Review of revised hess-2024-173

Title: Multivariate and long-term time series analysis to assess the effect of nitrogen management policy on groundwater quality in Wallonia, BE

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Review summary

I thank Elise Verstraeten and co-authors for their extensive replies and revision in response to my quite critical review. While I still have some fundamental concerns with the revised version it is a good rebuttal and that is where science is about. We could refer to remaining issues as "agree to disagree". The revised manuscript is a major improvement and has addressed most of my points. The current discussion section reflects quite well uncertainties and limitations of the chosen data driven approach. So I recommend publication after some additional requests and suggestions; see below

Review remarks in more detail and suggestions

1. For reasons unclear to me, the authors mainly see problems and disadvantages of using process oriented models (including disqualifying the latter somewhat by referring to it as "traditional") . I agree that process oriented model have limitations regarding spatial detail, but they could be superior regarding capturing temporal detail. I would therefore recommend to also mention the potential of combining the power of data driven models and process oriented models. At least in the discussion (now one line 449-450) and perhaps even in the summary. I don't agree with the classical request for more data and monitoring, I think this route is less promising and could be more costly than teaming up with process oriented models.
    a. This open access paper that I found today, may help to get a more nuanced view on the use and potential of different approaches: "Rawat, M., Sen, R., Onyekwelu, I., Wiederstein, T., & Sharda, V. (2022) Modeling of groundwater nitrate contamination due to agricultural activities—a systematic review. Water, 14(24), 4008"
2. I still disagree with your conclusion that this approach allows conclusions about the effectiveness of nitrogen management policies (L462). While nitrate trends are interesting for policy makers to report about compliance with the Nitrates Directive, policy makers also want to know why nitrate concentration decreased and if their polices are effective. Your approach can detect trends and differences between aquifers/regions, and their association with land use, but not with actual policies. So I suggest to remove the phrase "…., and nitrogen management policies" or rewrite this as future work if you could get access to spatially detailed data about policy related trend of N surplus.
    a. To illustrate my point: Your statistical models account for structural effects of land use on nitrate, as you write in L348. However text in L356-360 tells that increasing trends are associated with more cropland area which is plausible and indeed may indicate that PGDA is not effective. Conversely, if PGDA would have been effective in cropland, your statistical analysis would show that decreasing trends are associated with cropland area, if I am correct. I would think that this does not mean that the policy advice is to convert forest land or pasture to crop land?
3. L363: How effective can promotion of deep rooted crops be to recover nitrate from accumulated pools in deep aquifers? Crops don't root deeper than one to a few meters?

4. Your suggested unavailability of groundwater depths, precipitation surpluses (L431-433), N fertilizer rates and N surpluses (APLs) for this study are brought as absolute realities while I think it means that you were not able to disclose or quantify these for your study. This is of course not unusual and acceptable. However, I would suggest to make these statements less absolute and rather formulate these as future opportunities (for you or others) and if possible how. This also relates to my early remark about the potential of combining statistical and process oriented models.
    a. The same is true for the evaluation reports of the Nitrates Directive in Wallonia. These evaluations are mandatory, but reports indeed may be hard to get to, sometimes they are treated confidentially. For a Publication in 2012 (you refer to) we e.g. used this report: "Directive Nitrates (91/676), Rapport vise a l'articele 10, Partie I, Bilan et evolution 10 de la qualite des eaux et des pratiques agricoles en Region Wallonne, Ministere de la Region Wallonne, Direction Generale des Ressources Naturelles en de l'Environnement, 2008" [I have uploaded it for your inspection]

Some minor points for revised ms.

1. L38: also mention the input of atmospheric deposition, especially for forests
2. L71: "can differ"; aren't they always higher?
3. Check syntax L348 regarding use of "were"
4. L367-369: and also that forests simply have lower nitrogen inputs
5. L388-389: please be more specific about what you consider shallow vs deep