Afforestation impacts on terrestrial hydrology insignificant compared to climate change in Great Britain

Response to the Editor

Comments/Text of the Editor is in **black**, our response is in **blue.**

We thank the Editor for providing the opportunity to revise the manuscript and to provide responses to their helpful comments.

Dear authors,

Thank you for responding to the two reviews. The reviewers' comments are mixed, and contain some reservations. Your revised manuscript will be sent to both reviewers again. In addition to their comments, I have additional comments listed as follows.

1. The title may be misleading as you only assessed broadleaf woodland, I suggest you add broadleaf to the title. This also leads to my next question.

We will change the title of the manuscript accordingly.

2. You did not explain why only broadleaf woodland is investigated in your study. Please see below excerpt from https://cdn.forestresearch.gov.uk/2022/10/UKFSPG027.pdf that points out conifers have much great water use compared with broadleaves, and differences in effects tend to be greater between broadleaf species.

"Tree type has a marked effect on water use and thus the impact on flood volumes. Water use is generally much greater for conifers compared with broadleaves, especially in winter periods. Conifer canopy interception is typically twice that of broadleaves, resulting in larger evaporation losses during storm events and higher and more sustained soil moisture deficits, with a greater capacity for conifer soils to absorb rainwater and reduce flood run-off (but also to increase water shortages in drought periods). By contrast, soil infiltration rates tend to be similarly high under both tree types, provided woodland is well managed (e.g. avoiding ground compaction), while the hydraulic roughness created by trees and associated shrubs, ground vegetation and deadwood tends to be significantly greater under broadleaves, depending on tree age and the depth of floodwaters.

Tree species effects are generally small, especially within conifers. Differences tend to be greater between broadleaves, with the relatively high water use of willow and poplar species (when well supplied with water, such as in riparian and floodplain habitats) resulting in higher soil water deficits and a greater potential for below-ground floodwater storage. Tree species selection should be primarily driven by site suitability and habitat, but water impacts should be considered where significant."

We thank the Editor for noting that the use of just broadleaf woodland is not clearly explained in the original manuscript. This has now been edited to ensure that it is properly explained. Only broadleaf is used as a representative vegetation for woodland across the UK for several reasons. Firstly, the implementation of broadleaf in JULES is shown to be more accurate than needleleaf (Broadmeadow *et al.*, 2018). Secondly, at the spatial and temporal resolution of the model it would be inaccurate to extrapolate precise species responses to these scales. Finally, there is no clear map of the precise plant species that could be planted in different locations across the country, therefore this work aims to provide an estimate of the potential hydrological responses to afforestation, from which others can draw inferences about how individual tree species may compare.

Broadmeadow, S. et al. (2018) Valuing flood regulation services of existing forest cover to inform natural capital accounts, The Research Agency of the Forestry Commission. Available at: https://www.forestresearch.gov.uk/documents/5499/Final_report_valuing_flood_regulation_services_051218.pdf.

3. The Plausible Afforestation Scenarios you used need further justification.
I checked the Forest Research, 2021a cited by you. They state '13.3 thousand hectares of new woodland were created in the UK in 2020- 2021, with conifers accounting for 55% of this area.'
The two scenarios you proposed are (1) 900 000 hectares of broadleaf woodland is randomly 'planted', at a 25 m resolution (2) 450 000 hectares of woodland is made to represent afforestation at similar present rates (Forest Research, 2021a). Present rate of 13,300 is not similar to 450,000.

You also stated "Arguably these scenarios are a restrictive level of afforestation, but they appear ambitious when compared to current afforestation rates of approximately 10 000 hectares per year (Forest Research, 2021b)." This is a vague statement, and did not explain why your scenarios are 90 or 45 times of the current rate. Is it because the changes would be negligible if not ambitious? It is also not clear if the 900k hectares broadleaf woodland is newly planted or includes the existing one. According to (Forest Research, 2021a), the area of woodland in the UK at 31 March 2021 is estimated to be 3.2 million hectares. If we take away 9% in NI, the area for conifers is 1,601,600 and remaining is 1,310,400 hectares. I still cannot see where 900k or 450k comes from.

Thank you for noting that this point requires clarification. It is correct that the amount of woodland planting is approximately 10 000 hectares per year in the UK. The government seeks to increase this rate to 30 000 hectares per year as specified in the manuscript (Committee on Climate Change, 2018). The 900 000 hectares of additional woodland is equivalent to 30 000 hectares over 30 years (this is now clarified in the manuscript). The 450 000 hectares is equivalent to 15 000 hectares over 30 years. This rate is higher than the 10 000 hectares currently being planted and that is why we say that rate would be ambitious.

We would also like to emphasize that this work is for Great Britain and thus does not include Northern Ireland (NI).

Committee on Climate Change (2018) 'Land use: Reducing emissions and preparing for climate change', (November), p. 100. Available at: www.theccc.org.uk/publications.

4. Figure 2: numbers at 50% and 100% don't seem to match up even if rounding errors are taken into consideration. For example, 5.6 and 11.4.

This is because the weighting mechanism for planting trees in our conceptual planting model means it is not necessarily spatially uniform across the country when randomised.

5. In your response to Reviewer 2, you state the follows.
"Catchment hydrological models can be calibrated to produce accurate output (such as streamflow) but at the cost of compensatory parameters and an inability to elucidate realistic processes generating changes. This means that it is impossible to deduce potential realistic process responses to afforestation as a more finely calibrated model would alter processes to create an accurate output. We have chosen to use a physically based model that enables exploration of multiple systems and interactions between them."
It is possible for an HM to deduce potential realistic process responses to afforestation. Please note there are physically based hydrological models that "enables exploration of multiple systems and interactions between them". In most cases, HMs are used for simulating streamflow and hence calibration centres on streamflow. They can also be calibrated using multiple criteria where not only streamflow can be calibrated but also other intermediate outputs within a HM.

We agree with this statement in the broadest terms but stand by the point made in our response. It is not entirely clear what the precise definition of a HM is in this case. Our statement is still accurate as HMs can generate 'realistic process responses to afforestation' but this can come from compensatory parameters or high epistemic uncertainty by not including faithfully all relevant processes. There are a range of hydrological models covering a spectrum of configurations and purposes; we are not saying that the model used here is better than other hydrological models, but that it is more appropriate for the questions asked in this manuscript.

6. You stated "Considering streamflow and runoff, the model configuration used is that developed by Martinez-de La Torre et al. (2019) that achieve an NSE score of over 0.8 for the River Thames." Your study covers GB. What are the NSEs for all the catchments covered in your study.

These are provided in the supplementary material (stated in the main manuscript).

7. Both reviewers asked for comparison with experiment sites. You say “The question of this study was to understand the potential hydrological impact of widespread realistic afforestation in the UK compared to climate.” But if your results cannot be validated against several experiment sites in GB, how much credibility is it in understanding the potential hydrological impact of widespread realistic afforestation? What is the spatial resolution of your model setup? Did you use the Hydro-JULES? "LSMs are intended to explore processes at countrywide and continental scales". Is this why you don’t validate your results using the experiment sites?

A new paragraph is added on the validation studies undertaken with JULES. The spatial resolution is stated explicitly in the manuscript in the first paragraph of Streamflow Analysis subsection of the Methods. We used JULES; Hydro-JULES is the name of a project to improve the hydrological representation within JULES. As previously stated, the reason why results cannot be validated for our specific experiment is that there are no experiments at this scale. Thus, we need to use models that can extrapolate the potential consequences of afforestation using physically represented processes.

8. Reviewer 2 commented “Further, some hydrography showing the changes might be useful for the presentation since the study evaluates hydrology.” Can you please respond to this comment?

We apologise for not answering this comment before. We respect the point the Editor and the Reviewer make; however, this is already a complex and long piece of work and we believe that adding more figures will not add to the story. In particular, considering the spatial and temporal scales of the study, we feel that adding a hydrograph of a single catchment would not be particularly helpful to address the questions asked in this work.

I look forward to receiving your responses and the revised manuscript.

Sincerely,
Yi He, HESS Editor

We are grateful for the Editor’s questions, which have helped us clarify important points in the manuscript.