

Comments to Jonathan O'Donnell (Referee) of „Organic carbon and total nitrogen stocks in soils of the Lena River Delta”

by S. Zubrzycki et al.“

J. O'Donnell, general comments:

1) The authors present new data for soil organic carbon and total nitrogen stocks from the Lena River Delta, and provide estimates of C and N pools for the region. This represents an important dataset from a region of the northern circumpolar permafrost region that is not well represented in current estimates of the global permafrost C pool. Soil cores were collected from two geomorphic units (active floodplain and Holocene terrace) that represent a large percentage of the greater Lena River Delta.

2) I have made a number of editorial comments in an attempt to improve the clarity and concision of the text and the presentation of the data. See below.

3) The authors should include in-depth descriptions of the soil profiles that were sampled from these different geomorphic units. Soil core were sub-sampled at various reference depths, but it's not clear why the authors chose those depths. C and N contents from sub-samples were then used to estimate stocks down to each reference depth, a calculation which assumes some degree of uniformity in soil properties along these vertical sequences. In my opinion, the selection of these reference depths and stock calculations deserves some justification based on soil descriptions.

4) I recommend adding some text to the Discussion section to better address sources of uncertainty in estimating C pools. Also, since prior estimates by Tarnocai et al. (2009) used just a few samples from alluvial deposits, how might this new dataset be used for refining estimates for all arctic river deltas? Are the data generalizable in that way, or should we be sampling directing sampling efforts to other major river deltas in Eurasia and North America?

(1, 2) We thank the referee for the helpful comments to improve the clarity and conciseness of the text and the presentation of the data. (3) Photographs (Fig. 2) and brief descriptions (Table 1) of representative soil types were included in the revised version of the manuscript for a better understanding of the differences between the two investigated geomorphic units. The selection of the reference depths as well as the C and N stock calculations were discussed as suggested (see also detailed comments). (4) The discussion section was extended as recommended including a more detailed uncertainty discussion (Page 17281, Line 24-29, Page 17282, Line 1-3) as well as general discussion of the added value of the presented dataset (Page 17284, Line 20-23).

J. O'Donnell, detailed comments:

Page 17264, Line 15 – *Important to note here that the estimate of 113 Tg is actually for permafrost at the depth increment 50-100 cm, and does not include the deep (> 1 m) alluvial deposits.*

This important note was included as suggested.

Page 17264, Lines 24-26 – *Awkward wording here. Sentence needs to be reworded for concision and clarity. Also, statements would be strengthened by including some recent citations.*

Rephrased to: “Degradation of permafrost is affected by climate change (e.g. Grosse et al., 2011; Romanovsky et al., 2010) but also results in important feedbacks to climate change (e.g. Schuur et al., 2009; Schaefer et al., 2011). Therefore, the characterisation of permafrost-underlain areas, permafrost-affected soils, and their soil organic carbon and nitrogen stocks are important for understanding interactions of the biogeochemical cycle with global climate.”

Page 17264, Line 26 – *I recommend adding acronyms in parentheses here: soil organic carbon (SOC) and nitrogen (N). Replace full text with acronyms throughout manuscript.*

Changed as suggested.

Page 17265, Line 3 – *Change text to state “north of 50°N”*

Changed as suggested.

Page 17265, Line 15-16 – *Omit “progressive”*

Changed as suggested.

Page 17265, Lines 16-17 – *Omit “turnover and mineralization” and replace with “decomposition”. Also, omit “climate-relevant” modify sentence to state “...release of greenhouse gases carbon dioxide and methane to the atmosphere.”*

Changed as suggested.

Page 17266, Line 8 – *Omit “respectively”.*

Changed as suggested.

Page 17266, Line 22 – *I would argue that the soil depths of 50-100 cm are not “rarely investigated”, but perhaps this is accurate for most regions in Siberia. In my opinion, it’s the*

measurements greater than 1 m that are truly rare. Also, I recommend replacing “permanently” with “perennially”

We agree and rephrased the sentence to: “Of special interest in this region were the rarely investigated currently perennially frozen layers from 50 cm up to 100 cm depth.”

Page 17267 – *The description of the study area is a little confusing as written. Start by stating clearly that in this study, you sampled soils from two geomorphic units: modern floodplain and Holocene terrace on Samoylov Island. Then state that the Lena River Delta as a whole contains additional terraces of pre-Holocene age that were not characterized by your sampling.*

Sentence added at the end of line 12, page 17267: “Within this study only the two Holocene deltaic units were sampled.”

Page 17267, Lines 22-23 – *Change micro-scale variability in “landscape” to “topography”.*

Changed as suggested.

Page 17268, Lines 6-8 – *Omit “Average observed maximum depth of seasonally thaw.” and replace “mean active layer thickness” and add variance (standard deviation) to 50 cm average. Also omit “in summer” on line 8.*

Rephrased to: “Mean maximum active layer thickness at the river terrace was about 50 cm in August.”

Unfortunately, there are no variances published in cited paper.

Page 17268, Lines 23-24 – *Put “August” in parentheses.*

Changed as suggested.

Page 17268, Lines 26-29 – *Sentence confusing as written. Modify to state -12.5 °C from 1998-2011 and...190 mm for years 1999-2011.”*

Changed as suggested.

Page 17269, Lines 7- 8 - *Note that the SIPRE corer was designed originally by the Cold Region Research and Engineering Laboratory (CRREL).*

Rephrased to: "... and a Snow-Ice-Permafrost-Research-Establishment (SIPRE) coring auger (Jon's Machine Shop, Fairbanks, Alaska) originally designed by the Cold Region Research and Engineering Laboratory (CRREL)."

Page 17269 – *On line 9, the text states that core were of "1 m length", and then on line 11, it states "sample should be "≥ 1 m". Please correct this.*

Corrected to: "We collected 37 frozen cores of minimum 1 m length in April and May 2011"

Page 17269 – *I think you can omit the text regarding the soil cores that were not included in this study.*

Changed as suggested.

Page 17269, Lines 17-18 – *Why did you choose these depth increments for sampling? This needs some explanation. It also gets at the need for more descriptions of soil horizons and composition (see general comment above).*

Sentence added at the end of line 18, page 17269: These depths were selected to get detailed information of the depth distribution of the carbon and nitrogen pools. The depth of 2 cm and 10 cm were selected to detect differences in SOC and N pools of the youngest soil accumulation. The depth of 30 cm was selected for comparison with literature citing this special depth (e.g. Stolbovoi, 2002; Hugelius et al., 2010; Zubrzycki et al., 2012) as well as the depth of 100 cm (e.g. Post et al., 1982; Ping et al., 2008; Tarnocai et al., 2009; Bliss and Maursetter, 2010). 50 cm was the mean maximum active layer thickness in August and was selected to clearly differentiate between the active and perennally frozen layer. The depth of 75 cm was selected to have additional information for the perennally frozen layer between the depths of 50 cm and 100 cm.

Page 17269, Line 23 – *Were all samples mineral soil only? If you collected organic-soil samples, then this temperature is too high and does not follow standard protocol (65 °C, I believe).*

All samples were analysed complying to the standard DIN ISO 10694 (Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis) (ISO 10694:1995))

Page 17271, Lines 4-5 – *I'm curious about the calculation of soil OC and N stocks based on the assumption that soil properties were vertically homogenous from sample depth increment*

down to the reference depth. Can you provide some more detailed information on the soil horizons and properties to justify these calculations?

For subsampling of the frozen cores we decided on a standardised method preselecting six reference depths. Doing so we tried to avoid problems associated with soil-horizon-like sampling and calculations of weighted mean values for the sampled cores assuming the same soil horizon distribution within the investigated area. Sampling these “standard depths” could lead to biased results when only a single core was regarded. However, using the mean values of our core collection we can average the variability of the single core properties. Therefore, the standard deviations are high, reflecting not only the great spatial variability but also the great heterogeneity across the depth.

We did not assume vertical homogeneity of the soil properties between adjacent reference depths; instead we estimated the volumetric carbon and nitrogen contents of the non-sampled soil layers between these reference depths by linear interpolation in 1-cm intervals.

Page 17271, Line 13 – *Reword “high river bank dynamics” for clarity. Perhaps “dynamic geomorphic processes occurring along the river corridor” or something like that.*

Changed as suggested.

Page 17272, Line 8 – *Is “mosaicking” a word? If so, is it spelled correctly?*

“mosaicking” is a correctly spelled word (Br. Engl., request of BG)

Page 17272, Line 23 – *Add “s” to “dataset”*

Changed as suggested.

Page 17273, Line 2 – *I think this section on “supervised classification” needs more explanation for those readers not familiar with this technique. What is meant by “supervised”?*

Rephrased and extended the section on “supervised classification” to: “As a result of prior knowledge of the investigated area based on personal field experience a supervised classification technique was selected. Based on our field knowledge we were able to set up training areas for the classification and assign them to a class category. Specifically, we created ten training sample areas per target geomorphic unit in the Lena River Delta. Based on general geomorphic classifications of the Lena River Delta by Grigoriev (1993), the target units for our image classification were (1) the Holocene river terrace, (2) the active floodplains, and (3) the water bodies, all of which are spectrally largely dissimilar. We then performed a “Maximum Likelihood Classification” with the training sample areas.”

Page 17273, Lines 10-12 – *I recommend omitting the different functions here (e.g. “function: Region Group”) – more detail than necessary.*

This section was shortened and simplified to: “A post-classification generalization of the results was performed in ArcGIS. After grouping connected pixels of the same class into regions we merged isolated pixels surrounded entirely by pixels of a different class with that class. Lastly we re-assigned class identity for pixels in regions consisting of less than four pixels to identify and assign the most appropriate class for such pixels from its nearest neighbours.”

Page 17274, Lines 5-6 – *Can you describe in detail what you mean by “various accuracy parameters”?*

Awkward meaning - rephrased to: “Data points were then cross-tabulated and classification accuracy for all investigated classes calculated according to Congalton (1991).”

Page 17274, Line 12 – *Omit “bulk densities” and just use symbol.*

Changed as suggested.

Results section – *In general, it is important to report standard deviations or standard errors with mean values. I recommend doing this throughout the results section so the reader can better evaluate uncertainties for each value.*

Standard deviations were reported throughout the result section in the revised version as suggested.

Page 17247, Lines 23-24 – *Why not report volumetric ice contents instead of or in addition to gravimetric values? Also, it’s important to distinguish between ice contents for active layer and permafrost. Since, samples were collected in April and May, most active layer samples were probably frozen, but perhaps not surface samples? Please clarify.*

Since the samples were collected in April and May the entire profiles were frozen and therefore treated equally.

We extended the existing information on ice contents by adding volumetric ice contents (see also Table 3).

Page 17275, Lines 4-6 – *Should report P-values associated with R correlations.*

Added as suggested.

Page 17275, Line 14 – *ANOVA analyses were not mentioned in the Methods section. Please add text to the “Statistics” subsection and describe details of ANOVA (primary effect variable, post-hoc analyses?).*

There were no post hoc analyses performed since we had only two samples (river terrace, floodplain).

Section rephrased: “Descriptive statistics, correlation analyses as well as analyses of variances (response variables: c_{OC} and c_N ; samples: river terrace, floodplain) for soil data were performed using the SPSS package version 16.0.1.”

Page 17276, Line 4 – *What does the number 42.0 kg m⁻² represent? The range is 6.5 – 48.6, is it the median?*

We changed the sentence to: “The estimated SOC (100 cm) had a minimum of 6.5 kg m⁻² and a maximum of 48.6 kg m⁻².”

Page 17276, Lines 16-17 – *Omit sentence beginning “Pronounced differences...”*

Rephrased to: We found pronounced differences between the soils in these two units.

Page 17276, Lines 18-19 – *This sentence needs to be clarified and elaborated upon: “This characteristic increased with increasing reference depth”. What figure are you referring to here? In Figure 5c and 5d, this increasing trend with depth is not apparent. In Figure 7, it does increase with depth, but that’s not particularly interesting because each depth increase is a cumulative total, so of course they would increase with depth.*

Sentence removed due to its awkward meaning.

Page 17280, Line 14 – *Report standard deviation with mean here.*

Added as suggested.

Page 17281, Line 6 – *Add standard deviation here too.*

Added as suggested.

Page 17281, Lines 9-10 – *I’m a little confused about the use of the terms “allochthonous” and “autochthonous” here. These terms are typically used for aquatic systems like lakes and rivers, not soils. However, I generally get what you are referring to. Perhaps reword to state “terrestrial organic matter” and “aquatic peat”?*

The terms “allochthonous” and “autochthonous” are often used for soil related descriptions since one important soil forming process is translocation. Translocation can be related to organic and mineral (parent) material that can be redeposited and therefore is allochthonous. It is not exclusively related to aquatic peat. Quite the contrary, as in the study area erosion and redeposition of organic and mineral material is important and results in accumulation of allochthonous organic matter.

Page 17282, Line 17 – *What do you mean by “current of water of flat plains”?*

Wrong wording changed to:

“High intensity of flooding including sometimes strong water currents moving over these flat plains prevents plant growth resulting in low volumetric organic carbon contents in higher profile depth.”

Page 17283, Line 23 – *Replace “seasonally thaw depth” with “active layer”*

Changed as suggested.

Page 17283, Line 28 – *What do you mean by “recent” active layer?*

Recent active layer means the active layer observed today. This term was used to highlight that this layer can be different in the future – it could be incorporated in the perennially frozen layer under high soil material accumulation dynamics, or it can deepen due to the projected climate change.

Page 17284, Line 2 – *I’m not sure that permafrost C is “inherently decomposable”. There’s a high amount of uncertainty in biodegradability driven by differences in OM composition, microbial communities and activities, and physical protection and stabilization, not to mention sensitivity to temperature and moisture.*

The reviewer is correct that there currently is a high degree of uncertainty in biodegradability of permafrost OM. Since we do not access most of these factors mentioned we removed the entire sentence. The remainder of the discussion of our results is not affected.

Page 17285, Lines 15-16 – *Revise sentence to state “As a limiting nutrient for plant productivity...”*

The sentence was revised as suggested.

Page 17286, Line 1 – *Replace “About” with “Approximately”*

Changed as suggested.

Page 17286, Line 15 – *Revise to state, “Here we investigated...”*

Changed as suggested.

Page 17286, Line 16 – *Omit “correspondent” or replace with “complimentary”*

Changed as suggested.

Table 1 – *Wow, those standard deviations for bulk density are pretty big!*

The presented standard deviations are indeed large. These large standard deviations reflect large spatial variability of the soil properties (here bulk density) as well as large heterogeneity of the properties across the depth. Additionally, the high variability of the ice content within the investigation area leads to a high variability of the bulk density resulting in these high standard deviation values. A “reduction” of these standard deviations only was possible when analysed on the soil unit level.

Table 4 and 5 – *I think it would be clearer if the different sites/soil types were labeled directly in the table instead of labeling with A through E (Table 4) or A through H (Table 5).*

Changed as suggested.

Table 6 – *What do these values represent? Are there units associated with these numbers? Define user’s accuracy vs. producer’s accuracy.*

These values represent the calculated classification accuracy for all investigated classes. The unit is per cent.

Generally accuracy assessment is based on a comparison of the classification with an independent reference dataset. This reference in our study is the high resolution satellite imagery. The probability that a certain land-cover (active floodplain, Holocene terrace, water,

other) of an area on the ground is classified as such is expressed as the producer's accuracy. The probability that a pixel labeled as a certain land-cover class in the map (active floodplain, Holocene terrace, water, other) really belongs to this class is expressed as the user's accuracy (Congalton, 1991).

Table 7 – *These are not really “depth distributions” as stated in the legend. You are basically reporting cumulative stocks with increasing reference depth. It'd be more accurate to state “C stocks for different depth increments. Also, I think it would be useful to show vertical distribution by reporting C density (kg m⁻³) vs. depth – see Harden et al. 2012 (GRL) Figure 2.*

Table 8 – *The columns for C stocks and N stocks (not mass or pools) are redundant with Figure 4 – I recommend omitting these from Table 8. Also, these values are reported with a different number of significant digits. Please be consistent and consider accuracy of C and N measurements.*

Tables 7 and 8 were edited. In the revised version we removed the columns for C and N stocks to avoid redundancy. Instead of these we included depth distributions (vertical distributions) of the C mass versus reference depths.

The legends were changed to: The vertical distributions of the total soil organic carbon (total nitrogen) mass within the seasonally thawed and perennially frozen soil for the Holocene river terrace and the active floodplain levels in the Lena River Delta. Represented are the estimated mean carbon (nitrogen) mass (Tg) for all investigated soil horizons and the estimated mean soil organic carbon (nitrogen) mass (Tg) for different depth increments with the respective standard deviations.

Figure 2 – *I recommend omitting this figure. It's okay just to report averages and trends in the study site description.*

Changed as suggested.

Figure 3 – *Omit, unnecessary.*

Changed as suggested.

Figure 5 - *I recommend omitting the legends for each figure and instead label the x-axes with appropriate depth increments. Also y-axes need labels and units. In legend, I recommend removing text stating “volumetric contents” – volumetric is C density in kg m⁻³, stocks are areal in kg m⁻². In my opinion, a better way to report the variations with depth is to switch axes, with depth on the y-axis and % or stocks on the x axis.*

Removed legends, x- and y-axes labelled as suggested. For clear differentiation we left the descriptions “volumetric” and “gravimetric” as they were, instead of doing the suggested changes. For conformity reasons the axis were not switched as suggested (compare Figures 6, 7, and 9, discussion paper).

Figure 6 – *Label y-axis and add units.*

Changed as suggested.

Figure 7 - *Label y-axis and add units.*

Changed as suggested.

Figure 8 – *I recommend moving this figure up front with the other map of the study area.*

The authors recommend keeping this figure as a separate figure showing results of soil classification as well as carbon stock analyses. We feel that mixing the study site description and the result section would not be helpful for clarity reasons.

Figure 9 – *Label y-axis and add units. Abbreviations along x-axis need to be defined somewhere.*

Changed as suggested.

Additional literature that was added in the revised paper:

Congalton, R.: A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. *Remote Sensing of Environment* 37, 35-46, 1991.

DIN ISO 10694: Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis) (ISO 10694:1995).

Hugelius, G., Kuhry, P., Tarnocai, C., and Virtanen, T.: Soil Organic Carbon Pools in a Periglacial Landscape: a Case Study from the Central Canadian Arctic. *Permafrost and Periglacial Processes* 21, 1: 16–29, 2010.

Romanovsky, V. E., Drozdov, D. S., Oberman, N. G., Malkova, G. V., Kholodov, A. L., Marchenko, S. S., Moskalenko, N. G., Sergeev, D. O., Ukraintseva, N. G., Abramov, A. A.,

Gilichinsky, D. A., and Vasiliev, A. A.: Thermal state of permafrost in Russia. *Permafrost and Periglacial Processes* 21: 136–155, 2010.

Schaefer, K., Zhang, T.J., Bruhwiler, L., and Barrett, A.P.: Amount and timing of permafrost carbon release in response to climate warming. *Tellus Ser. B-Chem. Phys. Meteorol.*, 63 (2) 165-180, doi: 10.1111/j.1600-0889.2011.00527.x, 2011.