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Introduction

Despite their importance in soil functioning, consistent monitoring of earthworm biodiversity has been lacking due to funding, labor, and time constraints. Large-scale studies have revealed global patterns but lack the detail needed to capture the dynamics of earthworm communities in different environments (Phillips et al., 2019). Citizen science emerges as a valuable tool to overcome this lack by involving the broader public in data collection, thus enhancing spatiotemporal resolution and providing insights into earthworm dynamics. This approach supports sustainable land management, crucial in the face of environmental challenges like climate change and urbanization. While concerns about data reliability in citizen science persist due to potential biases and varied participant expertise, studies show that with proper training and validation, citizen science data can be highly reliable (Aceves-Bueno et al., 2017). Addressing gaps in understanding the factors affecting data reliability, could further enhance the value of citizen science in ecological research.

This study evaluates the reliability of classifying earthworms into four morphotypes within the '500 ENI' (Non-intended Effects) Monitoring Network in France, which involves annual sampling by non-specialist participants in agricultural lands, followed by identity verification by earthworm taxonomists.

Materials & methods

500 ENI (Non-intended Effects) network

- The 500 ENI network, launched in 2012 by the French Ministry of Agriculture (DGAL), monitors changes in indicator species like earthworms due to agricultural activities.
- The network covers 500 fields across metropolitan France and Corsica, focusing on annual crops, vineyards, and market gardening (Fig. 1).
- Participants, mainly agricultural advisors without formal biodiversity training, received workshops from earthworm specialists on ecology and sampling techniques.
- Sampling was followed by a debriefing session to review results and correct errors, with ongoing access to online resources for classification.

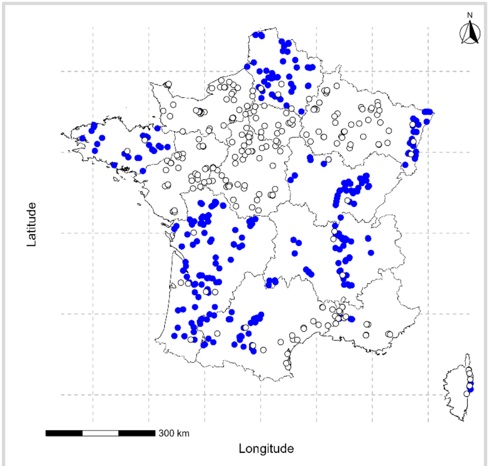
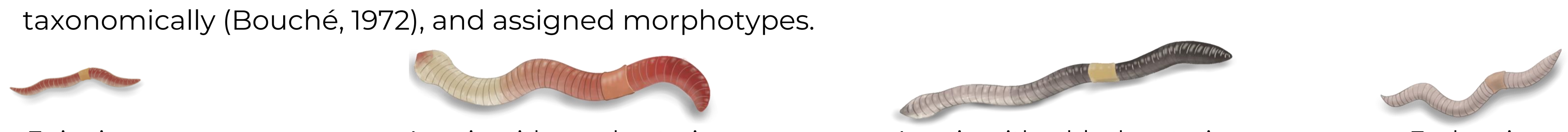


Fig. 1: Location of the 500 ENI network plots across France, including Corsica. Blue circles show plots for which the participants returned samples to the laboratory at least once, while empty circles indicate plots for which no earthworms were returned (2012-2018).

Earthworm sampling and data collection

- Between 2012 and 2018, participants sampled earthworms each spring using a chemical extraction method across 500 plots, with three 1 m² sampling areas per plot.
- Mustard suspension was applied twice per plot to surface earthworms, which were then collected, counted, and classified into developmental stages and four morphotypes: epigeic, anecic (with red or black anterior), and endogeic.
- Earthworms were preserved in alcohol, photographed, and sent to the University of Rennes for classification validation; only 27% of samples reached the laboratory (Fig.1).
- In the lab, earthworms were counted, categorized by developmental stage, identified taxonomically (Bouché, 1972), and assigned morphotypes.



Epigeic — Anecic with a red anterior — Anecic with a black anterior — Endogeic

Reliability indices

- To evaluate participants' classification reliability, the study calculated two indices for each plot: misclassification rate (MR) and undetected rate (UR).
- MR measures the percentage of earthworms misclassified within each morphotype, while UR measures the percentage of earthworms overlooked within a morphotype.
- A higher MR indicates more frequent misclassification, while a higher UR indicates more non-detections.
- These indices differentiate between morphotypes that are correctly identified but hard to detect (low MR, high UR) and those that are easy to detect but often misclassified (high MR, low UR).

$$[1]\ \text{Misclassification Rate}(MR_{MTx}) = (Nv_{MTx} - Nm_{MTx}) \times 100 / Nv_{MTx}$$

$$[2]\ \text{Undetected Rate}(UR_{MTx}) = (Ns_{MTx} - Nm_{MTx}) \times 100 / Ns_{MTx}$$

With MT (morphotype), Nv (total number of individuals assigned to a morphotype by a participant), Nm (number correctly attributed by specialists), Ns (number assigned by specialists).

Statistical analysis

- A one-way ANOVA compared earthworm counts by participants and specialists to evaluate abundance reliability (Fig. 2).
- GLMMs analyzed the effects of participant experience, total earthworms sampled, total plots sampled, and earthworm-to-plot ratio on MR and UR, with participant ID as a random factor and zero-inflation components (Fig. 3).
- Additional GLMMs examined how plot-level earthworm abundance, proportion of adults, number of morphotypes, and specific morphotypes impacted MR and UR, accounting for inter-annual variability (Fig. 4).
- Models used Poisson and Tweedie distributions, with diagnostics for overdispersion and multicollinearity, and focused on data within the 2.5% to 97.5% quantile range for robustness.

Results

Total abundance reliability (Fig. 2)

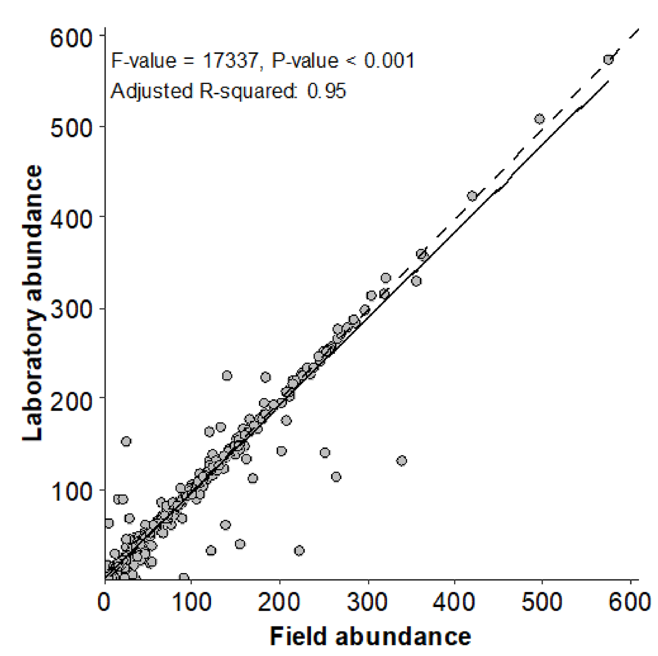


Fig. 2 : Relationship between total abundance of earthworms recorded by the participants (field) and specialists (laboratory). Each point represents a sampling plot. The dashed line depicts a line with slope of 1, indicating perfect correlation between earthworm abundance values recorded by participants and those derived from specialists. The solid line represents the regression line fitted to the data. Statistical analysis above the scatterplot displays the F-value and P-value from the ANOVA, plus the Adjusted R-squared value.

•Strong relationship between the total number of earthworms counted by participants and specialists, *aligns with similar findings (Aceves-Bueno et al., 2017)*
•Participants counted a cumulative total of 49,751 earthworms across all plots.
•Specialists counted a slightly lower total of 48,946 earthworms.
•On average, specialists reported 0.88 fewer earthworms per plot than participants (± 15 SD).

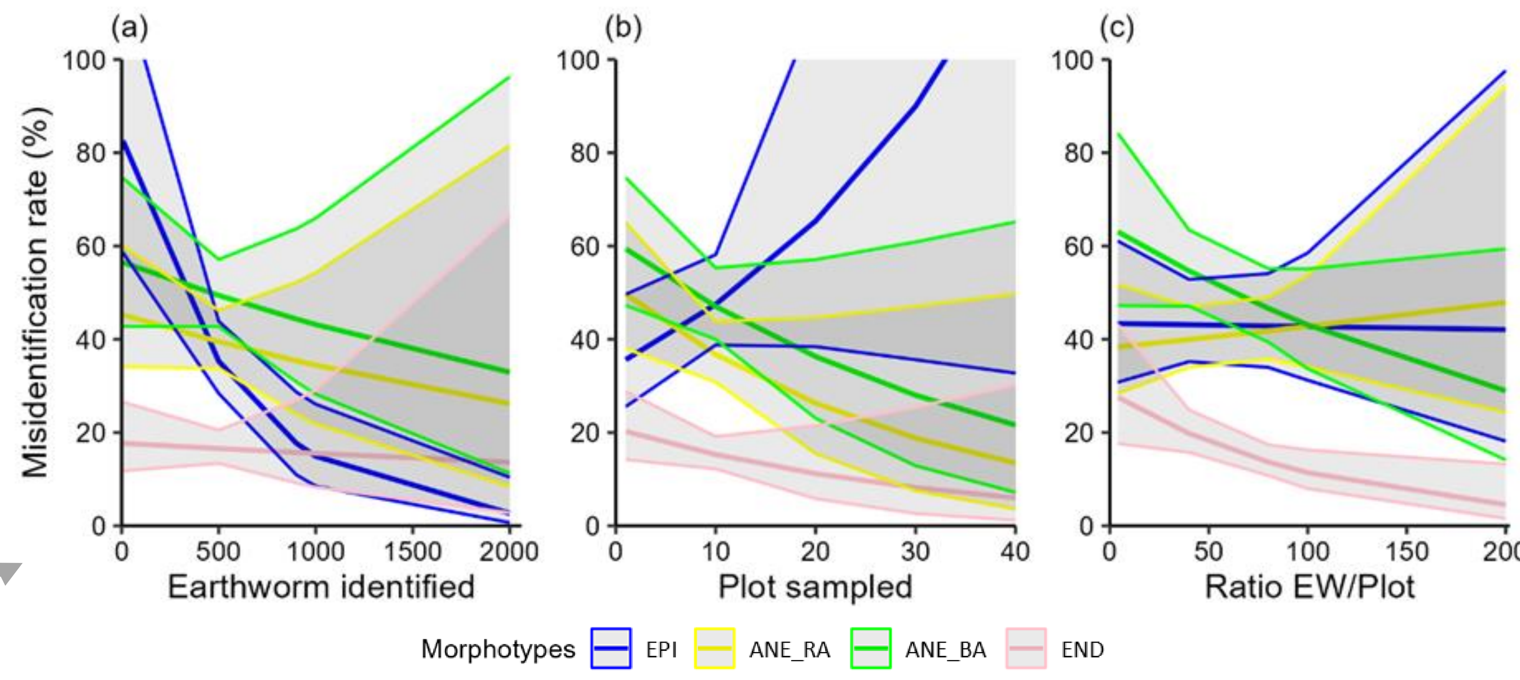


Fig.3 : Predicted Misclassification Rate (MR) ± standard deviation across (a) total number of earthworms identified, (b) total number of plots sampled, and (c) ratio of total earthworms identified/total number of plots sampled. Earthworm morphotypes abbreviations: EPI (epigeics), ANE_RA (anecics with a red anterior), ANE_BA (anecics with a black anterior), and END (endogeics).

Human factors explaining data discrepancies (Fig. 3)

•The misclassification rate (MR) significantly related to the total number of earthworms identified, the total number of plots sampled, and the ratio between these factors, with effects differing by morphotype.
•Increasing the total number of earthworms sampled decreased the MR for all morphotypes, with a steeper decrease observed for epigeics (Fig. 3a)*=> practical experience plays a crucial role*
•Sampling more plots decreased the MR for anecics (both red and black anterior) and endogeics, but increased it for epigeics (Fig. 3b) *=> practical experience plays a crucial role*
•A higher ratio of earthworms sampled to plots sampled decreased the MR for anecics with a black anterior and endogeics, but increased it for epigeics and anecics with a red anterior (Fig. 3c).
•The number of years of participation in the network did not significantly affect the MR.

Earthworm community parameters explaining data reliability (Fig. 4)

•MR was related to the number of earthworm morphotypes per plot, percentage of adult earthworms, and total earthworm abundance, with varying effects by morphotype.
•Increasing earthworm abundance decreased MR for anecics with a black anterior and endogeics, while it increased MR for epigeics; no significant effect on anecics with a red anterior (Fig. 4a)
•Increased proportion of adult earthworms: decreased MR for epigeics, anecics with a black anterior, and endogeics; increased MR for anecics with a red anterior (Fig. 4b) *=>adults are more easily recognizable than juveniles*
•Increasing the number of morphotypes decreased MR for all morphotypes, with the most significant decreases observed moving from three to four morphotypes for epigeics and anecics with a black anterior, and from one to two morphotypes for endogeics (Fig. 4c)*=> contrasting patterns seems to help classifying earthworm*

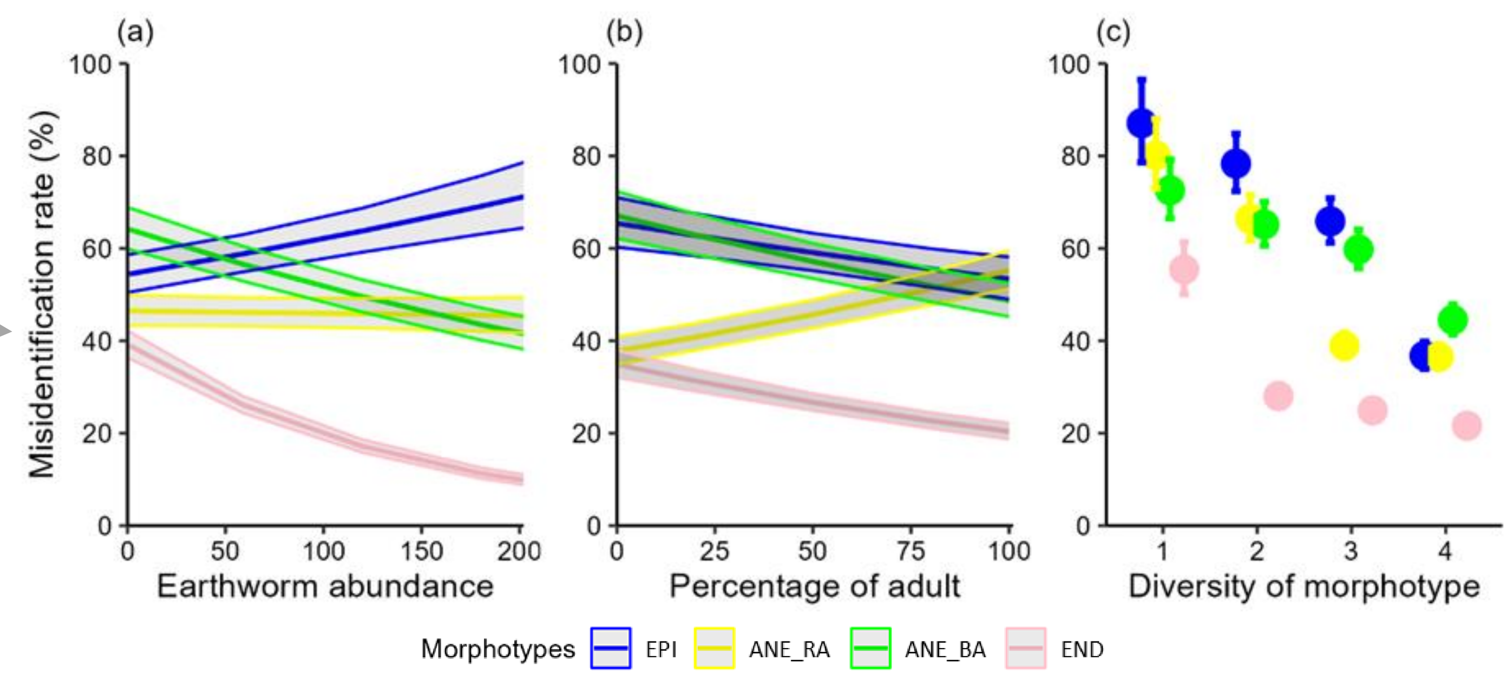


Fig. 4 : Predicted Misclassification Rate (MR) ± standard deviation across (a) the total abundance of earthworms, (b) the percentage of adult earthworms, and (c) the number of earthworms morphotypes per plot. Earthworm morphotypes abbreviations: EPI (epigeics), ANE_RA (anecics with a red anterior), ANE_BA (anecics with a black anterior), and END (endogeics).

Conclusions

- Significant correlations were found between citizen and specialist data on earthworm abundance, showing non-specialist data can be reliable.
- Variations in misclassification and undetected rates between morphotypes highlight challenges in morphotype assignment by non-specialists.
- Errors are influenced by sampler experience and community diversity
- Less diverse and juvenile-dominated communities are more challenging for accurate classification.
- More earthworms collected and more plots sampled improve reliability.
- Enhanced participant training and adapted sampling strategies can make citizen science more effective in understanding and conserving soil ecosystems.

References

Aceves-Bueno, E., Adeleye, A. S., Feraud, M., Huang, Y., Tao, M., Yang, Y., & Anderson, S. E. (2017). The Accuracy of Citizen Science Data: A Quantitative Review. Bulletin of the Ecological Society of America, 98(4), 278–290.
Bouché, M. B. (1972). Lombriciens de France: Écologie et systématique (INRA-Annales de Zoologie Ecologie Animale, Vols. 72–2). INRA
Phillips, H. R. P., Guerra, C. A., Bartz, M. L. C., Briones, M. J. I., Brown, G., Crowther, T. W., Ferlian, O., Gongalsky, K. B., van den Hoogen, J., Krebs, J., Orgiazzi, A., Routh, D., Schwarz, B., Bach, E. M., Bennett, J. M., Brose, U., Decaëns, T., König-Ries, B., Loreau, M., … Eisenhauer, N. (2019). Global distribution of earthworm diversity. Science, 366(6464), 480–485. https://doi.org/10.1126/science.aax4851

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