Soil parameters have higher predictive importance for earthworm abundance and species richness than climatic ones

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Background

- Earthworms are major part of **soil biodiversity** → often used as **indicator** organisms in soil health monitoring.
- **Agriculture** has a major impact on earthworm biodiversity.
- However, combined impacts of agricultural management, soil properties and climate parameters on earthworm biodiversity are not well described.

Research question

Which factors among **agricultural management** and **soil** and **climate parameters** are the most important drivers of earthworm abundance and species richness at European scale?

Methods

1. **Collation and harmonization** of earthworm and complementary agricultural, soil, and climate **data** from biodiversity databases (e.g. Edaphobase, GBIF), public datasets, literature, and unpublished datasets.

   More than **11,000 data points** distributed over 35 European countries (Figure 1) from 1928 to 2023 were collated.

2. **Imputation** (R package missForest) of unreported soil and agricultural **data**.
3. **Data analysis** using **gradient boosted decision trees** (CatBoost) and **Sh**apley **a**dditive ex**pl**anation (**SHAP**) to determine the most important variables.

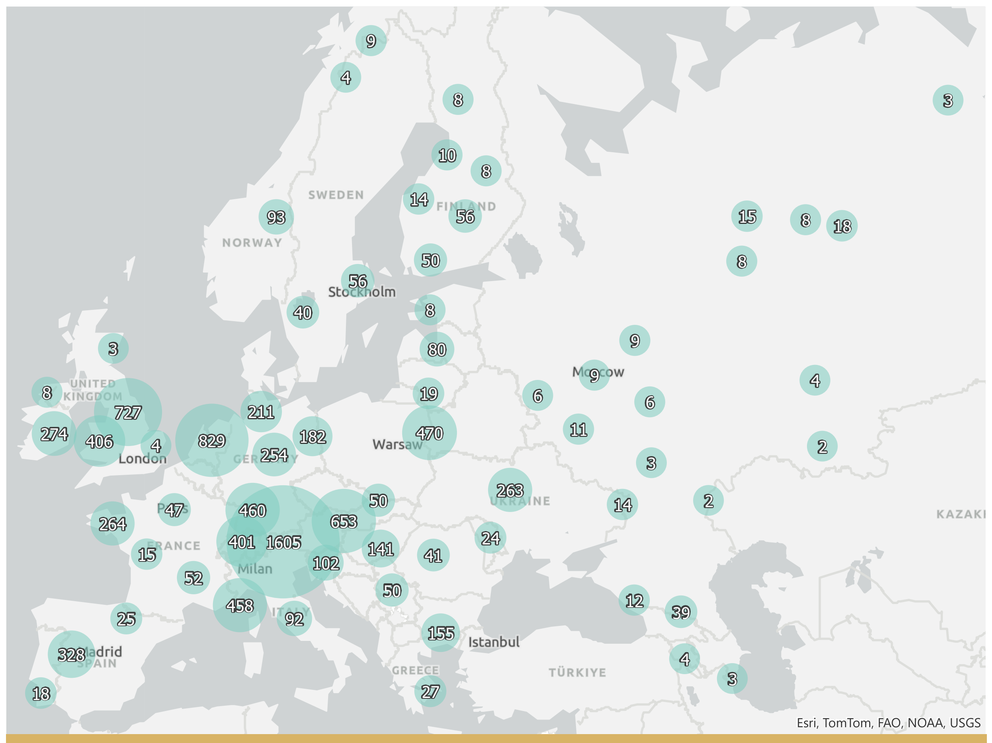

Figure 1: Distribution of data points within Europe.

Results

Earthworm abundance and species richness (Figure 2):

- **Order of importance** of predictive parameters:
  Soil parameters > agricultural management > climatic parameters
- **C/N ratio** highest importance
  Lower C/N ratio (<12) → higher abundance and species richness
- Importance of **soil texture**
  Higher silt content → higher abundance and species richness
- **Bulk density**
  Lower (<0.8 g cm^{-3}) and higher bulk density (>1.2 g cm^{-3}) → lower abundance
- Effect of applying **fertilizers**
  Fertilized sites→ higher species richness

Data collation:

- **Complementary data** on agricultural management, soil, and climate often **insufficiently reported**.
- **Data availability bias** within Europe -> Western and central Europe vs the rest
- Earthworm **abundance**: 153.5 ± 242.4 worms m^{-2} (Median: 51.9 worms m^{-2})
- Earthworm **species richness**: 2.3 ± 2.1 species per site

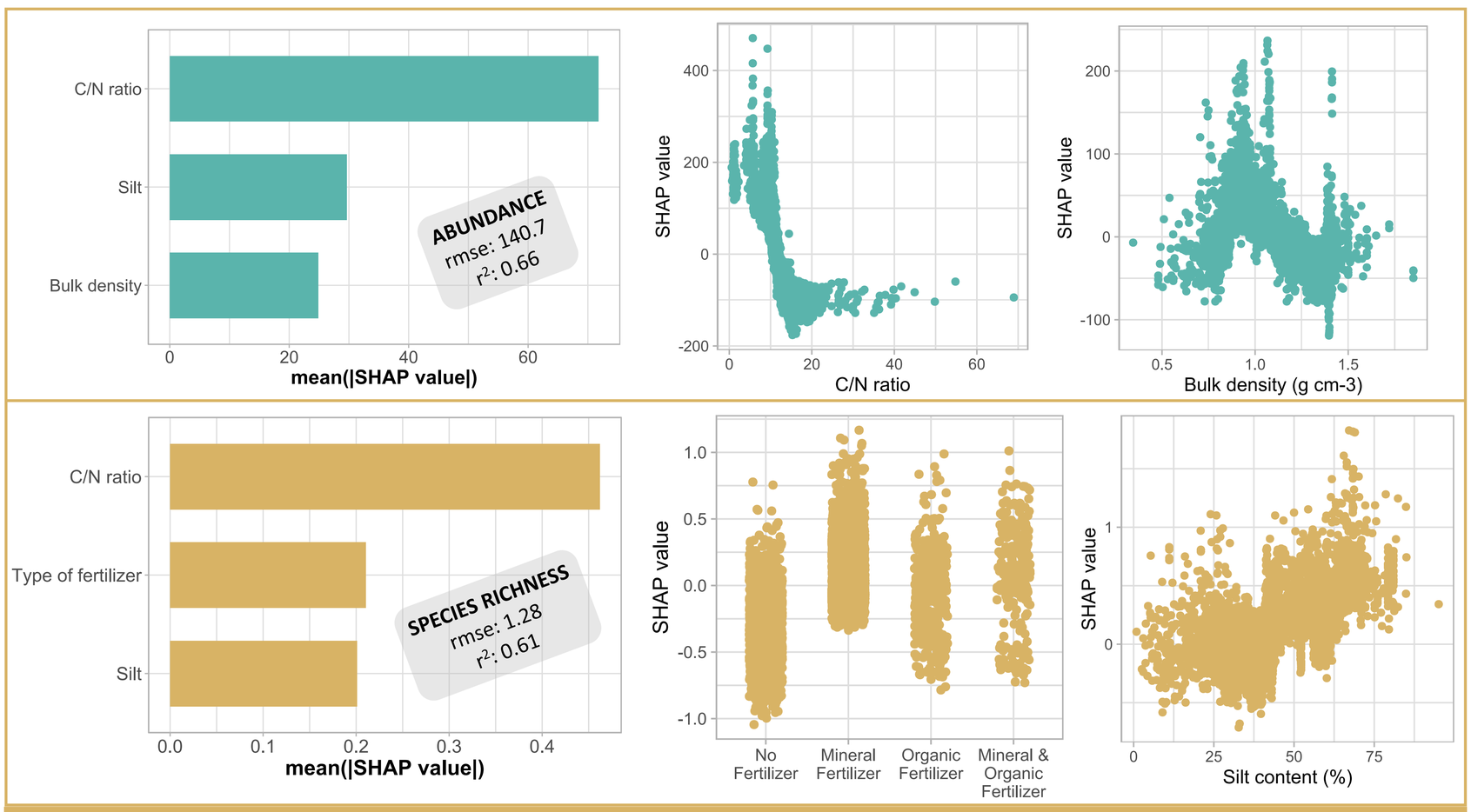

Figure 2: Select results of Catboost models visualized using SHAP values in importance and dependence plots. Top row: Earthworm abundance. Bottom row: Earthworm species richness.

Conclusion

- Both abundance and species richness were affected by some of the **same predictors** (C/N ratio and silt).
  - Higher **silt** content → higher available water capacity of the soil
  - High abundances with lower **C/N ratios** → more N in the soil, likely due to fertilization
- **Fertilized plots** had **higher species richness**, irrespective of whether applied fertilizers were mineral or organic.
  - Fertilizer increases plant biomass →
  - increases soil organic matter input →
  - increases biological activity of the soil.
- **Ideal bulk density** for earthworms between ~0.8 and 1.2 g cm^{-3}
- **Low** importance of **climatic** parameters.

Take-home message: Maintaing soil parameters in optimal ranges is key for fostering earthworm biodiversity.
Some aspects can hardly be changed (e.g. soil texture), but others can be controlled with management measures (C/N ratio, bulk density).

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