

Interactive comment on “Are maps of nitrate reduction in groundwater altered by climate and land use changes?” by Ida Karlsson Seidenfaden et al.

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The authors investigate how nitrate reduction is affected by climate and land use changes for one Danish catchment. This is important as nitrate reduction maps are usually considered to be constant in time, which might not be appropriate for water quality management. With a modelling approach using MIKE SHE and Daisy, the authors show that climate has a stronger impact on nitrate reduction.

General comments: - The introduction is too brief; it should inform why land use and climate changes are relevant to NO₃-reduction. This is not explicitly mentioned. The key word “denitrification” also needs to be included. - The methods should be more

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clearly described and structured. It is hard to follow the steps sometimes. Why are there three subsections on the nitrate model in the Method section? Is there potential to merge them? From reading the titles I do not directly know where to expect what content. Why do you define the terms in the very end of the chapter, not when talking about the data or modelling periods? Consider restructuring. - The evaluation of the model needs to be more in depth. The calibration approach needs to be better explained. Was there no calibration with nitrate concentrations? Validation results should be presented and model uncertainties in relation to the calibration/parameters need to be discussed. Maybe a sensitivity analysis would be helpful. The results are very long compared to a very short discussion and no conclusion section, consider streamlining and moving content to supplemental material. - Please revise the consistency (e.g. N, nitrate, nitrogen usage (e.g. L124) or L 126) and language (e.g. sometimes singular and plural are mixed or incomplete)

Specific comments: - L9-11 long first sentences, consider splitting. - L10: impact “of” climate change - L14: consider rewording “potential errors”, what errors? This is unclear to me at this point - L20: What do the authors propose to constrain the uncertainty of model formulation and assumptions?

Introduction: - L35: “The amount of nitrate reduction occurring in groundwater depends on the flow paths and the depth to the redox interface.” is very brief considering for example the Damköhler number. This part would benefit from a bit more in depth. What about availability of electron donors? - L36: “In areas with Quaternary sediments characterized by groundwater dominated flow patterns and a relatively shallow redox interface, the N-reduction in groundwater can be the dominant removal process.” Please provide a reference - L43: I do not know why showing maps is considered as “a new approach”. Merz et al. 2009, for example, also showed retention maps and NO₃ half-life times. - L47: “produced N-reduction maps with a 100 m spatial resolution for a 101 km² catchment in Denmark,” is not helping the argumentation, can be removed. - L50: This sentence has to be checked for grammar. It is also partly redundant with

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the next sentence. - L55: “the effect hence is relatively large” please be more specific, “effect” is too vague here. - L57: This sentence is not clear to me. You are saying that N-reduction maps can be used more easily than hydrological models, but actually those models are used to produce the maps. This contradicts. - L60: Please revise the sentence.

Methods: - L74: “best”, “long”, “near-complete” Please, specify - L76: “The average discharge amounts to 4.4m³/s and the load is approximately 14 kg NO₃-N/ha/year.” Reference or more details needed - L79: reformulate “There were measurements” - L84: revise “100 meter redox depth map“, I assume you mean the resolution - L84: “This map” reference unclear, as citations mismatch, it is not clear to me. - L110: Please give a reference or indication why drains are needed, if locations are unknown. How do you define the “drain level” without this information? - L119 typo “percolation” - L119: “following methods” specify. Do you use several? - L121: when is the simulation period? Calibration was mentioned, but what about validation period? - L129: this is not a sentence - L135: bad title - L139: “If the particle penetrates the redox interface, the nitrate is assumed to be removed completely and instantaneously by denitrification.” Please, reflect more on this assumption. - L143: section 0 - L175-181: Please, specify how you can state that this was or was not the case? How did you further investigate the stuck particles? How many particles get stuck? It seems quite a lot if the correction causes changes between -7 and 9%. - L183: Revise the sentences. Also, what was tried to improve the numerical difficulties? - L184: I did not understand how the correction was done and also why this approach was used. Please, explain. - L196: The reference seems quite old for climate projections. Thus projections for the end of this century might contain much higher uncertainty. Please explain why you used this one and not a newer study. - L197: I do not know why bias-corrections are necessary, please explain. - L200: a “combined” median model? - L210 I do not understand “3% point reduction”. What is point telling here? - L218f.: I do not understand this combination that was done: “compared to the climate model results found for the reference period 1990-2009 using the same land use scenarios, resulting in 32 scenarios.” I think

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formulations are overcomplicated and Table 3 should be placed here.

Results: - L240: “observed trends in nitrate yields” where are these trends shown? - Table 3: I think this should be presented in the Methods? 3.6 scenarios? What does the grey shade mean? How can the climate scenarios be used for 1990-2009? Or is it necessary? I do not see them later in the presented maps. - Table 4: Do you have an idea why the standard deviations of all models are that similar (Table 4, 0.36-0.39)? Can you comment on that, please? - L295: “To investigate to what degree land use changes and climate change affect the reduction map, the difference between these scenarios and the reference scenario is shown in Figure 4.” Does not seem to fit here if the next section title is “4.4 Impact of land use change on reduction maps”. - Figure 3 and Figure 4 seem a bit redundant to me, considering that 4 is just the difference between the map shown in Fig2 and Fig3. I think one Figure could be economized here by merging or moving to the supplements - I think it is not necessary to show Fig7 and Fig8, especially because Fig.8 is mainly a reprint of Fig.12 in Karlsson et al. 2016, while the maps in Fig.7 do not allow to recognize more details than the general observation of land use changing little, two climate scenarios becoming wetter and two drier, which is also clear from Fig.5. Again I think redundancy should be reduced and plots removed or to the supplements.

Discussion/Conclusions: - L510: “such effects” reference unclear. Please explain further how 10% change in nitrate reduction over almost a century relates to the uncertainties of nitrate reduction maps. Is it really essential to consider changes in nitrate reduction for management, if the tool itself is already quite uncertain? - L512-516: “single case study” how representative is this case? What do you expect for other sites? Compare to other studies. General spatial differences between nitrate reduction could be considered. - L513-516: You mention uncertainties of input data (climate and land use) and model structure (though very briefly) but do not discuss the uncertainties related to the model and its parameters. - L516: This is not a nice ending. I would collect the conclusions in an extra Conclusion section.

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Data/code availability: - “owned by the DMI” - what does this mean? Where and how to access it?

Figures: - F1: typo at “Market driven”. Odd start of the caption as the Figure is showing the study area and land use scenarios and not a “red square”. - F2: I think the map titles should be linked to the legend color bars. Maybe increase letter size of legend, add unit at left panel. To me it is unclear, what the text on the y axis refers to “Observed climate...”, it seems unconnected. In the caption specify what the reduction refers to e.g. from... to... - F5: I suggest to remove redundant subplot titles, this should be explained in the caption. - F9: The caption is unclear to me. What combinations are shown? What is meant here “or the reduction map from the scenarios”?

References: - There seems to be an error in the display of the references – is it double or some other problem?

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