Biogeosciences Discuss., author comment AC1
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Reply on RC1

Jody Daniel et al.

Author comment on "Climate, land cover and topography: essential ingredients in predicting wetland permanence" by Jody Daniel et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-200-AC1, 2021

Response to Reviewers

Thank you kindly for these constructive reviews. We very much appreciate the helpful suggestions and feedback. We have endeavoured to respond to each comment in turn, by inserting our responses between the paragraphs written by Reviewers in the letter below. To better differentiate our comments from those of the Reviewers, we have highlighted our text in yellow and use Times New Roman font to contrast with the sans serif font of the text written by Reviewers.

In our responses, we describe how we will revise the manuscript to address any concerns raised and to incorporate the suggestions that we agree will improve the final paper. We also provide additional data on wetland sizes and climate normals for precipitation in our study area to better contextualize our work. In addition, we describe how future research should address some of the interesting questions that Reviewers have raised.

We hope that our responses and the changes we pledge to make to the manuscript are considered sufficient to warrant consideration of a revised draft for publication in Biogeosciences.

Please see the attachment as fonts and figures did not paste over to this reply.

Sincerely,

Dr. Rebecca Rooney (on behalf of co-authors Dr. Jody Daniel and Dr. Derek Robinson).

Page Break

Reviewer 1

Overall, the paper “Climate and topography: the two essential ingredients in predicting wetland permanence” is written very clearly and represents a needed analysis of the individual and combined effects of climate, land use, and topography on the permanence of wetlands in the Prairie Pothole Region. The authors looked at several variables in each category and region and predicted the permanence classes of wetlands. They found that terrain was a nearly as important to predicting permanence class as climate in two regions. This works stresses the importance of including terrain in modeling the effects of climate change on wetlands in the PPR.

General comments:

Many relevant results/methods are relegated to the appendices. Specifically, the variables used and their definitions (especially the topographic variables where the name of the variables doesn’t make it obvious how it was calculated) should be in the main text. There are also analyses, the PCA analysis specifically, that are mentioned in the methods but not discussed in the results and only have a figure in an Appendix. Even if the analyses don’t warrant an actual figure in the main text, the results should be mentioned in the main text.

We agree. There are some analyses that are mentioned in the methods that are not explicitly discussed in the Results section and are instead provided in the appendix. We will incorporate the overall outcome of these methods in the Results section as well as add more references to the results in appendices to the Results section to better link the materials in the appendices with the main text. We will ensure all variables are defined clearly and explained in the main text.

Several potentially correlated variables are used in the analyses and could present issues when interpreting the variable importance. For instance, including % of land cover types as independent variables in the same model is potentially problematic, i.e. a wetland with more % cropland will automatically have less of the other land cover types. While correlation itself is not an issue with gradient boosting models, it could affect the inference of the importance of these variables. The variable importance could be split among % cropland and % natural because the two are likely negatively correlated but if you remove one, the other could have a higher variable importance. Had you considered limiting the correlated variables % cropland or % natural veg vs. including both?

We agree that when variables are highly correlated, their relative importance can be obscured in xgboost, especially when they were not selected the same number of times across iterations/trees. We recognize that this could be true in our models; however, we sought to compare the importance of variables in aggregate (i.e., land cover vs. climate vs. terrain) across Natural Regions, rather than focusing on comparisons of importance among different land cover types. Also, the degree of correlation among land covers varied between Natural Regions. For instance, the Pearson correlation between cropland and natural cover was only –0.64 in the Parkland but was -0.9 in the Grassland, where cropping was the dominant land use, which we have tried to describe in Appendix C, panels D-F. We agree that by removing either cropland or natural land cover would likely increase the importance of the remaining land cover type in the final model. However, that removal should not affect the relative importance of land cover overall, which was still the second most important predictor of permanence class in the Grassland. Thus, we do not believe that removing natural cover or cropland would change the rankings of climate, land cover/land use and terrain in predicting permanence class.

It seems like one of the largest factors in determining the permanence class of a wetland would be wetland depth/volume and wetland size I can't see how/where you are getting at either of those. You might be getting to a proxy of depth this with some of the terrain variables but if I understand correctly, those are only calculated in the wetland buffer?? Also knowing the average size of the wetland will help determine how effective a DEM of 25 meters is. Is a wetland generally about 1 cell or several cells? You discuss not including soils in the models in the discussion but including other variables that are likely to make a difference in permanence class will be helpful.

The designation of wetland permanence class comes from the Central and Southern Alberta Wetland Inventories and is not something we derived from data on water volume, wetland size or depth. We describe this briefly around L70 and Figure 1, but agree it needs to be made more explicit and will revise the manuscript to better describe these data rather than rely on the citation.

Likely, water volume is the main determinant of permanence class as the wetland will retain open water until the entire volume has evaporated, transpired, or infiltrated, and our focus on external factors is likely why our predictive power was not very high. Unfortunately, we do not have data on the water volume or depth of the 40,000 wetlands in our analysis, and so we could not include estimates of volume. There is no extensive dataset on wetland bathymetry, though this would be very valuable and a timely acquisition of bathemetric LiDAR data over large areas might facilitate future development of such a dataset, or as new technologies come available that are able to use satellite-based methods in shallow waters. We agree that these data would certainly improve model fit over our initial efforts with currently available data, though we contend that our approach is still useful in assessing the role of larger scale domains of variables in determining permanence class. We will include mention of these forthcoming technologies in the discussion section of the paper as future research directions.

Thank you for the excellent suggestion to incorporate wetland size, which we do have access to from the wetland inventory. We agree that this would be helpful in contextualizing results and will add this information in the next draft of our manuscript. Here is some information on wetland size as background information to assess the suitability of the DEM. The median size of wetlands from the inventory that we drew the random selection of 40,000 sites from was 0.245 ha. If the wetlands were square, this would be about 50 m by 50 m, which would encompass 4 “cells” of the DEM. Importantly, the distribution of wetland sizes was skewed, so the average size is quite a bit larger than the median (see also our response below, which includes a frequency histogram of wetland sizes by natural region). Also, our terrain metrics were calculated for each focal wetland’s catchment, which contains more cells than the wetland itself.

Specific comments:

Line 10/line 29 – I am not sure that wetlands that hold water year-round are most sensitive to climate change. Wouldn’t temporarily ponded wetlands that have a decrease in hydroperiod and disappear completely also be pretty sensitive to clime change? The reference provided state they are the most rare so justify why they are most sensitive

This seemingly counterintuitive prediction comes from work by Fay et al (2016) and others, who noted that the effects of climate change on evapotranspiration rates in the PPR are projected to be greatest later in the summer when evapotranspiration rates are maximized. Because seasonal and temporary class wetlands are already naturally drawn down by this time, they are spared the impact of increased peak evapotranspiration later in the summer. Yet, semi-permanent and permanently ponded wetlands that 'normally' hold water through the late summer will be subjected to the effects of this higher summer evapotranspiration and are thus predicted to be more sensitive to the projected effects of climate change in the Prairie Pothole Region.

Fay, P. A., Guntenspergen, G. R., Olker, J. H. and Carter Johnson, W.: Climate change impacts on freshwater wetland hydrology and vegetation cover cycling along a regional aridity gradient, Ecosphere, 7(10), e01504, doi:10.1002/ecs2.1504, 2016)

Line 30 – this citation refers to potential -20% or +205 changes in precipitation that included with warming may decrease hydroperiod but doesn't specify a 20% decline in hydroperiod definitively

Thank you for catching this. We will revise the manuscript to more accurately represent the projected precipitation changes.

Line 83-84 – providing average and sd of wetland size in each region would be helpful

Below, we provide the median, mean and standard deviation of wetland areas from the Alberta Merged Wetland Inventory covering the three different Natural Regions in our study. We emphasize that while there are differences in wetland size among Natural Regions, wetland sizes evidence a similarly skewed distribution with most wetlands being smaller than the average size and few reaching an order of magnitude larger than average.

Region	Median (km2)	Mean (km2)	Standard Deviation (km2)
Boreal	0.0226	0.08008235	0.9564564
Grassland	0.0058	0.02209926	0.2327619
Parkland	0.0154	0.04341342	0.3077994

Figure 1: Histogram showing the frequency distribution of wetlands by their area for the Boreal, Grassland, and Parkland natural regions of Alberta, based on the Alberta Merged Wetland Inventory.

Line 97 – why only one year of climate data? Some studies have suggested that longer time frames of climate data explain water levels better. A justification for this is needed. Also, is this time frame in any way related to when the permanence classes for the wetlands were determined for the wetland inventories?

We considered both of these issues prior to submission and agree that they are important points. which both Reviewers raised, and we should have more explicitly addressed. We pledge to better defend and address these two points within the manuscript if a revised draft is permitted. In particular, we will revise mentions of “climate data” to ensure we are clearly describing annual data for climate variables, rather than long-term climate normals or other index values, which were not available in the same spatial detail as the annual values for our study region.

To address this question, we selected one year of climate variables for three reasons. First, the year we selected – 2014 – was a very typical year, in that the annual conditions closely agreed with the climate normals for the study area. For example, below we show cumulative precipitation for the 2013-2014 period compared to the 1981-2010 climate normal for the Grassland and Parkland Natural Regions. Testing for deviations from the 1981-2010 climate normals in terms mean annual precipitation, we find no significant differences in 2013-2014 or 2014-2015: neither in the Grassland (2013-2014 – paired t-test: t = 1.833, *p*-value = 0.652, df = 9; 2014-2015 – paired t-test: t = 1.833, *p*-value = 0.878 , df = 9) nor the Parkland (2013-2014 – t-test: t = 1.833, *p*-value = 0.344, df = 9; 2014-2015 – t-test: t = 1.833, *p*-value = 0.315 , df = 9) is negligible.

Second, though we agree with Reviewer 2’s comments (see below) that the influence of climate variables on wetland permanence classes will exhibit time lag or legacy effects, these will be moderated by things like soil storage, groundwater movement, vegetation succession within the catchment, etc. Consequently, we considered that the temporal window of relevant weather would be site-specific and we felt we lacked a defensible justification on which to base a threshold. Should we include data from the past 3, 5, 10, Or 30 years? This is complicated by the designation of wetland permanence class in the Central and Southern inventories comprising a temporal mosaic. Confronting the need to make an arbitrary decision on what data to include or exclude in considering climate and knowing that 2014 was a particularly “normal” year, we elected to focus on our primary goal: comparing the relative importance of different domains of influence on aggregate (i.e., Climate vs. Terrain vs. Land cover). We concluded that fine-tuning how climate was defined with respect to the permanence class designation of each wetland would only strengthen the relative importance of climate variables, which were already identified as the most important predictor category in our models and so we did not modify our characterization of annual data on climate variables. Though we recognize the need to make this scoping clear in the manuscript and will revise to do so. Consequently, using the annual data on climate variables from the study period is representative of average conditions for the study area. Incidentally, the same argument could be made about land cover having legacy effects that are not captured by using a snapshot of cover types, but we suggest that the complexity of weighted averages or other indices integrating land covers or climate variables through time are best reserved for follow-up research and we opted for simplicity and comparability in our initial effort to better integrate terrain into considerations of the drivers of permanence class and hydroperiod in PPR wetlands.

Third, we have some practical considerations that influenced the selection of 2013-2014 annual data on climate variables. This includes that the terrain and land cover data also came from 2014, and so using the same time span was defensible for comparison purposes. More, this corresponded with field work we carried out as part of a larger research program on PPR wetlands in Alberta between 2013 and 2015. By using annual data on climate variables from the same period, we were able to better relate this project to the field work we conducted and satisfy stakeholder and funding requirements.

Figure 2: Comparison of cumulative precipitation from 2013-2014 against the 1981-2010 climate normals in two Natural Regions of Alberta. We do not show the Boreal here because the wetlands we included from this Natural Region were restricted to the very southern margin and are not likely representative of the full Natural Region (see Figure 1 in the manuscript), climatically they are more similar to the Parkland than the Boreal.

Line 100 – Appendix B - I think moving these variables into the main part of the paper would be helpful. Knowing the specifics of how each of these were calculated, especially the topographic variables which aren't as obvious.

As we describe in our response to general comments above, we pledge to better

integrate these appendices into the main text. However, we are cognizant of space limitations and defer to the editor’s recommendation around whether to move appendix materials directly into the main text or rather to enhance the degree of reference to them and bring in only limited details.

Line 113-115 - Does this mean that it is only using data from the buffer and not the wetland itself? DEMs don't tend to get below surface water unless the data is collected in a particularly dry time. Thus, the DEM is not likely able to get at depth of a wetland although that may be an important factor in wetland permanence. But depending on how big these wetlands themselves are and when the DEM data was collected, you might be better to include the wetland itself as well

This is correct, the characterization of terrain was within the wetland catchment, and not the bathymetry of the wetland basin, itself. Regarding the relative size of the wetlands and the DEM cell size, please see our comment above.

Line 119-120 – How did you use the PCA analysis and was it used to reduce the number of variables? Does Appendix B represent the reduced set of variables or was it further refined? Providing some additional information about why/how you did this and used the results of the PCA will be helpful. Many permanence classes appear to overlap here a lot so how did you use the PCA to visualize if wetlands could be partitioned?

We used the PCA to visualize any partitioning of permanence classes in accordance with the climate, land cover, and terrain variables and to facilitate comparison among the three Natural Regions. We incorporated it to help the reader see how the permanence classes in the Grassland appeared better aligned with all three domains of variables than those in the Parkland and especially in the Boreal Natural Regions. We did not use these PCAs as a variable reduction technique. We describe how the climate, land cover and terrain variables were selected in more detail in Appendix B and in the main text at around Line 90. For climate and land cover metrics, we carried out a literature review to identify key variables likely driving wetland permanence class and then selected representative metrics for each of these variables based on available data. For the Terrain metrics, we used those identified in a previous study (Branton and Robinson 2019), which did incorporate some control on collinearity: specifically, they generated a large list of candidate metrics based on a literature review and then refined that list based on correlation coefficients and selecting representative metrics from each correlated group, and then they used PCA to further refine the set of representative metrics. This study was carried out on the same wetland inventories and using the same datasets as we used in our study, and so we deemed it an excellent source of terrain metrics.

Line 134 – remove parentheses

We will make this change.

Line 142 – you mention the high error rates here but have again moved this information to an Appendix so it gets lost and might be better if discussed further

As in reference to the other comments about important information in our Appendices, we defer to the editor on whether to include it entirely in the main text or to better reference it in the main text but leave the details in an Appendix for brevity.

Line 153-167 and throughout – please check the Figure numbers in this section and throughout because a few appear to be referring to the wrong figure. An Appendix I is referred to but there is no Appendix I. It is also difficult to tell if you are referring to Figures 5 & 6 with "(Figure 5-6)" or Figure 5-VI. Using letters instead of roman numerals in those figures might also be helpful

Thank you for catching this error – it should be revised to say:

"Our findings suggest that wetland permanence class in the Prairie Pothole Region of Alberta is sensitive to climate, terrain and, to a lesser extent, to surrounding land cover/ land use. Generally, across the three Natural Regions, wetlands with shorter hydroperiods (e.g., temporary and seasonal) were typically situated in landscapes with higher spring snowpack amounts (Figure 4IV-VI) and spring temperatures (Figure 5IV-VI). Longer hydroperiod wetlands were typically situated in landscapes with more summer precipitation (Figure 4VII-VX) and lower spring temperatures (Figure 5IV-VI), occupying relatively low topographic positions (Appendices F-H) with steep slopes (Figure 7 X-XII), and were surrounded by less natural cover (Figure 6X-XII). Interestingly, the relative importance of variables in predicting the occurrence of both shorter and longer-hydroperiod wetlands were shared, and this agreement was strongest between the Southern Boreal and Grassland (Appendices F & H)."

Line 215 – add space before citation

We will make this change.

Line 238 – while you account for elevation, it could be better accounted for with a higher resolution DEM and including a more direct proxy for wetland depth/volume could also help improve the models

Yes, we agree that a higher resolution DEM would be valuable, if one were available for the whole of our study region. We used the best data available for our study area. Finer resolution DEMs are available for small sections of Alberta's PPR, such as the Beaverhills Subwatershed or the area immediately around Calgary, but not the full extent of the PPR.

Line 247 – add space before citation

We will make this change.

Please also note the supplement to this comment:
https://bg.copernicus.org/preprints/bg-2021-200/bg-2021-200-AC1-supplement.pdf