

Responses to the comments on bg-2021-237

Dear Editor, we are grateful to you and the two reviewers for providing thoughtful and astute comments, and constructive suggestions, which we think have greatly improved our manuscript. We are very excited to know they found this manuscript of interest and relevant to *Biogeosciences'* readership. Here, we provide responses following the comments by the reviewers (in blue). In addition, in the revised manuscript, we marked revised words/sentences in blue.

Associate Editor

Your Ideas & Perspectives manuscript has received very constructive and positive comments and suggestions by two reviewers with solid expertise in this field and context. Based on their recommendations, my own reading of your manuscript, and the author replies you provided, I see no major obstacles for you to revise your manuscript accordingly. I therefore anticipate that a suitably revised version will be accepted after an editorial check and perhaps some minor final suggestions, but without a need to be sent out for external review.

Response: Thank you very much for encouraging comments. We are very excited to know that the Associate Editor found the paper interesting and useful. We tried to improve the manuscript furthermore based on the comments from the reviewers. In addition, we provided a new figure (Fig.1- as below; in section 2 Existing gaps in C and GHG research in developing countries) showing the number of published observations on soil organic carbon (SOC) changes driven by land management, land-use changes, and climate change (cumulative observations per million km²) in each region in 1960-2020. The new figure supports the idea that accurate C pools and long-term monitoring data are lacking in developing countries.

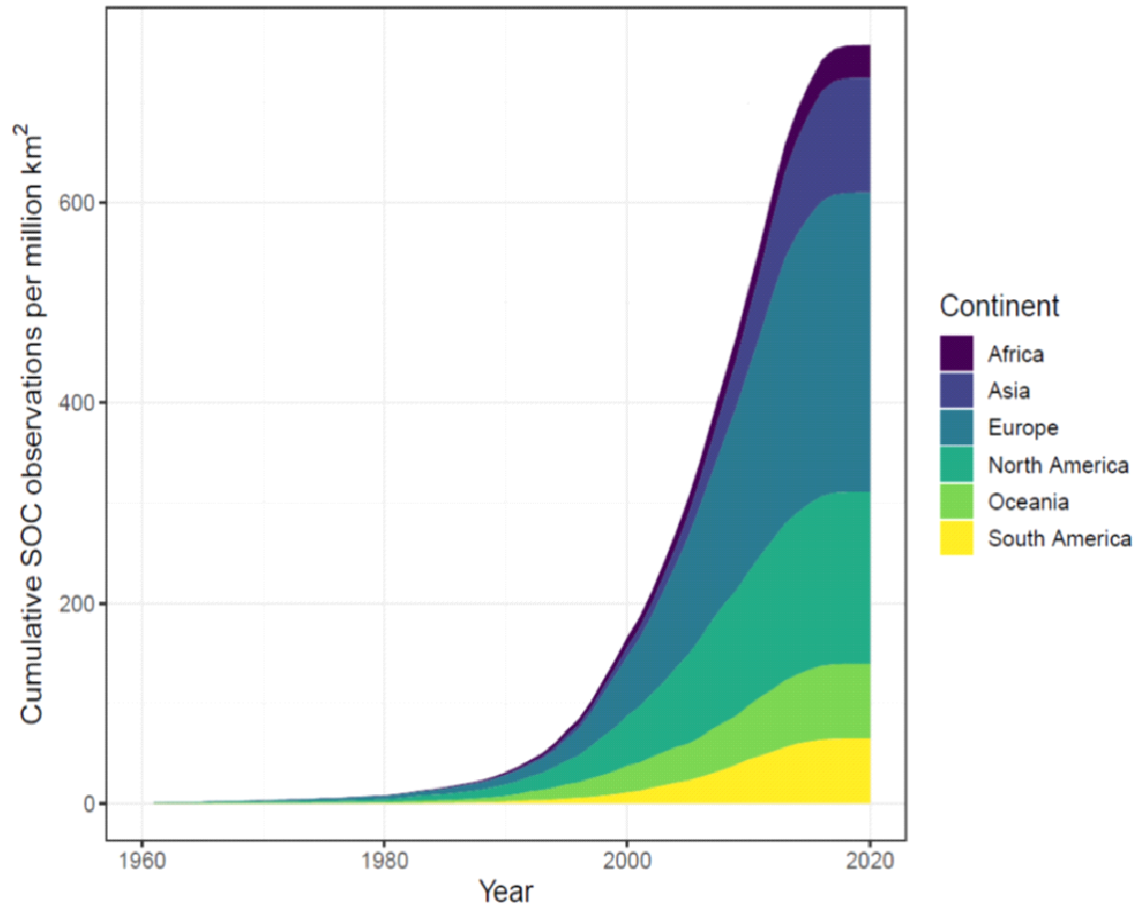


Figure 1: Number of published observations on soil organic carbon (SOC) changes driven by land management, land-use changes, and climate change (cumulative observations per million km²) in each region. An observation indicates a set of measurements conducted in a site during a certain period. Data source: Beillouin et al. (2021)

Reviewer 1

Overall I think the paper is well written and is within the scope of a Biogeosciences’s “Ideas and Perspectives” paper. The abstract, title and figures are all appropriate. It raises important issues of inequalities in science and carbon stock and flux data scarcity across certain regions of the globe, which are mostly a result of these inequalities. I particularly liked figures 1 to 3, as they very clearly illustrate the issue.

Response: We first want to express our appreciation for your sharp analysis and thoughtful and inspiring comments. Here we provided our responses to the comments and modifications made in a revised version of our manuscript.

The paper focuses on the use of what is termed “appropriate technology and approach” and how it can be used to overcome primarily financial and technological barriers to the acquisition of data on carbon stocks and fluxes. However, I feel the authors could be a bit more cautious about not overselling the ability of AT&A to overcome these barriers and solve the issue of carbon stock/flux data scarcity. It is not always the cost or the technological complexity of the method that is the prohibiting factor in data acquisition. I do not disagree with what the authors have written, but I would like to see a more balanced discussion, which gives perhaps a more realistic consideration of the role that AT&A can play.

Response: Thanks, this was also a point that we discussed and tried to clarify all the limits in the manuscript. Throughout the manuscript, we revised the texts to be sure that the message is realistic and balanced, especially in Section 5.

Some specific points for discussion, which the authors do to a degree mention, but I feel do not give enough consideration to or acknowledgement of, are the following:

-Fieldwork: Fieldwork, even when using low tech methods, is expensive, but especially so when operating in a low-income country which lacks public transport infrastructure, meaning that private transport is often required, or working in large, remote forested areas where accessing the field site is difficult and time consuming and therefore expensive. Filling in the blanks on the map at a sufficient temporal and spatial scale with in situ measurements is unavoidably going to require a lot of funding.

Response: Thanks for the comment. We agree that this is an important point which was not addressed in the paper. Accessibility, and transport are important aspects that we added them in the section 3.1 Technical expertise and infrastructure (Line 124-126):

“Carbon and GHG research often require technical expertise and infrastructure such as advanced instruments, IT technologies, reliable and stable electric power supply and network service, highly specialized research technicians, and a well developed transport system to ensure accessibility.”

-Sometimes there is no alternative technology/approach: It would be nice for balance if in section 4 the authors acknowledged that sometimes there is no cheaper or low-tech alternative. For example the authors mention the lack of flux towers early on in the text. Whilst there are lower cost alternatives for measuring GHG fluxes on a very localised spatial scale and remote sensing

products give you a regional scale estimate, is there a low cost, low-tech for measuring fluxes at an ecosystem level?

Response: It is true that for some technologies there are not (yet) equivalent low cost alternatives, however our point is that starting with what is available and possible is a crucial first step. We added the limitation pointed by the reviewer in section 5 (Line 287-289):

“Fourth, AT&A may mitigate, but does not solve, the problem of technical capacity because there are cases where it does not exist yet a real cheaper or low-tech alternative to some of the methods.”

-The way science funding is awarded and how that impacts long term monitoring and participation equality in collaborations: In section 3.2 and in line 155 & 391 the authors mention the lack of equality in relationships between high-income and low-income country collaborations and a lack of long-term investment in these relationships. This to me is one of the most important issues. Whilst I believe that high-income country collaborators could go much further in their efforts to address these issues, one thing not really mentioned and which helps drive this outcome is the way that science is funded. Even if there is a genuine will on the side of the high-income country partner, the short-term basis on which funds are awarded prohibits long term monitoring, or long-term technological support or training for low-income country partners. And often funding bodies stipulate how project money can be spent, limiting what can be spent on partners at other institutions in other countries. Therefore perhaps a brief comment on the how the structure of science funding helps to inhibit the capacity building of low income countries to monitor carbon fluxes/stocks.

Response: This is a valid point but also a very complex issue that involves political and financial aspects that often follow decision procedures not fully connected to the scientific suggestions. In addition, observatories in developing countries can be supported in the first phases but then it would be important to ensure local support. This is what we tried to give as a message. We have added a sentence in section 6.2 noting that political and financial decisions on the high-income countries investment in developing countries should also consider the long-term perspective (Line 350-353):

“Second, it will be needed to provide various funding opportunities for establishing scientific communities of AT&A and supporting their activities such as identifying, developing and utilizing AT&A. Especially, political and financial decisions on the high-income countries investment in developing countries should also take into consideration the long-term perspective and periods not covered by the initial funding.”

More minor comments are as follows:

-L167-168/286-287- is it really that likely that funders/policy makers are not aware of the importance of research into carbon stocks/fluxes? I would say it is well recognised at this level that C and GHG data is important.

Response: Considering increasing attention of developing countries to international events on climate change (e.g., Conference of the Parties), it seems science managers and policy makers in developing countries are getting aware of the importance of C and GHG since these are very critical issues in international relationship and negotiation. However, it doesn't mean that they are also interested in research on C and GHG and are willing to allocate finance and establish appropriate policy for them in their education and research systems. We revised the sentences at the beginning of Section 3.3 to avoid misunderstandings (Lin 176-179):

“Developing countries often struggle to manage local climate change related emergencies such as droughts or flooding and establish adaptation strategies to the issues (IPCC, 2014). For these reasons, investment in long term research and science on C and GHG may receive less attention in developing countries even if needed to better understand and quantify C and GHG balances and dynamics.”

-L299-300: “Fourth, AT&A may mitigate, but does not solve, the problem of technical capacity in less-developed countries.” More discussion and consideration of this point is what I am referring to above in the general comments.

Response: We tried to revise the text to ensure that the limits are also clearly explained and added a sentence in Section 5 (Line 288-289):

“Fourth, AT&A may mitigate, but does not solve, the problem of technical capacity because there are cases where it does not exist yet a real cheaper or low-tech alternative to some of the methods.”

Minor typos:

-L139 – should read “However”

-L160- should read “support”

-L369-should read “country”

-L385- should read “citizens”

-L390-should read “AT-A”

Response: Thanks for pointing these out. We corrected them.

-L374- are some words missing here?

Response: To make it clear, we revised it (Line 363-364):

“For developed countries, AT&A will provide new measurements to fill the gap in the data needed for applications, modelling, and estimations using advanced techniques.”

-L376-are some words missing or the sentence needs restructuring?

Response: We revised the sentence (Line 364-366):

“Also, AT&A diffusion will bring new research and development opportunities for science industry working on low-cost instruments, since it will promote their development and commercialization.”

-Figure 5. White 4 and 5 are not referred to in the caption, so I wonder why they are there.

Response: White 4 and 5 are referred in the text (Line 301) but now we added them also in the caption of Fig. 5 as below (Line 322-324):

“To achieve a certain level of uncertainty (same value on the Y axes) it could be possible to either use i) a high accuracy technology for a short-term campaign (white dot 1) or ii) lower accuracy technologies for a longer campaign (white dot 4 or 5).”

Reviewer 2

The Ideas and Perspective article by Dong-Gill Kim et al. is well written, important, and timely. The authors propose to adopt the ‘appropriate technology and approach’ strategy (AT&T) in order to overcome constraints to conduct research on carbon pool and greenhouse gases in developing countries. This is especially critical -as the authors correctly point out- since there is a fundamental lack of greenhouse gas research from developing countries from which many uncertainties arise. I very much enjoyed reading this article as the authors nicely demonstrate the extreme gradient between developed and developing countries when it comes to greenhouse gas research and related disciplines. I also very much agree with their argumentation that this is oftentimes caused by limited resources and training to equip, operate, and maintain the necessary instrumentation to conduct these measurements. Their description of problems attests a wealth of experience on the ground and align with my own experiences. The recommendation to focus on low-cost and low-technology instruments, open source software and data, as well as networking-based research in these countries seems therefore as an appropriate suggestion and a first step into the right direction if proper measures are taken to overcome their respective limitations. Generally, I must say that this is a difficult subject to tackle as reasons for the lack of data can be very country-specific or even region-specific. Just the sheer lack of reliable power in many regions of the world pose a significant challenge to even conduct the most basic science. Therefore, -even though it is a delicate matter on various ends- advocating and adopting AT&A is a good start to build local capacities and sever the dependence of developing countries on outside support to conduct these important measurements.

[Response: We are very grateful to your sharp analysis and criticism and thoughtful and encouraging comments. Here we provided our responses to the comments and modifications made in a revised version of our manuscript.](#)

Detailed comments:

Line 17: I would refrain from using the wording ‘skilled technicians’ as it is a broad term and could be perceived wrongly by the readership. It somewhat implies that there are no skilled technicians available in resource constraint developing countries which is not true. However, I do understand what the authors are trying to convey and suggest rewording to ‘highly specialized research technician’ or simply ‘specialized technicians’ to give a bit more nuance.

[Response: Thank you, this is an important point because it is crucial to not give the wrong impression. All the technicians have a certain level of skills, and they contribute to research activities in various ways. What we meant was a highly specialized research technician who is](#)

familiar with highly advanced instruments and techniques. We changed in the abstract “*skilled technicians*” with “*highly specialized research technicians*” and then added a sentence at the beginning of Section 3.1 to clarify the meaning:

“Carbon and GHG research often require technical expertise and infrastructure such as advanced instruments, IT technologies, reliable and stable electric power supply and network service, highly specialized research technicians, and a well developed transport system to ensure accessibility.”

Line 19: suggest adding ‘often’: are the same countries -> are often the same countries

Response: Thanks, we added it as suggested.

Line 78: suggest adding ‘Further’: Further, various global meta-analyses..

Response: Thanks, the whole sentence has been rephrased with the addition of the new figure.

Line 93: mention where the other 30% of studies were carried out (in between missing South America and Australia).

Response: We added this information (Line 98-100):

“Africa and Asia comprised only 5% and 11%, respectively, while studies carried out in Australia/New Zealand, Europe, North America, and South America were 15%, 21%, 33%, and 15%, respectively.”

Potentially swap section 3.2 and 3.1 as Technical expertise and infrastructure is the first requirement which needs to be met.

Response: We followed the suggestion of the reviewer and swapped the two sections in the new version.

Line 149: suggest to write ‘reliable electric power supply’ instead of simply ‘electric power’ since many of the instruments do not like power disruption and surge peaks.

Response: This is a good point—thank you. We changed this to “reliable and stable electric power supply” (Line 125)

Line 149: skilled technicians – see earlier comment.

Response: Yes, we changed it (Line 17, 125).

Line 153: add (PIs) after Principal Investigators

Response: Yes, we added it (Line 130).

Line 153: suggest adding ‘often’: While the PIs often define

Response: Yes, we added it (Line 130).

Line 159: consider rewriting the sentence starting with ‘After the project funding ...’. It currently reads a bit off.

Response: We have revised this (Line 136-138):

“After the end of the project that supported material purchase, installation and technical support, it is often not possible to get funding or collaborations to further support the research and monitoring activities.”

Line 166: I cannot follow the logic in the argumentation and how it is connected to the previous statement. Why do research and science managers do give less attention to C and GHG dynamics and mitigation issues because they struggle to manage locally occurring climatic events?

Response: Thanks for the comment. We propose to revise it in this way (Line 176-179):

“Developing countries often struggle to manage local climate change related emergencies such as droughts or flooding and establish adaptation strategies to the issues (IPCC, 2014). For these reasons, investment in long term research and science on C and GHG may receive less attention in developing countries even if needed to better understand and quantify C and GHG balances and dynamics.”

Line 184: tree -> trees

Response: corrected (Line 193).

Line 191: Maybe mention here the School2School Initiative by the TAHMO.org project as a good example. <https://tahmo.org/school-2-school-initiative/>.

Response: Thank you very much for the suggestion and reference that is very relevant and interesting. We added in the revised manuscript the reference to the initiative in section 4 (Line 197).

Line 174: I appreciate the authors efforts to list various AT&A which are mentioned in the subcategories of section 4. However, somehow this ‘listing’ of methods lacks a bit of a clear line of what defines a technology to be qualified as an AT&T. For instance, mid- and near infrared spectroscopy methods require a rather complex post-processing and calibration with local soil libraries. Thus, there is a lot of initial investment necessary to turn this into an AT&A. Similarly, low-cost sensors are excellent innovations, and I am curious on where R&D will lead us in the future but as for now these sensors still require -at least to my knowledge- a lot of careful postprocessing as there are several interferences such as from humidity or temperature. Therefore, I suggest to the authors to consider turning all information provided in Section 4 into a large table, simply listing the various AT&T in their subcategories with a brief explanation and adding their respective references. In this way the ‘Idea and Perspective’ article can also substantially reduced in length and be given a more concise focus to the general concept which is put forward.

Response: Thanks for the comments. Your concerns on AT&A are valid. We already addressed the problems and potential solutions in section 5, and we revised the texts to be sure that the message is realistic and balanced. We also agree with your suggestion turning information provided in Section 4 into a table (Table 1). We added a table containing lists of identified AT&A and shortened and simplified the text (Line 261).

Fig 5: Red and black can hardly be distinguished on a b/w printer. Consider alternative color.

Response: Although the journal publishes all online in color it is true that if printed the red color would be missed. We now use different types of lines in order to be distinguishable and accordingly revised the figure caption.

Line 318: Suggest changing to: ‘With an even higher available budget... ‘

Response: Yes, we changed it (Line 306).