Earth System
Dynamics
Discussions

Interactive comment on "Groundwater nitrate concentration evolution under climate change and agricultural adaptation scenarios: Prince Edward Island, Canada" *by* D. Paradis et al.

D. Paradis et al.

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We would like to sincerely thank M. Vanclooster, A. Shepherd and M. Crucifix for their valuable time and constructive comments on our manuscript. Here below are answers to general and specific remarks raised during the review process.

Hoping that these responses will be to your satisfaction,

Daniel Paradis

General remarks from M. Crucifix (Editor)

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1. This is an original and overall well designed contribution, which will be acceptable for publication in Earth System Dynamics. Both reviewers confirm the relevance and quality of the material presented here.

2. The GCMs used here are not quite the latest generation. Reviewer A. Shepherd C687 also notes that crop data are rather old. I do not see any of these being a major issue, but possible shortcomings should nevertheless be discussed, and this discussion requires somehow an inspection of the most recent available datasets.

It should be noted that climate and agricultural scenarios were selected to be used as exploratory boundary conditions to study the sensitivity of the PEI aquifer system rather than an attempt to exactly predict future groundwater nitrate concentration. So, our objective is to study the relative impact of climate, agriculture and aquifer system dynamics on groundwater nitrate concentration. Nevertheless, new GCMs scenarios were produced and discussed, and expected boundary of the agricultural scenarios better discussed.

3. The study unavoidably requires a number of subjective decisions about scenario and other hypotheses. Uncertainties associated with these decisions should be better discussed.

Please see answer for comment #7 from A. Shepherd below.

4. The challenge is to address these comments without increasing the manuscript length. In other words the barycenter of the manuscript must be shifted towards the discussion and analysis sections. One solution is indeed to revise the number of citations (though it is not so overwhelming). Line-by-line edition targeting communication efficiency may substantially enhance the quality of the manuscript.

We address this issue in our revised manuscript.

5. Abstract is sound and informative. Figures are well-designed and legible, except perhaps Figure 7, because the various shades of blue are not immediately recognis-

able on the Figure itself.

Fig. 7 was modified using shades more easily recognizable.

Specific remarks from M. Vanclooster (Referee)

1. P8, Line 9. Reference to Fig. 3b is wrong.

Agree: We should read "Fig. 2b" instead of "Fig. 3b.

2. P16,line 11. During the calibration of HELP, the initial water content was calibrated. This is very surprising given the fact that initial water content is not sensitive (page 14, line 25). Can this contradiction be resolved?

Explanation: We do not see a contradiction here. It is true that initial water content for our specific hydrogeological context does not have a large influence on recharge. But, it does not mean that a calibration is not needed. For a different context than our humid environment, the sensitivity of the recharge in initial water content variations could have been more important.

3. P16, line 23. The correlation coefficient is used here as a model performance indicator. Also this parameter is rather low (64%). Can the authors justify the use of the correlation coefficient as performance indicator and explain what threshold should be considered as appropriate?

Explanation: We modified performance indicator for HELP to be consistent with other models. Please see answer for comment #3 from A. Shepherd below.

Specific remarks from A. Shepherd (Referee)

1. The series of models all need statistical validation independently: GCM simulated historic scenarios from CGCM2 and HadCM3 vs observed historic, plus separate validation of HELP, RSN, and FEFLOW simulations against observed data. Instead of graphing a lot of simulated-observed data, a more correct and concise way is to display statistical results for comparison. A very good guide is Smith P. et al. (1997) in

Geoderma, 81, 153-225, also see L.Wu et al. (2015) Science of the Total Environment, 530-531, 76-86, Table 6 for the use of this in a concise Table. Try to be consistent, tabulating all models and with the same statistical indicators for comparison of weakest link in your chain of processes, which should be part of your critical assessment of the process at the end.

Agree: The statistical tests suggested by Smith et al. (1997) was used to evaluate the calibration performance of all models used in our study. In particular, we retained: root mean square error, modelling efficiency, relative error and correlation coefficient. A new table was produced to report all statistics.

2. Results relating to different IPCC scenarios A2 and B2 should be reported separately, not averaged (p.1364, line 3-5). The scenarios are distinct and different situations.

Agree: We deleted the last sentence (p1364, l3-5) and modified the following sentence as follow (p1364, l1-3): "In general, a decrease in groundwater recharge is expected for the 2040–2069 period (between 2.1 to 12.4%); only the CGCM2-B2 scenario leads to an increase in recharge of 6.7%."

3. The average of 10 stochastic climate simulations (p.1351, line 12-13). A mathematical mean of 10 precipitation datasets would eradicate zero rain days, and so be in error. Explain how you deal with precipitation.

Agree: It is true that averaging daily precipitations may be not appropriated because of the nature of the stochastic processes, but after verification we used only one of the available synthetic data: "Note that in this study, daily synthetic climate data corresponds to one of the ten stochastic simulations with average precipitations."

4. Figure 3b does not exist (p.1346, line 9).

Agree: We should read "Fig. 2b" instead of "Fig. 3b.

5. No mention of Fig. 2c: conceptualization of N transport in aquifer.

Agree: The reference to Fig. 2c was missing. We added reference to this figure at p1346, l7.

6. Introduction: the initial summary is good leading the reader to expect further description in that order, but confuses when the following sections do not match. Initial: GCM, downscaling, RSN, HELP, FEFLOW. Sections: downscaling, HELP, RSN, FELOW. Rearrange to match order. Strive for consistency in a paper.

Agree: The order of RSN and HELP were interchanged in Section 3 ("Initial") to match with the next sub-sections.

7. Suggest adding an extra section for discussion, including the relative uncertainty of each model used, the area of most uncertainty, and listing all the assumptions made. Comment on the fact that uncertainty or error increases, the more models you use. No comparisons with any other studies' results have been made. Compare results from other studies on each individual model, and any previous groundwater nitrate modelling results for PEI or a nearby region.

Agree: In the revised manuscript we add a new section where we discuss model uncertainties. However, it should be noted that despite the inherent uncertainties relative to various assumptions adopted in this study, the strength of the proposed approach is to rely on a comprehensive model calibration workflow that help to quantify and narrow the range of uncertainties about groundwater nitrate concentration. The final calibration of the FEFLOW model with nitrate concentrations measured in wells integrate indeed all modelling errors related to groundwater recharge (HELP) and nitrate leaching (RSN) estimate as well as all the various assumptions that are often difficult to quantify. So, error propagation could be quantified at the end of the calibration process at least in the limits defined by the performance of the FEFLOW model to reproduce historical records. We think that this point was not well explained in our initial submission and it is better explained now in our revised manuscript.

8. Compare results from other studies here.

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See previous comment 7.

9. Enlist co-authors to help re-write more concise. There is a lot of repetition, eg. p.1363, line 5; p.1358, line 26; p.1350, line 17-21.

Agree: We reviewed the text to be more concise.

10. This many references are not needed and they are increased unnecessarily by long lists (P.1343, line 6-10), use 3 key references as examples of your statement.

Rebuttal: Those references are the most relevant studies that we found and we think that it is important to cite them.

11. Give a reference for the statement of doubling of CO2 by 2050 (P.1365, line 21).

Agree: At p1349, l17-18 the following sentence was added: "The time period 2014-2069 is approximately corresponding to a doubling of atmospheric CO_2 concentration (Qian et al., 2010)." with the following reference :

Qian, B., Gameda, S.B., DeJong, R., Falloon, P.D., et Gornall, J.: Comparing scenarios of Canadian daily climate extremes derived using a weather generator, Clim. Res., 41, 2, 131-149, doi : 10.3354/cr00845, 2010.

Also, we deleted the following sentence at p1365, l21-23:"Given that the doubling of CO2 in the atmosphere is to be reached in 2050, the future climate scenarios for temperatures and precipitation are available for the 2040–2069 period only."

And, added this sentence at p1366, l14-15: "Note that for the sake of simplification results are presented for 2050 (middle of the period 2014-2069)."

12. Explain technical terms the first time they are mentioned, examples are the term red beds and fining (p.1345), nodes (p.1357, line 26), anisotropy (p.1359, line 22).

Agree: p1345, l8-10: "red beds are now defined as: "PEI is a crescent-shaped cuesta of continental red beds, Upper Pennsylvanian to Middle Permian in age, dipping to the

northeast at about one to three degrees that consist of conglomerate, sandstone and siltstone in which sandstones are dominant (Van de Poll, 1983)." p1357,l25-27:"nodes" was deleted and the text was modified as:"However, the first layer was allowed to adjust to water table fluctuations in order..". p1359, l19:"anisotropy" was defined as:"The hydraulic conductivity anisotropy ratio (the ratio of vertical to horizontal hydraulic conductivities) for...".

13. Describe the 6 soil classes on PEI (p.1352, line 6).

Agree: P1352: The soil classes were listed as follow: "There were a total of 953 unique soil types identified on PEI that were regrouped into 6 distinct soil classes according to the dominant soil texture (A-Sand or coarser, B-Loamy sand or gravelly, C-Sandy loam (<8% clay), D-Fine sandy loam or very fine sandy loam, E-Loam or silt loam, and F-Sandy clay loam or clay loam)."

14. Define the term N load, is it the agricultural input to RSN or the output of RSN (p.1357, line 9)?

Explanation: At p1355, l3-4 we already define the nitrogen load, but using the term "nitrogen mass" instead of "nitrogen load" as follow:"The nitrogen mass available for transfer to groundwater was estimated with the residual soil nitrogen (RSN) indicator". To be consistent we replaced the term "nitrogen load" with "nitrogen mass" to avoid confusion (see p1357, l9 and p1357,l12).

15. Figure 6c. caption error : ". . .bars span the observed concentration interval", Fig.6c shows bars spanning simulation concentration.

Agree: We modified the figure.

16. P.1364, line section 4.,3 residual soil nitrogen: is this annual, should the units be in kg N / ha / year?

Agree: "kgNha-1" was replaced with "kgNha-1yr-1" in the text as well as in Fig. 8.

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Interactive comment on Earth Syst. Dynam. Discuss., 6, 1339, 2015.