Dear Reviewer,

Thank you very much. We appreciate your time and effort for providing your valuable feedback on our manuscript. We will incorporate changes to address your main concern and hope you will find our replies to your comments and suggestions on this manuscript satisfactory**.**

Our replies to the comments are highlighted in bold.

Best Regards,

Dushyant Kumar and co-authors

Interactive comment on **"Climate change and elevated CO_2 favor forest over savanna under different future scenarios in South Asia"** ***by*** **Dushyant Kumar et al.**

Anonymous Referee #1

Dear Editor,

Review of the manuscript "Climate change and elevated CO2 favour forest over savanna under different future scenarios in South Asia.

The manuscripts read well and has the most relevance topic covered for the day given we are experiencing unprecedented climate change impacts and resultant pandemic. The aim to look into this south Asian scenario on forest biomass and changing forest cover over the region given the major of the population are dependent on natural resources for their livelihoods. No doubt these models developed point at the future direction and provide policy makers sufficient time to plan and execute appropriate policies aiming to conserve limited natural resources and protect the livelihoods of millions.

Reply: Thank you for your appreciation and the positive feedback on the relevance of our work.

The manuscript postulates that elevated CO2 levels improve the C3 function to enhance biomass productivity, which is quite simple to understand and model based on this assumption. However, at molecular level, the RUBP carboxylase has a different function based on the CO2 concentration, temperature and sunlight. Photosynthetic enzyme RUBISCO has dual function that fixes carbon when there is higher concentration of CO2 while at arid situations may act as RUBP oxygenase i.e., reduce carbon instead of fixing it. Thus, I request authors to go through the following articles which provide molecular basis of carbon fixation and how this might be helpful to model the scenarios under climate change.

1. James R Ehleringer and Thure E Cerling 2002, C3 and C4 Photosynthesis 2002 Volume 2, The Earth system: biological and ecological dimensions of global environmental change, pp 186–190 Edited by Professor Harold A Mooney and Dr Josep G Canadell in Encyclopedia of Global Environmental Change (ISBN 0-471-97796-9) Editor-in-Chief Ted Munn, John Wiley & Sons, Ltd, Chichester

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2. Ian E. Woodrow and Joseph A. Berry 1988 ENZYMATIC REGULATION OF PHOTOSYNTHETIC CO2 FIXATION IN C3 PLANTS Ann. Rev. Plant Physiol. Plant Mol. Bioi. 1988. 39:533-94 https://www.annualreviews.org/doi/pdf/10.1146/annurev.pp.39.060188.002533

Reply: Thank you for highlighting these two articles that provides detailed information on CO_2 fertilization under different environmental conditions. We will add these two references in our revised manuscript.

Thank you as well for pointing out your concerns about the effect of augmented photorespiration and its representation in the model at higher temperatures. We are well aware of how photosynthesis works and the dual nature of the ribulose-1, 5-bisphosphate-carboxylase-oxygenase enzyme. The photosynthesis implementation of Collatz et al. (1991, 1992) of the Farquhar photosynthesis scheme (Farquhar et al., 1980), combined with the Ball et al. (1987) implementation of stomatal conductance in aDGVM2 (as in many other DGVMs) accounts for these effects. The calculation of the CO_2 compensation point (gammastar) in this scheme depicts the dependency of carboxylation vs. oxygenation as a function of oxygen partial pressure and temperature (the latter via a Q10-function), and the CO_2 compensation point is then used further to determine Je (electron transport-limited photosynthesis, this also takes into account photosynthetically active radiation, i.e., PAR) and Jc (CO_2-concentration-limited photosynthesis, this also accounts for temperature-dependent Vcmax). Vcmax, the maximum carboxylation velocity in the implementation in the version of aDGVM2 used in this study, is temperature-dependent and reaches a peak around 37 °C for C3 plants (42 °C for C4 plants), and declines again at higher temperatures. This mimics the combined effect of decreasing enzyme activity due to the increased competitory binding of O_2 at higher temperatures and eventually enzyme degradation at very high temperatures.

We will add more details on this in the model description section of the manuscript to emphasize more clearly that the physiological basics and processes adequately represent CO_2 and temperature effects on primary production in aDGVM2.

Furthermore, the manuscript under discussion line 349 (page 12) predicts expansion of woody forests compared to Savannas in mountainous regions. Similarly predicts that in Deccan plateau may change to evergreen forests from deciduous forests. This appears a very sweeping statement, given there is variation in rainfall associated with increasing temperatures Deccan region of the south Asia may experience floods and frequent droughts. It is well established that soils in Deccan region are low in nitrogen and other micro-nutrients, which support higher biomass production. I am not sure whether such physical attributes were considered while modelling the forest cover change. In fact, the regions of the deccan plateau currently experience severe droughts which may cast uncertainty of the results obtained by the Authors. Under these situations the conclusions drawn seems to be quite simplistic without applying appropriate knowledge in the forestry sector.

Reply: We agree that a DGVM run at a 0.5 ° spatial resolution cannot capture all the fine regional details required to provide in-depth detailed management advice to local forestry. There are other types of vegetation models that are better suited to conduct detailed studies at the local to regional scale. We are however confident that the results from DGVMs are nonetheless valuable because they can indicate more general trends of vegetation trajectories across larger spatial and temporal scales. We will make this more clear in discussion section 4.7.

We are also aware that the model results depend on the climate and soil input data provided as forcing parameters to the model. If extreme events such as droughts and torrential rainfalls are provided by the input data, the effects of such events on vegetation can be simulated. As we depend on climate simulation scenarios conducted with General Circulation Models (GCMs) to conduct simulations for future vegetation dynamics, the uncertainty of the climate model projections with respect to representation of future climate naturally also affects our simulation results. We tried to address this issue by conducting simulations for two alternative climate projections (RCP4.5 and RCP8.5) that reflect different possible climate futures in order to evaluate a range of possible vegetation states associated with these climate projections. Also in response to the review of Hitashi Sato, we now provide additional supplementary material (Figs. S1, S2) that illustrate spatial distribution and temporal trends of the climate input variables we used to drive the aDGVM2 simulations.

Nutrients and nutrient cycling are so far not included in aDGVM2, therefore such effects cannot be captured by the model. Where such limitations are known to occur, we expect aDGVM2 to potentially over-predict vegetation productivity. We will point this limitation out more strongly in the discussion section 4.7.

We would like to emphasize that the model does not predict transition of deciduous to evergreen forest in the Deccan region. Rather, it predicts that both savannas and woodlands in the Deccan region may transition to deciduous forest due to increase in tree biomass and canopy cover. A transition from deciduous to evergreen forests has been simulated for the mountainous regions, i.e., the Himalayas and the Western Ghats. We will rephrase the corresponding sentences in the manuscript to clarify this more explicitly and avoid misunderstandings.

We will add more details in the revised manuscript to clarify these points.

The authors at page 13 line 376 explain aptly that decreased biomass due to various limitations of rainfall and other conditions in the plant photosynthetic process contracts the previous conclusions. Thus authors are making simplistic claims without considering the holistic impact of CO_2 increasing concentrations on the biomes that are less studied at the molecular levels and at the experimental forest dynamics due to changing temperatures. Overall, I confirm that current level of understanding and justifications provided does not warrant the publication of this article.

Reply: We would like to highlight here that the raised concern is taken care of by the photosynthesis routine implemented in the aDGVM2. Like many other DGVMs, the aDGVM2 is a process-based model, which implies that it represents physiological, phenological and demographic processes that integrate from the leaf level to the plant level to the community or stand level, and from there to larger spatial scales. This entails that all the effects you claim are lacking in our study, with the exception of nutrient limitation effects, are actually represented by the explicit implementation of the responsible processes. Effects caused by changing atmospheric CO_2 concentrations and rising temperatures, including changes in carboxylation vs. oxygenation, are captured by the Collatz et al. (1991, 1992) implementation of the Farquhar photosynthesis model (Farquhar et al., 1980), as explained in our response to your first point. Effects of water limitation on stomatal conductance are represented by the Ball et al. (1987) implementation of stomatal conductance that ties photosynthesis to stomatal conductance via a diffusion-gradient definition.

We will gladly include the respective references in the model description part to highlight the detailed representation of the specific processes relevant to our study. The explicit strength of DGVMs lies in their ability to not only represents such relevant processes explicitly, but also to be able to scale them across a multitude of scales.

To make this more clear for readers who are not familiar with the workings of DGVMs, we will add some more information on this in the introduction section where we advertise why a DGVM is an appropriate tool to address our research questions.

On page 13 line 376 we referred to the prediction under fixed CO_2 scenarios, where the CO_2 fertilization does not happen and as a result biomass decreases, whereas biomass increases under eCO_2. The change in mean annual precipitation and mean annual temperature shown in Figure S2 supports our statement that CO_2 fertilization compensates the effect of high temperature and reduced precipitation in some areas. We will rephrase the corresponding sentence in the manuscript to avoid confusion.

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