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 2:

This is a well-constructed paper which clearly compares different methods of generating past land cover maps from partial data derived from pollen records, and merits publication somewhere. The paper uses auxiliary data from other land-cover reconstructions (e.g. Dynamic Vegetation models or population-based land cover models) to inform extrapolation, which apparently improves performance but also introduces new assumptions, which are not clearly addressed. To this non-expert reader, an element of circularity seemed to be present in some of the data combinations this is quite possibly my misunderstanding, but given the journal's audience could usefully be refined.

My principal comment is that, like the first referee, I'm not sure that Climate of the Past is the right place for this article. The content focuses on model choices and assumptions, and although the relevance to palaeoclimate is clearly stated, it's not well brought out and there is no clear take-home message of interest or use to a palaeoclimate scientist. As is, I don't see this paper being of much relevance/appeal to most readers of the journal, and therefore it might get lost to some extent.

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.

- The paper lacks a clear conclusion relevant to the wider community of the different combinations tested, which is recommended for use by future researchers?

  Reply: An important point of this evaluation study is the robustness of the method to different auxiliary datasets. To clarify this important feature the following text has been added to Page 15, line 16:

  "... remains unchanged. *Therefore, the model can provide reliable results using a variety of land cover data sets that capture important spatial patterns from vegetation models and past human land use, absent good covariates elevation can be used as the only auxiliary dataset. An important feature of the suggested model is the estimation of different weights for each of the auxiliary datasets (see table 2), thus capturing the spatial patterns and not the absolute values in the auxiliary datasets. Our validations indicate that auxiliary datasets obtained using different climatic drivers produce very similar reconstructions, which are all close to the pollen based proxy data.*"

- What is the best strategy for multiple time periods, and is the recommendation likely to extrapolate beyond Europe or is this something that needs to be carried out in each area and for each time period?

  Reply: We have high hopes that the method should be generally applicable across a broad range of regions and time periods. The current status of pollen proxy data has been expanded on by additional text on Page 15, line 19:

  "... (e.g. Gaillard et al., 2010; Strandberg et al., 2015). The results also indicate that the model has a very good performance and will be very useful for large-scale, continental reconstructions of past land cover. The spatial model tested in this paper can provide an important tool to generate regional to global scale land-cover maps based on proxy data. Such, pollen based past land cover reconstructions with global coverage are currently produced by the PAGES (Past Global changES) LandCover6k initiative [1] for most of globe."

- How significant are the improvements in model output from adding the auxiliary data? I can see the numbers in tables 3 and 4, but I find it hard to judge what they mean in terms of actual improvement gained, and whether that is actually worthwhile given that including the auxiliary data generally also involves adding more assumptions to the reconstruction, thereby increasing other kinds of uncertainty.

  Reply: This point is partially related to the question regarding the model's robustness to different auxiliary datasets raised above and by reviewer 1. Using more spatially explicit auxiliary datasets is likely to

[1] `www.pastglobalchanges.org/ini/wg/landcover6k/intro`

help with fine scale detail (e.g. effects of coastal and mountainous climates). In addition to changes at Page 15, line 16 outlined above we have also added a paragraph to page 10, line 12 and a new table (Table 3):

"... 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 ..."

A couple of minor points:

1. I was not convinced by the testing method of comparing vegetation reconstructed for 1900 CE with modern EFI data, since a great deal has happened to land cover and forestry in Europe in the last 100 or so years, yet the authors treat the comparison as if it is like for like. That may be a valid assumption, but I'd expect to see that considered overtly rather than assumed in a paper like this.

   Reply: To clarify this issue we have added extra text to Page 10 , line 10 "*Although a temporal misalignment exists between the PbLCC data for the 1900 CE time period (based on pollen data from 1850 to the present) and the EFI-FM (inventory and satellite data from 1990-2005); EFI-FM provides the best complete and consistent land cover map of Europe for present time, making it a reasonable choice for the comparison. The main differences between the EFI-FM and the PbLCC data for the 1900 CE time period are: 1) lower abundance of broadleaved forests for most of Europe, 2) higher abundance of coniferous forest in Sweden and Finland, and 3) higher abundance of unforested land in North Norway in the EFI-FM data than in the PbLCC data (Pirzamanbein et al. 2015).*"

2. A table of the algebraic symbols used would be useful at the moment, terms are not always defined at time of first introduction, or easy to retain, especially as many single symbols refer to matrices rather than individual values.

   Reply: A list of notations has been added as a new table (Table 1) for clarification.