General:

The aim of this paper is to present and evaluate a methodology that produces spatially explicit land cover reconstructions from pollen based proxy data. The methods sensitivity to different auxiliary variables is tested, and shown to be very low. Finally, we provide past land-cover maps that can be used directly in the climate models.

Although the paper is somewhat mathematical we feel it to be relevant for climate of the past since: 1) Palaeoecological proxies, such as pollen, are valuable source of information on past environmental conditions, but hardly applicable by climate modellers as input in their original format, and therefore heavily underused; 2) We present a general way of extracting spatially continuous land cover from pollen proxy data producing spatially explicit proxy based land cover maps directly usable in climate models; and 3) The resulting reconstructions of past land-cover for Europe during two important time windows are provided as auxiliary material in the paper. These pollen based land cover reconstructions could be used in climate models to facilitate mechanistic studies on past climate-land cover relationships.

To clarify these points, text (outlining the points above) have been added to the abstract, introduction, results and discussion, and conclusions sections.

Reviewer 1:

Pirzamanbein et al. present a statistical method for producing past land cover reconstructions from pollen and model data. More specifically, they explore present and test a statistical model that can be used for linking pollen-based land cover data with different auxiliary variables, such as the past vegetation simulated with dynamic vegetation modeling and anthropogenic land cover change modeling. The idea of combining pollen-based land cover data with auxiliary data derived from various simulation approaches is interesting. The paper has a clear focus and it is for most parts clearly presented and well illustrated, deserving a publication.

My main comment is, however, that the authors should reconsider whether Climate of the Past is the right and best forum for this paper. It is certainly true that past land cover patterns are important for understanding past climates, but this paper is really not presented from the palaeoclimatological perspective. Its emphasis is in the use of the statistical model for land-cover compositions, and the mathematical basis of this model is presented and tested in detail on pages 4-8. As a consequence, the paper is mostly a methodological description of the model, including its testing. There is barely any description or discussion why this model might be important in palaeoclimatology and I fear that the number of palaeoclimatologists interested in the details of this particular statistical model is very limited. My view is that there are other journals, which would be more suitable for this paper, for example Environmetrics, Biometrics, Computers and Geosciences or possibly Journal of Applied Ecology.

Reply: The abstract, as well as initial paragraphs of the sections on "results and discussion" and "conclusions" have been updated to illustrate how the method and results (i.e. publicly available datasets of land-cover reconstructions) can be used to facilitate the mechanistic studies on past climate-land cover relationships. These changes are discussed in more detail in the general comments.

More detailed remarks.

- page 1 line 2: "However, observation based reconstructions of past land cover are rare". This paper deals mostly with land covers before human-made observations, so a better term instead of "observations" would be "proxy-based reconstructions".

  Reply: We agree, and have changed "*observation based reconstructions*" to "*proxy based reconstructions*" referring to pre-historical pollen data throughout the text.

- It is stated in the abstract that five different auxiliary datasets were considered in the study. However, on page 3 the authors write that "Four different model derived datasets were considered as potential auxiliary datasets". This seems contradictory. I believe that the fifth auxiliary dataset is the elevation dataset? In any case, it would be best to amend the wording either in the abstract or in the method description.

  Reply: To clarify we have added extra text to page 3 line 5.

  Four different model derived datasets, depicting past land cover, along with elevation (based on SRTM data) were considered as potential auxiliary datasets.

- I agree with the authors when they write that "The final land-cover reconstructions achieved by fitting the models to the observed PbLCC are very similar". This is demonstrated by maps in Figs. 4-6. But I find this outcome surprising because earlier in the paper (page 8 lines 15-20 and Fig. 1) it is stated that the available auxiliary datasets exhibit large variation in the extent of coniferous and broadleaved forests, and un-forested areas for all of the studied time periods. It is hard to understand how it is possible that when these different auxiliary datasets, showing such large variation, are combined with one and the same pollen based dataset, the resulting land-cover reconstructions are nearly identical. This can lead to a sceptical view about the performance of the statistical model presented in the paper.

  Reply: An important point is that the model estimates the a weighting of the auxiliary datasets allowing us to capture spatial structure even when the values might disagree with those in the pollen proxy data. To clarify we added a new table (Table 3) and the following paragraph (page 10 line 12):

"... datasets used. *At first the similarity among the reconstructions might seem contradictory, but recall that the model allows for, and estimates, different weighting (the regression coefficients, $\boldsymbol{\beta}$:s) for each of the auxiliary datasets. Thus, the resulting reconstruction do not rely on the absolute values in the auxiliary datasets, only their spatial patterns; Table 3 illustrates the substantial discrepancies in the estimated coefficients, $\boldsymbol{\beta}$. Although* ..."

- page 15 line 11: "The performance of the statistical model to reconstruct the pollen based observations was tested" The model is not used "to reconstruct the pollen based observations". It would be more correct to write that the statistical model was used to test the sensitivity of the pollen-based land cover reconstructions to the use of different auxiliary datasets".

  Reply: We agree and have changed the sentence on page 15, line 11 changed to

  "*The ability of the statistical model, explained in Section 2, to create continuous pollen based land cover reconstructions from observations was tested; and the sensitivity of the reconstructions to the use of different auxiliary datasets was evaluated.*"

- the possible palaeoclimatic importance of the results presented is totally lacking from the Discussion from the Conclusions.

  Reply: see the first reply.

- figures and captions should be made more user-friendly. The caption of Fig. 1 is very tedious to read with many abbreviations

  Reply: The following text added to the caption of figure 1.
  "... the land-cover compositions, *coniferous forest* (CF), *broadleaved forest* (BF) and *unforested land* (UF)."

- Fig. 2 is hard to understand given the short and uninformative caption.

  Reply: To clarify figure 2 and further explain the proposed model the following text has been added to the caption.
  "... on the estimations. *The model can be interpreted as an empirical forward model (direction of arrows) where parameters affect the latent variables which in turn affect the data. Reconstructions are then obtained by inverting the model (i.e. computing the posterior) to obtain the latent variables given the data.*"

- Figure 9 is only briefly mentioned in the text and the caption is uninformative.

Reply: Figure 9 is part of the model evaluation regarding the uncertainties in the reconstructions. To clarify this and how the figure links with methods introduced in Section 2.2 the following text has been added to page 10 and to the caption of figure 9:

Page 10, line 9: "... similar reconstruction uncertainties (Figure 9). *Analogous to the reconstructions the uncertainty regions (the transformed ellipses are described in Figure 3) are very similar in both size and shape irrespective of the auxiliary dataset used. Further the PbLCC data almost always falls within the uncertainty region illustrating that the reconstructions are consistent with the data.*"

Figure 9 caption: "The prediction regions and fraction of the ternary triangle covered by these regions are presented for three locations, the six models (see Table 1), and the 1900 CE, 1725 CE and 4000 BCE time periods. *Construction and interpretation of the prediction regions are described in Section 2.2 and Figure 3.*"