

Revisions made in response to reviewer comments on Soild-2-537-2015

Comments listed as “Comment:” Author responses listed as “Response:”

Response to Editor’s decision comments

Topical Editor Initial Decision: Revision (20 Oct 2015) by Karsten Kalbitz

Comment: Comments to the Author: Dear authors, At first I have to apologize for the very long review process. This was mainly caused by quite opposite views of the first two reviewers and therefore I wanted to have an opinion of one of the experts in this field of research and that took even more time.

Response: Understood. We are glad to now have the opportunity to respond and revise our manuscript.

Comment: As indicated by the reviewers / posted comments your paper is a very timely and important piece of work. However, the paper needs a thorough revision before it can be accepted for publication in SOIL. Please incorporate in your revision the very useful comments of the last reviewer. I particularly agree with the first reviewer as well that the “synoptic information is in some cases rather superficial”. That should be a strong selling point of such a review paper.

Response: We have now revised the paper thoroughly based on the comments from all reviewers. We outline our responses, and provide details of these revisions below.

Comment: In some parts, the review is quite superficial with a lot of text book knowledge. You should check the whole manuscript to avoid that and to use the space for a more holistic and profound view on the relationship between biogeochemical cycles, biodiversity and ecosystem functioning.

Response: We were trying to make the paper accessible to non-soil specialists, but we recognise that the level of detail was uneven. We have now tried to harmonise the detail so that the paper is accessible to non-specialists, while still providing insights for soil scientists.

Comment: The abstract should be completely rewritten. In the second part no substantial information is given for the scientific community.

Response: Done – second half of the abstract made more specific about what needs to be done by the soil science community to aid knowledge exchange.

Comment: I am not sure whether the section “C cycling” is needed. It is a very rough summary but is not closely related to the main topic – ecosystem services. The very rough and superficial description of the factors influencing soil C storage goes not far beyond textbook knowledge. You should make a decision which of the factors (most important for ecosystem services) should be elaborated more detailed. For sure, this paper cannot be a review about controls determining the turnover of soil organic matter. Karsten Kalbitz

Response: We feel that the section on C cycling should be retained as soil organic matter transformations are critical in underpinning so many ecosystem services (soil, water and air quality, nutrient cycling etc.), and it would be odd to talk about C stocks and not C flows – but we agree that the text was too generic, so we have focussed it more specifically on the ecosystem services that C cycling underpins.

Response to Anonymous Referee 1 (SOIL Discuss., 2, C273–C276, 2015 www.soil-discuss.net/2/C273/2015/)

Comment: Biogeochemical cycles and biodiversity as key drivers of ecosystem services provided by soils Smith et al. General comments: The group of authors presents a review on soil functions, i.e. carbon cycling and storage, nutrient cycling and supply (with focus on N and P), water storage and filtration, as well as soil as a habitat for organisms. Background information on these aspects, which especially addresses human impacts on these functions, is combined with an overview on existing knowledge gaps and recommendations for management activities. The topics researched from about 170 references are backed by five tables summarizing major aspects of some of the soil functions and management effects thereon. Additionally three figures are presented. This is a well-written and concise manuscript, suited for publication in SOIL. It nicely summarizes the state-of-knowledge on several general aspects in soil functioning and will be of special interest for a readership from adjacent disciplines being interested in soil science. Yet some critical comments might be given. Due to the wide range of topics discussed, the synoptic information is in some cases rather superficial.

Response: We thank Referee 1 for these supportive and thoughtful comments. We have discussed these suggestions among the author team and agree with all of the points raised and the weaknesses identified. We have made these changes in full (with very few exceptions – see below) in preparation for publication in SOIL.

Comment: Specific comments - 540/2: It is rather the diversity than the richness (the latter being the number of different species).

Response: We agree. We have changed "richness" to "biodiversity".

Comment: 540-541: There are also other soil services defined, i.e. soil as source of raw materials such as sand or clay, soil as a surface for building infrastructure, soil as an archive for landscape development and history of human soil use (see for example Blum W.E.H., 2002, in: Land degradation - Contributions to the International Workshop "Land degradation" 5-6 December 2002, Ispra, Italy; Jones R.J.A. & Montanarella L.; Eds.). Similarly, also Fig. 1 is incomplete. It might be discussed whether soil formation is a service that soils provide to the ecosystem (see also 549/16).

Response: We have added these additional services, but also noted that we focus on those listed in the MA – and we have added the reference.

Comment:545/6: This sentence is misleading. I guess the authors intended to say that aerobic soils exist where all transformation of SOM leads to CO₂ Actually the information reads like "all SOM is mineralized" so that no SOM would remain in soil.

Response: We agree – we have reworded accordingly.

Comment: 545/10: What is meant with the information "an element of the climate regulation service"?

Response: We have reworded to: "...the largest terrestrial flux of CO₂ to the atmosphere (~60 Pg C; the sink of carbon on the other hand contributes to the climate regulation service; Smith 2004)"

Comment: 545/12-14: A reference is missing for the methane formation and oxidation.

Response: We added the following reference: "Reay, D, Smith, P. & van Amstel, A. (Eds.) 2010. *Methane and Climate Change*. Earthscan, London, 272 pp."

Comment: 545/18-19: Change the sentence to "A decrease in soil C storage has been observed initially after fire, but . . .". What kind of fire is this? The effect of fire very much

depends on the occurring temperatures, which are largely different for example between a forest fire and burning of a stubble field.

Response: We agree. We are discussing natural fires, so we have reworded to reflect this context specificity.

Comment: 548/27: There are many other soils rich in pedogenic oxides. It is unfitting to reduce this statement to rice paddies alone.

Response: We agree. We have made the statement more generic and given the paddy rice reference as one example.

Comment: 550/26: Soils also provide the species of N and P suited as nutrients. Delete “when they are needed”; this is an euphemism.

Response: We agree – we have removed the whole qualifier: “...in the amounts and proportions needed, when they are needed”

Comment: 550/27: What is meant by “buffering in soil organic matter”? Is it the fact that SOM amounts react rather slowly to changed conditions or is it the chemical buffering function of organic molecules’ functional groups?

Response: We meant storage – so we have removed reference to buffering as this was confusing.

Comment: 552/2-3: This statement is too general and oversimplifying. Numerous examples could be given showing the opposite.

Response: We agree. The text has been changed to: “In some regions of the world mineral fertilizer is applied in excess of plant requirement, but in other regions, in particular in Sub-Saharan Africa where economic constraints limit the use of fertilizers, productivity is strongly limited by soil available N and other nutrients, notably P and K (N and P; Fig. 3)”.

Comment: 553, Section 4: This section very much repeats textbook knowledge. References are missing in most parts of this section.

Response: This review is meant to serve as a primer for non-specialists so we want to keep the detail at an appropriate level. But we have now added the following references to this section so that the reader can follow up:

Guswa, A. J., Brauman, K. A., Brown, C., Hamel, P., Keeler, B. L., Sayre, S.S.: Ecosystem services: Challenges and opportunities for hydrologic modelling to support decision making, *Wat. Resour. Res.*, 50, 4535-4544, 2014.

Kirkham, M. B.: Principles of soil and plant water relations, Academic Press, San Diego, CA, 2014.

McDowell, R. W., Srinivasan, M. S.: Identifying critical source areas for water quality: 2. Validating the approach for phosphorus and sediment losses in grazed headwater catchments. *J. Hydrol.*, 379, 68-80, 2009.

Das, B., Chakraborty, D., Singh, V. K., Aggarwal, P., Singh, R., Dwivedi, B. S., Mishra, R. P.: Effect of integrated nutrient management practice on soil aggregate properties, its stability and aggregate-associated carbon content in an intensive rice-wheat system. *Soil Till. Res.* 136, 9-18, 2014.

Bolan, N. S., Adriano, D. C., Kunhikrishnan, A., James, T., McDowell, R. W., Senesi, N.: Dissolved organic matter: biogeochemistry, dynamics and environmental significance in soils, *Adv. Agron.*, 110, 1-75, 2011.

McDowell, R. W., Houlbrooke, D. J., Muirhead, R. W., Müller, K., Shepherd, M., Cuttle, S. P.: *Grazed Pastures and Surface Water Quality*, Nova Science Publishers, New York, NY, 2008.

Comment: 553/26: "cultural services such as landscapes and water bodies". These are not truly soil ecosystem services. Soils are parts of landscapes, while surface water bodies belong to the part of the hydrosphere not overlapping with pedosphere.

Response: We agree – we have changed the wording to show that soils contribute to these cultural services as vital ecosystem components – but are not truly soil ecosystem services.

Comment: 555/3: I agree that macropores very much control the "transmission of water through the soil". However, why would macropores define the water holding capacity of soil?

Response: We agree that they by themselves do not – we have removed this statement.

Comment: 555/23: The term "excessive precipitation" is inadequate. A positive water balance is found in many regions of the Earth and does not necessarily lead to waterlogging in soil. Vice versa, waterlogged soils are also found in regions (lowlands) without "excessive precipitation".

Response: We agree – we removed the statement about "excessive precipitation" since waterlogging can occur in many situations.

Comment: 560/23: Nitrogen fertilizers produced by the Haber-Bosch process are synthetic fertilizers. If other (mined) fertilizers are also meant, then the authors should write "mineral fertilizers".

Response: We agree: "synthetic" changed to "mineral" – also elsewhere in the text.

Comment: Table 2: Regular organic fertilizers such as manure or compost are not mentioned (in contrast to biochar).

Response: We agree – this now reads: "(e.g. manure, composts and biochar)"

Comment: Table 4: Land use change should have more than aesthetic implications.

Response: We have reworded (under cultural services): "Change from traditional values and aesthetic value"

Comment: Table 5: The "production of (precursors to) industrial and pharmaceutical products" is mentioned as a provisioning service impact from all management actions. Yet, this use of soil biota is rare and thus, assumed consequences on this function are rather speculative.

Response: We do not agree – About 90% of known antibiotics were isolated from soils, so we have left the statement in.

Comment: Technical comments – 540/3: Correct to "functionality".

Response: Done

Comment: 542/22: Change to "waterlogged soils, e.g. peats (Smith et al., 2010)".

Response: Done

Comment: 542/26: Correct to “components”.

Response: Done

Comment: 543/1: The way the sentence is written, it might be misinterpreted that the maximum depth of peat soils is 8 m.

Response: Reworded.

Comment: 543/5: Correct to “bicarbonate”.

Response: Done

Comment: 544/27: Add a bracket to “(Thevenot . . .)”.

Response: Done

Comment: 545/9: Here and elsewhere: Change “PgC” to “Pg C”.

Response: Done throughout

Comment: 546/16: Correct to “provide”.

Response: Done

Comment: 548/21: Why is this in contrast? Skip this term. –

Response: Done

Comment: 548/25-26: Suggested to skip the comparative by changing to “occurrence is very much geographically restricted”.

Response: Done

Comment: 549/19: Correct to “soils continue”.

Response: Done

Comment: 550/8: Change to “production and (future) “.

Response: Done

Comment: 551/22: Correct to ”Generally”.

Response: Done

Comment: 552/8: Correct to “through”.

Response: Done

Comment: 552/20: Correct to “of P and N”.

Response: Done

Comment: 554/6: The authors should add a reference to the end of this sentence.

Response: We already have two references that cover all aspects of the sentence so no new reference added.

Comment: 559/24: Correct to “synthesis is” or “syntheses are”.

Response: Done

Comment: 563/2: Correct to ”achieving”.

Response: Done

Comment: 564/15-16: Incomplete sentence, rewrite.

Response: Done – word “which” was missing.

Comment: 564/19-20: “but we know enough to start to make a difference now”. This euphemism is very imprecise and could mean all or nothing. Delete.

Response: Agreed. We have changed to: “Despite knowledge gaps, best practices are well characterised and can be implemented immediately.”

Comment: Tables and figures: Often it is referred to the tables and figures at the end of the respective section, making them an appendage that is only marginally mentioned in the text.

Response: We agree. We have now made more reference to the tables and figures throughout the text, to better integrate the information they contain with the main text.

Response to Anonymous Referee 2 (SOIL Discuss., 2, C412–C412, 2015 www.soil-discuss.net/2/C412/2015/)

Comment: The focus of and motivation for the review by Smith et al is entirely appropriate for SOIL, and the experience of several of the co-authors is certainly highly respected and global, and the reader might expect a seminal overview of the ecosystem service delivery by soils. Surprisingly, it is not very good, and I would expect that several of the authors would come to the same conclusion as me if they were given this paper to review, i.e. that it needs a complete redraft to be acceptable for publication.

Response: We are sorry that the review did not meet the expectations of referee 2. Referee 2 does not specifically say what he/she found “not very good” about the manuscript, or exactly what he/she would like to see in a redraft of the paper, which makes the comments rather difficult to deal with. We have, however, revised the manuscript substantially in response to the comments of Referees 1 and 3 (see above and below), which we hope addresses Referee 2’s call for a complete redraft.

Response to Anonymous Referee 3 (<http://www.soil-discuss.net/2/C540/2015/soild-2-C540-2015.pdf>)

Comment: General comments: The objective of this paper is to describe the current understanding of biogeochemical cycles and biodiversity in soil and relate them to the provisioning, regulating, supporting and cultural ecosystem services which they underpin. Thus the paper is timely, relevant and should be of interest to readers of SOIL. The manuscript is well written, contains a good overview of biogeochemical cycles and biodiversity and integrates this information to various ecosystem services. The most important aspects of biogeochemical cycles and biodiversity are pretty well described and discussed. There are some very important and valuable discussions in the manuscript. For example, Section 5 contains a very good synthesis and integration of data about how soils serve as a genetic resource; the discussion on linking new biodiversity measures to specific soil functions (Page 19) is particularly noteworthy.

Response: Thank you for these supportive comments.

Comment: There are however a few shortcomings that make the coverage of topics uneven, but these could be overcome by revising the manuscript. There are many good things in the manuscript but for the purpose of providing constructive criticism I will provide some examples below that the authors might want to consider revising to improve the manuscript.

Response: Thank you for these suggestions. We have implemented all of them (as detailed below), which has helped us to improve the manuscript.

Comment: Very little information about cultural ecosystem services is discussed in any detail in the manuscript. It seems that the authors have included this so as to fully cover all the dimensions of ecosystem services. But the impact of biogeochemical cycles and biodiversity on cultural services is listed on the tables but this topic is not fleshed out in the discussion. It therefore may be best for the authors simply to admit that this will not be covered in detail; Alternatively they should either revise the objectives statement or provide more information and discussion about this aspect of ecosystem services.

Response: This is true. We have now added three examples of how soils underpin cultural services: “Examples of cultural services underpinned by soils are the terra preta soils of the Amazon basin, representing the historical cultural heritage of the region before European settlers, histosols which are a vital component of peatland landscapes, underpinning the landscape / amenity value of these valued wild areas, and soils used as building material for traditional houses providing cultural heritage values, such as the mud brick houses in Bam in Iran, and in Shibam in Yemen. This paper focusses on biogeochemical cycling and soil biota, cultural services are not discussed further in detail in this review.

Comment: The discussion about relating biogeochemical cycles and soil biodiversity to the provisioning, regulating, and supporting ecosystem services is not balanced with regards to the cycling of water. This is because there is little or no discussion (section 7.2 ff) about how specific management actions affect the water cycle. For example, soil tillage/residue management, application of organic amendments and diversification of crop production systems all affect the soil water cycle and its impact on provisioning, regulating and supporting ecosystem services but these are not described or discussed. This should be described and discussed in more detail so as to provide a holistic assessment of biogeochemical cycles and ecosystem services.

Response: We have now strengthened the relationships to water cycling in all of the management interventions listed in section 7.2. There is a specific subsection on water management, but for all of the other management impacts, we also note their impact on soil water, as suggested.

Comment: There is little exploration or discussion about how the water cycle affects soil biota (biodiversity) because the latter play such a pivotal role in ecosystem services. Soil biota are mentioned only briefly on page 18, and then only in the context of the bypass of water where biota are located. It seems that it would be worthwhile to include some discussion about the interaction between water cycling and soil biota is warranted. For example, in order to provide a holistic perspective on this interaction it might be useful to provide some information about the effect of water potential on the structure, growth and activity of the soil microbial community. (A good source of data/information on this topic is: Water Potential Relations in Soil Microbiology, 1985 [published by the Soil Science Society of America]).

Response: Good suggestion – while we do not have space to add much additional text, we have now included a sentence showing the importance of water potential on structure, growth and activity of the soil microbial community, as suggested, and we have included the reference (which is actually from 1981 rather than 1985).

Comment: A primary conclusion of the paper is that a significant challenge for researchers is to effectively share the knowledge about the potential of soils to deliver ecosystem services with soil managers and policy makers. A sentence or two describing specific examples of

how researchers could raise awareness of this issue would be helpful information for the reader interested in doing just that.

Response: Good suggestion – the conclusions have been rewritten to suggest what soil scientists need to do better so that this knowledge exchange might be realised. Essentially, this is to better communicate the aspects which we do know, rather than to dwell on the complexity and knowledge gaps. We know enough to start moving in the right direction, while we conduct research to fill in our knowledge gaps.

Comment: Specific comments: Note: the following page numbers and lines refer to pdf version of the manuscript. Page 5, Line 15-17. “an increase in soil C storage, could reduce atmospheric CO₂ concentrations: : :.. All three reservoirs are in constant exchange but have various turnover times,: : :.”

Response: Revised accordingly.

Comment: Page 7, Line 9: “C input is not quantitatively or qualitatively homogeneous”

Response: Revised accordingly. No simply reads: “C input is not homogenous within the soil profile”

Comment: P. 7, L. 13: What does “processed” mean? It will help the reader if you can be more specific.

Response: Reworded for clarity. Sentence now reads: “The majority of plant litter compounds pass through and are modified by the soil biota”

Comment: P. 8, L. 23-27. This is redundant information because it repeats the statements in P. 6. L. 14-16.

Response: It is on page 7 – found it. First instance deleted.

Comment: P.8, L. 8. “A decrease in soil C storage: : :”

Response: Revised accordingly.

Comment: P. 8, L. 33. Environmental conditions (temperature, precipitation) also control soil C storage. This is described later but it may be good to include a mention of these factors here.

Response: Agreed – environmental controls added here.

Comment: P. 9, L. 2-3. Higher levels of plant residue inputs support higher SOC stocks up to a point. This is an important point because the relationship (higher plant residue inputs = higher SOC) does not continue indefinitely because it has been shown that crop yields tend to level off at some upper level of SOC. For an example see Figure 4 and text in Zvomuya, F., Janzen, H.H., Larney, F.J., Olson, B.M., 2008. A long-term field bioassay of soil quality indicators in a semiarid environment. Soil Science Society of America Journal 72, 683-692. For a more detailed description of this feedback between plant inputs and SOC stocks see page 40 in Govers et al. 2013 (<http://www.stapgef.org/managing-soil-organic-carbon-for-global-benefits/>)

Response: Agreed – revised accordingly and Zvomuya et al., 2008 reference added.

Comment: P. 10, L. 9-10. That glomalin plays an active role in aggregate formation and SOC stocks is stated as a fact. However there is considerable controversy about the detection, quantification and role this protein plays in processes related to soil organic matter.

Response: Sentence now wording with less certainty. Sentence now reads: “In arbuscular mycorrhizal fungi, it has been suggested that glomalin, a highly resistant glycoprotein, has an active role in aggregate formation and SOM stocks (Rillig, 2004).”

Comment: P. 23, L. 5. “use of cover crops during traditional bare fallow periods helps to increase C returns: : :”

Response: Revised accordingly.

Comment: P. 23, L. 21-22. I don’t think that biochar is a “technology”, per se. Applying it to soil is part of a strategy to increase C sequestration and thus achieve negative C emissions.

Response: Agreed – reworded.

Comment: P25, L. 10. “: : :most efficiently”

Response: Revised accordingly.

Comment: Figure 3 is too small to clearly see and identify what regions contain high/low levels of applied N and P and excess N and P.

Response: This will not appear so small in the final version of the paper – a high resolution version has been supplied.