Comment on essd-2022-123
Anonymous Referee #1

The manuscript "Pan-Arctic soil element availability estimations" by P. Stimmmer presents Pan-Arctic concentration maps for amorphous silica, available Si, available Ca, available Fe, available P, and available Al based on selective extractions from 574 Arctic soils. I do appreciate the effort from the authors to provide this first order estimate as I think this contribution on mineral element distribution in Pan-Arctic soils is very much needed but I would like to see the limits of the approach more clearly stated. The dataset generated from the selective extractions on soils is certainly to report in ESSD. The concentration maps derived from the extractions are based on several hypotheses. Before publication, the manuscript should clarify some of the hypotheses, bring nuance in some of the conclusions, and clarify (especially in figures) that the concentration maps are for selectively extracted elements (available pool) to avoid any confusion or misuse of the data.

General comments

1. The concentration maps produced are for available elements (Si, Ca, Al, Fe, P) resulting from selective extractions (extracted by Mehlich III solution) and amorphous silica resulting from an alkaline extraction. For amorphous silica, this is clear that this is a portion of the Si pool. But for the available elements, this should be clarified throughout the entire manuscript to prevent from confusion with total element concentration, and especially in the title of the manuscript, in the title of the results section, in the text describing the data, and in the caption of the figure maps (Figure 4, 5, 6, 7, 8). This is mentioned in the method section but not enough in the data description, figures and conclusions. The suggestion is really to use a dedicated term for the element extracted by Mehlich III solution, such as "available Si, available Ca, available Fe, available P and available Al" throughout the text to discuss the data and to refer to these data in the figure caption. I suggest to clarify the "bioavailability" in the title of the manuscript (such as "First estimates of Pan-Arctic soil bioavailable element concentration maps"). This is to prevent a misuse of the data in the future or misunderstanding by the reader.
2. The approach of the authors is to use the geological map to extrapolate their data and create the maps (L91-92). Using the geological map to extrapolate selective extractions from soils requires the following hypothesis to be true: “that the soil parent material is the bedrock located underneath”. This hypothesis should be discussed and more nuances should be given to this point especially in the Arctic. Indeed, abrasion by glaciers and transport of moraines by glaciers have generated and redistributed unconsolidated material (with mixed lithologies) at the surface in some Arctic regions. And in these regions, the soils are derived from this unconsolidated material integrating mixed lithologies (with a composition which may differ from the geological bedrock underneath). See the following publication https://doi.org/10.1130/G38626.1. Given the implication for the creation of the concentration maps, this is a very important point to discuss in the text to explain the limit of the approach.

3. The dataset presented comprises amorphous Si concentration and available Si concentration extracted by Mehlich III solution. The authors should clarify in which form is Si extracted by Mehlich III solution, and discuss the influence of the different forms of Si on P.

4. The concept of “element availability or bio-availability” should be more clearly explained in the introduction. It is mentioned L103 that this is about “biological available element concentration”. This same term should be used throughout the entire manuscript to avoid confusion.

Specific comments

L58-59: the sentence compares sediments and soils. Do you mean Arctic soils derived from these sediments? The sentence and the references should be clarified.

L64-65: The influence of plant cycling and external inputs should also be considered.
L89: the impact of vegetation on mineral availability in soils is well demonstrated (Jobbagy and Jackson, Biogeochemistry 53: 51–77, 2001). In the Arctic, vegetation shift are suspected to influence element availability (e.g., https://doi.org/10.5194/bg-19-2333-2022, and also https://doi.org/10.1016/j.geoderma.2022.115915)

L96: “limiting nutrients for CO2 binding” the sentence should be revised

L118: the samples were oven dried at what temperature? Could you discuss the potential influence on the selective extractions (Mehlich III solution and De Master).

L127: the amorphous silica extraction should be presented in a different paragraph. The term “available amorphous silica” is used. Could you clarify the availability of this pool given that this is a solid pool of amorphous silica. Can you explain how the De Master extraction technique for ASI used in the range of Arctic soils can be compared: can you discuss if there is a matrix effect? Can you explain the difference with the Si extracted by Mehlich III solution.

L160: The use of word Era is inappropriate. Intervals of geological time scale are given formal names according to their length. There are four Eras: Precambrian, Paleozoic, Mesozoic, and Cenozoic. This should be revised.

L208 and L210 are saying the opposite. Can you clarify.

L212 and L289: it should be mentioned clearly that this is fully expected for Ca to be the highest in the Limestone.

L247-248: The sentence should be “Here, basalt and gneiss are dominant”. Because basalt is always mafic, and gneiss is always metamorphic. If the aim of the authors was to insist on the fact that igneous and metamorphic rocks were dominant, the sentence could be “Here, igneous (lithological class 1; basalt) and metamorphic (lithological class 2; gneiss) are dominant.

L269: here “available Si” should have been clearly defined earlier in the manuscript and well distinguished from the term “available amorphous Si”. The differences between the two Si forms should be clarified. The term “available Si” should be used in the title of section 3.3.2. The same applies for section 3.3.3 for “available Ca” etc for the other sub-sections of the results.
L364: a reference if needed. For complex or variable, do you mean “heterogeneous”?

L365: the sentence should be revised because I do not see what the authors mean by the parent material of the sedimentary rocks. Sedimentary rocks can be the parent material for a soil. And sediments of diverse origin can contribute to form a sedimentary rock.

L370: the sentence should be revised to bring more nuance because I do not see in the manuscript where it is “shown that changes in element availability will occur during permafrost thaw”.

L371: this part of the sentence is not necessary as it describes what will come in section 4.4.

L385-386: See earlier comment - the impact of vegetation on mineral availability in soils is well demonstrated (Jobbagy and Jackson, Biogeochemistry 53: 51–77, 2001). In the Arctic, vegetation shift are suspected to influence element availability (e.g., https://doi.org/10.5194/bg-19-2333-2022, and also https://doi.org/10.1016/j.geoderma.2022.115915)

L387: a reference is needed to support the statement that “the vegetation involved in forming the soil ASi pool may be different”, and the sentence should be clarified to explain “different than what”.

L392: “higher ASi concentrations” than what? The authors should clarify if this ASi is available, what is the form of this Si, and how this form can compete for binding sites for P.

L396 until L411: this paragraph is presenting a large amount of information but the link with the presented data is not always clear (as explain here below for several examples). The objective of this ESSD manuscript is to report the selective extraction data, and to provide a first attempt to produce concentration maps for selected available elements. This is a valuable contribution. And no further speculation or over-interpretation of the dataset should be included in the discussion.

L399-400: This sentence should be revised or removed. It should be clarified if the authors refer to calcium carbonate dissolution (weathering) consuming CO2, or calcium carbonate formation releasing CO2.
L401: a reference is needed for this statement about Ca in Yedoma.

L401-402: the authors mention that “Ca concentrations are usually lower in deeper than in upper layers”. A reference is needed. The authors should also consider the work from Kokelj and Burn, Can. J. Earth Sci. 42: 37–48 (2005), and several other papers by the same authors showing increase in cations in deeper layers depending on thaw history. This sentence should be revised and discussed with the available data.

L403: “widespread decrease in Ca concentrations” in what? In soils? In sediments at depth? In selective extracts from soils? This should be clarified.

L407: “amorphous aluminosilicates that mineralizes slowly”? the authors mean “crystallize slowly”? This should be verified because I do not see how an aluminosilicate can mineralize.

L407-408: the sentence about the role of Al on cytotoxicity is a statement that should be connected to the form of Al discussed in the manuscript. Is the Al extracted by Mehlich III solution a form of Al comparable to the form of Al cytotoxic? And can the authors clarify “OM respiration”: respiration, or OM decomposition, respiration by microorganisms.

L422 (and elsewhere in the manuscript): (higher available Ca and available Fe concentration in permafrost layer).

L427-428: it should be mentioned that this is certain conditions

L441: what is “free Si”? what form?

L453: Increased “available” Fe concentration, in what? In soils? In solution?

L454-455: the authors should better explain the second part of the sentence, “may only occur in the Canadian Shield”. In soils developed on the Canadian Shield. Why? Here and Line 464, the generalities about these large areas should be nuanced, by saying “according to the sites studied within these lithological classes”.

L453: Increased “available” Si concentration, in what? In soils? In solution?
L465-472: within this paragraph, the transfer of elements from soils to the sea is discussed. But processes during transfer should be accounted for and considered to nuance the discussion.

L499: concentrations in available Si, Ca, Fe, P and Al between different Arctic regions.

L500: the statement “the availability of the elements will change” should be removed, and replaced by “the exposed pool of the elements will change which will likely lead to difference in their availability according to our data.”

Table 1 caption: can you revise the caption and provide a general description before the column description. For L173-174, the last sentence of the caption is unclear.

Figure 1 caption: Can you revise the first sentence of the caption as this is not a “Map of extrapolated element concentrations” but these are lithologies.

Figure 2: the X-axis is unclear. It should be clarified that class 1 is igneous, class 2 is metamorphic and the rest is sedimentary, or sedimentary and mixed.

All captions from Figure 4, 5, 6, 7, 8 should be clarified to mention that this represents concentrations in available Si, available Ca, available Fe, available P and available Al (extracted by Mehlich III solution). This is essential to avoid confusion or misuse of the data in the future.

Figure S4: the caption is not in the same standard than the other captions. Arctic with capital A.

Figure S6: clarify that it is considered that organic layer and mineral layer are part of the active layer.

Technical corrections
L71: these elements

L73: here and throughout the entire manuscript, all chemical formula should be with numbers in indices (Si(OH)$_4$). This is true for many places in the document, for CO$_2$, etc...

L76: binds

L124-125: “The analysis was done by” should be replaced by “The concentration in Si, Ca, Fe, Al and P was measured by inductively coupled.....”

L151: using Equation 1

L396: Calcium instead of Ca to avoid starting the sentence with a chemical symbol.

L429: emissions

L436-437: in some conditions

L441: seems to limit

Figure S3. Arctic with capital A

Figure S7: should be Phosphorus (not Phosphor)