# Inventory of the abundance of earthworm *Lumbricus terrestris* in grasslands on sandy soil

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## Abstract

The deep, vertical burrows of anecic earthworm *Lumbricus terrestris* contribute to the ecosystem service of water regulation in grasslands. They facilitate water flow and deeper rooting, thereby supporting the prevention of flooding and improving drought tolerance. In Europe, these earthworms occur in agricultural grasslands on various soil types. However, their distribution pattern is heterogeneous and not well-understood. Through characterisation of *L. terrestris* distribution patterns, we aim to grasp their potential for climate adaptive water regulation. In a field inventory (*n*=62) we assessed the relationship between *L. terrestris* population density in grassland on sandy soils and: soil silt concentration; epigeic earthworm population density; and grassland age. Soil silt concentrations and *L. terrestris* population densities correlated positively. Population density of *L. terrestris* correlated negatively with *L. rubellus* abundance. Population density of *L. terrestris* was not significantly related to grassland age. Unexpectedly, we found *L. terrestris* in some very sandy soils. Our data were fitted into an existing predictive model, yielding 63% accuracy.

**Keywords:** deep-burrowing earthworms, grassland, water regulation, ecosystem functioning

## Introduction

Grasslands play a vital role in water regulation. Global climate changes cause prolonged dry periods and intensified peak rainfall (Pachauri *et al.*, 2014) both of which entail major impacts on plant growth, biogeochemical cycles and nutrient losses in agricultural grasslands. As soil ecosystem engineers, earthworms cause soil bioturbation and improve water regulation (Deru *et al.*, 2018). Deep-burrowing earthworms, e.g., *L. terrestris*, create vertical, semi-permanent burrows, reaching down to 2 m. The burrows can increase soil infiltration rate and infiltration capacity, helping to avoid waterlogging and flooding (Blouin *et al.*, 2013), while increasing rooting space, which can promote drought tolerance. It is known that *L. terrestris* distribution is heterogeneous at field and landscape scale, but we lack a set of parameters explaining their occurrence, especially on grasslands on sandy soils. Our objective was to improve our understanding of the factors that define *L. terrestris* presence and abundance in this habitat. A field inventory was executed, focussing on (1) soil texture, (2) groundwater level, (3) competitive interaction with resident earthworm species and (4) land use and management.

## Materials and methods

Thirty-one grasslands belonging to eleven farms on sandy soils in the Dutch province of Noord Brabant were sampled in the spring of 2021 (Van de Logt *et al.*, 2023). With geodata, we selected grasslands of varying geomorphology, interrelated with soil types, texture classes and ground water stages. Grasslands were categorised 'young' (≤3 years) and 'old' (>3 years), by the number of years since renewal (*n*=11 and *n*=20 for young and old resp.), as *L. terrestris* is known to be sensitive to tillage. In each grassland, two plots were sampled (*n*=62) on representative spots >10 m from the fence, >40 m between two plots. Per plot, a cube of soil, 20×20×20 cm, was excavated, hand-sorted, and all earthworms present were counted and identified to species. Three additional soil cubes were dug out to create a square pit of 40×40×20 cm, and 4 l of 0.01% allyl-isothiocyanate (AITC) solution was then applied to the pit to collect *L. terrestris* from deeper soil layers. All earthworms emerging within 20 minutes were collected, rinsed with water and stored in containers. Using an auger (ø 10 cm) the soil profile was assessed (0–120 cm). Gley depth (cm) was used as a measure for temporary max. groundwater or pseudo-groundwater tables. Fifteen soil samples for chemical analysis were taken from the topsoil (0–10) and 30–40 cm soil layer with a gouge auger (ø 2.5 cm) within a 2 m radius from the earthworm sampling pit. SOM, pH and silt concentration were analysed (see Van de Logt *et al.*, 2023). Soils were categorised as loam-poor, light loamy or loamy sands, according to a Dutch texture classification (Van der Meulen *et al.*, 2007). R was used for correlative analysis of the data; data were also fitted into an existing model (Lindahl *et al.*, 2009) as this model predicts *L. terrestris* density $m^{-2}$, based on land-use type and soil texture.

## Results and discussion

Silt concentration at a depth of 30–40 cm was positively correlated with total ($R^2$=0.21; $p$<0.001), adult ($R^2$=0.33; $p$<0.025) and juvenile *L. terrestris* density for ($R^2$=0.15; $p$<0.025) (Figure 1). Surprisingly, a very loam-poor grassland hosted a high density of *L. terrestris*. Highest abundance was observed in soils with 20–40% silt (Figure 1). Higher *L. terrestris* densities in loamier soils were also reported in other studies (Decaëns *et al.*, 2003). Possibly, better moisture and nutrient retention in loamy sand provide a more favourable environment than loam-poor sand. Previous research suggested that earthworms suffer from the coarse texture and drought proneness of sandy soils (Hawkins *et al.*, 2008). However, *L. terrestris* has been reported to occur in coarsely textured soil, albeit in lower densities than in medium-textured soils. For 63% of the samples, the model by Lindahl *et al.* (2009) gave an accurate estimation of *L. terrestris* density (low, medium, high; <3, 3–10, >10 $m^{-2}$, respectively). The accuracy of the classification tree for medium-textured soils and coarsely textured soils was 51% and 69%, respectively. Gley depth correlated positively with *L. terrestris* total densities in a model with the silt concentration predictor ($R^2$=0.25; $p$<0.05). Gley depth correlated negatively with both silt and clay concentrations at 10 and 40 cm depth ($p$<0.05). Absence of compaction layers prone to waterlogging and associated formation of temporal shallow pseudo-groundwater levels indicates well-structured soils. Valckx *et al.* (2011) suggest that well-structured, porous and deep-drained soils are suitable for anecic earthworms. *Lumbricus rubellus* density and *L. terrestris* total and adult densities correlated negatively ($R^2$=0.10; $p$<0.025 and $R^2$=0.11; $p$<0.025, respectively). No significant correlations were found between *L. rubellus* densities and *L. terrestris* juvenile densities. Negative interactions between the two species were also suggested in previous research under semi-controlled conditions (Lowe and Butt, 2002) but not yet in a field inventory.

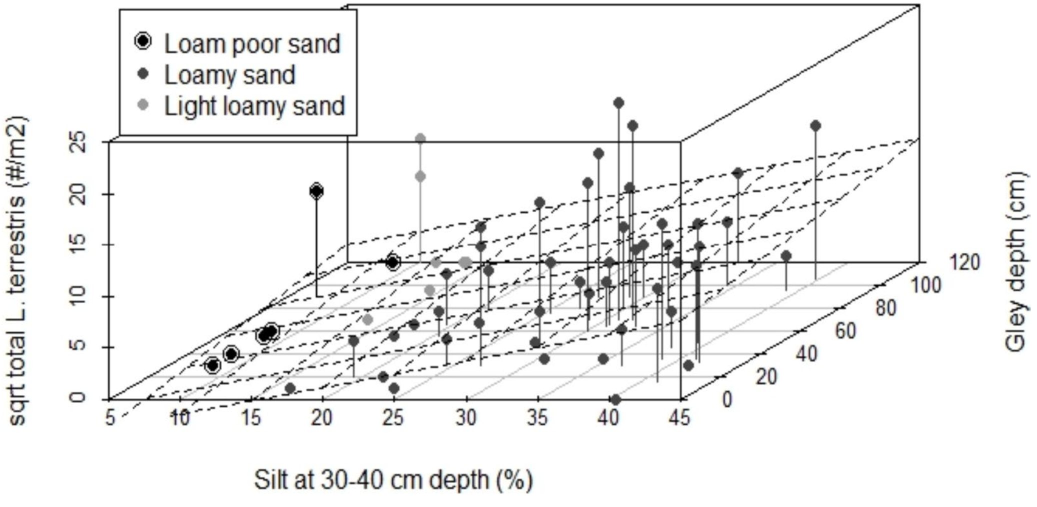

Figure 1. Correlation between soil silt concentration at 30-40 cm depth, gley depth and total *L. terrestris* population densities $m^{-2}$. The plane represents the related linear model. Total *L. terrestris* population densities are square root transformed.

A negative correlation could emerge from interspecific competition for limited food sources, both species feed on surface organic material. *L rubellus* has a higher reproduction and growth rate than *L. terrestris* and may therefore outcompete the latter (Uvarov, 2009). Unexpected was that grassland age did not significantly correlate with *L. terrestris* population densities, possibly due to a slightly unbalanced dataset, with eleven young grasslands and twenty old grasslands, which was the result of limited availability of young grasslands in the area.

## Conclusion

*Lumbricus terrestris* was more abundant in soils with a higher silt percentage, likely because of positive relationships between loaminess and other soil factors that create favourable living conditions. Unexpectedly, *L. terrestris* was also abundantly present in a grassland on loam-poor sand. The model by Lindahl *et al.* (2009) correctly predicted the level of *L. terrestris* abundance based on land use and soil texture in 63% of the samples. A weak positive correlation was observed between *L. terrestris* density and gley depth; waterlogged layers could create an unfit environment. A negative correlation with *L. rubellus* abundance was shown, likely due to competition for food, perhaps combined with slightly diverging habitat preferences. The study did not reveal significant differences in *L. terrestris* abundance based on grassland age, possibly because the dataset was not sufficiently balanced for sward age. Overall, this correlative study provides further insights into *L. terrestris* habitat selection.

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