Author response to Anonymous Referee #1 comments:

All author responses appear in grey italics below specific comments from Anonymous Referee #1.

The topic of the study to investigate the N cycle, in particular shifts in the nitrate concentration in the soil pore water in permafrost soils, affected by the N_2 fixation of alder (*Alnus viridis* ssp. *fruticosa*) is generally interesting. However, the study and the structure of the article has some major flaws and is a listing of observations instead of presenting a study with a clear focus. The structure of the article may be improved, but -unfortunately- several limitations of the design of the study cannot be corrected anymore (in retrospective).

The authors thank Anonymous Referee #1 for their feedback and agree that there are some limitations of the data presented due to the disparate nature of field access and sampling campaigns. While a continuous time-series would have been preferable, we were limited due to scheduling permissions and availability but firmly believe there is inherit value in the data that we were able to collect and the following text details our motivation for the various campaigns. Since there had been no actual measurements of nitrate concentrations in soil pore water of Arctic alder stands at the time this investigation began, we conducted an initial reconnaissance study in year 1 to gain insights to the distributions and concentrations of pore water nitrate. We augmented these data with additional targeted sampling campaigns in the following year but were limited on timeframes of the follow-up investigations.

Aspects to can be improved:

Many aspects that emerge in the result section, are not adequately described in the M&M section. Some descriptions given in the Supplementary Material

- "Seep" has not been explained in M&M

  The authors thank Anonymous Referee #1 for this suggestion. The seep was initially defined in the Figure 3 caption but have added the following definition in the main text in section 2.1 for improved clarity. 'The A1 transect includes a sampling location we identify as a 'seep', which is a direct seep from the ground located at the slope transition between upland and lowland zones. The volume of water sourced from this seep was too small to measure directly but is estimated to be < 2 cm^3 s^{-1}. However, water actively trickled from this seep location during all sampling campaigns and is likely representative of active layer melt that surfaced at the upland-lowland transition.'

- Patch of Alnus shrubland: dimension/ size of the patch not defined. Valuable pieces of information would be height of bushes, density of alder branches per m2. Please add.

  The authors thank Anonymous Referee #1 for this suggestion. Figure 1c visually shows the scale of the alder stands we investigate and the respective sizes of A1 (~3400 m^2) and A4 (~6400 m^2) were already in the main text section 2.2. Salmon et al. (2019a) has published detailed vegetation parameters in a co-located study that we have added in as a reference in this section to direct readers who are interested in these metrics.

- Authors present the total numbers of measuring points or samples (including soil pits), but it remains unclear what is really a replicate; a transect contains how many measuring points? The structure of the measuring points is also key for the statistical analysis. Both, temporal and spatial variability has to been taken into account in the statistical analysis. Here, one gains the impression, that one and then the other has lumped together. To emphasize that non parametric versus t-tests have been used is not adequate here.

  The authors thank Anonymous Referee #1 for this suggestion and believe that the clarifying details we added to the text provide the needed context for interpretation of the results.

  At present, Figure 4 visually represents the relative locations and number of distinct rhizon clusters along the A1 and A4 transects, this information can be found in more detail in Table S5 in the Supplement, which identifies each specific sampling location that is clustered within the different sampling regions (i.e. A1_WI_Up, A1_WI_Mid, and A1_WI_Down, represent three distinct sampling locations that are located within Alder Stand 1 (A1)).

Table S6 in the Supplement displays the setup and results from the Mann Whitney rank sum tests performed for each constituent. The intention of the Mann Whitney statistical analyses is to look at the difference between 'upland' and 'lowland' sampling locations (spatial differences) and not between seasons (not temporal differences). Thus, here 'n' is the total number of samples collected in each location (upland and lowland) from both July and September 2018 combined. Based on advisement from a statistician consult, this approach appeared to be the best way to directly compare differences in 'upland' and 'lowland' sampling sites overall. The individual rhizon nests that make up 'upland' and 'lowland' are defined in Table S5. Text has been added to section 2.6 to communicate these distinctions and provide needed context to the reader.

We have modified and added text to the main manuscript to detail that the Mann Whitney statistical tests performed on nutrient data were not intended to highlight temporal variation, but to identify significant differences between the upland and lowland site geochemistry regardless of season.

Because of the discontinuous nature of our sampling campaigns, our data is not suited for temporal comparisons of nitrate but we were interested in the influence of seasonality and precipitation events on water isotopic signatures. Thus, the only temporal statistical analysis performed was on the water isotopes (Table S7), which looked at differences between each season and the overall mean of $\delta^{18}O$ of water (not nitrate). The total number of samples collected within each campaign define 'n' for each campaign (samples not grouped spatially). These samples are not divided into 'upland' and 'lowland' samples but are lumped holistically to show seasonal trends as opposed to spatial trends. The 'n' varies widely between months because the number of days per campaign varied. Because of the disparate temporal nature of our data, we have moved the analysis of temporal variation to the Supplemental material to allow the main text to focus on spatial variability and not detract from those findings.

- The term "Alnus savanna" simply does not exist and is misguiding, please remove this term throughout the whole text!

The authors thank Anonymous Referee #1 for this comment but note that we use the term 'alder savanna', not 'alnus savanna'. As such, we respectfully disagree with removing this language as we can provide instances of 'alder savanna' terminology usage in both highly-referenced and recent literature and have added the following text to the manuscript to clarify any confusion that arises from use of this term for our audience.

The authors have added the following text to the manuscript to provide context to the term: 'The term 'alder savanna' was defined by Frost et al., (2013), who identified 'Such shrubland communities, colloquially referred to as 'alder savannas' (Frost et al., 2013), have been described at several locations in Low Arctic, interior montane Alaska (Racine 1976, Racine and Anderson 1979, Chapin et al., 1989; Salmon et al., 2019a; Sulman et al., 2021). Regular spacing of alders in 'alder savannas' has been attributed to intra-specific competition for limiting nutrients (Chapin et al., 1989).''

The following references have been added to the manuscript:

Chapin, F.S., McGraw, J. B., and Shaver, G. R. Competition causes regular spacing of alder in Alaskan shrub tundra. Oecologia 79, 412–416, https://doi.org/10.1007/BF00384322*, 1989.*

Frost, G. V., Epstein, H. E., Walker, D. A., Matyshak, G., and Ermokhina, K. Patterned-ground facilitates shrub expansion in Low Arctic tundra. Environ. Res. Lett. 8, 015035. https://doi.org/10.1088/1748-9326/8/1/015035, 2013.

Racine, C. H. Flora and vegetation: Biological Survey of the Proposed Kobuk Valley National Monument. Final Report ed H. R. Melchior (Fairbanks, AK: Alaska Cooperative Park Studies Unit, Biology and Resource Management Program, University of Alaska) pp 39–

139, 1976.

Racine, C. H. and Anderson, J. H. Flora and vegetation of the Chukchi-Imuruk area Biological Survey of the Bering Land Bridge National Monument: Revised Final Report ed H. R. Melchior (Fairbanks, AK: Alaska Cooperative Park Studies Unit, Biology and Resources Management Program, University of Alaska) pp 38–113, 1979.

Sulman, B. N., Salmon, V. G., Iversen, C. M., Breen, A. L., Yuan, F., and Thornton, P. E. Integrating Arctic plant functional types in a land surface model using above- and belowground field observations. J. Adv. Model. 13, e2020MS002396, https://doi.org/10.1029/2020MS002396*, 2021.*

Flaws in the design (cannot be correct anymore)

- The nitrate concentrations in soil pore water of Alnus shrubland along the hill is compared to those in the soil pore water in the lowland. However, authors stated that the soil was partly covered by standing water and the alder bushes were much smaller in the lowland area or do not even exist in the lowland (Figure 4!) So, standing water on one hand may dilute the nitrate concentrations and create denitrifying conditions, and on the other hand smaller Alnus shrubs have for sure a lower N_2 fixation. These two aspects cannot be disentangled. So, it is obvious that the nitrate concentration is lower under such conditions, described here as major result (please avoid overstatements in general). Furthermore, it has already been shown that the nitrate concentrations in the soil water under Alnus stands is much higher than under non-Alnus stands due to the N_2 fixation (not a new result!)

  The authors thank Anonymous Referee #1 for this comment and have modified the field location descriptions to clarify and accurately represent the conditions present in the uplands versus the lowland sampling sites. The lowland sampling sites are comprised of alder savanna, where alder are present but not in dense stands as they are in the uplands. The findings observed provide insight to the transport and mobility potential of nitrate from dense alder stands in upland environments: topography/gradient and precipitation/moisture in tundra environment with alders largely control this potential. So although nitrate availability may increase directly in the soil-pore water of dense alder stands, the moisture/precipitation and topography/gradient conditions of the alder environment likely limit/control of the mobility potential of this critical nutrient to downslope environments that we already know do not produce as much nitrate because of redox conditions and lesser alder density. The authors believe we have now properly clarified this point and have critically assessed the major results discussion and removed instances that could be interpreted as overstating outcomes.

- On site weather station is fully missing. Although authors stated precipitation events as key for leaching processes.

  A weather station has been installed for continuing studies at this NGEE field location but was unavailable at the time of the study presented here. We agree that measurements provided by a weather station would have been useful but are unable to retroactively obtain this information. Weather records of towns ~50 km away from the field site are accessible and referenceable but not a direct representation of the weather conditions at our remote field site and there are differences between these records and our recorded observations so we know they are not truly representative of our field conditions. Field observations of precipitation events are included for additional context of trends and variability observed. While we are unfortunately not able to quantify the extent of precipitation events, we are able to identify trends correlating with observed precipitation events that provide insight to nutrient transportation responses to weather observed.

- A measuring campaign during 4 days (year 2017) is simply not representative for a seasonal measure (overstatement).

  The authors agree with Anonymous Referee #1 and have modified the language accordingly to avoid temporal overstatements. While we do not have a full seasonal time series, the multiple

short time-series we have captured provide valuable insights to snapshots of compositions and variations that may exist within short timeframes within specific seasons.

Detailed comments:

Abstract: Line 11: in the Arctic with capital letter, but arctic ecosystems with small letter. Please adapt throughout the MS.

The authors thank Anonymous Referee #1 for pointing this inconsistency out and have ensured all instances of 'Arctic' are capitalized.

Line 13: Simply not true, please consult the literature and adapt

The authors appreciate the intention behind this suggestion and have modified this text to be better received while still communicating that knowledge gaps in this research area exist and identify the intention of our work to contribute to better understanding N dynamics (form, availability, and transportation potential) in a permafrost hillslope landscape.

Line 14: Edaphic controls for the nitrate concentrations has not been shown.

The authors have deleted 'edaphic' from the text.

Line 18: I do not agree that all the nitrate is produced by degradation of N-rich alder shrub organic matter…or depends on your definition of organic matter..Are the corolla structure of the alder roots/nodules where the N2 fixation takes place, organic matter (I think not!)? The majority of the nitrate is already released during the N2 fixation.

The authors thank Anonymous Referee #1 for this comment but believe there is misinterpretation of our phrasing, which is accurate as intended. The isotope ranges we calculated were for values corresponding to nitrate from the microbial degradation of N-rich alder shrub organic matter. This statement is not claiming that other forms/sources of nitrate production do not exist, it is identifying that we used isotopic ranges linked to microbial degradation of alder organic matter (from Kendall and McDonnell, 1998) to identify if the nitrate-N observed at our field location was produced from these processes/sources. Independent of these semantics, the authors have moved the isotopic component of our work to the Supplemental online material refocus attention on our non-isotopic nitrate variability story resulting from our geochemical work, so the language associated with this comment is no longer in the main text.

Line 19, etc.: In general, better to express the nitrate concentrations as nitrate-**N** (enhanced comparability to other N compounds, atmospheric N deposition)

The authors thank Anonymous Referee #1 for this comment and have changed 'nitrate' to 'nitrate-N' and 'NO_3^-' to 'NO_3^--N' when discussing/referencing concentrations.

Line 23: denitrification buffers nitrate mobility. Strange description! Nitrate is transformed into N2 (complete) or N2O (incomplete) denitrification. From an ecological point of view the production of N2O is worse than nitrate mobility! Please adapt.

The authors are not claiming that the production of N_2O isn't ecologically important, we are stating that nitrate-N is unable to be transported if it is converted to other N-species. Text has been modified to read 'denitrification limits the mobility of NO_3^--N by transforming it to other N-species' and has been moved to the Supplemental online material with our other isotopic text.

Line 24. Nutrient production is a misguiding term. Through N2 fixation nitrogen as a nutrient gets available, then it is transformed or lost again through complete denitrification..please adapt.

The authors have altered text from 'nutrient production' to 'nutrient availability' here and in the remaining text.

Line 40: Nutrient availability instead of nutrient production

The authors thank Anonymous Referee #1 for this suggestion and have deleted this sentence due to a comment from Anonymous Referee #2 but have changed the language from 'nutrient production' to 'nutrient availability' in several other instances in the text where that phrasing is more appropriate.

Line 46: Latin names – italic

The authors thank Anonymous Referee #1 and have changed the formatting in this instance accordingly and have verified that all Latin names are now in italics.

Line 48: instead of microbes, add here: *Frankia* bacteria

The authors thank Anonymous Referee #1 for this suggestion and have altered the text from 'microbes to 'Frankia bacteria' as suggested.

Line 51, line 57: Wrong!! Brühlmann et al. 2014, Hiltbrunner et al. 2014: Both studies are located in the montane (not in the alpine vegetation belt of the Alps), but clearly not on permafrost soils! Increase of alder shrubland due to changes in land use, not increasing temperatures. Please correct and add this aspect of land use changes.

The authors thank Anonymous Referee #1 for identifying this discrepancy and have modified the language in the original line 51 to refer to these studies as taking place in cold environments instead of permafrost environments. The authors have also modified the language associated with the reference in the original line 57 reference upslope/downslope nutrient mobility observed regardless of permafrost presence. We attempted to add text referencing land-use changes as a cause of shifting nitrate availability but found that because land use changes are not present in our study landscape, it introduced another factor that detracted from a streamlined introduction. Thus, we chose to modify the text associated with the references in question rather than introduce land use changes.

Line 68-70: Necessary?

The authors have deleted this text from the Study Objectives section because these details are already included in the Acknowledgements section.

Line 73-76: Hypotheses rather weak as already widely known that alder shrubs through their N2 fixation are source for nitrate. And your measuring campaigns cover some days in July and September, not seasons. And see comments on line 18 and 23 (comments are not repeated here).

The authors thank Anonymous Referee #1 for their feedback and believe we have strengthened the hypotheses listed with additional details and have modified the language to avoid any interpretations that seasonal variation was formally investigated in this study.

Line 80: unusual format for coordinates, add elevation of the KG hillslope, please adapt

The authors have edited the coordinate formatting to match that from Salmon et al. (2019a) and have added in the elevation range of the hillslope (40-140 m.a.s.l.).

Line 95ff, add species names of the dominant species of graminoids and dwarf shrubs.

The authors have added in examples of species names as identified in associated studies by Salmon et al. (2009a-b).

Line 101-112: rather unclear and wordy description. Be more precise here! Avoid expression such as initial phase and comprehensive informed phase (rather empty expressions).

The authors thank Anonymous Referee #1 for this comment and have modified and added to this section to more precisely describe our sampling location.

Line 114-135 unclear what means additional transect here, how many sampling points per transect?? Shorten! Please be more precise.

The authors have shortened this section and added references to the supplemental tables that detail the number of sampling points per transect per sampling campaign. The number of sampling locations per transect increased with each campaign to get more detailed spatial resolution of nitrate variability along the transects. The authors have chosen to keep these details in a table in the Supplement since they are extensive and distract from the take-aways points we convey in the main text. However, the authors have also have moved some text from the Supplemental material to the main text (in section 2.3) that provides context to the number of rhizons per nest and the timeframe that the rhizons were installed.

Line 140ff: a nest of macro-rhizon: please define in the main text (not in the Supp. Material)- I wonder

how long lasted the installation, for such short sampling intervals (of 4 days) the installation duration may affect the water sampling of the first day. Please explain!
The authors thank Anonymous Referee #1 for this suggestion and have added these additional sampling details to the text in section 2.3.

Line 167. Unclear description, which transect (?) and soil 0-15cm has not been sampled?
The authors have modified the language in this section to improve clarity.

Line 180: Why five litter samples when A1 and A4 have three sampling locations each, unclear…
The authors modified and added the following text to the manuscript to clarify, 'Alder leaf litter was collected in September 2018 from six locations along the A1 and A4 transects (3 samples from each transect), stored in sealed plastic bags frozen, and homogenized prior to analysis (n=6). A contamination issue occurred with one of the leaf litter samples collected from the A4 transect, leaving us with n = 5.

Line 184: instead of each water sample…*In situ* parameters were measured for each water sampling location …
The authors thank Anonymous Referee #1 and adapted the text from 'each water sample' to 'each water sampling location.'

The whole M & M section needs to strongly streamlined, now it is a potpourri of very different measurements and reader often does not know why for what purpose a measurement was carried out, besides when and how many times…I suggest to present all these different locations and campaigns in a Table.
The authors thank Anonymous Referee #1 for suggestion. These details were already included in Supplemental Table S4 but could have been referenced more effectively in the main text. The authors have moved the isotopic text to the Supplemental material to avoid distracting from the nitrate variability story. The authors have also streamlined the main M&M text with appropriate references to the relevant supplemental material and have identified the intended purpose of each parameter collected within the M&M subsections. These edits and added references have improved the flow of this section and provided additional context to the readers.

Line 191-203 Statistical analysis: Weak description, no information how normal distribution, outliers, etc were handled. Weird description of processes acting on nitrate production.
Authors have added in the requested details to the main text and additional details of the statistical analyses approach can be found in the Supplemental material. Authors met with a statistical consultant to verify that approach used was appropriate for the dataset obtained and have been reassured that the approach used is valid and appropriate given the nature of our data collected.

Line 205: I assume that soils (and correspondingly patches) along the slope differ from soils in the inundated lowlands. And permafrost occurrence and thickness of the layer- were they similar along the hillslope as in the lowlands? Please specify!
The details of soil depth and soil moisture in the upland (UA + WA) and lowland (DA) sampling locations are included in Table S4 in the Supplement and the authors have added sentences and modified language in the main text to clarify similarities/differences and direct the reader to the Supplemental Table (S4) that contains additional details. Text already existed that identified that the active layer depth was greater in the lowland portions of the transects than the upland portions of the transects for September 2017 and July 2018.

Line 208: personal observation of whom? Mean gravimetric soil moisture content
The personal observation was by those who participated in the field campaigns, who are identified in the 'Author Contributions' section. The authors have added clarifying text to this reference. The authors have also altered the text 'mean soil moisture content' to 'mean gravimetric soil moisture content' as suggested.

Line 209: unclear: which other sampling campaigns?
The authors have updated the text here from 'other' to 'the July 2017 and July 2018' for clarity.

Line 212: what are logistical and sampling challenges? Unclear.
The authors feel that detailing the logistical challenges experienced over these campaigns is unnecessary and would distract from the findings of the study but wanted to acknowledge that original plans had been disrupted and we were unable to get some of the data we had planned to get despite best intentions due to some logistical and sampling (field and equipment access) issues. The authors have chosen to leave the text as is.

Line 213: adapt subtitle, 4 measuring days do not allow to delineate synoptic results (overstatement)
The authors have modified the subtitle to 'initial results…' instead of 'synoptic results…'.

Line 214: you mean.. nitrate concentration was higher … please adapt
The authors thank Anonymous Referee #1 and have modified the text from 'was significantly greater' to 'concentrations were significantly higher'.

Line 216: Strange description on atmospheric condition, air temperature, mean or maximum, please be precise, brief precipitation event, add where this has been measured and the exact rain amount.
The authors have modified this text and have stated that a quantitative rain amount is unfortunately not available for this precipitation event.

Line 220: Seep? Not introduced in M& M.
As commented on above, the authors have introduced the Seep in section 2.1.

Line 221: relative to the other three sampling days in July
The authors have modified the text from 'all other sampling days' to 'the other sampling days from the initial July 2017 sampling campaign.'.

Line 222: avoid such blue sky interpretation! Adapt
The authors thank Anonymous Referee #1 for their caution but believe this explanation is the likely reason this seep exists and have phrased this sentence as such. We do not see a reason to overcomplicate an explanation that the field team agrees with after months of interacting with this location over several years.

Line 224: 58.61 mg L-1 Typing error, such high values are not presented in the Figures nor in Tables!
The authors thank Anonymous Referee #1 for identifying this typo and have adapted the text accordingly.

Line 230: please describe the weather conditions during your campaigns properly
The authors thank Anonymous Referee #1 for this suggestion and agree that this study would benefit from these details if they were available but we were unable to obtain several quantitative weather parameters (ex: mm precip.) due to equipment access issues and equipment malfunction.

Line 234-237: two times the same results with very different outcomes? Rather weird description, please improve.
The authors have reworded these lines and added details to improve clarity.

Line 228-258: Not fully clear what you like to present as results here, rather repetitive description on the different campaigns, not really convincing, please improve
The authors thank Anonymous Referee #1 for this feedback and have modified the text and removed any obvious campaign description repetition from the text but believe that this structure allows for the authors to communicate major observations/results from within each separate field campaign of Phase 2 of this study. However, we believe the modifications we made have improved this section even though the structure remains the same.

Line 259-271: Rather a potpourri of observation, in M &M section you mentioned 5 litter samples, now there are 10. What do these results tell you.
The authors have moved this section to the Supplemental material and added in clarifying details including that we performed replicate measurements of the original 5 samples collected, making the total number of analyses points for the leaf litter, n = 10.

Discussion: Obvious that the N2 fixation is the main source for the nitrate! So, please reorganise the whole discussion, now it reads like another result section! Please adapt

The authors thank Anonymous Referee #1 for this feedback, have moved the source/isotopic text to the Supplement material, and have restructured the discussion section accordingly.

Line 325-326: what kind of additional controls? Please avoid such empty sentences.

The authors have added examples of possible additional controls including denitrification bacteria, assimilation, and hydrologic flushing.

Line: 329: A new aspect emerges: the comparison with the global meteoric water line! Why do you expect evaporation ins such a wet landscape? See line 244 Water flows even during periods without rain…

The authors acknowledge the evaporation was negligible and made the comparison to the GMWL as standard practice / common reference. Text cited from Line 244 was to active layer thaw seepage, which is a constant presence of moisture but still susceptible to evaporation. The authors have removed the sentence with the reference to the GMWL to avoid distracting the reader.

Line 386: Future research? Rather bizzare that the authors list all the requirements for a more solid study. I would not declare these points as future research but as prerequisites for the current study!

The authors have modified the language in this section to acknowledge areas that future studies could build off of and not dwell on the perceived shortcomings of this study. The authors also respectfully argue that inviting the community to participate in more research in this area with suggestions to improve research outcomes is not bizarre, it is collegial and asks for engagement from the community. The goal of this text is to call on the community to increase our collective understanding of the ways in which NO_3^- availability and mobility will change with changing climate in a variety of landscapes and environments. Knowing what we now know, we would have made some modifications to this study design and/or incorporated additional parameters and want to share these insights with other studies to they can build off of what is already known and maximize the outcomes of their research. Despite the challenges and learning opportunities encountered during this study, we still obtained data that increases our understanding of the highly variable nature and limited mobility of NO_3^- in permafrost landscapes with alder shrub communities despite the increasing availability of NO_3^- with warming climates and expanding alder stands.

Line 401: Really unclear how such a single hillslope study should be of value for ESM

This research was completed with oversight and support of the Next-Generation Ecosystems Experiments (NGEE Arctic) project. NGEE Arctic is supported by the Office of Biological and Environmental Research in the U.S. Department of Energy – Office of Science. Field and lab outcomes and observations collected under NGEE Arctic are used to inform Earth System Models (ESM) through the collection and incorporation of experimental data in the face of increasing Arctic temperatures. A major motivation for this program is the use of modeling outcomes to inform experimental design and the use of experimental observations to inform models. We obtained experimental observations during this study that were shared with the modeling team to help inform the project on the appropriateness of incorporating small-scale spatial and temporal variations into models. While a single hillslope may not be incorporated into a larger ESM, processes observed within that hillslope can inform models of the general geochemical trends expected from expanding alder shrubs on Arctic hillslopes.

Line 4902: bolster??

The authors have replaced 'bolster' with 'increase'.

Conclusion: Already established that alder fix atmospheric N and therefore contribute to higher nitrate concentration in soil water. Rather redundant conclusions.

The authors have removed this phrasing from our conclusions but are also of the mindset that publication of additional studies that support known relationships add to n and increase the scientific community's broader understanding on nuanced variability within this known relationship. Corroborating studies are useful especially when they take place in different

landscape or climate settings.

Figures

Figure1 (a) better to insert a map
The authors have modified Figure 1 accordingly.

Figure 2 a, b: Redundant to use different size of symbols and different colours. Please use for the same nitrate concentration the same colour! It is not really convincing to present means AND single values
The authors find that although different size symbols and different colors for different NO_3^--N ranges may be redundant, it is useful to visually emphasize where the higher concentrations exist. The color and range of concentrations between Figures 2a and 1b have been verified for consistency.

Figure 3: add sd (of bars) and add weather conditions (at least air, soil temperature and rain in mm)
The authors had included the sd information in Table S5 in the Supplement but have also added sd markers to Figure 3. The authors are unable to add the requested weather conditions that correspond to our field site due to equipment malfunction but the figure contains asterisk that denote days on which precipitation events were observed by those involved in the field campaign. We wish we were able to quantify the requested weather parameters but have indicated which days precipitation occurred to provide further insights to our data interpretation.

Figure 4: There are no alders in the lower part of both transects, correct? I have some doubts whether the log Y scale really helps here. Table with the values (mean ± sd, number of replicates would be for sure more informative)
There are no dense alder stands in the lowland sampling locations but there are small interspersed alders present (defined by alder savanna landscape). However, our transect did not directly intersect with any alder shrubs in the lowland area. Tables S5 and S6 in the Supplement contain this requested information. The authors have included a reference to these tables in the Figure 4 caption. The authors have created this figure in both linear and log scale and prefer the log scale to emphasize differences in the measured redox concentrations.

Figure 6. Boxplots largely overlap, that means no significant differences. How did you get this $P<0.05$? Though single t-tests? (Multiple mean test would be correct). Add n here…
Table S7 in the Supplement contains n, max, min, mean, sd, and p-values for the $\delta^{18}O$ data portrayed in the original Figure 6. Authors moved the isotopic portion of this manuscript to the Supplement because it seems to distract from transportation outcomes and is the only part of the manuscript to focus on temporal variability so we separated the isotopic work including this figure from the main body of the manuscript.

Author response to Anonymous Referee #2 comments:
All author responses appear in grey italics below specific comments from Anonymous Referee #2.

General comments

This study presents a comprehensive dataset which illustrates how substrate source (alder litter) and spatial connectivity in a sloping permafrost landscape may be larger control on NO_3^- presence in uplands than soil moisture content, how increased NO_3^- related to N fixer presence may be mobile in the landscape, and how redox conditions related to soil moisture and topography impacts the spatial extent of this mobility. This is a valuable contribution which underlines the importance of considering topography and N fixers as plant functional type in predictions of future plant N availability and potential N_2O emissions.

However, this is a complicated dataset, and the study could benefit from a more coherent storyline, where the different datasets are presented not only in sequence, but are used together to tell a common story and the reader understands why the methods were chosen. This is done nicely in the abstract, but lacks in the discussion, where the $\delta^{18}O$ results and the $\delta^{15}N$ and NO_3^- concentration results are, I suspect, not intended to be two separate stories, but they appear as such at the moment.

The authors thank Anonymous Referee #2 for acknowledging the contribution of this study and for their constructive feedback. The authors have made note of the 'two separate stories' comment and have decided to move the isotopic data from the main text to the Supplement since it may distract from the main nitrate variability and mobility findings of our study. The authors have reworked the remaining discussion in the main text to ensure the storyline is cohesive.

A few more specific section comments:

Introduction: The language could use an overhaul, mainly a condensation of the text, where some points are repeated and some sentences/sections come out of context (see specific comments below).
The authors thank Anonymous Referee #2 for their insights and have substantially reworded and condensed the introduction to streamline our message.

Materials and methods: The sample design is very comprehensive and complicated and as such benefits from a detailed description. However, the information could be more closely related to Figure 1b and 1c for clarity and condensed. The description of isotopic calculations is clear and useful. There is a lack of a quantitative estimate of precipitation (now currently addressed simply as "Precipitation events") from e.g. a micrometeorological station, as the precipitation downslope movement of NO_3^- is such a central part of the results.
The authors thank Anonymous Referee #2 for their insights and agree that the text should be linked more closely to Figure 1 for a visual reference to our design and have modify the M&M text to include additional references to Figure 1 accordingly. The authors also acknowledge that the precipitation events are lacking detail as these are based on in-person observations in the field and we unfortunately did not have the equipment to quantify precipitation adequately. However, not including these qualitative in-field observations of precipitation that correlate strongly to observed NO_3-N transportation downslope along our transects, would be a disservice to the audience of this manuscript. So, although we are left with qualitative rather than quantitative information for precipitation events, we choose to leave this information in the text.

Discussion: The storyline of the discussion is not clear and appears more as a list of results related to literature than a use of results to illuminate your research questions. As an example, the discussion of $\delta^{18}O$ related to precipitation events (line 328-339) comes a bit disconnected from the NO_3^--story, but I suspect there is a point related to N transport, which needs to be clarified. The discussion needs to be restructured and condensed to tell the study story based on the results.
The authors thank Anonymous Referee #2 for their insights and have modified the discussion to better emphasize the connections between our geochemical observations and N transport. The authors have also decided to move the isotopic work to the Supplement to allow the main body of text to center around NO_3^- N.

Because of the large revisions needed in the communications of the results, I recommend that the manuscript can be reconsidered after major revisions.
The authors thank Anonymous Referee #2 for their suggestion and have worked to improve the quality of the writing to streamline our findings and strengthen emphasis on our outcomes.

Specific comments with line numbering
Line 35-37: Which links and why is it important? Give one or two examples for a more engaging story.
The authors thank Anonymous Referee #2 for this suggestion but have ultimately decided to remove this sentence since we felt it detracted from the streamlined revised nature of our introduction after adding in examples of C and N links and their importance. The authors feel that focusing on N without the introduction of C is more appropriate for the goals of this manuscript.

Line 51-56: This second half of the paragraph seems a bit out of place, because the text introduces alder effects on soil chemistry above and continues below. Consider moving it and even skipping line 51-52 or replacing the sentence in line 39-40 as they say much the same.
The authors thank Anonymous Referee #2 for their insights have altered the text from original lines 39-40 to encompass the content from original lines 51-52 since it was repetitive. Original lines 53-56 have been moved to the previous paragraph to avoid breaking up the alder effects on soil chemistry text. This arrangement seems to transition between and address topics in a more fluid manner.

Line 68: Alternatively "situated in a hillslope landscape"
The authors have reworded the phrasing in the text from "on a hillslope landscape" to this better suited suggestion.

Line 91-91: I don't understand the function of this sentence in relation to the next sentences.
The authors thank Anonymous Referee #2 for this comment and have reworded this sentence and the following sentences for improved clarity. These sentences are intended to highlight the unique characteristics of an 'alder shrubland' designation versus an 'alder savanna' designation and we believe the edits made clarify these distinctions.

Line 160: A sentence on how $\delta^{18}O$ from H_2O (soil solution) in your NO_3^- is derived would be useful here.
The authors thank Anonymous Referee #2 for this suggestion and have added in a sentence to clarify where $\delta^{18}O$ from H_2O came from: "Isotopic data for $\delta^{18}O$ - H_20 was measured directly from soil pore water samples using a GV Instruments Multiflow peripheral instrument (Heikoop et al., 2015)." This text has been moved to the Supplemental material along with our other isotopic text and figures.

186-190: Iron, sulfate and Manganese enter the story a bit abruptly here. If they have a function in the study design (as it is later clear that they have), please add a sentence earlier when explaining the study scope and strategy, adding the function of measuring those parameters.
The authors thank Anonymous Referee #2 for bringing this to our attention and have added text to section 2.2 Sample Design to explain the importance of these supporting redox sensitive elements to our experiment earlier in the text.

Line 269: You define all the other pools, but SON is not defined (Soil Organic Nitrogen, I assume)?
The authors thank Anonymous Referee #2 for identifying this location of SON that would benefit from further clarification. Yes, SON is Soil Organic Nitrogen. The authors previously define SON in section 2.4 but have added in the full term here for consistency in the sentence structure and to avoid any confusion of the term.

Line 284: This is an interesting finding from this study
The authors thank Anonymous Referee #2 for noting this and have modified text within the conclusion section to circle back to this point.

Line 290-91: This statement, referring to Boshers et al. (2019) should be explained further. While the equation 1 is nicely explained previously, the argumentation for choosing this method should be discussed in relation to alternatives. You mention that "both possibilities" (line 291-292) are shown in figure 5. By this, I take that you mean the H_2O-derived only and the Eq. 1 determined predictions (?), however, I see only one interval of predictions in figure 5. The text and the link needs a better explanation.
The authors thank Anonymous Referee #2 for this comment and have added clarity to this text. Upon further investigation the authors determined that the range provided in this figure encapsulates both predictive ranges so instead of showing two smaller ranges, we combined the predictive ranges into one that covers both predictive ranges (from Kendall and McDonnell, 1988 and Boshers et al., 2019). This text has been moved to the Supplement online material along with the other isotopic work presented in this study to allow the main text to focus on the nitrate variability and mobility story.

Lines 328-339: This section is interesting and coherent in its argumentation, but its place in the story of the manuscript is not clear. The point may be that there is a connection to the NO_3^- transport and –source, however, this link needs to be clearer for this section to be relevant to the overall story.
The authors thank Anonymous Referee #2 for this insight and have moved the isotopic story to the Supplement associated with this manuscript because it seems to detract from our primary findings and

acts only as support to show that we investigated beyond just NO_3 variability and transport: we also gained insights to the NO_3^--N sources present at our field site but did not find a clear linkage between transport and source. Thus, these findings may distract from our transport findings more than they add to it so it may be most appropriate to briefly acknowledge that this data exists and readers can reference it in the Supplement if interested.

Line 375-385: This section is a good example of clear, well-written communication/discussion of the results. !

The authors thank Anonymous Referee #2 for highlighting this section and used it as a reference to improve and streamline other sections.

Technical comments with line numbering:

Line 19: The parentheses around NO_3^- concentrations are not necessary and should either be removed or the sentence restructured

The authors thank Anonymous Referee #2 for this suggestion and have removed the parenthesis around the first instance of nitrate-N concentrations to improve the flow of the sentence.

Line 32: Consider using "near-surface hydrologic conditions" in order to exclude e.g. subpermafrost groundwater

The authors thank Anonymous Referee #2 and have changed the language from 'hydrologic conditions' to 'near-surface hydrologic conditions' as aptly recommended.

Line 181: a comma is likely missing between "bags" and "frozen".

The authors thank Anonymous Referee #2 for catching this typo and have added a comma.

Line 184: Soil temperature at which depth?

The authors took soil sample measurements from the depth at which each rhizon was inserted, which was 15 cm for the majority of sampling locations. The authors have added these clarifying details to this line of text.

Line 185: Introduce DO as Dissolved Oxygen before abbreviating

The authors thank Anonymous Referee #2 for pointing out this oversight and have added '(DO)' after the first reference to 'dissolved oxygen' in the previous sentence to clearly define this abbreviation.

Line 200-201: Back up this statement with a reference?

The authors have added the following references to at the end of this statement: O'Donnell and Jones, 2006; Moatar et al., 2017, and have added the Moatar et al., 2017 reference to the reference list.

O'Donnell JA, and JB Jones. 2006. Nitrogen retention in the riparian zone of catchments underlain by discontinuous permafrost. Freshwater Biology 51: 854-856.

Moatar F, Abbot BW, Minaudo C, Curie, F, Pinay G. 2017. Elemental properties, hydrology, and biology interact to shape concentration-discharge curves for carbon, nutrients, sediment, and major ions. Water Resources Research 53: 1270-1287.

Line 214: The beginning of this sentence should be reformulated – for once, the comma seems misplaced before "2017"

The authors thank Anonymous Referee #2 and have removed the comma and reformulated this sentence for improved clarity.

Figure 4: the lower part of the figure is cut off by the caption

The authors thank Anonymous Referee #2 and have edited the placement of Figure 4 and the corresponding caption to ensure the full figure is visible in this version of our submission.