

Response to Ref 1

General comments

We note that the referee appreciates our openness in discussing the shortcomings of the model and feels that this is appropriate for a Discussion paper.

Point 9. Does the abstract provide a concise and complete summary? The abstract is concise but I don't think it fully summarizes the paper. Having read the paper, more than once, I do not think it can be said to be 'broadly capable of simulating the timing.....', since there are some very large differences between modelled and actual results. A difference of two and a half months in the mean estimate of the sowing date of spring barley, which may have a growing season of six months is a very large error. An error of almost 1.5 months in the date of the first fertilisation of winter barley is also a significant error, given that top dressing of nitrogen fertilizer for this crop would not often exceed 2 months. It would be more consistent with the findings of the paper to write something like 'while for some crops a reasonable agreement was obtained in the prediction of the times of field operations there were some very large differences which need to be corrected'.

Response: We have revised the Abstract according to the referee's suggestion.

Detailed comments

Page 10586, lines 4-7. Is this a very good example? Surely little fertilizer nitrogen is now applied before sowing. A better example would be the application of N fertilizer to silage ground in early spring.

Response: As we state in the Introduction to the paper '*these data are often not available for the past or present in Europe*', so we do not know how representative this operation is for European crops. Local experts from the case study areas confirm that fertiliser N is certainly applied prior to or at the time of sowing in some countries. For urea, application and then incorporation would be considered good agricultural practice, since it would reduce ammonia emissions. We therefore know that it is reasonable for some countries. Using the application of N fertilizer to a silage crop would not be appropriate; silage is predominately made from grass (which we do not consider here) or maize (which is a C4 crop and therefore not particularly representative of European crops).

Page 10586, lines 9-13. These are sensitive to short-term weather conditions to some extent but isn't long-term weather more important when assessing annual emissions? With respect to nitrate leaching the prime meteorological consideration is hydrologically-effective rainfall (HER) over winter. Apart from perhaps once in a century events HER is a cumulative response to rainfall over the winter months which is a long-term weather impact.

Response: The focus of this paper is mainly but not exclusively on how to obtain driving variables for model studies related to climate change. The main elements of greenhouse gas budgets for arable crops are the direct emissions of N₂O, the indirect emissions of NH₃ and NO₃ and changes in C sequestration in the soil. While NO₃ leaching and C sequestration respond to medium to long term variations in climate and management, N₂O and NH₃ emission respond to much shorter term variations.

Page 10586, line 28. The mid 1990's are relatively recent but the cereal varieties grown then will now have been largely replaced and there has been a trend toward earlier harvesting so can the author's be confident data from that era are still representative. Plus sowing date is somewhat opportunistic, being related to rainfall and soil conditions rather than temperature (page 10587, line 1). Were there any unusual autumn weather patterns in those years that might make the results untypical?

Response: We recognize that there has been a shift in the varieties sown. This was included indirectly in the paper on page 10599, where we write '*In addition, the data do not reflect the effect of climate change and crop breeding on the movement of the northern boundary for the cultivation of certain crops, such as maize.*'. We have modified this statement to read '*In addition, the data do not reflect the introduction of new crop varieties or the effect of climate change and crop breeding on the movement of the northern boundary for the cultivation of certain crops, such as maize.*'

Regarding the presence of unusual short term weather patterns - in Denmark, precipitation in October 2007 was the second lowest for the previous 20 years. However, for most crops, the sowing would have occurred before this time. In the two other case study areas, the weather was not exceptional. We do not consider that the weather in during the period for which we have records of the timing of field operations was exceptional but acknowledge that a more geographically comprehensive, multi-year comparison is necessary

Page 10589, lines 1-3. I consider this to be a major weakness since neither sowing nor harvest are particularly associated with temperature, although there may be a broad correlation. For example, sowing of cereals. There is a very good correlation between sowing date and yield, as sowing is delayed in the autumn yield tends to decrease. Hence farmers will drill as soon as they can depending on the cereal type and rotational position. They will not be delayed by unusually warm or cool weather, but they may be delayed by rain. I appreciate it would be very difficult to include rainfall in the model, given its unpredictability in the maritime regions and near impossibility of forecasting medium term deviations from the long term mean. However, I do think the authors must acknowledge that their assumption is weak, albeit it may be the only one that can be reasonably made. I appreciate the text goes on to acknowledge 'these were gross simplifications', but perhaps that caveat could be placed earlier in the paragraph (e.g. middle of line 3).

Response: On page 10596, we acknowledge that '*it is likely that other factors play an important role in determining the date of sowing e.g. soil moisture constraints on trafficability and workability or competition for labour and machinery*'. On the same page we

state ‘The model might therefore be improved by taking into account the effect of soil moisture conditions on workability and trafficability.’ We then add ‘*However, this would require the addition of a soil water model, which is non-trivial and would demand an increased numbers of input variables and parameters. These are important considerations if the model is to be used for large areas.*’ We therefore feel we have dealt with this matter in the paper.

Page 10589, line 14. Minor point perhaps, but line 28 dated the observations to the mid 1990’s.

Response: This is an error (‘early’ should be ‘mid’). However, we also notice that very similar information is provided in the Introduction. We have therefore shortened the Introduction and corrected the error identified by the referee.

Page 10589, lines 17-18. And for cereals at least major changes in the varieties grown. New crop varieties are extensively field trialled before becoming commercially available and so any tendencies toward earlier maturing, which can have an influence on the sowing date of subsequent crops as well as on harvest date, should be available.

Response: We are not sure what the referee is suggesting here. It is likely that commercial breeding companies have these data. Is the referee suggesting that these companies would permit researchers to have access to these data?

Page 10591, lines 22-23. Is there a reference for this? It seems an unrealistically short interval given that many European soils have a significant clay content and will need further cultivations before a seedbed has been created.

Response: It is correct that three days would be a short time for working a clay soil into a seedbed. We suspect that in practice, the heavier clay soils will tend to be treated similar to those we followed in Poland i.e. ploughing in preparation for spring cropping would occur in the autumn, with seedbed preparation in the spring. This means that rather than make minor adjustments to the timing of the spring ploughing for clay soils, we should implement a water model to allow trafficability and workability to be considered.

Page 10591, line 28 - Page 10592, line 2. Again a reference for this would be useful. I think it is an unrealistically small gap which might be good practice but not common practice. If no reference can be provided for this assumption and the one above then the uncertainties of both should be recorded.

Response: We have added the following sentence ‘*As a consequence, such practices are either mandatory for land within areas identified as being vulnerable to nitrate leaching under the EU Nitrates Directive (EEC, 1991) or advisable for all arable land (Chambers et al, 2001; Webb et al, 2013).*’. We are aware that we have no data to prove that farmers follow the law or the advice and suspect that quite a few farmers still choose to apply manure when it is convenient (e.g. in mid winter, on frozen soil) rather than when it will result in an effective use of the manure nutrients. We consider this is an appropriate approach, in the absence of good statistical data.

Page 10592, lines 10-11. In the arable regions of w Europe at least this assumption is wrong. It is not standard practice to apply 80% of the recommendation, which can be around 160 kg/ha, in one dressing, which is a large amount to apply in one go. Good practice is to apply about half the main dressing at early stem extension. The remainder is then applied once the first round of application has been completed. This reduces the risk, if the weather turns wet and halts spreading, of a delay in N application to some of the crop area.

Also the assumption of the application taking place after 20% of the growing season has elapsed could be improved upon. For combinable crops the main N applications are made at the time of specific crop growth stages. For cereals the first dressing would be at tillering (GS 21-25) the main dressing at the stem erect stage. Cereal growth stages can be related to accumulated temperature, there will be papers in the literature, and this is the approach that should have been used. This needs to be acknowledged in the text.

Response: This may be true and suggests we need better advice in the future concerning some fertilisation practices. We are not aware of any statistics concerning the timing of fertiliser or Europe-wide guidance and the referee comment was not accompanied by a reference to such. If we assume that statistics are not likely to be available any time soon, one option for the future would be to initiate a Europe-wide survey of national guidance.

Regarding the cereal growth stages, we have added the following to the end of the first paragraph of the section Scope for Improvement '*and the timing of the second application to cereal crops could be improved by relating it to predictions of the appropriate cereal growth stage*'.

Page 10594, line 26. Mean differences between mean recorded and predicted dates are given in Table 2. Looking at Table 2, spring barley, given my comment above about ploughing often taking place well in advance of sowing I'm not surprised at the large difference. However, since the predicted date tends to be close to the sowing date I would have expected it to be later in the year and hence a positive number.

Response: Correct - there were two errors in Table 2 and one in Table 3, all relating to the timing of ploughing. These have been corrected. The errors do not affect the interpretation of the results.

Page 10599, line 6. Given the text in line 2 of the previous page I think the authors meant to write that 'the chances of such inconsistencies arising would decrease...'

Response: The original statement is correct. However, it does not add to the information given in the preceding sentences, so we have removed it.

Page 10594, line 4. It looks odd to give names of the locations in Denmark and France but only the grid reference for Poland.

Response: This is a typographic error; the location name for Poland was added to that of the French case study area. This has been corrected.