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Interactive comment on "The impact of atmospheric CO_2 and N management on simulated yields and tissue C : N in the main wheat regions of Western Europe" *by* S. Olin et al.

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Thanks for the comments and corrections. Comments are included in this document within "" followed by answers with updated texts.

"*While figure 2 does show the productivity results for different N treatments, the manuscript could be improved by more explicitly addressing whether the model is appropriately sensitive to N addition or whether it is too N limited or not N limited enough. What processes in the model control the sensitivity to N addition?*"

The sensitivity to N addition is a combination of several processes, most important

are the C:N of leaves and roots and their effect on the N-uptake, but also soil C–N dynamics plays an important role. In order to address the question, we added:
Modelled grain and above ground biomass C mass per kg N applied (19 and 46 kg C kg N^{-1}) were in line with the observed response of 22 and 42 kg C kg N^{-1}, which indicates appropriate sensitivity of yield and growth to nitrogen addition.

We also added the following:
N demand from leaves and roots depend on their current C : N status, as the plant seeks to reach optimal C : N in leaves and roots. The mineral N accessible for the plant, depends on soil temperature and fine root biomass: see Smith et al. 2014 and Zaehle et al. 2010 for details.

"*Other areas for improvement: The introduction leaves out any discussion about N20 emissions from croplands. N2O emissions are relevant to the goals of the manuscript because getting the N uptake correct is an important step to modeling the N that is available for N20 production.*"

The reviewer is of course correct, and while this aspect is not the focus of this current manuscript we revised the introduction as:
Still, only a few of today's DVMs account for crop processes and C–N coupling in crops (e.g. Arora, 2003; Drewniak et al., 2013), which is a prerequisite to accounting for fertiliser input, the associated effects it has on yields and the C cycle. These improvements will also facilitate global-scale modelling of N_2O emissions from agricultural soils, since accounting for N uptake through plants is important to constrain soil nitrogen available for N_2O production. While not the focus of this manuscript, the ultimate goal will be to assess how ecosystem fluxes affecting atmospheric composition and climate vary with changing environmental and socioeconomic conditions.

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"*More description about how the model handles the labile C pool would be helpful. Is there a max size of the labile C pool? What happens when the labile C pool become unrealistically large? Similarly, is there a labile N pool or is N allocation directly linked to N uptake from the soil?*"

We tested the ability of the model to simulate C allocation using data from Groot et al. (1991) (not shown). The ability to simulate the allocation to all organs improved significantly when adding the labile carbon pool as suggested by de Vries 1989. In order to clarify this a bit further, we have added the following statement to the model description:
Regarding carbon, the maximum C-mass in the labile C-pool is 40% of the stem C-pool (line 10 page 1058 of the old manuscript). We revised this as:
To represent this in the model, a labile C pool is filled with a fraction of the C allocated to the stem, set here to 0.4 for wheat (Penning de Vries 1989), and thus has a cap of the allocation to stem (g_{St}) times 0.4.

On line 4-6 on page 1062 of the old manuscript, the transport of N to the labile N-pool is described. We added here:
In contrast to the labile C pool, there is no explicit cap on this pool, but the amount is constrained since leaves and roots act as labile N sources.

"*Equation 11: Why is the nitrogen availability a function of projected leaf coverage by the plant?*"
Reflecting the historical development of many DVMs, in LPJ-GUESS, there is some difference in level of detail between above ground and below ground. The fine root fraction is assumed to be proportional to the leaf, analogue to how the relationships for activities and masses of C and N are treated. M_N,avail We have updated the text related to eq. 11:

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where φ is the fraction of projected leaf coverage by the plant (proportional to the fine root area, similar to the functional balance concept Eq. 10), $M_{\mathrm{N,soil}}$ is the mineral N mass of the soil and θ is the mean water content of the soil profile.

"*Please provide a more thorough description of LAIn on page 1059 line 15. How does it differ from LAI?*"
We have added a description on where LAI_N stems from and also its purpose, as it is a bit disconnected to Eq. 13 where it is used:
From theory on optimal N distribution in a crop canopy, Yin et al. 2000 derived a relationship between the LAI that can be supported given the amont of N that is currently in the leaves ($\mathrm{LAI_N}$) and $\mathrm{k_N}$:

$$LAI_N = \frac{1}{\mathrm{k_N}} \ln(1 + \mathrm{k_N} \frac{M_{\mathrm{N,L}}}{\mathrm{N_b}}) \tag{8}$$

where $M_{N,L}$ is the leaf N mass and $\mathrm{N_b}$ (Eq. 9) is the minimum N requirements for the leaf to function.

$$\mathrm{N_b} = \frac{1}{\mathrm{C\!:\!N_{L,max}SLA}} \tag{9}$$

where $\mathrm{C{:}N_{L,max}}$ reflects the minimum N required for photosynthesis and SLA is the specific leaf area ($\mathrm{m^2\ kgC^{-1}}$). $\mathrm{LAI_N}$ is then compared to LAI to determine the N status of the canopy, see Sect. 2.1.3.

"*It seems that the authors did not have data at the FACE site on the total magnitude of N addition, timing of individual N additions, and magnitude of individual N additions. To overcome this lack of data, they simulated an ensemble of magnitudes and timings and used the combination that produced yields that best fit the observations. One limitation to this approach is that it assumes that the rest of the model structure and parameters are correct. To address this assumption, it would be helpful to show the sensitivity to*

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N addition from the ensemble of magnitudes and timing. Is the range large, therefore fitting the model to the yield data is critical, or is the range small, therefore choosing the magnitude and timing of N addition is not absolutely critical? The authors could also be clearer about whether the total magnitude of N addition over the growing season is known but just the timing and magnitude of individual additions are unknown"

Regarding the FACE simulations, the description in the original manuscript was a bit vague, we have modified to read as follows:
Due to the lack of information on the timing and amount of the individual fertiliser applications, these parameters were set using the results from the regional comparison (Sec. 3.3), total amount of N added in the experiments are listed in Table 3.

The reviewer also raises an important issue about the sensitivity to timing and application rates of N fertilisers. Although fertiliser application rate is the most important thing to consider, timing has also a pronounced effect. This can be seen when comparing the different experiments in terms of the mean yield (averaged over all grid cells and permutations within one simulation setup) and the range of grid cell means across all permutations within one experiment setup. We have added the following to the revised version of the manuscript:
The grid cell average yield over the region and all permutations in the $F_{opt(T,A)}$ simulations was 5.2 ton. ha^{-1} y^{-1}, ranging from 2.4 to 10.3 ton. ha^{-1} y^{-1} between the different application rates and timing. For $F_{opt(T,a)}$ the same measures were 5.5 ton. ha^{-1} y^{-1} (3.1–8.7 ton. ha^{-1} y^{-1}) and for $F_{opt(t,A)}$, 5.2 ton. ha^{-1} y^{-1} (3.2–8.6 ton. ha^{-1} y^{-1}). The average yields for all simulations were of the same order of magnitude. For $F_{opt(t,A)}$ and $F_{opt(T,a)}$ the ranges in yield were also of similar size whereas the range for the $F_{opt(T,A)}$ was larger although smaller than the sum of the ranges of $F_{opt(t,A)}$ and $F_{opt(T,a)}$. Most importantly, both the optimisations with either fixed timing or application rate, resulted in a better agreement with the reported yields compared to a mean

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uniform N management over the region (Ft,a, Table 5), but optimising the application rates gave a considerably better fit than optimising the timing. While timing had a large effect, these results imply that highest priority is to obtain data on application rates.

We also revised the conclusion as to:
These findings support the aim of this study, to find a level of complexity in the implementation of the N management that can be applied on larger regions. Such implementations are crucial e.g. for studying the effects of climate and global environmental changes on simulated yield at regional to global spatial scale. Regional differences in timing as well as total application rates are required to fully capture cropland dynamics in simulations of global C and N cycles. However, since this level of detail is rarely available in future projections of fertiliser use, our results demonstrate that as long as estimates of total N applications are available for a given region, adopting a mean fertiliser timing that is based on the development stage is sufficient for representing the mean and variance of regional yields.

"*How does this study show the crop model is applicable under climate change? The response to climate is not described or evaluated.*"

The reviewer is correct in that we have not here included experiments addressing climate change impacts. The main reason was to keep focus of the manuscript on model description and evaluation (and hence focus on near-historical and present-day data and simulations), see answer to previous question.

"*Table 1 – the three columns under N app need more explanation. Are there three different treatments applied to three different plots or three different times within the year?*"

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The caption of the table was revised as:
Site and treatment specific data after Groot et al. 1991. For all trials (I–VI), three experiments with different applications of N fertiliser were performed (1,2 and 3). Their timing is expressed here by the development stage (DS).

"*Table A.3. The column NUTS2 needs to be defined so that a reader just looking at the table can understand.*"

NUTS2 is now spelled out in the revised table caption:
Nitrogen fertiliser applications and timing for each NUTS2 (Nomenclature of Territorial Units for Statistics in the EU; statistical administrative areas) region used in the regional simulations resulting from optimising modelled yields against observations ($F_{opt(T,A)}$), see Sect. 3.3, together with the statistics (the 2 last columns). Number of years with reported yields for each region (n. y), fraction of the wheat area covered by winter variety (Ar.), fraction with spring variety: 1 – Ar., reported yields and AgGrid N input data for each region.

Interactive comment on Biogeosciences Discuss., 12, 1047, 2015.