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Interactive comment on "Soil fauna: key to new carbon models" *by* J. Filser et al.

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Dear editors,

please see our final comment in the text below and in the attached file.

Best wishes,

Juliane Filser, on behalf of all authors

We appreciate the high quality and detail of the referees' comments, in particular by referee #1, which have righteously criticized several points that we improved in the revised version. Looking at the wealth of information asked for, it should be clear that it is impossible to cover all this within a single review article – especially with one written mainly by empiricists and pointing out research needs. In the new version we have better pronounced why we think that these needs are still there although the issue as such had been raised decades back: these are mainly a) missing information, b) too much detail, irrespective of spatial scale, and c) too little communication between empiricists and modellers.

Thus, and probably most importantly, we made now clear why we included the COST Action KEYSOM (which addresses right these issues and associated research needs), and added some more information on its contents and activities. Main aim of KEYSOM is to test the hypothesis that the inclusion of soil fauna activities into SOM models will result in a better mechanistic understanding of SOM turnover and in more precise process descriptions and predictions, at least locally. Current activities are mainly workshops and additional literature reviews, yet also modelling: Next to implementing fauna activity in already existing SOM models, a new basic SOM model structure is being developed. Ongoing literature reviews include faunal contribution to SOM turnover in different biomes and potentials and limitations of global SOM models for including soil fauna effects. Finally, a large-scale European field experiment into the impact of soil fauna composition and abundance on SOM breakdown, distribution and aggregate formation will start in autumn 2016.

Fig. 3 of the revised manuscript (see below) shows a form of a "roadmap" how KEYSOM is contributing to the challenges identified by our review. This is further explained in the accompanying text, where we also address a number of other issues raised by the referees. Please note that this roadmap mainly functions as a decision tree with potential actions and feedback loops at every step, for instance to initiate research (literature review or experimental studies) before proceeding further. Effects of fauna abundance or biomass (in comparison to presence-absence) on the shape of the function will be addressed as well (Fig. 3A, bottom). Note, however, that to date necessary data for such an approach appear to be limited (García-Palacios et al., 2013). As many existing models, also the new model should have a modular structure so that different modules can be used and combined according to the respective biome- and scale-specific scenario (Fig. 3C). It can also be seen that we do not aim to include every detail everywhere: in some situations (Fig. 3A) the impact of soil fauna on SOM dynamics might be too small (or existing information too scanty) to be included, and not all input parameters will be feasible or relevant at each scale (miniature in Fig. 3C). This keeps the model manageable, and also flexible enough to allow for more precise predictions in critical scenarios, like in the case of earthworm invasions sketched in the next paragraph. We generally think that focusing on such critical scenarios (analogous to e.g. global biodiversity hotspots) is a crucial precondition for well-informed management decisions, one of the final aims of KEYSOM.

To further substantiate our point of view, we followed the suggestion to add more quantitative figures. This was already partly shown in the table or in the text of the MS and further supplemented. In addition we included a more elaborate example based on the comparatively well studied impact of invasive earthworms. The meta-analysis of (Lubbers et al., 2013, already cited in the MS) suggests that the effect of earthworms on total SOC contents is on average relatively small. In contrast, in certain situations earthworms can strongly affect greenhouse gas emission. These data were however mainly obtained in relatively short-term experiments. Over a period of months to years and even decades, earthworms can reduce C decomposition by physical protection of C in aging casts (Six et al., 2004, already cited in the MS).

Thus, long-lasting effects of invasive earthworms on the total SOC storage cannot be determined with certainty in short-term experiments, whereas field observations are rather controversial. For instance, (Wironen and Moore, 2006) reported ca. 30% increase in the total soil C storage in the earthworms-invaded sites of an old-growth beech-maple forest in Quebec. Other studies (e.g. (Sackett et al., 2013; Resner et al., 2014) suggest a decrease in C storage. (Zhang et al., 2013) introduced the sequestration quotient concept to predict the overall effect of earthworms on the C balance in soils of different richness, but the question remains strongly understudied.

These well documented examples of the impact of earthworms on soil C storage are related to invasive species. The presence of these species cannot be inferred directly from the climatic, soil and vegetation properties. The distribution of European invasive earthworms in North America (and also in North European forests) is largely driven by human activity; often fishing (!) is more important than habitat transformation; without human's help earthworms are not active invaders (Stoscheck et al., 2012; Tiunov et al., 2006; Wironen and Moore, 2006). Thus the presence of earthworms is an "independent" parameter.

The term "humic substances" is now referred to in a more neutral way.

We also have elaborated in more detail why we addressed different biomes and land use types: not only because the key players generally differ, but also because their identity (e.g. which and how many species of earthworms or termites) and activity (modified abundance, burrowing activity etc.) may change with both climate and land use. In a global meta-analysis spanning several continents, (García-Palacios et al., 2013) show that across biomes and scales the presence of soil fauna contributes on average 27% to litter decomposition. Depending on the situation this contribution can be substantially lower or higher. For instance, the authors report an average increase in decomposition rates of 47% in humid grasslands whereas in coniferous forests this figure amounts to only 13%. The high impact of soil fauna in humid grasslands is all the more important as such grasslands are among those ecosystems that are most severely affected by global environmental change. (García-Palacios et al., 2013) also provide additional evidence on the argument that soil fauna activity is not merely a product of climate, soil properties and land use but an independent parameter. We offer some explanations for this phenomenon by referring to niche width (e.g. temperature or drought may become critical for both survival and invasion of species), and to the relevance of human activities for soil fauna beyond impact on global warming and land use change (e.g. pollution).

New references were added wherever appropriate. Any other referee comments were taken into account – if we did not do so we explained why in the text. Exceptions from this are: - Paper in review (recommended by referee 3) cannot be cited - Suggestions concerning the graphical quality will be taken care of when the final version is accepted

- The table of the manuscript does contain quite a number of figures detailing that treatments with fauna sometimes differ from the control without by even more than 40%. We made this more clear in the abstract

Acknowledgement We are confident that our manuscript has further improved and thank the referees for their thorough work. Sure we hope that the editor acknowledges our additional efforts.

References

García-Palacios, P., Maestre, F. T., Kattge, J. and Wall, D. H.: Climate and litter quality differently modulate the effects of soil fauna on litter decomposition across biomes, Ecol. Lett., 16(8), 1045–1053, doi:10.1111/ele.12137, 2013. Lubbers, I. M., van Groenigen, K. J., Fonte, S. J., Six, J., Brussaard, L. and van Groenigen, J. W.: Greenhouse-gas emissions from soils increased by earthworms, Nat. Clim. Chang., 3(3), 187–194, doi:10.1038/nclimate1692, 2013. Resner, K., Yoo, K., Sebestyen, S. D., Aufdenkampe, A., Hale, C., Lyttle, A. and Blum, A.: Invasive Earthworms Deplete Key Soil Inorganic Nutrients (Ca, Mg, K, and P) in a Northern Hardwood Forest, Ecosystems, 18(1), 89–102, doi:10.1007/s10021-014-9814-0, 2014. Sackett, T. E., Smith, S. M. and Basiliko, N.: Soil Biology & Biochemistry Indirect and direct effects of exotic earthworms on soil nutrient and carbon pools in North American temperate forests, Soil Biol. Biochem., 57, 459–467, 2013. Six, J., Bossuyt, H., Degryze, S. and Denef, K.: A history of research on the link between (micro)aggregates, soil biota, and soil organic matter dynamics, Soil Tillage Res., 79(1), 7–31, doi:10.1016/j.still.2004.03.008, 2004. Stoscheck, L. M., Sherman, R. E., Suarez, E. R. and Fahey, T. J.: Exotic earthworm distributions did not expand over a decade in a hardwood forest in New York state, Appl. Soil Ecol., 62, 124–130, doi:10.1016/j.apsoil.2012.07.002, 2012. Tiunov, A. V., Hale, C. M., Holdsworth, A. R. and Vsevolodova-Perel, T. S.: Invasion patterns of Lumbricidae into the previously earthworm-free areas of northeastern Europe and the western Great Lakes region of North America, Biol. Invasions Belowgr. Earthworms as Invasive Species, 23–34, doi:10.1007/978-1-4020-5429-7_4, 2006.

Wironen, M. and Moore, T. R.: Exotic earthworm invasion increases soil carbon and nitrogen in an old-growth forest in southern Quebec, Can. J. For. Res., 36(4), 845–854, doi:10.1139/x06-016, 2006. Zhang, W., Hendrix, P. F., Dame, L. E., Burke, R. a, Wu, J., Neher, D. a, Li, J., Shao, Y. and Fu, S.: Earthworms facilitate carbon sequestration through unequal amplification of carbon stabilization compared with mineralization., Nat. Commun., 4(OCTOBER 2013), 2576, doi:10.1038/ncomms3576, 2013.

Please also note the supplement to this comment:
http://www.soil-discuss.net/soil-2016-19/soil-2016-19-AC1-supplement.pdf

Interactive comment on SOIL Discuss., doi:10.5194/soil-2016-19, 2016.

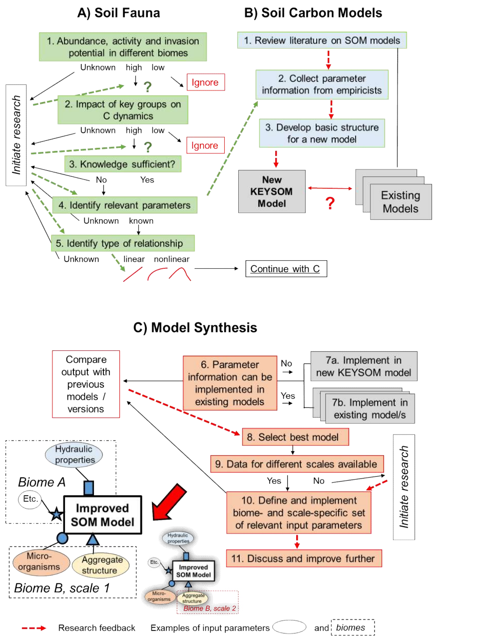

Figure 3: Flow scheme for an improved understanding of the role of soil fauna for soil organic matter (SOM) turnover. This scheme is basically followed within the COST Action ES 1406 (KEYSOM). Activities in A) and B) run parallel, followed by C) which ends with an improved SOM model. Exemplarily shown are scenarios for two biomes; the shaded miniature displays a different scale for one of them. Further explanations see text.

Fig. 1. Flow scheme for an improved understanding of the role of soil fauna for soil organic matter (SOM) turnover. This scheme is basically followed within the COST Action ES 1406 (KEYSOM). Activit

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Discussion paper

Author comment – Soil Fauna: key to new carbon models

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Fig. 2. formatted author comment

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