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Biogeosciences Discussions

Interactive comment on "Current state and future scenarios of the global agricultural nitrogen cycle" *by* B. L. Bodirsky et al.

Anonymous Referee #2

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Biogeosciences Discussions 9:2755-2821 Title: Current state and future scenarios of the global agricultural nitrogen cycle Authors: B.L. Bodirski et al. This paper describes a modeling approach to simulate the nitrogen dynamics in the world's croplands for 1995 and a set of future scenarios. In comparison with existing literature, this approach adds a number of aspects, including the nitrogen released by soil organic matter loss following land tranformations. The text is rather brief about the methods, since these are described in the Appendix, which I assume will be published as online supplementary information. After reading the manuscript a couple of times the list of questions and rather fundamental problems is long, and my recommendation is to invite the authors to submit a thorough revision.

1. My first suggestion is to change the world agriculture into cropland, since the model

used does not cover the role of grasslands. In addition, there are some important questions regarding the approach to compute the nitrogen inputs in crop production systems, and the efficiency of nitrogen use.

2. A second suggestion is to add a discussion of the nitrogen use efficiency as used in agronomy. There are various definitions. The definition used in this paper is completely different from what is generally used, and a comparison and discussion is needed of the advantage of the definition used compared to others.

3. On page 2787 it is assumed that “no losses from the internally fixed Nr occurs, while the Nr fixed by free-living bacteria or in symbiosis with algae in rice paddies is assumed to underly (?) the same proportion of losses as the other Nr inputs”. It is absolutely unclear what is meant here. Is N fixation by free-living bacteria lost? And is the N fixed by legumes not part of the soil-plant system, where the straw and roots are decomposed after harvest and subject to losses? But losses like surface runoff, denitrification and leaching are not computed directly.

4. In figure 2, N fixation is 25 Tg, of which 15 in belowground tissue. So I wonder why this is not considered as being subject to losses, just like all other input terms. Or is this amount from free-living bacteria and the fixation in rice paddies?

5. The difference between the N fixation in the harvested parts in this study and other recent papers needs more attention (different base year, plant growth functions and N content of the grains), It is not clear what the reason is for this large difference. How can plant growth functions be of influence, because it is the production and N content that determine the result, and production is (hopefully) equal to the data from statistics. If the N content is different, why is that? And why not take the N content of Herridge in order to be consistent with that inventory?

6. The N fixed by legumes is thus assumed to be in the harvested parts only. This is not correct, since the N fixed is also in the straw and root tissue. Another problem is the nitrogen fertilizer applied to leguminous crops, which may be considerable in some

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countries like Egypt. This means that the fractions of nitrogen in the harvested parts which is assumed to be from nitrogen fixation, is actually from fertilizer, so nitrogen fixation needs to be corrected for this. 7. A further question is about the contribution from soil organic matter loss. The authors state that they considered the conversion of forest and grassland to cropland for the period 1980-1990. It is peculiar that 1980-1990 data is used for 1995, since the cropland expansion for 1990-2000 is much less than in the decade before. In addition, FAO does not provide the conversion of grassland to cropland, so I wonder where this information is coming from. The expansion of cropland according to HYDE is 69 million hectare for 1980-1990. With a soil N loss of 28 Tg in 1995, this means that 400 kg of N is lost per year and per hectare, or 4 tonnes of nitrogen for a 10-year period. I assume that the soil organic matter loss after the conversion to cropland takes 10 years. The soil organic carbon loss would thus be 6100 kg C, or 12 tonnes of soil organic matter, or 120 tonnes of soil organic matter over a 10-year period. As a global average this sounds like a large amount, and this important term in the global cropland nitrogen balance needs more explanation for readers to understand.

8. The inclusion of this soil loss term in the global nitrogen balance is fine, but it needs to be stressed that this term does not add to the nitrogen to all croplands, but only in those areas where recently forest has been cleared for cropland expansion. And since it is such a large amount that cannot be taken up by the crops, most of it is probably lost by surface runoff, leaching and denitrification and does not contribute to crop uptake. This will occur if this term is used in the regional nitrogen budgets.

9. For the future, this term is fixed exogenously according to the scenario assumptions. This sounds strange, because the model simulates land transformations, so can calculate forest conversion and thus the nitrogen from soil organic matter loss, instead of the assumptions on page 2765. For example, the assumption that in the B1 and B2 scenarios, forest clearing will be halted may not be correct if biofuel production will increase rapidly in future (which could be in B1 and B2).

10. Regarding the scale of the calculations, it is not clear if the nitrogen balances are calculated on a regional basis, or spatially explicit. I assume that it is on a regional basis, but this needs to be stated more clearly.

11. If this is so, the nitrogen use efficiency is lumped at the scale of the 10 MagPie regions. This is another problem. If the crop mix changes, for example if the share of nitrogen fixing crops increases, or the share of rice, the use of the nitrogen use efficiency as a scenario variable is not correct.

12. On page 2763 the soil nitrogen use efficiency is defined as the ratio between Nr soil inputs (fertilizer, manure, residues, atmospheric deposition, soil organic matter loss and free-living Nr fixers) and soil withdrawals (harvest and crop residues minus seed and biological fixation by legumes and sugarcane). It is not clear if biological N fixation by legumes and sugarcane is part of the withdrawal or not. I would argue that it is added to both the withdrawal AND to the inputs.

13. The way the efficiency is calculated implies that any deficit is compensated for by fertilizer nitrogen. In other words, deficits are assumed not to exist?

14. Although the Appendix presents many details about the methods, data and model, it is not possible to understand how the model works and how scenarios were constructed. For example, the food demand is expressed as EJ (figure A2). Readers would be grateful to see the actual regional domestic production in tonnes, and also the cropland areas, yield development and fertilizer use. That would also clarify a bit more why fertilizer use increases so rapidly under A1 assumptions, and decreases so rapidly in B2 and not in B1.

15. In the A1 scenario fertilizer use increases very rapidly. This is peculiar, because at present fertilizer use efficiency is increasing in industrialized countries, and one could expect that the same will happen in developing countries. China and India are currently the major consumers of fertilizer nitrogen, determining a large part of the global total and its increase. When China and India develop, subsidies will probably decrease

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or be stopped, so the efficiency will have to increase. This will not be only in the environmentally oriented scenarios.

16. Page 2771, last paragraph: global simulated fertilizer use for 2005 agrees with the statistics, but the regional results do not. This is rather frightening, if after 10 years the model already deviates from the data, because the effect of wrong scenario assumptions will be dramatic after 100 years. The regions where fertilizer use is underestimated are those where nitrogen use is most important globally (see also #15 above), and this means a considerable overestimation in other regions. It is also interesting to discuss the large difference between IFA and FAO regional data, which seems to be especially large in the period 2005-2010.

Some minor comments are: - Page 2759, last para: the existing model must be extended, or has been ?

- Atmospheric deposition: is it the same for all scenarios? That is strange, because the scenarios are so different, probably also causing differences in emissions and thus deposition.

- Page 2769, last para: N accumulation is not considered in this paper.

- Page 2771, first para: using constant excretion rates implies that the feed conversion ratio decreases and excretion per unit of product decreases, which reflects an improving efficiency. Simply assuming an increasing efficiency sounds counterintuitive.

- Page 2779: the IMAGE model also accounts for nutrient withdrawal by fodder crops.

- Page 2791, line 19-23: a comparison with 20120 food demand statistics is needed here.

- Table 1: fertilizer use in some world regions is insignificant. When fertilizer use increases in such places, efficiency will go down. I do not know how the soil organic matter loss would add to the inputs and determine the efficiency, but this needs explanation on a regional level, for example with a few examples.

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- Table A4: units are missing. Tables need reference to Table A1 and A2 for the symbols.

- Figure 2: what is meant by “as they depend largely on the definition of pasture land.”

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