Earthworm Communities in German Agricultural Soils: Patterns, Drivers and Chemical Risk

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Introduction and Study Objective

Earthworms play a crucial role as ecosystem engineers and serve as sensitive indicators of soil health. Agricultural soils face numerous stressors, such as intensive management practices and exposure to chemical mixtures. However, comprehensive field-scale data linking these factors to earthworm populations across a national landscape remain scarce.

This study aims to evaluate the influence of land use, soil characteristics, and combined chemical risks on earthworm communities within German agricultural soils.

Sampling Methodology

- 51 agricultural sites were sampled throughout Germany, including arable land (33 sites), grasslands (12 sites), orchards (3 sites), and vineyards (3 sites).
- Nine arable land sites were sampled thrice, approximately six months apart.
- Earthworm collection followed DIN EN ISO 23611-1 standard (hand-sorting & liquid extraction), 0 to 20 cm depth.
- Specimens were identified to species level and categorized into ecological groups (epigeic, endogeic, anecic) as well as developmental stages (adult and juvenile).
- Simultaneous measurements of soil properties (such as pH, organic carbon content, texture, moisture, and bulk density) and assessment of chemical contamination using cumulative risk indices (RI) were performed. The RI per site was calculated as the sum of measured chemical concentrations divided by related regulatory acceptable concentrations for earthworm communities.
- Land management practices, such as ploughing, could not be included.

Results

Earthworm Communities (Fig. 1)

- The median abundance, but not the biomass, of adult and juvenile earthworms was significantly lower in arable land compared to grassland.
- 4 species (*A. calignosa, L. terrestris, A. rosea*, *A. chlorotica*) were frequently detected (findings in ~ 60% of all sites).
- 6 species (*L. friend*, *A. longa ripicola*, *A. cupulifera, A. diomedea*, *H. oculatus*, *M. miniscula*) were found only at a single site.

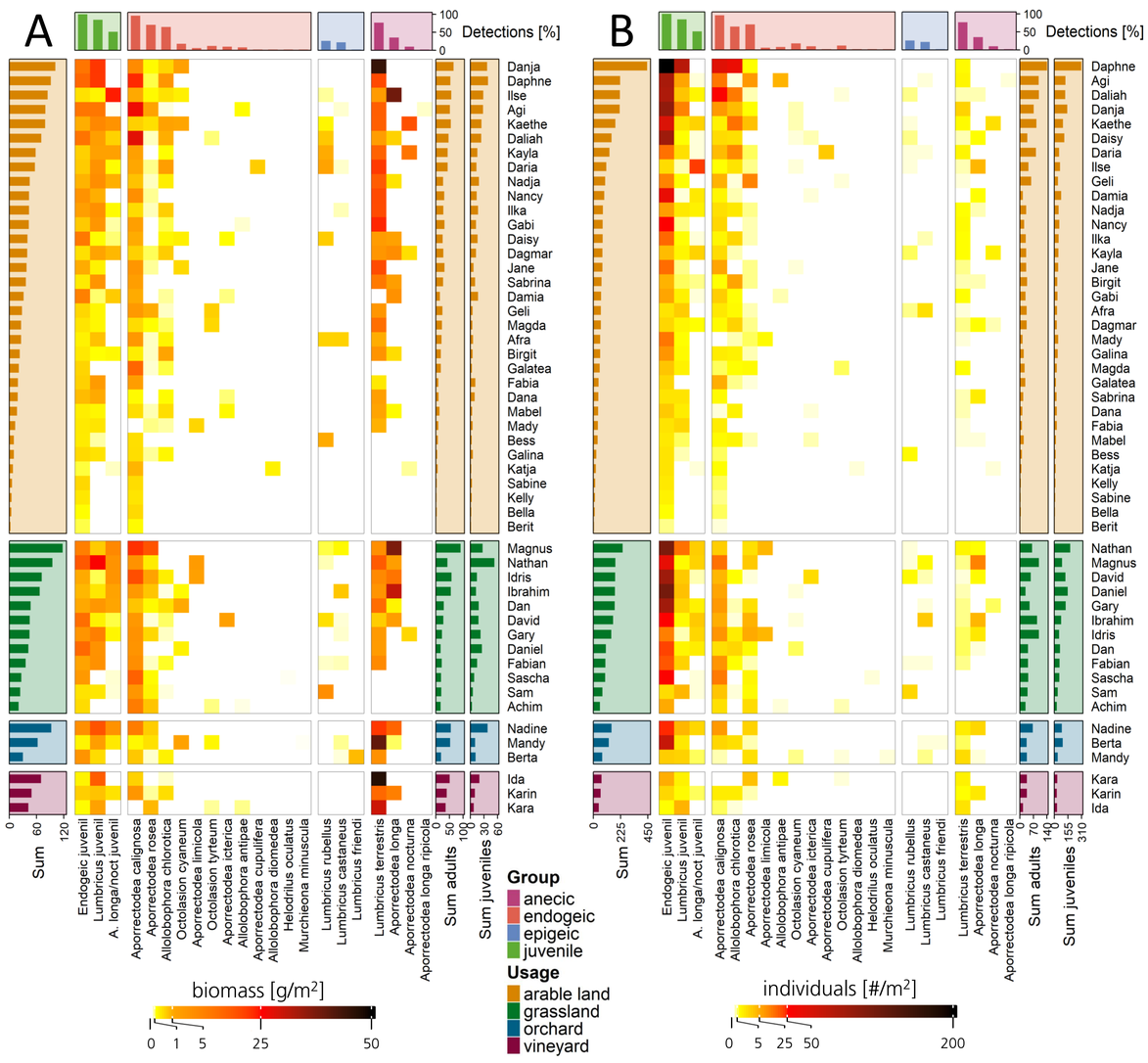

Figure 1: Heatmap of earthworm biomass (A) and abundance (B), grouped by ecological/developmental group (columns) and land use type (rows). Sampling sites (rows) are anonymized using human names. Annotation bar charts show detection frequency (top) and summed values per site (left: adult and juvenile combined; right: adult and juvenile separated)

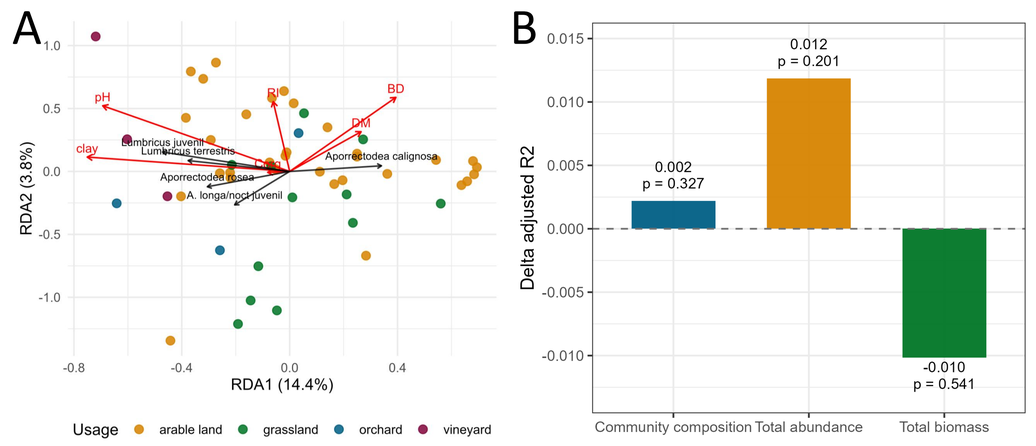

Figure 2: Redundancy analysis (RDA). (A) Exemplary RDA biplot for earthworm abundance showing sites colored by land use, soil parameter vectors (red), and the top 5 species vectors (black). BD = bulk density, RI = $\log_{10}$(risk index), C_{org} = organic carbon, clay = clay content, DM = dry matter (field fresh). (B) Additional contribution of chemical residues after accounting for soil properties, expressed as the change in adjusted R^2 after adding the RI to the model. Bars are shown for community composition, total abundance, and total biomass; associated p-values indicate that the additional effect of chemistry was small and not significant in all response metrics.

Influence of soil parameters and chemical residues (Fig. 2)

- Separate Redundancy analysis (RDA) for abundance and biomass identified soil properties as main drivers of earthworm community variation.
- Strongest unique effects were texture-related factors: clay content and bulk density (BD) (both endpoints significant).
- pH showed consistent significant effects on both abundance and biomass.
- C_{org} contributed significantly to biomass, but not clearly to abundance.
- Risk index showed only a very small and non-significant additional effect after controlling for soil properties across community composition, total abundance, and total biomass.
- Potential effects on individual species were not examined in this analysis.

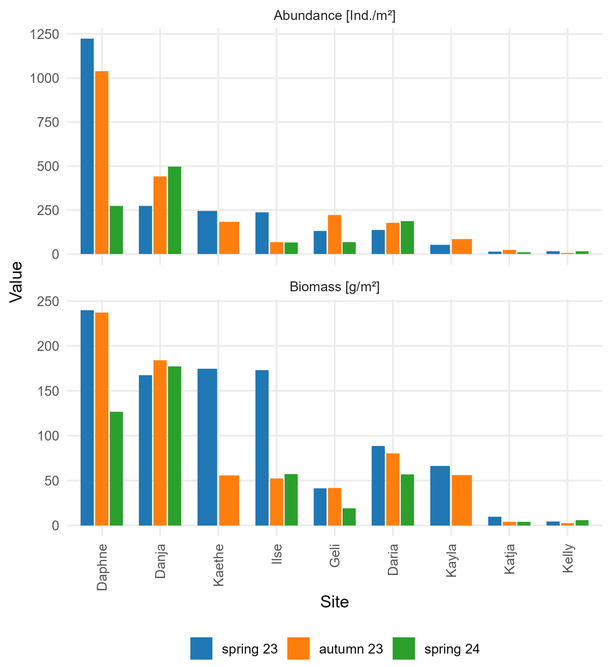

Figure 3: Temporal variability of earthworm abundance and biomass

Temporal variability (Fig. 3)

- Variability between sites exceeded variability over time.
- Seasonal deviations are likely driven by meteorological conditions.
- Compared with Katja and Kelly, the high-abundance sites Daphne and Danja were characterized by lower bulk density, higher pH, higher C_{org}, and slightly higher clay content.

Conclusion:

- Four species dominated the earthworm community.
- Total abundance and biomass (not significant) were lower in arable land compared to grassland.
- Soil characteristics dominate over the aggregated risk index for chemical contaminants in explaining earthworm patterns.
- Variability over time was lower than variability between sites.
- Land management practices and meteorological conditions should be included in future samplings and evaluations.

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