Reply to Anonymous Referee #1

B. Abis and V. Brovkin

Dear Referee,

Thank you for your positively constructive review and for your insightful comments. In this document, we will provide an answer to your comments and queries. We will not make a distinction between your general, specific, and technical comments.

Best regards,
B. Abis and V. Brovkin

C1. "Overall, this study is interesting and novel. However, I think that, especially in the Introduction Section, it is not sufficiently framed in the context of cited references regarding the boreal forest biome. In this regard, I suggest to expand the description of the current knowledge about the boreal forest biome."

A1. Thank you for your comment. We agree that to better frame our work in the context of the boreal forest biome, more information could be beneficial. Following your suggestion, we will expand and restructure the Introduction, to make the boreal forest description more prominent, including details regarding the main feedbacks, and a more detailed explanation of the findings of Scheffer et al. 2012.

C2. "Overall, the scientific approach and the applied methods are valid and good, however I think that the links between the different statistics involved should be better described. For example, it should be better clarify in the text how the information learned by applying one statistic are useful for making decision in applying the others."

A2. From this and other comments, we understood that our explanation of the analysis performed is not straightforward to follow, especially with regards to the flow of decisions and results. Hence, we agree on providing further clarifications and details in the text, to better guide the reader.

C3. "Finally, I suggest to revise the structure and the text of the paper in order to avoid repetitions and make the manuscript more readable. In this regard, in particular I suggest to merge the Discussion and Conclusion sections."

A3. Having evaluated all the comments received, we agree to restructure part of the paper to make it more readable. To this avail, following the comments, we will introduce major modifications to the following sections: Introduction, GAMs Results, Discussion, and Conclusions.

C4. "[Page 2, lines 6–10]: "To such avail...[] (Reyer et al. 2015)" I suggest introducing the boreal forest biome before this sentence or immediately after."

A4. Following your comment, we decided to restructure the Introduction. We will introduce the boreal forest biome after this sentence and expand its description with further details to better frame it in the research context.

C5. "In general, I suggest to reduce the description of the bimodality in tropical vegetation and to expand the description of the boreal forest, because at the moment in the manuscript they have almost the same importance. Since the study is about the boreal forest I think that the Introduction should be focused mainly on the state of the art of the study about of this biome, in order also to highlight the novelty of this study."

A5. Dear Referee, the topic of multistability in tropical vegetation is currently an important hotspot of discussion, with debates over several different aspects of the savanna-forest transitions. Such discussion influenced the way we structured and performed our work. For these reasons, we think that an overview of the discussion ought to be mentioned and that it is not possible to reduce its description. However, we do agree on improving the balance of the Introduction in favour of the boreal forest and on the state of the art of the study of this biome.

C6. "In particular: [page 2, lines 29–33]. Since most of these environmental variables are those considered in this work, could you give more information about their role in the boreal forest biome, and also more information about the cited studies? E.g. if these papers considered only some specific areas, the main knowledge about the variable interactions..."

A6. We agree that to improve the comprehension of the paper, we should provide more information about this environmental variables. Following your second suggestion (comment 9), we will include a paragraph in the Environmental Variables Datasets section about the role and the importance of the environmental variables we used.

C7. "[Page 2, lines 33–34]: In order to explain better the role of boreal forest in the climate system, could you provide a more extended description of some feedbacks between each other?"

A7. We will include a more extended description of the main feedbacks playing a role, so that we can also refer to them more clearly in the Discussion section. Particularly, we will introduce the way boreal forests influence climate through albedo, evapotranspiration, and carbon sequestration.

C8. "[Page 3, lines 3–7]: I suggest to describe more extensively the main outcomes of Scheffer et al. 2012, in particular detailing what they found about the existence of multiple states under the same environmental variables in boreal forest, in order to better introduce the current knowledge about multimodality, what is missing and thus the timely of the study reported in this manuscript."

A8. Following your comment, we will provide a more thorough description of Scheffer et al. 2012 findings, as they represent the base for our study.

C9. "[Page 3, lines 20–21]: More information about current knowledge on the importance of these variable in the boreal forest biome, which I suggested to include in the Introduction, could alternatively be reported here."

A9. As stated in the answer to comment 6, we will report here more information about the current knowledge on the boreal forest biome, and on on the role and importance of the variables used.

C10. "[Page 3, line 21]: "[...] they are summarised in Table 1". I suggest to modify the sentence for inserting also the kind of information provided by Table 1."

A10. We agree on providing within the text a description of the variables and hence on the information contained in the Table 1.

C11. "[Page 3, line 22]: Please insert at the beginning of the sentences the name of the tree cover dataset (i.e. MODIS). Although Table 1 has the references of all the datasets, I suggest to provide, in the text or in an additional column of Table 1, a brief description of all the variables, or at least of the variables that need a definition (e.g. what the permafrost index indicates, the type of soil texture, the definition of GDD0, the depth at which the soil moisture refer to...)."

A11. We will implement your suggestion and we will provide information about all the variables and their role in the boreal forest biome within the text. Furthermore, we will add a more detailed caption for Table 1.

C12. "Could you report in the text the information about the GAM implementation? Such as the assumed error distribution of the data and the implemented link function."

A12. Dear referee, we think that full details of the GAM implementation will not contribute to improve the paper, as they will make it more technical and harder to read. However, we will mention, as you ask, the family and link function used in our analysis through a suite available on R. Furthermore, additional details regarding not only GAMs, but our entire setup, including all the packages and scripts used, are already present as supplementary material.

C13. "[Page 5, line 22]: why do you use only 6 variables for the multiple-dimensional phasespace instead of 8? This is currently explained later on, but to improve clarity I suggest to explain the reason here, or to refer directly to Sec. 3.2 for the explanation."

A13. We agree with you and we will include a reference to Section 3.2 for improved clarity.

C14. "How many are the total found classes?"

A14. Dear Referee, the total amount of found classes is 2915, of which, 1185 are found in Eastern North Eurasia, 438 in Western North Eurasia, 457 in Eastern North America, and 835 in Western North America. Of these, 19 are multistable or fire disturbed. We will include this information in the text.

C15. "[Page 10, lines 1–2]"Qualitative [. . .] high." Is it possible to provide the quantitative values of the extremes of the qualitative index for each variable? For example, what are the extreme values of the qualitative range called medium-low for FF? Furthermore, how do these ranges change for the different regions?"

A15. To make Table 4 more readable, we initially decided to include the information you ask in the supplementary material only. However, we will change this and make Table 4 more complete, with all the ranges and the number of gridcells per class.

C16. "[Page 13, line 4]: "Depending on the conditions, only one of the three possible vegetation states is attained." It is possible to provide some examples?"

A16. Essentially, in 95% of the cases, the class uniquely determines the vegetation state (either treeless, open woodland, or forest). Hence, we will easily provide an example for each case.

C17. "[Table 1] I suggest including in the table also the measure units of the variables."

A17. We agree that this will improve the information conveyed by Table 1, hence, we will include units and a more detailed caption.

C18. "[Table 4] I suggest adding a column with the number of gridcells found in each class."

A18. We agree that this will add an important information to Table 4, hence we will add such a column.

C19. "[Page 5, line 19]: "or" instead of "ot", please fix the typo."

A19. We beg your pardon for the typo; we will correct it immediately. Thanks for noticing.

C20. "[Page 6, line 10]: Please rephrase the sentence "(generally at least 1% of the gridcells with the same vegetation state)"."

A20. Following your comment, we realised this sentence was somewhat vague. We will rephrased it in a more clear and concise way.

C21. "[Table 1] Please replace "0.05° MODIS MOD44B V1 C5 2010 product" with "0.05° MODIS MOD44B V1 C5 2001-2010 product"."

A21. We will implement your suggestion.