REFEREE REPORT(S):  
Referee: 1  
  
COMMENTS TO THE AUTHOR(S)  
Rotating Maize Reduces the Risk and Rate of Nitrate Leaching  HR Pasley et al.  
  
This paper describes an important topic of leaching rates from cropping systems based on long-term experimental data combined with modelling. The way the authors used the Apsim model to structure and organize their thinking about continuous maize and maize-soy cropping is elegant. The paper is well organized, and reads easily, and is concise and to-the-point. However, I have some major problems.

Thank you for the positive feedback and suggestions. Your input improved the clarity of the paper. We have made changes according to your suggestions: they are both recorded using track changes in the document and detailed below.  
  
I wonder how to interpret the following sentence from 4.3: “As such, our leaching model can be applied across multiple sites and years to determine the degree to which increasing the N fertilizer rate impacts the leaching load but should not be used to calculate the total leaching load from multiple sites/years at a given N rate”. Does this mean that we should not take the absolute numbers of leaching? I do not quite understand why it is “as such”. However, perhaps the major concern is that apparently “year” is a variable in the analysis. The year of the experiment is meaningless, and should be replaces by variables such as precipitation and other variables that describe what the difference is between years.

Response: We adjusted this section to explain what is included in the term “year:”

*“We found that the cropping system dictated the shape of the leaching response and breakpoint while the site and year (which encompasses annual differences in plant growth, temperature, precipitation, and soil N pool size/composition) explained the variability in the magnitude of the leaching. Therefore, while our leaching model can be applied across multiple sites and years to determine the degree to which increasing the N fertilizer rate impacts the leaching load, use of an average site-year prediction should be avoided in calculations of total leaching load from multiple sites/years at a given N rate. The significant effect of site and year on the baseline leaching load is further evidence of the important role soil and weather have in determining the fate of residual N over multiple seasons.”*

A further concern is why the model does so well for yields some of the experiments and so poor (IN2) for some others (Suppl. Figure 2), while nitrate leaching (Suppl. Fig. 5) looks pretty good. This is strange and needs discussion, for example in section 4.3. In this section I also miss a discussion on the robustness the model results for AONR

Response: Thank you for catching this: we discussed the limitations to the MI dataset, but didn’t explain the limitations in IN2. The following was added to the results section:

*The APSIM model simulated yield, drainage, flow-weighted NO3-N, and NO3-N leaching load well with ME values falling primarily between 0.7 and 0.95. In two studies, however, model accuracy evaluation metrics reflected modeling limitations caused by a lack of reported data: leaching and flow-weighted NO3-N data from MI [43] were reported as 3 year averages, resulting in an ME of 0.46 and yield data from IN2 [47] were reported as 6 year averages, resulting in a high RMSEYield (11.22 kg/ha) (Supplementary Figures 2-5; Supplementary Table 7).*

We also added to the captions of the supplementary figures specifying which studies reported annual data and which only reported averages.  
  
I have some minor comments and questions, which I will list below in the order in which they occur in the text:  
  
Line 167: add figure  or table reference where we can see these results.

Response: done  
  
Line 222-225: add figure  or table reference where we can see these results.

Response: done  
  
Figure 2: I know what a violin is, but do not know a violin plot. This requires some more help to readers like me: what is on the X axis? What are the bars within the violins? What are marginal estimated responses at the rotation level? And what are marginal estimated pivot points?

Response: We adjusted the caption to have more clarity:

*Figure 2: (a) Violin plot of the difference/buffer between the leaching breakpoint and the agronomically-optimum nitrogen rate (AONR) in continuous maize (Zea mays) and rotated maize (i.e. maize rotated with soybean in a 2-year cycle (Glycine max)). The thick dark horizontal line in the middle of the violin is the mean. The shape and finer lines show the distribution of the data. (b) Maize yield and (c) NO3-N leaching response to N fertilizer. Gray lines in (b) and (c) are the bilinear model predictions for each site-year, colored lines are statistical model predictions at the rotation level. Colored bars along the x-axis indicate the statistical model predicted breakpoints continuous (orange) and rotated (blue) maize for each site.*

Does the model predict yields 0-8 tonnes/yr for 0 N rates? That sounds like something to be very worried about.  
Response: We added in a sentence in section 4.3:

*The significant effect of site and year on the baseline leaching load is further evidence of the important role soil and weather have in determining the fate of residual N over multiple seasons. Residual N can be leached from the soil profile or taken up by the plant, resulting in high leaching loads and/or grain yields even in seasons when no N fertilizer is applied.*

Figure 3: what is rotated soybean and what is rotated maize. Nowhere in the text has this been explained, so I have no idea.  
Response: We added a note about what rotated soybean and rotated maize is into the text:

In section 2.1.3: *For the 2-year rotation, the model was run twice: one set of simulations with maize followed by soybean and the other with soybean followed by maize such that we could compare the outputs from rotated maize (maize in the 2-year maize-soybean rotation) with continuous maize each year.*

And in section 3.3: *Within the maize-soybean rotation, at N rates above the breakpoint, leaching loads during the soybean seasons (rotated soybean) were higher than those under maize (rotated maize), pointing to the residual effects of applying excessive amounts of N during the maize season (Figure 3).*  
  
Referee: 2  
  
COMMENTS TO THE AUTHOR(S)  
Fig. 2 has color code mixed up, in the text at least? 2a, 2b looks to have continuous maize in orange and rotated in blue, but description has reversed? And this color code is swapped in Figure 3.

Response: Thank you for catching this. We made the appropriate changes to the figures/caption.  
  
Regarding text lines 229-234 and their correlation with Fig. 2c. Using just a quick calculation, continuous maize at 100 kg/ha N (below the breakpoint) would leach 8 kg N, rotated maize at 100 kg/ha would leach 10 kg/ha. And in the text, it is stated that more No3-N was leached from rotated plots. Those text lines would match if blue was rotated (but your figure description states orange).

Response: You are correct that below the breakpoint, leaching is occurring at a higher rate from the rotation than from the continuous maize. We clarified/reorganized that paragraph to make sure that was clear to the reader. Thank you.

*The parameters defining the slope below and above the breakpoint as well as the breakpoint itself differed significantly with system. Site location and year, however, did not have a significant influence on these parameters. Below the breakpoint, continuous maize lost an estimated 0.08 kg NO3-N per kg N applied while the maize-soybean rotation lost 0.1 kg NO3-N. There was then a breakpoint at the fertilizer N rate 129 kg N/ha (SE: 0.6) for continuous maize and at 116 kg N/ha (SE: 1.9) for the maize-soybean rotation at which the rate of leaching changed. Above the breakpoint, continuous maize lost an estimated 0.6 kg NO3-N per kg N applied (95% CI: 0.54-0.63), but the maize-soybean rotation only lost 0.4 kg NO3-N per kg N applied (95% CI: 0.37-0.43).*  
  
Also, Fig 2c, Above the breakpoint, for example, at 200 kg N/ha, your text implies that continuous would be at 120 kg/ha leached, and rotated would be at 80 kg N/ha leached. At 300 kg N/ha applied, continuous maize would leach 180 kg N/ha, rotated 120 kg N/ha. Are you sure your trendlines are correct? At 200 and 300 kg/ha they show still almost the same amount of leaching, which doesn’t compute.  
Perhaps your model is extrapolating too much and should be more limited to the experimental values (fertilizer applied) used? And perhaps, limit Figure 2b and 2c X axes, too.

Response: We have made changes in the text that will clarify this for readers and (see comment above) make the figure easier to interpret. In your calculation, you assumed from what we said in the text that the rate of N leaching was the same below and above the breakpoint when in fact the rate of N leaching (slope) is actually different below and above the breakpoint. We hope that our additions clarify our findings and make it easier for our readers to interpret. While simulating up to 300kg N/ha is an extrapolation, APSIM has been found to be capable of accurately conducting such simulations and our statistical model was found to be robust.   
  
Could you possibly add a column with range of N fertilizer values used in the different states at least to Figure 1?

Response: Absolutely. We added in the range of the average N rate applied over 35 years (1984-2018) in each state.  
  
  
If the average AONR for continuous maize was 111 kg N/ha, and rotated at 70 kg N/ha (lines 211-212), how could a ‘leaching breakpoint’ of only 46 kg N/ha (line 239) be 66% above 70kg/ha? Similarly, how can 17 kg N/ha be 16 % above 111? Please clarify.

Response: We clarified our text:

In those lines: *There was a greater margin for error in rotated maize than in continuous maize around overestimating a given field’s AONR without drastically increasing the rate of NO3-N leaching. The margin for error was 46 kg N/ha (95% CI: 44-49 kg N/ha) in the maize-soybean rotation but only 17 kg N/ha (95% CI: 14-20 kg N/ha) in continuous maize (Figure 2a).*

And then added to our discussion section 4.1:

*Our findings were consistent with that of Zhou and Butterbach-Bahl’s [1] meta-analysis: the leaching breakpoint occurs at N rates that are at least 15% above AONR in maize (our breakpoint was at 66% above AONR in the maize-soybean rotation and 16% in continuous maize).*  
  
Figure 3 is really funky, as the Y axis really isn’t plotting the N rates, but, a distribution of observations? The N fertilizer rates should be placed on the figures similar to the a, b, c of Figure 2, not be on the Y axis. And these were hypothetical observations from your model, correct? Please state as such on the Figure legends (and other legends as appropriate).

Response: Yes, it is plotting the distribution, at the various N rates. We shared the figure with other researchers who initially also shared your concern and after our adjustments, they found that the stacked density plots are a more concise way of showing the information compared to panelized plots, as the panelized plots have an enormous amount of white space. We clarified the y axis labels and changed the figure caption to make sure readers understand these are data density distributions at various nitrogen fertilization levels. Colors were changed to be consistent with other figures.   
  
Line 295 states that ‘Our simulations found that soybeans experienced more drainage and leaching that maize (rotated or continuous) (Figure 3).’ To me, on Figure 3, the soybean plots have moderate (in-between) levels of leaching. More than rotated, but less leaching than continuous maize. Please clarify

Response: We clarified our text:

*Our simulations showed that within the 2-crop rotation, soybeans experienced more drainage and leaching than rotated maize (Figure 3).*  
  
Supplementary Table 3- could you please give us non-soil people a clue as to your table header acronyms? I can guess about half of them. But I shouldn’t be guessing.

Response: Yes. We added in a key to the caption:

Supplementary Table 3: Soil data summary for modeled sites. Abbreviations: BD is the bulk density, LL is the soil water lower limit (wilting point), DUL is the soil water upper limit (field capacity), SAT is the soil water holding capacity (saturated), KS is hydraulic conductivity, OM is organic matter, F-inert is the fraction of organic matter is stable/cannot be broken down, pH refers to the soil’s acidity/alkalinity level.