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## ***Interactive comment on* “The significance of nitrous oxide emission from biofuel crops on arable land: a Swedish perspective” by Å. Kasimir Klemedtsson and K. A. Smith**

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Received and published: 27 September 2011

The authors' responses to Anonymous Referee #2

Referee #2: The paper addresses the importance of nitrous oxide emissions from cereal production in Sweden for the fossil fuel GHG reduction from substituting fossil fuels with bioethanol produced from cereal grains produced in Southern Sweden. The paper makes the point that nitrous oxide emissions from the production process largely determine whether the substitution can meet the requirements of the EU RE Directive. The paper also addresses the uncertainties associated with the N<sub>2</sub>O emission estimates and how this will affect results. The paper is well written and clear in its argumenta-

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tion, and the paper also addresses an important and pertinent issue. The study uses measurement data from published studies in Europe and data from measurements at two sites in Sweden. However, the details on the methodology used for the measurements in Sweden are not given in the paper. Also there should be a description on how the measurements (presumably chamber measurements) were upscaled to obtain an annual estimate.

**Authors' response:** We are glad the referee found the paper well written and with a clear argumentation. But we accept the need for more details on measurement methodology and how annual estimates were obtained, and will include them in the revised version.

**Referee #2:** The text on “Estimation by use of process-based models” in the materials and methods should be removed, since these modelling procedures are not applied in the paper. Instead some of this text may go into the discussion for a qualitative assessment of other modelling procedures. However, I do not believe that the conclusion “Process based models can be a help in achieving this objective in the future” can be made. No proper assessment of whether process-based models would actually help has been made, and therefore such a conclusion is unwarranted. In many cases development and testing of process-based models are hampered by the availability of high-quality datasets against which to do this, so I would suggest also to consider this aspect in the discussion.

**Authors' response:** We accept these comments. We plan to remove much of the model descriptions from the paper. Other parts of the Methods section will be moved to the Discussion, and the issue of availability of high-quality datasets will be discussed.

**Referee #2:** Figures 3 and 4 should be omitted since these details of seasonal variation in emissions are not essential for the discussion and conclusions made. In fact none of these detailed results are used in the discussion.

**Authors' response:** The results and discussion section begins with a description of the data presented in Figures 3 and 4, and what irregularities in emissions were found.

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In contrast to this suggestion, to delete Figures 3 and 4, Referee #1 instead found it important to stress the importance of emissions due to thawing conditions which are common in northern systems. Thus we would prefer to retain the figures, and complement them with supplementary data on frequency of data collection and duration of measurement, and also whether winter or thawing emissions were recognized. We think the arguments are reinforced by showing the figures instead of only describing the data; a picture is often better than many words.

Referee #2: The paper only very briefly touched upon the issue of attribution, i.e. how much of the nitrous oxide emissions (direct and indirect) can be attributed to growing the cereal crop for biofuel production. The paper simply assumes that all of the emissions can be attributed to the biofuel production. However, even native ecosystems (e.g., forests or permanent non-fertilised grasslands) would have N<sub>2</sub>O emissions, and I suggest that the authors at least give a range for such emissions in Sweden.

Authors' response: We conclude that the emissions are an integral part of agriculture and cannot be subtracted or attributed to a background emission. We propose to add in section 4.5 data on emissions measured in forest ecosystems in Sweden which show low values, close to zero, justifying the argument that all emissions from the cropping of wheat for ethanol should be attributed to the crop.

Referee #2: There is another issue, which is not mentioned in the paper, i.e. that bioethanol production from cereal grain in modern biorefineries will result in a residual protein product that can be used for feeding livestock, and which will substitute protein feed production. This will thus reduce nitrous oxide emissions elsewhere, which is an aspect typically included in LCA. This aspect should be considered.

Authors' response: Yes, this aspect is typically included in LCA analysis, but it should not be taken for granted that a reduction in GHG-emissions results. A reduction will occur if some of the energy use in the refinery causing CO<sub>2</sub> emissions is allocated to the spent grains, and not all to the biofuel. And also the reduced production of protein

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feed crops will result in lower overall N<sub>2</sub>O emissions. But, as we have discussed, more nitrogen into the system will inevitably result in higher N<sub>2</sub>O emissions, not lower. Including the livestock sector can also be regarded as an indirect emission, which may result in even higher total emissions. Nonetheless, we propose to include a more thorough discussion of the contribution of distillers grain (as animal feed) to the overall GHG balance, in section 4.5.

Referee #2: Based on these considerations I recommend that the paper is accepted after major revision.

Authors' response: We are making a major revision, as indicated above and in our response to Referee 1, and hope the revised manuscript will be accepted.

Specific comments and answers:

Page 6744, line 5 Change "strong" to "potent". A: Accepted

Page 6744, line 14 Change "procedure" to "approach". A: Accepted

Page 6745, line 2 Change "rules" to "standards". A: Accepted

Page 6746, line 4 Change "know" to "assess". A: Accepted

Page 6746, line 6 Change "from" to "from arable". A: Accepted

Page 6746, line 13 Change "regions" to "regions in Sweden". A: Accepted

Page 6749, line 6 It is not clear what the values 117 and 128 refer to. A: This will be clarified

Page 6750, line 21 Change "soils" to "soils may". A: Accepted

Page 6751, lines 18-20 Is this soil DRY weight? A: There was some uncertainty about this in the paper by Freibauer Kaltschmitt but we used dry weight in our calculations, and we will make this clear in the text.

Page 6753, line 14 Change "newly" to "emitted from newly". A: Accepted

Page 6753, lines 18-20 I do not understand this sentence, and would suggest to remove it. Also I suggest to remove figures 3 and 4 and replace them with a short description in the text. A: This paragraph is being rewritten. Our choice is to keep the figures, as explained above.

Page 6754, line 18 Change “emissions” to “variation in emissions”. A: Accepted

Page 6754, line 20 Change “tons” to “several tons”. A: Accepted

Page 6755, line 19 Change “was predicted” to “were predicted”. A: Accepted

Page 6757, line 3 Change “harvest size” to “crop productivity”. A: Accepted

Page 6757, line 26 Change “needs agricultural production” to “means that agricultural production needs”. A: Accepted

Page 6758, line 22 Davidson (2009) is missing in the references. A: Accepted

Page 6759, line 26 Change “an increased” to “a higher”. A: Accepted

Page 6759, line 28 Change “this” to “these”. A: Accepted

Page 6760, line 6 Change “soil type” to “soil type that”. A: Accepted

Page 6761, lines 3-7 This text on process-based models is pure speculation and wishful thinking. It should be removed or rewritten with references to document these claims. A: We plan to delete much of this text, retaining a short comment on using models in section 4.3 and 5. We agree that process-models need field data, but we wish to keep a sentence to the effect that if data are combined with models it can be a help in evaluations.

Table 1 The heading should state that this is for spring wheat. A: The heading of Table 1 will be rewritten to make this clear.

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Interactive comment on Biogeosciences Discuss., 8, 6743, 2011.

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