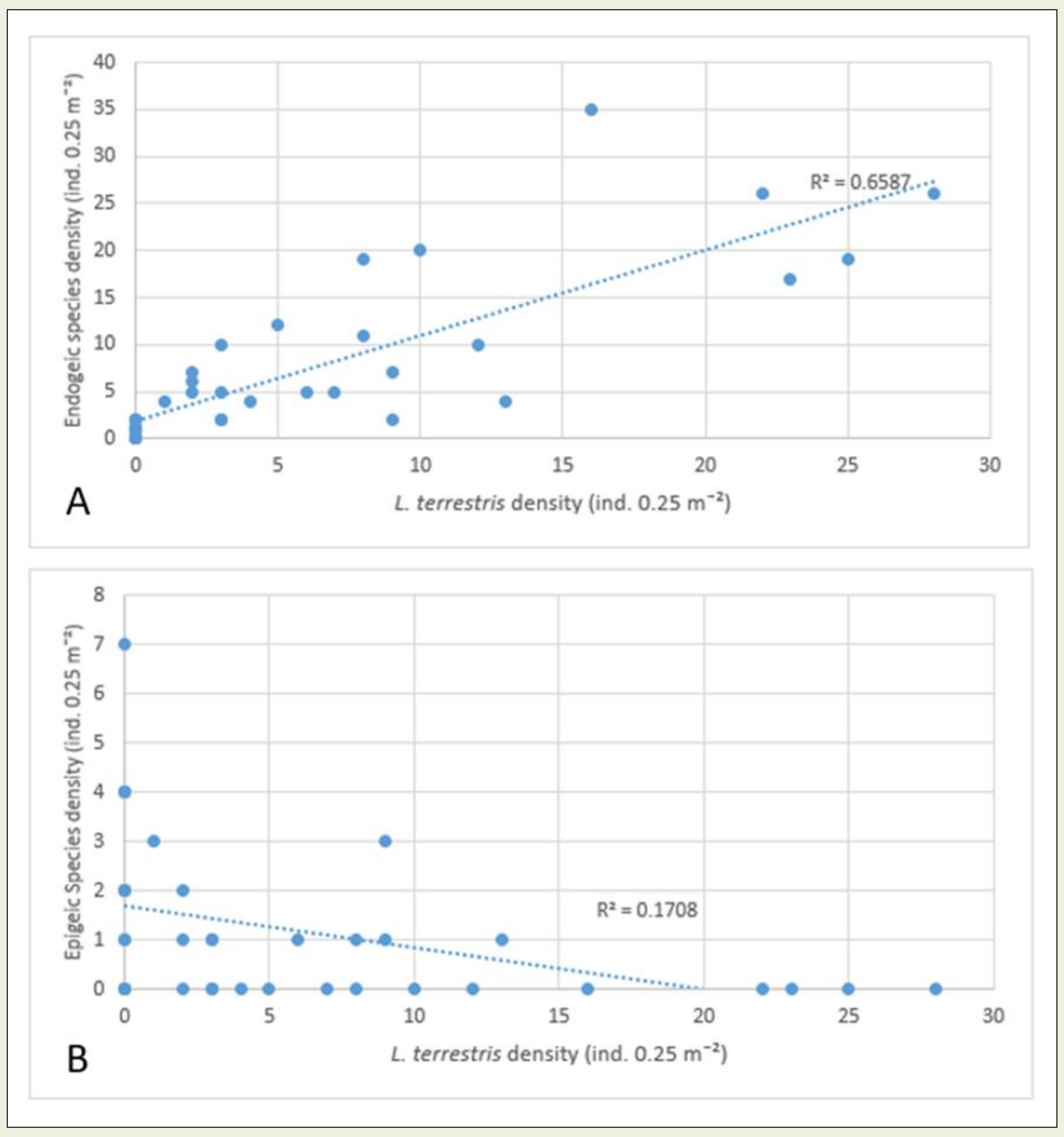


Figure 5. *Relationships of L. terrestris density with (A) endogeic species density and (B) epigeic species density (ind. 0.25 m^{-2}) at experimental end.*

In this experiment, the mass of casts remaining in straw residues increased with *L. terrestris* density, where a significantly higher average mass of casts was recorded at Kiikoinen compared with other sites (Figure 3). A higher total mass of casts within the Kiikoinen site could have been caused by higher densities of *L. terrestris* present when compared with other sites (Table 1).

However, in addition to *L. terrestris*, other species likely contributed to soil addition on residues through surface casting, a notable species is the endogeic *A. caliginosa*. They commonly cast within their burrow system but also on the soil surface (Haynes et al, 2003; Whalen et al. 2004; Capowiez et al, 2014a, 2014b). Observations made at experimental end at the Kiikoinen site indicated heavy endogeic casting on the soil surface, where the mean mass of casts removed from surface residues were the highest (Figure 4).

Figure 4. *A. caliginosa casts on the soil surface and on oat residues at Kiikoinen at experimental end.*

Relationships between *L. terrestris density* and earthworm ecological groups indicated a positive correlation with endogeic population density (Figure 5A) and a negative correlation with epigeic population density (Figure 5B). This could imply positive interspecific interactions occurring between *L. terrestris* and endogeic populations. However, further experiments would be required to clarify this. Contrasting information occurs on the inter-specific effects between *L. terrestris* populations with endogeic species (Lowe and Butt, 2003; Butt and Lowe, 2007; Eriksen-Hamel and Whalen, 2007). Increased *L. terrestris* activity could have reduced the availability of a litter layer habitat of epigeics. A high density of juvenile *L. terrestris* recorded within LT+ treatments (Table 1) could have also increased food competition, where both juvenile *L. terrestris* and epigeics species can gain from *L. terrestris* middens. However, it is also possible that *L. terrestris* populations facilitate epigeics through the development of a midden (Butt and Lowe, 2007).

This study highlights the significant effect *L. terrestris* activity has on soil engineering in agroecosystems, where activity has been recorded during winter months where reduced activity will be expected. Further experiments could explore the effect of *L. terrestris* populations on straw residue decline over a full season and in different geographical locations.

References

Butt, K. R., Lowe, C. N., (2007) Presence of earthworm species within and beneath *Lumbricus terrestris* (L.) middens. *European Journal of Soil Biology*, **43:1**, S57-S60.
Capowiez, Y., Bottinelli, N., Jouquet, P., (2014a). Quantitative estimates of burrow construction and destruction, by anecic and endogeic earthworms in repacked soil cores. *Applied Soil Ecology*, **74**, 46– 50.
Capowiez, Y., Sammartino, S., Michel, E., (2014b) Burrow systems of endogeic earthworms: Effects of earthworm abundance and consequences for soil water infiltration. *Pedobiologia,* **57**, 303-309
Eriksen-Hamel N. S., Whalen, J. K., (2007) Competitive interactions affect the interactions between *Lumbricus terrestris* and *Aporrectodea caliginosa* (Lumbricidae, Oligochaeta) in single and mixed species laboratory cultures. *European Journal of Soil Biology*, **43:3**, 142-15
Haynes, R. J., Fraser, P. M., Piercy, J. E., Tregurtha, R. J., (2003). Casts of *Aporrectodea caliginosa* (Savigny) and *Lumbricus rubellus* (Hoffmeister) differ in microbial activity, nutrient availability and aggregate stability. *Pedobiologia*, **47:5**, 882–887.
Lowe, C. N., Butt, K. R., (2003) Influence of food particle size on inter and intra-specific interactions of *Allolobophora chlorotica* (Savigny) and *Lumbricus terrestris*. *Pedobiologia*, **27**, 574-577.
Whalen J. K., Sampedro L., Waheed T., (2004) Quantifying surface and subsurface cast production by earthworms under controlled laboratory conditions. *Biology and Fertility of Soils*, **39**, 287–291.