Geoderma 429 (2023) 116244

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

The effects of soil fauna on soil functioning through the prism of traits

The functional traits of organisms are defined as the morphological, physiological, phenological and behavioral characteristics of organisms that influence both their response to environmental constraints and their effect on the functioning of their habitat (Violle et al., 2007; Pey et al., 2014a). Trait-based approaches have been used for a long time in plant and aquatic ecology and they have been more recently conceptualized and developed for soil creatures (Pey et al., 2014b). This framework has proven its usefulness in identifying mechanisms linking 'response traits' of soil organisms and communities to human (pollutants, etc.) and natural (flood regimes, etc.) disturbances (Salmon et al. 2014; Andriuzzi et al. 2020). On the other hand, 'effect traits' are directly involved in the organismal contribution to ecological function(s). However, the link between belowground biodiversity and soil functions is traditionally studied within a paradigm that directly related soil processes and functions with the representativeness of the so-called functional groups (e.g. Bouché's ecological categories of earthworms), without explicit quantitative testing of causality between these two mentioned soil biota metrics (Bottinelli and Capowiez, 2021; Jouquet et al., this issue). Hence, not enough efforts have been dedicated so far to the identification of effect traits and their reflection in soil functioning (see e.g. Raymond-Léonard et al. 2019). The complexity of soil communities, their sensitivity to environmental changes and engagement in many soil processes and functions makes such an analysis even more challenging. As the first step on this research track, this Special Issue was initiated as a forum for promoting novel research on trait-based approaches for linking soil biodiversity to soil functionality.

The Special Issue contains six articles, divided into two parts. The first three articles proposed conceptual links between soil invertebrate traits and soil functioning, either globally (Hedde et al, 2022), in the context of ecological restoration (Auclerc et al., 2022) or to understand soil organic matter turnover (Coq et al., 2022). The three remaining articles experimentally explored these links for ecosystem engineers, such as earthworms (Le Mer et al. 2022) and termites (Jouquet et al., 2022) and for microbial-feeding nematodes (Brondani et al., 2022).

Hedde et al. (2022) challenged the definition of various soil fauna classification. They provide a critical overview of the characteristics and limitations of the existing classifications in soil ecology, and propose clarifications and alternatives to current practices. They summarized the similarities and differences in how classifications have been created and used in soil ecology. They preached for harmonization of the current concepts and terms and suggested a common framework to define classifications based on functional traits that would allow for a better and unified understanding of changes in soil biodiversity and ecosystem functioning.

Auclerc et al. (2022) started with the report that ecological engineering of degraded ecosystems often manipulates plants and rarely soil invertebrates, despite their major role in many soil ecological processes and in plant-soil feedback processes. In addition, while ecological restoration and ecological engineering approaches successfully incorporate plant traits, soil invertebrate traits remain underused. The authors conducted a narrative review and identified a set of soil invertebrate functional traits with great potential in ecosystem restoration. This paper also proposed guidelines for stakeholders and identified avenues for future research.

According to Coq et al. (2022), even if our understanding of plant litter decomposition and soil organic matter formation has been substantially improved, critical blind spots remained not addressed, particularly, the role of detritivores in these key soil processes. They proposed the characteristics of faeces as predictors of detritivore effects on organic matter turnover across the large detritivore diversity. By focusing on similar features rather than differences, this approach has the potential to break down barriers of this highly fragmented soil animal group, in particular between earthworms that are often studied as ecosystem engineers and classical litter transformers such as millipedes, woodlice, or snails..

Le Mer et al. (2022) investigated the effect of six earthworm species on soil organic carbon (SOC) mineralization. They produced casts under controlled conditions, and casts were subjected to laboratory ageing for 140 days. They showed contrasting properties of fresh casts in accordance with the earthworm species' morphological or behavioral strategies. The authors conclude that earthworm species-specific traits may play a significant role in organic carbon immobilization through their impact on microstructural cast properties.

Most of the termite species use their faeces, oral secretions or soil aggregates to protect themselves when they forage. The few available data showed that termite 'sheeting' properties are highly variable. Jouquet et al. (2022) determined the factors controlling the physical and chemical properties of soil sheeting produced by termite species encompassing all feeding and building categories using a dataset representative of an important diversity of biotopes. They showed that sheeting properties were explained by the properties of their environment and that classic hypotheses related to termite feeding and building strategies were often not validated. They highlighted the need to redefine termite functional groups using an accurate trait-based approach.

Bacterial-feeding nematodes are abundant soil animals regulating microbial communities and enhancing plant nutrition and growth. Brondani et al. (2022) determined the effects of eight bacterial-feeding nematode genera on soil bacterial communities and plant growth and nutrition from organic N and P supplied in a high P-adsorbing soil. A panel of morpho-anatomical traits was shown to explain soil and plant

https://doi.org/10.1016/j.geoderma.2022.116244

Available online 3 November 2022

function more than did species identity or life strategy groups. The authors discussed the relevance of bacterial-feeding nematode traits as promising biological metrics for a better understanding of the soil microbial loop.

The guest editors would like to thank Geoderma, through its editors Yvan Capowiez and Jan Willem van Groenigen, for the kind invitation to manage this virtual special issue. We also sincerely thank the authors and the anonymous reviewers for the fruitful and stimulating idea exchanges that allowed us to obtain this selection of very interesting papers.

References

Andriuzzi, W.S., Franco, A.L.C., Ankrom, K.E., Cui, S., de Tomasel, C.M., Guan, P., Gherardi, L.A., Sala, O.E., Wall, D.H., 2020. Body size structure of soil fauna along geographic and temporal gradients of precipitation in grasslands. Soil Biol. Biochem. 140, 107638.

Auclerc, A., Beaumelle, L., Barantal, S., Chauvat, M., Cortet, J., De Almeida, T., Dulaurent, A.-M., Dutoit, T., Joimel-Boulanger, S., Séré, G., Blight, O., 2022. Fostering the use of soil invertebrate traits to restore ecosystem functioning. Geoderma 424, 116019.

Bottinelli, N., Capowiez, Y., 2021. Earthworm ecological categories are not functional groups. Biol. Fertil. Soils 57, 329–331.

Brondani, M., Plassard, C., Ramstein, E., Cousson, A., Hedde, M., Bernard, L., Trap, J., 2022. Morpho-anatomical traits explain the effects of bacterial-feeding nematodes on soil bacterial community composition and plant growth and nutrition. Geoderma 425, 116068.

Coq, S., Ganault, P., Le Mer, G., Nahmani, J., Capowiez, Y., Dignac, M.-F., Rumpel, C., Joly, F.-X., 2022. Faeces traits as unifying predictors of detritivore effects on organic matter turnover. Geoderma 422, 115940.

Hedde, M., Blight, O., Briones, M.J.I., Bonfanti, J., Brauman, A., Brondani, M., Calderón Sanou, I., Clause, J., Conti, E., Cortet, J., Decaëns, T., Erktan, A., Gérard, S., Goulpeau, A., Iannelli, M., Joimel-Boulanger, S., Jouquet, P., Le Guillarme, N., Marsden, C., Martinez Almoyna, C., Mulder, C., Perrin, W., Pétillon, J., Pey, B., Potapov, A.M., Si-moussi, S., Thuiller, W., Trap, J., Vergnes, A., Zaitsev, A., Capowiez, Y., 2022. A common framework for developing robust soil fauna classifications. Geoderma 426, 116073.

Jouquet, P., Harit, A., Hervé, V., Moger, H., Carrijo, T., Donoso, D.A., Eldridge, D., Ferreira da Cunha, H., Choosai, C., Janeau, J.-L., Maeght, J.-L., Doan Thu, T., Briandon, A., Dahbi Skali, M., van Thuyne, J., Mainga, A., Pinzon Florian, O.P., Malam Issa, O., Podwojewski, P., Rajot, J.-L., Henri-des-Tureaux, T., Smaili, L., Labiadh, M., Aroui Boukbida, H., Shanbhag, R., Muon, R., Ann, V., Cheik, S., Fall, S., Traoré, S., Dupont, S., Chouvenc, T., Mullins, A.J., Syaukani, S., Zaiss, R., Minh Tien, T., Šobotník, J., Auclerc, A., Qiu, R., Tang, Y.-T., Huot, H., Sillam-Dussès, D., Bottinelli, N., 2022. The impact of termites on soil sheeting properties is better explained by environmental factors than by their feeding and building strategies. Geoderma 41, 115706.

Le Mer, G., Bottinelli, N., Dignac, M.-F., Capowiez, Y., Jouquet, P., Mazurier, A., Baudin, F., Caner, L., Rumpel, C., 2022. Exploring the control of earthworm cast macro- and micro-scale features on soil organic carbon mineralization across species and ecological categories. Geoderma 427, 116151.

B. Pey, J. Nahmani, A. Auclerc, Y. Capowiez, D. Cluzeau, J. Cortet, T. Decaëns, L. Deharveng, F. Dubs, S. Joimel, M. Guernion, F. Grumiaux, M.-A. Laporte, A. Pasquet, C. Pelosi, C. Pernin, J.-F. Ponge, S. Salmon, L. Santorufo, M. Hedde A thesaurus for soil invertebrate trait-based approaches PLOS One, 9 (2014a), p. e108985.

Pey, B., Nahmani, J., Auclerc, A., Capowiez, Y., Cluzeau, D., Cortet, J., Decaëns, T., Deharveng, L., Dubs, F., Joimel, S., Briard, C., Grumiaux, F., Laporte, M.-A., Pasquet, A., Pelosi, C., Pernin, C., Ponge, J.-F., Salmon, S., Santorufo, L., 2014b. Current use of and future needs for soil invertebrate functional traits in community ecology. Basic Appl. Ecol. 15 (3), 194–206.

Raymond-Léonard, L.J., Gravel, D., Handa, I.T., 2019. A novel set of traits to describe Collembola mouthparts: taking a bite out of the broad chewing mandible classification. Soil Biol. Biochem. 138, 107608.

Salmon, S., Ponge, J.-F., Gachet, S., Deharveng, L., Lefebvre, N., Delabrosse, F., 2014. Linking species, traits and habitat characteristics of Collembola at European scale. Soil Biol. Biochem. 75, 73–85.

Violle, C., Navas, M.L., Vile, D., Kazakou, E., Fortunel, C., Hummel, I., Garnier, E., 2007. Let the concept of trait be functional! Oikos 116, 882–892.

Mickael Hedde[a,*], Marie L.C. Bartz[b,e], Andrey Zaitsev[c,d]

[a] *Eco&Sols, INRAE, IRD, CIRAD, Institut Agro, Montpellier, France*

[b] *Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Coimbra, Portugal*

[c] *Soil Zoology Division, Senckenberg Museum for Natural History Görlitz, Sonnenstr. 6/7, 02826 Görlitz, Germany*

[d] *A.N.Severtsov Institute of Ecology and Evolution RAS, Moscow, Russia*

[e] *Center for Organic and Regenerative Agriculture, Idanha-a-Nova, Portugal*

[*] Corresponding author.

E-mail address: mickael.hedde@inrae.fr (M. Hedde).