Community Comment on Sweeney et al. Egusphere-2024-1523

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General comment

Estimates of forest cover during the Holocene inferred from pollen data may be useful for e.g. climate modelling (e.g., REVEALS-based forest cover was used in regional climate modelling for Europe in Strandberg et al. 2014 in CP, 2022 in QSR, 2023in CP). The REVEALS-based estimates of plant cover have the advantage (above MAT and pseudobiomization) to provide cover for each of the plant taxa used in the reconstruction, which allows to then calculate the cover of various groups of taxa that may be very useful in e.g. climate modelling. In e.g., Strandberg et al. studies, evergreen trees were separated from summer-green trees. Nonetheless, it is most useful to produce as many reconstructions as possible using different methods to test a) the effect of the method itself on the result, if results differ between methods, and b) the effect on e.g., climate of the differences between the various forest/tree cover products. Therefore, producing pollen-based estimates of forest/tree cover using different methods is of value even if the comparison can be done only for forest cover versus open-land cover and cannot be done for more detailed land-cover units. The study by Sweeney et al. is thus welcome.

I have read the review of Thomas Giesecke and agree with his concerns and comments. Therefore I won't repeat the questions and comments provided by Thomas but wish to add some additional points, questions, and information/references for consideration by the authors. One of my major concerns relates to the discussion on the comparison between the reconstructions from this study's model and the REVEALS model. The authors should acknowledge that their model reconstructs FOREST cover based on a specific definition of forest, i.e. A definition among OTHERS, while the REVEALS model estimates TREE cover. In Serge et al. REVEALS reconstructions TREES include the taxa *Buxus*, Ericaceae, *Juniperus*, *Phillyrea* and *Pistacia* that may not belong to the definition of FOREST you are using in your model. This should be considered in the discussion, most importantly for the Mediterranean region. I also comment on this issue in the comments below.

Detailed comments – a mix of major and minor ones

61-68: The REVEALS reconstructions by Trondman et al. (2015) and Githumbi et al. (2022) were produced for the study of land use as a climate forcing (biogeophysical forcing) in Europe during the Holocene using climate models (papers by Strandberg et al.). The scale of the reconstructions (1 degree) and protocol used was motivated primarily by the primary aim of these reconstructions. These authors produced estimates of plant cover for 25 respectively 31 taxa. These data can be freely accessed in PANGAEA (references to be found in Githumbi et al.). As said above, Strandberg et al. used the total cover of three groups of taxa, open land taxa, evergreen tree taxa and summer-green tree taxa. This is only one possible use of these datasets. Similarly, the REVEALS reconstruction by Serge et al. (2023) was produced for specific use in the European Terranova project (terranova-itn.eu). The focus of these reconstructions was NOT to just reconstruct open land versus forest cover. **The above should be clarified here**.

70-87: data demanding versus less data demanding methods: I would not "classify" methods as such. They are ALL data demanding, if RPP is not necessary something else is needed, in your case a good remote-sensed data on tree cover! Then all methods have their assumptions (very thoroughly stated in the case of REVEALS, Sugita 2007a) and difficult decisions to take in terms of data handling and interpretation. The

only difficult issue with REVEALS is the need of RPPs. Obtaining RPPs is indeed time consuming although it can be done relatively fast if some money for field work and "man/woman power" is available. This was possible in China for which there is to date many RPP values for most of the major taxa; these were produced within the last 6-7 years. Moreover, this work could be realized in much less time with the technology at hand today, i.e. drones for plant surveys and automatic pollen counting. MAT, PB and your new method use other ways to account for the inter-taxonomical differences in RPP. All methods assume that RPP were stable through time. All methods are challenging, and they all have their pros and cons. None of them can be judged as more or less robust. We should rather use them as "ensembles", as is done with climate model simulations using several different models. Four reconstructions using four different methods/models (Europe) can be considered as an "ensemble". More reconstructions would of course be better; I am sure new models will constantly be created and more parameter data will be produced (e.g. RPP). My advice is therefore to avoid evaluation of the methods "against" each other but rather do a synthesis evaluation considering/acknowledging all pros and cons of each method. Here (lines 76-80), do not speak of data demanding method (REVEALS) versus other methods. Similarly, in abstract, discussion, and conclusions, do not grade methods. I do not think there is ONE best method/model.

106-108: there are more vegetation classes that could be considered as "non-natural" such as planted forest, cultivated trees, even grazed land if strongly fertilized isn't "natural", as well as ley. You perhaps rather mean "non-pollen producing land" in the case of crops like most cereals (except rye) that do not release pollen as long as they are in the field, i.e. before collected and treated to get the grains. But there are other crops. Do the remote-sensed data provide details on the crops. Do all the crop areas you deleted correspond to areas that do not produce much pollen?

126: Githumbi et al. did not exclude large bogs, which would certainly have been better. But the decision came from Trondman et al. 2015 in which it was decided not to exclude sites based on this criterion; instead, cells including large bogs were emphasized as providing less reliable results. The correct reference for large bogs being not recommended for REVEALS reconstructions, even when multiple sites are used for one reconstruction, is Trondman et al., 2016 in VHA.

130: I would also refer here to Marquer et al. 2020, QSR 228-106049.

144-154:

- It is true that the area represented by a REVEALS reconstruction of plant cover using pollen data from large lakes might correspond to Zmax as defined in Sugita 2007a "distance within which most pollen comes from", i.e. the maximum distance from a large lake from which pollen is coming and deposited in that lake (my words). However, this might not be true for small sites; in fact, we do not know as this has never been tested because single small sites are not appropriate for REVEALS applications. Small sites can only be used for REVEALS reconstructions if they are used together, i.e. within a grid cell, and a mean REVEALS estimate is calculated. That's fine you use Zmax for all your sites, but **you should acknowledge that you ASSUME that Zmax is also the area represented by a REVEALS reconstruction using pollen from a small lake, but this has never been tested**. A longer discussion on the "spatial scale" of a REVEALS reconstruction can be found in Li et al. 2020 in ESR, page 5, upper left column: "*In theory and practice, however, the strict definition of the pollen source area is difficult for REVEALS application. Sugita (2007a) defined it*

as the area within which most of the pollen comes from. Simulations and previous empirical studies (e.g. Sugita, 2007a, b; Hellman et al., 2008a; Sugita et al., 2010; Mazier et al., 2012) have indicated that, when the radius of the source area defined varies from 50 km to 400 km, the REVEALS results of regional vegetation reconstruction do not change significantly. The basin size is potentially important for REVEALS-based estimate of regional vegetation because differences in basin size among sites can lead to a significant site-to-site variation in the pollen assemblages. However, as long as the multiple study sites are located within a region that satisfies the first assumption as described above (no gradients in the overall vegetation composition), the averaged REVEALS estimates effectively represent the regional vegetation composition as demonstrated in Hellman et al., 2008a. The accuracy of the reconstructed vegetation against the observed vegetation composition was assessed for areas of 50 km × 50 km and 100 km × 100 km around each site in two regions of southern Sweden. The pollen records used are from 5 large lakes in each region, thus 10 lakes in total, that vary in size between 76 ha and 1965 ha. The results support the main conclusions and implications for the REVEALS application based on the theory and the simulations described in Sugita (2007a). Such evaluation is an essential step for credible application of the REVEALS model."

- Why use 70% of pollen rather than 80% or 90%?
- Why use the median FS 0.03 and not simply estimate the distance for the lightest pollen type you use in your reconstruction, which would be Zmax? If you use 0.03 you get a Zmax for a vegetation composed of taxa such as *Pinus*, *Ulmus*, *Buxus*. But your total vegetation is composed of taxa with pollen grains that come from much longer distances (most herbs but also several common tree taxa with lower FS values). Why do you assume/think that this isn't important to define the area around each of your sites, i.e. the area that is represented by the pollen assemblages in those sites?

200-203: **I do not fully understand how you handled the Serge et al. REVEALS estimates of tree cover for comparison with your reconstruction.** There is doubtless a problem in comparing single site reconstructions within the site's "70% Zmax" with REVEALS reconstructions representing at minimum the area of the 1-degree grid cell including the pollen sites used in the reconstruction. Wouldn't it be fairer (for each method!) to calculate the median tree cover from your single site reconstructions covering +/- one or several 1-degree grid cells of the REVEALS reconstruction before comparing the results? The REVEALS estimates are mostly based on several sites in each grid cell. If you compare your results for each site with the median forest cover from several grid cells in the REVEALS reconstruction, you'll compare the vegetation cover between two areas of different sizes, smaller size for your reconstruction than for the REVEALS reconstruction (size of several 1-degree grid cells). Please, acknowledge this issue. – Now I see in Supplement S6 that you seem to have done what I am suggesting above as fairer, although I am not sure.

Figures 3 and 4:

- I am not astonished that your reconstruction performs better than other reconstructions given that you use the same source of forest data to establish your model and test it – Note that I understand you haven't used the same sites to create the model and test the model, of course!!! – Your model is entirely dependent on the forest data you have used, and there must be good chances that your predictions will be relatively good when compared with the same data source of forest cover.

- Further, REVEALS (Fig. 4C) is closer to your reconstruction (Fig. 3B) than Zanon (Fig. A4) in terms of the spread of the points between low and high predicted % cover. Here, as said above, I am not sure to understand how you made the comparison between your results and Serge et al. The points in Figures 3 and 4 represent your sites. **I do not see how the REVEALS values can be constrained to represent the plant cover for your "pollen source area" (i.e. Z max for each of your site) as these REVEALS estimates are valid for at least the 1-degree grid cell including the sites used for the reconstruction, i.e. a much larger area; it is NOT valid for a much smaller area.** You write on line 269-271 "*The correlation between etc…. is only 0.5. This is partly caused etc….. but even when taking this into account etc…. were still lower (0.59)*". **From Supplement S6 I understand you took the scale of reconstructions into account, but I am not sure how.** In any case it increases the correlation, which is good news! **Could you please clarify.**
- Does your model produce error estimates on the predicted forest cover? If so, why are they not provided in the graphs; similarly, why not use the error estimates provided with the REVEALS-based forest cover?

Figure 5B: Can't see the different colors for the smoothing half-width in the graph, probably because the curves are very similar? Find another way to illustrate this, or have only -none and 500-year, and comment in the text for the other two?

Figure 7: Could the high values of forest cover in Zanon 10-8 k be due to over-representation of Pinus and Betula? In your reconstruction there is the same tendence.

370-376: You write: "*This could reflect the conservative nature of our moder-day tree cover model*". YES, I think this might well be the major reason to this difference. Can't this also explain the same "phenomenon" in the MAT reconstruction (Zanon)?

379-385:

- I do not understand this reasoning. First, you did not account for all "anthropogenic land use", you only excluded non-pollen producing areas, including crops (see also my comment above on methods and in relation to crops). You write "We account for this (land use/" non-natural vegetation") in defining modern source areas in our model, since the pollen only provides evidence of the natural vegetation." This sounds very odd. Pollen provides evidence of natural vegetation AND human-influenced vegetation, i.e., not only crop cultivation but also grazing, managed woodland, planted forests etc…. It is the purpose of the REVEALS model and MAT and pseudo-biomization (PB). The purpose is NOT to reconstruct natural forest cover, but the "actual" forest cover. **Please clarify, this section is very confusing. What you did was to exclude non-pollen producing areas, which is good (I only have concerns about crops, see comments above). You did NOT exclude anthropogenic land use.**
- Note that in Roberts et al 2018 (Scientific Reports, Figure 2), the REVEALS and PB (closed sum) reconstructions agree with each other and agree with the Corine remote-sensed forest cover. Roberts et al. (2018) write "*A second means of testing the different forest reconstructions is to examine how well they match modern forest cover for the same grid cells. While remotely sensed estimates of forest might be expected to offer the clearest results and the most rigorous test, in fact the Corine and Forest Map 2006 data have strongly different outcomes, i.e. 45% and 29% modern forest cover, respectively. This inconsistency partly reflects the ontological question of "what is a forest?"*

Corine uses distinct land-cover classes, and land classified as forest may include some open areas as the minimum required crown cover for a forested class is only 30%. The Forest Map 2006 is based on a minimum 50% tree crown cover with 5m used as a minimum height of trees. It also highlights the epistemological problem that differences in spatial resolution of measurement can fundamentally alter results30, in this case between 25m and 100m measured spatial resolution. An alternative data source for modern forest cover derives from surface pollen samples. We have transformed the surface pollen data set for Europe27 using both variants of the PBM, which leads to modern forest cover estimates of 49% (PBMsc) and 54% (PBMlcc). Overall, most estimates of modern forest cover for the grid cells used by Trondman et al. 10 are between 45% and 49%; that is, close to that reconstructed for the 100 to −65 BP REVEALS time window.". **This is the kind of issues you should acknowledge in this discussion. Please see my major comment under "General comment" above, i.e. REVEALS reconstructs tree cover, while your model reconstructs FOREST cover based on a specific definition of FOREST.**

419-424:

- In this discussion, you do not attempt to explain why REVEALS estimates > 65% tree cover around 6-5.5 k BP while both your model and Zanon's MAT predict forest cover < 50% (40-45%) 8.5-5 ka (your model) respectively 9.5-4 ka BP (Zanon). I would emphasize here the major difference between MAT, your model and REVEALS in terms of WHAT is reconstructed. REVEALS estimates TREE cover and NOT FOREST cover. The authors using REVEALS may define taxa as trees in various ways. You need to consider what taxa are defined as trees in Serge et al. and think about weather these taxa may belong to land-cover types your remote-sensed data define as non-forest vegetation.
- You write (412-424) "……*the more rapid decline in tree cover during the last millenium shown ….. , and shown more dramatically in the Zanon …. And Serge …. reconstructions, is more difficult to explain - …… Human influence on the landscape MAY help explain etc…..* ." I do not understand why you are so careful/doubtful on whether human impact may explain tree/forest cover decline from 6k, 5.5 k, 4k (depending on the region) and more so from 2k BP. This is documented and has been tested in a large number of publications by palaeoecologists, archaeologists, historians, etc… over past decades; I can't see what is problematic or controversial with this. In Strandberg et al. 2023 (CP), Figure 1 (based on Githumbi et al. REVEALS reconstruction, see figure copied below) shows clearly the increase in mean and median tree cover in three major biomes of Europe (note that we did not separate the Atlantic region, which would indeed have been interesting) from mid Holocene, accelerating around 2 k BP, and more so around 1 k BP. Strandberg et al. (2023) write:" *The recent pollen-based reconstruction of land cover in Europe (spatial resolution of 1 ◦ ; Githumbi et al., 2022) suggests that the earliest of the two major deforestation episodes before the start of the Modern period (1500 CE (0.45 ka) – present) took place between ca. 4 and 2.5 ka, i.e. the period during which the Bronze Age culture expanded from southeastern (Turkey, Greece) to central and western Europe (Mediterranean area included) and northern Europe (Champion et al., 1994; Coles and Harding, 1979). The second deforestation episode (before the Modern time deforestation) occurred ca. 0.9–0.5 ka, during the Middle Ages (ca. 500 (1.45 ka)–1500 CE in most of Europe, started 1050 CE (0.9 ka) in*

northern Europe) (Fig. 1a). The difference in open land cover between 4 and 2.5 ka of ca. 10 % (in either mean or median cover; Fig. 1a) is assumed to represent deforestation of Europe by Bronze Age cultures. This change in the land cover of Europe was also explained by deforestation for agriculture in the study of Marquer et al. (2017). If we consider …etc., the Bronze Age deforestation corresponds to an increase in open land cover by 200 % since 4 ka. etc. … (Githumbi et al., 2022)." And "*The time around 3 ka (the Bronze Age) was also pinpointed as the time when "the planet [was] largely transformed by hunter-gatherers, farmers, and pastoralists", as suggested by an archaeological global assessment of land use from 10 ka to 1850 CE (ArchaeoGLOBE Project, 2019*)." There is no doubt that deforestation caused by land use did strongly influence forest/tree cover in Europe over the last ca. 3000 years.

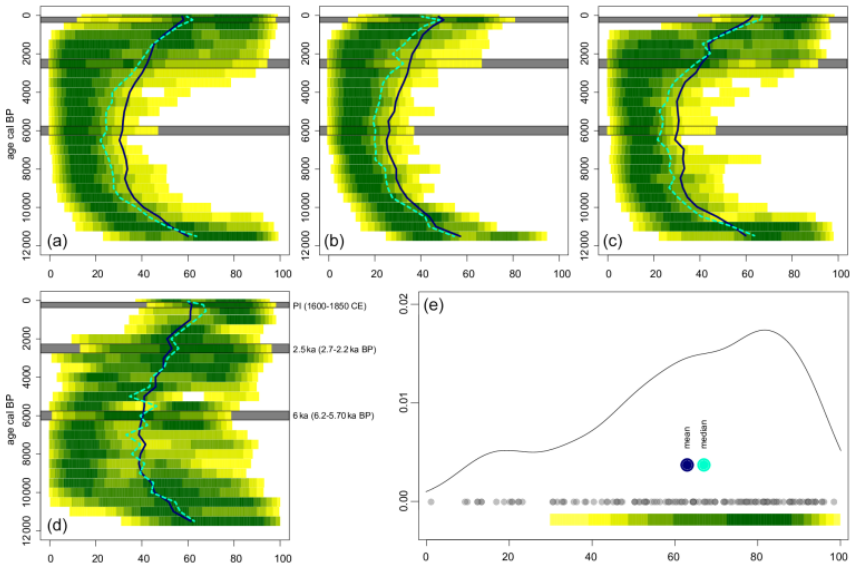

Figure 1. Density plots of REVEALS-based open land (% cover) for **(a)** all European grid cells, **(b)** the boreal zone, **(c)** temperate Europe, and **(d)** Mediterranean Europe. Full black lines represent the mean value of open land cover, and dashed green lines represent the median value. Panel **(e)** is illustrative of how the density plots are derived for one time window, showing data values for all grid cells (opaque grey circles), the derived density function as a curve and expressed on the colour gradient, and the mean and median values. Key time intervals (6, 2.5 ka, and the PI period) are highlighted on panels **(a–d)** by the grey bars.

Abstract and conclusions:

Please revise the abstract and conclusions following the revisions you might consider making in response to the comments above. Among other, the statements "*our approach is more robust and less data-demanding than previously applied methods*" (abstract) and "*Our simple approach produces …. etc…. using more complex methods, and thus provide a less data-demanding approach… etc… of the world*" (conclusions) should be revised. There are no less/least data-demanding method/model and/or best (most robust) method/model; there are several possible methods/models that all are data-demanding and have their pros and cons.