Review comment 2:

General comments

Chou et al. present a manuscript that evaluates the extent to which large scale re/afforestation in the UK will help the UK achieve net zero emissions. The authors explore carbon uptake under various future climate and CO2 scenarios by running the vegetation demography model JULES-RED at 300 sites across the UK.

This is an important topic, and the results of such an analysis will be of interest to policy makers. However, the methods section is lacking many important details making it difficult to evaluate the relevance of the results, for example how JULES-RED represents tree physiological stress, mortality and recruitment. The authors also use a parameterisation of a Sitka Spruce PFT, calibrated to a single highly productive site, at all 300 sites across the UK. As a result, they may overestimate carbon uptake potential in many regions.

The manuscript would be improved by some restructuring of the methods and results section to provide important details and justification. The introduction and discussion would benefit from more linkages to previous work on this topic.

We thank the reviewer for these comments. As described in our response to the other reviewer, we will revise the manuscript overall for structure and detail, and include more detail about the mortality, recruitment, and stress functions in the model.

We agree that the limited availability of suitable calibration data does introduce the possibility of bias to process-based modelling. We can include some additional statements in the discussion section to further acknowledge that this study is subject to these limitations.

Specific comments

- *The title could be updated to indicate that this is a GB specific study.*

  We could add the GB to the title.

  Evaluation of the National Greenhouse Gas Removal Potential in Great Britain under a Changing Climate Using a Process-based Land Surface Model

- *L36-39. This section needs references on how these environmental variables are predicted to change in the UK.*

  We have references on the potential environmental variables changes in the UK in section 2.3 (Robinson et al., 2022). We will summarise those contents in the introduction.

- *L41-47. This paragraph is lacking references to other land surface models and previous work using LSMs to quantify the impact of re/afforestation on biogeochemical and biogeophysical dynamics as well as potential risks.*

We will add more information on the wider research area to this section. For instance, a recent study, Eckes-Shephard, et al. (2025) evaluated nine different demographic LSM across boreal, temperate, and tropical sites and chronosequences. Furthermore, this is a comparison against eight independently developed demographic LSMs, with varying degrees of process representation, for the JULES-RED model.

- *L49. References?*

  Uncertainties refers to UKCP18 science overview report (Lowe et al., 2018).

- *L52. More information is needed regarding the probabilistic projects. What data are they based on?*

  The data is based on CHESS-met reanalysis observations (Robinson et al., 2020), we will put the information into table.

- *L81. I think this section would be easier to follow if details of PFT calibration came after the model description.*

  We will rearrange these paragraphs.

- *L85. More information on the forest management implementation in JULES-RED would be relevant here. Which processes are represented?*

  For this study, we decided to assume an unthinned stand of trees planted at 2,500 trees per hectare, as this avoids additional assumptions with regards to thinning. Additional forest management practice is outlined using JULES-RED in the literature (Argles et al., 2023).

- *L86. How are growth, recruitment and mortality represented in JULES-REDD? Are they sensitive to climate, if so, how? Many details are missing which are relevant here.*

  The physical processes represented in JULES-RED are described in detail in the model development paper (Argles et al., 2020). We explained the parameters we used in Section 2.2 with our model calibration part. We have supplement this with additional detail about growth, stress, recruitment, and mortality.

- *L94. So JULES-RED was calibrated to a highly productive site and then run across 300 new sites? Does this mean that carbon uptake is likely overestimated at many of these sites? More explanation is needed for how much dynamics are determined by parameterisation versus response to soil and climate forcings. It is not clear which parts of section 2.2 are summarising new work, versus results from Argles et al. 2023.*

  The processes of carbon cycle are estimated following a physically-based simulation, which the dynamics are more determined by the soil and climate forcing according to the range of carbon simulation. The Sitka Spruce parameters was calibrated in a highly productive site with soil and climate forcings more suitable for vegetation growth, which does not mean these parameter sets lead to overestimation in the rest of sites. Section 2.2 mainly summarised the parameters we used, which were given in Argles et al. 2023. We can revise this section with a view to providing greater clarity.

- *L93-100. Given that simulations were run across GB it would be more appropriate to calibrate the Sitka Spruce PFT to data from across the whole study region for the historic period, and then project forward in time, rather than use a parameterisation from a single site which is characterised as being maximally productive.*

  JULES-RED is mainly simulated following physically-based processes, which is different from the empirical model approach. We will add to the Discussion section describing the limitations that arise from insufficient model calibration.

- *L111. What is boundary mass?*

  The boundary mass is a critical parameter used to define the smallest plant size considered in the simulation (Argles et al., 2020, 2023). We will put the description on the next revision.

- *L111. Recruitment rates and baseline mortality are likely to vary spatially depending on climatic and edaphic conditions. Are there additional sources of mortality in JULES-RED that will vary spatially? Is recruitment a function of mature tree biomass at all? It is difficult to understand the meaning of these parameters without further details about JULES-RED. What does alpha=0.005 mean? Is that number of plants per m2 per year? Or some amount of carbon?*

  As the JULES-RED model is relatively new and still in development, we have not yet implemented climate-coupled mortality rate such as windthrow or drought. Recruitment rates are dependent on both the productivity and the canopy cover within the model, so they are dependent on the local climate and competition within the model. Alpha is the fraction of how much carbon assimilate (kg C/m2/yr) is devoted to seedling production. Alpha is very low as to mimic low recruitment rates seen in Sitka spruce (Mair 1973). As we are dealing with even-age stands, where most individuals are the same age, the impact of recruits on carbon growth is low.

- *L119-124. Please provide details of how the 300 sites were chosen. Was a clustering algorithm used? Did you consider the current land use of each site, and whether it had previously been forested?*

  300 grid points represent the different climate and the most dominated soil classifications in United Kingdom are selected by a Stratified Sampling method. We excluded the urban area from the selection. The previous forested states were not considered as we assume to planted from a clear-cut land.

- *L132-141. It might help the reader if these two ensemble members were given more informative names in the paper, e.g. EM15=low warming, EM06=drying.*

  We will change the description to low warming (EM15) and drying (EM06).

- *L162. We would expect high CO2 to reduce sensitivity to water stress so it would have been interesting to quantify that effect by assessing the sensitivity of vegetation growth to meteorological drivers under all three CO2 concentrations.*

  This additional piece of modelling work is outside the scope of the current study. JULES is relatively sensitive to CO2 fertilisation, so higher CO2 futures tend to include larger increases in productivity.

- *L165. See note on Figure 5 also. I don't understand the rational for classifying results in this way, rather than presenting the full distribution of vegetation carbon.*

  We have presented the full distribution of vegetation carbon on the missing Figure 4. We will fix this in the next revision.

- *L170. Why are forests at 30 and 55 used to calculate carbon uptake at year 42.5. I don't understand the need for equation 3. You could calculate total carbon taken up over by the total forest area given the age distribution in year 2080.*

  We assuming plant 30,000 hectares of new woodlands every year from 2025 onward, which means not all the forest has the same age in year 2080. This is why we use equation 3 for calculation.

- *L176-189. I think this section along with Fig. 3 and Table 1 belongs in the methods after the paragraph from L132 – 141.*

  We will move the contents to method section.

- *L196. I don't understand what is meant by "at forest age of 55 years".*

  We plant new woodlands every year from 2025, which the forest will be 55-years old in the year 2080.

- *L199. Or the parameterisation does not allow growth under those conditions.*

  The forest still growth with lower speed under those conditions.

- *Figure 4. The figure does not match the caption. It looks as if figure 5 has is replicated.*

  We have misplaced Figure 4, which will be fixed in the next revision.

- *Figure 5. This figure would be more informative if continuous colour scales were used, rather than four discrete bins for each variable. It is also best to avoid red-green colour schemes in general.*

  We will update to continuous colour scales in the next revision.

- *L245. I think these results would be easier to understand as a figure rather than a table.*

  We have presented these results in the missing Figure 4, and then use the table for completeness. We will fix Figure 4 in the next revision.

- *Figure 7. What are the two blue lines in panel a? I see this explained in the text but a short description in the figure caption would be helpful.*

  The blue lines are trend of the vegetation carbon (L249), we will add a description in the figure caption.

- *L260. This whole paragraph belongs in the results section. These numbers haven't been mentioned previously (except in the abstract) and there is no discussion of their significance here.*

  We will move the section to the results.

- *L269. I don't understand this sentence. The previous paragraph states that vegetation carbon flux is higher in 2080 than in 2050 in both scenarios. But then this sentence states that vegetation carbon has considerably reduced.*

  The vegetation carbon in the 84-percentile site has considerably reduced comparing EM15 to EM06 simulations (Table 4).

- The discussion summaries the results but does not really put them in the context of previous work. For example, there is a large literature on the potential for soil nutrients to limit CO2 fertilisation but this is not mentioned anywhere in the section discussing the increases in vegetation growth under future CO2. There is also no discussion of potential biogeophysical impacts of afforestation/reforestation, biodiversity impacts, or carbon permanence (e.g. risk of forest loss from fire or pests/pathogens) which should also be considered by policy makers alongside carbon uptake.

  We will strengthen the Discussion section overall with a broader view of the environmental effects of afforestation.

Technical corrections

Overall, the manuscript could use a close read for grammar. Tenses are frequently mixed up within a paragraph. The 2 in CO2 is often not subscript.

See comment above about figure 4.

We will revise the manuscript throughout for language, grammar, and clarity. We will fix Figure 4 in the next revision.

<u>**References**</u>

Robinson, E. L., Huntingford, C., Shamsudheen, S., & Bullock, J. (2022). CHESS-SCAPE: Future projections of meteorological variables at 1 km resolution for the United Kingdom 1980-2080 derived from UK Climate Projections 2018.

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Argles, A. P., Moore, J. R., Huntingford, C., Wiltshire, A. J., Harper, A. B., Jones, C. D., & Cox, P. M. (2020). Robust Ecosystem Demography (RED version 1.0): a parsimonious approach to modelling vegetation dynamics in Earth system models. Geoscientific Model Development, 13(9), 4067-4089.

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