Interactive comment on “Forests on drained agricultural peatland are potentially large sources of greenhouse gases – insights from a full rotation period simulation” by H. He et al.

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This study addresses a very interesting and important question: how do the carbon and greenhouse gas balances of a drained forested peatland change in the long run, during the whole tree stand rotation. Such long time series of GHG data are not available, which means that modeling is the only relevant method to solve the question. Thus, COUP-model was used to simulate the forest and soil development on a fertile, afforested peatland in southern Sweden. COUP-model is one of the few models that can, to my knowledge, handle organic soil processes, in which the water table dynamics, and the resultant changes in soil chemical and physical conditions, are the key-issues. In the model, soil is divided to layers, the characteristics of which can then be simulated following changes in weather, C input etc. Thus it would seem suitable for the job.

- *The CoupModel has a strong basis in soil physics and the model also use well-known equations. Therefore it is generally applicable for all soil types (Jansson, 2012), including organic soil. Besides, in He et al., (2016), CoupModel was calibrated to described the water, heat, C and N cycling of Skogaryd (the same site as this study). The calibrated model successfully reproduced the measured data during 2007 to 2009. Here our aim was to upscale the calibrated model (He et al., 2016) to simulate the long term dynamics of drained peatlands, mostly GHG fluxes. However, this revealed problems and challenges which are discussed in the paper and also commented by you below.*

The model in these simulations, however, seems to have some very serious shortages. According to the manuscript, it cannot simulate changes in the water table, nor changes in the soil physical characteristics. This seems odd, and since water table is an important feature controlling e.g. organic matter decomposition, it is a big lack. Even in their own tests GWL was very important (Table 1), and water table seems to have changed quite a lot during the simulation period (Fig. 5f). A question rises, how is the water level simulated in Fig. 4, if the model cannot simulate water level? And still, water table level was set to constant 50 cm, but no grounds for the 50 cm were given. Maybe it produced results closest to the observed ones?

- *I think the misunderstanding is due to that we do not describe it clearly. It is easy to mix drainage depth and GWL. The drainage depth is a parameter used for estimation of horizontal flow of water out of the site due to drainage. This parameter was set by calibration, described in He et al. 2016. Thus the model of course can simulate the variable GWL, which fluctuates over time. By comparing the simulated GWL with the measured data during 2006 to 2011,* *the model simulates the GWL well, with coefficient of determination R^2 of 0.78 and mean error close to zero (Figure 4c). Thus it is not the GWL that is set to 50 cm, rather the drainage depth that is set to 50 cm (The GWL is simulated in daily scale, see Figure 4c & 5f). The drainage depth (50 cm in reference model) was obtained by previous calibration, see Table 3 in He et al. (2016) The drainage depth parameter was calibrated because the drainage system at Skogaryd is quite complex, having both parallel drainage ditches and a major drainage ditch (Fig. 1).*

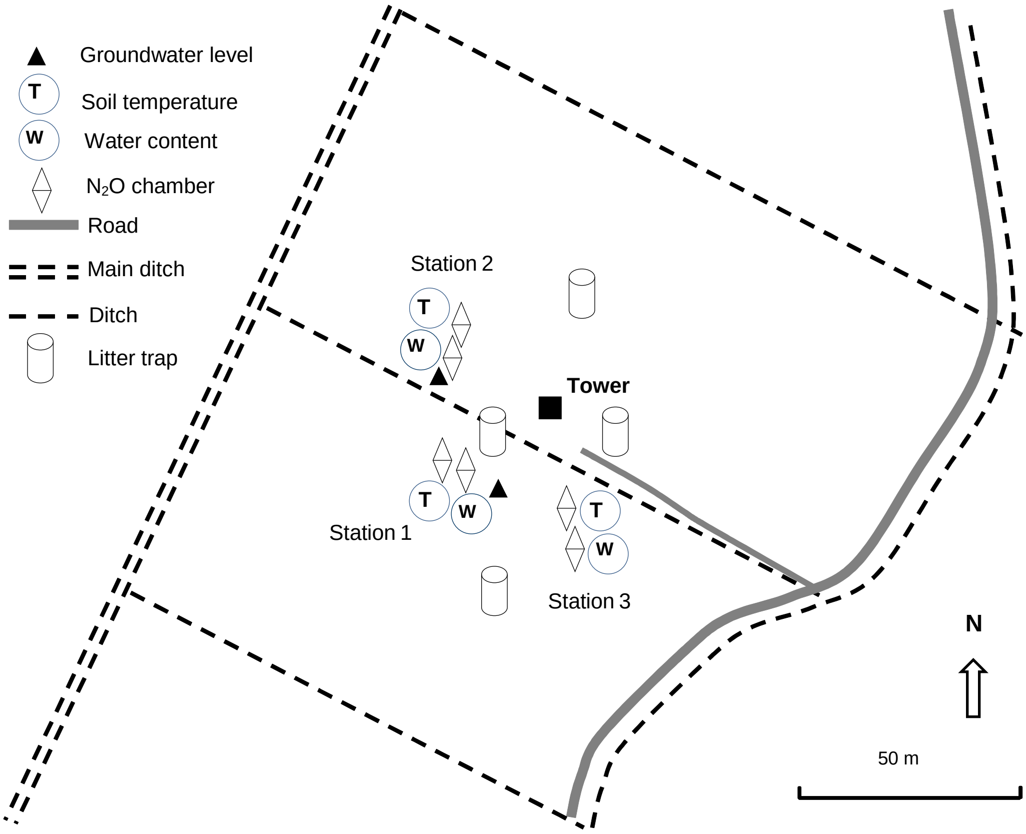

Fig. 1. Brief scheme of Skogaryd site

- *We agree that the assumption that the soil physical properties do not change during the rotation period might bring some uncertainty. This is indeed a challenge and difficult issue, since so far we do not know exactly the mechanisms (and data) on the change of the peat soil physical properties during the long term drainage. Our assumptions were based on 1) this site has been drained for many years (starting in 19th century), why physical soil compaction might not be large during the last 60 years, and 2) soil properties were not found to be the major GHG emission influencing factor. As the results of sensitivity analysis in He et al., (2016) shows the drainage depth determines the GWL, thus regulates GHG fluxes and also possibly the plant growth.*

The second phase was to define the initial soil C content in 1951. This was predicted using an IPCC emission factor, calculating backwards from the present soil C pool. Then the COUP-model was used to simulate the peat decomposition from 1951 to the present – producing very similar soil C stock than where started. One might ask: Does this mean that IPCC EF is as good a model as COUP for estimating peat decomposition? But seriously, it is not told WHY the C content is needed in the first place, and HOW is the carbon in peat divided to the soil layers. For decomposition, it is not important only how much carbon there is in peat soil, what is important is that how much carbon is in AEROBIC conditions, i.e. above GWL. If 100 cm peat layer is simulated, and GWL is in 50 cm, a significant part of the C pool is anaerobic and it does not matter if that C pool is increased or not. So please explain: why is the soil C pool important for the fluxes?

- *Since the CoupModel simulates the soil C decomposition based on linear kinetics which is dependent on soil conditions (e.g., temperature and moisture),* $C_{PeatDecomposition} = k_{peat} f(T) f(\theta) C_{peat}$ *, Where* $C_{PeatDecomposition}$ *is the decomposition rate of soil peat, parameter* k_{peat} *decomposition coefficient, f(θ) and f(T) are the common response functions for soil moisture and temperature,* C_{peat} *is the total C in peat. Therefore the total peat C has strong impact on the peat decomposition. We do not say the IPCC EF is good or bad, just one way to back calculate a possible C content in 1951. The high uncertainty also was the reason why the sensitivity analysis was performed, Table 1, showing a low initial soil C to result in lower peat decomposition, and the opposite, high initial soil C higher decomposition (emissions). We need to clarify this in the paper. And of course carbon in aerobic conditions are the most important.*
- *This is estimated by soil water content impact on the peat decomposition through water response function (range from 0 to 1), whereas the decomposition activity stops (f(θ)=0) when the soil is extremely dry or flooded (anaerobic conditions).Therefore the decomposition only occur at the aerobic conditions.*
- *We assume the total soil carbon (C) at 1951 was uniformly distributed in the soil profile (till 1m deep), based on measured data in 2007 (Table 1 below) showing close to uniform distribution of soil C across the profile (He et al 2016). The influence of initial soil C on the overall results is discussed based on a sensitivity analysis, see Table 1 in this paper.*

Table 1, measured Skogaryd soil properties

Measured stations	*Measured soil layer/depth (cm)*	*C content (kg/m^2)*	*N content (kg/m^2)*	*Total C/N*
station 1	*3-13*	*11,51*	*0,48*	*24,09*
	22-32	*12,14*	*0,49*	*24,78*
	42-52	*14,76*	*0,55*	*26,78*
station 2	*5-15*	*11,04*	*0,46*	*24,09*
	30-40	*9,50*	*0,38*	*24,78*
	48-58	*10,68*	*0,40*	*26,78*

station 3	*5-15*	*12,33*	*0,48*	*25,82*
	30-40	*10,58*	*0,44*	*24,09*
	70-80	*6,95*	*0,31*	*22,77*

Are the initial soil layers realistically described? Could you describe them to the readers? It would help if the used soil layers and their physical and chemical characteristics, and their development, were shown (fig or table). IF the original C peat C pool was important, then the present value should be checked: It is given that the original C content in 50 cm layer in soil was 11.6 kg C m-2. This is an unbelievably small value! With bulk density of 230 kg m-3 and and 85% organic matter content (Meyer et al. 2013), C concentration would have to be as low as 12% of OM (230 kg/m3 *0.5m = 115 kg m2; 115*0.85=98 kg OM m2; 98*12%=11.6 kg m-2), while it is usually close to 50% of OM. There must be an error in the C content value, it is way too low.

- *We will add better description on the soil layers characteristics.*
- *We have checked the soil C content of the peat soil in Skogaryd upon which this study is based and we agree with the reviewer that we used a way too low C concentration. Unfortunately this was an error by us using numbers for 10 cm depths as it was 50 cm, thus too low. We are awfully sorry for this mistake. By using the measured data from Table 1 (above), the measured C content in the upper 50 cm should be 55.3 kg C m^{-2} instead of 11.6. Then the OM concentration should be 57.2%. We will now rerun the model with the new C content and revise the paper. Current peat decomposition is probably underestimated.*

There are some issues with terminology of soil C fluxes. Soil C balance, which should be the most interesting variable here, is the sum of soil organic matter (peat and litter) decomposition and litter production. It is not always clear what the authors mean by “peat decomposition”. Sometimes “peat decomposition” is given as if it were the soil C balance (e.g. comparison with IPCC EF-values, which are soil C balances). These are two different things and have to be kept separate.

- *Yes, the soil C balance represents a net balance of soil peat decomposition, litter decomposition and also litter inputs. In this study we want to highlight the CO_2 emitted due to peat decomposition in a context of a forest producing both living and dead matter (litter). The CoupModel subdivide the soil organic matter into “litter” and “humus” pool, fast and slow decomposition. For peat soils this is somewhat difficult since there is both new litter added, which have fast and slow components, and old stored peat. In our study the ‘humus’ pool was assumed to represent peat only, and the decomposition of this pool is thus ‘peat decomposition’. We will make it more clear in the updated version*.

In results the authors state that “The GHG fluxes are composed of two important quantities, the forest carbon (C) uptake, 405 g C m-2 yr-1 and the decomposition of peat soil, 396 g C m-2 yr-1.", it is unclear to me what do they mean with the latter – the decomposition of peat, or the soil C balance. Please be more specific with the terms.

- *We will make it more clear, also see above*

The simulation itself shows (Fig. 5) that the "peat decomposition" rate in the 100 cm soil layer continuously almost linearly decreases. I guess the authors here observe the initially 100 cm peat layer, which in the end is not anymore 100 cm (or is it?) but 50 cm. This is interesting to see, but as litter and humus are also produced (Fig. 3), and as they form a large part of the soil C balance, they should be presented with the peat decomposition fluxes.

- *The model does not simulate the surface subsidence therefore the soil layers are the same at the end of the simulation, 100 cm. However the peat decomposition decreases due to lower soil C content.*
- *We agree with the reviewer and the accumulated litter and humus values are important in the overall soil C balance, this is partly included in Fig. 3. However this figure is unclear, since it shows what the model perceives as accumulated litter and peat (not humus) decomposition. It is confusing for readers when we use and intermix the terms humus and peat. We will improve this in the revision.*

The conclusion of this study is that more C and other GHG have been lost than has been bound to the growing tree stand and that forestry is not sustainable. This conclusion seems reasonable with the given, measured NEE, forest growth and soil efflux values (Meyer et al. 2013). Does this simulation study add our understanding of the system? Yes, I think it would, but there are still many unclear things in methods, terms etc. mentioned above and in the commented MS (appendix) that should be clarified before this paper be published.

- *We are grateful for your effort to find faults and weaknesses of our paper. We will take them all into consideration to improve for an updated version of the paper. Especially we need to be more clear in the use of terms and definitions throughout the paper and in the appendix.*

References mentioned

- He, H., Jansson, P.-E., Svensson, M., Meyer, A., Klemedtsson, L., and Kasimir, Å.: Factors controlling Nitrous Oxide emission from a spruce forest ecosystem on drained organic soil, derived using the CoupModel, Ecological Modelling, 321, 46-63, 10.1016/j.ecolmodel.2015.10.030, 2016.
- Jansson, P. E.: CoupModel: model use, calibration, and validation, Transactions of the ASABE, 55, 1335-1344, 2012.