Reply to comment by Van de Ven et al. on our paper "Crop yield gap and stability in conventional and organic systems"

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Reply to comment by Van de Ven et al. on our paper "*Crop yield gap and stability in conventional and organic systems*"

We have read thecomment on Schrama et al. (2018) "*Crop yield gap and stability in conventional and organic systems*" by Van de Ven et al. (2018) with interest. In our paper, we compared three farming systems, one based on organic farming (ORGBIO), one conventional farming system based on mineral fertilizer (CONMIN), and one conventional farming system based on fertilization by slurry (CONSLU). We showed that in 2013, thirteen years after the start of the experiment, the organic farming system had lower spatial variation in pH, nitrogen mineralization and availability and abundance of soil biota, and lower nitrate concentration in groundwater than both conventional farming systems. Moreover, between 2001 and 2013, there was an increase in the yield index, calculated over all crops, in ORGBIO, but not in both conventional farming systems, so that in that period ORGBIO converged towards both conventional farming systems. Also, we showed that there was a decrease in nitrate concentrations in groundwater under ORGBIO, but not in CONMIN and CONSLU. An important conclusion of our study was that '*Analysis of spatial and temporal stability reveals that differences in the performance of farming systems may not always become expressed in the means, but that differences may show much stronger in the spatial and temporal variability of the systems.*' Key points in the comment by Van de Ven et al. (2018) are that the ORGBIO treatment was not randomized in space with the two conventional systems and that the convergence does not show for the individual crops.

The reason that ORGBIO was not randomized with the two conventional systems was that 'organic' is a protected term (https://www.skal.nl/home-en-gb/about-skal/). In order to fulfil the legal requirements for being named 'organic', the ORGBIO farming system was not allowed to be fully randomized with the two conventional farming systems. Indeed, we were also critical about comparing the three farming systems as one experiment. However, this is a phenomenon that characterizes quite a number of long-term field studies (e.g. Goulding et al., 2000; De Ruiter et al., 1994, 1995; House and Parmelee, 1985), which nevertheless have yielded key insights. In order to test whether the non-randomized treatments can be compared, we carried out a number of checks. First, we analyzed results of a previous randomized experiment at the same research site (1993–2000) and found that there was no significant block effect in yield and nitrate concentration in groundwater, as outlined by Schrama et al. (2018). In addition, we have also checked available soil fertility parameters and groundwater level data from 1993 to 2000 (Fig. 1). K-values, pH-KCl and available mineral nitrogen in November, before the start of the leaching season, were not different between blocks. Phosphate in all farming treatments were different between farming systems but were all at levels rated as "more than enough" for crop production (see fertilization advice in www.handboekbodemenbemesting.nl).

Also the groundwater levels in the period 1993–2000 did not give rise to an a priori concern that ORGBIO (located in Block 3) started with different groundwater conditions than both conventional systems (located in Blocks 1&2). Groundwater level measurements from the end of 2015 and onwards, at which Van de Ven et al. (2018) point, indicate a difference between ORGBIO and the other two systems. They are probably caused by changes in the drainage system in ORGBIO in 2004. These changes most likely had an effect on the groundwater level only in ORGBIO, because block 3, in which ORGBIO is situated, is hydrologically separated from the Blocks 1&2. However, already before that change in the drainage system, directly after the start of the current experiment, the nitrate concentration in groundwater in ORGBIO started to decline compared to the period 1993–2000 (see Fig. 1D in Schrama et al., 2018), thus indicating that the change in the drainage system may not explain the decrease in nitrate leaching in ORGBIO. Besides, the expected effect of the difference in groundwater level on nitrate concentrations in groundwater is smaller than the difference measured between ORGBIO and the conventional systems (Fraters et al., 2012).

The 0.5 percent point difference in organic matter between ORGBIO and the two conventional farming systems that Van de Ven et al. (2018) point at has existed throughout the entire period of 1993–2000 prior to the experiment described in Schrama et al., 2018 (Fig. 1), whereas in that period there was no block effect in yield, as we have demonstrated (Schrama et al., 2018). Therefore, although we agree with Van de Ven et al. that the soil organic matter was 0.5 per cent higher in ORGBIO and that the ground water level in ORGBIO in 2015 will have been higher, our point remains that the difference in soil organic matter cannot have accounted for the temporal trend in relative yield or nitrate leaching in ORGBIO. Besides, in 2013 the difference in organic matter content has increased to 0.7% compared to CONSLU and 1.4% compared to CONMIN.

Indeed, as van de Ven et al. (2018) point out, the farming systems initially consisted of different crop rotations. In Schrama et al. (2018) the full complexity of the experiment has been outlined: "*To avoid bias, we only included those crops that were present in all three cropping systems. Not all crops were present in all years and varieties of maize differed between organic and conventional systems in the early years of the experiment*" (see Table S1 in Schrama et al., 2018). Van de Ven et al. (2018) statistically analyzed a relative yield of the individual crops and found no statistically significant convergence and found a significant divergence of one crop (barley). However, in our study we were interested in analyzing the farming systems as a whole and not in the individual crops. Moreover, we felt that analyzing the crops individually would cause a typical Type II error due to low statistical power, as individual crops could not be analyzed in all years. Therefore, in order to compare the farming systems over all 13 years, we have performed an aggregate analysis using a yield index that enables integration of the farming systems over the entire time period. When considering the fresh yield data, in 4 out of 6 crops there is a converging trend, whereas in one crop (leek) trends in yields are parallel and only in one crop (barley) yields

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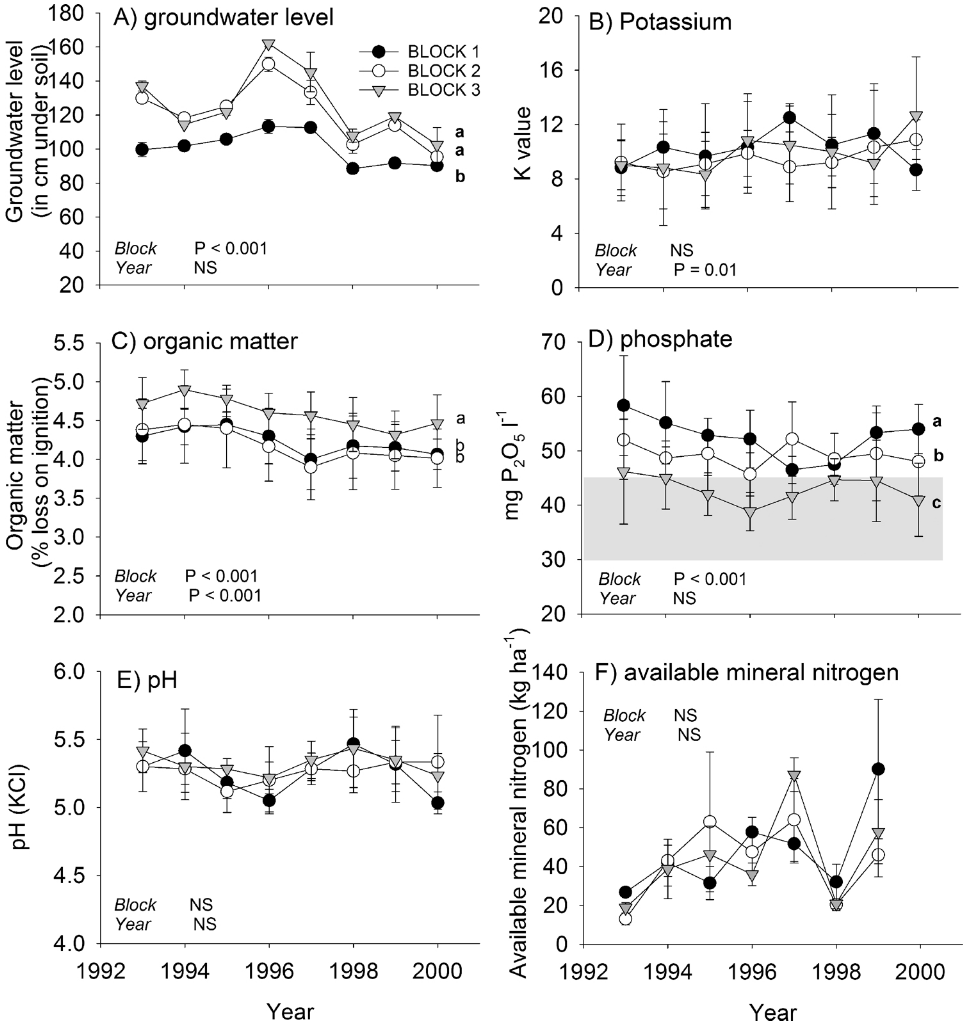

Fig. 1. Analysis of block effects prior to establishment of experiment: average groundwater (A) K-values (B), organic matter (C), P-water (D), pH (E) and available nitrogen at the start of the leaching season, in November, 0–90 cm deep (F). Grey shaded area in D indicates a phosphate fertilization that is considered "more than enough" (www.handboekbodemenbemesting.nl). Mind that not all parameters were measured every year. To assess effects of year and block, a mixed model with year (as a continuous variable) and block (as a categorical variable) was used. Test results are shown in each of the 6 panels. Different letters indicate significant differences between blocks as calculated with a post-hoc Tukey test. Both conventional systems (CONSLU & CONMIN) were located in Block 1 & 2, ORGBIO was located in Block 3. See Fig S2 in Schrama et al. (2018) for an outline of the setup of the Vredepeel experiment.

visibly diverge (Fig. 2; note that in this Figure the data 2014–2017 ha s also been included but trends were calculated based on data from the period 2001–2013). Therefore, the conclusion of Van de Ven et al. (2018) that the individual crops do not show significant convergence does not discard our conclusion that the ORGBIO farming system as a whole converged towards both conventional systems. Considering all crops in one relative yield index as done by Schrama et al. (2018) apparently resulted in a more powerful test.

Finally, we see some problems regarding Van de Ven et al's. (2018) analysis of the data from 2011 to 2016 with respect to our study. First, this period neglects the first ten years of the experiment, which we think is a crucial period for soil conversion from conventional to organic, as the soil biological system may need to change from mainly mineral to merely organic fertilizer inputs. A similar phenomenon with comparable time scales has been shown for conversion from high input-output agricultural use to semi-natural management (Morriën et al., 2017). Second, we feel that it is inappropriate to compare the farming systems in the period before and after 2013 without acknowledging that the experimental conditions have changed in 2013. Until 2013, the farming systems comparison has been carried out a as 'double blind' experiment: neither the practitioners nor the scientists were aware of the outcome of the comparison. After our analysis and presentation of the results in 2013, this situation changed, as the practitioners became aware of the results. Therefore, we think that it is more appropriate to present the results as in Fig. 3.

There are of course several other possible explanations for the relatively poor performance of ORGBIO in 2014 and 2016. In 2014, in early July there was an extreme rainfall event (126 mm in 3 days), whereas in June 2016 there were several extreme showers, adding up to the excessive amount of 240 mm rain fall in one month (https://www.knmi.nl/kennis-en-datacentrum/achtergrond/zware-onweersbuien-op-22-en-23-juni-vol-extremen). These extreme weather events have led to severe pathogen (including *Phytophthora*) outbreaks, and it is known from other years (2003, 2007, 2011, 2012) that in those years ORGBIO, where no biocides are applied, is underperforming compared to the conventional farming systems. In order to understand these differences, and also whether or not loss of spatial soil stability was due to this phenomenon, would have required further and detailed analyses of the performance of the soils over this period, which are currently not available.

In conclusion, we do not agree that Van de Ven et al. (2018) that the difference in soil organic matter between ORGBIO and both conventional farming systems will have strongly influenced our conclusions on temporal patterns in relative yield and in nitrate concentrations in the groundwater. The nitrate concentrations in groundwater dropped already before the groundwater level may have increased, as that drop already occurred before the drainage system was changed. Moreover, we think that their consideration of the individual crops will have invoked a Type II error (not finding a difference due to low statistical power) and that their consideration of 2011–2016 will have missed out

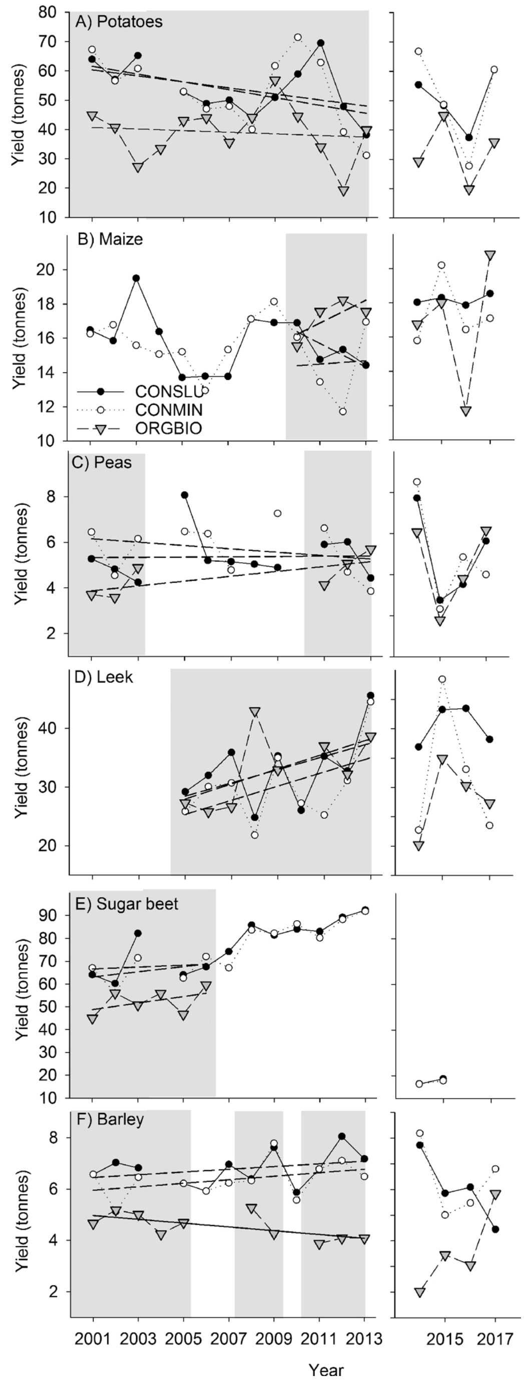

Fig. 2. Converging and diverging effects of the various crops on the yield index used in (Schrama et al., 2018). Maize has a converging effect on the original yield index because the yields for ORGBIO increase more those than for in the both conventional systems. Grey areas show the time periods that were included in the original yield index based on 2001–2013 (Schrama et al., 2018). In the graphs, the most recent data (2014–2017) have been included (see text for explanation of change in experimental conditions since 2013). Only points within the grey-colored time periods were included to calculate trend lines.

on the first ten years of the experiment, where important changes in spatial stability of soil properties appear to have taken place. Nevertheless, we do agree with Van de Ven et al. (2018) that there remains an on average difference between the conventional and organic farming systems. Nevertheless, these differences can be minimal, or even non-existent, in a number of years (2008, 2013, 2017), which may inspire to search for best practices and underlying mechanisms. Therefore, we agree that there is a need for more rigorous and long-term experimental comparison of farming systems. As also pointed out by Schrama et al. (2018), we think that such rigorous comparisons should include replicate farms and different soil types in order to find out how environmental sustainability and nature inclusiveness of high-productive agriculture may be enhanced.

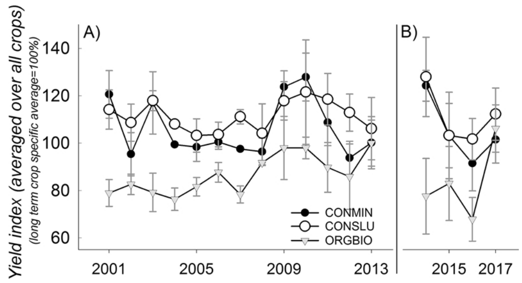

Fig. 3. Yield index between 2001 and 2013 (A), similar to Fig. 1C in Schrama et al., 2018. Until 2013, the experiment has been carried out as a 'double blind' experiment (see text). After 2014 onwards the farming systems comparison entered the second phase (B). For further explanation, see text.

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